NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT

Deploying and Sustaining Rural Telecommunication Broadband Network for Rural Economic Development in Botswana

By

Malebogo Babutsi
(Student Number: 24379263)

Department of Computer Science
School of Mathematical and Physical Sciences
Faculty of Agriculture, Science and Technology
North West University Mafikeng Campus
South Africa

Dissertation submitted in Fulfilment of the award of Master of Science in Computer Science

Supervisor: Prof. M. B. Esiefarienrhe

Co-Supervisor: Dr. N. Gasela

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Declaration

I declare that this research project on Deploying and Sustaining Rural Telecommunication Broadband Network for Rural Economic Development in Botswana is my work, and has never been presented for the award of any degree in any university. All information used has been acknowledged both in text and in references.

Signature..................................... Date...............................

Malebogo Babutsi

Approval

Signature..................................... Date...............................

Supervisor: **Prof. M. B. Esiefarienrhe**

Department of Computer Science

Faculty of Agriculture, Science and Technology

North West University

Mafikeng Campus

South Africa

Signature..................................... Date...................................

Co-Supervisor:**DR. N. Gasela,**

Head of Department

Department of Computer Science

Faculty of Agriculture, Science and Technology

North West University

Mafikeng Campus

South Africa

Dedication

I dedicate this work to Lapologang Mokeresete, for his support, encouragement and commitment in the completion of this study.

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Abstract

It is critical for developing countries to investigate why despite enormous investments in both capital and infrastructure efforts, broadband development remain a mammoth challenge to achieve. Thus, this study reviews critical frameworks and processes that Botswana has put in place to deliver universal access to broadband. Rural areas have always had inferior services, due to deployment of less area focused technologies; often offline services, thereby increasing disparities between rural and urban areas significantly. Thus, we argue for a separate broadband connectivity approach to rural areas. In this work we present the results of a network model and its simulation using OPNET 14.5 mainly simulating WiMAX IEEE802.16standard based technology. The telecommunication industry has ranked WiMAX as the top broadband access technology, against the Asymmetric Digital Subscriber Lines (ADSL). It is also a point to multipoint mobile access based up to 72Mbps symmetric broadband speed capable of operating in the frequency range of 10GHz – 66GHz, with less interference and adequate bandwidth which makes it sustainable for rural areas. The simulation was done at various distances whereby a base station sends and receives signals from a transmitting point to a receiving point (10km, 20km and 30km), since about 15% of the overall population live beyond 50 km of the current deployed fibre optic network, which is the backbone infrastructure. The population cannot be reached without deploying a hybrid network system (either fibre or satellite with WIMAX as the last mile). The study noted that putting in place policy efforts or strategy plans to provide universal access to broadband without addressing the question of the right technology and network topology is not effective. Lack of infrastructure development seriously affects the state of economic development in developing countries. Generally wireless technologies require less infrastructure compared with wired technologies, therefore they can be deployed to solve the problem of a lack of telecommunication infrastructure in rural areas. From the results obtained, this study concluded that to tackle rural connectivity challenges, which amongst other issues is affected by a serious lack of infrastructure and inferior quality of service, a deployment of Hybrid Satellite Terrestrial Systems (HSTS)/fibre optics where present, and IEEE802.16 WiMAX at last mile level can help to provide sustained broadband deployment to Botswana rural areas.

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List of Acronyms and Abbreviations

3G - 3rd Generation

4G –4th Generation

5G- 5th Generation

ADSL- Asymmetric Digital Subscriber Line

BBC - British Broadcasting Corporation

BOCRA- Botswana Competition Regulatory Authority

BoFiNet -Botswana Fiber Network

BPL- Broadband Power Line

BPSK- Binary Phase-Shift Keying

BTCL- Botswana Telecommunication Company Limited

BTV- Botswana Television

BWP- Botswana Pula (Botswana currency)

CNN- Cable News Network

CRASA-Communication Regulators' Association of Southern Africa

CTO-Commonwealth Telecommunications Organization

FSO -Free Space Optics

FTP- File Transfer Protocol

FTTH-Fibre to Home

GDP-Gross Domestic Product

GNI- Gross National Income

ICT- Information Communication and Technology

IEEE- Institute of Electrical and Electronics Engineers

ITU- International Telecommunication Union

KHz – Kilohertz

LAN- Local Area Network

LOS- Line of Sight

LTE- Long Term Evolution

MAC- Media Access Control

MHz- Megahertz

NGO- Non Governmental Organisations

NLOS- Non Line of Sight

NSS- New Skies Satellite

OFDM - Orthogonal Frequency Division Multiplexing

OPNET- Optimized

PHY- Physical

QAM- Quadrature Amplitude Modulation

QOE- Quality of Experience

QOS- Quality of Service

QPSK-Quadrature Phase-Shift Keying

SABC-South African Broadcasting Corporation

SADC-Southern African Development Community

USD- United States of America Dollars

VSAT- Very Small Aperture Terminal

Wi-Fi- Wireless Fidelity

WiMAX- Worldwide Interoperability for Microwave access

WMAN- Wireless Metropolitan Area Networks

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Chapter 1

INTRODUCTION

1.1 Overview

1.1.1 Importance of Infrastructure Development: The Case of Developing Countries.

Investment in infrastructure development and economic growth are inseparable and intertwined paradigms in both developed and developing countries. The only confusing question is which one should come first. It is common in developing countries to avoid infrastructure development under the pretext that it is expensive which, actually is not true. Sustainable and long term economic growth strategies are normally the results of planned infrastructure investments[1]. Thus, the tendency of developing countries to delay infrastructure investments often leads to an underdevelopment syndrome. The syndrome is characterised by indecisiveness on when and to what extent to invest, lack of momentum to usher in benefits as realised in the developed "first world" countries, and poor advisory consultations that in some instances have been rejected in developed countries and in some cases cause developing countries to take development loans worth USD billions. A Plethora of reports suggest that the state of "development lag" in developing countries is a direct result of lack of infrastructure development[2]. However, the same cannot be said for ICT services such as television and communications. Therefore, there are other factors besides higher infrastructure costs that could lead to digital divide between rural and urban areas[3].

1.1.2 Satellite as Alternatives: The White Elephant Situation

Satellite technology has over many decades been available and important broadband(a high speed and high capacity ICT technology[4]) infrastructure to both developed and developing countries[5]. It has played an anchor role in the television and media industry. Many news channels both international and local have relied on satellite to collect and broadcast news. For example, the British Broadcasting Corporation (BBC), Cable News Network (CNN), Al Jazeera, Botswana Television (BTV), South African Broadcasting Corporation (SABC) among others, broadcast field stories and news through satellites e.g. Intelsat, NSS, Astra etc. The entertainment industry which in developed countries is another contributor to Gross Domestic Product (GDP) and Gross National Income (GNI) per capita, reaches the world population through satellite technology. In Africa, Rwanda and Ghana have rolled out Internet to rural areas through VSAT technology[6]. However, the view that satellite access is prohibitively expensive is not valid, since optimal use could outweigh satellite access costs[7]. This view of satellite access has gained more credence in developing than developed countries. The telecommunication industry has entrenched the belief that accessing satellite is not a viable option. In the context of Botswana, satellite has to date remained the monopoly of the government. Amongst the recommendations reached during the consultations leading to the establishment of the Botswana Competition Authority (BOCRA) 1, 2, 8 and 33 (which are the Botswana National Broadband Strategy recommendations) prefer a market based frequency bandwidth access model that could usher in more economic benefits than the government controlled model[8]. This implies that, for the successful deployment of rural broadband, several factors are important to be considered such as shopping for the appropriate technology, which is affordable, sustainable and compatible with the complex rural areas topology. Also essential for deployment of rural broadband are the right policies, laws and the involvement of the public and private sectors.

1.1.3 ICT Facilitation of Economic Development and Growth

Information Communication and Technology (ICT) has taken a central and pivotal position as a catalyst for national economies across the globe[9]. Comparatively, ICT has assumed a global lead against traditional economic strategies, such as minerals and agriculture. It is clear globally that mining, financial and industrial production based economies experience slow economic growth due to economic recessions, political instabilities and other geo-political factors. This has given the telecommunication industry a catalytic role, as it facilitates economic development and growth through digitalization of services. ICT could save the general population and commercial businesses loss of resources, transport and time. Moreover, this study appreciates the broad diversity of the telecommunication industry in terms of technologies; hence it gives credit to the broadband technologies that have been found to possess these catalytic properties that transform national economies[10]. These benefits are derived from the broadband capacity to enhance services, through speedy communications systems, timely business decisions and expansion of market platforms. Today diamonds are auctioned globally from previously less known countries such as Botswana to the rest of the world, whose platforms rely on broadband networks. Medical, educational and fiscal services continue to reach previously difficult areas due to broadband telecommunication networks. Observations and documentation on the broadband telecommunication benefits are endless.

1.1.4 Policy, Broadband Plans and Liberalization: Telecommunication Industry

Countries across the globe have developed policies and programmes to reform the telecommunication industry and to optimize the economic benefits on a level ground. Policies and programmes ensure that strategies are focused, conflicts are addressed and managed, and country commitment is demonstrated. Policies and programmes help to measure the extent to which both the government and private sector could go towards investing in ICT infrastructure development services. Conflict is an inherent societal phenomenon between a diverse myriad of interests, and therefore various interested groups, some involved at the end user service line, others at infrastructure development level and some at the regulation level. The players could be any of the following stake holders; private, public, Non-Governmental Organizations (NGOs) or state.

1.1.5 Affordability, e-programming, Regulation and Private Sector: Successful Broadband Deployment

Without explanations of the reasons why it is necessary to have policies to manage conflicts and guide investments in the ICT and broadband, noble projects by the private sector such as the famous India eye e-medical services[11, 12], a Wi-Fi technology based e-programme, would not be a successful effort. In Botswana the lack of policy on who is supposed to regulate the mobile-money services through easy money transfers, banking and online shopping could be compromising the vulnerable ordinary population. The extension of ICT and broadband services to other aspects of society such as e-programming requires that countries need to speedily enact and adopt policies and laws to ensure that service end users are protected against poor services and unjustified fees. Services intended to run through ICT are also subject to regulations like other non-ICT services that are regulated to manage their provisions. Another important factor to note is that, without adopting policies on ICT services, beneficiaries would be subjected to the ICT service providers' discretions. However, in Botswana, discomfort evident at various "ICT Pitso", forums for ICT stakeholders show that both government and the private sector boardrooms may be pointing to something beyond the ICT and broadband deployment cost and rural areas characteristics as the impediments to ICT and broadband deployment. The Botswana Telecommunication Company Limited (BTCL) representative raised an issue that although the government has given Botswana Fiber Network (BoFiNet) the role to lead and manage infrastructure development, legally it is not clear to the private sector. This is based on lack of statute to back the development as is the case with other parastatals However, Botswana is yet to adopt the broadband strategy of 2013. This led to concerns by the general population that broadband is yet to usher in the same benefits as in developed countries. The chairperson Parliamentary Portfolio Committee on Communications, Works, Transport and ICT, raised concern that the lack of implementation of the ICT policy and broadband strategy hampers national economic growth. The concern is viewed on the background that Botswana has massively invested in the ICT and broadband sector, yet the country continues to experience minimum benefits.

1.1.6 Characteristics of Rural Areas: Obstacles to Successful Deployment

There is consensus that, to reach the general population through the global "access for all to communication" commitment by 2016, countries should develop broadband strategies. Also, the rapid changes in broadband technologies will put to an end the practice of leaving rural areas behind or making them the "last to service tendency" by governments. Thus, rural broadband has gained preference as an economic development strategy or solution for rural economic development, especially in developing nations. It is perceived to be the epitome of economic development transformation [6]. However, there are obstacles and challenges peculiar to developing countries' rural areas that may hinder efforts to transform rural economies. These include sparse population and low density, lack of backbone infrastructure, lack of skilled human resource base, lack of political will and policy to direct how to tackle rural development approach [13]. These challenges have collectively determined the extent to which developing countries deploy broadband and ICT services (Figure 1:1) for example the deployment of broadband infrastructure in rural areas for community use such as free internet services in public areas compels to increase in number of internet subscribers. Some countries in Africa are still experiencing politically motivated conflicts. The same can be said of some countries in Eastern Europe. In all these regions, the lack of political stability, social unrest and other socio-political and economic challenges have led to a lack of investors' confidence across economic sectors including ICT industry.

