3G Broadband Solution for Small and Medium Enterprises

Haruna U. Adoga

Department of Computer Science, Federal University Lafia,
Lafia, Nasarawa State, Nigeria

Abstract- Broadband internet access has been a challenge in most developing African countries for some years now, it costs a lot to get a steady internet access in most developing countries. This paper presents a solution that can be used to provide reliable and affordable internet access using equipment that are inexpensive and robust at the same time. This basically works with a 3G wireless gateway router that is available with telecommunications service providers across Africa. For this paper, Airtel telecommunications company was used i.e. the Huawei B683 Airtel 3G wireless gateway router, this device basically supports a simultaneous connection of about 32 to 70 nodes shared over a Local Area Network(LAN) using an Ethernet switch and wireless access points, with proper collision control mechanism, the Ethernet switch that was used to accomplish this work is the 24-port D-Link DES1024DEthernet switch which uses the inbuilt Carrier Sense Multiple Access with Collision Detection (CSMA/CD) mechanism to prevent devices on the Local Area Network from experiencing collision during the transmission of data.

With proper authentication, Wireless users within the coverage area of the network can also gain access via the TP-Link access points which in turn gets their internet connection from the ISP gateway device. The flexibility provided by this work in terms of data size and cost of deployment is fascinating. Organizations deploying this solution can choose what data size they wish to purchase from the service provider and also they can decide when to subscribe as against the V-Sat option in which clients pay huge amount of money for internet access in which they end up not utilizing to full capacity, the issues of money being wasted on unused data will be drastically reduced.

Keywords- *Broadband, WLAN, Local Area Networks, SMEs*

1. Introduction

Internet access has always been and still is a major component of all aspects of the human life, World Economies, healthcare infrastructure, the financial sector and even our social life needs the internet to compliment it. Computer networks have evolved a great deal over the years, with different technologies used to access the internet. The challenge however is to find a cheap and affordable internet access solution for small and medium scale enterprises (SMEs) with about 32 to 70 users as a substitution to the expensive V-Sat option that is widely available and used by many users. This approach is affordable for small businesses, an environment with both wired and wireless users that need internet access. Installing, configuring and maintaining the broadband solution presented in this paper has proven to be cost effective and also reliable. The structure and makeup of the internet has adapted as the needs of its community have changed. Today's Internet serves the largest and most diverse community of network users in the computing world. [4]

Wireless communication continues to enjoy exponential growth in the cellular telephony, wireless internet and wireless home networking arenas. With the advent of Wireless LAN (WLAN) technology, computer networks could achieve connectivity with a useable amount of bandwidth without being networked via a wall socket. New generations of handheld devices allows users access to stored data even when they travel. Users could set their laptops down anywhere and instantly be granted access to all networking resources. This was, and is, the vision of wireless networks, and what they are capable of delivering [8].

Broadband internet service is a form of high speed internet access. In fact, the name "broadband" has come to be synonymous with high speed internet use in general. Since speed is measured by bit rate, the number of bits processed per unit of time, broadband internet service is defined as being 256 Kbit/s (kilobits per second) or faster. Broadband typically downloads at a much faster speed than that. As a result, broadband internet service is categorized into two different connection groups: Tier 1 (T1) broadband connections range from 1.544 Mbit/s to 2.048 Mbit/s, and Tier 3 (T3) broadband connections range from 44.736 Mbit/s to 159.2 Gbit/s. With these rates of data transmission, broadband represents an evolution from the original high speed internet service, Integrated Services Digital Network (ISDN), and is by far a significant improvement upon the original internet service, dial-up. [7]. The latest development in broadband internet service is the incorporation of wireless capabilities. Wireless broadband internet service is exactly what the name

implies: it is your high speed internet access without cables or wires. The versatility of wireless internet, and its potential for increasing productivity by users, has consumers demanding the service at an increasing rate. They want it in their homes, offices, even at their local coffee shop or bistro. Hence the development of wireless broadband internet service: it is a packaged internet service deal that provides the ability to access the internet wirelessly from any location within the service's coverage area. [7]

2. Review of Literature

Wireless and LAN networks have been in existence for a very long time now, these networks work mostly integrated together in the same infrastructure. The whole idea of having a wireless network is for mobile users to connect to the same network services from any location that is within the coverage area of the access points, this helps in eliminating the physical restrictions that comes with connecting to a network using Ethernet cables.

