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International Journal of Computing and ICT Research

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Africa Can Greatly Benefit from Virtualization Technology – Part 1I

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INTRODUCTION

In my last issue in Volume 6 Issue 1, I articulated the benefits of virtualization technology and in particular, I focused on how Africa might benefit if there is a drive to embrace this computing technology. In this follow-up piece, I was to go deeper into the virtualization technology and how Africa, especially African Higher Education institutions chocked with the scarcity of resources and severely under funded, can benefit from virtualization technology. Since in part I of this series on virtualization, we defined virtualization, we will, in this follow up article, give a brief definition of virtualization, just to bring everyone to par in the understanding of the technology.

As in part I of this series, we will focus on computing virtualization, ignoring all other areas of virtualization which the reader many check out in other publications if interested. Virtualization, in general, is a process through which one can create something that is there in effect and performance but in reality not there – that is virtual. Computing virtualization is a little more restrained, referring to the virtualization process in which computing resources like software and hardware are cleverally used to create virtually unlimited computing resources for the user. VMware.com, a software developer and a global leader in the virtualization market defines computing virtualization as a process in which software creates virtual machines including a virtual machine monitor called 'hypervisor,' that allocates hardware resources dynamically and transparently so that multiple operating systems, called “guest operating systems” can run concurrently on a single physical computer without even knowing it (VMware.com) For example using software virtualization, one can, using the existing underlying hardware and software resources like operating systems create and run several independent virtual operating systems on top of one physical operating system using the existing hardware resources to execute independent system tasks. Hardware virtualization also takes the same concept where several servers or client machines can be created based on one underlying hardware. The virtualization concept has been with us for sometime.

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As we ponited out in part I of this series, the potential power of virtualization in substantially increasing the performance of computing systems such as hardware and software through division of the underlying physical computing resources into many equally powerful virtual machines, has increased the popularity of the technology in the last twenty years and this love continues today. The rush to virtulization is driven by its resulting server consolidation, preventing server sprawal and creating savings to be invested in new IT initiatives such as cloud computing, mobility, data analytics, and use of social media for business purposes. These benefits are crutial and essential for not only African businesees but more so for African institutions that are increasingly beginnimg to depend on computing systems and technologies for the delivery of services. We will talk more about this later. This rapid growth is a reflection of the changing benefits of virtualization from being used only as a tactical tool to drive consolidation and higher system utilization to leveraging the mobility of virtual machines to improve management and operations of IT environments. The virtualization concept now includes a host of new use cases that range from high availability and disaster recovery to hosted clients and true utility computing.

Types of Computing System Virtualization

In part I of this series, we outlined two types of virtualization as: platform and application. We described platform virtualization as the virtualization software package that emulates the whole physical computer functionalities into multiple virtual machines each with with either the same operating system image like the physical machine or different operating systems. We also gave two subdivisions of platform vitualization as workstation and server. We defined server virtualization as the process of having a physical server run a server-based virtualization software called a hypervisor to divide the physical server into multiple isolated virtual environments. Each one of these virtual environments functions as a virtual machine, homed on a virtual server and has all the functionalities of the physical server it is homed on and runs a virtual operating system called a guest operating system. The virtual machines created are known by different names including virtual private servers, guest machines, instances, containers or emulations. We refer the reader not familiar with these subdivisions of virtualition to part I of this series.

For the remainder of this part we are going to concentrate on how African institutions, including small businesses can greatly benefit from this evolving technology. Like many new computing and telecommunication technologies including mobile computing, virtualization technology has a grat potential of being an equalizer technology for African institutions. So we will quckly review the benefits of virtualization given in part I of this series but in this article we want to discuss the needed basics for realizating these benefits and the transitioning route needed to take the institution to the benefits of this technology.

Quick Look at the Benefits of Virtualization for African Institutions

As we pointed out in part I of this series, the following are the benefits virtualization technology makes available to the institution intending to take the plunge:

- Minimization of hardware costs
- Save on energy
- Faster server provisioning
- Provision of better and faster disaster recovery
- Better load balancing
- Creating a better and faster software testing environment
- Increase uptime
- Isolate applications
- Extend the life of older applications

Problems in the African Technology Exapansion

To fully understand the potential of virtualization technology to African institutions one has to understand the existing problems that must be overcome in order to reach the springboard for technology take off that will bring about the full benefits of virtualization technology to the African institutions. In a number of essays in this journal, I have articulated these problems in different articles. These problems include:

- Small but encouragingly growing technology capacity.
- Scarcity of basic technology resources needed to form a strong base for technology growth.
- Limited enabling environments for technology growth.
- Limited ability to sustain an acquired technology growth.
- Limited resources both financial and human capacity to develop new technologies based on existing technologies.
- Limited academic research required to initiate, fertilize and maintain new and existing technologies.

Buiding a Strong Base for Sustaning and Benefiting from Technologies

Although we have outlined problem bottlenecks limiting the growth, full utlization and benefits of technologies in African institutions, none of these problems are likely to stay in place for long. There are promising signs that is changing fast. To speed up this rapid growth of technology acquisition and statainability, I will outline a few of the needed starters. These include:

- Relevant training to create the needed human capacity to overcome many of the problems outlined above. Training includes education in all post secondary institutions.
- Increasing the basic and necessary resources needed. This is necessary because every institution needs a starting inventory level as the basic springboard for the technology.
- Transitioning human capacity into the technology. This of course means training beyond the class room. For example training people to build networks and maintain servers. With transitioning human resources into new technologies, institutions reap more immediate benefits. For example, using virtualization to scale into cloud computing resources creates immediate unlimited resources for the institution without the huge investments it requires to own these resources.

I am not going to elaborate more on these here because, I have written about these many times in my previous editorial essay in this journal. By virtualizing and encapsulating the limited number of resources on the ground, African institutions can increase more than ten times the potential of the real resources on the ground and hence improve the institutions' output without needing costly new resources.

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VMware.com

An Assessment of the Role of ICT in the Readiness of Nigerian Bank Customers for the Introduction of Cashless Transactions

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ABSTRACT

There are lot of problems associated with a cash-based economy such as money laundering, insecurity of cash, delayed banking payments, and slow development in the country's economy. To improve these problems, the Central Bank of Nigeria has championed the introduction of cashless economy. In this paper we assess the role of ICT in readiness for the implementation of cashless transactions in Nigeria and identify the challenges associated with the implementation of the proposed cashless transactions as affecting the bank customers. Structured questionnaires were administered randomly among the customers of the banks in Akure, Ondo State. Also, data on the volume of transaction of the alternative payment systems in use in Nigeria was collected from the Central Bank of Nigeria. The analysis of the customers' responses and the secondary data revealed that poor communication network; poor power supply among others could hinder the effective role of ICT in ensuring the success of the cashless policy. The paper recommends improvement in communication facilities, improvement in electricity supply, capacity building and massive deployment of alternative payment systems as panacea to these problems.

Key words: ICT, Banking, Cashless Transaction, Nigeria, Economy

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INTRODUCTION

The World Bank defines ICTs as "the set of activities which facilitate by electronic means the processing, transmission and display of information" Rodriguez and Wilson [2000]. ICTs can be described as a complex varied set of goods, applications and services used for producing, distributing, processing, transforming information- (including) telecoms, TV and radio broadcasting, hardware and software, computer services and electronic media [Marcelle, 2000]. ICTs represent a cluster of associated technologies defined by their functional usage in information access and communication, of which one

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embodiment is the Internet. Hargittai [1999] defines the Internet technically and functionally as follows: "the Internet is a worldwide network of computers, but sociologically it is also important to consider it as a network of people using computers that make vast amounts of information available. Before the emergence of modern banking system, banking operation was manually done which is error prone. .

Nigeria adopted electronic banking system in the early 2000s. The use of raw cash for transactions was said to have bred corruption through the "cash and carry syndrome". A cashless society is a culture where no one uses cash, all purchases being made are by credit cards, charge cards, cheques, or direct transfers from one account to another through mobile banking. The cashless society envisioned refers to the widespread application of computer technology in the financial system. According to Valentine [2011], the cost of minting the Naira is so high that the best alternative is to have an economy where less or no cash is required for various transactions. The average cost of producing a Naira note is about N4. For instance, you need N4billion to mint N1billion notes. This does not include the cost of maintaining the notes which are subjected to different kinds of abuse. This partially explains why the Central Bank of Nigeria [CBN] is calling for a cashless economy so as to reduce cost involved in minting and maintaining Naira notes. The Central Bank of Nigeria pegged a limit of daily cash withdrawal and lodgment with commercial banks by any individual and corporate customer to N150,000 and N1 million respectively with effect from April. 2012. This latest development, according to the apex financial regulatory authority is coming on the heels of increasing dominance of cash in the economy which leads to huge cost of cash management to the banking industry, security, money laundering, among others. According to Valenntine [2011], it seems that all the central banks across Africa are bracing up for a cashless economy because almost all African countries have the same problems associated with cash based economy. There is slow processing time involved in counting and queuing for deposits in the bank, he said. In the other way round, Naira is not durable and security of handling cash is not guaranteed. Cash is difficult to document because you cannot really capture it all in the financial system ". The transactions are more difficult to monitor. This makes it difficult for proper planning by government. Cash based economy encourage money laundering activities and give room for high level of tax evasion.

e-Tranzact is a multi-channel electronic payment system that facilitates real time settlement of financial transaction using Internet SMS, WAP, Voice XML and bank outlets. Some banks are already on the e-Tranzact platform, including intercontinental Bank, Access Bank, FCMB, Guaranty Trust Bank, Oceanic Banks et cetera. Customers can shop, effect money transfers online and pay bills with e-Tranzact.

According to Valentine [2011], the benefits of a cashless society to banks and merchants include larger customer coverage, reduction in cost of operations, international products and services promotion and branding, increase in customer satisfaction and personalized relationship with customers, and easier documentation and transaction tracking. On the other hand it facilitates adequate budgeting and taxation, improves regulatory services, improves administrative processes, and reduces cost of currency administration and management for government. To the customer, it aids convenience, as it is available 24 hours ` a day and days a week (24/7). Also it reduces transfer costs and processing fees, supports multiple payment options and also facilitates immediate notification of all transactions on customer's account. It is believed that effective implementation of the policy would curb corruption in all forms of transactions. The cashless transaction has already started as a pilot scheme in Lagos which is regarded as the economic capital of the Federal Republic of Nigeria. The scheme if it succeeds in Lagos will be implemented in other parts of Nigeria. The success of cashless transactions in any economy depends on a number of factors, chief among which is ICT. This paper therefore, presents the report of a study on the role of ICT on the introduction of cashless transactions in Nigeria.

OVERVIEW OF MODERN PAYMENT AND BANKING SYSTEMS

Electronic Payment Systems (E-Payment Systems)

A payment system is used for transferring money. Most modern payment systems employ cash-substitutes. E-payment can be defined as payment by direct credit, electronic transfer of credit card details, or some other electronic means, as opposed to payment by cheque and cash. According to Humphrey et al [2001], electronic payment refers to cash and associated transactions implemented using electronic means. Typically, this involves the use of computer networks such as the Internet and digital stored value systems. The system allows bills to be paid directly from bank accounts, without being present at the bank, and without the need of writing and mailing cheques. Agimo [2004] defines e-Payment Systems as a payer's transfer of a monetary claim on a party acceptable to the beneficially. The term (e-payment) includes debit cards, credit cards, electronic funds transfers, direct credits, direct debits, internet banking and e-commerce payment systems[Wikipedia,2012a]. A good payment systems should afford the users opportunity for convenience(s) of the payment (including the flexibility), reliability and security of the payment method, the service quality (such as the speed with which payment are processed), taste and demographic; and the feedback mechanism to improve service delivery.

In developing countries, the underdeveloped electronic payments system is a serious impediment to the growth of e-commerce. In these countries, entrepreneurs are not able to accept credit card payments over the Internet due to legal and business concerns. The primary issue is transaction security. The absence or inadequacy of legal infrastructure governing the operation of e-payments is also a concern. Hence, banks with e-banking operations employ service agreements between themselves and their clients. The relatively undeveloped credit card industry in many developing countries is also a barrier to e-commerce. Only a small segment of the population can buy goods and services over the Internet due to the small credit card market base. There is also the problem of the requirement of explicit consent (i.e., a signature) by a card owner before a transaction is considered valid - a requirement that does not exist in some of the developing countries.

RECENT TRENDS IN ELECTRONIC PAYMENTS

Some of the emerging methods which use electronic means to make payment are discussed in this section. Some of the techniques represent automation of existing methods of payment, while others are new.

Card Payments

a. Automated Teller Machine (ATM)

ATM is a combined computer terminal, with cash vault and record-keeping system in one unit, permitting customers to enter the bank's book keeping system with a plastic card containing a Personal Identification Number (PIN). It can also be accessed by punching a special code number into the computer terminal linked to the bank's computerized records [Rose, 1999]. Mostly located outside of banks, it can also be found at airports, shopping malls, and places far away from the home bank offices, and offering several retail banking services to customers. Although it was first introduced as cash dispensing machines, it now provides a wide range of services, such as making deposits, funds transfer between two or more accounts and bill payments [Abort, 2004].

b. Electronic Purses/Wallets

There are two categories of e/wallet, these are: (i) E-wallets that store card numbers. This is a virtual wallet that can store credit card and debit card information. Other information that can be stored on this card is passwords, membership cards, and health information. Some of the e-wallets make it easier for consumers

to buy goods using the card. (ii) E-wallets that store card numbers and cash. The second category of a digital wallet is where consumers store digital cash, which has been transferred from a credit card, debit card or virtual cheque inside their e-wallets. It operates like having a virtual savings account where charges are made for on-going purchases, particularly micro-payments.

c. Electronic Funds Transfer at Point of Sale (EFT/POS)

EFT/POS is an online system that involves the use of plastic cards in terminal on merchants' premises and enables customers to transfer funds instantaneously from their bank accounts to merchant accounts when making purchases. It uses a debit card to activate an EFT process [Chorafas, 1988]. It actually comprises two distinct mechanisms: debit and credit cards.

d. Credit Cards

This is a plastic card that assures a seller that the person using it has a satisfactory credit rating and that the issuer will see to it that the seller receives payment for the goods or items delivered. This represents the automated capture of data about purchases against a revolving credit account.

e. Debit Cards

These were a new form of value-transfer, where the card holder after keying of a PIN, uses a terminal and network to authorize the transfer of value from their account to that of a merchant. Introduced more recently, debit together with credit cards represent the most rapidly growing method of payments in several OECD countries. When a payment is made through a debit card, the funds are immediately withdrawn from the purchaser's bank account. The advantage is that the buyer has the funds to make the purchase and paid for right away, so there's no credit card shock when the statement arrives in the mail.

f. Smart Cards

A smart card is a plastic card with a computer chip inserted into it and that store and transacts data between users. The data, in a form of value or information is stored in the card's chip, either a memory or microprocessor. "Smart card-enhanced systems are in use today throughout several key applications, including healthcare, banking, entertainment and transportation Smart Card Basics [2004]. One of the features of this card is that it improves the security and convenience of transactions. The system works in virtually any type of network and provides security for the exchange of data.

g. Mobile

According to Zika [2005], a mobile payment is regarded as an electronic payment made through a mobile device (e.g., a cell phone or a PDA - A Personal Digital Assistant (PDA) is a small handheld computer.). This uses a mobile device to initiate and confirm electronic payment. In the field of payments, mobile phones opportunity is seen in the embedded SIM (smart) card used to store information of users. Costello [2003] envisaged that further developments in the mobile payments content were inevitable in the near future. Mobile devices might be used in micro-payments such as parking, tickets, and charging mobile phones.

h. Telephone Banking

Telephone banking or telebanking is a form of virtual banking that deliver financial services through telecommunication devices. Under this mechanism, the customer transacts business by dialling a touch-tone telephone connected to an automated system of the bank. This is normally done through Automated Voice Response (AVR) technology. Balachandher et al [2001] described numerous benefits of Telebanking for end users. For the customers, it provides increased convenience, expanded access and significant time saving. Instead of going to the bank or visiting an ATM, retail banking serves the same purpose for

customers to get the services at their offices or homes. This saves customers time and money, and gives more convenience for higher productivity [Leow, 1999].

i. Personal Computer Banking [Home Banking]

This term is used for a variety of related methods whereby a payer uses an electronic device in the home or workplace to initiate payment to a payee. In addition to computer technology, it can be performed using the telephone and IVR - Interactive Voice Response [IVR] is a software application that makes use of both touch-tone keypad and voice telephone input selection and ensures that response is received by way of fax, voice, email, call-back or other media [Chorafas, 1988]. Abor [2004] considers PC-Banking as a service which allows the bank's customers to access information about their accounts via a proprietary network, usually with the help of proprietary software installed on their personal computer. It is used to perform a variety of retail banking tasks, and offers the customer 24-hour services. Balachandher et al [2001] described PC-banking as having the advantage of reducing cost, increasing speed and improved flexibility of business transactions.

j. Online/Internet Payments

This is the means by which customers transact business with a bank through the use of the Internet network. Customers can access their bank accounts and make transfers through a website provided by the bank and complying with some rigorous security checks. The Federal Reserve Board of Chicago's Office of the Controller of the Currency (OCC) Internet Banking Handbook [2001], describes Internet Banking as "the provision of traditional (banking) services over the Internet". The Internet is able to offer instantaneous settlement of transactions and the prospect of a highly cost effective payment system for low value transactions. The Internet has the potential to reach majority of customers since it can disseminate "advertising material" through World Wide Web.

k. **Internet marketing**

Internet marketing, also known as digital marketing, web marketing, online marketing, search marketing or e-marketing, is the marketing [generally promotion] of products or services over the Internet. Internet marketing does not only refer to marketing on the Internet, it also includes marketing done via e-mail and wireless media. Digital customer data and electronic customer relationship management [ECRM] systems are also often grouped together under Internet marketing. Internet marketing ties together the creative and technical aspects of the Internet, including design, development, advertising, and sale. Internet marketing also refers to the placement of media along many different stages of the customer engagement cycle through search engine marketing [SEM], search engine optimization [SEO], banner ads on specific websites, email marketing, and Web 2.0 strategies [Wikipedia, 2012b].

Internet marketing is inexpensive when examining the ratio of cost to the reach of the target audience. Companies can reach a wide audience for a small fraction of traditional advertising budget. The nature of the medium allows consumers to research and to purchase products and services conveniently. Therefore, businesses have the advantage of appealing to consumers in a medium that can bring results quickly. Internet marketers also have the advantage of measuring statistics easily and inexpensively. This implies that almost all aspects of an Internet marketing campaign can be traced, measured, and tested. The advertisers can use a variety of methods, such as pay per impression, pay per click, pay per play, and pay per action. Therefore, marketers can determine which messages or offerings are more appealing to the audience. The results of campaigns can be measured and tracked immediately because online marketing initiatives usually require users to click on an advertisement, to visit a website, and to perform a targeted action.

l. Electronic Cheque

Electronic cheques are synonymous to paper cheque. The clearing between payer and payee is based on existing and well known banking settlement system. The only difference between paper and electronic cheques are the dematerialization of the payment instrument which is passed on via computer networks like Internet in the later technology. Electronic cheques also known as e-cheques are virtual cheques that allow consumers to use Internet in making cheque payments. The buyer fills out a form [that looks like a cheque on the screen] with the necessary information, and then clicks the "send" button. The information then goes through a computer or a transaction service, depending on which way one chooses to accept check payments [Rudl, 2012].

m. Digitized 'E-Cash' Systems

E-cash payment system takes the form of encoded messages and representing the encrypted equivalent of digitized money. One key attraction is that it avoid the time and expense associated with becoming an approved credit card accepting merchant. Digitized e-cash system does not require the use of an intermediary; therefore anyone can effect payment directly. However, most present schemes require the direct involvement of a bank for its system of digital cash issuance. A bank is vital to the scheme as it is required to hold collateral and to provide ultimate settlement of e-cash to more directly convertible currencies."

n. Digital Person-to-Person (P2P) Payments

Bank-based P2P enables anyone with an email address or mobile phone number send money from bank accounts and credit cards electronically. It employs e-mail services to notify recipients of an impending funds transfer. Most bank-based P2P requires the sender to register with the P2P site. Most of the providers allow users to move a limited amount of money around the world. Companies offering P2P payment services include MasterCard, VISA card etc.

FACTORS AFFECTING PAYMENT CHOICE

a. Customers' Wealth/Level of Income

In Kwast and Kennickell [1997], wealth was posited as having an important role to play in terms of consumer's decisions on payment choice. Consumers' wealth may influence payment choice and the availability of payment instruments that one can choose. For instance, while wealthy consumers may be able to fund their obligations generally, consumers that experience brief financial shortfalls may not find electronic bill payment desirable as a payment instrument. In such a situation, the consideration of the risk factor may make some consumers avoid using pre-authorized electronic bill payment [Mantel, 2000].

b. Educational Level

Educational level of customers may determine whether consumers will adopt electronic payment or not. Studies have shown that highly-educated people patronize electronic payment products than less-educated people. According to Annon [1999] the technicalities involved in some electronic payment transactions discourage less educated customers to patronize its use. Also, Kwast and Kennickell [1997] illustrates how education play important role in determining household use of e-money products. The study concluded that the US market e-transaction products is still highly specialized, with the demand coming almost entirely from higher income, younger, and more educated households that have accumulated significant financial assets.

c. Employment Levels

Those in paid employment who receive their pay through the banks are more likely to use electronic means of payment. Employees, through their constant contacts with banks are more exposed to payment products, and are therefore, likely to patronize the products. According to Ferguson [2000], more than half of the workers in the US, in 2000 received a direct deposit of their pay through the Automated Clearing House (ACH).

d. Personal Preferences

Another factor that may influence choice of payment instrument pertains to customers' personal preferences. Some of the personal preferences of customers may include: control and customer service, budgeting and record keeping, incentives and low cost, convenience; safety, ease; privacy and security.

e. Transaction-Specific Factors

This relates to the specific nature of the payment being made, where it is being made, and how the consumer views their relationship with the merchant [Mantel, 2000]. The use of a particular payment instrument may depend on the value of the bill [whether it is large or small]. Also the availability of payment infrastructure determines the choice of payment instrument.

f. Marketing Campaigns

Increased use of electronic payment instruments may be achieved through large-scale consumer marketing campaigns funded by some financial institutions. According to Mantel [2000], the marketing activities employed by the financial institutions are expected to aid utilities by educating consumers as to the benefits, ease of use, convenience, and security of paying bills electronically.

MATERIAL AND METHODOLY OF RESEARCH

a. Area of Study

The study was carried out in Akure, the Ondo State capital. All the commercial banks in Nigeria have their branches in Akure. Akure being the state capital is the hub of economic activities in Ondo State. With its large population of civil servants, students, small/medium scale entrepreneurs and political elites, it is expected that the introduction of cashless policy by the Central Bank of Nigeria will have some socio-economic effects on the residents.

b. Method of Data Collection

The study was carried out in March 2012. Data was collected with the aid of structured questionnaire. Thirty copies of the questionnaire were randomly administered to bank customers by enumerators in twenty bank branches within the town. Since the questionnaire was personally administered by enumerators, the problem of delay and of not returning questionnaire was eliminated. In all, a total of 600 copies of the questionnaire was administered and collected for analysis. In addition, secondary data on payment systems transactions form 2008 to 2010 was collected from the Central Bank of Nigeria website.

c. Method of Data Analysis

Data collected was analysed with the aid of table of frequency distribution and charts.

RESULTS AND DISCUSSION

Analysis of Socio-economic Characteristics of the Respondents

a. Age Distribution of Respondents

Table 1, showed that 29.0% of the respondents were between 15 and 25 years of age, 58.0% were between 26 and 45 years of age, 8.0% were between 46and 60 years and 5.0% were 60 years and above. The result showed that the modal age was between 26 and 45years. A closer look at the results showed that 87.0% were between 15 and 45years. This age group represents the economically active and most productive age in any economy. Hence, it could be observed that the study covered those that are active and productive economically.

b. Distribution of Respondents by Gender

The result presented in Table 3.1 also showed that 54.0% and 46.0% of the respondents were male and female respectively. This showed that the both male and female gender was adequately represented in the sample taken.

