KEMI-TORNIO UNIVERSITY OF APPLIED SCIENCES

# LTSP: Developing Information Technology in Developing Country

## A Case Study of Nigeria

Rasheed Akintunde

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ABSTRACT

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This Thesis work is focused on the implementation of Linux Terminal Server Project (LTSP) with a view to providing a very effective and affordable Information and Communication Technology for the Nigerian educational and business sectors. It is meant to make Nigeria relevant in the business world. Information Technology could be regarded as the 'life-blood of the world economy' today. Meanwhile, an average stakeholder, in the developing countries, is financially constrained to be able to afford the required facilities for information technology. The research work involved an exploration of the development and operation of LTSP, which was basically invented to ease the cost of Information Technology to make it affordable for everyone. It also involved the establishment of facts about LTSP and making suggestions on how to improve on its operation.

The work is essentially meant for the developing countries, using Nigeria as a case study. Nigeria has been endowed with highly talented individuals in every facet of technological ideas and innovations, the ability of Nigerian institutions to undertake in-depth research is often hampered by lack of appropriate technological resources caused, majorly, by financial constraints for their acquisition. This work is targeted at resolving this problem by proffering an affordable and highly effective technology to them.

Exploratory research method was employed to carry out this work, while the basic technique adopted was an informal and open discussions held with some people that possess vast knowledge in LTSP operation. These options had been engaged to enhance my in-depth knowledge and technical know-how of the LTSP. It involves its painstaking studies and understanding.

The major output of this work is the identification and acknowledgement of an easy-to-use, highly economical LTSP server which will afford the less-privileged and developing countries the opportunity to be part of the information technology world. This will, in effect, enhance rapid economic development in these countries.

Keywords: LTSP, ICT in Nigeria, LTSP Set Up, LTSP Booting process

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# 1. INTRODUCTION

## 1.1 Motivation and Background

The impact of Information and Communication Technology (ICT), in today's world economy, can not be overemphasized. The educational sector has also not been speared. Indispensability of ICT has impacted positively on the quality and quantity of learning and research in the various institutions of learning, especially in the developed world. Needless to say that ICT improves learning through its vibrant, interactive, flexible, and appealing content (Kwache 2007, 1).

Technology has once been referred to as "a valuable mode of literacy and creative tool for learning", and it was also said that access to information, electronic collaboration and ability to communicate clearly using technology are foundational needs for school communities (Petersen 2008, 1). A basic knowledge of ICT in education is essential to remain relevant in rapidly changing technologies (Iloanusi & Osugwu 2009, 1331). In recognizing the criticality of ICTs in economic development, the United Nations Commission on Science and Technology for Development (UNCSTD) conducted a study on the linkages between ICTs and development, between 1995 and 1997. The resultant effect of this study was the introduction of digital divide on global development agenda. (Afolayan 2010.)

It is also wise for educational institutions to be equipped to provide basic computer training for modern life. This could be achieved through the provision of computer labs, which are one of the most popular Information Technology infrastructures for technical training in the primary, secondary, and Tertiary institutions. (Martinez-Mateo & Munoz-Hernandez & Pe'rez-Rey 2010, 1.)

However, establishing a computer lab may be too expensive in terms of both the initial purchase and subsequent maintenance costs. Economic situations of most educational institutions in developing countries may be a constraint for them to set up a computer lab. Some may not even have at all due to unaffordable costs. Hence, it is worthwhile to carry out a research on a cost effective, efficient, and high performing information technology system. (Martinez-Mateo & Munoz-Hernandez & Pe'rez-Rey 2010, 1.)

This Thesis therefore, deals with the input of Linux Terminal Server Project (henceforth, LTSP) in its capability to meet all the above stated qualities in the improvement of Information Technology in today's world business economy and education. This Thesis is carried out with a view to alleviating the problem of Information Technology in developing countries, using Nigeria as a case study with particular reference to The Polytechnic, Ibadan.

This work is necessary to ascertain the effectiveness and affordability of LTSP. If adopted, it could make the developing and underdeveloped countries equal to the developed countries in the world of information technology today. It was innovated for use in environments where a large number of computers are needed and strict economical constraints prevail. (Russo & Lamanna & Baldoni 2003, 1)

It is crystal-clear that Nigeria is yet to have a place in the history of Information Technology; this is due to its poor financial state and literacy level. The imperativeness to invent an affordable and effective Information Technology has also been established (Ogunsola & Aboyade 2005, 8). Hence, this thesis work is carried out to identify the ways by which LTSP, which is of very low cost and high performance (CIO 2003, 130), could elevate Nigeria to the much desired position in Information Technology.

LTSP is a free and open source project, instituted by Jim McQuillan, along with some others, to reduce costs and improve productivity by giving everyone access to technologies and knowledge. It allows many people to use the same computer at a time. It only entails running thin client computers in a GNU/Linux environment. (Gnome 2003.)

LTSP is a package, specifically designed for Linux, which allows the connection of lots of low-powered workstations, otherwise known as thin clients, to a Linux server. It is designed to use minimal hardware for the workstations. It affords people the opportunity to use computers without having to purchase expensive ones. (Jean Jordan 2005 4.)

LTSP was to be my presentation topic during my Introductory Project course, and since then, I have been motivated to carry out more research on it to establish its usefulness for my country, Nigeria because it is said to be highly cost-effective, easy to maintain, requires much reduced power and generates low heat (Rijal & Bhandari). Therefore, it

will be highly beneficial to the developing countries which have been constrained because of the high cost of technological facilities, and which power generation is at low rate. It will serve as a great opportunity for them to be part of the modern information technology world, as it is not only cheap to set up, but also cheap to maintain.

Figure 1 below displays the press using Linux Terminal Server Project (LTSP) Thin Clients in the Media Centre during the 2004 Linux World Conference & Expo at the Jacob Javits Center in New York City ( January 20-23, 2004). It was reported that LTSP workstations worked flawlessly, throughout the four days used for the event, and they required no support from anybody, in spite of their heavy use. (Linux World Conference & Expo 2004.) All the thin clients were connected to only one server, and they worked well without hitches. This is enough indication that LTSP will be a perfect solution to the lingering problem of Information Technology in Nigeria because of its low cost and high performance qualities.

**Figure1.** LTSP being used in a World Conference in New York (Linux World Conference & Expo 2004)

## 1.2 Objective

The objective of this Thesis work is to provide a lasting solution to the lingering problem of inadequate Information and Communication Technology in Nigeria. My aim is to study LTSP and its operation, comprehensively, and thereby, introduce it for use in Nigerian educational and economic sectors. LTSP is flexible, cost-effective and highly efficient in its operation, and has been recommended for schools, businesses and other organizations worldwide (LTSP 2009). With its use, Nigeria will have access to affordable and effective ICT and thus, will be able to participate actively in the business world. In effect, this work will provide a road map for successful implementation of Information Technology system in Nigeria.

## 1.3 Structure of the Thesis

I have divided this Thesis work into seven different chapters. Chapter two of this Thesis work addressed the research questions and their relevancies to the main subject of research, research methods adopted in this work and limitations, and the expected outcome of the research work. Chapter three of this work deals with the operation of ICT in Nigerian context. It analyzes the current ICT system in Nigeria with particular reference to educational and business sectors, using The Polytechnic, Ibadan as a case study for educational system. It also discusses the cost consideration of LTSP and how it could be cost-effective to be used for the enhancement of ICT system in Nigeria. This chapter also discusses the anticipated problem of software and hardware accessibility in the setting up of LTSP. The forth chapter is channeled towards the main subject (Linux Terminal Server Project), its evolutionary background, its mode of operation, setting up mode, and its advantages and disadvantages. This chapter also analyzes some success stories as indicated by various LTSP users from different parts of the world. Chapter five is used to explain the prospects of LTSP, its benefits and limitations, while chapter six deals with the requirements for setting up LTSP, vis-à-vis, the hardware requirements, software requirements, and the set up distribution requirements. It also analyzes the process that is involved in the installation and configuration, and its booting process. The last chapter, which is chapter seven, is based on the discussions

and conclusion of this work. Inculcated in this chapter are; the results of the work, its implication on further research, and my conclusion on the significance of the topic.

# 2 RESEARCH QUESTIONS AND METHODOLOGY

## 2.1 Research Topic and Questions

Research involves a process of finding out, and, it is pertinent to analyze all the information one needs to find out. These should be developed through the topic being addressed and the reasons for doing the research work. (University of Wollongong 2008.)

The title of my Thesis work is "LTSP: Developing Information Technology Systems in a Developing Country-A Case Study of Nigeria". This research work will look at the process involved in setting up of LTSP, with the aim of channeling it towards the enhancement of information technology in the educational and economic sectors of developing countries, focusing on Nigeria. The outcome of this research work will determine the benefits derivable by the developing countries if they eventually adopt the project.

In determining these derivable benefits, I address four different questions in order to fulfill the objective of this work, viz;

RQ 1. In what ways can LTSP be beneficial to Nigerian educational system and economic environment?

The significance of ICT problem in Nigerian educational and economic sectors cannot be overlooked. Investments in ICT in Nigerian education is said to have yielded no reasonable expectations. (Iloanusi & Osugwu 2009, 1331.) The objectives of ICT in education have been categorized into four consecutive phases, namely; emerging, applying, infusing and transforming phases. It was analyzed that 90% educational institutions have only attained the emerging phase, why only 10% fall in the categories of applying, infusing and transforming phases. (Iloanusi & Osugwu 2009, 1332.)

Furthermore, the outcome of a study carried out by Umunna N. Opara, a Senior Lecturer of the Department of Library and Information Science, indicated that the constraints of ICT in education are; inadequate or lack of ICT facilities, overpopulation of students, and inadequate funding, among others (Opara 2009).

LTSP has been proven to be highly flexible, cost effective and efficient. It has been recommended for educational and business environment (Open Source Schools 2009).

There have been many success stories from various LTSP users all around the world, including Europe and America.

According to Peterson, the annual operation cost for a school using Linux/K12LTSP workstations is about ½ that of the school running the same number of traditional PCs using Windows (Peterson 2008, 11).

Kohtamäki states that the management of his school has improved the provision of computer education and school network, during the last three years, with the use of open source software and LTSP application. According to him, the management has also built a network in the school using LTSP technology and has achieved the target of student-to-computer ratio defined in the Information Society Programme. (Kohtamäki 2006.) – Municipality of Noormarkku, Education Services, Winners of the [Finnish] Prime Minister's Awards for Best Practices 2006.

This work is ultimately aimed at improving the information system of the Nigerian educational and economic environments. Therefore, it will be highly necessary to identify the benefits, via affordability and effectiveness, which could accrue to Nigeria, if LTSP is adopted for the provision of information technology.

Very meager amounts are being allocated to the educational sector in Nigeria. It was also established that the use of computers and information technologies will increase productivity in educational sector. (Dike 2002.) Therefore, it is imperative to strike a balance between the scarce resources available to this sector and the imperativeness of information technology, hence, this work.

RQ 2. What is the scalability of LTSP, in a real-world installation, to economic and educational environment?

Scalability is to establish LTSP's capacity to continue to function well when it is changed in size or volume in order to meet a user need. It is also to take full advantage of the change in terms of performance, as regards user response time and the increase in the number of users that could be handled. (SearchDataCenter.com 2010.)

Furthermore, the question of scalability is considered very crucial because of the strong need for LTSP to be fast and efficient. The event illustrated in figure 1 above is a testimony that it is fast and efficient enough to perform up to expectation.

The scalability of LTSP is also evaluated with its ability to boot the clients at approximately the same time, even if one has already booted, within 50 seconds, in an upgraded version, and 70 seconds, in the first set up. Also, once an instance of an application is running, the second instance starts faster. (SearchDataCenter.com 2010.)

Moreover, it should also be easy to add another workstation to the network and software to be installed on the workstation must regularly be done from a central location, which is the server. Any unit of the computers that is faulty can be replaced without the need to diagnose faults at the machine. (SearchDataCenter.com 2010.)

RQ 3. What are the problems associated with LTSP's operation?

It has been clearly stated in the previous parts that this work is aimed at improving the information technology system of the Nigerian educational and economic environments. Therefore, it is imperative to also identify the problems associated with its operation, so as to proffer lasting solutions to them. Ironically, the issue of the problems with its operation has never been a common topic of discussion, for instance, people hardly mention the problem associated with many workstations from a single server.

Moreover, computer installation and securing the installation and other required software have always posed a problem in Nigeria (Alabi 1994). Finding Linux based software could pose more problems, although, it is free and could be downloaded from the internet; the problem associated with this option is that transfer is very slow, even in cyber cafés (Alabi 1994).

Furthermore, in case the server's hardware fails, there may be no available replacement. Hence, the educational institutions or Investment Companies may have to place the spare parts in reserve before hand, meaning that additional cost may have to be incurred.

In view of the above, it is my intention to identify these problems and make suggestions for solutions, where it is possible.

RQ 4. What is LTSP's prospect and how can it be improved upon?

The main aim of LTSP project was to transform a regular workstation into a terminal server with a view to using it as thin clients. These thin clients could either be old computers, which are recycled, or specialized minimal computers, which are diskless and also without moving parts. (Stgraber 2009.)

There is, therefore, the need for the establishment of the prospects of this project, and as well, the identification of where it can be improved upon in its bid to fulfill this purpose. This will afford the developing countries, especially Nigeria, to have the fullest opportunity of its benefit.

## 2.2 Research Method and Limitations

Research could be regarded as a scientific and systematic ways of searching for information on a specific topic or subject (Rajasekar & Philominathan & Chinnathambi 2006, 1-2). Research Methodology is the act of solving research problems in a logical way. It describes the methods to be used in conducting a research. Research methodology discusses the research design, the population to be studied, and the tools required to carry out a research.(Kothari 2004, 1.)

My research work is a Case Study using Exploratory Research. Exploratory Research method is a preliminary study of an unfamiliar problem about which researcher has little or no knowledge. It incorporates the development of concept, theory and assumption. It is used to gain familiarity with an observable fact or to achieve new insight into it. (Kumar 2008.)

Figure 2 below shows the process involved in Exploratory Research: from Preliminary understanding to View point A to View point B to View point C to View point D and lastly, to Deeper understanding. The figure indicates that a researcher must have an original point of view and an identified problem about the project work, after which the researcher will need to gather only such experiential knowledge that is related to the work. This will make the research work easier. **(**Routio 2007.)

However, the researcher will need to gather a lot of materials before the final result of the project work could be defined, while a larger percentage of these materials may prove to be worthless in the final analysis. These view points change the more the researcher studies and understands the project work. The research work is accomplished only when the researcher has recorded a commendable and experiential understanding of the work. **(**Routio 2007.)