Wireless communications is one of the big engineering success stories of the last 25 years – not only from a scientific point of view, where the progress has been phenomenal but also in terms of market size and impact on the society. Companies that were completely unknown 25 years ago are now household names all over the world, due to their wireless products, and in several countries the wireless industry is dominating the whole economy. Working habits, and even more generally the ways we all communicate, have been changed by the possibility of talking “anywhere, anytime.” For a long time, wireless communications has been associated with cellular telephony, as this is the biggest market segment, and has had the highest impact on everyday life. In recent times, wireless computer networks have also led to a significant change in working habits and mobility of workers – answering emails in a coffee shop has become an everyday occurrence.Besides these widely publicized cases, a large number of less obvious applications have been developed, and are starting to change our lives. Wireless sensor networks monitor factories, wireless links replace the cables between computers and keyboards, and wireless positioning systems monitor the location of trucks that have goods identified by wireless Radio Frequency (RF) tags. This variety of new applications causes the technical challenges for the wireless engineers to become bigger with each day.[12]

2.1 Wireless Networks Standards

802.11 wireless LAN is an IEEE standard that defines how radio frequency (RF) in the unlicensed industrial, scientific, and medical (ISM) frequency bands is used for the Physical layer and the MAC sub-layer of wireless links. When 802.11 was first released, it prescribed 1 - 2 Mb/s data rates in the 2.4 GHz band. At that time, wired LANs were operating at 10 Mb/s so the new wireless technology was not enthusiastically adopted. Since then, wireless LAN standards have continuously improved with the release of IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, and draft 802.11n.Typically, the choice of which WLAN standard to use is based on data rates. For instance, 802.11a and g can support up to 54 Mb/s, while 802.11b supports up to a maximum of 11 Mb/s, making 802.11b the "slow" standard, and 802.11 a and g the preferred ones. A fourth WLAN draft, 802.11n, exceeds the currently available data rates. The IEEE 802.11n should be ratified by September 2008. The figure compares the ratified IEEE 802.11a, b, and g standards. The data rates of different wireless LAN standards, are affected by something called a modulation technique. The two modulation techniques that you will reference in this course are Direct Sequence Spread Spectrum (DSSS) and Orthogonal Frequency Division Multiplexing (OFDM). You do not need to know how these techniques work for this course, but you should be aware that when a standard uses OFDM, it will have faster data rates. Also, DSSS is simpler than OFDM, so it is less expensive to implement. [9]

802.11a

The IEEE 802.11a adopted the OFDM modulation technique and uses the 5 GHz band.802.11a devices operating in the 5 GHz band are less likely to experience interference than devices that operate in the 2.4 GHz band because there are fewer consumer devices that use the 5 GHz band. Also, higher frequencies allow for the use of smaller antennas. There are some important disadvantages to using the 5 GHz band. The first is that higher frequency radio waves are more easily absorbed by obstacles such as walls, making 802.11a susceptible to poor performance due to obstructions. The second is that this higher frequency band has slightly poorer range than either 802.11b or g. Also, some countries, including Russia, do not permit the use of the 5 GHz band, which may continue to curtail its deployment. [9]

802.11b and 802.11g

802.11b specified data rates of 1, 2, 5.5, and 11 Mb/s in the 2.4 GHz ISM band using DSSS. 802.11g achieves higher data rates in that band by using the OFDM modulation technique. IEEE 802.11g also specifies the use of DSSS for backward compatibility with IEEE 802.11b systems. DSSS data rates of 1, 2, 5.5, and 11 Mb/s are supported, as are OFDM data rates of 6, 9, 12, 18, 24, 48, and 54 Mb/s.

There are advantages to using the 2.4 GHz band. Devices in the 2.4 GHz band will have better range than those in the 5GHz band. Also, transmissions in this band are not as easily obstructed as 802.11a.

