

OPNET BASED SIMULATION FOR RURAL EDUCATIONAL ICT CONNECTIVITY

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Abstract— Rural areas are geographically distributed and if educational programs for such areas are to provide reasonable exposure, accessibility technological means has to be considered. There has to be an existing or planned infrastructure that could empower these educational programs to be conveyed. A major obstacle apart from the lack of infrastructure is the topography of the areas under consideration, which is a hilly terrain that tends to be a hindrance for communication companies to invest. This paper looks into deploying the information and communication needs for the majority of rural areas in Enugu State surrounding Nsukka in order to enhance education and economic growth. Educational programs for the rural areas cannot by themselves spread to all the communities under consideration. By analysing the topography via Google maps and verifying Line of Sight through Radio works, a WiMAX network solution to link the rural areas is simulated using OPNET.

Index Terms— Base Station, Line of Sight, OPNET, Subscriber Station, WiMAX, Wireless.

1 INTRODUCTION

Addressing the ICT requirements of rural areas is a fundamentally distributed and suitable exercise that requires planned budgeting [1]. The ICT capacity for development grows from the information processing and information sharing characteristics. Effective ICT deployment would improve basic services like education and health and boost revenue and job opportunities. For ICTs to make these impacts on the majority of the rural population there should be affordable access to it. In addition, the ability of rural population to improve their livelihood is not only limited by lack of access to ICTs and their applications in key sectors, but also by a complex web of constraints.

In Nigeria, most users currently access the Internet on GSM phones via 4 service providers. The service providers are prone to poor network in many parts of the rural communities in the country. Since the majority of Nigeria's population (52%) lives in rural areas, the lack of good Internet access has vast implications for the economic development of the nation. Thus the challenge is how to use ICTs to improve delivery of services and the well-being of rural people [2]. It must be pointed out that the challenge is how communication infrastructure can be exploited in communities without electricity. The role of education in economic development is unquestionable. However, to suggest that Nigeria can learn from developed countries that have invested heavily in education and been economically successful is immature [3].

1.1 OBJECTIVES

Setting up a communication backbone for the rural communities to bridge the digital divide and to provide access to the

populace, by providing internet access to the rural areas to serve as a conduit for knowledge.

Internet and ICT training for the students by providing localised ICT content, and to link students with other schools.

To ensure that Information Technology resources are readily available.

This paper deals with simulating a communication backbone for the rural communities using OPNET.

2 PROBLEMS FACING CHOICES WITH COMMUNICATION INFRASTRUCTURE

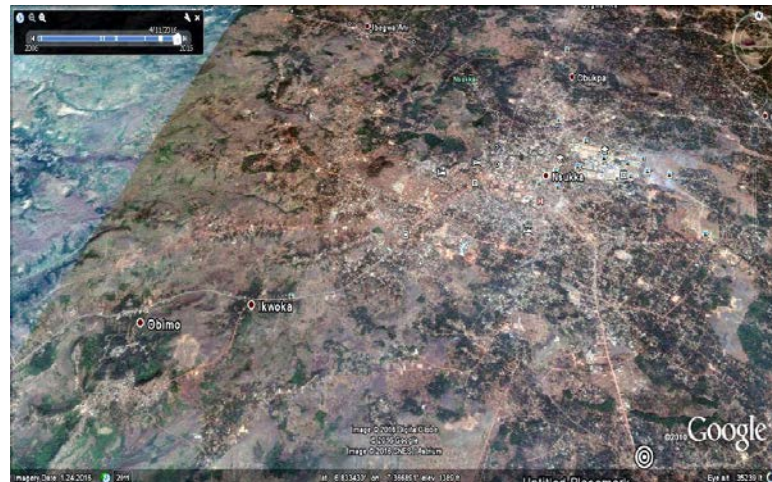


Fig. 1.0 Topography of the area under consideration © Google

A variety of choices could be considered in selecting and building communication infrastructure in rural areas. However, there are many challenges to providing rural communications especially in a developing country. Enugu State is made up of a vast, rugged, diverse terrain (hilly topography). There is a lack of confidence in local communication services, as they are prone to low bandwidth and are compounded with erratic service. The topography is a major drawback for communication infrastructure as it is difficult to set up any communication infrastructure. Due to these drawbacks communication companies fail to invest in setting up the required infrastructure as they feel it is not a profitable venture. Geographical challenges such as the hilly terrain as in figure 1.0 makes line of sight over long distances not possible.