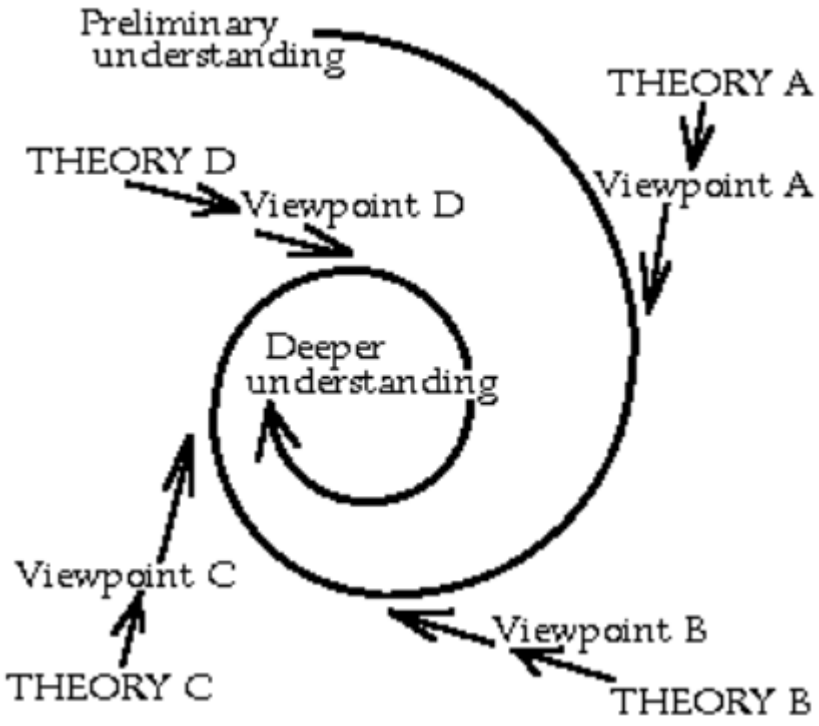


**Figure 2.** Indicating the process involved in Exploratory Research **(**Routio 2007)

Exploratory research method has been adopted so as to enable me have in-depth studies of the operation of LTSP as regards the technical know-how of its operation. It will also enable me to have an insight to its deficiencies, if any, and establish solutions, where required and possible, or make suggestions, where necessary.

This method will afford me the privilege of having necessary information as regards the economic benefits of LTSP to the less- privileged in the world of information technology. My research work is targeted at providing easy access to information systems by developing countries, especially, Nigeria.

Experiences garnered through this study will be experimented in The Polytechnic, Ibadan, Nigeria, which is my case study.

Sources of Information for Data collection:

The type of data collection that I have adopted is qualitative, which requires non-numerical data collection based on the attributes of the sources of data.

The Exploratory research method that I have adopted is the process of discussing a business problem with informed sources such as industry analysts, consultants, customers, and channel partners (all of which could be categorized as experts, falling under primary sources of data), and examining secondary sources of data (Lodato 2006, 6). This may help in discovering inventive ideas. The two major sources, Primary and Secondary, will be engaged in the collection of data for this research work.

Primary source: engaging in discussions with people who possess vast experience in LTSP operation, which is otherwise known as experience survey. These people are in a position to enlighten me on different aspects of my research work and their advice and comments will definitely be invaluable to me. Their responses will be used to evaluate the usability and benefits of this technology.
Secondary source: Literature review, such as Library materials, Internet information, Books, and Hand-outs – this is to be well conversant with relevant theories in the LTSP operation and installation.

## 2.3 Expected Outcome

The ultimate expected research output is the detailed study of LTSP and the acquisition of the knowledge to establish an easy-to-use, more economical LTSP server. It should be able to provide a lasting solution to the lingering problem of inadequate Information and Communication Technology in Nigeria.

I intend to study LTSP and its operation, comprehensively, and thereby, make recommendation of its use to Nigerian educational and economic sectors. This will eventually place the state-of-the-art Information and Communication Technology at the reach of all stakeholders in these sectors. LTSP is said to be flexible, cost-effective and highly efficient in its operation, and is recommended for schools, businesses and other organizations worldwide (LTSP 2009). With its use, Nigeria will have access to

affordable and effective ICT and thus, will be able to participate actively in the business world.

Moreover, this research work should be suitable enough to generate a significant effect on the information system in the developing countries, particularly in Nigeria.

Furthermore, since LTSP is Linux based, it is expected to be secure, stable and free of viruses or other attacks. Also, since the software that will be used in the setting up of the systems is all Free and Open Source Software, any software upgrade will also be cost-free.

# 3 ICT IN NIGERIAN CONTEXT

Going by various statistics of surveys carried out on the state of economy in Nigeria, one of which is Katsina's ( 2009), 70% or more Nigerians have been identified to be living below the poverty level, having been earning a living with less than USD 1 per day. While reporting a study carried out by the United Nations Development Project (UNDP), Katsina said that people estimated at about 90 million, in Nigeria, are living in abject poverty. (Katsina 2009.) Various documentations also claimed that there has been a continuous increase in poverty level in Nigeria (Ali-Akpajak & Pyke 2003). An average Nigerian could hardly meet his so called essential needs of food, clothing and shelter. Hence, there is no gainsaying the fact that he can not afford the money to acquire a computer of his own, which has been established to be very costly. In spite of Nigeria's high population, the trend of computer usage and promotion of ICT have not been encouraging (Kingsley 2008, 1). In this kind of situation, therefore, it is wise enough to promote Information Technology, amongst the citizenry, through school libraries and computer learning centers.

However, setting up of learning centers or school libraries, with the conventional models of computer technology, may be expensive for individuals and even the government, hence, the recommendation of LTSP, which is cost effective and will also provide high quality performance.

## 3.1 ICT in Nigeria (From Educational and Business Perspectives)

ICT – (Information and Communication Technology) is regarded as a technology that could be used in sharing, distributing, and gathering of information, and communicating through computers and computer networks (Ogunsola & Aboyade 2005, 7). ICT could be classified into two major segments, namely; the Telecommunications, which is otherwise regarded as voice telephony, and the Computer/ Internet services.

The development of ICT in the world economy has been beyond human reasoning. It has been moving at a very high speed, especially in the Western Countries. The rapidity of change brought about by these emerging technologies to the world economy can not be over-emphasized. It has not spared the educational sector as well, as the traditional method of teaching and learning has been greatly threatened. In today's world,

Information Technology has been having a major impact on all spheres of life. The world is now a global village, where information is at your reach and door step anytime. The rapidity of change in Information Technology has truly made learning a life-long activity; computerization has taken over every facet of life with advanced technology. Computers are now required to aid business and to enhance educational development, and they are readily available to aid communication and transfer information electronically. The use of Internet has revolutionized access to information for the business world and educational environments. Information Technology has continued to enhance the sharing of information especially in the educational sector, thereby, promoting rapid transactions in business, and supporting universal collaboration among individuals and business organizations.

However, as the developed countries are going technologically inclined, the reverse is the case in the developing countries like Nigeria. Nigeria is lagging behind in all spheres of technological development. The observation of the development in ICT has been a recent trend in the case of Nigeria.

The evolution of ICT in Nigeria started with the inception of Telecommunications, which was its oldest component, way back in 1923. It started with the introduction of a trunk telephoning system between two towns. (Ogunsola & Aboyade 2005, 10.) However, in spite of this early experience of telecommunications technology, there was no significant development until around 1950, when VHF radio systems were introduced. Thereafter, no substantial step was taken until 1984, when the organs of government responsible for telecommunications, comprising the Post and Telegraph Department and the Nigerian External Telecommunications Limited, were merged together and became a limited liability company called the Nigerian Telecommunications Company (NITEL). The argument was that this measure would enhance the development of telecommunications. (Ogunsola & Aboyade 2005, 10.)

As a matter of fact, the enhancement of communication with the outside world was given more priority than the promotion of domestic communications system then (Ogunsola & Aboyade 2005, 10).The first and second facilities (Antenna) that made Nigeria's external telecommunications fully operational were launched in 1971 and 1975 respectively. These facilities enhanced the use of telephone, telex, fax machines

and televisions. Also in 1975, Nigeria instituted its domestic satellite system, used in the transmission of television services. It is also worthy of note that Nigeria has always been having problems with the realization of its set goals towards the development of its Information and Communications Technology. Until year 2000, Nigeria's Telecommunications sector had suffered a serious setback, having to cope with outdated communications infrastructural facilities, epileptic services, and inefficiency among others. (Udutchay 2008.)

Overwhelming development was however, witnessed in the telecommunications aspect of ICT in Nigeria with the introduction of GSM, which happens to be a baby of the deregulation policy of the government in the sector, in year 2001. There was an astonishing increase in the number of telephone subscribers. The number of subscribers increased from the initial 450,000 to 3.8 million within three years of GSM introduction, and increased to about 38 million in year 2007 (Kenneth 2007). Users of GSM today are over 50 million, which indicates a tremendous growth in the telecommunications sector.

This tremendous growth in the telecommunications technology has endowed Nigeria with immeasurable economic gains such as:

- Employment generation
- Attainment of skills and local transfer of technology
- Improvement of access to telephone services
- Local investment motivation
- Increase in foreign earnings
- More tax revenue generation for Nigeria
- Collection of license fees to the tune of over 1 billion US Dollars
- Provision of economic power to indigenous people
- Empowering private local investors. (Ndukwe 2006, 5-6.)

Social life in Nigeria has been impacted by this development, as Nigeria could, today, be regarded as one of the fastest growing mobile markets in the world (Jidaw Systems Limited 2010). Nevertheless, the fact still remains that communications skill is very low and access to ICT is still inadequate when we consider the population of Nigeria, which is over 150 million.

Moreover, Nigeria needs to move beyond voice telephony in order to experience real economic growth as Information and Communication Technologies, in its entirety, is responsible for facilitating and delivering of services in the educational and economic communities. For instance, there is a notable disparity between voice telephony and Internet broadband density; this indicates that the growth in the former has not been commensurate with the growth in the latter. (Ogunsola & Aboyade 2005 10.)

Internet broadband density is ridiculously low. Moreover, the high cost of acquisition of Internet facilities, lack of adequate awareness, problem of technical know-how and access to these facilities have constituted serious stumbling blocks for many people to belong to the digital world. ICT still remains a strange phenomenon in a country like Nigeria where poverty is well pronounced. The majority of the populace is faced with the problem of affordability of computing and telecom resources.

It is also pertinent to mention that the little development witnessed in ICT has been in the urban areas while the rural areas still remain in the dark. This achievement is attributable to the efforts of the private sector of the economy and its impact is more visible in private companies like banks, insurance companies, other financial institutions, etc., while there is little or no impact felt in the public sectors like the educational institutions and government ministries. In the public sectors, presence of computer and its related infrastructures are either not felt at all or not adequately felt. (Kingsley 2008.)

To worsen the situation, over 60% of Nigerian population are concentrated in the rural areas, meaning that significant number of the people have been deprived of the privileges of computer and its related infrastructures. (Kingsley 2008.)

According to some theorists, the eras of civilization could be categorized into three stages, namely; agrarian, industrial, and information. The agrarians, they said, are the ones supplying agricultural and mineral resources, the industrial supplies cheap labours, while the information dominates others due to their vast knowledge and access to information. The larger size of Nigeria has been said to still be existing in the agrarian era, meaning that they still live on farming and agricultural production. This is unlike

developed countries in Europe and America who fall under information era that is rich in education, information, and technology. (Kingsley 2008.)

## 3.2 ICT in The Polytechnic, Ibadan, Nigeria

The significance of the Internet and computer usage, in the technological development of the world economy, especially the educational sector, cannot be overemphasized. However, in spite of the undisputable benefits of this device to knowledge acquisition, teaching and research projects, there are still many constraints to its connectivity and usage in the tertiary institutions in Nigeria, in which The Polytechnic, Ibadan is not an exemption.

A researcher, Mrs. Kofoworola Omolara Jagboro, carried out a study on Internet usage in Nigerian universities, using Obafemi Awolowo University as her case study. In her findings, she discovered that 45.2% of the Internet users have access to it through privately owned cyber cafés, 21.9% through departmental offices, 15.1% through Computer building of the school, while 8.2% access it through the Library. She however, attributed the low level of Internet usage in the departmental offices to their low level of connectivity and that of Computer Building to the few numbers of existing computers for use. (Jagboro 2003.) The problem could be ascribed to the non-availability of funds to purchase enough computers and embark on adequate Internet connectivity. This problem is peculiar to every educational institution in Nigeria, including The Polytechnic, Ibadan.

The Polytechnic, Ibadan, having been established in 1970, was originally using the analogue systems of record keeping. The use of manual typewriters was engaged in typing documents, while files were being maintained in form of paper documents. The teachings in the computer science department and other related departments were being conducted in theoretical form alone. There was no presence of computers to enhance students' learning.

However, in the late 1980s, some few privileged offices like the Rector and Registrar's offices engaged the use of computers for typing of documents and keeping of some records while manual files were also being used to keep records. The departments with

computer related courses were also provided with few but far from being enough computers. This was just to give them an idea of how a computer looked like, its features and its basic mode of operation. Students were not having access to it except during computer related course, and on the instruction of the teacher.

Early in the 1990s, some private cyber cafés were allowed to operate inside the campus in order to give the students the opportunity of browsing and accessing some educational instructions through the Internet. This is because the school could not afford the financial cost of acquiring its own Internet services; hence, the students were left to pay through their nose to the cyber cafés for these services.

Barely four years ago, an American based social club (The Vine Group) donated a library tagged "state-of-the-art library" to this institution, and also installed a large number of computers inside the library. However, the necessary internet connectivity, that would enhance students' learning, and the subsequent maintenance of these computers were left in the hands of this institution whose allocation from the government is hardly enough to cater for the administrative costs and day-to-day running of its affairs. This situation is coming when there is a peculiar problem of underfunding in the institutions of learning in Nigeria. Therefore, there is need for the management to strike a balance between the scarcity of funds and the provision of quality information technology system that will enhance students' and teachers' academic/intellectual progression.

Ironically, today, The Polytechnic, Ibadan does the bulk of its business transactions through the means of computer cum Internet. However, Internet services are only provided where they are essentially required for business transactions, such as; the Rector and Registrar's offices, where the day to day running of the institution's affairs takes place, the Bursar's office, where various payments and receipts of funds are carried out on daily basis, and the security department, in case of any emergency.