There is one important disadvantage to using the 2.4 GHz band. Many consumer devices also use the 2.4 GHz band and cause 802.11b and g devices to be prone to interference. [9]

802.11n

The IEEE 802.11n draft standard is intended to improve WLAN data rates and range without requiring additional power or RF band allocation. 802.11n uses multiple radios and antennae at endpoints, each broadcasting on the same frequency to establish multiple streams. The multiple input/multiple output (MIMO) technology splits a high data-rate stream into multiple lower rate streams and broadcasts them simultaneously over the available radios and antennae. This allows for a theoretical maximum data rate of 248 Mb/s using two streams. RF bands are allocated by the International Telecommunications Union-Radio communication sector (ITU-R). The ITU-R designates the 900 MHz, 2.4 GHz, and 5 GHz frequency bands as unlicensed for ISM communities. Although the ISM bands are globally unlicensed, they are still subject to local regulations. The use of these bands is administered by the FCC in the United States and by the ETSI in Europe. These issues will impact your selection of wireless components in a wireless implementation.

2.1.1Broadband

The term broadband refers to the wide bandwidth characteristics of a transmission medium and its ability to transport multiple signals and traffic types simultaneously. The medium can be coax, optical fiber, twisted pair, DSL local telephone networks or wireless. In contrast, baseband describes a communication system in which information is transported across a single channel. [15]

Mobile broadband is the marketing term for wireless Internet access delivered through mobile phone towers to computers, mobile phones and other digital devices using portable modems. Although broadband has a technical meaning, wireless-carrier marketing uses the phrase "mobile broadband" as a synonym for mobile Internet access. Some mobile services allow more than one device to be connected to the Internet using a single cellular connection using a process called Tethering.[16]
Roughly, every ten years, new mobile phone technology and infrastructure involving a change in the fundamental nature of the service, non-backwards-compatible transmission technology, higher peak data rates, new frequency bands, and wider channel frequency bandwidth in Hertz becomes available. These transitions are referred to as generations. The first mobile data services became available during the second generation (2G). [17]

Table 2.1.1 below gives a brief overview of broadband generations' evolution over the years and their various speeds.

Table 2.1.1 Broadband Internet Generations and Speeds

S/N	
1	**Second generation (2G) from 1991:**
	Speeds in Kbit/sdownlink/uplink • GSM CSD 9.6 Kbit/s • GPRS (2.5G) 56/115 Kbit/s • GSM EDGE (2.75G) up to 237
2	**Third generation (3G) from 2001:**
	Speeds in Mbit/sdownlink/uplink • UMTS W-CDMA 0.4 Mbit/s • UMTS HSPA 14.4/5.8 • UMTS TDD 16 Mbit/s • GSM EDGE-Evolution 1.6/0.5
3	**Fourth generation (4G) from 2006:**
	Speeds in Mbit/sdownlink/uplink •HSPA+ 21–672/5.8-168 •Mobile WiMAX (802.16) 37–365/17–376 •LTE 100–300/50–75 •LTE-Advanced: • Moving at higher speeds 100 Mbit/s Moving at lower speeds up to 1000Mbit/s

2.2 Wireless Networks Site Survey

A. Pre-Survey Data Collection

An engineer must understand the customer requirements to ensure that the survey accommodates performance criteria as stated by the customer, equipment and application vendors. Thorough analysis may reveal non-typical needs that affect the survey. For example, large outdoor areas with low user density would likely require a survey based on fewer AP installation points with more power and higher gain antennae. On the other hand indoor environments with high user density would likely require a survey based on a higher density of access points with lower power and less antenna gain to minimize coverage patterns therefore providing higher aggregate capacity.

B. Access Point Settings

The site survey should be conducted with the same equipment (specific AP and antenna models) that will be used for deployment. To maintain flexibility for RRM to power up and down it is highly recommended that access point power levels be set at least one or two power levels below maximum power. If there are ever any environmental changes that impact coverage then the installed network will be better able to adapt to the effects of those changes. All other AP settings should emulate the installed network such as data rate and channelization. Different antennas should be available to best fit the environment at each AP location. Antenna Diversity should be employed to enhance performance. This enhancement is most noticeable where WLAN devices are susceptible to effects such as multi-path. [2]

C. Environmental RF Assessment

A radio frequency (RF) spectrum analysis is used to thoroughly inspect localized radio spectrum. This analysis is commonly conducted to explore for sources of Radio Frequency Interference (RFI) where it is thought to be of concern. The analysis data can be helpful for equipment channelization and interference avoidance.