Line-of-sight propagation refers to electro-magnetic transmission that includes light emissions travelling in a straight line [4]. Thus any obstruction between the transmitting antenna and the receiving antenna will block the signal, just like the light that the eye may sense. This makes it difficult to set up wireless networks. Figure 1.1 shows LoS between University of Nigeria, Base Station (BS) and Ede Obala, Subscriber Station (SS). The length of the BS mast is 150 feet while the SS mast is 150 feet. It could be seen that in order to have Line of Sight between the two stations the length of the mast would have to be increased to over 200 feet.

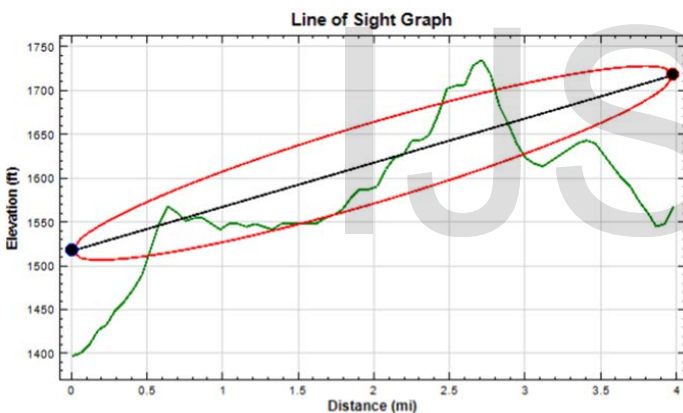


Fig. 1.1 Line of Sight between BS and a SS, UNN & Ede Obala

Path loss (or path attenuation) is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space is another problem. It is a major component in the analysis and design of the link budget of a communication system [5]. This term is commonly used in wireless communications and signal propagation. Figure 1.2 shows a path loss graph between the BS and SS's.

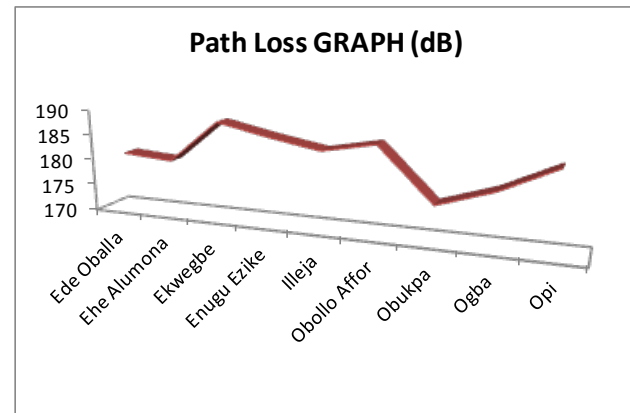
There is also the lack of infrastructure such as roads or stable commercial power, which would increase the cost of transport and power for the installation and running process.

2.1 SITE SELECTION CRITERIA

Selections of the sites for the implementation of the simulated network were based on the following criteria:

- a rural area with no telecommunications services available or extremely unreliable telecommunications services.
- should have the potential to benefit as many people as possible in the future hence an area of relatively high population density would be preferred.

Fig. 1.2: Graph depicting the path loss gain



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- should have the potential to benefit as many people as possible in the future hence an area of relatively high population density would be preferred.
- should provide as much information as possible within the shortest period of time.
- area of coverage, i.e. the more area that can be covered the better the site.

Deploying cellular networks or wired networks in rural areas is not a realistic solution because of the high infrastructural cost. Taking this into consideration the alternative that Worldwide Interoperability for Microwave Access WiMAX [6] proposes is the 802.16 family of wireless technologies. This is possible because of structure of the rural area, where there are no high rise buildings in the topography. With widespread acceptance of the technology, open/inter-operable standard, and competitive mass production, the equipment and chip sets are inexpensive.

3 OPNET

OPNET [7] was chosen as a simulator for the modelling because

- OPNET provides directional antenna support both at transmitter and receiver
- It provides graphical editor for creating antenna patterns
- OPNET has released the WiMAX (MAC) patch, which is used in the simulation.