The purchase of admission forms, checking of admission lists by prospective students, checking of results by the current students, payment of tuition fees, among others are being done through the purchase of scratch cards, and using same to access the institution's website from a private cyber café. This system makes the students to pay

through their nose before they could access the needed information. This situation is not economically wise for both the students and the institution itself, hence, the need for a palliative measure.

## 3.3 Cost consideration

It has been established that Nigerians are constrained to acquire the conventional model of computers, to aid Information Technology, due to non-affordability of cost. It has also been established that LTSP has a fundamental advantage of cost effectiveness, due to its ability to provide a low cost digital solution. Although, it operates just like Microsoft Terminal Server Project provided by Windows, but adoption of Linux platform makes it free and open source (Agrawal & Ansari & Tiwari 2005 169). Therefore, it is logical to conclude that its prospect will be enormous in a developing country like Nigeria. It will not be economically wise for a poverty stricken country like Nigeria to invest an exorbitant amount on Information Technology, when its citizenry is in dire need of essential services. Instead, the country will have to balance between quality IT and cost effective measure.

LTSP project operates under Linux platform, and since most of the software used in Linux distributions are free, users of LTSP are obviously going to enjoy the use of free software. Moreover, LTSP mostly uses old computers, making them to perform like new ones. These points, put together, make LTSP to be highly cost effective, as no software would be purchased, while more number of old computers could be purchased at highly reduced prices. This is a great economic advantage for school libraries and learning centers, as they require a high number of computers to function.

## 3.4 The non- windows issues

At the mention of operating system to an average computer literate in Nigeria, his mind will immediately go to Microsoft Windows. The bulk of computer users in Nigeria only operate on Windows, while they know little or nothing about Linux operating system. Therefore, it may be very difficult to initiate the use of Linux operating system to them. However, this problem could be resolved if LTSP is first initiated in an environment where there is not yet much awareness about IT system, vis-à-vis the use of computer.

In this regard, Linux would be used for the training from the scratch instead of windows (Shrestha & Shrestha 2007).

Moreover, for those that have already been using computers with windows, this situation could be resolved through the use of two servers; one having LTSP installed on it and the other one having Windows installed on it. A user can simply access windows programs by using the remote desktop facilities in the LTSP server. With this system, the user is still using the Linux based thin clients. (Shrestha & Shrestha 2007.)

## 3.5 The Digital Divide

Due to the financial constraints, restricting the acquisition of IT facilities to the haves, the computer literacy level has been discovered to be very minimal. While LTSP may not be able to out rightly eradicate this problem, it is, however, recommended for its drastic reduction. Since LTSP allows the use of old computers, and its years of usage could be elongated as new, it therefore, makes it affordable for the have-nots to acquire the same IT facilities like the haves. These could be acquired at very cheap prices. Moreover, old computers that are ready to be disposed of, by companies, could be donated to a school library or learning centers who would use them for computer labs, installing LTSP on them. This, in effect, will create the mostly needed opportunity for computer literacy among Nigerian students, in particular, and the populace, in general.

## 3.6 Anticipated Problems of LTSP Usage in Nigeria

As far as LTSP is concerned in the world of Information Technology, the advantages of cost effectiveness and high performance are inevitable. However, in the situation of Nigeria, as a developing country, there are some anticipated problems in using LTSP, vis-à-vis:

- Software Availability Problem – Software acquisition has never been a very easy thing to do in Nigeria. It is easier to get a pirated copy of any software than the original. Thus, since Linux based operating system is new to users of computers in Nigeria, there is likelihood that getting a Linux based software will pose a lot of problems. Moreover, downloading the software from the internet is

another big problem because of the slow nature of data transfer on our internet systems.

- Hardware Compatibility Problem – In most cases, computers are being assembled in Nigeria to suit the purpose of the user. One will just need to gather all the required hardware parts and assemble them together. However, since LTSP is run on Linux based platform, and Linux has not been a common Operating System in Nigeria, this may pose a problem in getting the hardware that may be supported by Linux or device drivers that are available in Linux. Where there is compatibility, in case there is need for replace of a faulty hardware in future, there may not be a readily available replacement, and so the company or institution may have to duplicate orders for the spare parts in advance and keep for future use. This means additional expenses for them.

# 4 LINUX TERMINAL SERVER PROJECT

Linux Terminal server Project (LTSP) is a free and open source add-on package for Linux, which allows many people to use the same computer simultaneously. With LTSP, applications run on the server with a terminal called thin client, otherwise known as an X terminal, handling both input and output (Sosa 2009.)

Thin clients are low powered, hard disk-free and are much noiseless than desktop computers. LTSP operates on thin clients. It is a cost effective solution. Thin clients can be used to surf the Internet, send and receive emails, produce documents, and they can be run efficiently on other desktop applications from Windows as well as Linux servers. Linux Thin client is reliable as it is virus-free and is also free from other forms of attack. It is also distributed under GNU General Public License, which is free and open software. (TETRA 2007.)

## 4.1 Background and Introduction

LTSP was originally established by a team, led by Jim McQuillan, for a client who required a terminal that could communicate with both an IBM AS/400 and a UNIX application server. The specifications by this client were for the terminal to be inexpensive and to be easy to maintain. Additionally, it was required to allow its users to browse the web, and also allow them to send and read mails. (Jim McQuillan 2002.) Its main goal then was for it to be able to implement purchasing, inventory, point of sales, general ledger, accounts payable, accounts receivable, and order entries (Shrestha & Shrestha 2007).

According to Jim McQuillan, they could have used a PC's running windows for the client, but for the fact that it would be too expensive in terms of investment and subsequent maintenance of the system. He said that his team considered using a Diskless workstation running the Linux Kernel and X-Windows. McQuillan further pointed out that after they had established the workability of their theory, they originally installed a server and 11 workstations for the client, thereafter, the client ordered for 22 more workstations. He claimed that the company now has over 100 workstations without any support problems. (McQuillan 2002.)

It is noteworthy to mention that terminal/server computing was in existence before the advent of LTSP. It is just that Microsoft Windows was not a good platform for its usage, while Linux was a great platform for this purpose. However, it was not easy, for the users of terminal/server system, to set it up on Linux, until the establishment of LTSP.

When a new computer is being installed and switched on, irrespective of whether it runs on Microsoft Windows or Linux, one expects to see a nice graphical user interface (GUI), with the impression of running any software on the computer.
However, if the computer is running on Linux, then the software running on this computer is divided into a number of separate units. Precisely, it comprises: The user interface, which consists of keyboard, mouse, and screen, all of which are being managed by an X server program; and the application programs (OpenOffice.org, Mozilla, etc), which are known as X clients. X clients communicate with the user through X server. Both the X server and X clients, in a computer, make up an X Workstation. (Shrestha & Shrestha 2007.)

Figure 3 below illustrates a simple function of a Linux based system, in which X clients are communicating through the X server to the user interface.

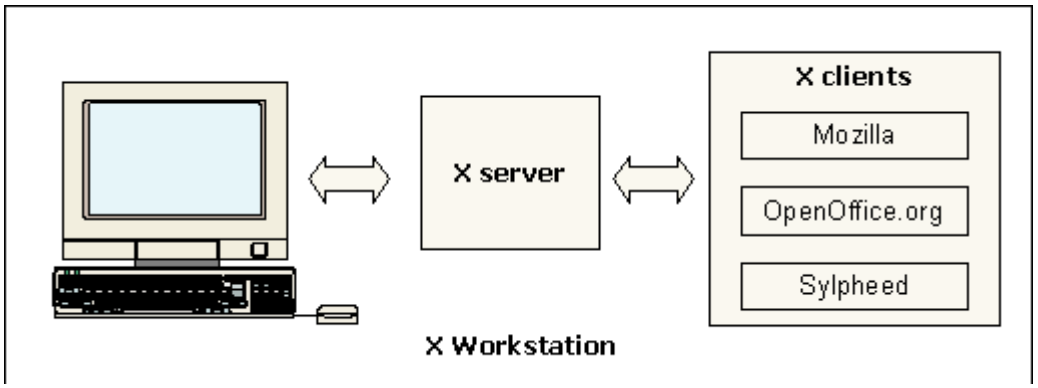


**Figure 3.** Illustration of an X Workstation (Shrestha & Shrestha 2007)
However, it is also possible to run the X server and X clients on separate computers.

## 4.2 Multi-User Terminal/ Server Computing

Generally, what is regarded as terminal server is a specialized computer that makes it possible for users to use multiple communication channels at one point. It can also be referred to as centralized computing. The system of centralized computing is a modern form for Linux desktop connecting to multiple user terminals, which is today regarded as "Thin Clients". (TETRA 2007.)

With a full terminal/server configuration, it is possible for one server to be used as X client to a number of X terminals. All the necessary software and data will be installed on the server, and the diskless X terminal downloads the software it needs to function from the server anytime it is being switched on. It can also be switched off anytime the user deems fit.

This computing system is highly efficient and cost-effective where many users on a local area network have similar computing requirements.

Figure 4 below illustrates a function of a Linux based system with a multi-user terminal (not LTSP), in which a number of X terminals are being connected to one X client (being used as server). Although it has the same advantage of cost saving, its installation proved to be difficult.

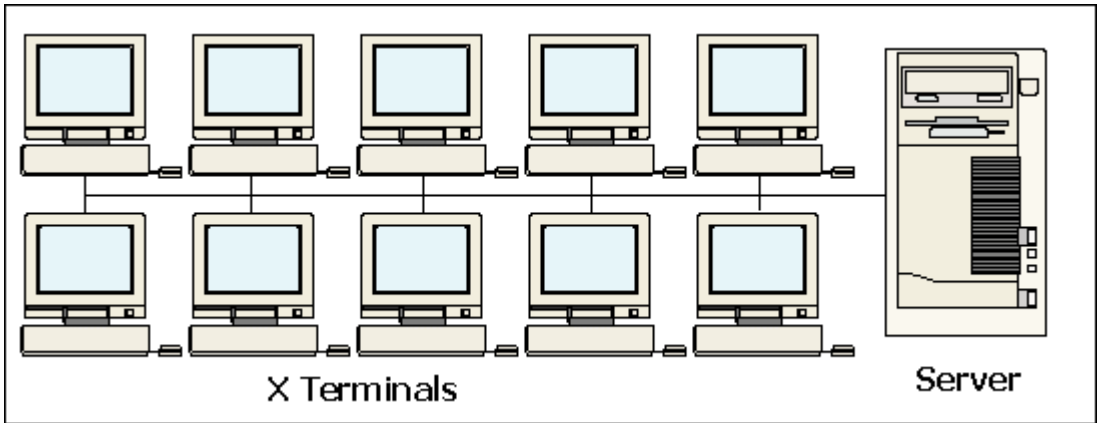


**Figure 4.** Multiuser Terminals/ Server Computing (Shrestha & Shrestha 2007)

## 4.3 LTSP as an alternative to Conventional Computer Networking System

The conventional method of setting up a computer lab in an institution of learning or a public cyber café is to purchase an essential number of identical computers and get an essential number of software to be installed on each of them. Although, this system works well, it however, tends to be very expensive and not affordable to many institutions. (Shrestha & Shrestha 2007.) Figure 5 below displays how it looks like setting up this system.

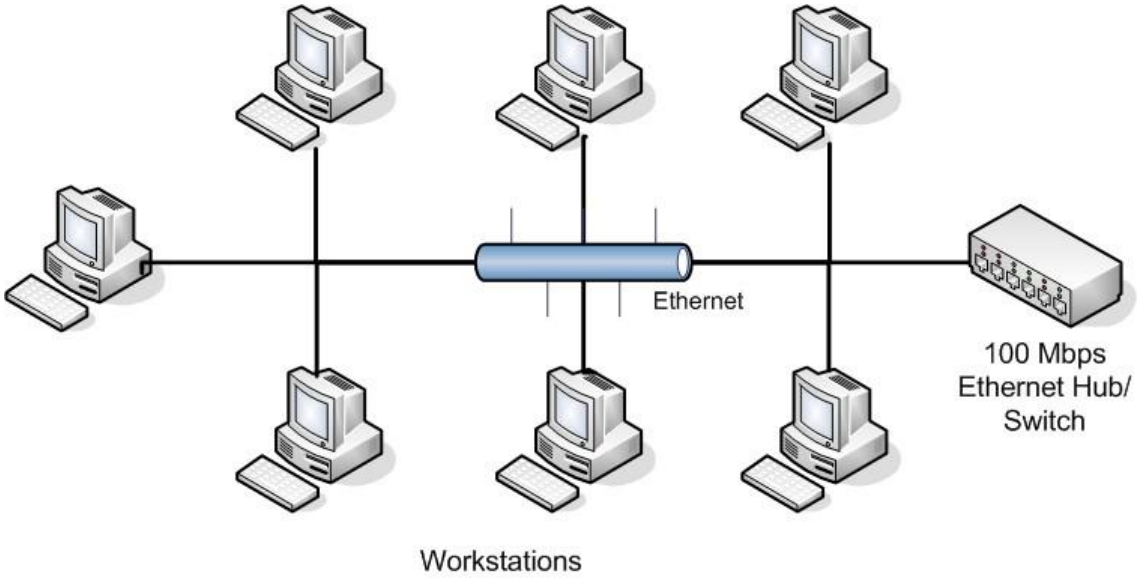


**Figure 5.** Conventional Networking Systems (Shrestha & Shrestha 2007)

There are various reasons attributed to the high cost implication of setting up this system, namely:

- Software Replication – the same software has to be installed on every required computer. The implication is that the amount to be expended on software alone depends on the number of copies made.
- Waste of Hard disk space – the required software can never fill up the available hard disk space in every computer, while files created are usually too small to fill up the disk. Thus, the money expended on the disk space tends to result in a waste, because it is never used.

- High-powered configuration required – each and every of the computers require the same configuration which has to be powerful enough. Thus, no centralized processing system is allowed to enable the use of low cost hardware on the rest.
- Maintenance tends to be burdensome – there is always a very serious problem in the maintenance of many computers at the same time. So, the lab will surely have a monotonous maintenance culture.

However, LTSP has come to serve as a solace to these institutions in setting up of computer labs. It encourages the use of server-client architecture. Figure 6 below indicates its functioning system.