D. Spectrum Analysis

The principle goal of spectral analysis is to search for and locate sources of RFI and then to reduce their impact on other equipment and end-user applications. RFI opportunities increase proportionally to the density of wireless devices. Areas such as medical, military, industrial and commercial environments which can have application needs that drive higher densities, can have more RFI. Other factors that effect RFI are band utilization from emitter oscillation and dwell times, identifying these elements may also identify the source.
The following methodology may be used to determine sources of RFI:

1. Choose location where RFI is suspected and visually inspect for obvious sources such as antennae and transmitters.
2. Inspect the equipment to gather any detailed information such as operating frequencies and statements of Effective Isotropic Radiated Power (EIRP).
3. Energize the spectrum analyzer with a zero gain multi-band antenna that can cross multiple frequencies. The antenna should be free of obstruction to enable proper reception of surrounding signals.
4. Readings should be taken across the spectrum with particular attention and detailed analysis in frequencies of interest. Frequencies of interest include known ranges used by equipment, nearby side bands and potential harmonics. This will show out of tolerance operations and potential sources of RFI.
5. If sources of RFI are observed then accurately measure the frequency, amplitude, dwell time and oscillation time to cross reference with known allowed emitters and determine the level of perceived interference.
6. Locate the sources of interference by moving the spectrum analyzer around and observing amplitude changes. Or use a directional antenna tuned for that particular frequency for rudimentary direction finding to zero into the area. [2]

2.2.1 Local Area Networks and Ethernet Networking

A LAN is a network that is confined to a limited space, such as a building or floor. It uses short-range technologies such as Ethernet, Token Ring, and the like. A LAN is usually under the control of the company or entity that requires its use. [13]

Ethernet is a contention media access method that allows all hosts on a network to share the same bandwidth of a link. Ethernet is popular because it's readily scalable, meaning it's comparatively easy to integrate new technologies, such as Fast Ethernet and Gigabit Ethernet, into an existing network infrastructure. It's also relatively simple to implement in the first place, and with it, troubleshooting is reasonably straightforward. Ethernet uses both Data Link and Physical Layer specifications.

Ethernet networking uses Carrier Sense Multiple Access with Collision Detection (CSMA/CD), a protocol that helps devices share the bandwidth evenly without having two devices transmit at the same time on the network medium. CSMA/CD was created to overcome the problem of those collisions that occur when packets are transmitted simultaneously from different nodes. Good collision management is crucial because when a node transmits in a CSMA/CD network, all the other nodes on the network receive and examine that transmission. Only bridges and routers can effectively prevent a transmission from propagating throughout the entire network.

With CSMA/CD, when a host wants to transmit over the network, it first checks for the presence of a digital signal on the wire. If all is clear (no other host is transmitting), the host will then proceed with its transmission. But it doesn't stop there. The transmitting host constantly monitors the wire to make sure no other hosts begin transmit-ting. If the host detects another signal on the wire,

it sends out an extended jam signal thatcauses all nodes on the segment to stop sending data (think, busy signal). The nodes respond to that jam signal by waiting a while before attempting to transmit again. Back off algorithms determine when the colliding stations can retransmit. If collisions keep occurring after 15 tries, the nodes attempting to transmit will then time out.[1]

Early LAN cabling had been based on various grades of coaxial cable. Shielded twisted pair was used in IBM's Token Ring LAN implementation. In 1984, StarLAN showed the potential of simple unshielded twisted pair by using Cat3 cable—the same simple cable used for telephone systems. This led to the development of 10Base-T (and its successors) and structured cabling which is still the basis of most commercial LANs today. In addition, fiber-optic cabling is increasingly used in commercial applications. Generally a LAN network uses Gigabit Ethernet cabling to the hub or switch (wired router, cannot be wireless), then the router connection is bridged to the wireless router.[10]

2.2.2 Third Generation (3G) Networks

3G, short for third Generation, is the third generation of mobile telecommunications technology. This is based on a set of standards used for mobile devices and mobile telecommunication use services and networks that comply with the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union. 3G finds application in wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV.