OPNET Modeller is one of the leading network and modelling simulation programs allowing one to model both wired and wireless communication systems. OPNET provides a wide-ranging development environment for modelling and routine evaluation of communication networks and distributed systems. The simulation tools consist of a number of tools focusing on particular aspects of the modelling task. These tools fall

into three major categories that correspond to the three phases of modelling and simulation projects:

- Specification
- Data Collection and Simulation, and
- Analysis.

Models in OPNET are structured hierarchically with specialized editors that address issues at different levels of the hierarchy. This provides a spontaneous modelling environment and also permits re-use of the lower level models.

3.1 MODELLING DOMAINS

There are three modelling environments in OPNET [8] that cover all the hierarchical levels of the model. They are illustrated in table 1.

Table 1: OPNET Modelling Domains

| Domain | Editor | Modeling Focus |
|---------|---------|---|
| Network | Project | Network topology described in terms of sub-networks, nodes, links and geographical context |
| Node | Node | Node internal architecture described in terms of functional elements and data flow between them |
| Process | Process | Behavior of processes (protocols, algorithms, applications), specified using finite state machines and extended high level language |

3.2 SIMULATION OF WIMAX NETWORK FOR RURAL ICT CONNECTIVITY

The IEEE 802.16e which is the mobile version of the Worldwide Interoperability for Microwave Access provides broadband and connectivity by connecting to the ISP even when roaming outside home. It is a good alternative for the mobile 3G or wireless networks and has the advantage of low cost of deployment and high speed data rates (up 40MbPS) over a very wide range. It is the only wireless system capable of offering high QoS at high data rates for internet protocol networks [9].

The main part of a WiMAX system is the SS and the BS. A BS can have one or more nodes, that is, subscriber units connected to it. These BS's and SS's form a cell with a point to multipoint (P2MP) structure. Multiple BS's can be configured to form a cellular wireless network. WiMAX based systems generally use fixed antenna at the subscriber station site, mounted on masts. A BS can use either directional or Omni directional antennae. A stationary SS uses a directional antenna while mobile or portable Subscriber unit use an Omni-directional antenna. The 802.16 standard can also be used in a point to point topology with pairs of directional antennas which increases the effective range of the system.

3.3 WHY CHOOSE WIMAX CONNECTIVITY TECHNOLOGY?

WiMAX supports several system architectures, including Point-to-Point, Point-to-Multipoint, and ubiquitous coverage. WiMAX supports Advanced Encryption Standard (AES) and Triple DES (3DES), where DES is the Data Encryption Stand-

ard. By encrypting the links between the BS and the SS, WiMAX provides subscribers with privacy (against eavesdropping) and security across the broadband wireless interface. Security also provides operators with strong protection against theft of service. WiMAX also features built-in VLAN support, which provides protection for data that is being transmitted by different users on the same BS.

Furthermore, WiMAX can be dynamically optimized for the mix of traffic that is being carried. Four types of service are supported which include Unsolicited Grant Service (UGS). UG which is designed to support real-time data streams consisting of fixed size data packets issued at periodic intervals, such as T1/E1 and Voice over IP (VOIP). Real-Time Polling Service (rtPS) which is designed to support real-time data streams consisting of variable-sized data packets that are issued at periodic intervals, such as MPEG video, Non-Real-Time Polling Service (nrtPS) which is designed to support delay-tolerant data streams consisting of variable-sized data packets for which a minimum data rate is required, such as FTP, and Best Effort (BE) which is designed to support data streams for which no minimum service level is required and which can be handled on a space available basis.

WiMAX deployment is fairly quick when compared to other wired services and the manner in which QoS is delivered is generally based on the Service Level Agreement (SLA) between the service provider and the end-user. As with current cellular systems, once the WiMAX SS is powered up, it identifies itself, determines the characteristics of the link with the BS, as long as the SS is registered in the system database, and then negotiates its transmission characteristics accordingly.