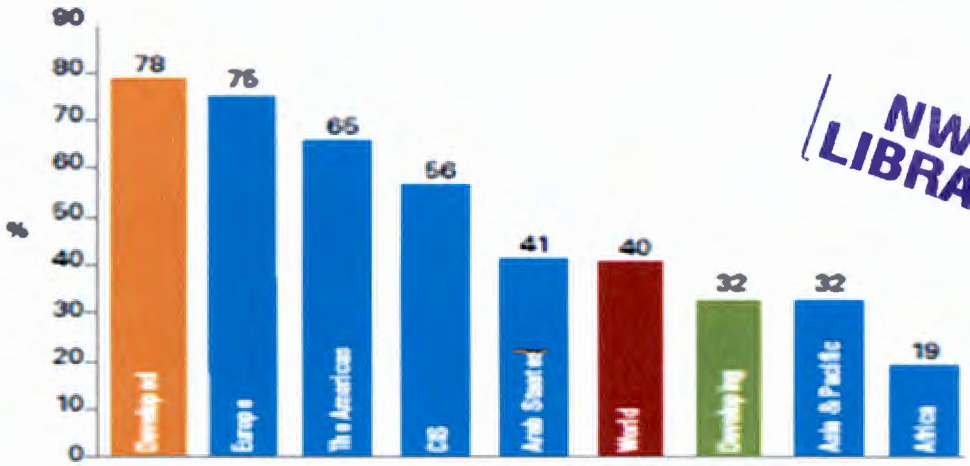

Figure 1:1Global Internet Subscribers by Region[14]

One of the critical areas that this study would demonstrate is how ICT and broadband could usher in economic advantages to rural areas, which has been presented in many reports. The African Development Bank (AfDB), International Telecommunication Union (ITU), CRASA and many other forums have argued the case for adoption of ICT and broadband as an economic strategy for developing countries. Some studies have established that 10% investment in broadband infrastructure increases GDP by 1.4% [6, 15]. An increase in GDP affects the lives of the general population in many ways. Although economic development as a concept has been defined in various ways, it adds up to job creation, training and skills development, industrialization and increased population mobility. As broadband deployment in rural areas opens, rural areas economic potential is realized as enterprises open for public consumption. In a nutshell economic development is an opportunity multiplier, which changes and improves lives. It has been argued that any viable economic development strategy should produce jobs, training and skills acquisition, various forms of industries and increased population opportunities[16]. On the other hand, rural areas may provide solutions to the rapidly growing unemployment challenge, boost tourism through expanding markets, enhance and grow the agriculture industry, and also encourage lifelong learning. The increase in GDP due to investment in ICT and broadband infrastructure development compel developing countries to invest into the ICT and broadband sector, if they are to emerge from their state of underdevelopment and match developed countries.

1.2 Background

1.2.1 General Definition, Concept and Challenges for Broadband Deployment

Several subareas which necessarily provide the background for this study are broadband definitions, the socio-economic status of the rural areas including Pandamatenga, institutional and policy efforts, state of infrastructure development in Botswana, state of broadband connectivity and a brief background to leading broadband technologies.

Traditionally, broadband is data transmission speed, which is the amount of data that could be transmitted across a network in a given time period[10]. Changes in speed and capacity to carry data across networks seem to change with current and new technologies. In future this development could bring about the challenge to precisely define broadband, since the definition affects how broadband services are classified and regulated. Thus, as new technologies get realized, the broadband definition shifts. Perhaps it is crucial to point out that, when the scientific broadband definition changes, the economic considerations gain more popularity as it means transacting business would be faster and more efficient, ultimately improving service delivery. Moreover, the ICT industry defines broadband as a "high capacity ICT platform that improves the variety, utility and value of services and applications offered by a wide range of providers to benefit users, society and multiple sectors of the economy". There seems however, to be another definition preferred for policy process[10]. In this case broadband is defined as an ICT platform that has a potential to influence the entire economy, acting as a catalyst[17]. Drawing from the definitions provided, two central factors emerge which cannot be ignored; data transfer speed across networks and its catalytic properties to all sectors of the economy.

These dominant definitions extend across the massive literature available on broadband technologies. Satellite, optic fiber, WIFI, WiMAX and others are a few of the current broadband technologies. The common factors amongst these types of broadband technologies are high speed and carrying capacity at which they transfer data across the network.

1.2.2 The Socio- Economic Status: Rural Areas in Botswana

Since this study proposes rural broadband network deployment as an economic strategy for Botswana rural areas, it is important to provide a brief economic background of the country and the state of its rural areas. The study also acknowledges that Botswana as a developing country shares almost similar challenges with other developing countries both within and outside the continent. The state of the lack of infrastructure development in developing countries affects rural areas more than urban areas. This phenomenon is in most literature referred to as the digital divide. Furthermore, the digital divide is blamed for marginalization of the rural areas both in terms of deployment and network topologies. The digital divide has been argued to be both technical and economic. The technical side of the phenomenon presents rural population with inferior services due to deployment of less area focused technologies; often offline services, whereas the economic part involves the state of affordability of the services by the population in the rural areas. The state of the lack of ICT and broadband infrastructure in developing countries means that disparities between rural and urban areas are significant, thus it is worth arguing for a separate rural broadband connectivity approach.

Botswana is a landlocked country with a population of two million (2 038 228) people[18]. It shares borders with four countries, South Africa, Namibia, Zambia and Zimbabwe. It is also a Southern African Development Community (SADC) member. Most of the SADC countries produce minerals especially diamonds distantly followed by copper and other minerals. Although minerals, especially diamonds account for approximately 40% of the Botswana income revenue and its GDP is currently at around 31.4%[19]. Rural areas' economies have remained stagnant with high unemployment and low skilled labour. Agriculture is the only major form of economic sustenance and engagement as the main socio-economic engine. Rural areas have high unemployment rates and low skilled labor bases.

Other infrastructure development efforts in Botswana are premised on the Industrialization Policy of 2005, including the complimentary Village Electrification Project program (VET). The project is intended to accelerate economic growth in rural areas; however there remain resource and other challenges for industrialization to get off the ground and succeed. Connecting rural areas to the power grid is another strategy that has potential to change the socio-economic status of rural areas in Botswana. Since power is an essential service support to ICT and broadband services at user level, successful VET would definitely decrease rural broadband access.

Pandamatenga, a rural area in Botswana, shares similar characteristics with other rural areas, such as Hainaveld in Ngamiland, Tuli block in Central District, Lobatse and Molopo farms as well as Ghanzi and Sandveld farms in the Central District. These areas share the obligation to secure and sustain Botswana food and beef production industries. Most of these areas are not connected to the power grid and other critical support infrastructure.

Noting that farm owners and workers would benefit from any facility that can manage time, while allowing business transactions, we surmise that without connecting rural areas to the main broadband network, their potential will remain untapped, and will not benefit the national economy. Therefore connecting Pandamatenga and the general rural areas would change lives tremendously. Four out of ten people in Botswana live in rural areas. This suggests that significant potential revenue due to tourism and agriculture to the GDP is lost, thus a compelling factor for rural broadband connectivity.

1.2.3 Institutional, Legislative and Policy Framework on ICT and Broadband Strategy

Another critical area for Botswana in gaining successful broadband deployment is to ensure that progress in creating both laws and institutions to manage the ICT and broadband industry involves a broad spectrum of interest groups. The Maitlamo National ICT Policy of 2007[20] and draft Broadband Strategy of 2013 have provided both institutional and legislative frameworks. Further, in place are the Telecommunication Act of 1996, paper no 15, BOCRA Act 2012 paper no 19, Broadcasting Act of 2004, and Broadcasting Act 2005 paper no 65 together with the Botswana Postal Services Act of 1989. New institutions such as BOCRA and BOFINET have been established to provide a regulatory oversight body and to lead infrastructure development respectively.

On the background of the institutions and laws developed, Botswana has recorded progress in laying infrastructure, regulation and licensing frameworks. Regulation to manage competition reduces monopoly, but over regulation could also stifle the market, thus leaving the government or investors with low returns and huge investment costs to settle.

1.2.3.1 Botswana ICT Policy (2007)

Some developing countries, including Botswana, have invested significantly into the ICT sector. These massive ICT investments, especially infrastructure development, operation and management, require clear policy directions. Perhaps we need to acknowledge that, although Botswana has enacted ICT laws, adequate progress has not been realised. The role of the policy is to clarify roles, set general intentions or direction and to show commitment within the desired time frame for deliverables. However, it has been observed that Botswana National ICT policy, "MAITLAMO" (2007) [20]needs review, to lure more efforts, especially from the private sector and the general public.

The Ministry of Transport and Communication has been running a series of "Pitso" conferences to evaluate progress. One striking observation is lack of research and funding to encourage innovations in the broadband area. Another critical area passively mentioned by the policy is the deployment of rural broadband network on the background of the many challenges including digital divide and rural areas characteristics. Another development mentioned in the National Maitlamo ICT Policy of 2007 is the establishment of the Information Age Council and Government ICT Steering Committee which is chaired by the Ministry of Transport and Communications which is also the secretariat. Although the council membership is intended to accommodate broad interests of stakeholders, government retention of the key positions may adversely affect the delivery of the whole broadband and ICT initiatives.

Although consultations continue to date on the ICT and broadband status in Botswana, the document does not address many emerging issues. Industry players have been left to speculate what is next? Who does what? We hold the view that lack of policy clarity and failure to address emerging issues in the broadband sector would stall progress, and bring about digital exclusion.

The exercise that led to the draft policy was based on benchmarking with other countries in the region, Europe and Asia. It has to be stated that, without policy benefits to ordinary population, broadband may remain elusive and marginal, rendering it unaffordable. The policy initiatives to establish community ICT Centres and the Nteletsa programmes (Rural Telecommunication development Programmes) have successfully introduced the broadband benefits to the general public. However, the relevancies of this policy remain to be tested by the rapid and complex developing ICT and broadband industry.

1.2.3.2 Botswana Competition Regulatory Authority (BOCRA)

Botswana Competition Regulatory Authority is a telecommunication regulatory agency for the ICT and broadband industry. Amongst its role is granting spectrum licenses for operation. It was created by an Act of Parliament through Botswana Competition Regulatory Authority Act of 2012. It runs alongside other existing laws and policies in the country. It is important to note that regulation of the ICT and broadband is essential to level the operation field and to ensure that the services are sustainable and affordable.

1.2.3.3 Broadband Strategy (draft 2013)

The draft broadband strategy shows commendable effort. It is clear that when it was developed benchmarking was done with other countries, seeking to place the country amongst the best now and in the future. However, there is only limited mention of satellite in the strategy, though the country has a bandwidth of 36MHZ, which is enough to accommodate broadband and other satellite needs.

From page 45 to 49 the draft Broadband Strategy outlines an ambition to connect rural areas, which includes tourism areas, farms and deep rural areas. These rural areas are grouped into three regional clusters; 1, 2 and 3, with a total population of about 723020 people, approximately 35.5% of the overall population, and this excludes areas with over 100 000 people [21]. Furthermore, the broadband strategy identified that, for broadband to penetrate rural areas other support infrastructure would need to be put in place, such as road networks and power (electricity). However, it does not explain why areas along national road highways and those within urban proximities have not been covered, such as Panda farms, Ghanzi farms, Kotolaname and other rural areas. Also, though mentioned in passing the draft strategy suggests that private companies that win the tender to connect rural areas would look into what technologies to use to connect difficult to reach areas. This study would demonstrate how this may prove a challenge since the satellite bandwidth has not yet been released to BOCRA for regulation, something which is tied to the state radio, television broadcasting and other needs.

1.2.4 Botswana ICT Infrastructure Status: Broadband Backhaul

Botswana has since independence in 1965, achieved significant milestones in advancing its once small and weak telecommunication network. The telecommunication network then covered only a few areas along the railway line. The network exchange only provided telephone and telegraph services. However, the story would later change due to the mineral fortunes and commitment to infrastructure developments. The country has over time invested in various telecommunication technologies as they evolved. As the country gross domestic product (GDP) would later demonstrate, Botswana's geo-political and economic statuses allow it to be amongst the leading investors in broadband and ICT infrastructure in the region.