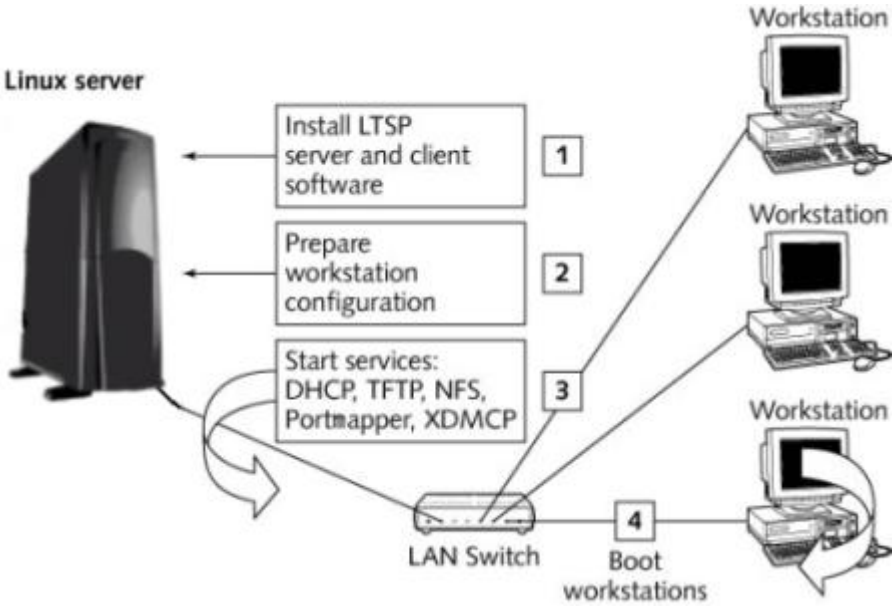


**Figure 6.** LTSP functioning system (About Linux Toys II 2005)

LTSP operation has been based on the approach of olden day's mainframe, in which a central mainframe computer would be connected to a number of character based terminals.

With LTSP system, a server functions as the central computer, accommodating all required software and disk space for all other computers. Most essentially, the server carries out all the processing jobs that are required of all other computers connected to it. Thus, there is just one centralized computer that shares its software, disk space,

processor time and configurations with all other computers that comprise the networking system.

On the other hand, all the other connected computers, which are known as the workstations, are usually diskless and have low processing power and speed. They are always connected to the server, and they rely on the server for processing of all works. In other words, the server does all the works and the workstations just display the output and take input from the user. A server usually have high-powered configuration, and so, multiple workstations can be connected to it at a time while they all function concurrently. (Shrestha & Shrestha 2007.)

## 4.4 LTSP Terminal/ Server Computing

Terminal server computing had been in existence before the advent of LTSP, both in Windows and Linux operating systems, but there had always been the problem of setting them up. However, the evolution of LTSP makes setting up of Linux-based thin clients very easy. (Berkhlz 2007.)

According to Lema (2001), he said Open Source movement could provide access to technologies for people and institutions in Latin America. Lema said Latin America was lagging behind in the use of computer technology because of lack of economic resources, proper infrastructure and technical education for the vast majority of the population, which has prevented it from reaping the benefits of the information revolution that the Internet has created. Lema reiterated that, by using cost-effective, easy-to-implement, open-source technology and free software, these countries can catch up with the industrialized world". (Lema 2001.)

Lema suggested the use of LTSP (http:/www.ltsp.org/) in Latin America, as he further asserted that many public and private institutions in Latin America could not afford new computers and costly software license fees. He also confirmed that LTSP provides an easy way to set up low-cost, diskless workstations, which would save them a huge amount of money and become more productive. Lema suggested that LTSP may also be

used in teaching children and workers the technical skills they would need in the future. (Lema 2001.)

In Lema's statements, he established that LTSP is an open source project, which is cost-effective and easy to implement. It is also capable of enhancing the economic and educational developments of developing countries, particularly, Nigeria by providing them with the required affordable and highly effective technology to aid the development of quality education and economic values. This will put them at par with their counterparts in the developed countries.

Figure 7 below displays Linux Terminal Server Project (LTSP) setup. In this setup, 10 Thin Clients are being connected to 1 single server. In other words, a number of X terminals are being connected to one X client (being used as server). Apart from its advantage of being cost effective and of high performance, it is also very easy to set up. Using LTSP, which is Linux based, in schools will make adequate provision of Information Technology facilities affordable for them. Also, since it is free and open source, it will free them from proprietary software like Microsoft Office, as they will be able to get free software and be able to customize the software to suit their purpose. Moreover, the cost of maintenance of these systems is also reduced to its lowest ebb as it is only necessary to maintain just one computer, which is the server.

**Figure 7.** LTSP Multiuser Terminals/ Server Computing (Maliondra 2010)

# 5 LTSP PROSPECTS, BENEFITS AND LIMITATIONS

## 5.1 Prospects of LTSP

The original intent of the inventors of the Linux Terminal Server Project, Jim McQuillan and other members of his team, was to proffer solution to the immediate need of a client who required a terminal that could communicate with both an IBM AS/400 and a UNIX application server. The specifications by this client were for the terminal to be inexpensive and to be easy to maintain. Moreover, the client required that it could be used to browse the web, and also allow them to send and read mails However, the inventors decided, overtime, for LTSP to go beyond these basic functions. It graduated to the use of Linux platform on a server, and using thin clients to connect to the server. This eventually led to the deployment of many Linux desktops for the use of LTSP. (Jim McQuillan 2002.)

Since its invention in 1999, many innovative measures have been taken to improve its functions and performances. Thus, today, it has not only been made very easy for LTSP to be set up on Linux distribution, a number of features have also been included. The latest proposal on this LTSP prospective measure is the idea of it having a local application support. This will enable some applications to run directly on the thin client, instead of the server. It will enhance the smooth use of multimedia applications, which is difficult to run on an LTSP network. (Jim McQuillan 2002.)

Among many advantages of this prospect, administrators will also be able to decide which packages will run on the thin clients and which one will run on the server.
The two latest versions of LTSP are; versions 4.2 and 5.0, with version 5.0 being the more recent version of the two. Version 4.2 gives room for thin client users to use USB flash drives, printers, and some other devices. Another developmental target is for users to be able to burn CDs on thin clients as well (Castro 2006).

Table 1 below shows the improvement in LTSP from Version 4.2 to the latest Version 5.0

**Table 1.** Difference between LTSP 4 and LTSP 5 (LTSP 2004)

| Purpose | LTSP 4 | LTSP 5 |
|---|---|---|
| GUI Export | XDMCP | ssh – X |
| Remote login(X display manager) | KDM/GDM | LTSP Display Manager (LDM) |
| Distribution method | LTSP tarball | Native distribution |
| Root file system | NFS | NBD |
| Authenticating server | XDMCP server | SSH server |

## 5.2 Benefits of LTSP Terminal over Conventional Server/ networked Computing

Apart from the glaring benefits of cost effectiveness and high performance that LTSP has over the conventional server or stand alone systems, there are still other numerous benefits that are derivable from giving it priority.

Table 2 below analyzes the essential benefits derivable from giving priority to LTSP Terminal over other conventional computing systems.

**Table 2.** Analyzing Benefits of LTSP Terminal over Conventional Server/ networked Computing (LTSP 2004)

| LTSP Terminal | Conventional Server/ networked Computing |
|---|---|
| Diskless X terminals require minimal hardware to run | Every PC needs to be fully specified with disk, memory, CPU etc. |
| Every user has equal access to computing resources | Each user can only use the resources provided by the PC on their own desk. |
| Terminals boot quickly as they have | Every user has to boot a complete |

| | |
|---|---|
| minimal software to load | operating system for their own PC |
| Applications are shared in the memory of the server, so programs load quickly and save memory | Every user has to load their own copy of every piece of software into their own PC's memory. |
| If a diskless X terminal fails, it can be swapped out with any other device | Rebuilding a complete PC from scratch requires tedious software installs/restore from backups. |
| New versions of application software only need to be installed once on the server. | Every new piece of software/ upgrade needs to be installed on every PC. |

## 5.3 Advantages of LTSP

LTSP has numerous advantages such that it establishes its capability to provide a long lasting solution to the problem of Information Technology in the developing countries, especially in the educational and economic sectors.

Firstly, LTSP is highly cost-effective; it helps to save so much money on hardware by allowing the use of older machines as thin clients. Moreover, since LTSP operates on Linux technology, its software will be free to acquire, use and modify. This cost advantage also has its long term effect on the followings:

* Installation and configuration of software is carried out on the server alone, thus saving cost of installation on all the thin clients.
* Only the server will be upgraded if there is any need for upgrade
* The workstations last longer, since they are diskless and have fewer moving parts.
* Since terminals can be acquired at very low cost, expenses on additional terminals are at insignificant rates. (Balneaves and other authors 2009, 9.)

Secondly, LTSP is endowed with Top-Level Security. The fact that LTSP is a GNU/Linux based operating system; it automatically enjoys the security advantage of Unix-like and open source heritages. It is free of spyware, viruses and all other attacks. Moreover, the fact that LTSP based systems are multi-user operating systems makes the completion of users' task to be hitch-free.

Furthermore, since the workstations do not store data, no data will be lost if they are being stolen. (Balneaves and other authors 2009, 10.)

Thirdly, LTSP possesses a feature of heat reduction. Generally, usage of computers generates heat, which leads to more power consumption. However, in the case of diskless systems, they only use 15 watts of power and produce virtually no heat (BeginLinux.com 2010).

Fourthly, LTSP is built for educational, government and business purposes. The server software enhances the creation of low cost computer labs for use in the educational environment, which gives users benefit of enjoying the opportunities of GNU/Linux and the Internet. Moreover, LTSP distros are in many languages and localization features. This will allow people in the business world to make judicious use of internet and other computing services. (Balneaves and other authors 2009, 11.)

Fifthly, LTSP has been known to be energy saving, as it has been established that thin clients use half the energy that is required by traditional workstations to function because they perform very little processing. This does not only save cost, but is also ecologically effective in avoiding electronic waste and high carbon emissions. (Balneaves and other authors 2009, 10.)

Furthermore, it has been well supported. LTSP has the support of many of the developers of the software included in it, including the developers of LTSP GNU/Linux platforms. The various forms of support available to LTSP include; mailing lists, Wiki websites, IRC channels, and bug trackers. Both LTSP and GNU/Linux also have some special support groups. (Rijal & Bhandari 2010.)

Moreover, it has an advantage of easy upgrading. It is easy to have additional workstation added to the existing network and also, the upgrading of existing software or installation of new ones will only be done on the server, instead of all the thin clients. Replacement of faulty units can also be done on the server alone, without having to diagnose faults on the clients. (Shrestha & Shrestha 2007.)

LTSP also has an advantage of effective administrative control, as permissions must be given to users, by the administrator, before they can load their own applications or

change the configuration settings. This is to guide against any use of unauthorized and unlicensed software on the network. (Shrestha & Shrestha 2007.)

Additionally, instead of having to provide back up for so many hard drives, there is need to back up only the server and a complete back up of every data on all the computers is guaranteed (Jordaan 2005).

Lastly, it is very simple and easy to maintain an LTSP thin client technology. Since the server runs all the applications and stores all data, the necessary maintenance, like software updates and administration, will be carried out on the server alone rather than on each individual workstation. It only requires a monitoring of a single server, rather than all the workstations, to administer an entire network. LTSP is highly beneficial in an educational environment. (Thomas & Channelle & Sicam 2009, 742.)

It is noteworthy to mention that it is also possible and beneficial to run applications locally on the workstations. Running applications on workstations tends to reduce the workload on the server. Also, missing application on one system will not have any effect on other systems. Moreover, it will not be complicating to configure a sound support which has its application running on the workstation. (McQuillan 2001.)

However, running applications locally from the workstations demands much more requirements that running it centrally from the server. It means the workstation would be needing more RAM and a powerful computer. Moreover, the startup of applications will tend to be slower as it will be read through NFS and this means there will be increase in the network activities. Also, there is need for the user to provide identification to the workstation through the (NIS) Network Information Service. (McQuillan 2001.)

Apart from the fact that Linux Terminal Server Project permits the user to do away with the cost of maintenance, support, and licensing of many computers, there are absolute benefits that are derivable from its usage of a Linux based platform for its operation. Since Linux operates with free and open source software, and LTSP is operated on Linux based software, it means that LTSP users enjoy all the benefits of Linux operating system, which are:

- Free and Open source software enables users to dispense with software vendors, as individual user will have the opportunity of making decisions on the software that will serve his or her business purpose, instead of software vendors telling them what to use or not to use.
- Users have the right to determine when to upgrade their system software.
- Users can customize free and open source software and even incorporate applications from different software, unlike in proprietary software where it is almost impossible.
- There is no specific owner of an open source software as it can be altered and customized to suit the user's purpose, while the owner of proprietary software is the lifetime owner and determinant its sales or otherwise.
- The license for open source software is free while it is very costly to obtain the license for proprietary software products. (Battistoni 2008.)

## 5.4 Limitations to the use of LTSP in Nigeria

As much as we desire to have LTSP as a cost effective and high performing Information Technology system, it is also necessary to identify the situations where it will not be convenient to use. Thus, the following situations may not be suitable for LTSP operation in Nigeria:

- Distance learning – LTSP is best used where there is physical presence of students in a classroom.

- Multimedia learning – LTSP technology is not suitable for multimedia learning systems, such as; video and audio. They are almost prohibitive using thin clients.

- Mobile Learning – thin clients do not support e-learning system. This situation requires special devices that are not currently supported by thin client technology. (Martinez-Mateo & Munoz-Hernandez & Pe'rez-Rey 2010, 5.)

- Centralized Failure Location – any failure or problem on the server means that everyone using LTSP server will be offline, since all networks rely on the server

to function. However, a spare server may be put on standby to avert this occurrence.

- Erratic Power Supply in Nigeria – the power supply system in Nigeria is highly unreliable. Although LTSP is known to consume low energy, it still requires a stable power supply, and so, a standby Generating set may be required for an uninterrupted operation.

- Level of the technical know-how in Nigeria – very few people really have the knowledge of computer operation in Nigeria. The awareness of computer operation only exists in the Urban centre, whereas, the majority of the populace are concentrated in the Rural Areas. There will be need for the Government to introduce computer course into the curriculum of every facet of education so as to encourage students to learn it.

- LTSP as a new technology – the majorly recognized operating system in Nigeria today is Windows, and so, LTSP operation may pose a problem at the initial stage because it operates on Linux based operating system. However, its constant use will surely bring perfection and users may likely develop passion for it.

- Government policy on education – although, LTSP is cost effective, it will still require some funds to be set up. The educational system in Nigeria is underfunded by the Government, while the educational institutions also face inadequate financial resources. This means that they will have to work within the scope of the little available funds to achieve their goal of putting in place adequate IT facilities.