3G telecommunication networks support services that provide an information transfer rate of at least 200 Kbit/s. Later 3G releases, often denoted 3.5G and 3.75G, also provide mobile broadband access of several Mbit/s to smartphones and mobile modems in laptop computers. This ensures it can be applied to wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV technologies. [14]

2.3 The Service Provider Router- Huawei B683 3G Wireless Gateway

Huawei B683 gateway Router was used to carry out this research work, it has the capacity of supporting 32 to 70 users and the inbuilt switch ports are used to connect to a switch to share the connection with LAN users that need internet access. This gateway router supports HSPA +/HSDPA/HSUPA/UMTS capable of up to 28.8 Mbit/s and 5.76 Mbit/s upload (900/2100MHz) on firmly embedded UMTS / HSDPA modem with support for GSM / GPRS / EDGE capable (850/900/1800/1900MHz), Built-in 802.11b/g/n WLAN / 300 Mbit/s and WPA (2) encryption, up to 32 devices/clients simultaneously, Web-based admin interface for setting of WLAN, UMTS / APN settings, encryption and routing functionality (including firewall, DMZ, DHCP, etc.). Supports Windows 2000, XP, Vista / 7 for the USB modem functionality, Wi-Fi, UMTS and router functionality Operating System independent

Figure 2.3: Physical view of the Huawei B683 Router with 4-port inbuilt Ethernet Switch

2.4 The TP-LINK Wireless Access Point

The wireless access point that was used for this research work is the TP-link access point which has an inbuilt four-port 100Mbps Ethernet switch and one 100Mbps WLAN port for uplink with a maximum data rate of 100Mbps across the LAN ports and a maximum wireless Data Rate of 300Mbps, this device functions with AC power, i.e. it does not have support for Power Over Ethernet(POE) and supports network connectivity over Wired - Ethernet (RJ-45), Wireless - Wi-Fi 802.11b, Wireless - Wi-Fi 802.11g, Wireless - Wi-Fi 802.11n.[4] The TL-MR3420 3G/4G Wireless N Router allows users to share a 3G/4G mobile broadband connection. The TL-MR3420 stands out with its 3G/ 4G and WAN connection back-up, which keeps users online when one connection fails. TP-LINK's 3G/4G Router provides users with both 3G/4G Preferred and WAN Preferred back-up modes, while other brands provide one or the other. This brings users a high degree of flexibility when users are setting up the networks with considering connection costs and length of downtime. In order to safeguard user‘s Wi-Fi networks, WEP encryption is no longer strong enough. The TL-MR3420 provides WPA/WPA2 encryptions (Both Personal and Enterprise),created by the WI-FI Alliance, promoting interpretabilities and security for WLAN, to protect against almost any threat that the Internet or intruders may harbor. [3]

Clients connecting to the internet via the TP-link router get their IP addresses automatically via DHCP as the access point has been configured to issue out IP addresses in that manner so no configuration is needed on the client side, all a client needs to do is set their device to accept IP addresses via DHCP.

Figure 2.4: The physical view of the TP-link 3G/4G access point with all Ethernet ports connected

2.5 D-LINK Switches

The DES-1024D Ethernet switch offers an economical way forSmall to Medium Businesses (SMB) to benefit from high-speed networking. It provides twenty-four ports for easy expansion of your network and a quick way to upgradeyour network to Fast Ethernet connectivity. With the D-Link 24-Port 10/100 you get speeds on each port of up to 100Mbps in half duplex and 200Mbps in full duplex mode with 100BASE-TX Fast Ethernet specification, it has 4.8Gbps switching capacity with a support for auto MDI/MDIX adjustment for all ports,With Auto-MDI/MDI-X support, there is no need for crossover cables when you are connecting to another switch or to a computer. Additionally, the DES-1024D will automatically sense if the connected network devices are running at 10Mbps or 100Mbps and adjust accordingly. Equipped with a comprehensive LED display, you can monitor the status and activity of every port at a glance. It uses the store and forward transmission method. 8k entries per device for MAC Address, uses star topology with CSMA/CD

Fig. 2.5 D-link 24-port Ethernet Switch

3. The Network Design

The network which is basically designed to provide internet access to fixed and wireless users was designed and tested each step of the way, Firstly a site survey was carried out to get a full understanding of what needs to be done. Table 3 below shows a list of all the devices and equipment that was used to carry out this research work.