Perhaps on the background of the investment on ICT and broadband infrastructure development achieved so far, it can be said that Botswana has not done well. Wired broadband is not accessible and affordable to the rural area population. Contributing factors involve higher deployment costs and lower returns on investments. These challenges continue to disadvantage the rural population from benefiting from broadband network services.

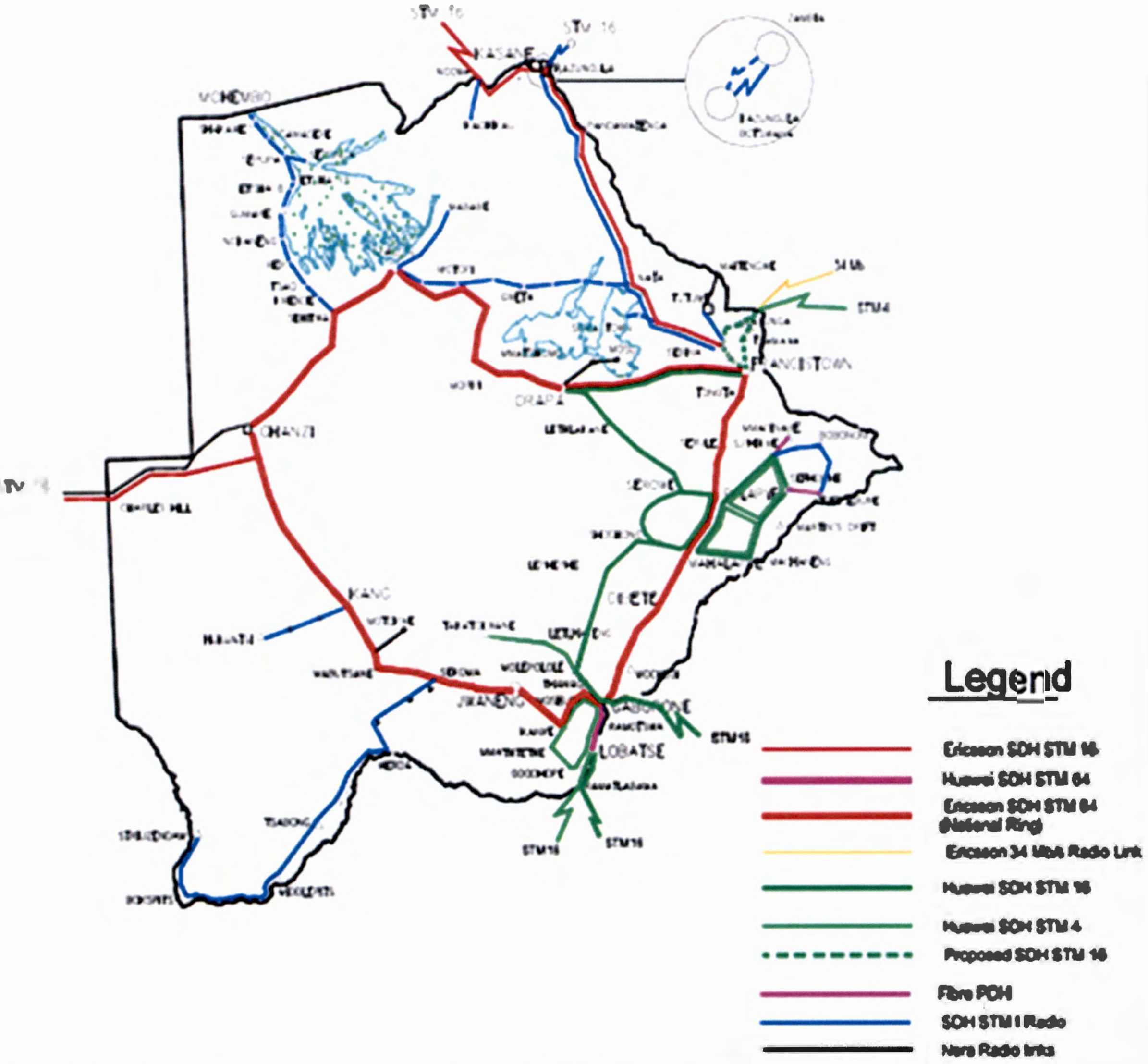

Figure 1:2 National Transmission Layout [22]

1.2.4.1 BoFiNet

Botswana has over 6000 +km of optic fiber as the main backhaul infrastructure as shown in Figure 1:2. It is planned to increase the line from Sekoma to Bokspits, Sehitwa to Mohembo, and Maun to Kasane through Moremi game reserve and Francistown to Kazungula. Figure 1:2 shows standard specifications. Botswana Fiber Network (BoFiNet), a government company, has been entrusted with providing broadband infrastructure development, the optic fiber line. However, since there are other fiber networks commonly referred to as "dark fiber lines" already in place, decisions are underway to put them under Botswana Competition Regulatory Authority (BOCRA) for regulatory purposes.

1.2.4.2 Department of Broadcasting Services (GOB)

As argued earlier in section 1.1.2, despite satellites underutilization in the region to bolster broadband strategies, almost all developing countries have access to these abundant satellite footprints. Botswana spends approximately USD 5000.00/MHz per month in satellite rental fees. This translates into approximately USD 2 000 000 per annum. On the other hand the use is limited to Botswana Television only as the main carrier, satellite news gathering, flyaway, radio and national security institution operations.

From the private sector, there are no indications of local business operations involving the 36MHz bandwidth Botswana rents from the IS- 7 satellite. Through satellite utilization, Botswana and other developing countries could enhance their broadband strategy and internet penetration. Also there is lack of satellite frequency spectrum liberalization documentations. This state suggests that the use of satellite has not yet been decided to be part of the broader broadband strategy.

1.2.4.3 Private Operators

Apart from Botswana Telecommunication Corporation (BTCL) optic fiber network, which has since been transferred to BoFiNet, the remaining private operators MASCOM (PTY) and ORANGE BOTSWANA (PTY) have deployed their own local optic fiber lines. They also have access to other optic fiber network lines operated by their partners such as MTN South Africa.

Although the ICT backbones have significantly covered both urban and rural areas, internet and other ICT services are least subscribed (see Figure 1:3). From a range of ICT services such as e-Government, private business and public services remains limitedly accessible to the rural population, therefore unnecessarily producing long queues and expenses for end users. Another observation is that there are many and fragmented ICT backbone infrastructures owned and operated by different government and private organizations. These have led to duplication of projects across various government ministries and the private sector. Although the parliament debates budgets for project prioritization and approval, the realization that similar projects compete for the same resources seems to elude it. Therefore, one can imagine the same parliament debating similar proposals to lay multiple backbone infrastructure worth US $ billions for different government companies. However, the same parliament may decide not to invest in similar projects based on the assumption that the exercise is expensive and is disadvantaging other deserving areas which require government funding.

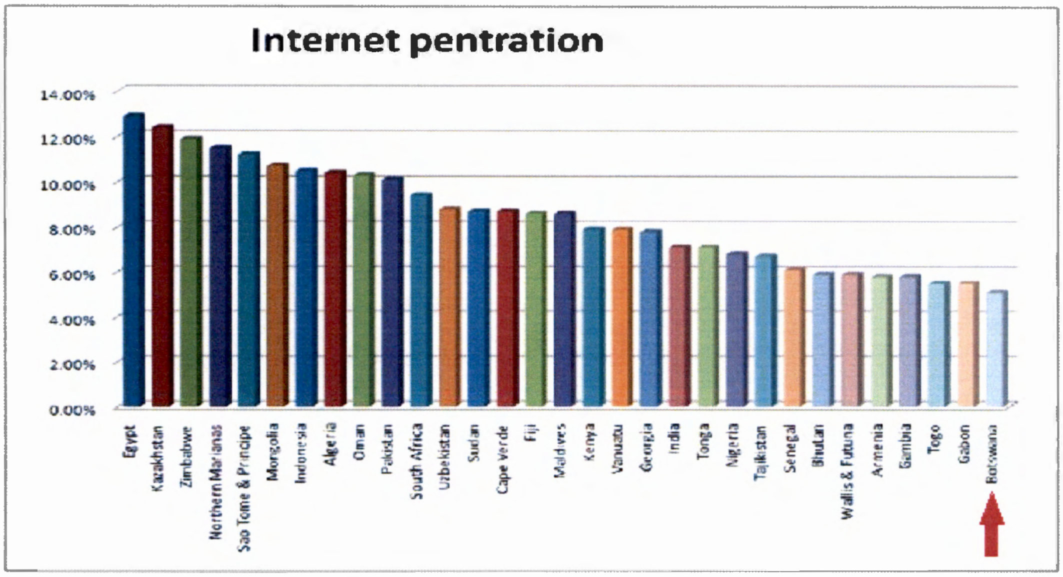

Figure 1:3 Internet Penetration[23]

1.2.5 Broadband Connectivity Status in Botswana

1.2.5.1 Satellite

With the ITU 2015 strategy for developing countries to have connected 40% of their household population to the internet some means seem to be left unutilized[6]. Documentation on the availability and use of satellite for telecommunication services in Botswana is difficult to find. This could suggest lack of use or poor record keeping for development purposes. This service is common to operations far into deep remote rural areas and disaster operations. However, due to the importance played by tourism as a significant GDP contributor, the need and use for satellite enabled internet and telephone services within tourism facilities is paramount. This may go along with the strategy to raise the standard to the premium status, low volume high value services.

1.2.5.2 BPL (Broadband over Power Line)

Also called Power Line Communication BPL, is another broadband technology for rural network deployment at the last mile level. BPL uses the existing power line infrastructure for the transmission of a signal. It harnesses the advantage of the already deployed power grid line infrastructure to carry signal (data, voice, video, etc.) to homes and businesses [24]. It derives its interoperability between power from the diminished interference between the power and radio frequency signal, which is minimal because the two signals are wide apart. BPL uses multi-carrier modulation technique, OFDM (Orthogonal Frequency Division Multiplexing) modulation; which is densely spaced orthogonal subcarriers each being modulated by low bit-rate digital stream in addition it uses adaptive modulation which ensures highest order modulation scheme (BPSK, QPSK, QAM16, QAM64, etc.) for each sub-carrier depending on the signal to noise (S/N) ratio[25]. BPL uses the frequency band from 2MHZ to 34 MHZ, and can provide 200 Mbps within a range of 1 to 3 km. Other technologies such as IEEE 802.16 WiMAX also provide services at these frequency band ranges.

However, the use of this technology is not common in developed countries or developing countries such as in Botswana. Although there are several factors raised as disadvantages of BPL such as specialised last mile infrastructure and lack of power energy, which is another imperative characteristic of developing countries, the industry views it as not effective unless heterogeneously deployed (Home plug + IEEE 1901). The status of household power connectivity is dire in developing countries including Botswana [26]. Thus, this may present serious challenges for rural broadband.

1.2.5.3 Wireless

Another area which proved difficult to find statistics to support is the penetration of wireless services for internet and other services in Botswana. However, efforts through infrastructure at the last mile level are noticeable around the country through live-box connections and public phone booths.

1.2.5.4 Fixed

As at 2013, Botswana ranked 128 out of 183 countries in terms of fixed broadband connectivity. In percentages this translates to 0.8%, while the highest country is at 41.9% (Switzerland). In Africa, Botswana ranked 11, with the top country at 11.70%, and Botswana at 1.4%. These numbers suggest that, although Botswana continues to invest into ICT and broadband infrastructure, institutional and legal framework results remain marginal as shown in Figure 1:4.