4 NETWORK MODEL

The network model comprises of eight nodes which are corresponding to eight rural locations surrounding Nsukka which are Leja, Ede Oballa, Ekwegbe, Opi, Eha-alumona, Obollo Afor, Ogba, Enugu Ezike and Obukpa, and are show with their distances in figure 1.3. The general network topology is also shown in figure 1.4

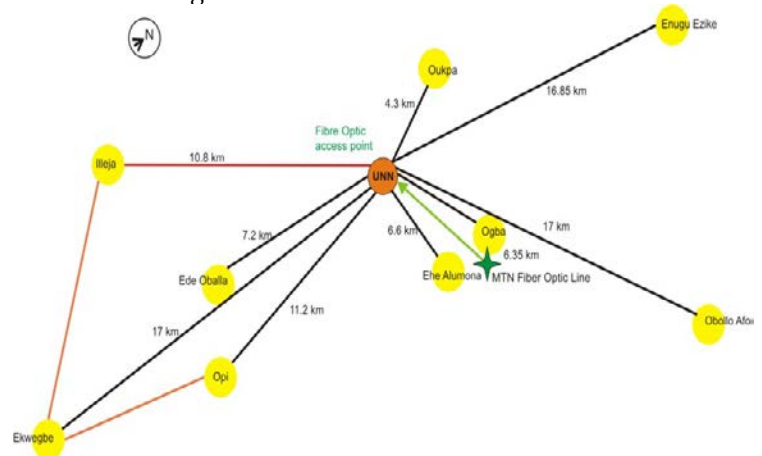


Figure 1.3: Distance from BS to SS's

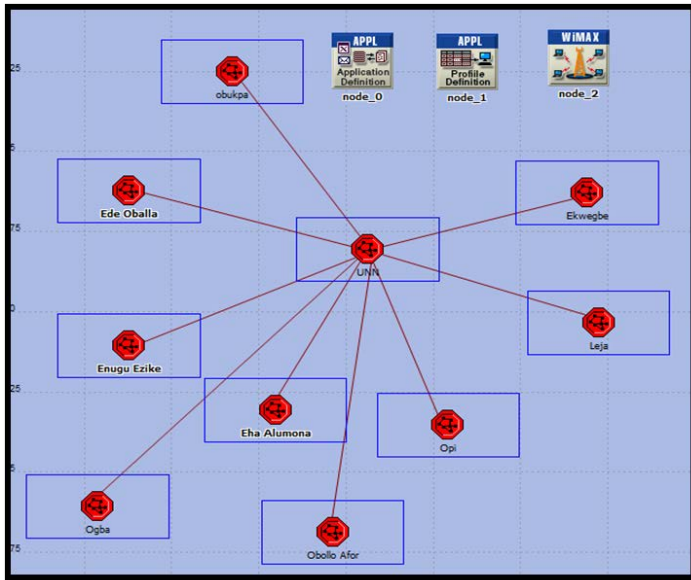


Figure 1.4: General network topology

Each location is a subnet with base station and repeater stations sited according to line of sight studies carried out on the areas. Each of the subnet shown above consists of mobile devices and fixed devices as shown in figure 1.5.