Table 3: A list of devices and equipment used for the research work.

S/N	Device/Item	Description/Specification
1	Service Provider Router	4- Port Ethernet HUAWEI Wireless Router From Airtel telecom.
2	Ethernet Switches	24-port D-link layer 2 switch DES 1024D
3	Wireless Access Points	TP-link 3G/4G Access Points with 4-port inbuilt Ethernet switch.
4	Unshielded Twisted Pair(UTP) Ethernet Cables	Category 6 Ethernet Cable 100/1000Mbps
5	Ethernet cable connectors	RJ-45 Ethernet cable connectors
6	Management Server	High performance Server for Network management tasks.

The design of the physical network topology was carried out based on the logical topology that is shown in figure 3.0 below. The conventional approach of designing networks into three layers was adhered to, this network can be viewed as having the core, distribution and access layers, the core layer here consists of the ISP internet gateway device and the management server, while the distribution layer is where the 24-port Ethernet switch is located, the access points and client computers are found at the access layer.

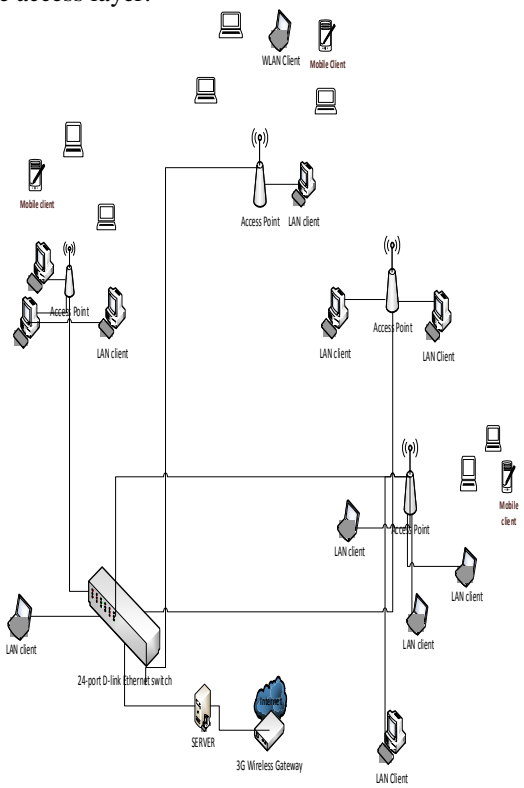

Fig. 3 Complete Network Topology

3.1 The LAN Design

Designing the Local Area Network for this network was done to meet the needs of 32 or more computers. The local Area Network basically starts from the Ethernet switch, where 100BASE-TX100/1000Mbps Ethernet cables were connected from the switch ports to the desktop computers and also cables were connected from the Ethernet switch to the inbuilt switches on the wireless access points, these access points supports four LAN clients each. The RJ-45 Ethernet cable was used which was crimped based on the requirements of the research work, distance between various devices on the network was measured.

3.2 The Service Provider Router Configuration

The service provider router which is a 3G wireless gateway router from Airtel Telecommunications company, was configured via the web management interface which can be accessed using the default class C IP address of 192.168.1.1 as shown in the URL in figure 3 below, the device was configured to handle both Local Area Network (LAN) and Wireless Local Area Network (WLAN) users that needs access to the network, for the wireless users that connect to the 3G wireless gateway router, the router was configured to provide IP addresses via DHCP in the range 192.168.1.100 to 192.168.1.150, this DHCP pool assigns addresses to 50 users, these users can connect to the 3G gateway device simultaneously using the default gateway IP address of 192.168.1.1.