Table 1: Socio-economic characteristics of respondents

a. Age	Response	Frequency	Percent	Cumulative Percent
	15 – 25	174	29	29
	26 – 45	348	58	87
	46 – 60	48	8	95
	60 and above	30	5	100
	Total	600	100	
b. Gender	Male	324	54	54
	Female	276	46	100
	Total	600	100	
c. Occupation	Civil servant	294	49	49
	Student	222	37	86
	Trader	84	14	100
	Total	600	100	

Source: Field Survey, 2011

c. Occupation of Respondents

Table 3.1 further showed that 49.0%, 37.0% and 14.0% were civil servants, students and traders respectively. The result showed that the people covered by the study have an account in the banks. Also, the nature of their occupation is such that they should know the importance of banking and the cashless transactions being introduced by the Central Bank of Nigeria.

Analysis of Respondents' Payment System

a. Payment system most often used

Table 2: Payment System Often Used

Payment System	Frequency	Percent	Cumulative Percent
ATM	270	45	45
Cheques and tellers	318	53	98
Credit card	12	2	100
Total	600	100	

Source: Field Survey, 2012

In terms of the payment system often used by the respondents, Table 2 showed that 45.0% used ATM, 53.0% used cheques and tellers and 2.0% used credit card. This clearly showed that majority of the respondents still prefer cheques and tellers to other forms of payment.

b. Closeness of the payment system to respondents' area

Table 3: Closeness of the payment system to respondents' area

Response	Frequency	Percent	Cumulative Percent
Yes	372	62	62
No	228	38	100
Total	600	100	

Source: Field Survey, 2012

Table 3 showed that majority (62.0%) of the respondents were of the opinion that the payment system that they often use is close to their area while 38.0% were of the opinion that it was not close to their area. This is a policy challenge to the banks and other financial services provider.

c. Problems encountered using the payment system

Table 4: Problems encountered using the payment system

Problems	Frequency	Percent	Cumulative Percent
Network failure	276	46.0	46.0
Inconsistency of the banks	46	7.7	53.7
High bank charges	120	20.0	73.7
Faulty systems	36	6.0	79.7
All of the above	122	20.3	100
Total	600	100	

Source: Field Survey, 2012

The results presented in Table 4 showed that 46.0% of the respondents indicated network problem as the problem encountered, 7.7% highlighted inconsistency of banks the operation of payment system, 20.0% indicated high bank charges as the problem encountered, 6.0% indicated faulty systems as the problem being encountered and 20.3% noted that it the combination of all the problems stipulated.

d. Preference of ATMs to using banking halls for financial transactions

Table 5: Preference of ATMs to using banking halls for financial transactions

Response	Frequency	Percent	Cumulative Percent
Yes	480	80	80
No	120	20	100
Total	600	100	

Source: Field Survey, 2012

Table 5 showed that majority [80.0%] of the respondents prefer the use of ATMs to going to the banking hall for financial transactions and 20.0% did not prefer ATMs to banking halls. This clearly shows that majority of respondents embrace the use of ATMs.

e. Preference of using cash for payment for business transactions

Table 6: Preference of using cash for payment for business transactions

	Frequency	Percent	Cumulative Percent
Yes	150	25	25

No	450	75	100
Total	600	100	

Source: Field Survey, 2012

In terms of preference of using cash for payment for business transactions, Table 6 revealed that 25.0% of the respondents preferred using cash while 75.0% did not prefer cash. This implies that majority of the respondents would prefer other methods of payment for business transactions.

f. Use of computer-based payment methods (smart card, money transfer, mobile banking and internet banking)

Table 7: Does your bank offer computer-based payment (smart card, money transfer, mobile banking, internet banking)?

Response	Frequency	Percent	Cumulative Percent
Yes	592	98.7	98.7
No	8	1.3	100
Total	600	100	

Source: Field Survey, 2012

The results presented in Table 7 showed that majority (98.7%) of the respondents indicated that their banks offer computer-based payment (smart card, money transfer, mobile banking and internet banking). This implies that most of the banks offer computer-based services to their customers.

g. Do you think that implementing cashless transactions in Nigeria would turn out well for Nigerians?

Table 8: Respondents' opinion about the introduction of cashless transactions in Nigeria

Response	Frequency	Percent	Cumulative Percent
Yes	480	80.0	80.0
No	120	20.0	100
Total	600	100	

Source: Field Survey, 2012

From the result presented in Table 8, most of the respondents [80.0%] were of the opinion that the implementation of cashless transactions would turn out well for Nigerians while 20% totally disagreed with this assertion.

h. Analysis of the Volume of Payment Systems (2008 – 2010)

Table 9 showed the volume of transaction of five payment systems operated in Nigeria between 2008 and 2010. The table revealed that ATM was the most predominant payment system during the period. In terms of percentage, Fig. 4.1 reveals that in 2008, 90.9% of the payment systems' transactions were by ATM, 2.4% were web-based, 4.8% were carried out through mobile payment; 1.8% and 0.1% were by POS and interbank transfer respectively. In 2009, Fig. 4.2 shows that in 2008, 95.2% of payment systems' transactions were carried out through ATM, 2.4% were web-based, 1.6% carried out through mobile payment; 0.8% and 0.1% was by POS and interbank transfer respectively. In 2010, Fig. 4.3 shows that 93.9% of the payment systems' transactions were by ATM, 2.5% were web-based, 1.8% was carried out through mobile payment; 1.7% and 0.1% respectively were carried out through POS and inter-bank transfer respectively. However, with the introduction of the cashless policy, it is expected that the volume of transaction on the alternative payment systems would increase

Table 9: Volume of Transaction of some payment systems in Nigeria

Payment System	2008	2009	2010
ATM	60133611	109161646	60133611
Web-based transaction	1601806	2703506	1601086
Mobile Payment	3179090	1809251	1156533
POS	1194600	918256	1072426
Interbank Transfer	66870	69341	86773

Source: Central Bank of Nigeria

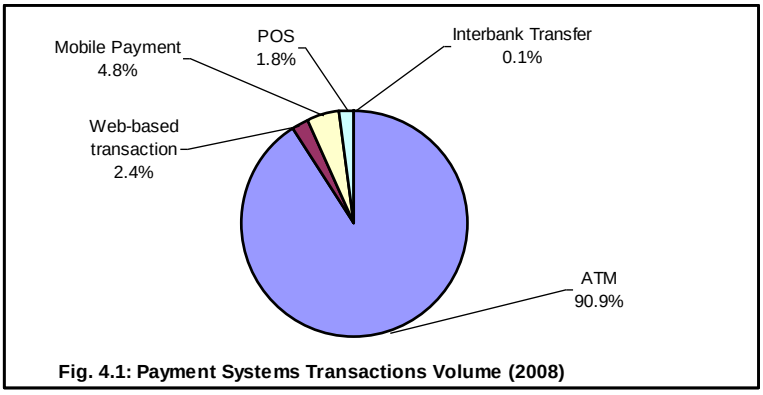

Fig. 4.1: Payment Systems Transactions Volume (2008)

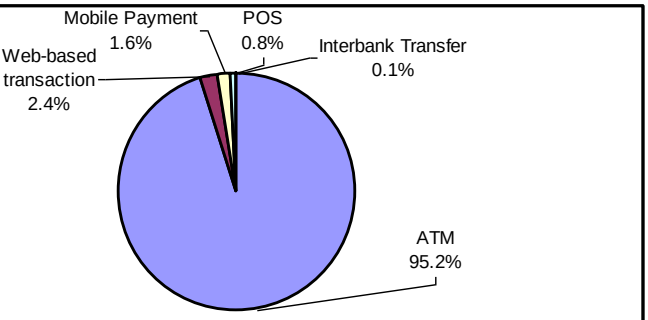

Fig. 4.2: Payment Systems Transactions Volume (2009)

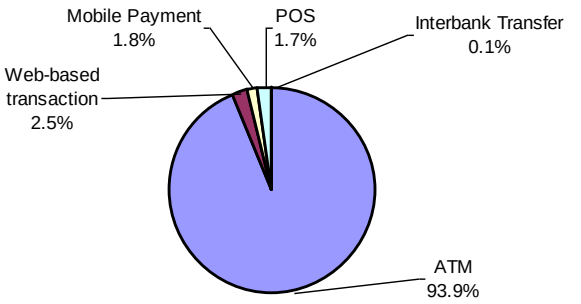

Fig. 4.3: Payment Systems Transactions Volume (2010)

CONCLUSION

This study examined the readiness of bank customers in Nigeria for the introduction of cashless transactions. If cashless transaction must succeed people must be ready to embrace the various alternative payment methods most especially the electronic and card-based methods. This study discussed the various electronic and cash based payment methods. It carried out a survey to ascertain the awareness, availability, usage and the problems associated with these payment systems. Results obtained from the study showed that most of the bank customers prefer cheques and tellers to other forms of payment such as ATM or credit cards. Also, a good percentage was of the opinion that the alternative payment systems are still far from their area of operation or residence. Problems associated with the electronic payment systems include; the issue of poor network, inconsistency of banks the operation of payment system, and high bank charges, In terms of preference of using cash for payment for business transactions, majority of the respondents would prefer other methods of payment to cash. The study also revealed that most of the banks in Nigeria are already using computer-based payment systems (smart card, money transfer, mobile banking and internet banking).

Finally, the most of the respondents were of the opinion that the implementation of cashless transactions would help to transform the Nigerian economy.

RECOMMENDATIONS

The Central Bank of Nigeria should ensure 24 hours uninterrupted network system. The network system must be evenly distributed to all payment systems without interference so that Nigerians would find them easier to use. The government should work on providing uninterrupted power supply as ICT infrastructures need uninterrupted electricity for optimum performance. Government should create adequate awareness to inform the public about the benefits derived from cashless transactions through the use of other alternative payment systems. Also, more ICT infrastructure should be provided. Skilled manpower that would operate

the various alternative payment systems being introduced should be employed while capacity building training programmes should be organized for the operators in the financial sector of the economy.

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An Energy-Efficient Dynamic Source Routing Protocol for Mobile Ad Hoc Networks

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ABSTRACT

The Dynamic Source Routing Protocol (DSR) is one of the most reliable and effective protocols in the Mobile Ad Hoc Networks (MANETs). It is also one of the few MANET protocols whose routing scheme can easily be optimized. But the routing overhead generated by its routing algorithm still leaves substantial amounts of energy being wasted. Route Request (RREQ) and Route Maintenance packets generate overhead control packets that occupy bandwidth, consume energy and may overwhelm a network if not controlled. This paper proposed EEDSR, an extension of DSR that reduces routing overhead by limiting the number of route discovery and maintenance packets in the MANET. The scheme involves bigger packet headers for the source route discovery packets since they contain information about the energy levels of the nodes in the route cache. In EEDSR, since the RREQ packets are flooded once for each communication period, routing overhead is minimized.

General Terms: Routing Overhead, Dynamic Source Routing (DSR), Energy-Efficiency

Additional Key Words and Phrases: Energy-Efficient Dynamic Source Routing (EEDSR), Mobile Ad Hoc Networks (MANETs), Power-aware, On-demand routing.

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1. INTRODUCTION

Mobile ad-hoc networks (MANETs) are wireless networks with no fixed infrastructure [Royer and Toh 1999]. MANET nodes can either be hosts or can act as routers when the two end-points are not directly within their radio range. A critical issue for MANETs is that nodes are normally power constrained [Djenouri and Badache 2006]. Available battery technology is not growing fast enough to meet this constraint. It is via routing and routing protocols that we can possibly alleviate this constraint. Extensive research in routing protocols for MANETs has been carried out, with particular emphasis being placed on reactive routing protocols as opposed to proactive ones at saving energy [Gikaru 2004].

Among the energy-efficient routing protocols, DSR has been found to be very useful especially in developing new power-aware routing protocols [Tamilarasi et al. 2008]. However, the continuous flooding of route request (RREQ), route reply (RREP) and route error (RERR) packets by the DSR algorithm brings with it high routing overhead that causes substantial energy exhaustion of the nodes. While previous research has looked at minimizing routing overhead as a means to saving node energy in DSR, few if any have looked at controlling the frequency of flooding the RREQ packets.

This paper proposes EEDSR, an extension of DSR that looks at controlled and periodic flooding of RREQ packets as opposed to that in the original DSR algorithm. At every communication period *T*, the algorithm sets E_{thresh} , the energy threshold and goes ahead to flood RREQ packets. It is only when 75% of the network nodes have energy below E_{thresh} , that another flooding of RREQ packets in the MANET is done.

2. RELATED WORK

In [Djenouri and Badache 2006], an extended DSR algorithm prolongs node lifetimes by basing on prediction of nodes' mobility patterns. It distributes the routing task to almost all network nodes.

In [Murugan et al. 2005] the DSR-C (DSR-Cache) reduces routing overheads and improves route discovery latency by utilizing a higher cache hit rate to minimize constant dissemination of routing information by the nodes.

In close relation to [Murugan et al. 2005], [Tamilarasi et al. 2008] reduces routing overhead by cutting down the number of route reply packets during route discovery to one selected route. Unlike the standard DSR, the header size of the data packets is also reduced. Data packets are also transmitted with as minimum energy as possible.

In [Gikaru 2004], there is an in depth approach to minimizing routing overhead. It is controlled at both node level and network level. The scheme is designed for all MANET routing protocols although the tests and the algorithm are done based on AODV. But DSR being better than AODV at energy optimization [Jiang and Garcia-Luna-Aceves 2001], extending DSR would result into a more energy-efficient protocol.

This paper is structured such that Section 1 introduces the work. Section 2 highlights related research on saving energy via minimizing routing in DSR. Section 3 gives a brief overview of the basic DSR protocol and outlines the adjustments made on the DSR algorithm. In Section 4, simulation results are presented and analyzed. We conclude THE findings in Section 5.

3. DSR PROTOCOL OVERVIEW

We make a brief presentation of the basic DSR protocol with emphasis on its route request, route reply and route maintenance behavior in the algorithm. A more thorough presentation of EEDSR shall be made, since it is mainly the impact of its attributes to energy optimization that we want to focus on in this paper.

3.1 Dynamic Source Routing Protocol (DSR)

The Dynamic Source Routing [Johnson et al. 2007] is an on-demand protocol based on source routing. It consists of two main mechanisms that allow the discovery and maintenance of routes in the MANET. In the Route Discovery mechanism, a source node, *S* wishing to send a packet to a destination node, *D* obtains a source route to the destination. If the source does not have a route to the destination, it performs a route discovery by flooding the network with route request (RREQ) packets [Sathish et al. 2011]. The RREQ packet contains the destination node address, the source node address and a unique *Request ID* [Doshi et al.

2003]. Any node that has a path to the destination in question can reply to the RREQ packet by sending a route reply (RREP) packet. The reply is sent via the route recorded in the RREQ packet [Sathish et al. 2011]. Several possible routes from *S* to *D* form a 'route cache'. If the 'route cache' possesses multiple routes to the destination, the routing logic selects the route with minimum hop to the destination.

In Route Maintenance, a node wishing to send a packet to a destination is able to detect, while using a source route to the destination, if the network topology and/or channel quality has changed [Johnson et al. 2007]. If this is the case then it must no longer use this route to the destination because a link along the route is broken. Route Maintenance for this route is used only when the source node is actually sending packets to the destination [Gikaru 2004]. In this case, route error (RRER) packets are sent to the source node via the intermediate nodes such that they update their caches by removing the route in error.

A routing entry in DSR contains all the intermediate nodes of the route rather than just the next hop information maintained in other reactive protocols. A source puts the entire routing path in the data packet, and the packet is sent through the intermediate nodes specified in the path [Royer and Toh 1999]. To limit the need for route discovery, DSR allows nodes to operate their network interfaces in promiscuous mode and snoop all (including data) packets sent by their neighbors. Since complete paths are indicated in data packets, snooping helps in keeping the paths in the route cache updated. To further reduce the cost of route discovery, the RREQs are initially broadcasted to neighbors only (zero-ring search), and then to the entire network if no reply is received. Another optimization feasible with DSR is the gratuitous route replies; when a node overhears a packet containing its address in the unused portion of the path in the packet header, it sends the shorter path information to the source of the packet (Automatic Route Shortening) [Jha et al. 2010].

Another important optimization includes the technique to prevent "Route Reply Storms" because many route replies may be initiated simultaneously a delay time proportional to the hop's distance can be used in order to give higher priority to near nodes.

DSR also employs "Packet Salvaging". When an intermediate node forwarding a packet detects through Route Maintenance that the next hop along the route for that packet is broken, if the node has another route to the packets destination it uses it to send the packet rather than discard it [Johnson et al. 2007].

3.2 Limiting Routing Overhead

This implementation of EEDSR includes two essential limitations:

- RREQ packets are sent periodically (once per communication period, *T)*. Strict route caching is done to minimize constant flooding of RREQ packets. Each node therefore ought to have a minimum energy required to route the standard packet size from itself to any destination in the network.
- Each node uses fixed transmit power/energy in order to avoid some nodes using more resources than others while performing similar tasks. In EEDSR route selection is dependent on minimum hop and remaining energy values of the nodes. The route selection is dependent on minimum hop and remaining energy values of the nodes. The route discovery and route maintenance mechanisms are so controlled for purposes of limiting routing overhead [Cameron 1998].

3.3 Optimal Route Discovery

Broadcasting of node power information in the whole network is done alongside RREQ packets as doing it separately may incur some overhead and also cause delays in data delivery. At the beginning of the route discovery process, shortest-hop is used as the metric since the nodes have same battery capacity/energy levels.

Shortest-hop metric here is still in consonant with minimum total transmit power. But as the nodes drain their batteries, remaining battery capacity is used as the metric. When an intermediate node receives a route discovery (RREQ) packet, the following steps are undertaken by the algorithm;

Step 1: Node checks the source node's energy level, E_s , source node *ID*, threshold energy value, E_{thresh}, that was advertised in the network, and the destination node *ID*. It saves these attributes in its route cache.

Step 2: It appends its node *ID*, energy level, E_i and forwards the packet to its neighbouring nodes.

Step 3: If the route discovery broadcast is not the first one (i.e, if it is another communication period, *T'*), the node will check its route cache to see if there exist routes to the destination.

Step 4: In case there is one, it chooses the one with shortest- hop and with minimum total energy to the destination. In case there are no routes, steps 1, 2 and 3 are performed.

3.4 Optimal Route Maintenance

The EEDSR route maintenance indicates change in link quality (especially in terms of energy). A link whose nodes do not possess the threshold energy, E_{min} or E_{thresh} minimum power required to receive and forward a packet to the next destination) shall be 'isolated' and later on dropped from active communication until the next period, *T*. flow of route maintenance packets, reduces the number of routing updates and conserves battery power in the process.

Optimal route maintenance packets are sent in the network when the following are experienced;

1- **Energy Depletion**: When any network node has its energy level or battery capacity going below the E_{thresh} for that period, route maintenance packets shall be sent to neighbor nodes informing them of 'isolation' of the depleted node from the network during the remaining time for that period.

2- **Excessive Mobility**: All network nodes take on a limited mobility level while running the EEDSR algorithm. If a node exceeds this level, communicating nodes shall 'neglect' it while forwarding packets. This is because in EEDSR, the positional stability of a neighbor node is a crucial factor. Packets shall be sent to less mobile nodes. The algorithm operates well in a fairly stable network topology. This limits the flow of route maintenance packets, reduces the number of routing updates and conserves battery power in the process.

A source route is considered 'broken' when the route it describes through the network is not viable. This is when more than 3/4 of the nodes in the route possess less than the required threshold power to forward the minimum data packet size, i.e,

$$\sum_{i=1}^{j-1} E_i \quad < \quad \tfrac{3}{4} E_{ij} \qquad (1)$$

where E_{ij} is the total energy of a route from node *i* to node *j* , E_i is the remaining energy in each node.

Each transmission has a specific quantity of data to forward. This in effect maximizes throughput while collectively increasing network lifetime as almost all nodes have a role to play in data forwarding. In addition, it reduces contention at the MAC layer hence avoiding or minimizing the flooding of route discovery packets.

3.5 Maximizing Network Lifetime

The EEDSR protocol algorithm selects routes such that the transmission and reception of packets is distributed on the network so as to maximize battery lifetime and therefore network lifetime. The remaining battery capacity of a node or host is taken as our measure for determining the node's lifetime. This in turn determines the network lifetime.

Assuming E_{ti} is the remaining energy or battery capacity of the node *i* at a time *t*. Node *i* will route the required minimum number of data packets with a probability *P*(*i*).

P(*i*) will be determined in terms of the remaining battery capacity or node energy E_{ti}. If E_{fi} is the battery capacity of a fully charged battery for node *i*, then,

$$P(i) = E_{ti} / E_{fi}, \qquad (2)$$

Where P(*i*) lies between 0 and 1 [Chen et al. 2004].

There is a minimum value for *P*(*i*) above which a node shall be considered fit to forward the required minimum number of data packets to the destination. A node whose value is below that shall not participate

in data forwarding and shall therefore be 'isolated'. This value is given by,

$$Pmin(i) = Emin/E_{f\,i.} \quad (3)$$

Where $P_{min}(i)$, is the minimum probability below which a node will be isolated [Doshi et al. 2003].

Therefore, for every communication period *T*,

$$Pmin(i) = Ethresh/Efi. \quad (4)$$

For each communication period *T*, $P_{min}(i)$, will be approximately the same for all nodes. The battery consumption model assumes that the node's battery lifetime reduces linearly with time if the node is neither transmitting nor receiving packets. This therefore means that the 'isolated' node is likely to run out of battery energy even if it is not participating in communication. At the next Route-Request broadcast, such a node will not receive the broadcast packet. To avoid this, the 'isolated' node goes in 'sleep mode' and only wakes up when the new threshold value E'_{thresh}, is being set.

3.6 EADSR Algorithm

The EADSR protocol is an energy-aware version of DSR. It is obtained by adding a power header to the original DSR packet header [Bhadhare et al. 2003]. The power header is a list of power values that are the minimum transmit powers for each link. This power value for every link is propagated by each node by adding a field to the header with the value.

The RouteTable adds these power headers. It also extracts these values from the headers and adds the information to the link cache. An extra input port that processes snooped packets and discovers new minimum energy routes is added [Bhadhare et al. 2003]. When new routes are found it sends out a gratuitous route reply to the source of the packet. This process also involves constantly mentoring the power cost of each link in the route.

The DSR source header is modified to include an additional flag that indicates a change in the power costs of the links in the route. The destination node checks this flag and sends out a gratuitous reply to the source informing it about the new costs of the route.

The RequestTable elements is also modified to implement minimum transmit power computation to calculate the minimum transmit power value of the link. This value is then added to the power list in the route request packet when it has to be rebroadcast. The RequestTable element now propagates the new metric through the network.

4. SIMULATION AND RESULTS

Simulation was done using NS-2.34 Simulator in Ubuntu-10.04-desktop-i386.iso Linux environment. The process took three major steps of:

1. **Preparation process:** This involved preparation and derivation of OTcl scripts. It also involved generation of nodes, node movement and/or traffic patterns. This also helped implement the protocol when a combination of C++ and OTcl scripts were added into the NS-2's source base.
2. **Simulation process:** Involved the description of the simulation in an OTcl script and actual introduction of the metrics and parameters into the simulation set up. It involved the practical simulation and derivation of the research data and results.
3. **Analysis of Results:** Results were analyzed via xgraph visualization using the generated trace files.

4.1 Simulation Environment

The simulations were carried out on DSR, EADSR and EEDSR under similar environments. The table I below shows the parameters that were considered in the simulations.

Table I. Simulation Parameters

Parameter	Value
Environment Size	800 * 800 m^2
Number of nodes	20
Initial node energy	1000 Joules
Traffic type	Constant Bit Rate (CBR)
Queue length	50
Mobility model	Random Way Point
Maximum node speed	20 m/s
Antenna type	Omnidirectional

4.2 Routing Overhead

Routing overhead is the sum of all transmissions of routing packets sent during the communication process. It is used here to compare the adaptation of the routing protocols to the limited bandwidth of MANETs, plus their efficiency in relation to node battery power. Generating more routing packets in the network increases the possibility of collision hence more energy consumption [Gikaru 2004]. Routing overhead is a determinant metric to many energy-efficient metrics like per packet cost (energy spent per packet). A high per packet cost means that much routing overhead has been incurred in transmitting one packet. This also translates into much energy spent per packet.