## 5.5 LTSP success stories

The successful implementation of LTSP for the original client, by the innovators, Jim McQuillan and his team members, made them decide that they had to share the project with the rest of the world. This was after several months of running it by the customer

without any support problems with the workstations. They also hoped that it would solve other people and/or institutions' problems. Obviously, they were right, as this same project is being used by notable companies and educational institutions today, even in the developed countries, both in Europe and America. It is therefore, pertinent to include in this Thesis work, those who have had live experiences about LTSP and their comments about its performance.

The followings are some of the success stories as expressed by the successful users of LTSP from different parts of the world:

Hancock Public Schools, Hancock, MI USA

According to Sherrill (2005), Hancock Public School, a small K12 School District, had been using LTSP and K12LTSP for some years, and the school discovered that a combination of Pentium 133s and K12LTSP works well for students in the classroom, using applications like OpenOffice, Firefox and the Gimp. Sherrill said the school also used LTSP as a delivery mechanism, for the office staff, running Win4Lin, thereby, fortifying old hardware and producing a thin client system that would be affordable and easy to manage. (Sherrill 2005.)

JC Cerberus – Hengelo, The Netherlands

According to Leeuw (2005), JC Cerberus was a place for young people to play or search for information on internet, and it was being run by volunteers, without any funding from the government or other institutions. Leeuw said the centre had ten computers with internet, running on Linux and LTSP, for chatting, homework, music playing or partying. Leeuw confirmed that it is cheaper running these ten terminals than one MS Windows system. (Leeuw 2005.)

Gould Academy – Bethel, Maine USA

Dresser (2004), said Gould Academy, a small private school, had been using LTSP since 2001, and that the school had around 90-100 diskless terminals all over campus. Dresser claimed that the school supported around 300 users and usually has 50 or more simultaneous sessions on a Dual Xeon 3.2G with 4GB RAM. She also said that the applications frequently used are OpenOffice.org, Firefox, Gaim, rox file manager. She said the school also offered terminal sessions remotely, using SSHVnc for day students

who wanted to use LTSP from a web. She confessed that LTSP was a significant part of the services the school offered the community. (Dresser 2004.)

Government High Schools, Kannur District, Kerala, India

Pullanhiotan (2008) asserted that children of Government schools in Kannur, Kerala now had access to their own computers running on GNU/Linux Operating system Pullanhiotan said introducing computer education facilities in Kannur, Kerala schools was one of the major development projects initiated by the Members of Parliament (MP). Pullanhiotan confirmed that a considerable amount of money could be saved, while many computer facilities would be set up by using GNU/Linux and Diskless workstation. (Pullanhiotan 2008.)

# 6 SETTING UP LTSP

In LTSP project, a diskless client is known to support multiple terminals that run from the same computer, which are connected through a considerably higher speed network (Jang 2009). Therefore, the system requirement is determined by the number of concurrent diskless workstations that are needed to access the server and the applications that are being run on them. The two essential aspects to be considered are both the server's memory and the network speed. However, the minimum requirement for an LTSP network server configuration is a Pentium-class computer with at least 64MB RAM and a 2GB hard disk drive. (Lema 2001.) Also, each of the workstations is required to have a 486 or K5 computer with 16MB RAM and a 1MB video card (Bookman 2003, 144).

## 6.1 Software and Hardware requirements

LTSP has been packaged to be installed on any Linux or UNIX server system and the server should include software for providing DHCP, TFTP, NFS and XDMCP services.

- DHCP – (Dynamic Host Configuration Protocol) this is needed to give each workstation its IP address and locations of such things as routers and DNS servers on the network and also to identify the location of the bootstrap or Linux Kernel each workstation needs to boot from. An IP address has standard four-group digits forming a number from 0 to 255. For instance, it may be 192.168.2.50; it is supplied found through the MAC address of the network card that is being used A server running DHCP service can provide an IP address, and DHCP automatically provides network settings to the computers on the network. (Agrawal & Ansari & Tiwari 2005, 169.)

- DNS – (Domain Name System) this service runs on a server. It plays the role of a phone book to computers; it is just that it deals with the storing of IP addresses instead of phone numbers. The computer communicates with a DNS server whenever reference is being made to another computer system with a name instead of an IP address. For instance, www.ltsp.org is a DNS hostname. (Balneaves & other authors 2009.)

- TFTP – (Trivial File Transfer Protocol) is used to download the bootstrap or kernel file to each workstation. In other words, it is used to boot diskless workstations to enable each client to copy the files it needs from the server. (Balneaves & other authors 2009.)

- Etherboot – this program is used in transferring of boot images and other programs, through the network access, from the server to the workstations (Bookman 2003, 144).

- NFS – (Network Files System) is used to provide directory structure from the server i.e. it shares the /opt/ltsp directory (for file system) and the /var/opt/ltdp/swapfiles directory (to provide a swap area).

- XDMCP – (X Display Manager Controller Protocol) – in connecting LTSP (thin client) to Linux Server, it is required that X display manager control protocol is first configured. This is to ensure that the client(X) communicates with the server (X display manager). It is used to configure a graphical login screen on the server. It handles how the clients' graphical displays are launched and how the initial graphical login screen appears and acts. (Bookman 2003, 144.)

Hardware requirements - in setting up an LTSP thin client environment, there are some basic hardware components that are required. These requirements will be determined majorly, by the function a PC is expected to perform, the number of clients to be connected to a server, and whether they will all be put to use simultaneously. (TuxRadar 2009.) Provisions will be made for both the server and the clients.

Server Requirements: LTSP requires one PC to be used as the server. The server should be the most powerful of the PCs available for use, and it has a minimum hardware requirement. Although, the minimum requirement for a server is a Pentium-class computer with at least 64MB RAM and a 2GB hard disk drive, while the requirements each of the workstations is a 486 or K5 computer with 16MB RAM and a 1MB video card (Lema 2001). However, for a server to function perfectly and for high performance, it is recommended that the server should fulfill the followings:

* RAM – the minimum total RAM required is 256MB + (50MB per thin client). For example, if you are setting up your LTSP server with 20 terminals or thin clients, then the sever needs 256MB + (50MB*20) = 256MB + 1,000MB = 1,256MB.
* CPU – (Centre Processing Unit) a server requires a CPU with 3000MHz, which could serve up to 30 units of terminals. One terminal, or user, will use 1% to 3% of the server's CPU.
Hard Disk Drive – A SCSI drive is recommended for a server. A 15K rpm drive is required to support more than 20 terminals or thin clients. (Ghanem & Sayej-Naser 2009.)

Thin Client Requirements - there is no limit to the number of thin clients, or terminals, that could be used, provided it does not exceed the maximum limit of your LTSP server. However, the minimum LTSP terminal requirements are as follows:
* RAM - 128MB. Although, a terminal can function on a RAM, even as low as 16MB, but its performance will not be encouraging. Hence, 128MB is recommended for high performance.
* Network boot facility – this is required in the BIOS of the motherboard (Network Card) in each terminal. (Ghanem & Sayej-Naser 2009.)

LTSP Network requirements - networking on LTSP requires the following conditions to be fulfilled:
* The server should be connected to the hub or switch
* The thin clients should be connected to a hub or switch, with the use of Straight Cables.
* 1GB connection should be between the server and the switch, and 100MB connections between the clients and the switch. (Ghanem & Sayej-Naser 2009.)

It is pertinent to note that a backup power supply should be provided in case the power supply for the server goes down. Moreover, there are two different types of networking, namely; Wired and Wireless networking systems.
Wired networking transfers packets through a cable. It can do this at a speed of 10MB/second or 100MB/second or 1000MB (1GB)/second. (Ghanem & Sayej-Naser 2009.)

Multiple computers can be connected in a network through the use of hub and switch. A hub has a lot of ports in the front, with a number of small lights matching each port. It receives a message from one port and resends it to all the ports. A switch, just like a hub, has many ports in the front, with a number of small lights matching each port. However, it can have multiple connections at a time, which makes it faster than a hub. (Ghanem & Sayej-Naser 2009.)

## 6.2 LTSP set up Distribution requirements

For a distribution to be used for the setting up of LTSP, it has to fulfill the following requirements:

* Netboot thin clients with PXE and Etherboot
* Local devices with a FUSE file system called LTSPFS
* Network-transparent sound and video
* Screen scripts, including XDMCP, Idm/sdm, rdesktop, telnet, shell
* Boot thin clients with 32MB memory or more
* Use LTSP tools such as getltscfg
* Pass VCI (Vendor Class Identifier) string from the client to the server (in initramfs)
* Transparent pass-through printing
* Network swap using methods such as NBD, iSCSI or NFS
* Configurable location of the LTSP chroot tree
* Control per-client options with a single file, lts.conf. (Berkholz 2007.)

LTSP can successfully run on the following sets of Linux distributions, among others:

* All Red Hat Distributions, including the latest Enterprise Linux 6
* Mandrake 10.1
* All SuSE, including the latest openSuSE 11.3
* Caldera eDesktop 2.3, 2.4, and eServer 2.3.
*All Ubuntu Distributions, including the latest Ubuntu 10.10

## 6.3 Installation process

LTSP installation could be carried out through different options. It could be done through CD installation, or downloaded LTSP packages online, or through Terminal installation system.

In carrying out LTSP installation through CD or Downloaded software, the first thing to ensure is the setting up of the services required by LTSP, such as; DHCP, TFTP, NFS and XDMCP. The following packages are also required to be installed: dhcp3-server, dhcp3-common (this is installed already by default, in Linux), dhcp3-dev, tftpd-hpa, nfs.kernel-server, xinetd, and libwww-perl (this is required for the installation of ltsp-utils). All these packages could be installed through the use of 'sudo apt-get'.

The next thing is to go to www.ltsp.org for the installation of a preferred package that will enable running of LTSP from the server. As stated earlier, some of the available packages on this site are Debian, Ubuntu, Red Hat/Fedora, among others. The package for any preferred Linux distro can be downloaded from this site.

However, for the purpose of this work, we will be considering Ubuntu distro, and so, we are going to use Ubuntu packages. Alternatively, LTSP-UTILS can be accessed through the use of terminal by typing the command below:

wget http://ltsp.mirrors.tds.net/pub/ltsp/utils/<latest_ltsp-utils_packages

The next step is installation of ltsp-utils utility. This is done by opening a terminal and navigating to where ltsp-utils has been downloaded. Type the following command: dpkg – i <latest_ltsp-utils_package.deb>

It is noteworthy that root privileges would be required in the installation of ltsp-utils. This could be acquired through the command; sudo su.

Having installed ltsp-utils package, the next step is to install LTSP packages, using the same terminal that has been used to install ltsp-utils. Follow the steps below to carry out the installation.

- Type: ltspadmin on the same terminal being used, the screen below will then appear:

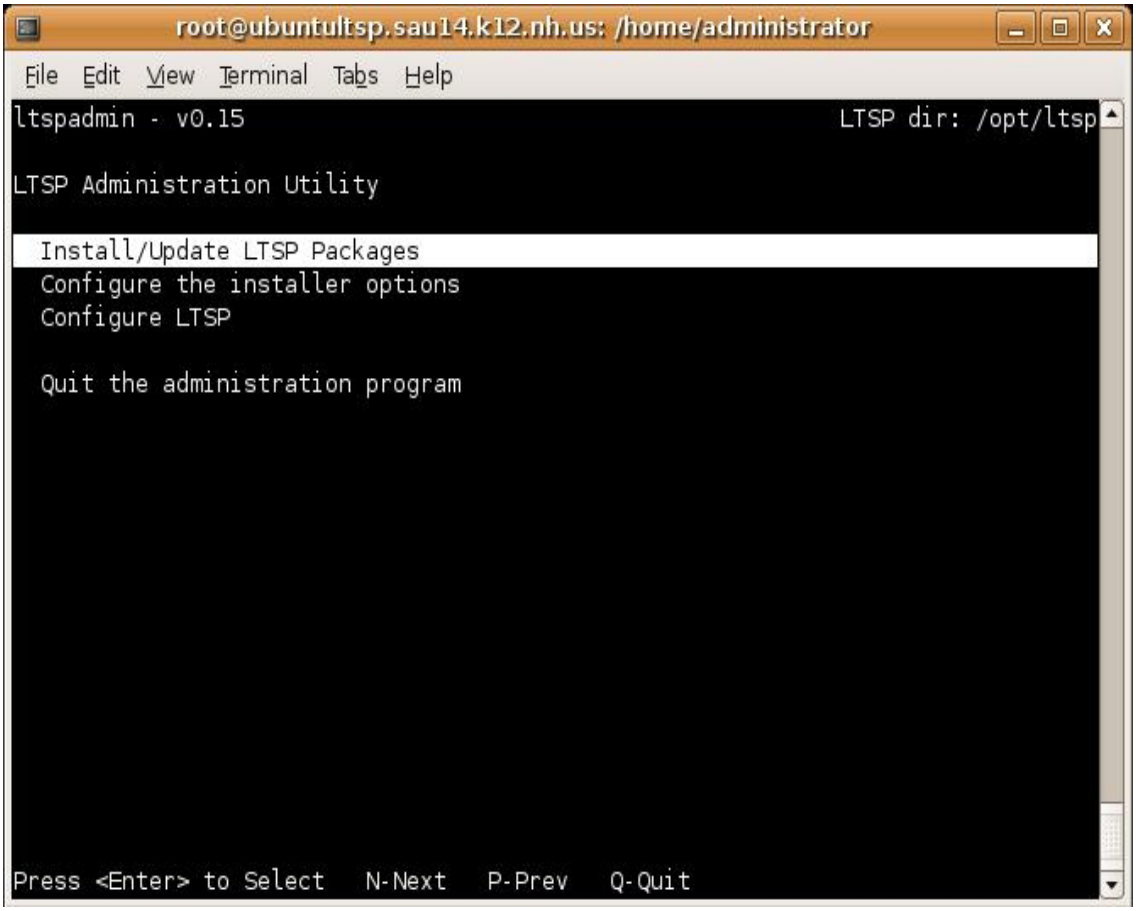


**Figure 8.** Displaying the Install/Update screen (Paul VanGundy 2006)

On the above screen “Install/Update LTSP Packages” has been selected by default, so just press “Enter” button on the keyboard. Below is the next screen that will appear:

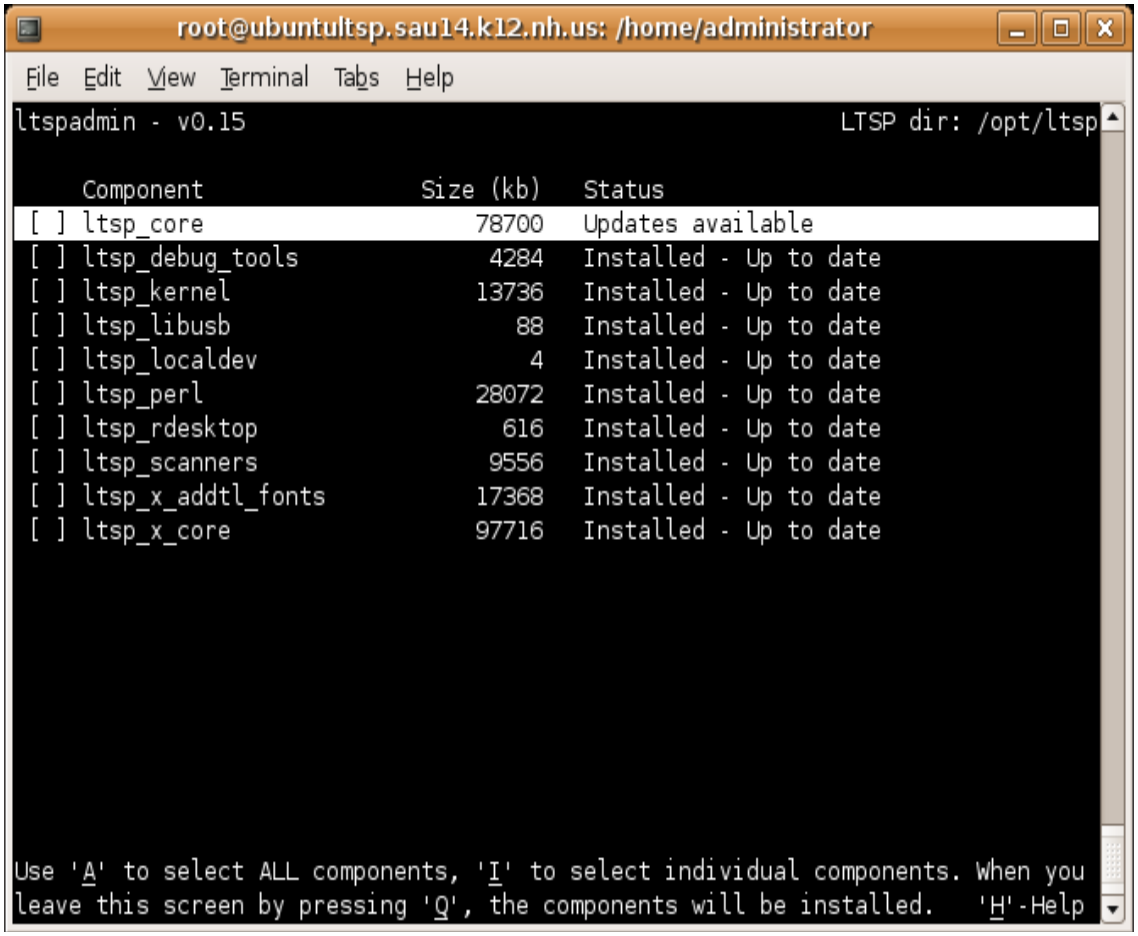


**Figure 9.** Displaying the list of LTSP components (Paul VanGundy 2006)

This screen displays the list of LTSP components. Press “A” button to select ALL components, and press “Q” to continue, you will be asked if you want to continue, press “y” to say yes. At this stage, the ltspadmin will begin to download the LTSP components.

Press “Enter” after the installation of these components, this brings you back to LTSP Admin Utility “homepage”. The next screen that will appear will lead you to the configuration of LTSP:

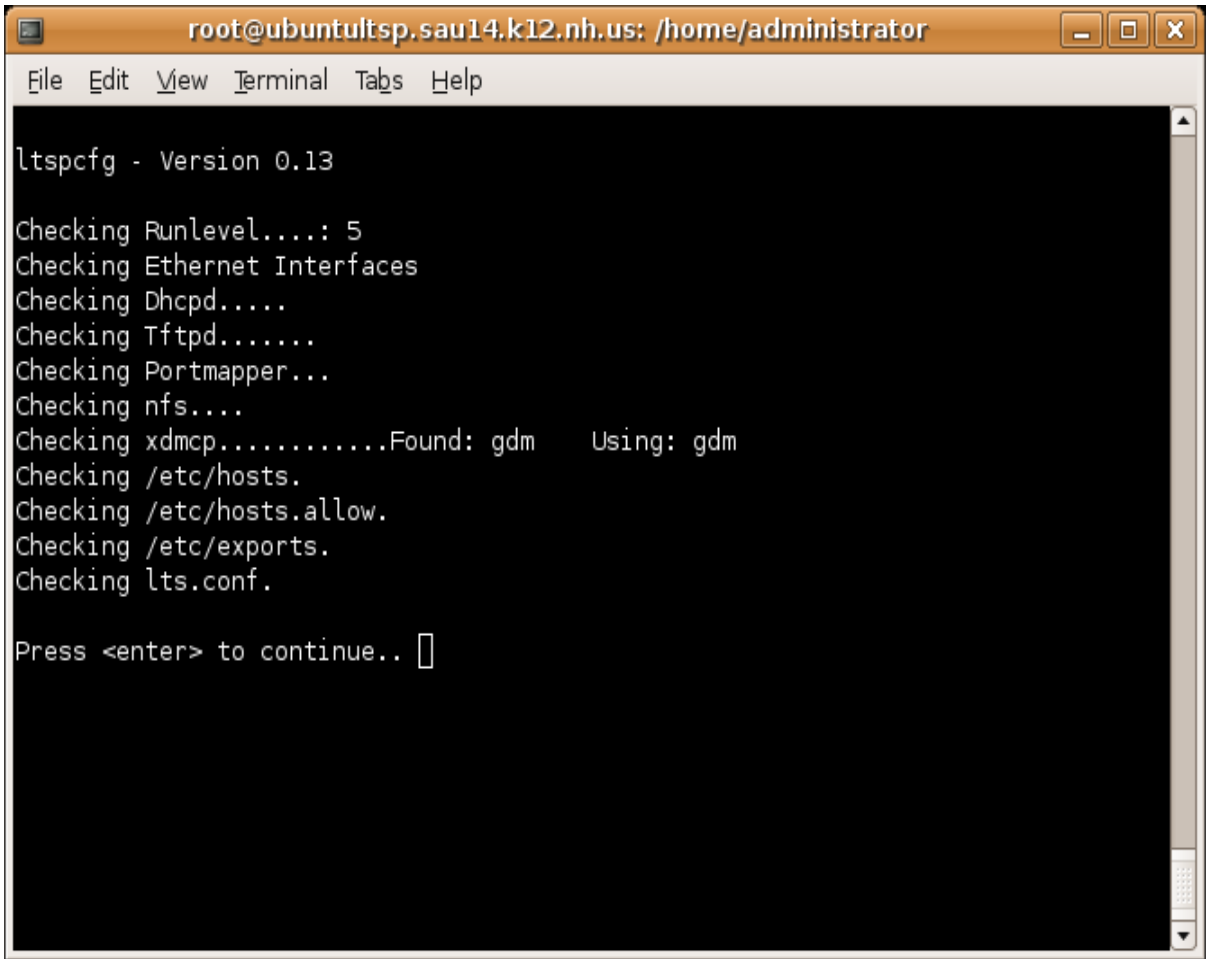


**Figure 10.**Checking LTSP configurations (Paul VanGundy 2006)

Press “Enter” to continue. The next screen will display the information below:

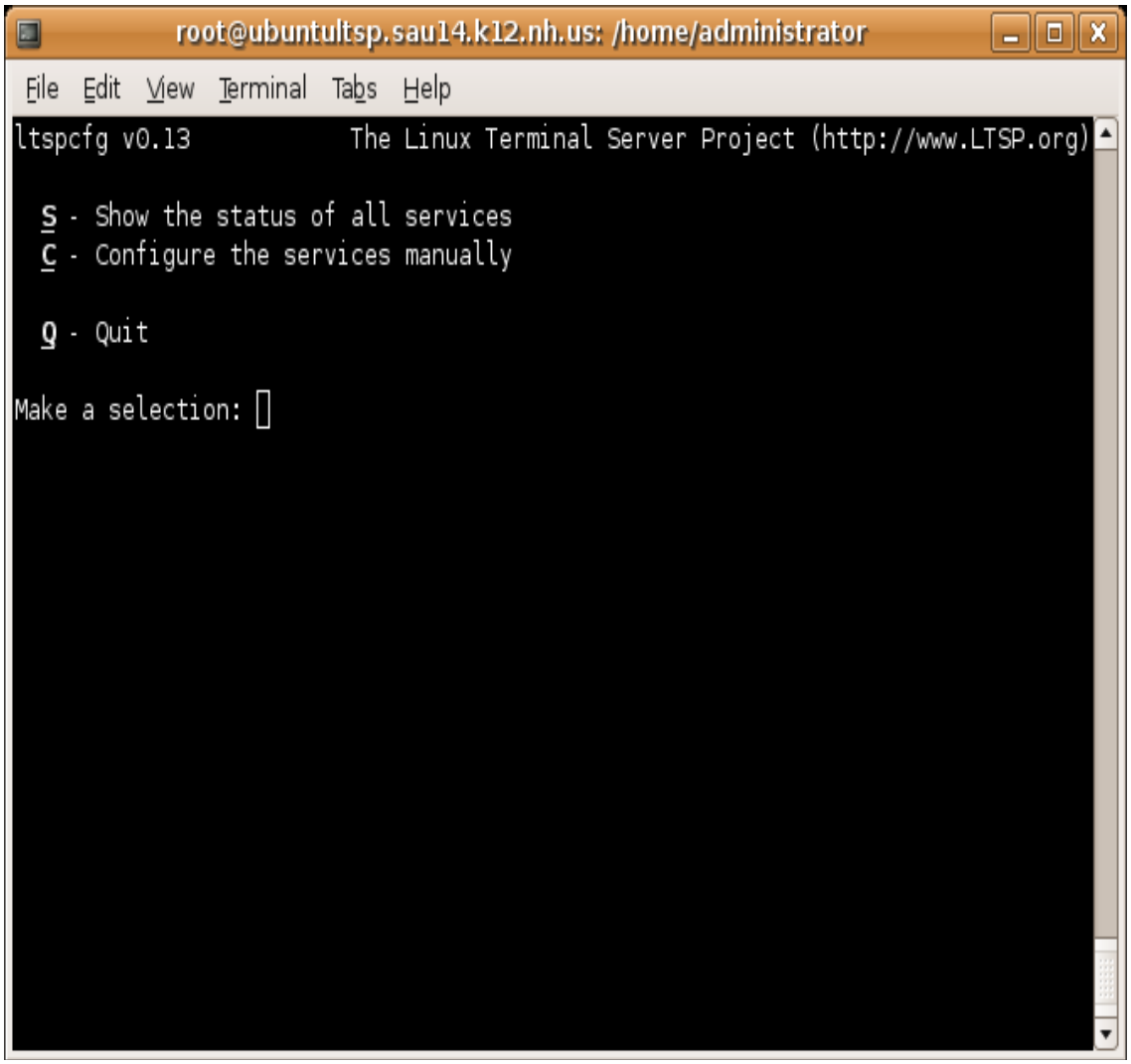


**Figure 11.**Displaying LTSP configuration utility (Paul VanGundy 2006)

The screen above displays the ltspcfg utility. This can also be achieved by opening a terminal and typing ltspcfg there.

In order to configure these services manually, press “C” button and press “Enter”. The screen below will appear:

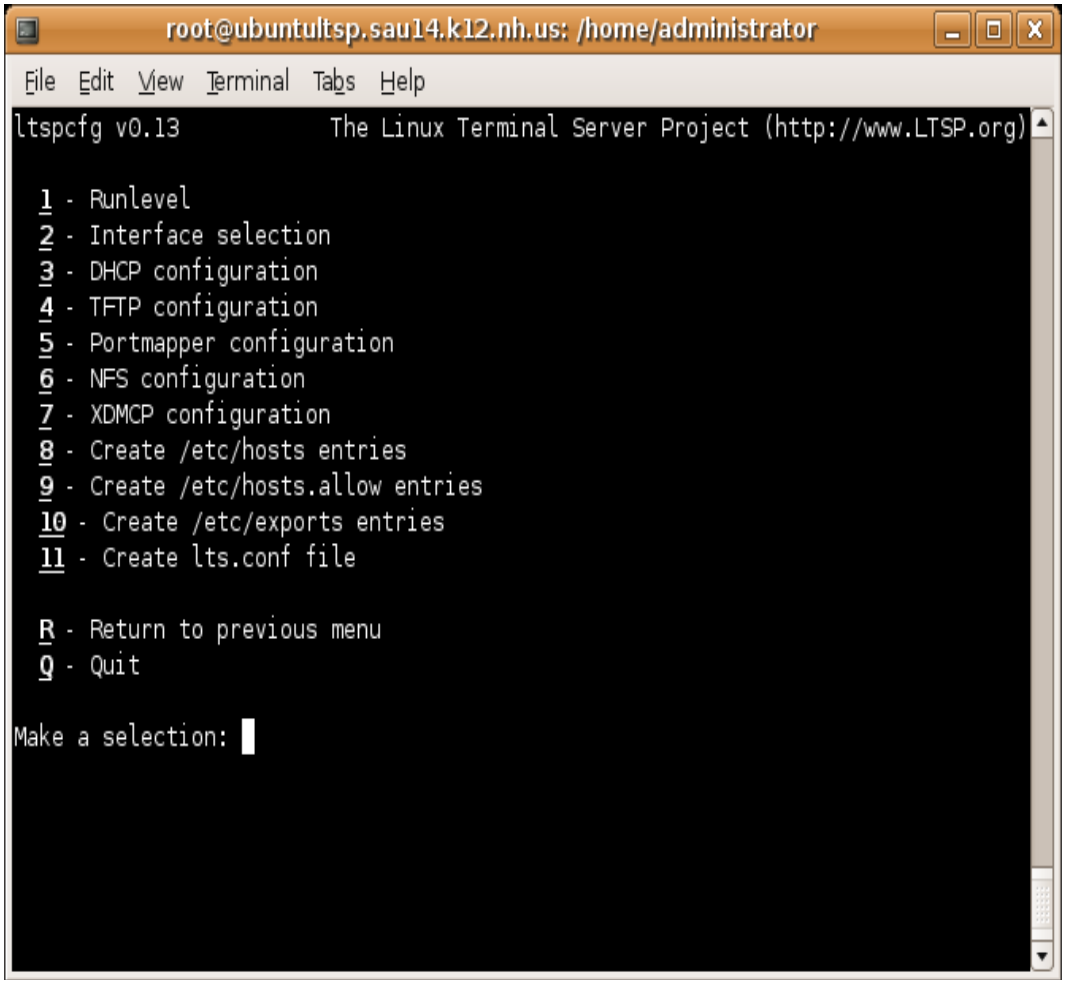


**Figure 12.**Displaying the list of LTSP configuration (Paul VanGundy 2006)

There is need to address the first 4 options that appear on the screen, vis-à-vis:

- Runlevel – this has to be set to 5 instead of 1
- Interface selection - unless there is only one NIC card being used, there is need for preferred interface to be selected.
- DHCP configuration – create dhcpd.conf file for ltspcfg. This should be labeled dhcpd.conf.sample and located in /etc/dhcp3. Thereafter, configure dhcp.conf in this location.