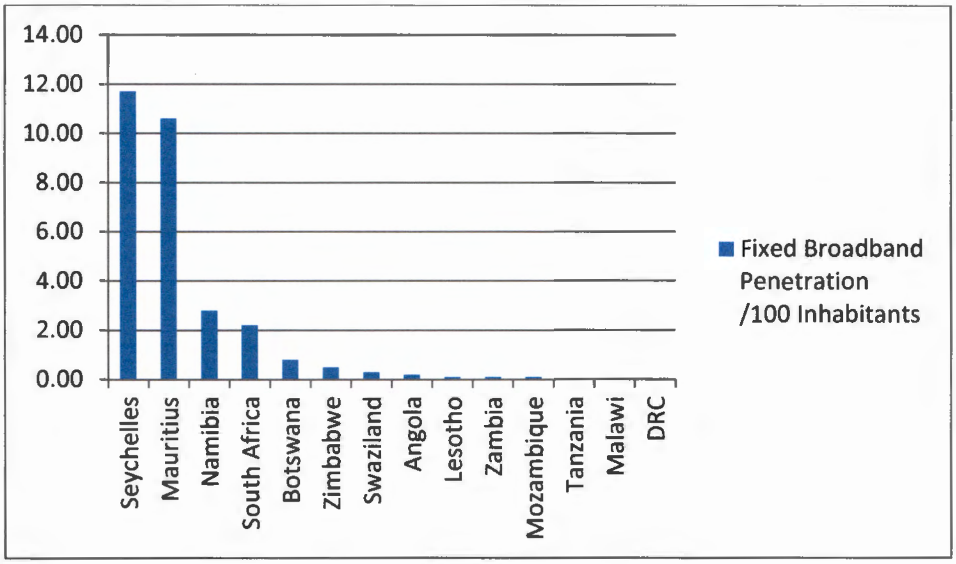

Figure 1:4 Fixed Broadband Penetration (SADC)[27]

1.2.5.5 Mobile

Mobile connection could be through personal computers, laptops, tablets, USB modems and headsets. In 2013, Botswana was ranked 76 out of 170 countries. This translates into 16.6%, and is ranked 7 in Africa, and 5 in the SADC region. Locally, the penetration of Botswana's population connected through mobile has reached 49%, which is almost half the country's population (Figure 1:5).

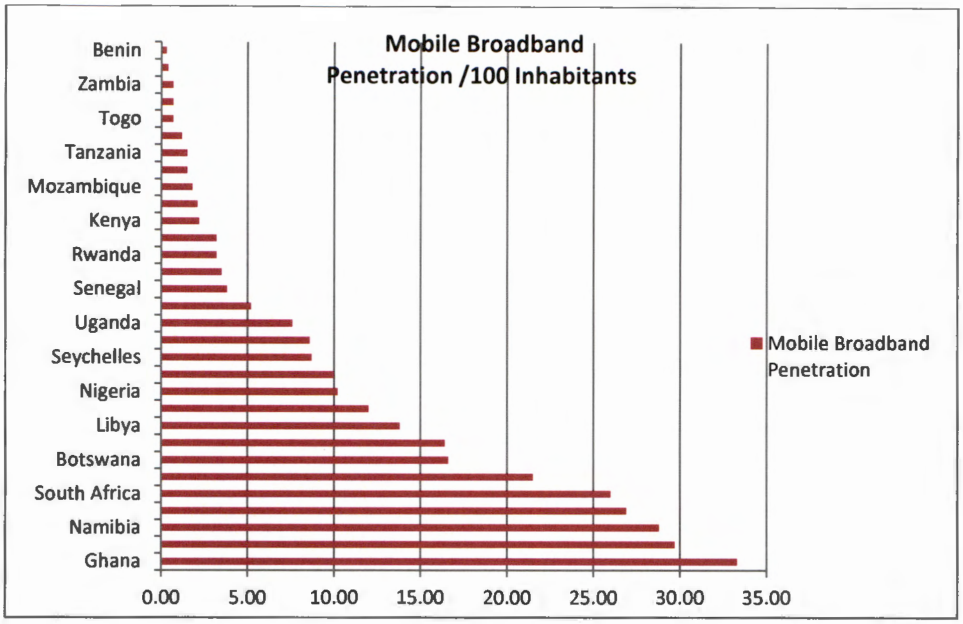

Figure 1:5 Mobile Broadband Penetration (Africa)[17]

Conclusively, these Figures (1:4 and 1:5) when used as connectivity indicators, may suggest a mammoth broadband penetration challenge for the country. The question is what is lacking? Is it due to the policy or the lack of the right technology or the lack of adequate infrastructure development or all these factors?

1.2.6 Is IEEE 802.16 WiMAX Future Rural Broadband Network Deployment Solutions for Developing Countries?

Worldwide Interoperability for Microwave Access (WiMAX) is an IEEE standard based broadband Wireless Access technology (BWA). It has relatively rapidly evolved from IEEE 802.16 in 1998/2001 to date with several versions, and the team has since focussed on enhancing its challenges which are; Quality of Service (QoS), compatibility with other technologies and throughput. The initial WiMAX version, the IEEE 802.16, was limited to the line of sight approach. This was followed by version IEEE 802.16a to IEEE 802.16j, including the IEEE802.16e which is a non-line of sight and supports mobile deployment. Advantages of the IEEE 802.16 WiMAX are its capability to connect high density population areas, with options for both Base Stations and Access Points as service end users access points, thus it is characterised as Metropolitan Area Networks capable. Also, it is recommended for sparse population areas such as rural areas. Summarily, IEEE 802.16' attractiveness is derived from its frequency range, bandwidth and maximum range of 50 km from the base station, which relies on minimal infrastructure. Later in the literature review, analysis of WiMAX challenges, advantages and its future will be assessed.

1.3 Problem Statement

The telecommunication industry has in the last two to three decades experienced phenomenal growth not only in terms of new technologies, but also liberalisation to allow competition. Different technologies compete for the market as well as different entities to provide services. The telecommunication technologies continue to evolve, and have presented ICT as an economic catalyst or strategy for economic development across a broad spectrum of industries [28, 29]. In spite of this growth, developing countries still lag behind in terms of economic transformation [6]. We see lack of job creation, poor government programme utilization by the general population[30] and lack of industrialization both in urban and rural areas. This scenario negatively affects the lives of the general population in how they access government services, public and private services to improve their lives. Strangely many developing countries [31] have access to broadband infrastructure, while rural areas connectivity remains a challenge.

Thus, the low internet and other ICT services penetration by developing countries has ensured that they continue to experience slow economic growth [8]. Contrary to developing countries experience of the ICT; developed countries have achieved phenomenal economic advantages due to their reliance on ICT as an economic strategy.

Although the poor ICT connectivity and low internet penetration in developing countries is in most cases attributed to the unstable socio-political and economic status, settlement patterns and lack of backbone infrastructure[28], it could also be due to lack of government to lead initiatives. Together, these factors would escalate the deployment cost of rural areas broadband telecommunication networks, thereby creating impression that rural area broadband network deployment is expensive and not viable.

It is inevitable, therefore, that solutions to address the question of economic development through deployment of rural broadband technology consider combining broadband technologies and policy commitment that could address challenges that hamper connecting rural areas. Hence, solutions to connect rural areas would require technologies that are affordable and sustainable in the case of Botswana and other developing countries.

1.4 Rationale of the Study

There are several general questions raised by a significant body of literature[32] that this study needs to answer concerning connecting rural areas to broadband technology. They include; a) why rural areas have remained marginally connected in terms of internet and general broadband services, when technologies have been available for several decades? b) Why is there a need to connect rural areas? c) What is the current state of rural areas connectivity? d) What initiatives have been done to connect rural areas? Above all, e) what is the status of e-programmes and services readiness both in the government and private sector for broad band strategy to benefit the general population? These questions show that connecting rural areas is dependent on several factors, and if they are not all considered, the effort to connect rural areas remains an uphill battle and a pipe dream, especially for developing countries such as Botswana.

Although new and advanced telecommunication technologies have been deployed in most developing countries, only a fraction of these in terms of mobile broadband have penetrated rural areas. We still witness huge disparities between developed and developing countries. This has not brought the desired goals of rejuvenating rural economies and diversifying national economies. Governments and the private sector continue to lose significantly due to lack of connectivity to an adequate rural broadband network. This study aims to identify an affordable (easily deployable, cost-effective and sustainable) network model suitable for most rural areas with similar terrains. The solution should provide a technology that is compatible with the prevalent low rates of literacy (functional) in rural areas.

1.5 Research Goal

The main goal of this research study is to propose a sustainable and cost effective rural broadband telecommunication broadband network model for rural economic development.

1.6 Research Objectives

In order to achieve the goal and answer the research questions we intend to use the following objectives;

I. Develop telecommunication broadband network model for rural economic development in Botswana.
II. Implement the developed telecommunication broadband network model.
III. Test the network for performance/(responsiveness, throughput and quality)
IV. Analyze results of the implemented model.

1.7 Research Methodology

This study is concerned with providing broadband connectivity to the rural population. It seeks to build a simulation model that when complete, may influence deployment and sustenance of rural broadband in the rural areas, especially in Botswana. A case study and quantitative approach will be used in the study. This arises from the premise that, approaching this study from a simulation dimension is much concerned with evaluating performance metrics to determine the network quality standards. Further, the research methods for this study focus on reviewing the literature and model construction and simulation. The latter part arises from the scientific position that research methods form an essential and integral part towards reaching any conclusive position about phenomena being studied at any time, including following necessary processes to reach conclusions.

To determine deployment and ways to sustain a rural telecommunication broadband network we intend to review literature across the spectrum of telecommunication network technologies, including IEEE 802. 16 WiMAX, and also build or construct a model to observe the behavior of the network, and evaluate model network efficiency.

1.7.1 Literature Review

Within the study, we intend to review closely related literature to provide insight into researches both past and present. This would provide insight into current and gap in knowledge. The study will also draw lessons from areas where IEEE 802.16 WiMAX has been deployed in various parts of the world. The evaluation of the performance of the deployed network is crucial for this study. Institutional, legislative and policy frameworks would also be reviewed to measure the state of preparedness for Botswana rural broadband network deployment. Research material will be acknowledged.

1.7.2 Setup a Network Model

Although models are abstract relative to the actual phenomena being studied, it is the only available way to put to test a network performance through simulation, using OPNET simulation 14.5 tools. This saves logistic resources and costs.

1.7.3 Implementation of the Network Model

Once the model has been setup, we intend to implement it. This part simulates the study situation. Attention would be placed on variable factors common to rural areas being studied, such as distance, topology, obstacles etc.

1.7.4 Network Model Evaluation

Model evaluation or model results analysis will conclude the simulation process. This stage is important as the whole study exercise results are premised on it. We intend to construct a model for this study to observe the behavior of the IEEE 802.16 WiMAX network against throughput, delay and amount of interference as additional access points are added.

1.8 Research Contribution

This study proposes a deployment of an affordable and sustainable rural broadband network. The study has noted the infrastructure challenge in developing countries due to several factors outlined in many reports presented at various local and international forums to influence policy decision and deployment of broadband networks. At these forums, reports have indicated the lack of infrastructure development as the primary factor that drives up the cost of broadband network deployment. Secondary and other factors are: rural areas' sparse populations over challenging topography, the inherent lack of technical skills base in developing countries to argue and sustain the best available technologies, and lack of market based policies and institutional framework to support service deployment.

Therefore this study proposes to influence broadband network deployment in Botswana, particularly to argue for IEEE 802.16 WiMAX standard and policy commitment for rural areas connectivity. Also, the study is made available for use by both the telecommunications industry and for academic purpose.

1.9 Included Publications

Part of the research reported in this project has been accepted for publication. The paper is

"REVIEW PAPER ON BROADBAND STRATEGY: BOTSWANA" **Authors**: *Prof. M. B. Esiefarienrhe Lecturer North West University, DR. N. Gasela HOD North West University, Malebogo Babutsi MSc Computer Science student North West University* in "The Journal of Information Technology for Development"

1.10 Chapter Outline

- **Chapter 1: Introduction and Background:** This presents an introduction and background theory of the proposed study.
- **Chapter 2: Literature Review:** Presentation of previous work done by other researchers in the proposed area of study.
- **Chapter 3: Model Development:** Presents the test model on which the study simulation is based.
- **Chapter 4: Implementation:** Provides the detailed process which will be followed to run the simulation, present study results for discussions and report on the findings.
- **Chapter 5: Summary and Conclusions:** Collects all the basic chapters themes and present analysed position on the study.