In figures 1 and 2, the average routing overhead for EEDSR is lower than for EADSR and DSR for all pause times. For lower pause times (less than 100), the EEDSR overhead are higher. This is due to the high node mobility which results into link breakages. Route caches are therefore visited more often to replace the broken routes. Soon, the caches run out and new route requests have to be flooded in the network. For higher pause times (100 to 400), there are less link breakages, hence lower routing overheads as the route caches are visited less often.

Figure 1. Average routing overhead against pause times for 10 traffic sources.

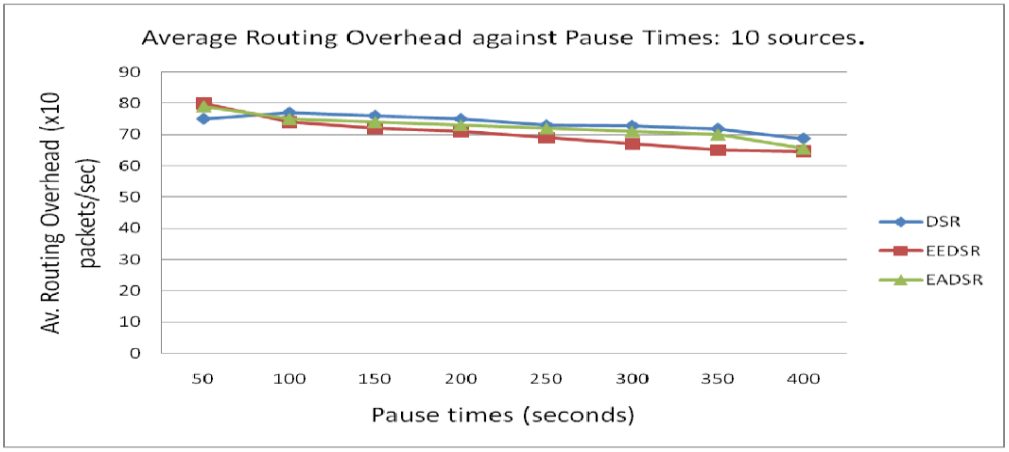
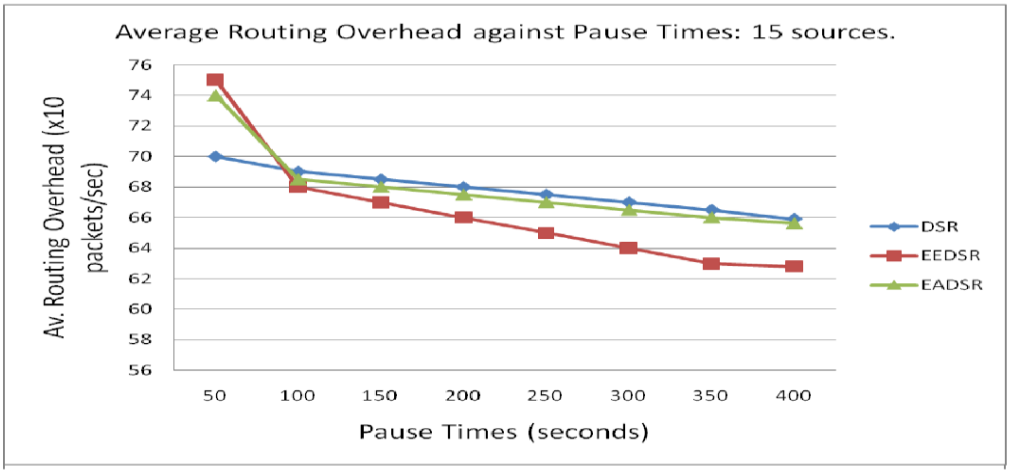


Figure 2. Average routing overhead against pause times for 15 traffic sources.



4.3 Network Throughput

Network throughput is the amount of data successfully sent and received (without errors) by the entire network within the simulated data transfer time. In energy terms, the higher the throughput the better performing the protocol [Tarique et al. 2010]. Nodes ensuring high network throughput are considered optimum with their energy sources, meaning that the underlying protocol algorithm is running efficiently.

Low throughput is the amount of data successfully sent and received (without errors) by the entire network within the simulated data transfer time. In energy terms, the higher the throughput the better performing the protocol [Djenouri and Badache 2006].

In figures 3 and 4, the poor network throughput for DSR is due to aggressive caching. There is no mechanism to expire stale routes or to determine freshness of routes when multiple choices are available. EEDSR improves this situation by 'isolating' low energy nodes and setting new communication periods. This improves freshness of routes and improves throughput in the process.

At high mobility (low pause times). EEDSR still has lower throughputs compared to EADSR. This is because the frequent route breakages result into invalidation of cached routes in EEDSR.

At low mobility (high pause times) throughput for EEDSR increases as there are less link breakages. The caches are visited less often, there are less overheads as RREQ and RERR packets are generated less.

Figure 3. Network throughput against pause times for 10 traffic sources.

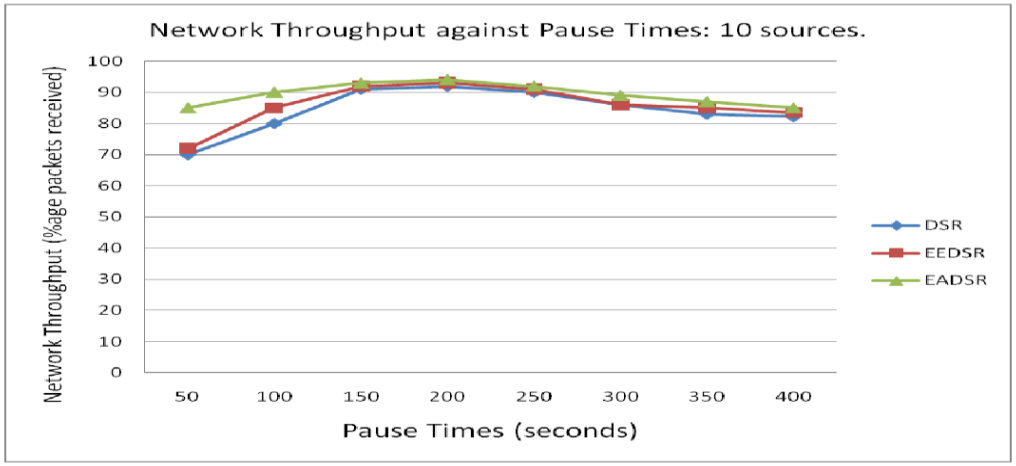
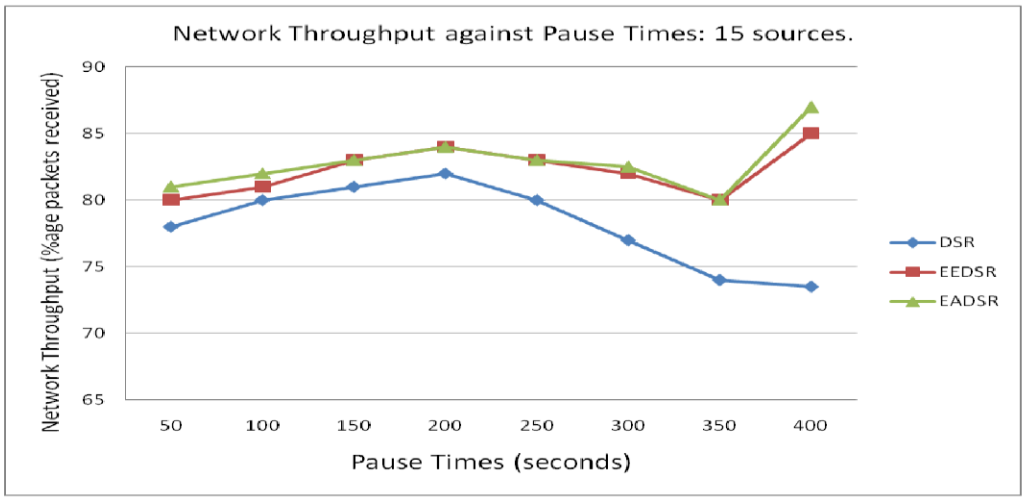


Figure 4. Network throughput against pause times for 15 traffic sources.



4.4 Network Lifetime

The remaining battery capacity of a node/host is taken as our measure for the node's lifetime. Here, network lifetime is defined as the time in seconds from the start of the simulation till when 75% of the total number of nodes in the network get exhausted of energy.

For high mobility (0 pause time), in figure 5, EEDSR and EADSR both have graphs that follow a pattern different from that of DSR. This is because both EEDSR and EADSR are energy-aware or power-aware algorithms whereas DSR is not. The network lifetimes keep decreasing with increasing sources because there will now be more packets generated at the nodes. The nodes forward more packets and therefore run out of battery energy faster.

In figure 6, at low mobility (pause time), EEDSR has fairly constant network lifetime values as compared to EADSR has fairly constant network lifetime values as compared to EADSR and DSR. Generally, network lifetime for EEDSR decreases with increase in number of sources and decrease in mobility.

Figure 5. Network lifetime against number of sources at zero pause time (maximum node mobility)

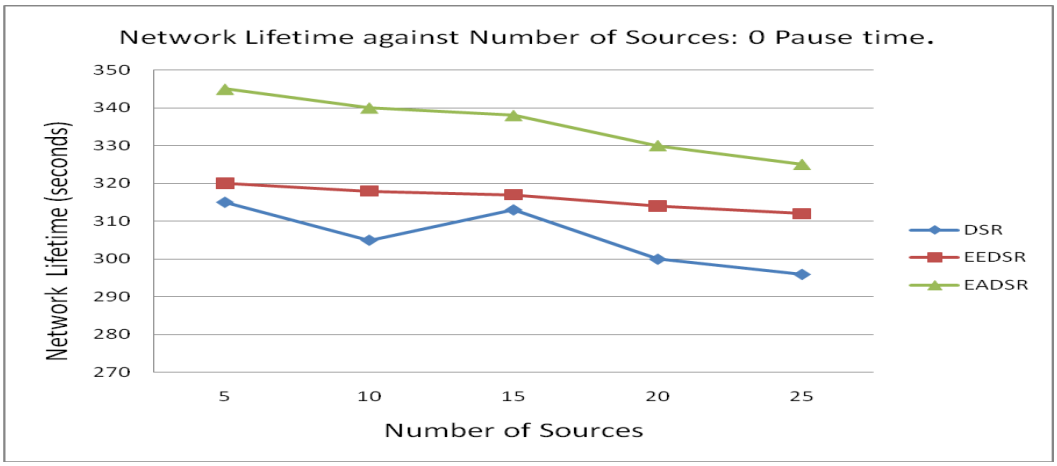
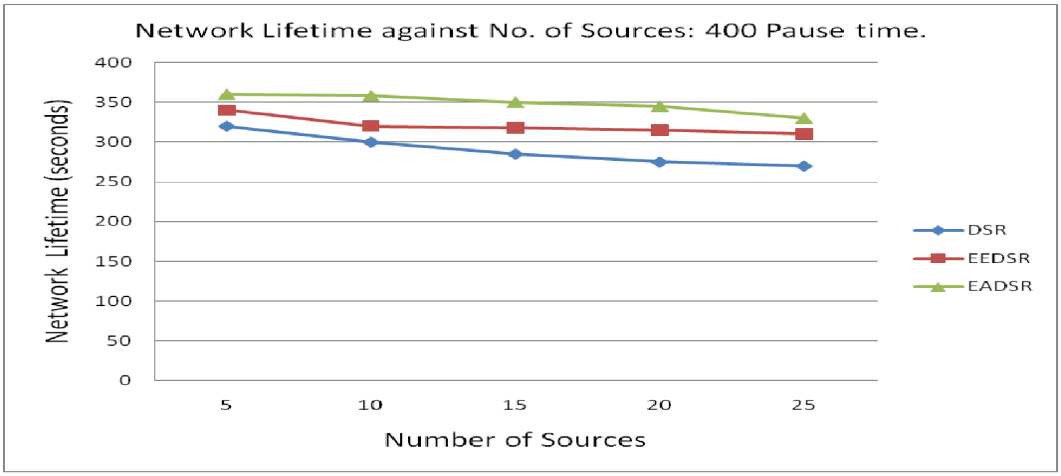


Figure 6. Network lifetime against number of sources at 400 pause times (minimum node mobility).



Limiting routing overhead is one of the ways of saving node energy in Mobile Ad Hoc Networks. In this paper, we showed that EEDSR limits routing overhead of DSR by minimizing the number of generated RREQ packets through periodically flooding them. Including EADSR in the simulations was meant to make performance comparisons between EEDSR and an already existing power-aware routing protocol.

Figures 1 and 2 show that EEDSR on average has lower routing overhead than EADSR and the original DSR especially at low mobility; making it a good energy efficient DSR algorithm at limiting routing overhead.

Figures 3 and 4 show substantially higher throughput for EEDSR compared to DSR especially at average mobility and low mobility. This means that EEDSR is more efficient at successive data delivery compared to DSR.

EEDSR is found to perform poorly at high node mobility as shown by the simulation results at low pause times. Future research would therefore emphasize improving performance at high mobility. More research could also look into a geographically controlled flooding of RREQ packets in the EEDSR algorithm. This would also greatly cut down on routing overhead as the geographical location of the destination node would be the basis for flow of RREQ packets.

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Experience of Course Migration from Blackboard to Moodle LMS – A Case Study from UDSM

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ABSTRACT

The University of Dar-es-Salaam (UDSM) deployed the Blackboard Learning Management System (LMS) in 1998, and after ten years of usage it decided to switch to an Open Source (OSS) LMS, principally due to the high cost of annual licensing for the proprietary system. At this time, OSS LMSs were receiving significant attention, particularly from institutions in developing countries who were seeking to alleviate costs (Cavus et al, 2007). Gozdiskowski and Chen (2007) point out that OSS LMSs were developing popularity in higher education because apart from the obviously lower associated costs, they adhered to other important OSS principles such as potential for customization and are often community driven and therefore community serving.

The institutional migration of courses from one Learning Management System (LMS) or Virtual Learning Environment (VLE) to another is a process that requires careful planning, involves both technical and managerial issues, and may be affected by several factors including user perception. In this paper, the experience of the University of Dar-es-Salaam (UDSM) in migrating courses from Blackboard to Moodle LMS's is explored primarily through aspects relating to institutional organization, staff development, as well as some technical issues experienced during the exercise.

In addition, this paper explores and analyzes the processes and outcomes of the migration initiative experienced at UDSM with a view to guiding internal future planning. While it emphasized that choice of

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the migration approach will depend on local available resources and particular environmental contexts, this experience could also provide other higher education institutions with a tried and tested migration process model for replication in similar projects.

Categories and Subject Descriptors:K.3.1 [**Computers and Education**] Computer Uses in Education; K.6.1 [**Management of Computing and Information Systems**]Project and People Management.

General Terms: Management
Additional Key Words and Phrases: *LMS Migration, Course Migration, Moodle Migration, UDSM Case study, Blackboard Migration*

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1. INTRODUCTION

Advances in Information and Communication Technologies (ICTs) have shaped our thinking and practice in education. The advocacy for and pervasive use of ICTs in education have been perceived both negatively and positively. Critics are skeptical about what they regard as an invasion of schools and classrooms by business conglomerates. They see all the advertisements about what technology can do to improve educational practice as being business gymnastics.

Higher Learning Institutions (HLIs) have adopted several systems that enhance the delivery of academic programmes. This includes the deployment of Learning Management Systems that automate the administration, documentation, tracking, and reporting of training events. Alias and Zainuddin [2005] defined a learning management system (LMS) as "a software application or Web-based technology used to plan, implement, and assess a specific learning process" (p. 28). Mohawk College [2009] suggested that an "L.M.S. can be broadly described as a web-accessible platform for the 'anytime' delivery, tracking and management of education and training. The deployment of LMS in Higher Learning Institutions varies in that some use proprietary LMS while others use Open source LMS. In recent years, Open Source LMS have become popular and widely used by many HLI's. Deployment of LMS includes processes and approaches, user perception management, technical issues, course and user migration.

The University of Dar-es-Salaam (UDSM) deployed the Blackboard Learning Management System (LMS) in 1998, and after ten years of usage it decided to switch to an Open Source (OSS) LMS, principally due to high cost of annual licensing for the proprietary system. In this regard, UDSM made the decision to resort to Open Source LMS. Initially KEWL LMS was installed and tested. It was realized that some of the features of KEWL were still under development and hence UDSM decided to opt for a more robust and stable LMS. Hence, Moodle Open Source LMS (which has a strong international user community) was installed in 2008 and few pilot courses were tested before the system was fully adopted, an exercise that took advantage of and benefited from the Partnership for Higher Education in Africa – Educational Technology Initiative (PHEA - ETI) project.

The systems were running in parallel hence the need for migrating users and courses from Blackboard to Moodle. The biggest challenge was how to perform the migration in a systematic way so as to avoid negativity from faculty and students with the environment, or other unforeseen circumstances that will lead to lose confidence in Moodle

2. THEORETICAL PERSPECTIVES

2.1. LMS deployments in Universities

Learning management systems have been available in their current form since the early 1990s. Internationally, LMSs have become nearly ubiquitous across the higher education sector as a core component of e-learning (also referred to as blended learning) [Pina 2010]. There are more than 90 different types of LMSs available [Pina 2010]. Selecting an LMS is a critical decision for any University, and is likely to have a major impact on teaching and learning policies over a number of years. As mentioned above, LMSs are available in two broad categories: propriety (paid for) and open source.

In this context, LMS deployment requires specific planning and attention. Different institutions have approached LMS deployment and integration differently. Saeedikiya[2010] suggests six stages in LMS implementation, namely: diagnosis, decision making, design, development, delivery and post delivery, in the implementation of e-learning in traditional universities. Khan [2004], also suggests six stages namely: planning, design, development, evaluation, delivery and maintenance. The stages cited by Saeedikiya and Khan above also provided guidance in terms of how institutions may approach course migration processes as both of them emphasize the need for planning and designing. At UDSM, these planning issues were considered and a four-stage model reported in Figure 1 that comes later in this paper was adopted.

2.2. Reasons why institutions are moving to open source software

The open source LMSs have received significant attention, especially from institutions in developing countries because, to them, the ability to acquire educational software without paying license fees is an important advantage [Cavus at el 2007]. Gozdiskowski and Chen [2007] state that open source systems are developing popularity in higher education “because they have a much lower cost, can be more customized, make license management easier, and they are community-driven and community serving” [Gozdiskowski & Chen, 2007, p.1] compared to the expense of commercial learning management systems. They argue that the speedy growth and community acceptance of open source products can lead to the creation of effective and reliable systems which measure up favorably to commercial software. Gozdiskowski and Chen [2007] argue “many open source projects appear to be highly organized and provide tool-support focused upon enhancing human collaboration, creativity, skill, and learning” [Gozdiskowski & Chen, 2007, p.1]. This process can lead to the development of superior software compared to the conventional process where a limited number of programmers have access to the source code Lawrie &Gacek, [2002] cited in Gozdiskowski & Chen, [2007].

Pan et al. [2007] in comparing higher education to “a ‘greenhouse’ for growing open source projects” [Pan et al. 2007, p.7], report that higher education is beginning to welcome open source by ensuing development of innovative products [Abel, 2005: Wheeler, 2004 cited in Pan et al. 2007]. Also, rationale for a university’s choice to implement an open source learning management system is illustrated in a study reported by Stewart et al. (2007) where three learning management systems WebCT, LotusNotes and Moodle were trailed at Athabasca University, Canada. Moodle was chosen due to its performance with an unambiguous lead according to various performance criteria examined by evaluators which included:

"flexibility in start and end dates for students enrolling in courses"; "support for paced and individualized study courses"; "affordability for students"; "accessibility for students with disabilities"; "access at different connection speeds" instructional design; systems administration functions; and teaching and learning criteria including "workable assignment drop box"; and "accommodation of XML and mobile device delivery" Stewart et al.. [2007, p.2].

2.3. General Challenges and lessons in LMS migration

Fitzgerald and Kenny [2003] describe the lessons learned during the course of migrating to an open source software solution. The two main obstacles encountered were: (i) change required in the mind-set of users when deploying the open source software solution and (ii) resistance from staff who feared being deskilled by moving away from a popular proprietary system. On the other hand Drozdik et al., [2005], urges that while migration to open source offers cost savings in the long run, deploying the new technology may involve considerable expenses.

KBSt [2003] identified the critical factors that lead to the sustainable success of a migration project. A migration project is successful if the desired aims and results for all stakeholders are achieved within the planned and agreed time and budget frames. The factors that contribute to the success of migration projects that were identified by KBSt [2003] includes Identification of clear-cut aims for the migration project, involvement and positioning of management and decision-making level, early information, involvement of target groups / staff and Creating a high degree of user acceptance for the target environment.

Other factors identified by KBSt [2003] includes:

- Structured time, project and resource planning, including project controlling
- Organizational measures to prepare the migration process, and establish a qualified project team
- Detailed stock-taking, including a definition of functional requirements
- Optimum project and service selection
- Well-timed, sustainable training
- Quality management and documentation

Some of these challenges and lessons were also observed and further discussed in this paper on challenges and lessons learnt in section 4.

3. UDSM MIGRATION APPROACH AND PROCESSES

3.1. Migration process

The course migration process at UDSM involved a series of steps categorized in four different stages namely preparatory stage, status identification stage, course and user migration stage, and evaluation stage as shown in Figure 1. This process model was created by UDSM through consultative meetings with several stakeholders in view of examining the best workable process within the context of the institution.

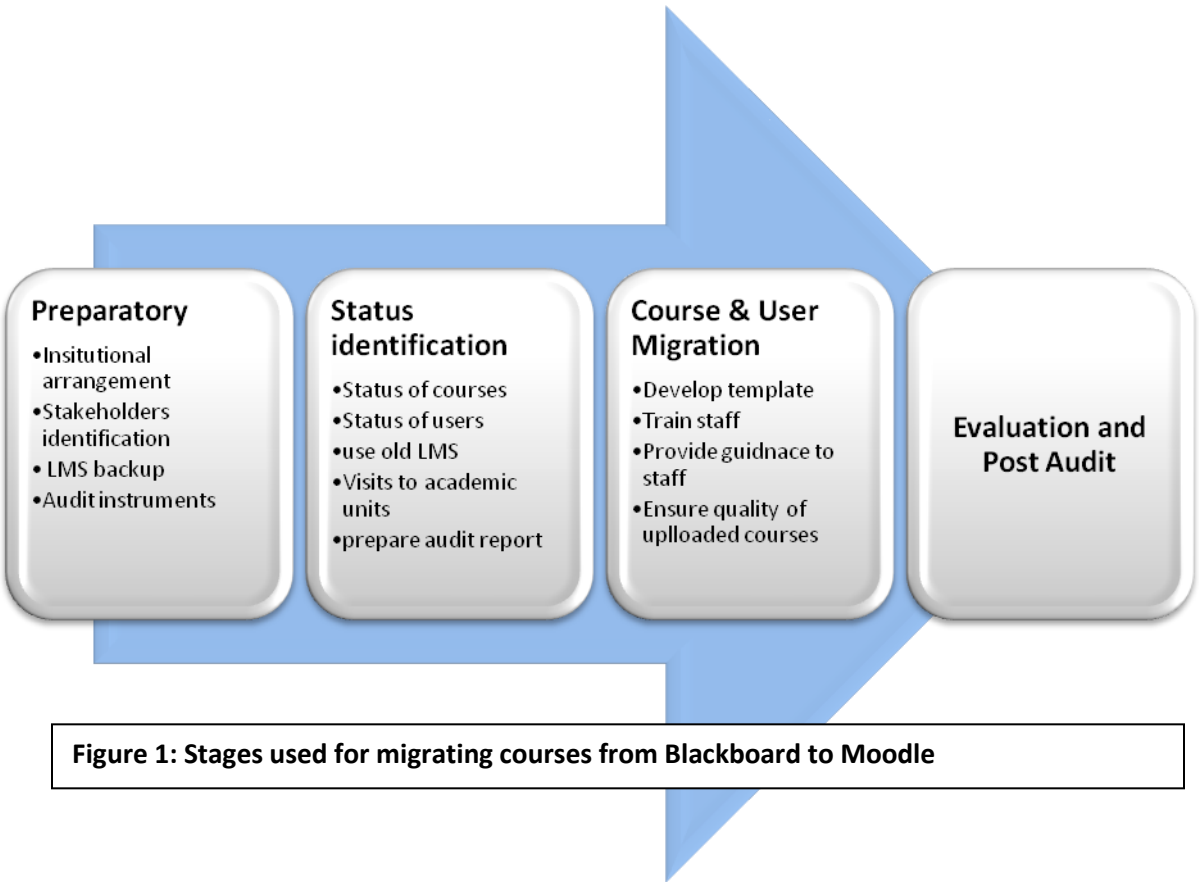

Figure 1: Stages used for migrating courses from Blackboard to Moodle

3.2. Preparatory Stage

The preparatory stage involved listing of activities that are necessary for the process for migrating courses. This includes technical preparations aimed at making sure that the LMS servers are up and running and accessible. The backups (online and offline) of Blackboard LMS in order to minimize the risk on the process once the server crashes. In addition, stakeholders were identified and roles defined during this stage as shown in Table 1.