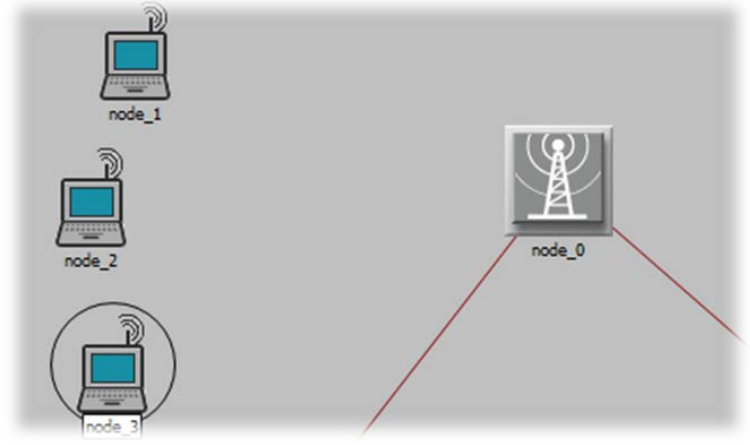


Figure 1.5: WiMAX access layer setup

4.1 NODE MODEL

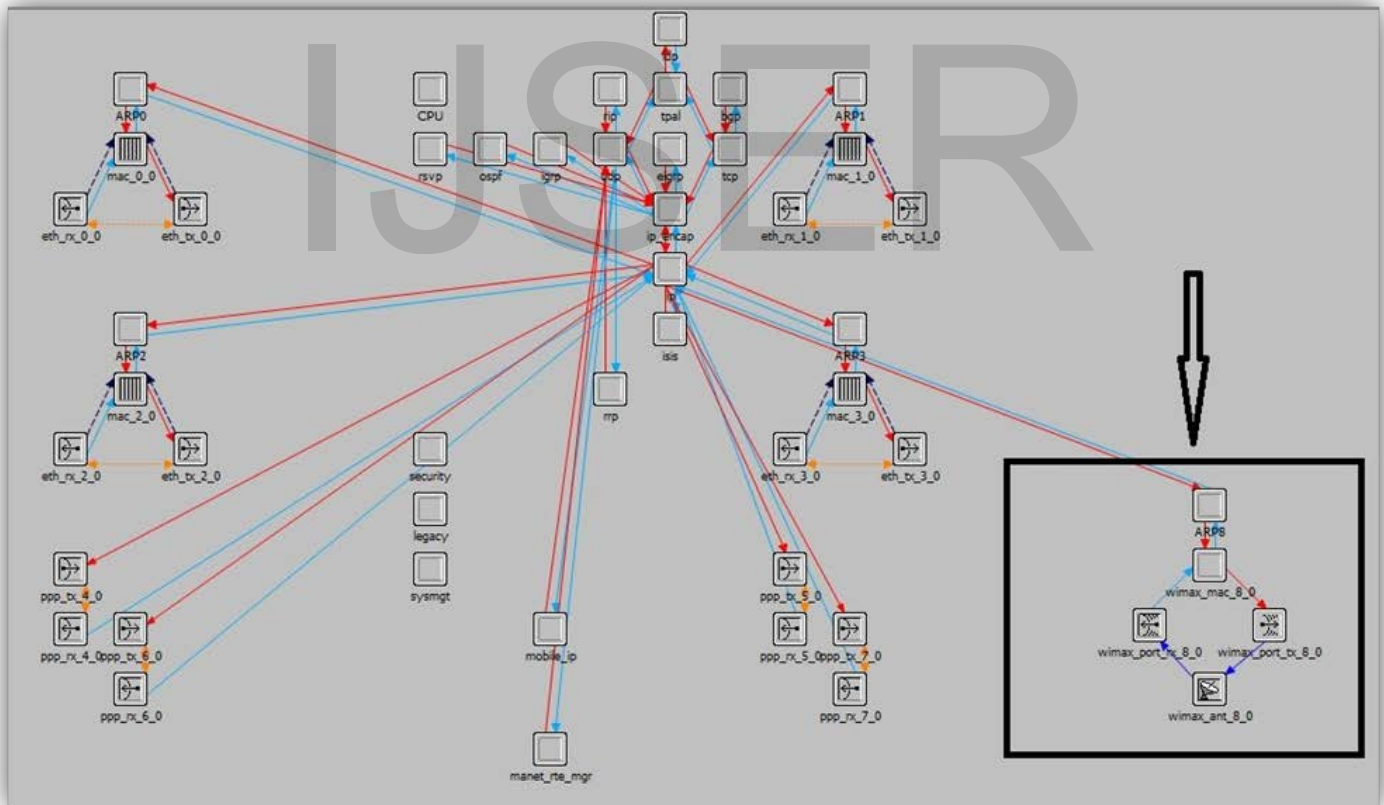


Fig.1.6: WiMAX base station Model

The OPNET Modeler node models contain a combination of processors, queues, transmitters and receivers to model the behavior of a given network object. Each solid gray rounded corner box represents a processor which in turn is associated with a process model. These processors are connected to each other using packet streams (blue arrows) and as statistical wires (red arrows).

The WiMAX PHY and MAC layer showing logical connections between a base station and mobile station of the two nodes are shown in figures 1.6 and 1.7. Each station contains a WiMAX receiver, transmitter and corresponding antenna system which are used to simulate WiMAX over the air (OTA). Additionally, WiMAX MAC layer CS and CPS are implemented in the MAC module in each station [10].