1.11 Chapter Summary

This chapter looked into the challenges presented by the rapid broadband definition changes that, in the not distant future may bring about infrastructure review, which may present a challenge to developing countries given their marginal income positions. Further, this chapter outlined the status of policy development in Botswana as a sample for most developing countries. Also, the chapter looked into the broadband network deployment state with the view to isolate any common direction amongst developing countries towards any particular technologies over others. The chapter also looked into the state of broadband network backhaul and backbone. The IEEE802.16 standard brief overview has been presented to preface later discussion.

Also included in the chapter is the economic state of rural areas in developing countries. It also gave a brief background on the state of rural areas infrastructure development, including power or electricity connectivity status and state of skills and training base.

Chapter 2

LITERATURE REVIEW

2.1 Chapter Overview

Chapter two presents literature reviews, observed trends, arguments by various scholars, policy views and positions by both government and private commercial entities on the state of telecommunication broadband initiatives in developing countries. Throughout the study it was observed that there is a concern that developing countries have not adequately invested into broadband connectivity initiatives[33] when compared to developed countries. Also observed is the mounting pressure to connect to broadband network line to reach the targets that the International Telecommunication Union (ITU), UNESCO and Commonwealth Organization (CTO) have set; ***making broadband policy universal, making broadband affordable, connecting homes to broadband and getting people online*** by 2015[34]. Also prominent across literature are the views that broadband connectivity in developing countries is inhibited by the lack of ICT infrastructure and high telecommunication equipment and deployment costs[35]. Similarly, the inherent and apparent lack of other basic support infrastructure services status such as lack of power (electricity) connectivity, roads network and the infrastructure and equipment security was noted.

The chapter also reviewed methods used to conclude other related studies. The other benefits derived from past reviewed literature were to put into focus researched concepts and trends in broadband deployment. This has provided clarity as to what has already been researched. The study also paid attention to the following areas: the current state of telecommunication connectivity in developing countries and the global status of the broadband penetration, the global status of rural areas with regard to broadband connectivity (including Botswana-Pandamatenga). Another area covered in the review is the shift to Public, Private Partnership (PPP) paradigm to enhance public service delivery and tackling the challenge of low returns faced by private commercial companies when they invest in public projects.

The chapter is structured in the following manner; introduction, definition of key terms and concepts, review of broadband technologies, state of rural areas in Botswana, the state of the Botswana broadband policy documents and legislation initiatives and institutional frameworks.

2.2 Definition of Key Concepts

2.2.1 Economic Strategies:

Countries, including developing ones, have enhanced their national economic growth through various strategies and ways. These involve institutional, policy and infrastructural development to foster rapid growth. For example some countries have focused on service efficiency and education investment as their main national economic catalysts[36]. Some have less government regulation and liberalized key economic areas, while other countries' national economies are "tax havens" common in the Latin countries[37]. Common with all these economic catalysts is that they have phenomenally influenced economic growth as evidenced by the increased GDP contribution. Although changes in economic status of the ordinary population in countries that have benefitted from enhanced economic strategies may not be visible, their national GDP indicate economic growth. Many developing countries are faced with inadequate diversified national economies. Although this could be due to many challenges, one reason could be failure to rejuvenate rural economies to contribute substantially to the national economies rather than to be a liability to the national economy, which in most instances is either mineral or urban industries based. Tourism, farming and indigenous knowledge systems are a few major pillars of rural economies, which in some countries [38] form the backbone of the national economies, and this could benefit from rural broadband deployment through accessing and enhancing markets online.

Rural broadband deployment promises to change the lives of the rural population through the opening of markets for rural produce, reduction in process time and travelling expenses to process forms and other services. Also, rural broadband deployment would increase agriculture based production through saving time spent by workers travelling to town to access services such as banking and education through e-services.

2.2.2 Characteristics of Rural Areas

Generally rural areas across developing countries have similar geographic characteristics, which present challenges for infrastructure developments. Challenges could be either natural or man-made, but all could influence higher infrastructure development costs. Some areas have been neglected due to political factors. Also, rural areas often lack connectivity to power grid lines, something which is an important limiting factor to many industries that want to open shop in the rural areas. Thus the lack of infrastructure in developing countries is an impediment to both economic growth and development.

On another perspective, rural areas have serious issues of lack of skilled labour. Skilled labor migrates to urban centres to look for employment and improved basic amenities. For any infrastructure development and maintenance to take place, skilled personnel travel from urban to rural areas temporarily at a significant cost. Similarly, the state of low skilled labour and lower income in the rural areas means returns on investment would be low therefore not sustainable, especially for private commercial investments. Thus, the Commonwealth Telecommunication Organization (CTO) 2015 and International Telecommunication Union (ITU) 2016 to universal broadband face serious challenges[26, 38].

2.2.3 Broadband Technologies:

Broadband Technologies include, “the Generation family” 3G, 4G and IEEE802.16 WiMAX and IEEE802.11 Wi-Fi, as well as ADSL, fiber, satellite, microwave link among other technologies see Table 1:1. These technologies are separated from one another by factors such as the cost of deployment, coverage range, speed, carrying capacity in Megabits/second and bandwidth[4]. These technologies are widely deployed in developing countries that include Botswana.

Technology	Spectrum Usage	Capacity shared	Capacity	Maximum Range	Advantages	Limitations
Fixed Line Technologies						
HFC (Hybrid fibre Coax)	7-860 MHz	Yes	40 Mbps-50Mbps	Up to 100 Km	Uses already existing TV Network	Limited bandwidth per channel, bandwidth is shared by many users, asymmetric- very low upstream data rates
ADSL (Asymmetric Digital Subscriber Line)	Up to 1.1 MHZ	No	12Mbps	Max 5.4: Km	Uses existing POTS	Limited bandwidth which is distance sensitive, asymmetric- order of magnitude lower upstream rate
BPL (Broadband Power Line)	1-30 MHZ	Yes	200 Mbps Typical: 2-3 Mbps	1-3 Km	uses existing Power lines	expensive power line upgrades, with amateur radio
Fibre	THZ	PON: Yes P2P: No	Up to 1 Gbps	20 Km	Relatively Unlimited bandwidth	Requires new fibre access network overlay
Wireless Technologies						
Microwave	2- 23.6 GHZ > 40 GHZ	Yes	Up to 155 Gbps per link	5Km	Quick setup	LOS point-to-Point
Mobile (3G,4G)	1.92-1.98 Ghz 2.11 - 2.17 Ghz (Licensed)	Yes	up to 2Mbps per mobile subscriber	Coverage area of host	mobile terminals ride on existing cellular infrastructure	costly spectrum limited applications
Wi-Fi (Wireless Fidelity)	2.4-5.7 Ghz	Yes	11-54 Mbps	up to 100m	Ethernet compliant standardized 802.11 a/b/g	For LAN applications only Security Issues
WiMAX (Worldwide Interoperability for Microwave access)	3.5 Ghz	Yes	2.8 to 11.3 Mbps	LOS- 30 to 50Km NLOS -3 to 8Km	For many types of high-bandwidth applications- at the same time, across long distances	Practical bit rate is 2Mbps per subscriber and indoor LOS cell size limited to 1-2km
Satellite	Ku-, Ka-, C-, L-, and S-band 1.5-3.5, 3.7-6.4, 11.7-12.7, 17.3-17.8, 20-30 Ghz	Yes	Up to 155 Mbps per downlink	Large coverage area of up to 1000 - 36000 Km	Large coverage suitable for multicast applications	Expensive to be built limited capacity per subscriber

Table 2:1 Broadband Technologies Summary

2.2.4 Policy Development and Implementation:

Policy development is a process that in most instances precedes ground actions. Ideally the process ends with policy documents to guide implementation. However, in some instances policy development may be a post phenomenon activity. For an example broadband network deployment in Botswana was rolled out before policy initiative to guide implementation. Although as a process policy development implies various activities, of importance in policy development is the ultimate product which guides implementation.

On the contrary, lack of a policy may result in social exclusion, high implementation expenditure, increase in poverty incidence and conflicts[39]. Therefore, investments on broadband also require having policies to guides its rollout. The apparent dominating involvement of elites in the policy development process as experts, presents challenges that require balancing to attain an all-inclusive document. For example, without the input of an ordinary participation into policy development process, policy and services may alienate or exclude or lack the views and aspirations of the ordinary population.

2.2.5 Liberalization and Regulation of the Telecommunication Industry:

Regulations normally appear either in the form of a Policy or an ACT of parliament. In many instances both are applied. A policy provides a guiding framework and an ACT of parliament ensures that legal obligations are met. Therefore, regulations provide for the prevention of conflicts, set license parameters and specify qualifications for licensing[40].

Liberalization advocates for pluralistic participation to manage monopoly, which affects business performance in many ways. Monopoly has also been found[41] to relate to a high incidence of unemployment. Thus, the need for Rural Broadband Networks regulation to be in place is important to ensure service delivery. In the case of Botswana, the liberalization of the telecommunication industry has increased employment, business and revenue needed for more development[42].

2.3 Rural Areas: Botswana

Pandamatenga is one of several areas that enjoy government support due to itr strategic value towards food security. Pandamatenga is a cereal based farming community. The farms are approximately 3000 hectares in size. Each farm has around 50 workers. The Pandamatenga village lies along the Francistown – Kazungula road, approximately 500 kilometers from Francistown as shown in figure 2.1.

Pandamatenga shares most of these characteristics with Sandveld farms, Hainaveld farms, Ghanzi farms, Kgalagardi district farms, Okavango delta (tourism) Tuli block farms and Borolong farms, which are also places with strategic value to the national economy.

In terms of infrastructure developments, these farms and villages have limited access to the national road network and power grid. Some of these areas have fiber optic backbone line passing through them and others fewer than 50 km away. Workers and employees in these farms have limited access to basic services such as health services, education, banking, shopping and other critical services[10].

Figure 2:1View of Pandamatenga Farms [43]

2.3.1 Benefits for Rural Broadband Network Deployment

Broadband networks provide the following advantages[44];

- Boost the rural markets- Tourism by providing direct contact between the rural areas and the market (normally outside localities).
- Enhance rural population participation in main the stream discourse.
- An opportunity for e-Government programmes.
- Opportunity potential for social communication platform.
- Potential to enhance democracy.
- Access to digital goods and broad ranges of services.

Botswana is similar to other developing countries in terms of the lack of infrastructure development to support economic development initiatives including basic services. These states of lack of infrastructure are worse in the rural areas, which presents challenges for rural broadband deployment.

2.4 Broadband Connectivity Status: Botswana

Botswana is landlocked by South Africa, Namibia, Zimbabwe and Zambia. It has a population of around 2 million people[45]. The main GDP contributor is diamond mining, followed by the financial sector, agriculture mainly beef export and tourism respectively. According to Statistic Botswana the literacy rate stands at 93%. Globally, efforts to connect rural areas face numerous challenges[46]. These challenges include high infrastructure development and deployment costs, low investment returns[46], lack of local content and applications and snail progress in terms of e-programming public services. Various countries have developed policies and laid backbone infrastructure to guide deployment of broadband technologies in rural areas[47]. For instance in Botswana more than 6000 km plus line of fiber optic has been laid. In addition, some infrastructures, referred to as dark fibers, that were previously developed to support other projects at backbone and backhaul infrastructure level are being considered to assist connect the entire country including rural areas. These efforts are also evident in many developing countries, as shown in Figure 1:2 and 1:3.

Although the regional clusters identified by the Botswana Broadband Strategy seek to map rural areas for broadband planning and ultimately connection, the grouping lacks clarity on which areas would present most the challenges to connect, given the current state of infrastructure development and available technologies. Connection of places such as Ukwe, New Xade, Okavango delta, Pandamatenga farms, Beetshaa, Gunotsoga and others have quite distinct characteristics, so that each may require to be assessed individually for connection, yet they hold significant value to the national economy to delay connecting it to the main broadband network. the 723020 people residing in the rural areas[48], it is only 296 924 that live beyond the optic fibre and IEEE802.16 WiMAX reach[38].

2.5 Broadband Technologies

Perception is firmly being entrenched that optic fiber alone, with the exclusion of other approaches such as BPL and satellite, is the solution to the universal broadband network connectivity[4]. On the other hand, high costs in terms of infrastructure deployment, and subsequently higher tariffs levied on service end users to mitigate low returns, appear to be some of the main challenges to broadband deployment in developing countries. Another observation is the infrastructure deployment duplication prevalent in developing countries, which tends to or dispels the view that higher broadband infrastructure deployment cost is one of the main challenges. Broadband power line and satellite remain some of the broadband infrastructure with significant footprints in developing countries to date, yet are least preferred for broadband access, especially in rural areas[49].