Table 1: Stakeholders and their roles

Key stakeholders	Relationship / Role	Degree of influence
Deputy Vice-Chancellor: Academic	Decision-making at institutional level, driver of Educational Technology Strategy	High
Principal, College of Information and Communication Technologies (CoICT)	Decision-making at College level and the Chairman of the Project Steering Committee	High
Centre for Virtual Learning (CVL)	Implementation of the key projects	High

Deans of Schools / Colleges, Heads of Departments (academic units)	Owners of programmes in their respective units due to the fact that all courses within a programme are owned by academic units.	High
Academic staff with Courses in Blackboard	Creators / users of new educational technologies	High
Students	Users of new educational technologies. Need to be trained and registered to use the migrated courses	Medium
Partnership of Higher Education in Africa (PHEA)	Financial assistance	High
South African Institute of Distance Education (SAIDE)	Technical Support	Medium

An audit instrument was created for the purpose of having consistency on the information collected by staff involved in the audit exercise. The sample of information collected is shown in Table 2.

Table 2: Course Audit Template

College/School					
Department					
Course ID	**Name**	**Instructor**	**Contact information**	**Status**	**Comments**

3.3. Status Identification Stage

The stage included the identification of status of courses and users within Blackboard in order to determine potential courses to migrate. A potential course was defined as a course which has reasonable amount of subject content in it, seen either in course documents or for some, in courses uploaded in the system. Moreover, other potential courses were identified by having a sizeable user enrolment, high number of postings into the discussion board and the extent to which they seem teachable. On the other hand, a non-potential course was defined as a course with a skeleton consisting only a course name and instructor, yet devoid of any substantial content to facilitate learning. In some cases non-potential courses (sometimes referred to as incomplete courses) would have fictitious names, for instance, a course with a name like xyz, demo etc.

The primary source of data was the Blackboard Learning Management system (LMS) accessible via the Uniform Resource Locator (URL) – http://blackboard.udsm.ac.tz or http://teil.udsm.ac.tz. The audit team was supplied with administrative password which was used to obtain all necessary statistics. The username, course code and e-mail address form a unique pattern was the basis for tracking all users and courses in the

system. The course audit template (see Table 2) created during the preparatory stage was used to document the status of courses in Blackboard. The courses were thereafter grouped into three categories namely, course to be migrated without change, courses that needed improvement before migration, and those which would not be migrated. It was found that, a total of 415 courses were registered in Blackboard by March 2010 of which 146 were potential courses for migration to Moodle. However, a total of 120 (28.9%) courses were found suitable for migration after eliminating repetitive and unused courses. It was observed that 73 courses (60.8%) out of 120 courses earmarked for migrations were active while the remaining 39.2% were inactive courses. Thus, the migration project at UDSM therefore involved a target of 100 courses, spread across disciplines and Colleges.

The stage also involved determining the status of instructors teaching the courses. In this regard, the team visited various departments, schools (initially called faculties) and colleges to find the actual status of some courses that included issues like whether the course is still relevant and/or within the curriculum/syllabus. Also the visits intended to determine the current instructor teaching the course versus the instructor registered in Blackboard. Some of the instructors were contacted via e-mail as obtained within Blackboard system. The team also prepared a work sheet and distributed to all colleges/schools to find new staff who would be interested in developing and delivering their courses via Moodle LMS. It was observed that some instructors were no longer working for the university, others on leave or deceased.

One of the biggest challenges was inaccuracy of data on the Blackboard system. It was difficult to obtain the exact number of registered users and actual number of created courses in the system. For instance; the Blackboard system indicated 19,528 users regardless of their status in terms of using the system. However, it was noted some of the system users had more than one account with a deferent login name (in some cases an individual has five accounts). Furthermore, it was noted that some instructors issued a common username and password to all students. An example of this was the course CS660 (Introduction to Computers and Software Engineering) and dp411a (Electrical machines and drives II) where all the students used the same username cs660.

Another challenge was the way the courses were re-categorized due to the fact 229 courses (55.1%) were not categorized. However these uncategorized courses belong to faculties /schools/colleges. Some of the courses were wrongly classified such as the only indicated course in the Faculty of Law IS342 (Networking). The course belongs to computer science where courses start with **IS** code whilst law courses start with the code **LW**. This implies that the majority of courses were not re-organized properly in Blackboard Learning Management System (LMS).

In addition, information in the Blackboard system was not updated after first registration. This resulted in the existence of invalid instructor's contacts such as e-mail addresses in Blackboard. For example over fifty percent of the e-mails were no longer valid as users, had either fictitious e-mail addresses or had changed their e-mail addresses without updating the system. In some cases instructors did not register e-mail addresses.

3.4. Course and User Migration Stage

During this stage the project team examined several migration options and their associated advantages and disadvantages. Four different options from Colgate University** - Information Technology Services (ITS)

**http://www.colgate.edu/

unit shown in Table 3 were examined and analyzed. These migration options are redesign, copy-best effort, hybrid and consultative in which the significance of technical staff and faculty involvement is shown in Table 3.

Table 3: Explored Migration Options as adopted from Colgate University - Information Technology Services (ITS) unit.

Methodology	**Faculty Involvement**	**Technical Staff will:**	**Faculty will:**
Redesign (Starting fresh)	Significant	• Extract materials from Blackboard • Provide materials to faculty or upload them to Moodle • Assist faculty with course design advice/Moodle orientation	• Design Moodle course layout • Insert transferred materials into course
Copy - Best Effort (Use existing automated conversion tools)	Minimal	• Extract materials from Blackboard • Use existing conversion tools to create analogous Moodle course site, normally in the current semester's course • Query the faculty when automation questions arise	• Provide guidance as requested by migration staff • Verify the migrated site, reviewing layout and checking course content
Hybrid	Minimal	• Do both of the above	• Provide guidance as requested by migration staff • Verify the migrated site, reviewing layout and checking course content
Consultation (Collaborative effort)	Some	Arrange one or more meetings with faculty to review existing course, design a Moodle equivalent, and implement the new Moodle course site	• Meet with technical staff as needed to design and develop the course • Optionally, assist with the course implementation

Source: https://sites.google.com/a/colgate.edu/moodle/Home/blackboard-content

The redesign approach involves technical staff extracting courses from Blackboard and uploading them into Moodle or giving the faculty to upload and just provide orientation on Moodle. Whilst it works, it does

not result in better courses in terms of quality. On the other hand, **The Copy – Best Effort approach** requires the use of automated conversion tools. However, since the course structures of Moodle are not fully compatible with Blackboard and since existing conversion tools are limited, this transfer process can not be fully or simply automated††. The **Hybrid** provides better content as it combines both copy-best effort and redesign approaches. Faculty will use the better-named, better-organized Redesign content as they update content uploaded via conversion tools. Finally the **consultative approach** requires arranging one or more meetings with faculty to review existing courses, design a Moodle equivalent, and implement the new Moodle course site. This is the best option due to involvement of faculty but it requires more resources.

A **consultative migration** option was adopted and thus, the stage involved a series of activities such as;

- Sensitization seminars that aimed at highlighting the need for course migration so as to have instructor's acceptance to the process.
- Downloading courses from Blackboard - The technical team downloaded all courses earmarked for migration from Blackboard and availed these courses to course instructors.
- Training sessions – Instructors were given the downloaded course files and were trained on how to create and re-upload the courses in Moodle LMS while following the created template. The aim of the template was to ensure quality and completeness of uploaded courses in Moodle. The information in the template included but was not limited to course objectives, schedules, assessment options, class activities, resources and references etc.
- Creation of course shells – The technical team created course shells, thereafter instructors used the course shells and their course spaces for uploading their improved courses.

The technical team registered all users based on their courses by making sure that all needed information is registered correctly. The use of automated tools for migrating users across learning platforms was not used due to incompleteness of information in Blackboard system. The use of such systems meant the importation of dummy information on users hence fresh registration was the most appropriate option. Based on this approach there were no technical difficulties experienced in the course of user registration.

A total of 96 courses were migrated while 23 new courses with good quality arose in the course of the migration process due to the awareness created as a result of involvement of all key stakeholders who were identified in the preparation stage. ***The challenges faced are discussed in the lesson leant section***.

3.5. Evaluation and Post Migration Audit

The evaluation and post audit of migrated courses was performed. This is a significant stage which enabled the University to realise the extent and success of the migration process. The audit team used a post migration audit template shown in Table 4.

Table 4: Post Migration Audit template

College/School	
Department	

††http://docs.moodle.org/22/en/Blackboard_migration

Course ID	Course Name	Instructor	Contact info	Instructor Information	Course Objective	Course calendar	No of Users	Course Modules	No of Assignment	No of Forums	No of Course Views	Remarks

4. CHALLENGES AND LESSONS LEARNT

There were several challenges faced and lessons learnt in the whole process of migrating courses from Blackboard to the Moodle Learning Management System, as discussed below.

a) Stakeholders involvement

The engagement of key stakeholders as identified in Table 1 was very important for the success of the migration process. Strategic involvement of stakeholders had resulted into achieving buy-in by university management and by educators. For instance, once the audit team visited the department to determine whether the instructors found in Blackboard were still teaching the courses, it was observed that some instructors were no longer working for the university, were on leave or deceased. It was likely that the instructors of 106 courses (out of 120 earmarked courses for migration) were still present and ready to shift their courses to new LMS. In addition, the heads of departments (identified initially as stakeholders) managed to provide alternative instructors for the remaining 14 courses.

Thus, the course migration exercise needs to be properly planned by determining the roles and early involvement of various stakeholders in the process.

b) Nature of Courses in Source LMS (Blackboard)

The Nature of the courses in source LMS (Blackboard) had a great impact in the migration process. For instance, in migration process it was found that 229 courses (55.1% of all courses in Blackboard) were not categorized despite the fact that they belonged to faculties/schools/colleges. Also, some of the courses were wrongly classified, hence the difficulties faced in obtaining actual information of the course from relevant departments. Some information of instructors such as contact information was either not registered or outdated. This brought challenges of contacting course instructors for the migration exercise.

There is a need to continuously update courses in LMS as well as having some contact information as mandatory fields (e.g e-mail, mobile phones etc) during registration of users in LMS's. This will help during migration process and you need to communicate with system users. Moreover, mechanisms need to be in place to avoid dummy information within LMS's – e.gdisableself registration.

c) Institutional policies on the use of LMS

Institutional policies of the use of LMS have impact in the migration process. Absence of such enforcement policies makes use of LMS voluntary for staff. For instance, initially some of the users at UDSM were reluctant to use the new system due to absence of institutional directives or policies on the matter. This was handled through specific directives issued by DVC Administration to all heads of academic units.

Thus, there is need to have institutional policies that enforce the deployment and use of Learning Management System. In addition, before the migration process, specific directives need to be given to all heads of units for the users to comply as the support from top management of the institutions adds value in the process.

d) Handling Technical Issues and Support mechanisms

Support mechanisms for LMS users are essential for building positive user perceptions on the use of LMS in teaching and learning. The support would either be technical or pedagogical as it was realized that some instructors did not want to migrate their courses due to lack of end user support while using Blackboard. For instance, in 2005 Blackboard LMS crashed and most lecturers lost their course materials. By then, the support structures at UDSM were not well established. These bad experiences impacted negatively on the process of course migration.

In addition, technical difficulties such as connectivity problems arose during the process of course migration. Offline facilities (e.g Poodle) were used to address connectivity issues. In this direction, there is a need of establishing good support structures that will assist in helping system users before, during and after the process of migrating courses. Technical support needs to make sure the system is available and necessary back-up is taken from time to time

e) Institutional Reforms

LMS maintenance and updating need to respond quickly to institutional reforms as it may impact the process of course migration. During the course of migration, there were several institutional reforms such as course modularization and institutional structural changes. The former had led into new curricular of some programmes while the later brought changes by demolishing faculties and establishing schools and departments. The structural changes had implications on course categorisation in the LMS. Despite the fact that these changes were done in 2008, they were not reflected in the LMS two years later and the courses in Blackboard were grouped in faculties that no longer existed.

Thus, there is a need of reflecting institutional changes in LMS systems to make easier the migration process.

f) . Quality of Courses in LMS

The migration process revealed that creating quality courses needs to be emphasized and planned for in the design of the migration processes. This includes having quality criteria and mechanisms to achieve the desired quality parameters. Modalities for involvement of academic staff need to be examined due to the fact that academic staff as key stakeholder have significant contribution on the output of the courses. For example, many academic staff at UDSM were very busy with other teaching, research or public service activities. This brought a lot of challenges as the success of the process depends so much on staff time devoted for the activity. The desired quality of many courses could not be achieved due to staff workload.

g) Pedagogical issues

Migration processes need not be technological driven as reflected in the UDSM LMS model. The model included a training component that focuses on both technical and pedagogical issues. The question remains, what kind of academic staff development should be pursued once the migration team has moved on? What we have learned is that the training to academic staff should provide reaction against the dull, under resourced, IT driven, passive service approach to course migration. It is more than just advocating a pedagogical stance. It is about academics taking ownership of what they do, carefully crafting a pedagogy adapted to a very flexible medium, and adding excitement, engagement and specificity to a bland institutional environment. The Trainings need to be designed so as to encourage ownership and unique pedagogical craftsmanship.

5. CONCLUSION

Like most Higher Learning Institutions, UDSM has successfully migrated courses from Blackboard to Moodle LMS. The experience in the process revel that it should not focus only on technological aspects but lather pedagogical issues need also to be taken on board from the design of the process. This is mainly due to the fact that there is really nothing significantly different about teaching through an open source LMS versus a commercial LMS. What is different is the tool itself, and the support and ease of use offered by competing systems.

The Four different options described in section 3 (Table 3) may be adopted by institutions willing to migrate their course from one LMS to another but the choice of the approach should depend on resources available and several experiences drawn for the case of university of Dar-es-Salaam and highlighted in the paper. Despite the choice on the approach there are issues that need to be critically examined that include stakeholder identification and involvement, institutional commitments and arrangements that include good support mechanisms. It is thus expected that other institutions will find this case study useful for systematic approach in LMS migration.

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Filling the Digital Divide in Rural Connectivity: Case for Last Mile Mobile Broadband Subscription

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ABSTRACT
Access to Information and Communication Technologies (ICTs) has been found to have a correlation with socio-economic development and gross domestic product. Despite efforts by governments across Africa to revamp the telecommunications sector e.g. the establishment of submarine cables, there is a widening gap between citizens with easy access to ICTs and those without. This study sought to investigate how to promote greater accessibility and higher uptake of broadband services in rural areas. This will minimize the digital divide of the underserved and unserved parts.

A model prototype for last mile mobile broadband subscription for rural Kenya was developed to enable mobile phone users purchase broadband services thus improving access to ICT in rural Kenya. This represents a model last mile connectivity as the closest network where majority of the people live.

In developing this prototype, existing subscription technologies were studied, a conceptual model developed, integration to the existing M-Pesa money transfer technology explored, existing connectivity methods studied, connectivity tokens designed, and linkage through modems using mobile phone achieved.

The prototype was tested by a link to WiMAX network via a local Internet Service Provider (KDN Butterfly). Files of different sizes were uploaded and downloaded. The time taken was measured using a bandwidth manager. The experiment was repeated with a Global System for Mobile Communications (GSM) broadband provided by a different service provider (Safaricom). The study showed that WiMAX broadband was faster than Safaricom GSM.

This research contributes a solution towards alleviating the broadband access gap experienced in rural areas of Africa. The provision of broadband Internet access through wireless technologies as an approach towards solving the digital divide that exist in rural areas has been demonstrated using the prototype developed. This solution would assist governments in planning and developing an appropriate policy on rural broadband access initiatives.

Key words: Last Mile, Mobile Broadband, WiMAX, Digital Divide

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1. INTRODUCTION

According to the United Nations Report (2010), over 77 per cent of the population in developing countries is able to receive a mobile phone signal. The digital divide between developed and developing countries continues to widen for technologies that drive modern information sharing such as broadband Internet connection (Sang et al 2007). On the demand side, the barriers to take-up broadband in developing countries are: affordability of broadband services and computing equipment; unreliable electricity supplies; and the paucity of local content. On the supply side, the limiting factors are: the shortage of and high price of international bandwidth; lack of incentives for operators to invest in rural roll-outs; limitations on access to spectrum; and the lack of a supportive, reliable and regulatory environment. There has been mass-market adoption of broadband in an increasing number of countries in the developed world, while take-up of broadband in many countries in Africa including Kenya, has been negligible, causing the broadband access gap to widen considerably. Wireless broadband technologies, such as HSPA and WiMAX, have a key role in filling the gap of broadband access in developing markets. According to CCK (2010), these technologies depend on the use of spectrum for the roll-out of wireless networks and therefore require regulatory intervention. In order to get connectivity in rural Kenya, cash is used to pay for scratch cards that are fed into slow GSM Networks. There are limited mechanisms of collecting users into a unified single system which could avail unprecedented bargaining power to consumers of broadband services.

The utilization of the National Fiber Optic Cable to facilitate access to ICT services is below the expected level both in rural and urban areas. The low rate of development in rural Kenya has multiple and mutually reinforcing causes which are exacerbated further by the lack of access to ICT. The people living in rural areas lack access to information about income earning opportunities, market prices for the goods they produce, health, their rights and public welfare. They lack access to knowledge, education and skills to improve their livelihood, and a voice in the political and development processes that can shape their lives (CCK, 2010).

The aim of this research was therefore to find out how to promote greater accessibility and higher take-up of broadband services in rural areas using WiMAX technology thus maximizing utilization of National Fiber Optic Networks. In order to achieve this, Kenya was used as a case study.

A model prototype for last mile mobile broadband subscription for rural Kenya has been developed to enable mobile phone users purchase a broadband service thus improving access to ICT in rural areas. The prototype represents a model last mile connectivity which is the closest network where the majority of the people in Africa live. The design of the prototype applies a connectivity layout similar to the one designed by Lu, Wang, and Madihian [2007].

In developing this prototype, existing subscription technologies were studied, a conceptual model developed, integration to the existing M-Pesa money transfer technology explored, existing connectivity methods studied, connectivity tokens designed, and linkage through modems using mobile phone achieved.

The prototype was tested through simulation to ensure the subscriptions and M-Pesa payments are functional and effective, the provision of token allocations via the mobile phone to a user in the rural is possible, and compare the performance of broadband versus the GSM modem.

International Fiber Optic Network is significant in enabling the country's broadband infrastructure to offer investors tremendous opportunities for their business. This will lead to more investment in all facets of the economy. The aim is to improve rural based businesses that provide ICT goods and services to majority of citizens through village kiosks that are run and managed by local entrepreneurs. Some of the services that can be provided are computer education, e-government, health insurance, e-commerce, and microfinance. A standard mobile broadband Internet access to the last mile home connectivity provides a uniform standard way of inter-module communication that is reliable and free from the current propagation delay found with satellite telecommunication.

2. LITERATURE REVIEW

The research reviewed literature on the existing subscription systems and found that dialup connectivity was commonly used for Internet access [Kenya Data Networks, 2009]. Dialup connections result in slow connections, high effects of noise, and congestion in the telephone line, thus making Internet access unreliable. To solve the problem there is need for a common database so that all details of subscribers need to be stored in a single database as suggested by Spool [2005]. Mobile devices are intended to experience displacement while maintaining functionality [Rebolj, 2002]. The growth of mobile phone technology has increased their style, functionality, capacity, application areas, features and usability. Subscription systems based on broadband is more effective than dial up lines or fixed lines [Begh and Kagioglou, 2004]. It is possible to increase the efficiency of registration of new subscribers by involving the centralized database approach [Cheng and Chen, 2002]. Mobile phones can have an influence in rural telecommunication [Flanagan et al, 2001a]. Pervasive computing is made possible by wireless mobile communication between embedded systems, handheld mobile devices, and stationery devices [Flanagan et al, 2001b]. The subscription module is faster than current existing manual subscription where a broadband user must physically look for Internet Service Provider agents to buy scratch cards. Sometimes these agents are scarce in rural areas.

This research, therefore, sought to design and implement a prototype that can enhance registration of subscribers and contribute to future planning on broadband requirements in rural areas.

To automate payments for broadband services, the research study focused on how to integrate M-Pesa payment to the prototype. This study focused on the factors influencing the mobile payments usage by the micro business operators and applied the theory of Technology Acceptance Model, a theoretical model that explains how users come to accept and use a technology. Adoption of mobile money payment in urban areas in China found that two primary determinants for adopting and using new technology was influence by variables such as security concerns, cost, convenience, and satisfaction [Lu et al, 2003]. M-Pesa integration to the prototype required to be secure. There was need to provide a service that incorporated use of a PIN and secret code financial transactions.

The IEEE 802.16 standard, also known as Worldwide Interoperability for Microwave Access (WiMAX), has emerged as the strongest for broadband wireless technology with the promises to offer guaranteed quality of service to wireless users. The design of WiMAX technology is aimed at providing last mile wireless broadband access at a cheaper cost [Murphy, 2006]. The "last mile" is the final leg of delivering connectivity from the service provider to a user in rural areas. This leg is typically seen as an expensive undertaking because of the considerable costs of wires and cables.

Varshney and Vetter [2002] in their research on prototype testing found that many businesses have

deployed mobile applications to gain competitive advantage. Such applications developed specifically for small mobile devices include daily news alerts, classified mobile advertising, restaurant and entertainment listings, wireless web portals, and mobile commerce. This research sought to test how the users in rural Kenya can use their mobile phone and gain competitive advantage by applying the prototype to make payment via M-pesa and get allocated a free token from the database.

3. METHODOLOGY

The study explored the last mile mobile broadband subscription and its application to ease the digital divide in rural areas. Analysis and design of the key components required for the broadband subscription system were developed using SSADM tools.

The situational analysis of the existing subscription modes applied in rural Kenya for enhancing ICT access was investigated. The limitations of each mode were identified. The current environment is such that broadband is provided to corporate organizations that pay directly to the service providers by travelling to the Head Office and making payments. Individual users buy scratch cards from mobile broadband agents. Sometimes scratch cards are not available, manual method of purchase not reliable, and the service is expensive as it is charged per bundle purchased. There is lack of economy of scale as the users are individualistic and a mechanism is required to bring them together so that they can enjoy economies of scale. In rural areas there is less impact on development of applications in ICT that can utilize the National Fiber Optic Networks that are found in major towns. More effort is required towards the penetration of National Fiber Optic Network coverage to extend their coverage.

The alternative system used in last mile broadband subscription is the Worldwide Interoperability Microwave Access (WiMAX) network. WiMAX is more reliable and provides for a reliable data transfer compared to connectionless provided by GSM networks. To enhance communication for data transmission the research proposes an integration of WiMAX into rural communication via national backbones, which cover most of the country [CCK, 2010].