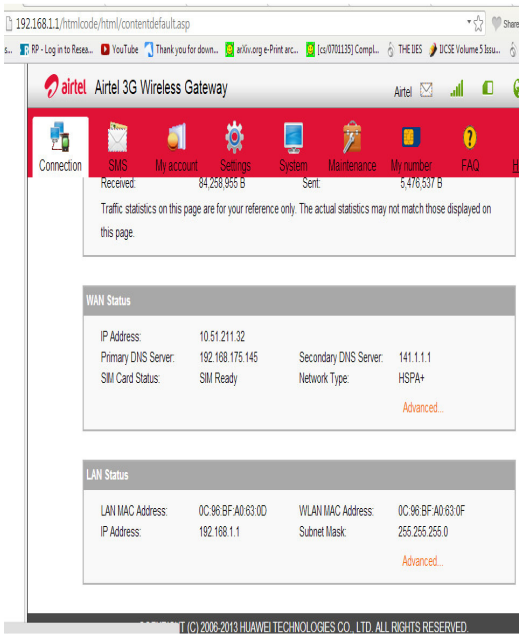

Fig 3.2a: Basic Local Area Network (LAN) and Wide Area Network (WAN) configuration of the 3G wireless gateway router.

Fig 3.2b: DHCP configuration

3.3 Wireless Access Point Configuration

The wireless access point was configured in such a way that Internet connection received via the WAN Ethernet port is shared with the devices connected to the four-port switch and broadcasted over the Omni directional Antennae on the access points for mobile users to connect with proper authentication. The web management interface can be accessed using the IP address 192.168.0.1 as displayed in figure 3.1.2 below, it simply means that wireless users that connect to the internet through the TP-LINK access point get their IP address via DHCP with the default gateway IP address of 192.168.0.1.

Figure 3.3 LAN and WLAN configuration as shown via the web management interface.

4. Conclusions and Future Work

In this paper, the design and configuration of a Local Area Network (LAN) and Wireless Local Area Network (WLAN) solution that can be used as a substitute for V-Sat solution for internet access used by Small and Medium Scale Enterprises (SMEs) was presented. Based on the results presented in this work, small businesses and offices that have 32 to 70 nodes (Users) can have steady and reliable internet access using this solution that has proven to be cost effective and flexible.

The performance of the network in general is a great success as network downtime is very minimal. This paper has shown that with proper design and implementation, a network can be designed with high performance and reliability which is affordable as an option for using V-Sat for internet access. The challenge however, not a constraint, is finding a GSM service provider that provides an uninterrupted connectivity to their network. Further research work can be done focusing on using Power over Ethernet (POE) enabled switches and access points also on implementing Virtual LANS (VLAN) on the network to enable users to be grouped based on requirements and privileges. More Switches and Access points can be introduced in the network to support more clients when needed, also network bandwidth can be increased by using a service provider that provides services over the long term evolution (LTE-4G) network.

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Author Biography

Haruna Umar Adogawas awarded the degree of Bachelor ofEngineering (Electrical and Electronic) with Second Class Honors (Upper Division) in University of Maiduguri, Nigeria on 18th December 2009. He attended the Cisco Networking Academy from 2009 to 2010 and got certified as a Cisco Certified Network Associate (CCNA) and a Cisco Certified Network Professional (CCNP), a graduate member of the Nigerian Society of Engineers (NSE). Haruna has worked as a contract instructor at InfoSoft Technologies where he taught the Cisco Certified Network Associate course, participated as a team member in the design and deployment of various data networks, the solution presented in one of his papers i.e. “3G broadband solution for Small and Medium Enterprises” has been successfully deployed at the Office of the Secretary to the Nasarawa State Government in Nigeria. He joined the department of Computer Science, Federal University Lafia in Nigeria on 14th May 2012 as a research and teaching assistant. Haruna has taught tutorial and practical courses in introduction to Computer Science, Computer Programming using both the Java and C++ programming languages, Net-Centric computing (Networks) and Computer Logic. Harunas is a strong believer in self-study and research as he has been working with several web technology platforms and technologies like virtualization, computer/network simulation and network emulation software. At the time of this writing, He is holding an unconditional offer to study MSC Computer Science at University of Hertfordshire, United Kingdom. His research interests are in the areas of Computer Networks, distributed computing and cloud computing.