Research in broadband telecommunication technology and deployment is one of the significantly covered areas especially with the recent global upsurge in connectivity of the mobile broadband. Available literature shows a significant inclination towards researching new technologies that are faster in speed and have higher carrying capacities with less deployment costs, such as mobile and wireless based technologies. This is exemplified by the rapid evolution of the "generation family technologies". For example, although most countries are still at the 3rd generation, already some countries are ready to roll out the 5th generation, as is the case in China[50]. Broadband deployment has come with rights and economic benefits as espoused by the Commonwealth Telecommunication Organization 2015[23] and International Telecommunication Union 2016 commitments[51]. Thus, the study suggests that for any developing country to meet these obligations within the time frame, it should adopt a broadband strategy which considers deployment of all forms of broadband infrastructure in a complementary manner. Further, this study discusses the broadband deployment at the last mile infrastructure level, wireless, wired and mobile, to appreciate developing countries' lack of deployment and connectivity status. A brief description of the broadband technologies is provided in the Table 2:1

Currently broadband deployment relies on mobile broadband technologies such as 3G/ 4G/LTE among others. Although there is no doubt that mobile broadband increases access to broadband services, the dilemma arises due to low functional literacy in rural areas against surging sophisticated gadgets and applications. The deployment of the rural broadband along the above technology approach is poised to further make it difficult and challenging. On the other hand, there are places with close proximity to the optic fiber line and last mile infrastructure yet not accessible through broadband networks such as Kotolaname (app 20km from Molepolole village) in region 2 and farms on the outskirts of Pandamatenga (app 10 to 15km). This connectivity challenge is attributed to the limited coverage range of both the non-line of sight and line of sight of the mobile technologies deployed.

While Table 2:1 suggests that wireless technologies, such as IEEE802.16 WiMAX, could provide a solution to rural areas' connectivity, based on its characteristics, it has not gained prominence with many operators. IEEE 802.16 WiMAX requires less infrastructure, has a long range (50 km) line of sight and up to 8 km for non-line of sight.

2.6 Broadband Network for Rural Economic Development: Botswana.

2.6.1 Broadband Infrastructure Development in Developing Countries: A challenge for delivering Botswana rural broadband network.

New Partnership for Africa's Development (NEPAD 2012) report " *bolstering regional infrastructure in Africa through the implementation of PIDA*", argue that economic growth is dependent on four drivers; being education, population growth, increase in trade and technology windfall. Rural areas characteristics demonstrates that deployment of infrastructure to support service delivery is a challenge due to, amongst other factors, large distances, natural features such as rivers, mountains and hills, and lack of road networks, power (electricity) and potable water. Although infrastructure development investment may show development growth, it has also been argued that it has causal effects to development growth and economic growth[33]. Some developing countries have gained significant growth than developed ones due to investment in broadband deployment[52]. Thus, this view sustain the position held by various infrastructure lobby groups that, for developing countries to transit into rapid economic growth, they need to invest in broadband and infrastructure development across services[53]. Further, the state of lack of infrastructure in developing countries compels for complementary or hybrid deployment, or to access satellite to address challenges brought about by the various rural areas characteristics. Participants at the African Monitor forums, conducted between 2008 and 2010 in different African countries, indicated that lack of infrastructure development is a contributing factor to the continent is growing poverty rate[27]. The absence of an all-inclusive broadband network suggests that, for rural areas economic potential to be realized another type of network other than the current which is fundamentally the combination of ADSL and mobile networks compel for a hybrid network system it is then that the network as proposed in figure 2:2 is adopted for Botswana broadband deployment network.

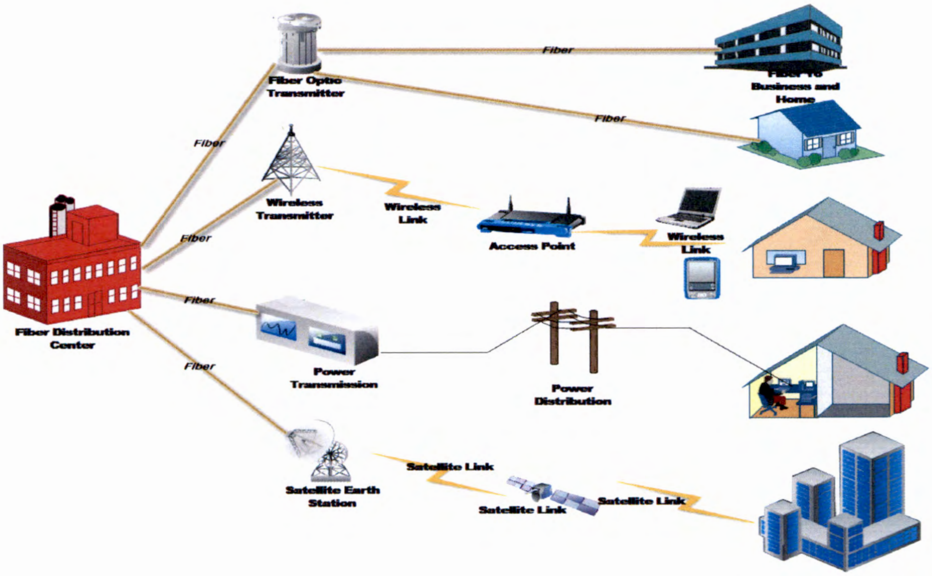

Figure 2:2 Proposed (pro-rural areas) Broadband Network

2.6.2 Policy and Institutional Frameworks in Botswana: Delivering Rural Broadband Network

Several initiatives in the form of policies, Acts of parliament and institutions are in place to pave the way for broadband deployment in Botswana. These involve the 1995 Telecommunication Policy, Maitlamo National I C T Policy of 2007[54] and several parliament Acts; Communication Regulation Authority of 2012[55], Broadcasting Act of 1999, Telecommunication Act of 1996[56] and institutional frameworks such as the establishment of BOCRA and BoFiNet. The Maitlamo National ICT Policy of 2007 is a progressive document. The policy seeks to put the country at par with developed countries. However, the continued dominant government role may paralyse delivery momentum and desired results. Regarding to the dominant government role, a research survey indicates that the word "government" appears over sixty times, while the "private sector" appears only six times and "public" ten times. At several "Pitso" forums to evaluate the ICT and broadband strategy, the private sector representatives decried their lack of involvement and exclusion by the government. Furthermore, another concern is that the government holds both the key functions of the Chair and Secretariat of the Information Age Council.

Coupled with the above developments, Botswana has also made impressive strides towards ICT infrastructure development in the form of over 6000km of optic fibre for backbone and backhaul[40]. Also, the country leases 36 MHZ of satellite bandwidth. Botswana has around 296 924 people, around 14% of the total population, that cannot be reached by the optic fibre network, but this is possible through satellite[23]. A high definition MPEG4 video running at 9Mbps and broadcast on a DVB- S2 carrier requires only 4.3MHZ of satellite bandwidth[50], the rest is adequate for other use including delivering broadband to the rural areas through satellite using DTHi[25] deployment approach or VSAT technology.

However, according to the Phase two study report on Botswana broadband of 2013, broadband penetration still remain marginal at 49% for mobile and 16.9% for fixed in Botswana[57]. The views suggested by the mobile and fixed broadband penetration in percentages seem to argue otherwise.

The 2015 targets by the "broadband commission", phrased: "*Ambitious but achievable targets*", identified four key areas namely; policy, affordability, connecting households and getting people online as necessary to ensure broadband penetration[43]. The 2015 targets emphasise the development of either policy or plan to entrench and lead broadband commitments. Although ICT policy has been in place since 2007, it seems little has been covered in terms of delivering broadband to the general population through e-programming both in the government and private sector. Also, in the ICT "Pitso"[57], participants continue to raise concern that, the broadband efforts excludes the private sector, citing the dominant government presence. However, though the strategy is being developed, the government and the private sector seem not to agree on how best to deliver broadband services. The private sector is lobbying for more concessions. Some countries[58] have contracted the private sector to deliver rural broadband services through satellite.

2.6.3 Service Price vs. Affordability

Another key factor to consider when delivering rural broadband and any other service is service affordability. The latter is influenced by other factors such as literacy, income and service relevance or content to the population's lives[59]. Thus, the low rate of literacy (functional) coupled with low unemployment rate and lower Gross National Income per capita (GNI) in rural areas, affects broadband affordability and delivery[36].

Determining broadband service prices without considering localizing the broadband content would also alienate the rural population. Therefore, the lack of active role in broadband participation by the private sector, whether supported by the strategy and ICT policy or hindsight by the government to control and manage the broadband strategy, realizing benefits remain on the distant horizon.

2.7 Chapter Summary

This chapter looked into the state of lack of infrastructure as pointed by many organizations as a contributing factor to lack of economic and development growth in developing countries. Also noted is the lack of use of satellite, despite its massive footprint over developing countries including Botswana. Amongst the contributing factors for lack of satellite access by developing countries is the alleged higher access cost, which means the ITU, CTO and UNESCO targets that entail universal access to broadband may not be realized. Furthermore, the chapter looked at the case of Botswana which already afford satellite, yet optimal use is not harnessed.

Similarly, this chapter looked into the rural areas characteristics to appreciate challenges for deploying infrastructure to support service delivery. Also the summary of the various broadband technologies have been presented to appreciate appropriate ones for rural areas set up. Further, the chapter looked into broadband affordability on the background of low rate of employment against high infrastructure development and deployment cost in the rural areas.

Chapter 3

MODEL DEVELOPMENT

3.1 Chapter Overview

This chapter presents the network model, simulation process and envisaged study results. WiMAX and Wi-Fi are IEEE standard based technologies. Wi-Fi is formally refereed as IEEE802.11, whereas WiMAX is refereed as IEEE802.16. The latter has several versions developed over successive years from 2001 up to date. For purpose of reference, this study network scope focuses on IEEE802.16 WiMAX.

The telecommunication industry has promoted WiMAX to the top of all broadband access technologies, against the Asymmetric Digital Subscriber Lines (ADSL). It is also a point – multipoint to mobile access based up to 72Mbps symmetric broadband speed. Another prominent feature identified with this technology is its capacity to operate in the frequency range of 10GHz – 66GHz with little interference and adequate bandwidth. However, WiMAX can also operate at lower frequency bandwidth from 2GHz to 11GHz. It is at this frequency level that WiMAX is appropriate for rural areas telecommunication network since it could tackle obstacles common in the rural areas such as trees and other environmental conditions. However, its performance at this lower frequency bandwidth comes with significant challenges, as it requires complex configurations to manage the interferences. These complex configurations included the following(Wireless MAN – SCA which is a single based carrier modulation, Wireless MAN –OFDM for Orthogonal Frequency Division Multiplexing Access and Wireless MAN – OFDMA for Orthogonal Frequency Division Multiple Access).

Thus, the model presented in this study evaluates the performance of the IEEE 802.16 WiMAX over five critical performance areas being traffic sent, traffic received, delay, and jitter including packet delay variation over the network at various distance ranges. This chapter also along the various simulation scenarios provides configuration details which guided the simulations

3.2 WiMAX Performance Metrics Used for the study.

3.2.1 Traffic Received

Traffic Received is the amount of data traffic which has been transmitted successfully and received by the WiMAX MAC from the physical layer either in packets/sec or in bits/sec, for example in video conferencing it is the average number of packets/data forwarded to the video conferencing application by transport the layer.

3.2.2 Traffic Sent

Traffic sent is the amount of data transmitted either in packets/sec or in bits/sec by the WiMAX MAC. In case of voice application it is the average bits/sec transmitted to the transport layer for network transmission as well as the FTP application and Video conferencing application.

3.2.3 Delay

Delay is the end to end delay of packets received. It is one of the most important performance measurements of any network. It specifies how long it takes for a packet/data to travel across the network from the sender node to the receiving node.

3.2.4 Jitter

Jitter is the variation in delay as the packets are sent through the network. Although the packets are sent in continuous sequence they arrive at the receiver fragmented. This can be mainly because of congestion.