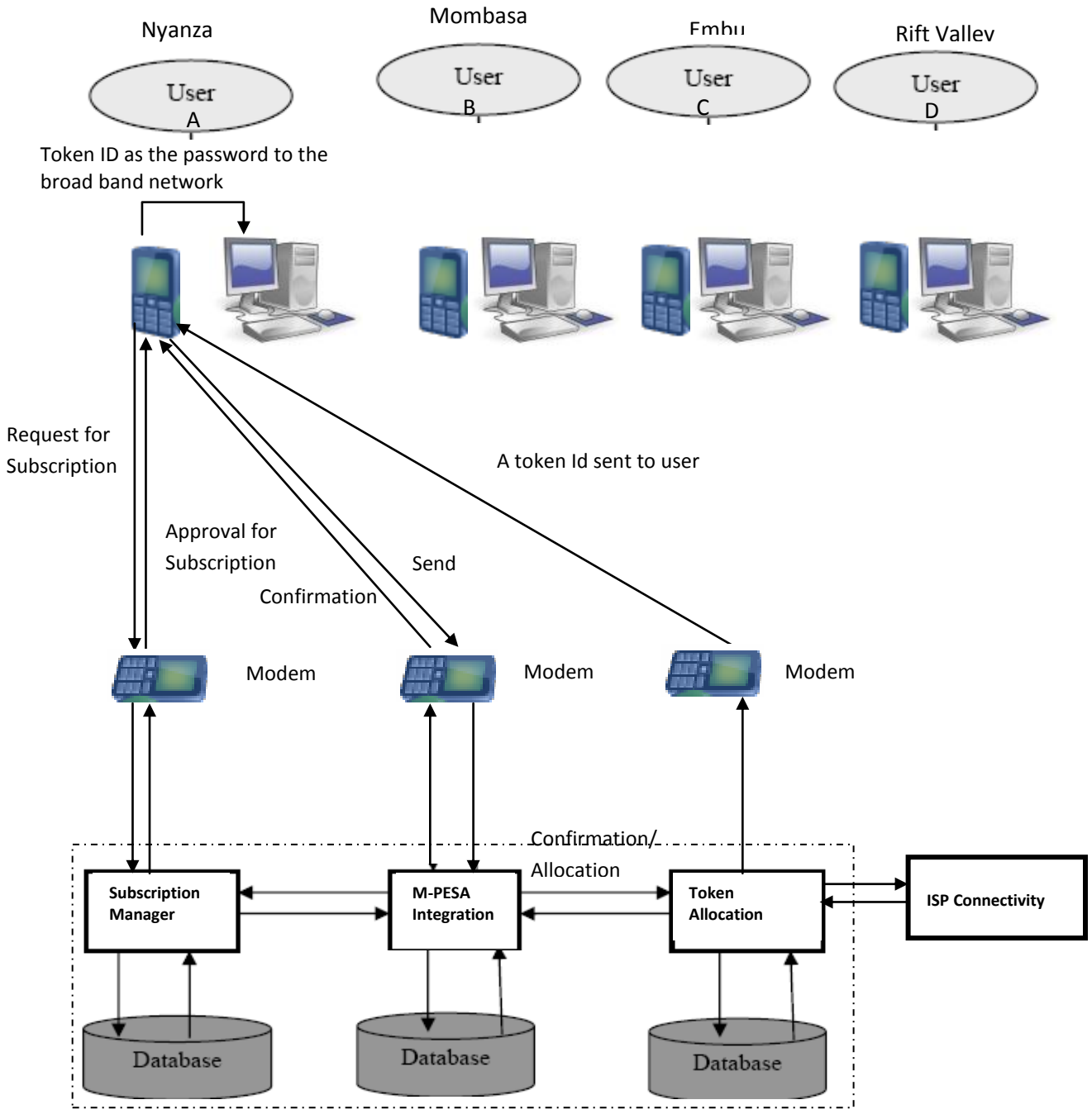
A model database to store details of users was required to support current ICT service demands and for the future. The database can retrieve, process transactions, provide payments for services and enable overall efficiency.

After evaluation, the best solution for the problem of data communication in rural areas was a model subscription system. The system should address the shortcoming of lack of centralized database, lack of faster payment for connectivity, an alternative to slow GSM communication, and enhance capacity of broadband available.

The conceptual design model consists of the following five components:

1. Subscription Manager: The module receives details of the user through a mobile phone.
2. M-Pesa Integration: Records payments and assigns a token id into the broadband system.
3. Token Allocation: Allocates the token based on the M-Pesa payments and tracks expiry dates.
4. Modem: Provides the link into the system via message transmission into and through mobile phone.
5. ISP Connectivity: Provides the connectivity for subscription system to the international gateway Internet service.

The components are unified into a single conceptual design as shown in Figure 1.



The mobile phone subscription module consists of a database to store the registration details as follows: Name of user, Identification Number, County, Division, Village and Phone Number. The other component of the mobile phone subscription module is the user mobile phone for sending messages to the database in the above format. A second mobile phone acted as a modem for real time message transmission via the

communication port of the laptop (16 & 17). The system is programmed to accept the information in the format:

username#id#county#division#village

Also required is communication protocols, and software for embedded programming to allow packets of data to flow through the ports.

The mobile payment module consists of the M-payment which is connected to the database through the Safaricom M-Pesa system. There are other M-payments such as Zap, Yu Cash, Orange Money available in rural Kenya. According to Safaricom Report [2010], the M-Pesa has been adopted as an ideal approach for E-commerce as majority of the people in rural areas are already registered as M-Pesa account holders (by end of March 2009, there were over 6.175 million registered M-Pesa customers with an average of 11,580 new registrations per day, representing a growth of 198% from the previous year). The report suggests a need for design of innovations that appeal and enhance the utilization of mobile phone to improve their lives. Similar research in Asia [Porteous, 2006], suggested that a mobile phone was a viable technological tool for mobile banking and mobile payment services across the country as there are more people with mobile handsets than with bank accounts. This study applied a similar design approach to Porteous [2006], such that rural people were enabled to automate payments for broadband connectivity through their mobile accounts.

To facilitate payments we have introduced token passing technology. On successful payment of the connectivity fee the mobile user is allocated a token code that is transmitted to the user electronically through their mobile phone number registered in the database. The payments are received in e-float from the user's SIM-card number account upon debit of the account and they are forwarded to the account of service provider. The user is provided with token codes that act as a password for last mile mobile broadband connectivity via the WiMAX. The designed module has a connectivity component that enables processing of token allocated and measures the duration of usage in the Internet by tracking the expiry date for each token.

According to Anurag et al [2009], the mobile phone is quickly becoming ubiquitous deployed technology, even among poor segments of the population. Penetration of mobile is 48% today and it is expected to reach 72% by 2014. This research applied the M-Pesa mode of payment as it is an easier form of cash delivery for payments for broadband and other business transactions. This M-Pesa designed approach was relatively affordable, personal and can be used anywhere and at any time.

The prototype designed used the approach adopted by IEEE 802.16 standard that was linked to WiMAX to provide the real connectivity. The prototype was linked to the KDN Butterfly Server which acted as a proxy to the WiMAX Gateway to enable measurement of the download and upload time for different file sizes using their network bandwidth manager. The future application of the prototype is in WiMAX distribution of Internet access to the people in rural areas who have limited access.

The subscription model acted as proxy to the WiMAX. Payments are made at a monthly rate. The system tracks the M-Pesa payment and computes the expiry date for each token that is issued to a user via a mobile phone. The token identification number is used as the password into the WiMAX broadband network.

The simulation testing showed the mapping of M-Pesa payments to the phone number that made the payment and in return the system allocated a unique token with an identification number and expiry date.

The connectivity tokens are purchased and fed into the database and the expiry date is determined for each user.

4. RESULTS AND DICUSSION

The last mile mobile broadband subscription was successfully implemented with the use of Java Development Kit (JDK) running on Windows XP with NetBeans Integrated Development Environment (IDE) and MySQL database. M-Pesa setup was done to enable transfer of details of the transaction using Safaricom. The subscription model setup was successful but with limitations of testing via the WiMAX server used for commercial services. The number of connectivity was dependent on token availability purchased with M-Pesa payments.

The last mile mobile broadband subscription model achieved its key functions of Internet access (user subscription, M-Pesa payment, connection management, and effectiveness) through simulation. The objectives of the simulation were to (a) test the functionality and effectiveness of the subscription model, (b) test the functionality and effectiveness of M-Pesa payments integration, (c) test allocation of tokens via the mobile phone, and (d) test the performance of broadband versus the GSM modem.

A remote user makes a request for subscription via a mobile phone. The modem receives the message and stores the details of the user in the database. The user will then make payments via the M-Pesa. The modem will receive the M-Pesa payment confirmation message and store the details in the database. The prototype will then allocate the user a connectivity token. Once the token is allocated, the system sends a message via the same modem to the user. The allocated connectivity token will be used as the password to the WiMAX network. Once in the WiMAX network, the user can download and upload files.

The simulation layout measured the time it took to download files of various sizes from 1KB to 20MB; one set of files from the broadband network using WiMAX, and repeat the same with GSM network. The results were recorded and a graph plotted to show the performance of the two networks. There are two methods of download or upload tests that were used to test the performance.

Download Test:

1. Small binary files are downloaded from the web server to the client to estimate the connection speed.
2. Based on this result, one of several file sizes is selected to use for the real download test.
3. The test is performed with cache prevention via random strings appended to each download.
4. Up to 8 parallel HTTP threads can be used for the test.
5. Throughput samples are received at up to 30 times per second.
6. These samples are then aggregated into 20 slices (each being 5% of the samples).
7. The fastest 10% and slowest 30% of the slices are then discarded.
8. The remaining slices are averaged together to determine the final result.

Upload Test:

1. A small amount of random data is generated in the client and sent to the web server to estimate the connection speed.
2. Based on this result, an appropriately sized set of randomly generated data is selected for upload.
3. The upload test is then performed in configurable chunk sizes (pushed to a server-side script via a POST).
4. The test can be done using up to 8 parallel HTTP threads (configurable).
5. Chunks are sorted by speed, and the fastest half is averaged to eliminate anomalies and determine the result.

The results of the tests are shown in figure 2 and figure 3.

The bandwidth manager was used to monitor the bandwidth utilization of the WiMAX network as shown in figure 2. The figure shows the preliminary stage where the link is under-utilized as the user session is being set up between the user machine and the servers as authentication message for the requested files is made by the operating system. From the figure at time 500 milliseconds, the actual download for each file commences until completion. At this time the WiMAX receives and transmit the data at its highest utilization of 100%.

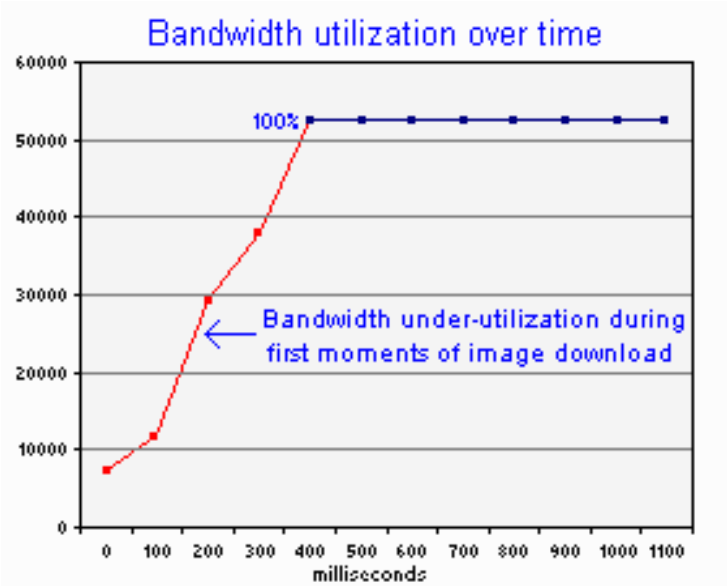


Figure 2: Bandwidth Utilization

The download speed test was done using the bandwidth manager for the various transmission bandwidth links (16KB, 64KB, 256KB, & 512KB) as shown in figure 3. The average round trip time (RTT) for packets was measured for the files downloaded. The data showed the speed of downloads is inverse to the average round trip time (RTT) for the packets of data downloaded. The result showed the higher the capacity of the bandwidth link the higher the speed of download.

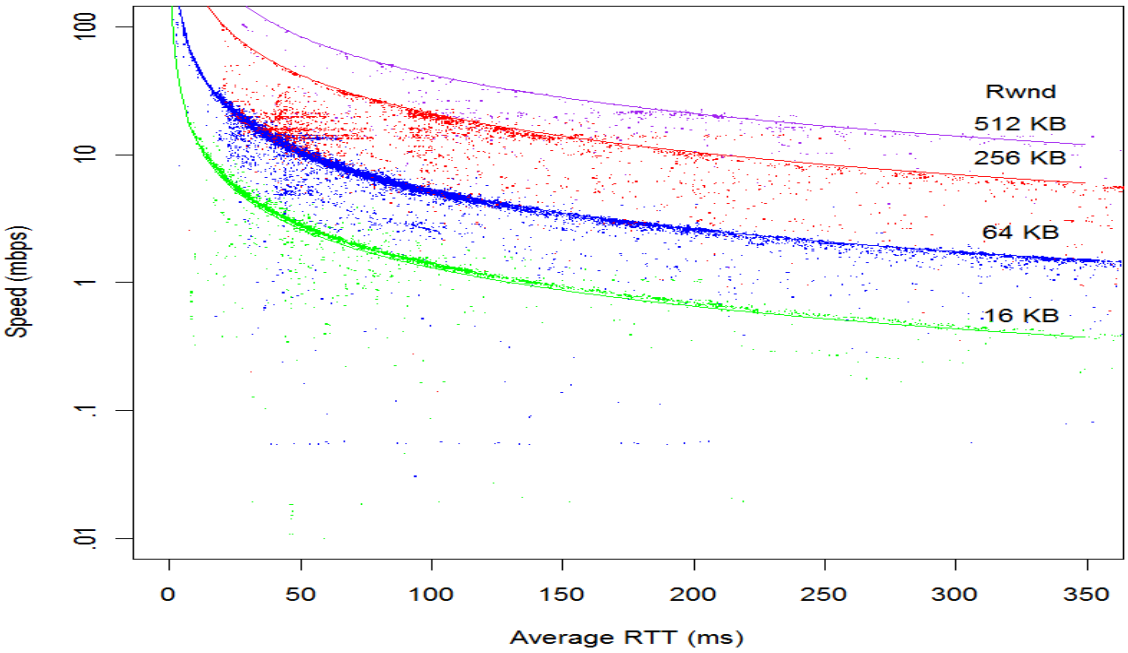


Figure 3: Download Speed Test

The performance of the prototype is shown in tables 1, 2, and 3; and graphs in Figures 4, 5, and 6.

Figure 4 shows that the file size determines the time of download, meaning that the bigger the file size the more time taken to download the file. The speed of the network determines the performance.

Table 1: Network Data Transfer Rate

File Size in Mb	Rate of Transfer in mbps	Time in Sec
5	1.66	3.01
10	1.66	6.024
15	1.66	9.036
20	1.66	12.04

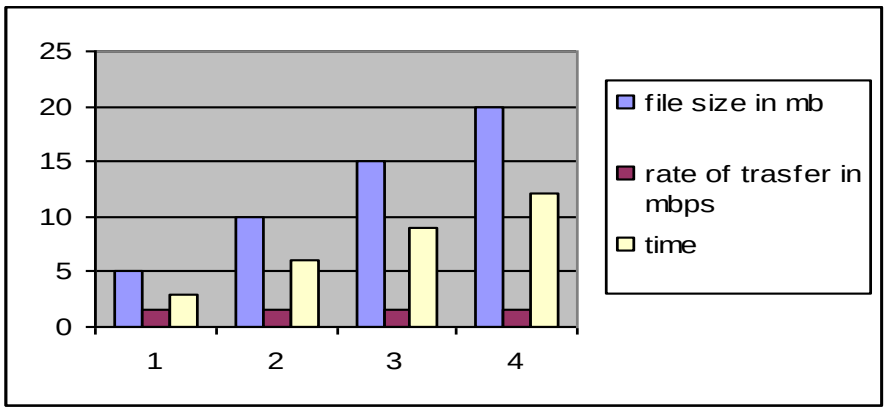


Figure 4: Rate of Data Transfer

Table 2: Last Mile WiMAX Performance

Download speed (Kbps)	upload speed (Kbps)	latency (ms)	jitter (ms)
2636	2829	178	226
11443	2830	173	226
16806	2852	19	3
1690	2907	36	41
16745	2870	17	2
16825	2837	19	6
Sum: 83114	**22729**	**778**	**1056**
Average : 10389.25	**2841.13**	**97.25**	**132**

Figure 5: Performance of the Last Mile Mobile Broadband Connectivity

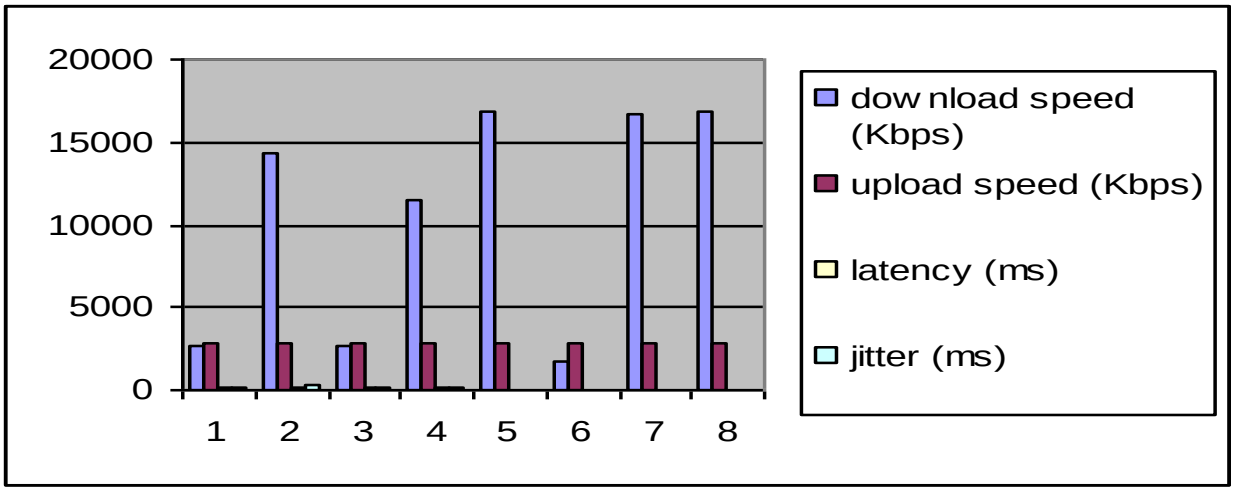


Table 2 shows that the performance of the WiMAX network is faster than the GSM network, which makes it more efficient and provides better performance to the network users. The test successfully shows that the performance of the last mile broadband connectivity for rural Kenya can be supported by the model. Figure 5 shows that the download speed is faster than the upload speed; the latency and the jitter are minimal showing that the network is reliable for commercial purposes. This information shows the network is linked to the fiber optic cable that supports very high data transmission rates.

Table 3: GSM Network Performance

Download speed (Kbps)	Upload/ speed (Kbps)	latency (ms)	Jitter(ms)
0.61	0	0	0
1.12	1	0.04	0.014
1.45	1.2	0.051	0.002
1.5	1.45	0.456	0.12
6.5	1.2	0.31	0.002
4.5	1.4	0.21	0.003
Sum: 15.68	**6.25**	**1.067**	**0.141**
Average: 2.61	**1.04**	**0.178**	**0.018**

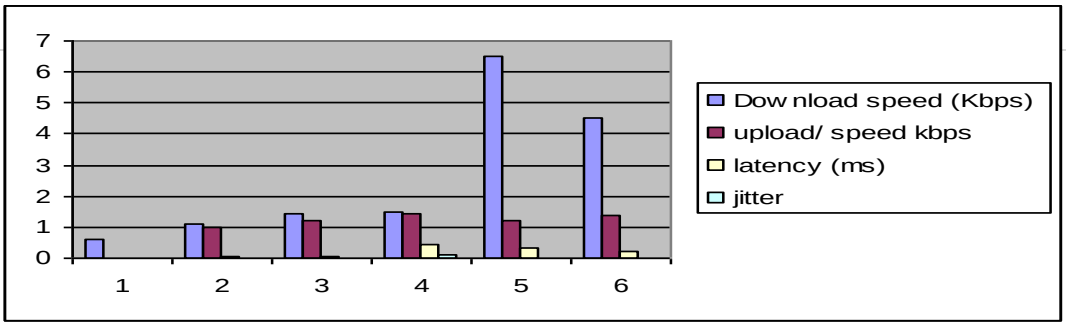


Figure 6: GSM Data Transmission Rates

Table 3 shows that the network had a download average of 2.61Kbps which is quite low and an upload of 1.03Kbps which was consistent with the standards rate provided by the International Telecommunication Union (ITU). The performance data is within the normal transmission rate through a GSM network as per the specifications of the ITU [ITU 1999, 2004]. This shows that the network performance is lower than WiMAX which is because of the Time Division Multiplexing (TDM) applied in GSM where the available links are shared among the users. The system allocates time slots for each user to download and upload data. This sharing results in delays that make the network slow and sometimes busy and connections become difficult resulting in delays as demonstrated in figure 6.

The WiMAX provide superior services because the infrastructure used in WIMAX are such that the links in WIMAX (16, 64, 256, 512) in figure 3 are leased to specific users thus more reliable as there is less sharing, less noisy, and are only used to service the specific organizations such that they are always available on demand. The research demonstrates how this service can be duplicated to the rural areas as an option towards increasing access to Internet connectivity that is more reliable.

The results from simulations done with the subscription model, M-Pesa payments and connectivity tokens lead to the following main findings and observations.

The subscription module (Figure 7) successfully achieved the registration of new users, their identification numbers, their county, division, and villages, by use of mobile phone which acted as the front-end processor. The details are stored into a MySQL database in the server in ascending order of identification number. The prototype was able to keep records of subscribers regardless of their location. The prototype demonstrates an alternative solution towards filling the gap of digital divide problem of low rural broadband connectivity as identified by Waema, Adeya, and Ndung'u [2010]. The research finding agrees to similar conclusions by Begh and Kagioglou [2004] who argued that subscription modules contribute towards alleviating the broadband access gap problem. This is therefore an applicable solution towards problems in rural Africa.

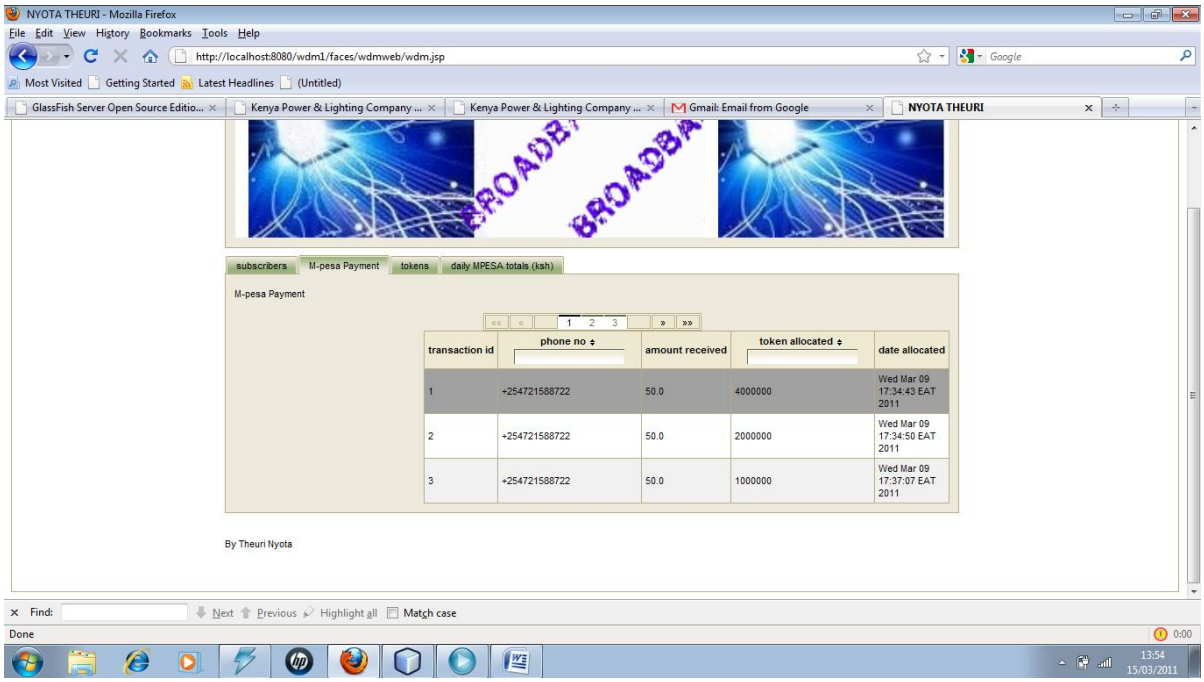


Figure 7: Subscription System Interface

The integration with M-Pesa enables the user to send payments for broadband and the user is allocated a unique token identification number. The message is sent to the user via the mobile phone. The system's interface records a message from M-Pesa confirming the amount of money send and the balance in the user's M-Pesa account. The prototype computes the expiry date for each mobile phone number upon receipt of payment and relays the expiry date to the user. The findings agrees with similar designed prototype by Khodawandi, Pousttchi and Wiedmann, [2003] who concluded that mobile phone was utilitarian and can be advantageous in automating payments compared to direct purchases from Internet Services Provider agents, which is the case in most areas. The prototype reduces the costs inherent in scratch cards or other electronic option available and twists expenses into benefits to all parties in the value chain as concluded by Lu, Yu, Liu and Yao [2003].