As it is, dhcpd.conf is now located inside /etc/dhcp3. It also means that dhcp.conf file is already in the folder replaced with dhcp.conf.sample file. The next step is to configure the dhcp.conf.sample file and save it as dhcp.conf. (See Appendix 1).

By default, the sample dhcp.conf file comes with the required information. For instance, creation of the dhcp.conf.sample through ltspcfg automatically changes the routers information to the server's IP address. All that is required is changing of the option domain-name to go with the current domain name. One may also wish to include other name servers to option domain-name-servers. Save dhcp.conf.sample as dhcp.conf and overwrite the current dhcp.conf in /etc/dhcp3.
The next action required is commencing the DHCP service by typing the command in a terminal: /etc/init.d/dhcp3-server start

It will inform you that DHCP is being started and later display "[ok]".
TFTP configuration – at this juncture, it will inquire if you intend starting TFTP. However, TFTP must first be configured to run, thereafter, you will click "y" button to answer yes.

The way xinetd is being configured for TFTP is to create a new file called tftp in directory /etc/xinetd.d, edit the tftp file with an editor such as; gedit, vi, etc. with the following information:

```
service tftp
{
disable                 = no
socket_type             = dgram
protocol                = udp
wait                    = yes
user                    = root
server                  = /usr/sbin/in.tftpd
server_args             = s /tftpboot
}
```

Save this information in tftp file and return to option four "TFTP Configuration" in ltspcfg and instruct it to start, then it will start tftp.

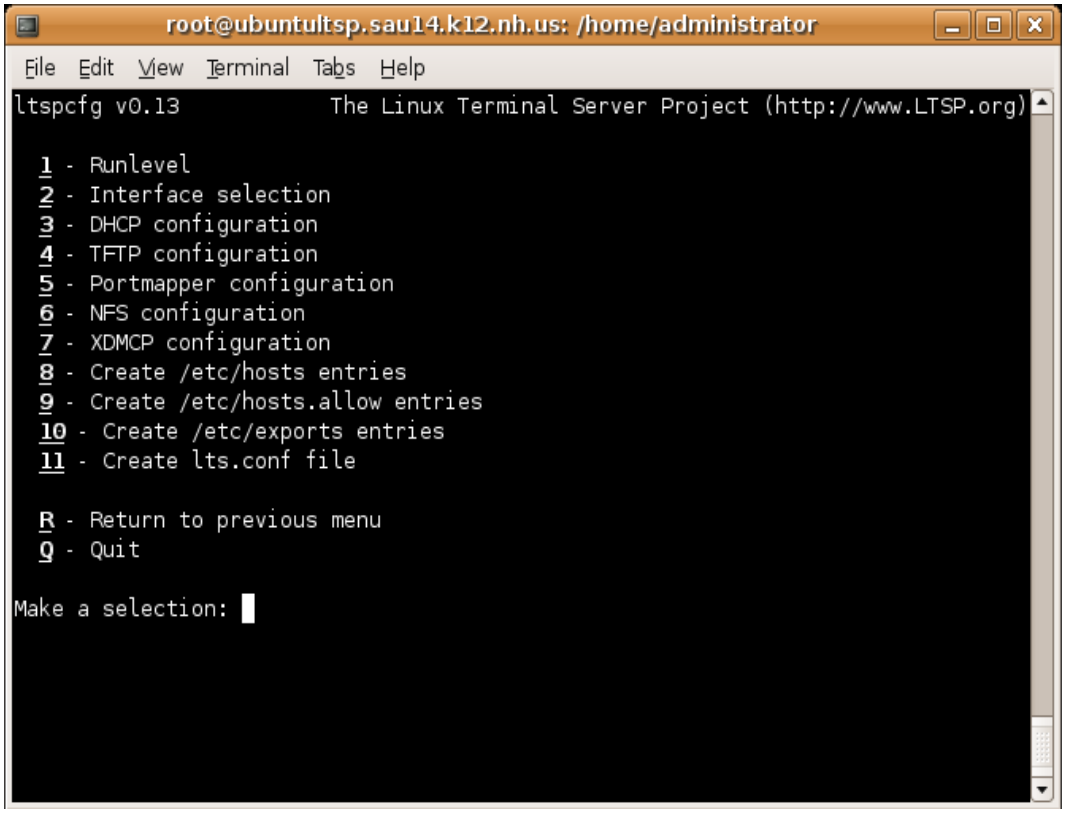


**Figure 13.**Displaying the list of LTSP configuration (Paul VanGundy 2006)

The next two steps, five and six, on the screen can be fixed in the terminal by the commands below:
/etc/init.d/nfs-kernel-server start (which starts the nfs server), and
/etc/init.d/portmap start (which starts the port mapper)

Please note that XDMCP is automatically running. To ensure that it is running, go to the desktop manager configuration file (e.g. EX: gdm, kdm, xdm) and enable XDMCP by setting it to Eable=true. Figure 14 displays XDMCP being set to Enable=true, which settles step 6 of the ltspcfg utility “XDMCP configuration”.

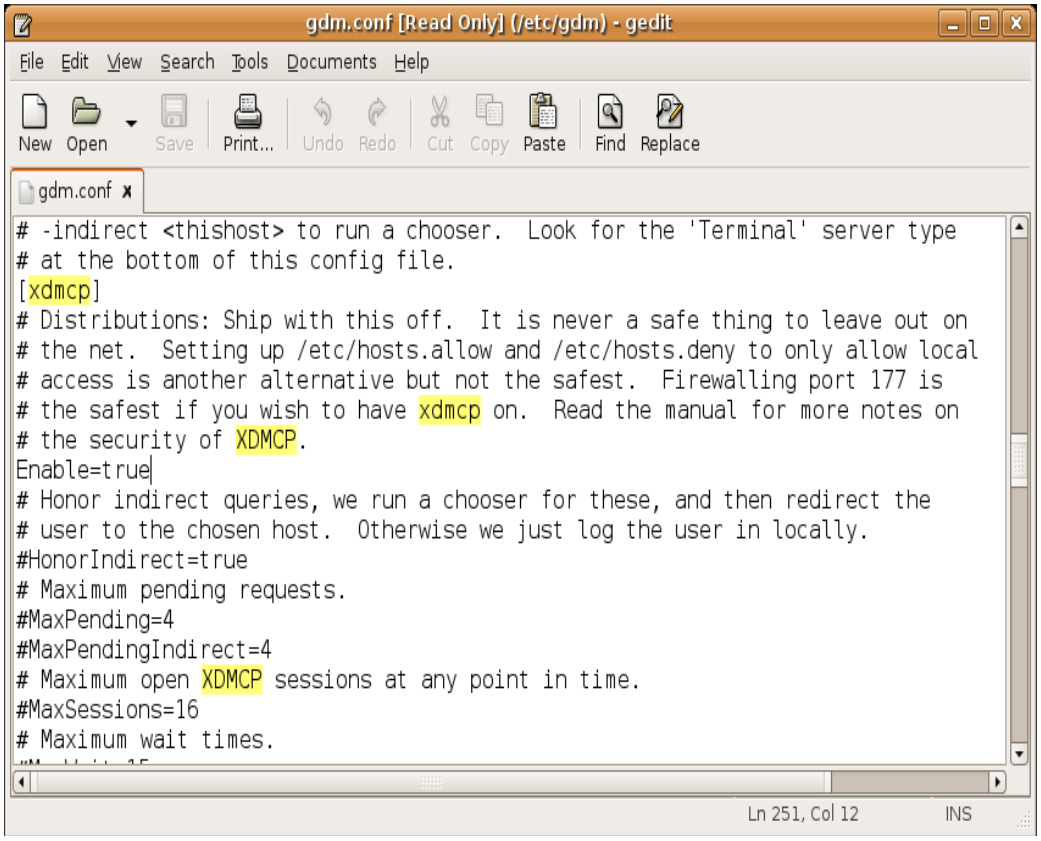


**Figure 14.**Displaying XDMCP being set to Enable=true (Paul VanGundy 2006)

From steps 8 to 11, make them create the files as instructed on the screen. For instance, step 8 should create /etc/hosts entries file, step 9 should create /etc/hosts.allow, entries file, step 10 should create /etc/export entries file, and step 11 should create /etc/lts.conf file. LTSP has finally been installed and services configured. All that is needed is to modify /etc/hosts file to conform to the network information.

To ensure that the DHCP, TFTP, NFS, Port mapper, and XDMCP are all running, run ltspcfg and select “Show the status of all services”. If they are running, then the screen below will display the information:

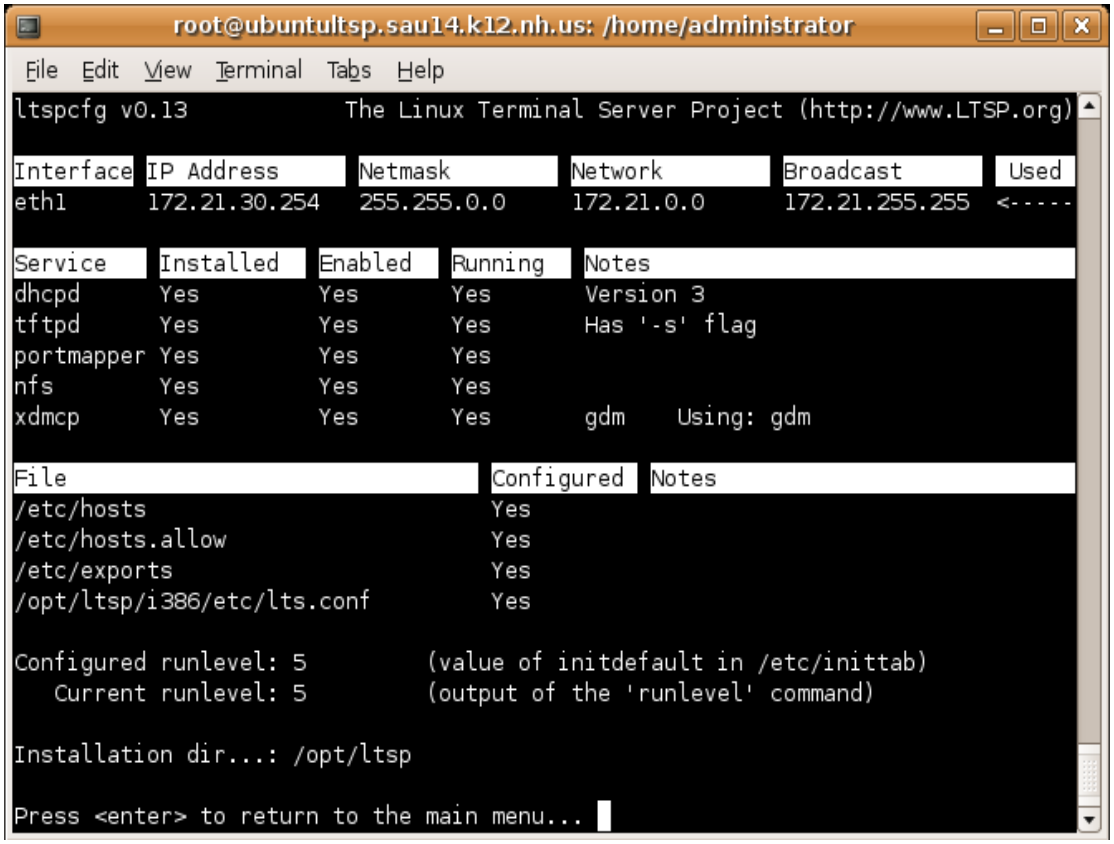


**Figure 15.**Acknowledging that DHCP, TFTP, NFS, Port mapper, and XDMCP are all running (Paul VanGundy 2006)

Thereafter, booting of clients can commence immediately (Paul VanGundy 2006.)
. IT is possible to boot clients in more than one way. However, the easiest way to boot a client is through the use of PXE-enabled network card, which is found in most modern onboard adaptors. (TuxRadar 2009.)

Also, the following commands can be used to perform installation of LTSP through Terminal system:

- The first thing is to display the terminal screen. Thereafter, enter the commands below for the installation process:
- sudo apt-get install ssh #(this command is needed for LTSP because it depends on ssh)
- sudo apt-get install ltsp-server-standalone #(it builds the server to conform with LTSP operation)
- sudo ltsp-build-client #(builds the client, including all files that would be needed to boot, it also permits you to specify the architecture you need for the client)

- sudo apt-get install nfs-kernel-server #(needed to export files for booting the client)
- sudo apt-get install tftpd-hpa #(makes possible the client to boot via PXE)
- sudo gedit /etc/default/tftpd-hpa #(configuring file for tftpd-hpa, make the tftpd-hpa to start as a daemon)
- RUN_DAEMON=”yes”
- sudo gedit /etc/exports #(configuring file for what would be exported via NFS, add the line)

/opt/ltsp (ro,no_root_squash, no_subtree_check)

- sudo invoke-rc.d nfs-kernel-server restart #(reload the nfs so that changes would be active)
- sudo gedit /etc/inetd.conf #(we need to comment with one line that looks like this)#tftp dgram udp wait root /usr/sbin/in.tftpd/usr/sbin/in.tftpd –s /var/lib/tftpboot
- sudo invoke-rc.d openbsd-inetd restart sudo invoke-rc.d tftpd-hpa restart #(tftpd-hpa would take effect)
- sudo gedit /etc/ltsp/dhcpd.conf #(we need to adopt the configuration of our dhcp for our network, or just use the default server, which is 192.16…….)
- sudo gedit /etc/dhcp3/dhcpd.conf #(the main configuration file of dhcp. Just add the line to the end of the file) include “/etc/ltsp/dhcpd.conf”;
  connect cable to the switch or hub from the server and to the client
- sudo ifconfig eth0 192.168.0.1 # (forcing to change the IP address of a server that would comply with the LTSP configuration)
- sudo invoke-rc.d dhcp3-server restart #(restart dhcp)
- power on the client and go to BIOS and change to PXE or NETWORK boot
  Installation of LTSP has been completed.