3.2.5 Traffic Dropped

Traffic dropped is the amount of packets sent that failed to reach their destination. This could be due to network interference and network congestion.

3.3 Experimental Setup

It was indicated in Chapter 1 that the simulation tool used is OPNET (Optimized Network Engineering Tools) 14.5 modeler. There are several network simulation tools, NS2, OMNET and others. OPNET was the most preferred tool as it is much easier to use especially through its Graphic User Interface (GUI) it also provides an environment for building protocols and device models including designing wired and wireless protocol technologies, designing real scenarios and producing results. OPNET is created using C and C++ source code. It is also used in different data communication courses and most research studies. Also, the tool is popular for use in the military.

The OPNET network simulation involves the following basic steps (see Figure 3:1);

- Creation of the network Model
- Choosing statistics to be collected
- Running the simulation

➢ And finally viewing and analyzing the results as per selected metrics

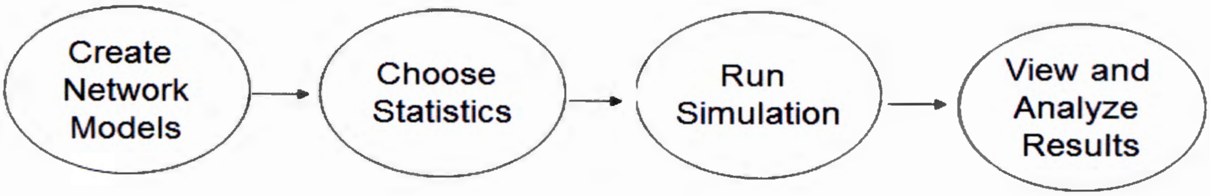

Figure 3:1 OPNET Work Flow

3.3.1 Structure of OPNET 14.5

Normally OPNET is divided into three main domains, the Network Domain, the Node Domain and the Process Domain;

I. Network Domain

In the network domain the scope of the network which is being simulated is shown in Figure 3:2. It depicts networks, sub networks, network topologies, and objects contained in the network and how they are configured.

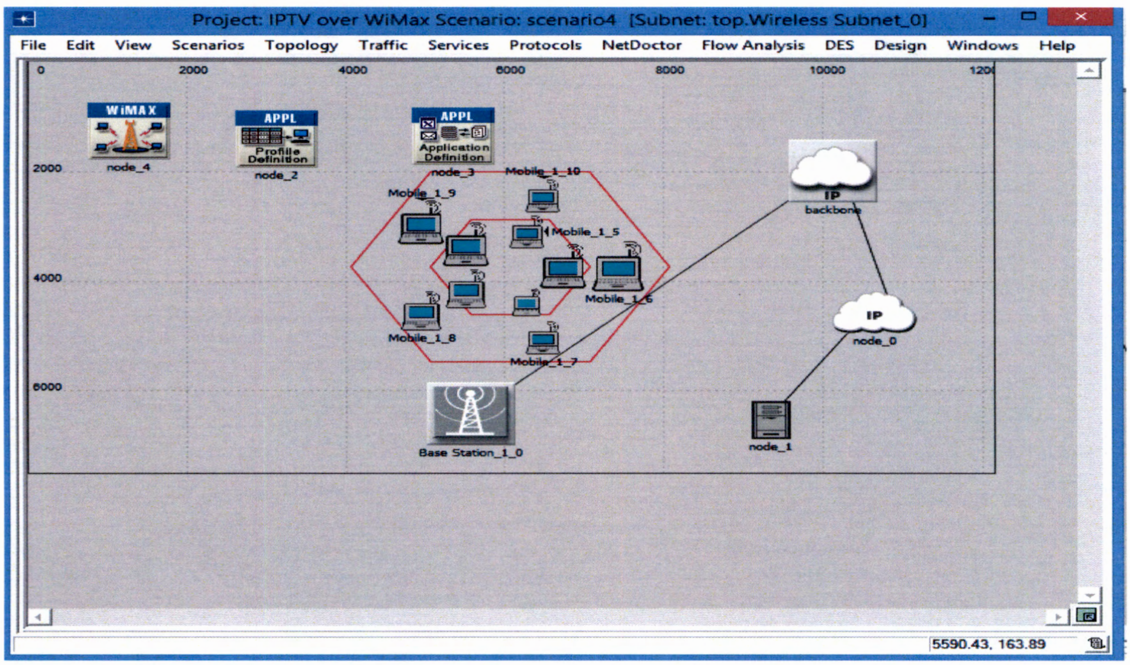

Figure 3: 1 Example of Network Domain

II. Node Domain

The node domain goes inside the actual structure of the network node. This can be the satellite terminals, base stations, subscriber stations, switches, servers, routers and etc. they can either be fixed or mobile. Figure 3:3 shows the subscriber station node model, which is used to build models of all the nodes used in the node editor.

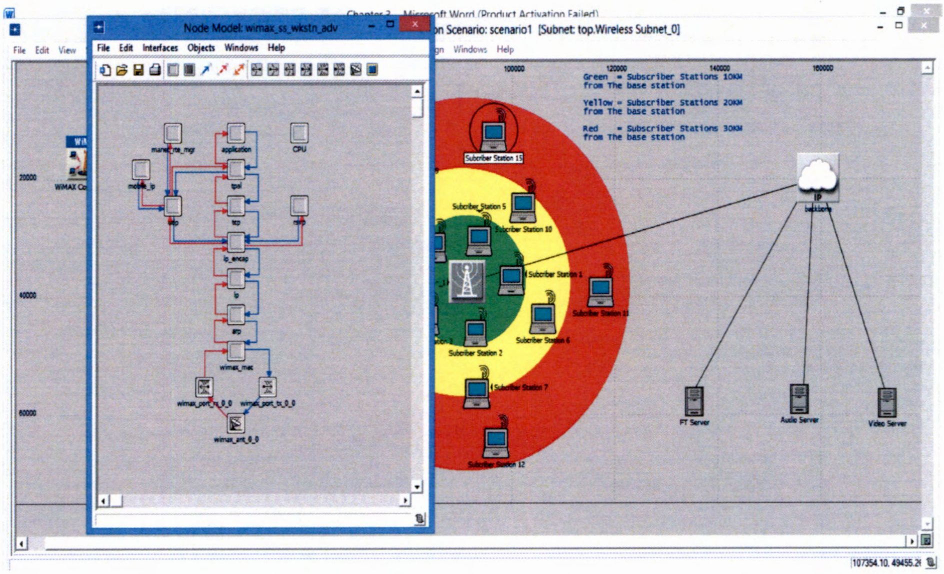

Figure 3: 2 Example of Node Domain

III. Process Domain

The process domain is expressed in C and C++ source codes, which also specifies how the processor model behaves. In general, it is used to design the process models which controls the basic functions of node models generated in the node editor as shown Figure 3:4

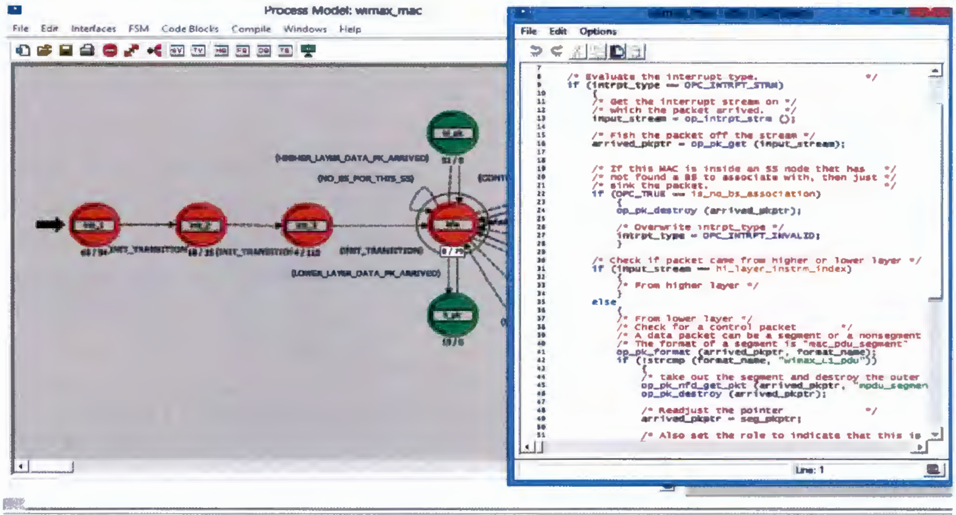

Figure 3: 3 Example of Process Domain

3.4 Network Model Implementation

3.4.1 Network Topology

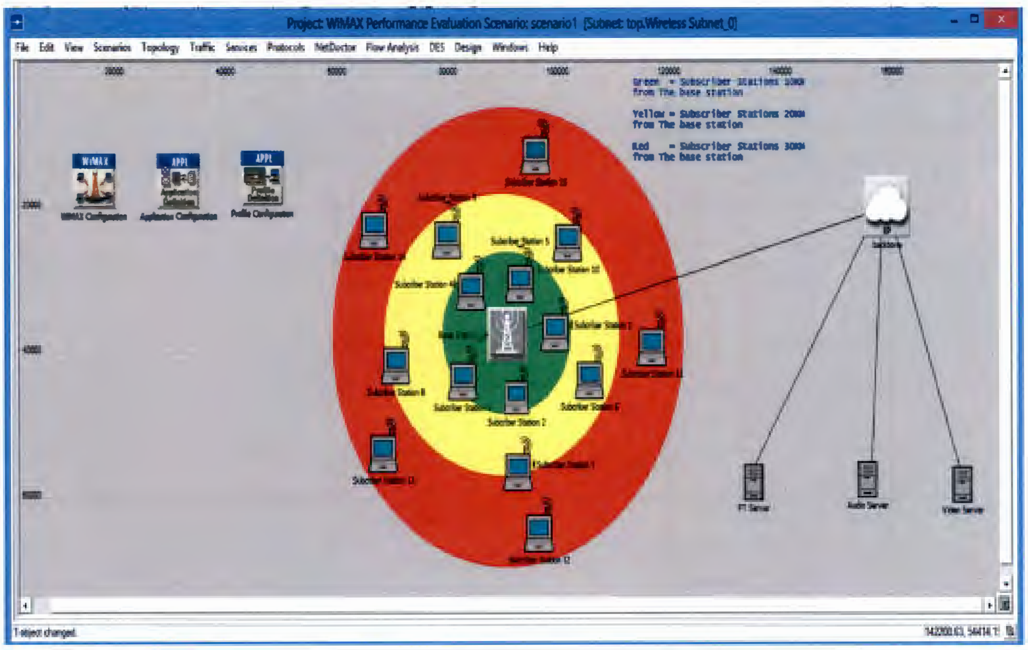

Figure 3: 4 Network Topology for the Study

The network topology for this study as shown Figure 3:5 has the following devices:

I) A base Station (Device Name: wimax_bs_ethernet4_slip4_router) - sends and receives signals from a transmitting point to a receiving point. For example in mobile/cellular communication it allows connection within a given area as long as it connects with the service provider.

II) Three Servers- (ppp_server model) represent a server node with server applications running over TCP/IP and UDP/IP. This node supports one underlying SLIP connection. The operational speed is determined by the data rate of the connected link. The servers were used to model File transfer, Audio and Video respectively.

III) The ip32_cloud- node model denotes an IP cloud supporting up to 32 serial line interfaces at a selectable data rate through which IP traffic can be modelled. IP packets arriving on any cloud interface are routed to the appropriate output interface based on their destination IP address. Routing protocols are then used to automatically and dynamically create the cloud routing tables to direct the transmitted packets.

IV) 15 WiMAX Subscriber Stations- often referred as CPE (Customer Premises Equipment) as they are placed at the customer side for access. For the study; 5 subscriber stations are placed at 10 kilometres from the base station, another 5 subscriber stations are placed at 20 kilometres from the base station and the last 5 subscriber stations are placed at 30 kilometres.

V) The ppp_adv point-to-point link connects two nodes with serial interfaces (routers with PPP ports) at a selectable data rate. For this study the link was used to connect the base station and the IP cloud to the servers.