5 OPNET SIMULATION RESULTS

Of importance in this project, is to show that WiMAX technology can connect with high reliability two widely separated areas wirelessly and its ability to support bandwidth consuming and delay sensitive network traffic like audio and video streaming. Figures 1.8 - 1.11 presents the sharp response of an initially idle WiMAX network to the maximum available bandwidth (first graph at the bottom). The transmitted packets are also received by the recipient almost within maximum available bandwidth with little loss in signal strength. Also from the topmost graph below, the BS and SS hops is fairly seamless.

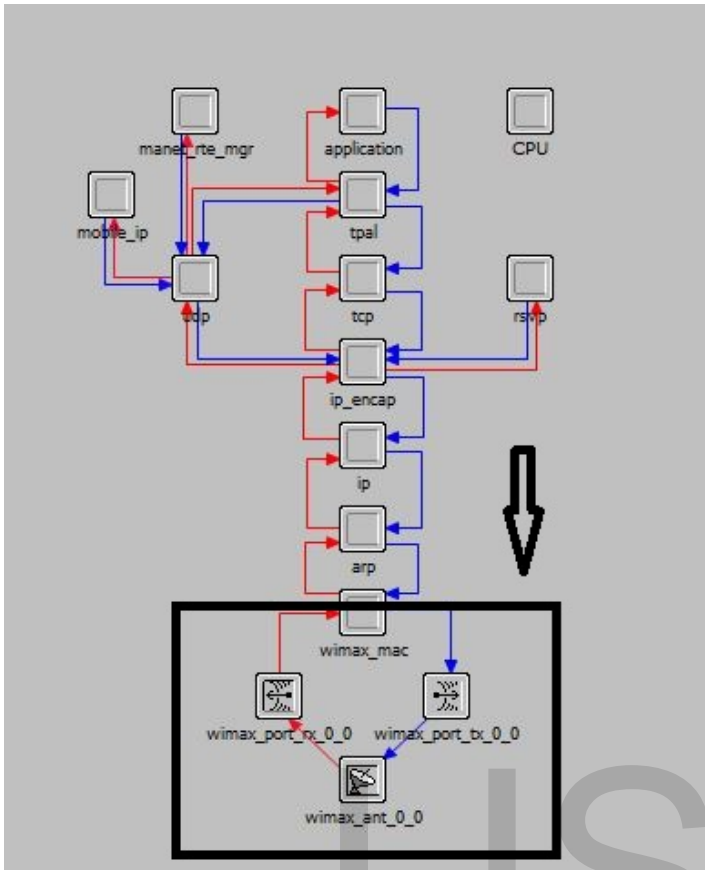


Fig. 1.7: host node model

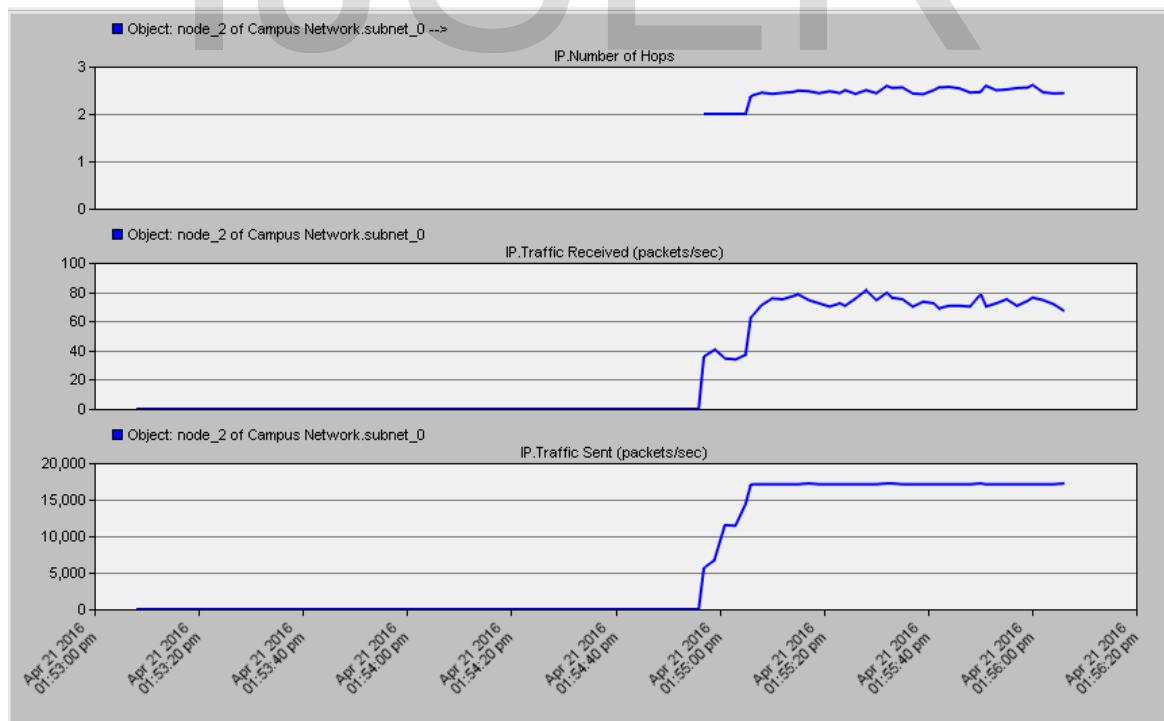


Fig. 1.8: General WiMAX Network Performance

| Statistic | Value |
|--------------------------------|-----------|
| Total Capacity (MSPs) | 12.422400 |
| Admitted Capacity (MSPs) | 0.000000 |
| Number of Admitted Connections | 6 |
| Number of Rejected Connections | 0 |

Figure 1.9: Base station control statistics

5.1 WIMAX MOBILITY

The IEEE standards for WiMAX was amended in 2005 and hence the IEEE 802.16e-2005 version of the 802.16 and it addressed the issue of mobility which was experienced in the 2004 fixed air interface version of the 802.16 WiMAX standards. 2005 amendments made the WiMAX available in vehicles with speeds up to 120km/h [11],[12].

The 2005 amendment presented three handover schemes for proper and good mobility of single WiMAX cell which are HHO, FBSS and MDHO but the OPNET modeler supports only HHO which is part of the mandatory scheme in the 2005 specification. The handovers are optimized in order to keep delays as low as possible (say below 60ms) [13].

| | Scanning Threshold (dB) | Scan Duration (N) (Frames) | Interleaving Interval (P) (Frames) | Scan Iterations (T) |