When the payments are received and confirmed the token access code is allocated to the user in the token allocation table. The prototype relays the identification number of the token and its expiry date via the mobile phone to the user. The unused token are given '0' status while the used are given '1' showing the tokens have been allocated hence prevention of double allocation making the model reliable and successful. The user then keys in the received token identification number into the Butterfly Network. This is similar to buying a scratch card and entering the reference number so as to get connectivity. On confirmation, the user's computer immediately gets broadband Internet access for one month.

The prototype was implemented using purely open source products. All the main modules were implemented and tested to make sure they are working within the expected time limit. The integration of WiMAX to the fiber backbone makes it efficient than the GSM that is expensive and sometimes unreliable. At the experimental stage, the prototype was linked to the KDN server by setting the public Internet Protocol and enabled the prototype to act as a proxy for WiMAX where the token identification numbers are defined in the server and WiMAX gateway at KDN provided the actual connectivity. The bandwidth manager was used to measure the speed of download and upload when access through the token identification number was made. Different file sizes were used and measurement of time, latency and jitter

done. The experiment was repeated for the Safaricom GSM modem. This research also comes up with an interesting finding that WiMAX can provide faster access to broadband despite earlier view. The results agree with the findings by Spool [2005] on centralized database approach for subscription systems. The tests made concurred with those obtained by Varshney and Vetter [2002]. It is possible in mobile e-commerce to extend electronic businesses to mobile devices. In this case, a user in rural Kenya is able to buy connectivity token where scratch cards are not readily available.

This study is closely related to the upcoming cloud computing platforms and pervasive computing that enables the computer users to have unlimited access to information in whatever form and at whichever speed. Using M-Pesa, consumers can quickly purchase token for Internet access without having to travel to an agent thus provides even stronger application of M-Pesa adoption and usability in rural areas.

The research results illustrate the following key practical implications apply:

1 Boost connectivity: The prototype for connection in rural areas is unreliable, lacking and difficult to achieve. In this research, connectivity was easily developed using M-Pesa payment platform.
2 Adoption of M-Pesa: The advantage electronic payments would boost the users' ability to use M-Pesa service for payment of services.
3 Penetration of broadband Internet access: The penetration of broadband Internet access and its distribution to as many users as possible hence boost of socio-economic status.
4 National Fiber Optic Network utilization: The ability of the model to connect to WiMAX implies it is possible to utilize the national fiber optic cable network by providing rural connectivity resulting in triple play. The model can act as a basis for transmission of voice, data and video to the rural areas of Africa resulting in a last mile broadband connectivity Internet for socio-economic development.

5. CONCLUSION

A last mile mobile broadband subscription prototype solution with the following features has been developed: subscription, M-Pesa integration, and connectivity tokens that provide Internet access through broadband network using WiMAX. This research contributes a solution towards alleviating the broadband access gap experienced in rural Africa. This solution would assist governments and Internet Service Providers in planning and developing an appropriate policy on rural broadband access initiatives. Acquisition of infrastructure, such as routers, gateways and powerful servers, will ensure that, instead of using the public telecommunications network, one can set up a complete broadband Internet access network that would be more reliable. Further work requires broadband benchmarking in order to determine the quality of application systems that can be developed to enable economical use of the broadband Internet access in rural areas that can support business process outsourcing. Also further work is required in integration to Global Positioning Systems (GPS) and integration to a spatial database, such that the location coordinates of each user is stored.

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APPENDICES

Appendix A: Sample worker.java file

```
package wdm;
import java.util.ArrayList;
import java.util.List;
import java.util.logging.Level;
import java.util.logging.Logger;
import org.smslib.AGateway;
import org.smslib.ICallNotification;
import org.smslib.IGatewayStatusNotification;
import org.smslib.IInboundMessageNotification;
import org.smslib.IOrphanedMessageNotification;
import org.smslib.InboundMessage;
import org.smslib.Library;
import org.smslib.Service;
import org.smslib.AGateway.GatewayStatuses;
import org.smslib.AGateway.Protocols;
import org.smslib.InboundMessage.MessageClasses;
import org.smslib.Message.MessageTypes;
import org.smslib.modem.SerialModemGateway;
import org.smslib.OutboundMessage;

public class WDMClient {

   Service srv;

   public void doIt(String cport) throws Exception {
      // Define a list which will hold the read messages.
      List<InboundMessage> msgList;

      // Create the notification callback method for inbound & status report
      // messages.
      InboundNotification inboundNotification = new InboundNotification();

      // Create the notification callback method for inbound voice calls.
      CallNotification callNotification = new CallNotification();

      //Create the notification callback method for gateway statuses.
      GatewayStatusNotification statusNotification = new GatewayStatusNotification();

      OrphanedMessageNotification orphanedMessageNotification = new OrphanedMessageNotification();

try {
         System.out.println("Example: Read messages from a serial gsm modem.");
         System.out.println(Library.getLibraryDescription());
         System.out.println("Version: " + Library.getLibraryVersion());

         // Create new Service object - the parent of all and the main interface
         // to you.
```

```
        this.srv = new Service();

        // Create the Gateway representing the serial GSM modem.
        //SerialModemGateway gateway = new SerialModemGateway("modem.com1", cport, 57600,
"Generic", "");
        SerialModemGateway gateway = new SerialModemGateway("modem.com1", cport, 9600,
"Generic", "");
        //SerialModemGateway gateway = new SerialModemGateway("modem.com1", "COM1", 9600,
"Generic", "");

        // Set the modem protocol to PDU (alternative is TEXT). PDU is the default, anyway...
        gateway.setProtocol(Protocols.PDU);

        // Do we want the Gateway to be used for Inbound messages?
        gateway.setInbound(true);

        // Do we want the Gateway to be used for Outbound messages?
        gateway.setOutbound(true);

        // Let SMSLib know which is the SIM PIN.
        //gateway.setSimPin("0000");
        //gateway.setSmscNumber("");
        // Set up the notification methods.
        this.srv.setInboundMessageNotification(inboundNotification);
        this.srv.setCallNotification(callNotification);
        this.srv.setGatewayStatusNotification(statusNotification);
        this.srv.setOrphanedMessageNotification(orphanedMessageNotification);

        // Add the Gateway to the Service object.
        this.srv.addGateway(gateway);

        // Similarly, you may define as many Gateway objects, representing
        // various GSM modems, add them in the Service object and control all of them.

        // Start! (i.e. connect to all defined Gateways)
```

Appendix B: Sample Client.java File

```
package wdm;
import java.util.ArrayList;
import java.util.List;
import java.util.logging.Level;
import java.util.logging.Logger;
import org.smslib.AGateway;
import org.smslib.ICallNotification;
import org.smslib.IGatewayStatusNotification;
import org.smslib.IInboundMessageNotification;
import org.smslib.IOrphanedMessageNotification;
import org.smslib.InboundMessage;
import org.smslib.Library;
import org.smslib.Service;
import org.smslib.AGateway.GatewayStatuses;
import org.smslib.AGateway.Protocols;
import org.smslib.InboundMessage.MessageClasses;
import org.smslib.Message.MessageTypes;
import org.smslib.modem.SerialModemGateway;
```

```
import org.smslib.OutboundMessage;
public class WDMClient {
   Service srv;
   public void doIt(String cport) throws Exception {
      // Define a list which will hold the read messages.
      List<InboundMessage> msgList;
      // Create the notification callback method for inbound & status report
      // messages.
      InboundNotification inboundNotification = new InboundNotification();
      // Create the notification callback method for inbound voice calls.
      CallNotification callNotification = new CallNotification();
      //Create the notification callback method for gateway statuses.
      GatewayStatusNotification statusNotification = new GatewayStatusNotification();
      OrphanedMessageNotification orphanedMessageNotification = new OrphanedMessageNotification();
      try {
         System.out.println("Example: Read messages from a serial gsm modem.");
         System.out.println(Library.getLibraryDescription());
         System.out.println("Version: " + Library.getLibraryVersion());
         // Create new Service object - the parent of all and the main interface
         // to you.
         this.srv = new Service();
         // Create the Gateway representing the serial GSM modem.
         //SerialModemGateway gateway = new SerialModemGateway("modem.com1", cport, 57600,
"Generic", "");
         SerialModemGateway gateway = new SerialModemGateway("modem.com1", cport, 9600,
"Generic", "");
         //SerialModemGateway gateway = new SerialModemGateway("modem.com1", "COM1", 9600,
"Generic", "");
         // Set the modem protocol to PDU (alternative is TEXT). PDU is the default, anyway...
         gateway.setProtocol(Protocols.PDU);
         // Do we want the Gateway to be used for Inbound messages?
         gateway.setInbound(true);
         // Do we want the Gateway to be used for Outbound messages?
         gateway.setOutbound(true);
         // Let SMSLib know which is the SIM PIN.
         //gateway.setSimPin("0000");
         //gateway.setSmscNumber("");
```

Appendix C: Sample Code for the user interfaces using Rich faces for Java

```
allocated">
                                    <f:facet name="header">
                                       <h:outputText value="token allocated" />
                                    </f:facet>
                                    <h:outputText value="#{Enrol.token}"></h:outputText>
                                 </rich:column>
                                 <rich:column>
                                    <f:facet name="header">
                                       <h:outputText value=" date" />
                                    </f:facet>
                                    <h:outputText value="#{Enrol.date}"></h:outputText>
                                 </rich:column>

                              </rich:dataTable>
                           </div>
```

```
                    </rich:tab>
                    <rich:tab label="tokens">
                       <rich:spacer width="1" height="5"/>
                       <br />
                       <a4j:outputPanel ajaxRendered="true">
                          <h:outputText value="tokens 0-available "></h:outputText>
                          <br />
                          <h:outputText value="tokens 1-used "></h:outputText>
                          <hr>
                       </a4j:outputPanel>
                       <br />
                       <rich:spacer width="1" height="15" />
                      <div align="right">
                          <rich:datascroller maxPages="200" id="pinlesscroller" for="pinless"/>
                          <rich:dataTable
                             onRowMouseOver="this.style.backgroundColor='#F1F1F1'"
                             onRowMouseOut="this.style.backgroundColor='#A1A1A1'"
                             cellpadding="0" cellspacing="0"
                             width="600" rows="3" border="0" var="Pinless" value="#{wdmbean.tok1}"
id ="pinless" >
                             <rich:column rendered="false" colspan="4">
                                <f:facet name="header">
                                   <h:outputText value="PINLESS" />
                                </f:facet>
                             </rich:column>
                             <rich:column breakBefore="true" >
                                <f:facet name="header">
                                   <h:outputText value="token allocation code" />
                                </f:facet>
                                <h:outputText value="#{Pinless.token}"></h:outputText>
                             </rich:column>
                             <rich:column>
                                <f:facet name="header">
                                   <h:outputText value="duration (days)" />
                                </f:facet>
                                <h:outputText value="#{Pinless.datatime}"></h:outputText>
                             </rich:column>
```

The Role of Mobile Phones and Public perceptions for Community Policing in Tanzania

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ABSTRACT

Information and communication technology (ICT) has been reported to increase the efficiency and effectiveness of various sectors and industries. This goes along with the aims of community policing is to enhance efficiency and service delivery in providing security in a society. ICT can also increase the effectiveness of community policing processes. However, the role of ICT, particularly mobile phones, in Tanzanian community policing has not been studied. The aim of the study was to establish the role of mobile phones and public perceptions in Community Policing activities. A survey of community members using a structured questionnaire was conducted. The results of the study show that in terms of ICT tools, mobile phones are playing the biggest role compared with all other ICT tools as a means of reporting crime incidents, accounting for a statistically significant proportion ($p<0.01$). It is however surprising to find that the majority (57.2%) of the respondents who reported crimes faced social disturbances as a consequence of providing information to the police force.

Key words: Mobile phones, Public perceptions, Community policing, Information and Communication Technology (ICT), Dodoma, Tanzania

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1. INTRODUCTION

1.1 Community Policing and ICT

The objective of Community Policing is to enhance police-community partnerships in solving problems related to crime, fear of crime, social and physical disorder within their localities. This objective can be achieved through: (i) enhancement of efficient police service delivery; (ii) enabling of joint problem

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identification and solving through effective police-community communication and interaction; (iii) improvement of local policing through the establishment of Ward Police and (iv) improvement of trust and confidence between the police and the community [Dominique 2010]. In 1994, the Community Policing Consortium of the United State of America Department of Justice, Bureau of Justice Assistance (BJA), proposed four goals for Community Policing initiatives: (i) to reduce crime and disorder, (ii) to promote citizens' quality of life, (iii) to reduce fear of crime, and (iv) to improve police–citizen relations. In order to achieve these goals an efficient and effective means of communication is necessary.

The potential benefits of Community Policing include: (i) preventing and reducing crime as well as fear of crime; (ii) reducing disorder and anti-social behaviour; (ii) increasing feelings of safety; (iv) improving police-community relationships as well as improving police - community accountability. Other benefits are: reducing corruption in the police service; enhancing respect for human rights; and increasing the community's capacity to deal with local problems and changes in police officers' attitudes and behaviour towards policing [URT, 2010].

Community Policing in Tanzania started as "*Sungusungu*" (a people's Militia) which was established by the People's Militia Law of 1973 (amended in 1989). *Sungusungu* was a type of Community Policing adopted by African countries such as Kenya and Tanzania [Heald, 2002]. This can be treated as the way of involving community members in policing activities with the aim of working together in order to fight against crime. According to the Ministry of Home Affairs (MHA) (2012), the core functions for the Tanzania Police Force are stated under section 5 of the Police Force and Auxiliary Service Act Cap 322 which states that "*The Force shall be employed in and throughout the United Republic for the preservation of peace, the maintenance of law and order, the prevention and detection of crime, the apprehension and guarding of offenders and the protection of property, and for the performance of all such duties shall be entitled to carry arms".* Community Policing can be regarded as a strategy of achieving police force core functions through the participation of Community members. According to Mwema [2008], most of democratic societies consider that law enforcement is a shared responsibility between the institutions that are directly responsible for law enforcement and community members.

In order for community policing to be effective and efficient, a fast means of communication is required. Meanwhile the adoption and the use of Information and communication technology (ICT) including mobile phones in various sectors have been reported to increase work efficiency and effectiveness [Sife et al. 2010, Forlin et al 2008]. Furthermore, public perceptions of the community in question can play a big role in influencing the decisions to adopt and use the technology. The use of ICT, particularly telephone services, has revolutionized policing activities in different places. In the United States of America telephones are available 24 hours everyday for seven days to serve the public problems such that citizens simply pick up the phones and inform police officers about crime incidents [Meghan 1999].

In Tanzania, the role and public perception of mobile phones in community policing has not been studied. Despite the fact that studies on this matter do not appear in the literature, a report from the Tanzania Communication Regulatory Authority (TCRA) (2011), shows that mobile phone subscriptions stood at 23.97 million in September 2011. Based on the Tanzania National Bereau of Statistics (TNBS) (2012), it is estimated that by 2012, the populations of Tanzania is 45,798,475. Mobile phone subscriptions therefore represent approximately 52% of the Tanzanian population. This means mobile phones has become very important means of communication.

Although research has not validated the use of mobile phones by Tanzanian subscribers in Community Policing activities, the police force in Tanzania has published mobile numbers which members of the community can call to report crime incidents [TCRA 2006]. The Police office in the Dodoma region has

also circulated mobile numbers to which citizens can send text messages to report any crime incident to police officers.

This study therefore intended to validate and establish the role that mobile phones have in Community Policing as well as to determine the public perceptions of members of the community on the use of mobile phones and community policing activities.

1.2 The Use of Mobile Phones

In policing activities, mobile technology has been employed to provide information in process of policing. Bouwman et al. [2008] claim that timely information is crucial to police officers in carrying out daily duties. Because police organisations are 'intelligence-led' and information-intensive, mobile phones can be very useful supporting policing activities. Mobile applications can bring in effectiveness and improved performance leading to an innovative image of the police service. Mobile technologies provide timely access of accurate information, minimize administrative work by police officers, and improve communication and quick retrieval and transmission of relevant information.

The use of mobile technologies aim to reduce manual work that involves working with paper files and moving them from one place to another. Mobile devices have enhanced the carrying out of a number of functions efficiently and effectively [Hampton and Langham 2005; Allen at al. 2008].

The use of mobile information systems by the police in the United Kingdom (UK) has transformed the activities of the police force. Hampton and Langhan [2005] indicated that smart phones in UK are used to reduce paperwork and cut the duplication of effort by giving officers out on the beat the opportunity to access information and to report activities.

Graham [2008] carried out a study which was commissioned by the Bedfordshire Police. His study revealed that 82% of police officers thought that the smart phone solution assisted them in doing their job and 75% of them indicated that it would negatively impact them if the force were to abandon the use of smart phones. In addition, the force experienced a 10% increase in the time officers spent patrolling the streets. Furthermore, Graham [2008] reports that the move towards making police forces more efficient was illustrated first in a national study commissioned by the Home Office back in 2001 entitled "Diary of a Police Officer". The study indicated that on average officers were spending almost as much time in the police station as they were on the streets. The report concluded that police forces should strive to use mobile technology.

1.3 Problem Statement

Mobile technologies can play a role in security planning and operations such as patrol activities. They can enable patrol officers to access real-time information and file reports via laptops or through personal communication devices e.g. personal digital assistants (PDA) and smart phones. Mobile technology can minimize the routine paper work that must be done at the station or police headquarters thus reducing the amount of time that officers must be out of service [Graham 2008]. The success of community policing depends largely on convenient, efficient and effective means of communication so as to build a good relationship between the community and the police force. This requires fast and reliable means of communication for the relationship to exist and for provision of the opportunity to report crime activities. This means mobile phones have the potential to enhance community policing in Tanzania. Furthermore the public perceptions and awareness of the community play a great role in advancing the objectives of security in the society.

While mobile phones can play a big role in community policing the extent of use of mobile phones for this particular purpose is not known in Tanzania. Furthermore, the public perceptions of the Tanzanian

community on the use and role of mobile phones has not been investigated. As a matter of facts, it is difficult to put forward a strategic plan by the law enforcers on enhancing security and peace through community policing. This study therefore intends to close this gap by determining the role of mobile phones in Community Policing as well as the public perceptions of the society.

1.4 Objectives

1.4.1 General Objective

To establish the role of mobile phones and public perceptions in community policing

1.4.2 Specific Objectives

1. To determine the extent of use of mobile phones in Community Policing
2. Establish the public perceptions of community members in Community Policing

1.5 Organisation of the Paper

The rest of this paper is organised as follows. The following section introduces the methodology that was adopted in this study. Section 3 presents results and discussion. The last section provides the conclusion and topic for future study. Furthermore, a questionnaire used in this study is attached as appendix A for reference of interested readers.

2 METHODOLOGY

2.1 Study Area Description

The study was conducted in Dodoma Municipality and Bahi as well as Chamwino district. Dodoma Municipality covers an area of 2,669 square kilometres [Bidya 2007]. Based on the 2002 National Population and Housing Census, the population was 324,347 people [Bidya, 2007]. The municipality is subdivided in four divisions namely; Urban, Hombolo, Kikombo and Zuzu. The main activities of the residents are commerce, farming, civil service employment and livestock keeping.

2.2 Sampling, Data Collection and Analysis

A total of 194 respondents were randomly selected. The sample size was determined based on financial resources constraints. A structured questionnaire was administered to collect data from the randomly selected the respondents. Data analysis involved coding, data entry to a statistical package namely SPSS (Statistical Package for Social Sciences data analysis program (SPSS v.17)). Computation of descriptive statistics such as frequencies, percentages and averages was done. Determination of statistical significance of the proportion of citizens who use mobile phones to report crime incidence was done as well.

3 RESULTS AND DISCUSSION

3.1 Demographic Characteristics of Respondents

Demographic characteristics have an important role in Community Policing since they provide

Table 1: Characteristics of Respondents

Variable Measured	Percentage (N=194)
Age	
Below 25	24.2
25-40	63.9
41-55	10.8

Variable Measured	Percentage (N=194)
Above 55	1.0
Gender	
Male	60.8
Female	39.2
Occupation	
Business People	34.0
Employed Workers	55.2
Peasant	10.8

the background and suitability of the population. The demographic characteristics of the sampled respondents are summarized in Table 1. In this Table it can be observed that a majority (63%) of respondents fall in the range of 25 – 40 years of age. This is a good representation of the adult population because the average life expectancy of Tanzanian is 58 (UN-HDR 2011).

It can further be observed that males (60.8%) outnumbered females (39.2%) due to the fact that the questionnaire was administered at work places where fewer women work outside the home in towns like Dodoma. This is common in African societies.

In terms of the occupation of the respondents, Table 1 indicates that the majority (55.2%) of the respondents are employed in different sectors within the region while 34.0% of the respondents are business people and 10.8% are peasants. Since the study was conducted in Dodoma municipality, this was expected as there are very few peasants in towns.

3.2 Community Policing Awareness

Awareness of community policing issues was measured by the number of respondents who have heard of Community Policing. Table 2 shows that a majority (83%) of respondents have heard of Community Policing (CP) while few (17%) of the respondents have not heard of CP. Then, the respondents were required to explain what they know about the CP.

A majority (55.9%) of those who had heard of CP were not able to explain what they know about CP, as shown in Table 3. This table shows that more effort is needed to create awareness of CP so that more people can participate. It is indicated that 44.1% of the respondents could explain CP. Those who could not explain CP said that they had heard about the concept but they never had an opportunity to be trained or given a seminar on CP. For many people to participate in CP, deliberate efforts are needed to sensitize and give them general understanding.

Table 2: Respondent's Awareness of Community Policing

Response	Frequency	Percentage
Yes	161	83.0

No	33	17.0
Total	194	100.0

Source: Field Survey Data

Table 3: Ability to Explain About Community Policing

Variable	Frequency	Percentage
Able to explain	71	44.1
Not able to explain	90	55.9
Total	161	100

Source: Field Survey Data

3.3 Means for Reporting Crime Incidents

Earlier we have shown that CP needs active participation of community members in various activities including communicating different information with police officers. This includes predicted crime incidents. Table 5 indicates that majority (53.6%) of the respondents have ever reported crime incidents whereas 46.4% have never reported such incidents. This might be a good indication that people are involved in CP by reporting crime incidents.