To add users:

sudo adduser user1 #(type the password)

Troubleshooting:

If this message appears: “This workstation is not authorized to connect to the server”

Run in the following order:

sudo ltsp-update-sshkeys

sudo ltsp-update-image.

## 6.4 The Boot Process

The booting process can take the form of PXE, CD, or USB. However, for the purpose of this work, we shall be looking at booting from PXE.

In booting from PXE, the network card boot up code will first be loaded. The network card will then be initialized in case it corresponds. Thereafter, options will appear on the screen for it to boot from either the network or locally. Network or local booting may be selected, however, it boots from the network, by design, if there is no selection made after some seconds. (Rais 2010.)

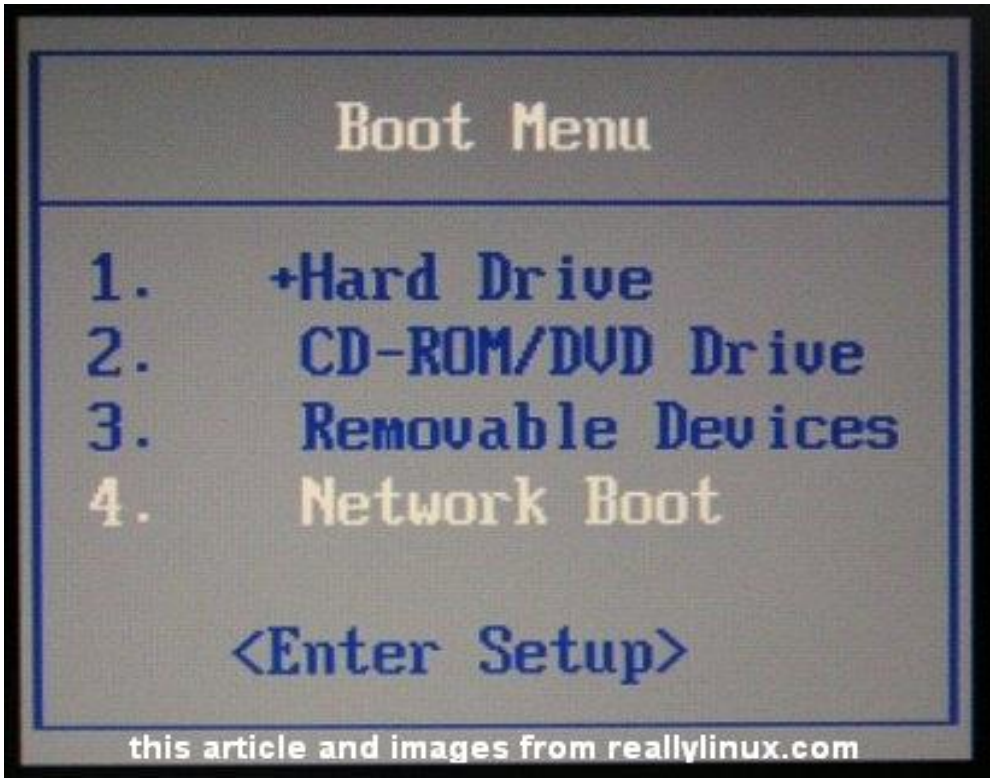


**Figure 16**.Screen displaying options available for booting (Rais 2010)

Selecting to boot locally will provide options for booting from Hard Drive, CD-ROM/DVD Drive, or Removable Devices like flash drives. Subsequently, the client (workstation) will relay its MAC address and search for a DHCP server. It is in accordance with this MAC address of the client that the DHCP will now issue an IP

address and other network parameters to it. A host name is provided for the IP address and it is used in the indication of the configuration parameters for every client machine.

Thereafter, the kernel will be moved from the server and booted by the client. The DHCP server makes available both the path of the kernel and the root file system. At the instance of the booting by the client, the X Windows automatically start up and displays a login prompt. Consequently, the screen will display user preferences, desktop, and file menus, while the user's home directory becomes available. (Rais 2010.)

# 7 DISCUSSIONS AND CONCLUSIONS

This chapter contains the results, implications for further research, and concluding notes on my Thesis work (LTSP: Developing Information Technology System in a Developing Country "A Case Study of Nigeria). The objective of this work is to study the LTSP and its operation, and subsequently, introduce its employ to Nigerian educational and economic sectors. In order to achieve this objective, the work addressed the whole research questions, which are; in what ways can LTSP be beneficial to Nigerian educational system and economic environment? What is the scalability of LTSP, in a real-world installation, to economic and educational environments? What are the problems associated with its operation? and what is LTSP's prospect and how can it be improved upon? The answers to these questions are provided in the results

## 7.1 Results

This research work has revealed that stakeholders in the Nigerian educational and economic sectors are financially constrained to acquire the necessary facilities to aid Information and Communications technology (henceforth ICT) development. ICT is also a pivot to the development of education and economy in Nigeria. Hence there is need to strike a balance between the scarce resources and the essential need for ICT development.

LTSP is highly cost effective, easy to maintain, highly secured because it operates on Linux platform, which is free and open source, and also possess a quality of high performance. Moreover, LTSP has been recommended worldwide, for use in the educational and business environments, including Europe and America. Therefore, it could provide a solution to the lingering problem of inadequate ICTs to aid economic development in Nigeria. It will not only be affordable, but also enable adequate provision of ICT facilities in every educational and economic environment.

LTSP possesses a capacity to continue to function well when it is changed in size or volume in order to meet a user need. It is also to take full advantage of the change in terms of performance, as regards user response time and the increase in the number of users that could be handled. LTSP is also fast and efficient enough to perform up to expectation. Therefore, its scalability has been confirmed.

However, in spite of the fact that LTSP is desired to be used, because of its high performance and cost effectiveness, some situations have also been identified as problems to its usage in Nigeria, while palliative solutions have been suggested where it is possible.

LTSP is a new technology in Nigeria, as the operating system widely used among the users of computer in Nigeria today is Windows. Very few people recognize Linux, and LTSP project operates on Linux based platform, therefore, there will be need to educate people on its operation. Also, since LTSP is cheap and easy to use, its constant usage will make it popular after a while.

Level of the technical know-how in Nigeria – although, Nigeria has a large population, very few people really have the knowledge of computer operation in Nigeria. The awareness of computer operation only exists in the Urban centre, whereas, the majority of the populace are concentrated in the Rural Areas. There will be need for the Government to introduce computer course into the curriculum of every facet of education so as to encourage students to learn it. Moreover, encouragement could be given to private businesses to establish vocational schools in computer studies.

Government policy on education – although, LTSP is cost effective, it will still require some funds to be set up. The educational system in Nigeria is underfunded by the Government, while the educational institutions also face inadequate financial resources. This means that they will have to work within the scope of the little available funds to achieve their goal of putting in place adequate IT facilities.

Erratic Power Supply in Nigeria – the power supply system in Nigeria is highly unreliable. Although LTSP is known to consume low energy, it still requires a stable power supply, and so, a standby Generating set may be required for an uninterrupted operation.

Centralized Failure Location – any failure or problem on the server means that everyone using LTSP server will be offline, since all networks rely on the server to function. However, a spare server may be put on standby to avert this occurrence.

Software Availability Problem – the common means of getting software in Nigeria is through piracy, as it is very costly to buy. Although, Linux software is free and can be

downloaded on the internet, the access to internet in Nigeria is very slow; hence it may be difficult to download. However, with the continuous use of this technology, the problem of slow internet speed will become history overtime, as much focus will be on its further development and necessary facilities will be made available by the stakeholders.

Hardware Compatibility Problem - In most cases, computers are being assembled in Nigeria to suit the purpose of the user. One will just need to gather all the required hardware parts and assemble them together. However, since LTSP is run on Linux based platform, and Linux has not been a common Operating System in Nigeria, this may pose a problem in getting the hardware that may be supported by Linux or device drivers that are available in Linux. Where there is compatibility, in case there is need for replace of a faulty hardware in future, there may not be a readily available replacement, and so the company or institution may have to duplicate orders for the spare parts in advance and keep for future use. This means additional expenses for them.

LTSP has been discovered to record notable prospects since its invention in 1999. The original intent of the inventors was for it to proffer solution to the immediate need of a client who required an inexpensive and easy to maintain terminal that could communicate with both an IBM AS/400 and a UNIX application server. They wanted it to be able to browse the web, send and receive mails. However, today, LTSP has not only been made easy to set up on Linux distributions, a number of features have also been included on it. The latest proposal on LTSP prospect is its having a local application support, which enables some applications to run directly on the thin clients, instead of the server. It will enhance the use of multimedia applications, which is difficult to run on an LTSP network. Another developmental target is for users to be able to burn CDs on thin clients as well.

Furthermore, open end discussions held with two members of staff in the BIT department, who possess vast knowledge in the operation of LTSP, revealed that could be a means to an end in the lingering problem of inadequate Information Technology facilities in Nigeria.

According to Deepak (2010), the platform to be used in setting up LTSP terminal server and the thin clients are determined by the user's requirements, taking into consideration the fact that LTSP currently supports only i386 architecture. So, the user has to ensure that whatever programs the thin client will be running upon is compatible with the platform of the server. For a set up of a basic LTSP, which includes one server and one diskless thin client, one will require a computer with a fast and strong hard disk, running on a platform that is supported by Debian Sarge, and with 256MB RAM or more, for the server. As for the thin client, each should have between 32 and 64MB RAM, and at least, a Pentium with1GHz speed. The benefits of LTSP were analyzed as ease of administration, maintenance, affordability and energy efficiency. Also, LTSP was established to be the best solution for developing countries, to partake in the rapid development in the information technology, as with less finance, they can also provide access to computer for many people by making use of old computers at very little costs and also have access to free and open source software, since LTSP operates on Linux based operating system. (Deepak 2010.)

According to Niska (2010), in setting up of LTSP, a high powered machine will be required to function as a server, which should operate on a Linux based platform. This is because LTSP is an open source package, and it should be able to operate on any Linux version. Moreover, some low powered or old machines could be used as clients to the server, while some network tools will be required to connect the client computers to the server. The main benefits of LTSP were also stated as its cost effectiveness and time saving because of its easy control/maintenance. It was pointed out that LTSP does not necessarily improve technology in the developed countries. ,and that its popularity is limited to schools, libraries, kiosks, cyber café's and some other places, whereas, its workability is not extended to the real working environment where information system is highly required. However, it was acknowledged that LTSP will be appropriate for developing countries because of its numerous benefits that could accrue to them. This is taking into consideration the fact that it does not require much funding, operates on free and open source software system, highly secured, and acts as a foundation for advancement in technology. (Niska 2010.)

## 7.1 Implications for future research

The uniqueness of this research work in Nigeria, as revealed by the information gathered on the Internet, from other research works, is an indication that there is need for further research. This research suggests possible implications for further research. For instance, since this work is based on only the educational and economic sectors in Nigeria, there is need for further research for ICT to be promoted in other sectors of the country's economy. This is because of the differences in the purposes of using ICT in the various sectors.

Furthermore, there is need to create common understanding among the users of technology in the various sectors. This is essential in order to fashion out meaningful interdisciplinary research structures and models. Otherwise, the research approaches will continue to be divided and benefits of multiple discipline research works will not be achieved. This also, has acknowledged the need for further research.

Finally, the sole objective of this research work is to provide a lasting solution to the lingering problem of ICT in Nigerian educational and economic sectors. Since LTSP is not the only technology that can be adopted for this purpose, there is room for future research on a technology that could even be more effective and cheaper to use than LTSP.

## 7.3 Concluding note

It is evident that Nigeria, as a developing country, has realized that the principal mechanism for developing human knowledge and accomplishment of economic growth is the education system. It is also evident, as revealed in this Thesis, that the pivotal nature of Information and Communications Technology, to the education and economic institutions, can not be overemphasized. In spite of her limited resources, therefore, it is imperative for Nigeria to make adequate provisions for the necessary facilities that will enhance the development of Information and Communications Technology. As a result, there is need to balance between the available scarce resources and the provision of these essential facilities.

Since LTSP is cost effective, high performing, and of high security, coupled with its recommendation for use in educational environments and the various success stories it has recorded worldwide, including developed countries in Europe and America, I conclude that LTSP is the ideal solution to the lingering problem of Information and Communications Technology in Nigerian educational and economic sectors, to ease the problem of development brought about by inadequate provision of Information Technology System.

LTSP operates on Linux based software and it will be ideal to promote the use of open source strategies to give the project the desired popularity. People will have to spend little and affordable amount to secure access to information needed for the development of their businesses or educations. LTSP will promote the use of Internet facilities, and this will enhance access to useful academic resources for the students, teachers and researchers.

Also, with LTSP, institutions will be able to afford the cost of setting up computer labs with fully installed Internet facilities. The availability of these facilities will develop the technological know-how of ICT in Nigeria. This means that common access to information that can bring about educational and economic development will be created. Consequently, there will be a constructive expansion of the country's economy.

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Configuring the dhcp.conf.sample file Appendix 1

1(1)

```
# dhcpd.conf
option subnet-mask                  255.255.0.0;
option broadcast-address            172.21.255.255;
option routers                      172.21.16.253;
option domain-name-servers          172.21.30.254, 172.21.16.13, 172.21.16.10;
option domain-name                  "sau14.k12.nh.us";
option option-128 code 128 = string;
option option-129 code 129 = text;

get-lease-hostnames         true;
next-server                 172.21.30.254;
option root-path            "172.21.30.254:/opt/ltsp/i386";

subnet 172.21.0.0 netmask 255.255.0.0 {
range      172.21.30.1     172.21.30.253;
if substring (option vendor-class-identifier, 0, 9) = "PXEClient" {
filename  "/lts/2.6.16.1ltsp-1/ pxelinux.0";
}
else{
filename  "/lts/vmlinuz2.6.16.1ltsp1";
}
}
##
If you need to pass parameters on the kernel command line, you can
# do it with option-129. In order for Etherboot to look at option129,
# you MUST have option-128 set to a specific value. The value is a
# special Etherboot signature of 'e4:45:74:68:00:00'.
#
# Add these two lines to the host entry that needs kernel parameters
#
#           option option-128    e4:45:74:68:00:00;     # NOT a mac address
#           option option129      "NIC=ne IO=0x300";
#
```

END OF FILE (Paul VanGundy 2006)