|---|-------------------------|----------------------------|------------------------------------|---------------------|
| 0 | 8.0 | 5 | 240 | 10 |
| 1 | 5.0 | 15 | 200 | 20 |
| 2 | 2.4 | 20 | 140 | 40 |

| Attribute | Value |
|---|-------|
| MS Handover Retransmission Timer (milliseconds) | 30 |
| Maximum Handover Request Retransmissions | 6 |
| Handover Threshold Hysteresis (dB) | 0.4 |
| Multitarget Handover Threshold Hysteresis (dB) | 0.0 |
| Maximum Handover Attempts per BS | 3 |

Fig 1.10: base station and subscriber station handover parameters

6 CONCLUSION

The importance of ICT in the rural areas of Nigeria cannot be overemphasized. The area under study is highly remote, hence the need for ICT solutions which are cheap, quick to install and less prone to maintenance. The functionality of worldwide interoperability for microwave (WiMAX) meets these requirements and at the access level, WiMAX services are plug and play which also makes it ideal for such areas. The OPNET simulation helps to envision the objectives of this work which is the deployment of educational ICT in the rural areas around Nsukka.

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| Service Subscriber | Direction | Class | Scheduling Type | Requested BW (b... | Polling Overhead (...) | Admitted BW (sps) | Modulation |
|--------------------|-----------|----------------|-----------------|--------------------|------------------------|-------------------|------------|
| node_0 | Uplink | System Default | BE | 0 | N/A | N/A | QPSK |
| node_0 | Downlink | System Default | BE | 0 | N/A | N/A | QPSK |
| node_1 | Uplink | System Default | BE | 0 | N/A | N/A | QPSK |
| node_1 | Downlink | System Default | BE | 0 | N/A | N/A | QPSK |
| node_2 | Uplink | System Default | BE | 0 | N/A | N/A | QPSK |
| node_2 | Downlink | System Default | BE | 0 | N/A | N/A | QPSK |
| Total | | | | 0 | 0 | 0 | |

Figure 1.11: Admitted connection status of the base stations