Table 4: Reporting of Crime Incidents by Citizens

Response	Frequency	Percent
Yes	104	53.6
No	90	46.4
Total	194	100.0

Source: Field Survey Data

Table 5 summarizes the common means used by the respondents for reporting crimes. In general, physical visit accounts for 40.7% while 20.6% of the respondents said that they report crime incidents using mobile phones. Other means, Radio Call and Letters, are least used with respondents with 0.5% and 2.1% respectively. Website, Fax, and Fixed Phones were not mentioned at all as means of reporting crime incidents. As far as ICT related technologies are concerned, mobile phones are playing a bigger role than all other ICT tools.

Table 5: Means of Crime Incident Reporting or Communication

Means used	Frequency	% of Who Have Ever Reported Incidents (N= 104)	Sample Overall Percentage (N=194)

Mobile	40	38.46	20.6
Fixed Phone	0	0	0
Radio Call	1	0.96	0.5
Website	0	0	0
Fax	0	0	0
Physical Visit	79	75.96	40.7
Letters	4	3.85	2.1

Source: Field Survey Data

We wanted to know whether there is a statistically significant difference between those who use mobile phones as a means of reporting incidents and those who use other means. The null hypothesis was: there is no significant difference between the proportion of citizens who use mobile phones and those who use other means. Analysis found that the difference is statistically significant ($p<0.01$).

Mobile phones are playing the biggest role among all ICT tools probably due to the fact that about 52% of the population in Tanzania are subscribers. Furthermore there is no interactive website which could be used to report crime incidents or the society is not aware of any such website.

In addition, the Police Force has publicized the official mobile numbers through which people can report crime incidents at any time. The number given out by the Police Force can be used for sending short messages to police officers reporting crimes. Mobile phone text messaging is a potentially powerful tool for promoting community policing thereby increasing security and peace in the country. Text messages are less expensive and can instantly reach a person. It is suggested that the police force should take advantage of this in improving the situation for better community policing.

3.4 Perceived Problems after Reporting Crime Incidents

In Table 6, we report that a majority (57.2%) of the respondents who reported crime incidents perceived problems as a consequence. This is more than half of the respondents. In other words for every two respondents at least one who reported a crime incident perceived problems. This situation is not desirable in the process of promoting CP. As a matter of fact, CP must create mutual trust between the police and the community members. Therefore, many people might be shying away from giving out any crime information if the environment is not changed.

Table 6: Respondents Who Perceived Problems after Reporting Crime Incidents

Response	Frequency	Percent
Yes	111	57.2
No	83	42.8
Total	194	100.0

Source: Field Survey Data

Table 7: Perceived Problems by Respondents After Reporting Crime Incidence

	Type of Problem Perceived	Frequency	Percentage (N=111)
1	Delayed response	23	20.72
2	Requested to bribe	15	13.51
3	Asked for Transport	6	5.4
4	Asked for Fuel	1	0.9
5	No action taken	12	10.81
6	Threatened	6	5.4
7	Disturbed	4	3.6

Source: Field Survey Data

Table 7 shows that 5.4% of the respondents were threatened. The threats were from the people whom they had reported to the police. It raised a concern that, the information they gave might have been released to criminals through the police officers. In addition, 3.6% of the respondents said they were disturbed by the police officers - that every time they meet the officers, they had to give something them something like buying them a meal, while 13.51% had even been requested to given a bribe.

This result gives an indication that more than half of the population do not trust the police officers. Their perspective is that when you communicate with the police force, you are inviting trouble into your life. One example is when the respondent explained: "*Giving information to police officers causes troubles in our lives. There is no need to report crime incidents to police officers, for they disturb us unnecessarily. It happens that if someone reports an incident sometimes police officers can instruct the person reporting to come to the station several times in the process of proving the reported incidence. We are trying to help but they (police) don't acknowledge our help*". This situation is not desirable in creating mutual trust and good working relationships. The police force must tighten the rules they have set to make the police officers accountable.

In Table 7, one critical thing can be observed. 20.72% of the respondents found that action is not always taken in time. Furthermore, respondents mentioned a situation that they report incidents but no action is taken. This accounts for 10.81% of the respondents who perceived a problem. This is a question of the inefficiency and ineffectiveness of the police force. In total 31.53% of the respondents are not satisfied with the efficiency and effectiveness of the police military force in Tanzania. This suggests that something has to be done to rectify the situation. One of the recommendations from this study is to utilize ICT in improving efficiency and effectiveness as described in Baker's [2008] work.

Table 8: Views on Trusting Police Officers

Response	Frequency	Percent
Yes	62	32.0
No	76	39.2
To some extent	56	28.9
Total	194	100.0

Source: Field Survey Data

Table 8 shows that 32% of the respondents do trust police officers whereas 39.2% of the respondents do not trust police officers and 28.9% trust the police officers to some extent. In strict sense, 68.1% of the respondents said they do not trust the police officers. These results imply that there are issues which do not satisfy the community.

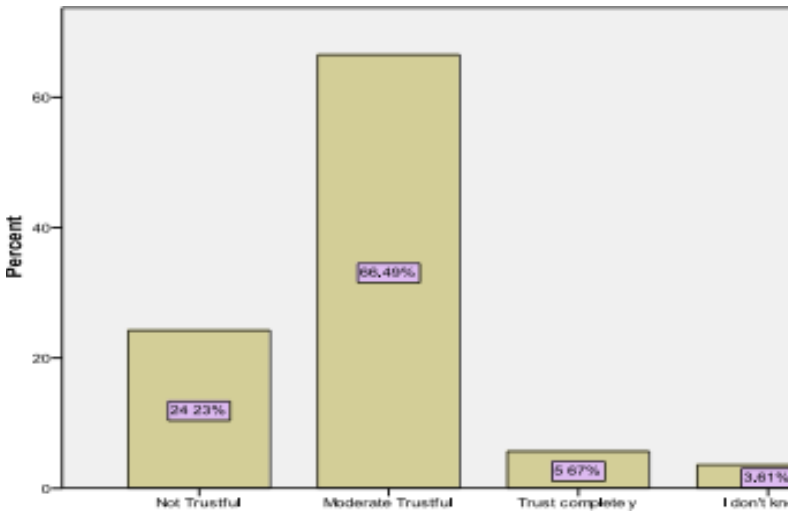

Figure 2: Extent of Trust shown to Police

Source: Field Survey Data

Figure 1 shows that, 66.49% have moderate trust in police officers whereby only 5.67% have complete trust in police officers. This situation is not conducive for creating mutual trust and respect without fear for both police officers and citizens. In order to build an efficient and effective community policing, citizens are required not to fear police officers. On the other hand police officers must be trustworthy so that there should be a conducive working environment.

4 CONCLUSIONS, RECOMMENDATIONS AND FUTURE WORK

4.1 Conclusions

We have discussed the role of mobile phones and public perceptions in Community Policing. A greater portion (20.6%) of respondents uses mobile phones to report crime incidents than other technological means. Our statistical analysis indicates that the proportion is significance ($p < 0.01$). This calls for the police force to make fuller use of this technology including setting up a computerized system which would remove manual processing of reports. It also calls for the authority to create awareness of the public mobile

phone numbers among a very large number of community members. On the other hand there is a negative perception of the police force in the Tanzanian society. Efforts are needed to change this situation.

4.2 Recommendations

Although a large proportion (83%) of the respondents acknowledged hearing about community policing, only 44.1% of them could explain what they know about it. More work on awareness creation and education is therefore needed. Strategies including seminars and workshops can be taken into consideration in order to impart enough knowledge about CP.

In addition, there is a need to utilize all avenues for the use of Information and Communication Technologies including establishing an information system which is interactive. This can contribute to the reporting process.

Respondents have indicated that they have negative attitudes towards the police force, which depends on them to bring efficiency to community policing. Efforts are required to change this situation since this is a detrimental perception in promoting peace and security.

4.3 Future Work

In this paper, we have investigated the role of mobile phones and public perceptions for community policing in Tanzania. The paper has not attempted to address the relationship between crime rate and the increase of number of users using mobile phones to report crime incidents. In future, it might be necessary to have a study on this matter. However, getting the data on crime rates in Tanzania over the years it might be a challenge. This is because considerable efforts have been made to obtain data without success.

Another area of study can be investigating the challenges that the police force is facing in adopting ICTs particularly mobile information systems. Such a study could propose steps to be taken for improved efficiency and effectiveness of policing activities.

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Appendix A: Questionnaire

Please you are requested to choose from the list by ticking (□) wherever appropriate or write in the space provided.

1. Please indicate your sex: (a) Male (b) Female

2. What is your age group: (a) Below 25 years (b) Between 25 and 40 years (c) Between 41 and 55 years (d) Above 55

3. What is your occupation? .....

4. Have you ever heard of Community Policing? (a) Yes (b) No

5. If you answered Yes in 4, could you please explain what you know about Community Policing? .....

6. Have you ever reported any crime incident to police officers? (a) Yes (b) No

7. Which means of communication did you use in reporting? (*Multiple selections are allowed*): (a) Mobile phone [ ] (b) Fixed telephone [ ] (c) Radio call [ ] (d) Email [ ](e) Website [ ] (f) Fax [ ] (g) Physical visit [ ] (h) Other (s*pecify)* .....

8. When you reported crime information to police officers, do you think there were any problem faced as a result of the information you gave? (a)Yes (b) No

9. If the answer is Yes in (8), state or list the problems .....

10. Do you trust your police officers? (a) Yes (b) No (c) To some extent

11. To what extent do you trust your police officers? (a) Not trust [ ] (b) Moderate trust [ ] (c) Trust completely [ ] (d) I do not know [ ]

Does Use of ICT Relate with the way it is Perceived? Evidence from Makerere University

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ABSTRACT

The survey sought to establish how perceived relative advantage, computability, user friendliness and observability related to use of ICT. Quantitative data was collected from 145 teachers, 124 administrators and 175 students using a questionnaire, whose validity and reliability were assessed using Confirmatory Factor Analysis and Cronbach's alpha respectively. Descriptive analysis was done using percentages and means, while hypotheses were tested using Multiple Regression. Results suggested that perceived relative advantage, user friendliness and observability were significant positive correlates of use of ICT, while perceived compatibility was not. These findings imply that to enhance ICT adoption in the University, ICT change agents have to raise and maintain perceived relative advantage of ICT among teachers, senior administrators and graduate students via training. They should acquire user friendly ICT whose user interfaces (e.g. screens) give clues to users on what to enter and how to enter, in addition to being accompanied by user manuals. The change agents should enhance perceived observability of ICT, during training, by bringing out vivid examples of teachers, senior administrators and graduate students in other universities that have benefited from integrating ICT in their respective endeavours as employees and clients of universities.

General terms: Higher education, ICT, innovation adoption, Makerere University, perceived innovation characteristics, regression

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1. INTRODUCTION

Scientific Management Theory propounded by Taylor [1910 cited in Mullins, 2010] asserts that to increase productivity and efficiency of employees for example, employees should work like or with machines. By extension, embracing machines such as ICT, productivity and efficiency of students should equally be

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enhanced. Basing on such assertions, many institutions in Uganda such as Makerere University have embraced ICT such as computers, with among other aims the intention of improving productivity and efficiency of employees and students. Unfortunately however, use of ICT in Makerere University has consistently been reported to be very low [e.g. Asiimwe, 2011 April 18 – 24; Makerere University, and; McGregor, 2007]. For example Asiimwe [2011, April 18 – 24] in the *East African* newspaper, quoted the Vice Chancellor of the University as decrying the non-use of online library services by students, thus;

> "Professor Baryamureeba says [that] students rarely use… [online] publications and some of the publishers are raising queries about this. He says [that] Makerere subscribes to 10,000 e-books and e-journals, which students have access to as long as they are within Makerere Campus. However, only a few students use them."

The Makerere Strategic Plan 2008/ 09 – 2018/ 19 (Makerere University, nd) Strategic Objective Two on ICT is "to promote effective and appropriate utilization of ICT resources by end of 2013" (p. 21), which implies that right now utilization of ICT resources in the University is not effective and appropriate. The report of the latest Visitation Committee to Public Universities in Uganda [McGregor, 2007] while on pages 23-24 (Subsection 2.1.3) noted with appreciation ICT – based teaching and learning initiatives in Faculties of Medicine, Agriculture and Computing and Information Technology, still concluded by observing that "widespread use of ICTs in teaching and learning… [in the University] is still constrained" (p. 24).

This failure to make optimal use of ICT in the University leads to several undesirable outcomes such as wastage of funds the University and donors have sank on underutilized or even unutilized facilities. Table 1 gives planning budgets for different ICT projects as per the Makerere University ICT Policy and Master Plan for the period 2000 to 2004 [Makerere University, 2001]. The aggregate budget sum of $10.7 million is really huge especially by standards of a developing country such as Uganda. Table 2 shows funds mobilized during the July 2000 and July 2004 period as per the ICT Policy and Phase II of the Master Plan (Makerere University, 2004). The total figure of $ 8.47 million is testimony that donors and Makerere itself have committed large sums to the cause of ICT. It was therefore appropriate to isolate the reasons why teachers, administrators and students in Makerere University were slow to embrace use of ICT.

Table 1. Planning budgets for different ICT projects in Makerere University, 2000 - 2004

Project	$'000
Skills training for end users	600
Library Information System (MakLIBIS)	300
Academic Registrar Information System (ARIS)	300
Finance Information System (FINIS)	300
Human Resource Information System (HURIS)	200
General Data Communication Infrastructure (backbone)	1,500
E-mail and Internet/ Intranet Access	350
Office Automation and Student Computers	6,600

Development of ICT Resource Management Unit	550
Total	10,700

(Source: Makerere University, 2001, ICT Policy and Master Plan, p. 6).

Table 2. Funds mobilized toward ICT by Makerere University, July 2000 to July 2004

Funding agency	$'000
USAID/ Leland Initiative/ Avaya/ Hewlett Packard	800
NORAD	1,100
Sida/ SAREC	3,300
Government of Uganda (African Development Bank Loan)	1,000
NUFFIC (E-learning pilot training)	120
Makerere University (Internally generated funds)	1,000
Carnegie Corporation (support to Main Library)	650
Various partners working through different faculties (computers and LANs)	500
Total	8,470

(Source: Makerere University, 2004, ICT Policy and Phase II of the Master Plan, p. 18).

2. THEORETICAL BASIS

The theory chosen to underpin this study, is Innovation Diffusion Theory (IDT) proposed by Rogers in 1958 after his doctoral studies [1953-1957] on adoption of agricultural innovations at Iowa State University, US. According to Rogers [2003], the theory stipulates that an individual's propensity to adopt or use any innovation, depends on the way that individual perceives the innovation in terms of its relative advantage, compatibility, user friendliness and observability. If the individual perceives the innovation to have relative advantage over similar products or services say in terms of speed of performance, then that individual will have high propensity to use the innovation. If the individual perceives the innovation to be compatible with the individual's work and interests, then that individual will have high propensity to use the innovation. If the individual perceives the innovation to be user friendly, then that individual will have high propensity to use the innovation. If the individual perceives that innovation to be observable, that is to have observable impact on work of colleagues, then that individual will have high propensity to use the innovation. On the basis of IDT, this study proposed that use for ICT (an innovation) by staff and students in Makerere University could be related to the way the staff and students perceived it (ICT) in terms of its relative advantage, compatibility, user friendless and observability.

3. RELATED LITERATURE

3.1 Perceived relative advantage and use of innovations

In his Innovation Diffusion Theory (IDT), Rogers [2003] defines perceived relative advantage (PRA) as the "degree to which an innovation is perceived as being better than the idea it supersedes, … [and] is often expressed as economic profitability, as conveying social prestige" (p. 229). It can also be measured in terms of convenience and satisfaction [Kelleher & Sweetser, 2012]. The greater the perceived relative advantage (PRA) of an innovation, the more rapid its use [Rogers, 2003]. Past studies relating PRA and use of innovations are very many [e.g. Hung, Hung, Tsai & Jiang, 2010; Kok, Kee, Ping, Khalid & Yu, 2011; Rezaei-Moghaddam & Salehi, 2010; Safeena, Date & Kammani, 2011]. For example Hung et al [2010] in their study of critical factors of adoption of customer relationship management (CRM) by hospitals in Taiwan, used Discriminant Analysis to establish that PRA had a significant influence on adoption of CRM.

Kok et al [2011] used Multiple Regression to identify determinants of internet adoption in Malaysian audit firms, and established that "perceived usefulness" (PU), synonymous with PRA [Davis, 1989] was a very significant determinant of internet adoption. Rezaei-Moghaddam and Salehi [2010] used Structural Equation Modeling to establish that perceived usefulness (PU) influenced intention to adopt "precision agricultural technologies" by agriculturalists in Khunestan and Fars Provinces in Iran. Safeena et al [2011] in their study of adoption of internet banking among students in an educational institute in India, used Regression Analysis to establish that PU synonymous with PRA was a positive correlate of internet banking adoption. Thus evidence in support of PRA as a positive correlate of innovation is massive. Given the overwhelming empirical evidence in support, in this study it was accordingly hypothesized that:

H1: Perceived relative advantage (PRA) positively correlated with use of ICT.

3.2 Perceived compatibility and use of innovations

According to Rogers [2003], perceived compatibility (PC) is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters. Rogers [2003] contends that an innovation can be compatible or incompatible with (i) socio cultural values and beliefs (ii) previously introduced ideas and/ or (iii) client needs for the innovation. Perceived compatibility is positively related to its rate of use [Rogers, 2003] in that an idea that is more compatible is less uncertain to the potential user and fits more closely with the individual's situation. Such compatibility helps the individual to give meaning to the new idea so that it is regarded as more familiar. Studies relating perceived compatibility (PC) and use of innovations can be found. For example Amutabi and Oketch [2003] in their qualitative study based on document review used lack of compatibility to explain why adoption of the African Virtual University (AVU) in Kenya had not succeeded. For example they observed that:

> In the case of AVU, one should find out if the working environment of the graduate will be an internet area as required by the AVU or in deep rural areas where there is no access to the Internet…. As an internet-dependent education system, its relevance to rural Kenya is out of the question (p. 63).

Azam and Quaddus [2009] in their quantitative study based on Rogers' Innovation Diffusion Theory (IDT), used Multiple Regression to establish that PC was a positive correlate of adoption of e-commerce by small and medium enterprises (SMEs) in Bangladesh. Garcia-Valcarel and Tejedor [2009] in their study of training demands of lecturers related to use of ICT in the University of Salamanca, Spain established lack of PC as a negative correlate of adoption of ICT. For example from their interviews with teachers, they established that "lecturers who do not use them [ICT] included among their reasons, lack of time, too many students and lack of knowledge" (p. 179). These issues reportedly lacking are aspects of Rogers' PC of ICT. Kelleher and Sweetser [2012] in their qualitative study of social media adoption among university communicators in Southeastern and Pacific Universities, established that PC was among main attributes that drew participants to adopt social media.

Poon, Blumenthal, Jaggi, Honour, Bates and Kaushal [2004] in their study of overcoming barriers to adopting and implementing computerized physician order entry systems (CPOE) in US hospitals, used interviews to establish that absence of PC was a major barrier to adoption. They noted that

> informants reported that many current vendor products did not fit the needs of their hospital, and extensive software modifications were required to accommodate workflow in the hospital…. CIOs [chief information officers] in hospitals with prior failed attempts at CPOE implementation recounted how poorly designed user interfaces and unacceptable processing speeds rendered early versions of CPOE unusable.

In other words, evidence postulating PC as a positive correlate of innovation adoption is massive. Hence in this study, it was postulated that:

H2: Perceived compatibility (PC) positively correlated with use of ICT.

3.3 Perceived user friendliness and use of innovations

In his Innovation Diffusion Theory (IDT), Rogers [2003] preferred to use the opposite of "perceived user friendliness" (PUF), namely "perceived complexity" which he defined as the "degree to which an innovation is perceived as relatively difficult to understand and use" (p. 257). However to avoid using a term "perceived complexity" which has negative connotation, while the other four independent variables (perceived relative advantage, compatibility and observability) have positive ones, in this study, picking a cue from Eason [1988 p. 133], the opposite term, "perceived user friendliness" (PUF) was used. PUF is the degree to which an innovation is perceived as relatively easy to understand and use. Eason [1988] also refers to Rogers' PUF as "usability" of a system, which he defines as the system offering its functionality in such a way that the planned users will be able to master and exploit it without undue strain on their capacities and skills.

Past studies that have positively related PUF and use of innovations are many [e.g Kok et al, 2011; Rezaei-Moghaddam & Salehi, 2010; Safeena et al, 2011]. Kok et al [2011] used Multiple Regression to identify determinants of internet adoption in Malaysian audit firms, and established that PEU was a positive correlate of internet adoption. Rezaei-Moghaddam and Salehi [2010] used Structural Equation Modeling to establish that perceived ease if use (PEU), a synonym of PUF [Davis, 1989] positively affected intention to adopt "precision agricultural technologies" by agriculturalists in Khunestan and Fars Provinces in Iran. Safeena et al [2011] in their study of adoption of internet banking among students in an educational institute in India used Regression Analysis to establish that PEU was a positive correlate of adoption of internet banking. From the above literature, the study postulated that

H3: Perceived user friendliness (PUF) positively correlated with use of ICT.

3.4 Perceived observability and use of innovations

Perceived observability (PO) is the degree to which results of an innovation are visible to others [Rogers, 2003]. Thus PO can also known as perceived communicability or describability of an innovation. Rogers [2003] observes that whereas some ideas are easily observed, communicated or described to other people, other innovations are difficult to observe, communicate or describe to others [Rogers, 2003]. For example, the innovation in this study, ICT, has two components; (i) hardware which is the physical parts of ICT, and (ii) software that consists of the instruction base for the technology. Thus the software component of a technological innovation (e.g. ICT) is not so apparent to observation. So innovations in which the software aspect is dominant possess less observability, and usually have a relatively slower rate of use [Rogers, 2003].

The observability of an innovation, as perceived by members of a social system (i.e. a set of interrelated units that are engaged in joint problem solving to accomplish a common goal, such as stakeholders in a university), is thus positively related to its rate of use [Rogers, 2003]. Studies relating perceived observability (PO) and use of innovations [e.g Azam & Quaddus, 2009; Poon et al, 2004; Putzer & Park, 2010; Rezaei-Moghaddam & Salehi, 2010] can be found. In particular, Azam and Quaddus [2009] in their study of small and medium enterprises (SMEs) in Bangladesh used Multiple Regression to establish that PO significantly related to willingness to adopt e-commerce. Poon et al [2004] in their study of overcoming barriers to adopting and implementing computerized physician order entry systems (CPOE) in US hospitals, used interviews to establish that absence of PO was a major barrier to adoption.

For example, they found that few vendors had established a track record of successful implementation in more than a few hospitals, and several chief information officers (CIOs) accused vendors of selling 'vapourware', referring to software functionality that was promised but never delivered. Putzer and Park [2010] in their study of effects of innovation factors on smartphone adoption by nurses in community hospitals in Southeastern United States, established that PO was a significant predictor of attitude toward using a smartphone. Rezaei-Moghaddam and Salehi [2010] used Structural Equation Modeling to establish that PO influenced intention to adopt "precision agricultural technologies" by agricultural specialists in Khunestan and Fars Provinces in Iran. From the above literature, the study postulated that;

H4: Perceived observability (PO) positively correlated with use of ICT.

4. METHODOLOGY

4.1 Measures

Using a quantitative approach and correlational survey design, data were collected using a self-administered questionnaire [SAQ, Appendix A] specifically developed for the study. As Appendix A illustrates, the SAQ had three sections, the first being for background variables, namely category of respondent (teacher, administrator, student), age and sex. The second section was on perceived characteristics of ICT, namely its perceived relative advantage (five items), compatibility (five items), user friendliness (seven items) and observability (five items). Respective scale items were developed based on existing literature. All items in the section were scaled using the five-point Likert in such a way that a minimum of 1 represented the worst case scenario (strongly disagree) while a maximum of 5 stood for the best case scenario (strongly agree). The third section (Appendix A) corresponded to the dependent variable, use of ICT operationalized as frequency of use of personal computer applications software (six items) and internet facilities (eight items). All items in the section were scaled using the five-point Likert from a minimum of 1 for the worst case scenario (very rarely or never) to a maximum of 5, which stood for the best case scenario (very regularly).

4.2 Population

The target population in the study were all the 1,200 teaching staff, 200 senior administrators and 1,700 graduate students in Makerere University. All the above categories constituted the population because although ICT started as "sophisticated" tools for scientists only, they are now tools for everyone. Junior workers and undergraduates however, were not considered on account of their apparently low interface with ICT. Due to time, cost and other constraints, the researcher found it more convenient to carry out the study on part of the target population, which was more accessible, which hence became the "sampled population". These were 1,000 full-time teaching, 200 senior administrators and 850 first year graduate students. Part-time lecturers were excluded because of their perceived little time to access and use ICT facilities in Makerere University given that they usually just time lectures and leave the University

immediately after. All senior administrators were considered accessible, given the sedentary nature of most of their jobs. First year graduate students were chosen because they were still attending lecturers and therefore still traceable. In Makerere, after graduate students finish coursework, tracing them is a tall order as they return to their places of work and only do research on part-time basis.

4.3 Sample

For the respective three sub-populations of respondents (i.e. 1,000 teachers, 200 senior administrators and 850 first year graduate students), Krejcie and Morgan [1970 Table, cited in Gay & Airasian, 2003] suggested minimum samples of size 278 lecturers, 132 senior administrators and 265 graduate students respectively. To attain the respective sample sizes from the three sub-populations, the researcher used two-stage (stratified-cum-cluster) sampling, whereby in the first stage, "academic units" that is schools, faculties or institutes were stratified into three. First, the technological sciences which were most inclined to ICT. These were Faculty of Computing & Information Technology; East African School of Library & Information Science; Faculty of Science; Institute of Statistics and Applied Economics; and Faculty of Technology. The second stratum was that of Arts/ Humanities which were least inclined to ICT. These were the Institute of Adult & Continuing Education; Faculty of Arts; School of Education; School of Fine Art; Institute of Languages; Faculty of Law; Institute of Psychology; Institute of Social Research; and Faculty of Social Sciences.

The third stratum was that of academic units in between the two earlier extreme strata. These were considered to be Faculty of Agriculture; Faculty of Economics & Management; Faculty of Forestry & Nature Conservation; School of Medicine; Institute of Public Health; and Faculty of Veterinary Medicine. Then in the second sampling stage, each academic unit in a given stratum became a "cluster" which was presumably "homogeneous" as far as ICT adoption was concerned. Then two representative clusters were randomly selected from the respective "cluster strata" as follows; Faculty of Computing & Information Technology and Faculty of Technology, later supplemented with Faculty of Science and Institute of Statistics & Applied Economics on account of slow and low response from the first "cluster stratum". Faculty of Agriculture and Faculty of Veterinary Medicine, later supplemented with School of Medicine from the second "cluster stratum". From the third "cluster stratum", School of Education and Faculty of Law were chosen.

Thus the sample sizes for the chosen "clusters" were as in Table 3. Following a principle of "cluster sampling" which dictates that each member in a chosen "cluster" automatically becomes a respondent [Gay & Airasian, 2003], and factoring in the expected non-response, all the 804 teachers, 27 administrators and 533 first year graduate students as shown in Table 3, received questionnaires. However according to Table 4, the majority of administrative staff were in purely administrative departments. And while the required minimum sample size for these administrators was 132 as suggested by Krejcie & Morgan [1970 Table, cited in Gay & Airasian, 2003], as per principles of "cluster sampling" and factoring in possible non-response, all those 196 administrators (Table 4) and 27 in schools (Table 3) received questionnaires.

4.4 Response rate

The overall response rates were as shown in Table 5, which reveals that in relative terms, administrators were the most wiling participants (94%) followed by graduate students (64%) and trailed by teachers (52%). Overall, of the required minimum 675 questionnaires, the study achieved 444 (66%). Such a response rate compared favourably with Aguila-Obra and Padilla-Melendez [2006] who in their study of "organizational factors affecting internet technology adoption" in Spanish firms, got back only 280 (7%) of the 4000 questionnaires sent.

Table 3. Academic units chosen as clusters and corresponding numbers of respondents in them

Cluster	Teachers	Administrators	First year graduate students
Technological			
Computing & Information Technology*	40	3	27
Technology *	85	3	18
Statistics & Applied Economics**	43	3	67
Science *	123	3	27
Subtotal	291	12	139
Middle –ground			
Agriculture*	114	3	48
Veterinary Medicine *	92	3	13
Medicine ***	186	3	61
Subtotal	392	9	122
Arts/ Humanities			
Education ***	80	3	160
Law *	41	3	12
Subtotal	121	6	172
Grand total	804	27	533

* Faculty of…. ; ** Institute of….; *** School of….

Table 4. Makerere's senior administrators excluding those in schools

Administrative unit	Number
Academic Registrar's Office	38
Agricultural Research Institute, Kabanyoro	3
Dean of Students Office *	43
Directorate of ICT Support	8
Finance **	26

Main Library	22
Planning and Development	7
School of Graduate Studies	5
University Secretary's Office ***	23
Vice Chancellor's Office	10
Total	196

* Main Office (8); Chapels and Mosque (3); Counseling and Guidance (4); Halls/ Wardens (14); Hospital (12); Sports and Recreation (2);

** Bursar's Office (22); Internal Audit (14)

*** Main Office (12); Appointments Board (3); Estates/ Works (6); Printery (2).

Table 5. Response rates per category of respondents

Category	Intended	Attained	% Attained
Teachers	278	145	52
Graduate students	265	175	64
Administrators	132	124	94
Total	675	444	66

4.5 Data management

Because the respective scale items were specifically designed for the study, their validity or relevance and reliability, that is consistency with which respondents reacted to them had to be ensured. Validity was assessed using Confirmatory Factor Analysis while reliability was assessed using Cronbach's alpha. Descriptive analysis was done using relative frequencies and sample means, while inferential analysis involving testing the four study hypotheses was implemented using Multiple Regression.

5. RESULTS

5.1 Background of respondents

Table 6 gives the demographic profile of the study sample. The sample consisted of 175 (39.4%) graduate students, 145 (32.7%) teachers and 124 (27.9%) senior administrators. According to age, 39% were aged between 30 and 40 years, followed by those below 30 years (35.8%) and the rest (25.2%) was above 40 years of age. In terms of sex, males (66.1%) dominated the sample, which was characteristic of Makerere University.

Table 6. Demographic profile of respondents

Item	Frequency *	%
Category of respondents		
Teacher	145	32.7
Administrator	124	27.9
Graduate student	175	39.4
Age of respondent		
Below 30	148	35.8
30 but below 40	161	39.0
40 and above	104	25.2
Sex of respondent		
Female	147	33.9
Male	287	66.1

*Item total frequencies differ because of non-responses

5.2 Dependent variable: Use of ICT

Use of ICT, the dependent variable (DV), as suggested by Appendix A, was conceptualized in terms of "use of personal computer applications software" (UPC - six items), and "use of internet facilities" (UIF - eight items) respectively. Each item was scaled in such a way that 1 = Very rarely or never, including never heard of it; 2 = Rarely use; 3 = Neither rarely nor regularly; 4 = Regularly; and 5 = Very regularly. Table 7 presents the study items for the respective two constructs on the DV, namely UPC and UIF, their means, factors and Cronbach alphas.

5.2.1 Use of PC applications software

Except for item UPC1 (Word processing) which attained a good rating of use, means on all other items on UPC in Table 7 were at most "3" which on the rating scale used corresponded to "at most fair", and hence, poor levels of use of applications software. Factor Analysis suggested that the six items on UPC belonged to one factor, with an eigenvalue of 3.15, and explaining almost 53% of variance in the construct. Considering factor loadings above 0.5 as being high [Foster, 1998], it is apparent that the factor loaded highly on all items of UPC, meaning that all six items on UPC were valid. Cronbach alpha on the six items was 0.8174, which was high since it exceeded 0.7 [Hair, Anderson, Tathan & Black, 1998], meaning that the six items constituted a reliable measure. An overall index on "use of PC applications software" (UPC) yielded a mean of 2.62, which corresponded to "fair" use of PC applications software.

5.2.2 Use of internet facilities

Still in Table 7, except for items UIF1 (Email) and UIF2 (Web surfing) which attained good ratings of use, means on other items on use of internet facilities (UIF) were about "2" corresponding to "poor" levels of

use. Factor Analysis suggested that the eight items on UIF belonged to two factors, with eigenvalues of 4.49 and 1.15 respectively. The factors explained over 56% and under 13% respectively of variance in the construct. Considering factor loadings above 0.5 as being high [Foster, 1998], it is apparent that while the first factor loaded highly on all items of UIF, the second factor highly loaded only on UIF1, UIF2, UIF4 and UIF5. Moore and Benbasat [1991, p. 207] refers to such items as these four loading highly on more than one factor, as "complex" and advises that they be dropped from analysis due to that "complexity". Thus only the remaining four items UIF3, UIF6, UIF7 and UIF8 were considered valid. Then Cronbach alpha originally 0.8864, which was high since it exceeded 0.7 [Hair et al, 1998], was recomputed yielding 0.8927, meaning that dropping items made the measure not only more valid but also more reliable. An overall index on the valid items of UIF yielded a mean of 2.32, which corresponded to "rare" use and hence poor levels of use of internet facilities.

Table 7 Means, validity and reliability analyses on use of ICT

Construct	Item	Mean	Factor on UPC [+]	Factors on UIF [+]		Cronbach, α
				Factor 1	Factor 2	
UPC	UPC1	4.04	0.685			0.8174
	UPC2	3.15	0.806			
	UPC3	2.33	0.808			
	UPC4	2.51	0.763			
	UPC5	1.73	0.650			
	UPC6	2.00	0.613			
UIF	UIF1*	4.21		0.606	0.662	0.8864 **
	UIF2*	4.00		0.671	0.627	0.8927 ***
	UIF3	2.49		0.797		
	UIF4*	1.67		0.701	-0.517	
	UIF5*	1.48		0.651	-0.576	
	UIF6	2.43		0.844		
	UIF7	2.23		0.854		
	UIF8	2.17		0.826		
Eigenvalue			3.15	4.49	1.154	
% variance			52.55	56.16	12.821	

[+] Only factor loadings above 0.5 reflected (as per Foster, 1998).

* Dropped from analysis due to complexity

** Before dropping items

*** After dropping items

5.2.3 Index on use of ICT

An overall index on "use of ICT" (UIT) from the two indices on use of personal computers (UPC) and use of Internet facilities (UIF) yielded a mean of 2.48, which further lent credence to the earlier finding that "use of ICT" was only poor.

5.3 Independent Variables: Perceived Characteristics of ICT

The study had four independent variables (IVs), namely "perceived relative advantage" (PRA), "perceived compatibility" (PC), "perceived user friendliness" (PUF) and "perceived observability" (PO) – see Appendix A. Each IV was multi-dimensional in that each of PRA, PC and PO had five items, while PUF had seven items. Each item in turn was scaled such that 1 = Strongly agree; 2 = Agree; 3 = Undecided; 4 = Agree; and 5 = Strongly agree. Table 8 presents the study items for the respective four IVs, their means, factors and Cronbach alphas. In particular, means for all items of PRA suggested good ratings of relative advantage of ICT. This was supported by the overall mean for PRA of 4.17 ≈ 4. For PC, except for the fourth item (PC4) which was poorly rated, means for other items suggested good ratings, though the overall mean for PC of 3.45 ≈ 3, corresponded to only fair rating of ICT in terms of perceived compatibility. For PUF, except for the first item (PUF1) which was rated good and PUF 4 rated poor, means for other items suggested fair ratings.

This was supported by the overall mean for PUF of 3.14 ≈ 3, corresponding to undecided, and hence fair rating of ICT in terms of perceived user friendliness. Lastly for PO, except for the first item (PO1) rated good and fourth one (PO4) rated poor, means for other items suggested fair ratings, and hence its overall mean of 3.13 ≈ 3, corresponding to undecided, and hence fair rating of ICT in perceived observability. Factor Analysis suggested that items on each IV belonged to only one factor, with the factors having eigenvalues of 4.12, 2.73, 3.99 and 2.70 respectively. The respective factors explained over 82%, almost 55%, over 57% and over 54% of variance of the respective four constructs. Considering factor loadings above 0.5 as being high [Foster, 1998], each factor loaded highly on all items of construct in question, meaning all items in each of the four constructs were valid. Further, each of the respective four Cronbach alphas namely 0.9456, 0.7832, 0.8695 and 0.7838 was high since it exceeded 0.7 [Hair et al, 1998], implying that the respective four IV constructs were reliable.

Table 8. Means, reliability and validity analyses on perceived characteristics of ICT

Construct	Item	Mean	Factors on +	Chronbach

							α
			PRA	PC	PUF	PO	
PRA	PRA1	4.17	.922				0.9456
	PRA2	4.11	.941				
	PRA3	4.11	.920				
	PRA4	4.20	.917				
	PRA5	4.00	.836				
PC	PC1	4.20		.684			0.7832
	PC2	3.61		.864			
	PC3	3.54		.838			
	PC4	2.19		.572			
	PC5	3.65		.699			
PUF	PUF1	3.86			.722		0.8695
	PUF2	3.23			.842		
	PUF3	3.16			.821		
	PUF4	1.99			.528		
	PUF5	3.31			.700		
	PUF6	3.36			.859		
	PUF7	3.10			.761		
PO	PO1	4.01				.683	0.7838
	PO2	3.31				.852	
	PO3	3.07				.827	
	PO4	1.89				.576	
	PO5	3.42				.703	
Eigenvalue			4.12	2.73	3.99	2.70	
% variance			82.42	54.64	57.02	54.02	

[+] Only factor loadings above 0.5 reflected [as per Foster, 1998].

5.4 Perceived characteristics as correlates of use of ICT

Multiple Regression Analysis of the aggregate index of use of ICT ("UIT") on the four perceived characteristics of ICT (PRA, PC, PUF and PO), yielded the results in Table 9, suggesting that the four perceived characteristics considered, were collectively good explanatory variables (F = 47.198) of use of ICT at the one percent level of significance ($p < 0.01$), accounting for more than 37% of the variation in the aggregate index use of ICT (Adjusted R square = 0.372). Table 9 further suggests that all the four perceived characteristics positively correlated with use of ICT (all Betas were positive), and all except one (perceived compatibility, PC) were significant correlates ($p < 0.01$), leading to acceptance of the corresponding three research hypotheses (H1, H3 and H4), while H2 was rejected.

Table 9. Regression of use of ICT on perceived characteristics

Perceived Characteristic	B	p
Relative advantage (PRA)	0.165	0.002 **
Compatibility (PC)	0.123	0.053
User friendliness (PUF)	0.246	0.000 **
Observability (PO)	0.203	0.005**

** $p < 0.01$; F = 47.198 (p = 0.000); Adj R square = 0.372

6 DISCUSSION

6.1 Perceived relative advantage and use of ICT

The study revealed that the higher the perceived relative advantage of ICT, the higher the use of ICT, in line with the theoretical assertion that perceived relative advantage is a significant influence on use of innovations [Rogers, 2003]. The results also corroborated such studies as Hung et al [2010]; Kok et al [2011]; Rezaei-Moghaddham and Salehi [2010]; and Safeena et al [2011]. Contextually, the finding has implications for ICT change agents in Makerere University such as the Directorate of ICT Support (DICTS), namely that ICT's perceived relative advantage should not only be raised but also maintained among teachers, senior administrators and graduate students as a means of enhancing use of ICT. This will be via training.

6.2 Perceived compatibility and use of ICT

Results showed that perceived compatibility was an insignificant correlate of use of ICT, a result inconsistent with theory that stipulates that perceived compatibility, which is the degree to which an innovation is perceived as consistent with the existing values, past experience, and needs of potential adopters, is positively related to the rate of use of the innovation; the observation that an idea that is more compatible is less uncertain to the potential user and fits more closely to the individual's situation; that such compatibility helps the individual give meaning to the new idea (innovation) so that it is regarded as more familiar [Rogers, 2003]. The study finding was opposing those of several earlier researcher [e.g Amutahi & Oketch, 2003; Azam & Quaddus, 2009; Garcia-Valcarel & Tejedor, 2009; Kelleher & Sweetser, 2012; Poon et al, 2004] who found perceived compatibility as a factor positively correlating with use of innovations.

The unexpected finding made the researcher suspect that his conceptualization of perceived compatibility (PC – Appendix A) of ICT in the study may have been inadequate, because as Rogers [2003] asserts, while an innovation can be compatible or otherwise with (i) socio-cultural values and beliefs (ii) previously introduced ideas and/or (iii) client needs for the innovation, the five questions used to conceptualize compatibility of ICT may not have adequately captured all these. Further studies are recommended to close this conceptual gap by using more standard instruments. In the context of teachers, senior administrators and graduate students in Makerere University in the meantime, the implication is that except where specific program needs dictate otherwise, those in charge of fostering use of ICT in the whole University (e.g. DICTS) should not lay undue emphasis on ensuring compatibility of ICT, say when procuring ICT hardware and software. They should buy standard ICT without bothering much to consult individuals on preferred brands.

6.3 Perceived user friendless and use of ICT

Findings revealed that perceived user friendliness correlated positively and significantly with use of ICT, a finding conforming to the researcher's hypothesis and formal theory such as Innovation Diffusion Theory [Rogers, 2003] to the effect that user friendliness of an innovation, that is the degree to which the innovation is perceived as relatively easy to understand and use by members of a social system, is positively related to its use. This finding corroborated earlier studies which found user friendliness as a catalyst to use of innovations such as Internet by audit firms in Malaysia [Kok et al, 2011]; "precision agricultural technologies" by agriculturalists in Khunestan and Fars Provinces in Iran [Rezaei-Moghaddam & Salehi, 2010]; and internet banking adoption by students in an educational institution in India [Safeena, et al, 2011]. In the context of teachers, senior administrators and graduate students in Makerere, the study finding has one major implication, namely that to enhance use of ICT in the University, change agents (e.g DICTS) should ensure that ICTs acquired have user friendliness. Thus they should for example acquire hardware and software whose user interfaces (e.g. screens) give clues to the user on what to enter and how to enter, in addition to being accompanied by user manuals.

6.4 Perceived observability and use of ICT

The study found significant positive correlation between perceived observability and use of ICT, a finding consistent with formal theory to the effect that perceived observability of an innovation, that is the degree to which the results of the innovation are visible to others as perceived by members of a social system, is positively related to its rate of use [Rogers, 2003]. The finding was in consonance with several past studies [e.g Azam & Quaddus, 2009; Poon et al, 2004; Putzer & Park, 2010; Rezaei-Moghaddam & Salehi, 2010]. The finding implies the more teachers, senior administrators and graduate students in Makerere first see "miracles" performed by ICT elsewhere or for other people, the higher their own chances of using the same. Hence the Makerere Directorate of ICT Support (DICTS) and other relevant change agents should lay due emphasis on enhancing perceived observability of ICT, say during training by bringing out vivid examples of teachers, senior administrators and graduate students in other universities that have benefited from using ICT.

7 CONCLUSION

Basing on Taylor's Scientific Management Theory, ICT is expected to boost productivity and efficiency of employees (e.g lectures and administrators) and clients (e.g students) in a university. Unfortunately however, use of ICT in Makerere University has consistently been reported to be very low. This study set out to isolate some of the reasons why, by examining the extent to which perceived characteristics (relative advantage, compatibility, user friendliness and observability) were correlates of use of ICT, basing on Rogers' Innovation Diffusion Theory (IDT). In so doing the study closed several gaps. For example, the

study was a pioneer in that no study had attempted to relate perceived ICT characteristics to use of ICT in the University. Indeed few studies of this kind have been done outside the developed world [e.g see reviews by Azmi & Kamarulzaman, 2010; Buabeng-Andoh, 2012].

The main findings of the study were that perceived user friendless and observability significantly positively correlated with use of ICT. These findings have practical significance to ICT change agents in Makerere University and comparable institutions of higher learning. In particular the findings imply that in their quest to enhance ICT adoption in Makerere University, ICT change agents such as the Directorate of ICT Support (DICTS) have to acquire ICTs that are user friendly. They should for example acquire hardware and software whose user interfaces (e.g screens) give clues to users on what to enter and how to enter, in addition to being accompanied by user manuals. The ICT change agents should lay due emphasis on enhancing perceived observability of ICT, during training, by bringing out vivid examples of teachers, senior administrators and graduate students in other universities that have benefited from integrating ICT in their respective endeavours as employees and clients of universities.

Despite the contribution of the study (e.g in terms of gaps closed and significance of results), as is typical of empirical studies, this study is not without limitations. For example the study used only four perceived characteristics as independent variables. Obviously there are other perceived characteristics such as perceived trialability [Buabeng-Andoh, 2012; Rogers, 2003] and perceived risk [Azmi & Kamarulzaman, 2010] among others that could have been considered. Further even if all possible perceived characteristics had been used - which was impossible, still as Buabeng-Andoh [2012] observes, apart from technological or perceived characteristics, "individual, organizational and institutional factors should be considered when examining ICT adoption" (p. 137).

Individual characteristics include ICT competence, self-efficacy, gender, professional experience and workload [Buabeng-Andoh, 2012]. Institutional/ organisational characteristics as per the same source include availability of ICT training, ICT accessibility, technical support and leadership support. Future studies should integrate more of these independent variables, and like many quantitative studies, the study relied on data based on self-report measures, which "raised the possibility of common method variance, which may inflate the true association between variables" [Pituch & Lee, 2006, p. 239]. Future studies could incorporate qualitative methods of observation and interviewing. However the above shortcomings not withstanding, the study has contributed to the ongoing debate on factors related to use of innovations in general, and use of ICT in particular.

Appendix A Study Instrument

Construct	Item	Measure
Section A Background Variables		
Background	BV1	Category of respondent (teacher, administrator, student)
	BV2	Age of respondent (in completed years)
	BV3	Sex of respondent (female, male)
Section B Perceived Characteristics of ICT *		

Perceived Relative Advantage (PRA)	PRA1	ICT has potential to raise speed at work **
	PRA2	ICT has potential to raise effectiveness at work
	PRA3	ICT has potential to raise efficiency at work
	PRA4	ICT has potential to make work more convenient
	PRA5	ICT has potential to raise job satisfaction
Perceived Compatibility (PC)	PC1	The personal computer fits in my work
	PC2	The school, faculty or institute LAN fits in my work
	PC3	The Makerere WAN (i.e. Maknet) fits in my work
	PC4	The African Virtual University (AVU) fits in my work
	PC5	The Internet fits in my work
Perceived User Friendliness (PUF)	PUF1	I find the personal computer user friendly
	PUF2	I find the school, faculty or institute LAN user friendly
	PUF3	I find the Makerere WAN (i.e. Maknet) user friendly
	PUF4	I find the African Virtual University (AVU) user friendly
	PUF5	I find the Internet user friendly
	PUF6	I find ICT in general, user friendly
	PUF7	I find ICT change user friendly
Perceived Observabilty (PO)	PO1	The personal computer has positively impacted my work
	PO2	The school, faculty or institute LAN has positively impacted my work
	PO3	The Makerere WAN (i.e. Maknet) has positively impacted my work
	PO4	The African Virtual University (AVU) has positively impacted my work

	PO5	The Internet has positively impacted my work
Section C Use of ICT * * *		
Use of Personal Computer Applications Software (UPC)	UPC1	Word processing
	UPC2	Spreadsheet management
	UPC3	Data base management
	UPC4	Presentation
	UPC5	Desktop publishing
	UPC6	Statistical data analysis
Use of Internet Facilities (UIF)	UIF1	Electronic mail
	UIF2	Web surfing
	UIF3	Bulletin board, mailing lists and discussion groups
	UIF4	Computer conferencing
	UIF5	Video conferencing
	UIF6	Electronic journals and newsletters
	UIF7	Electronic data bases
	UIF8	Online library catalogs

* All items in Section B were scaled using a five-point Likert scale in such a way that a minimum of 1 = worst case scenario (strongly disagree), to a maximum of 5 = best case scenario (strongly agree).

** Wherever the word "work" appears in an item was replaced by "studies" for students.

*** All items in Section C were scaled using a five-point Likert scale in such a way that a minimum of 1 worst case scenario (Very rarely or never, including never hear of it), to a maximum of 5 = best case scenario (Very regularly).

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