3.4.2 Profile Configuration

The profile configuration is mainly used to create user profiles which are specified on different nodes to generate application traffic in the network. The applications that are defined in the Application Configuration are then used to configure profiles. This means the applications must be created using the Application Configuration. Also the traffic patterns can be specified followed by the application as well as the configured profiles, as shown in Figure 3:6.

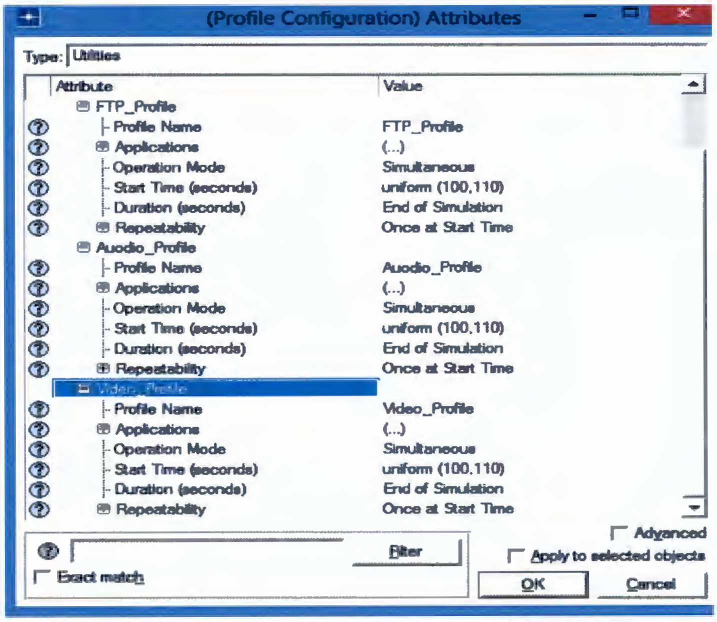

Figure 3:5 Model Profile Configurations

3.4.3 Application Configuration

The Application configuration is used to specify the application to be used. This involves specifying a name and description (corresponding) of any new application, as shown in Figure 3.7. File Transfer can be Low, Medium and High Load. Similarly, Voice application specifies parameters for each encoder scheme used for generating voice traffic in the network.

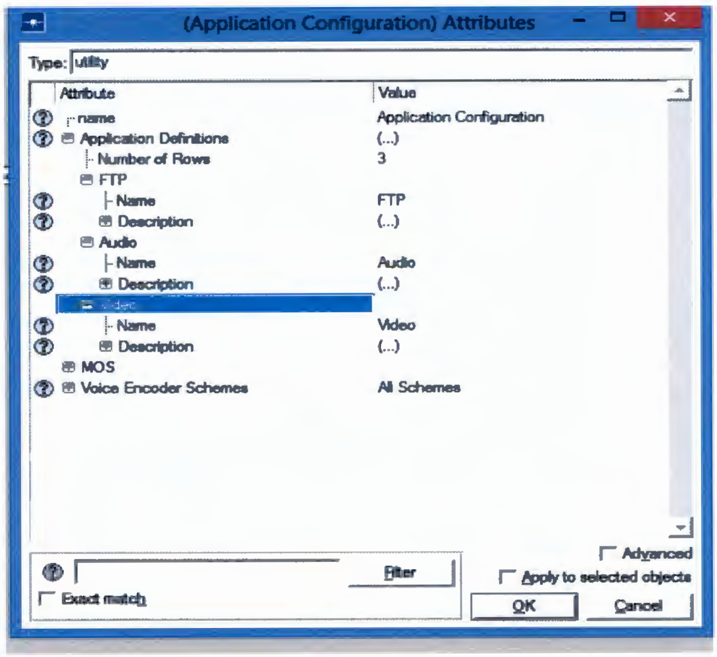

Figure 3:6 Model Application Configuration

3.4.4 WiMAX Configuration

The WiMAX configuration stores the profiles of PHYsical and service class which can be referenced by all WiMAX nodes in the network; it provides a common ground for all the WiMAX nodes in the whole network. See Figure 3:8

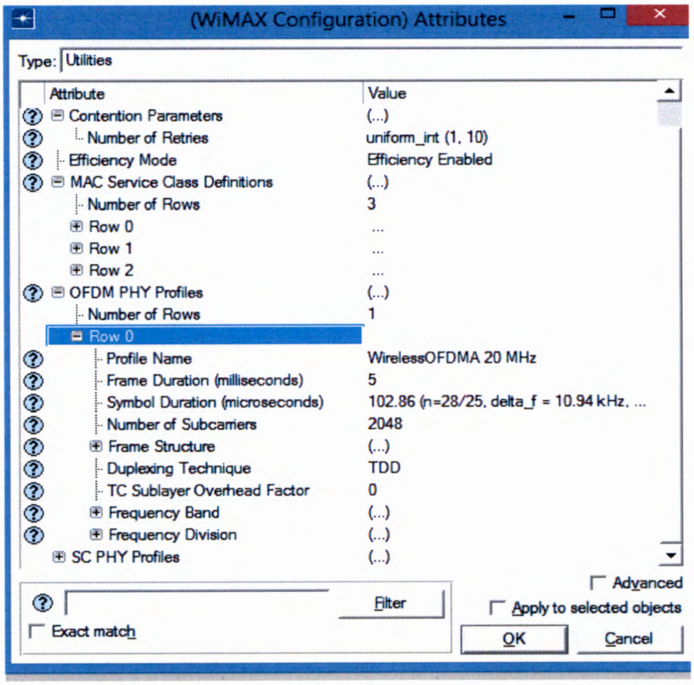

Figure 3: 7 Model WiMAX Configuration

3.5 Chapter Summary

Chapter 3 presented the telecommunication industry argument for WiMAX as the leading broadband access technology. Furthermore, this chapter presented the detailed model development process, performance metrics description and model experiment set up, including detailed structures of OPNET version 14.5.

Another critical component of this study covered in this chapter is the Network Model Implementation. The model implementation focused on the network topology, profile configuration and application configuration including WiMAX configurations. These four components are critical for a simulation to run and obtain testable results.

Chapter 4

RESULTS, DISCUSSION AND FINDINGS

4.1 Chapter Overview

The IEEE standard body has evaluated WiMAX in many studies in the past, some of which influenced this study. Past evaluations concluded that 802.16 WiMAX reaches 50 km (line of sight). This study acknowledges that the results obtained confirm many previous studies results on WiMAX. This chapter presents the simulation results and discussion.

The results are based on the simulated model which evaluated the performance of WiMAX with the subscriber station placed at different distances from the base station, at 10 km, 20 km and 30 km. The results are displayed according to the performance matrices explained in Chapter 3.

4.2 Simulation Results

4.1.1 Traffic Sent

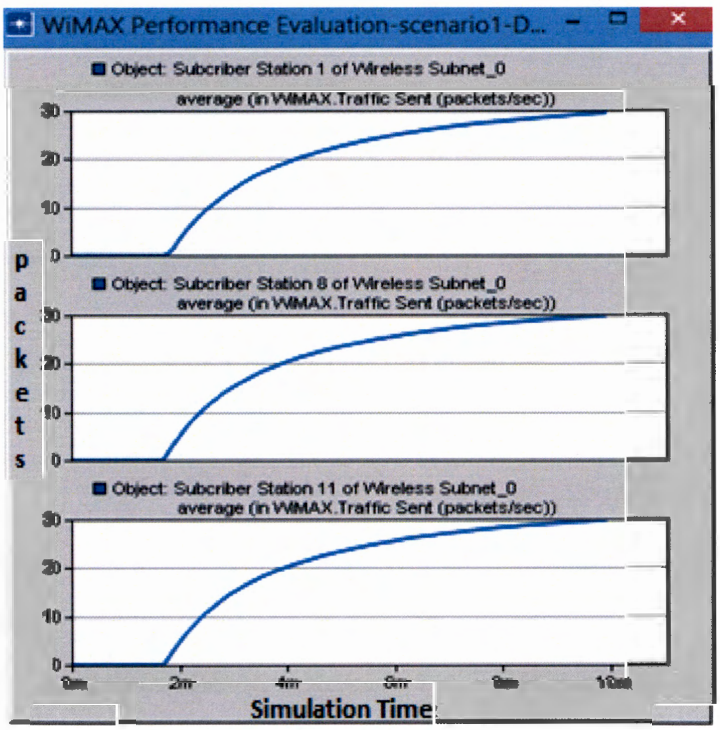

Figure 4:1 Traffic Sent (packets/sec)

Figure 4:1 shows results from Subscriber Station 1 which is at 10km, Subscriber Station 8 is at 20km and Subscriber Station 11 is at 30km. This means at the beginning of the simulation the same amount of packets (Y-axis) were sent across the network and the simulation time (X-axis) was equal.

4.1.2 Traffic Received

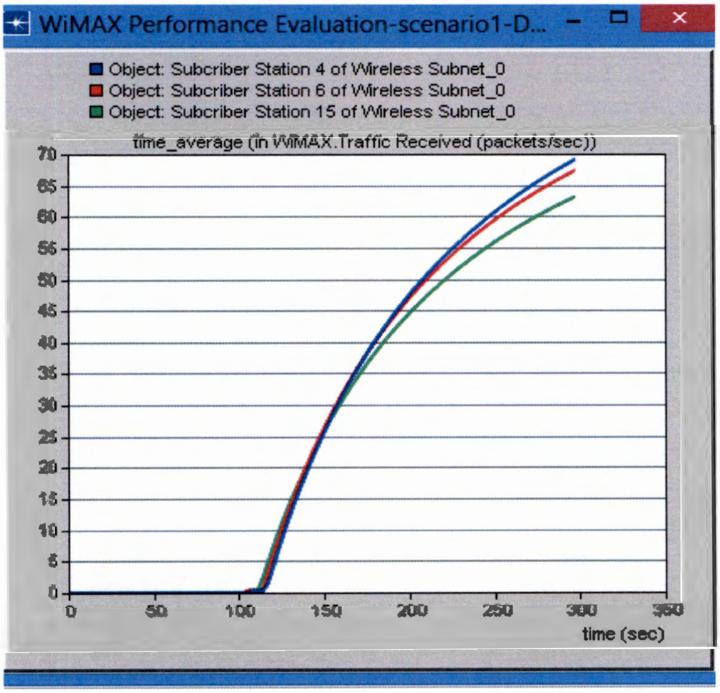

Figure 4:2 Traffic Received (packets/sec)

Figure 4:2 shows traffic received, based on the packets received by the network nodes, and indicates results at different distances from the base station. Unlike in Figure 4:1, the three distances scenarios are represented by blue (10 km), red (20km) and green (30km).

4.2.1 Delay

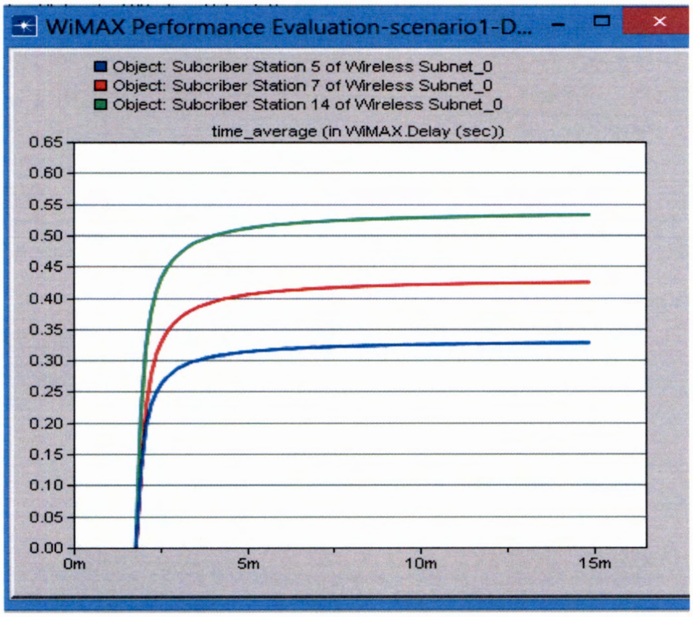

Figure 4:3 Average Time Delay (sec)

Figure 4:3 presents average time delay experienced by the traffic sent over the network to the three subscriber stations. The stations blue, red and green were 10km, 20km and 30km in respective order

4.2.2 Jitter

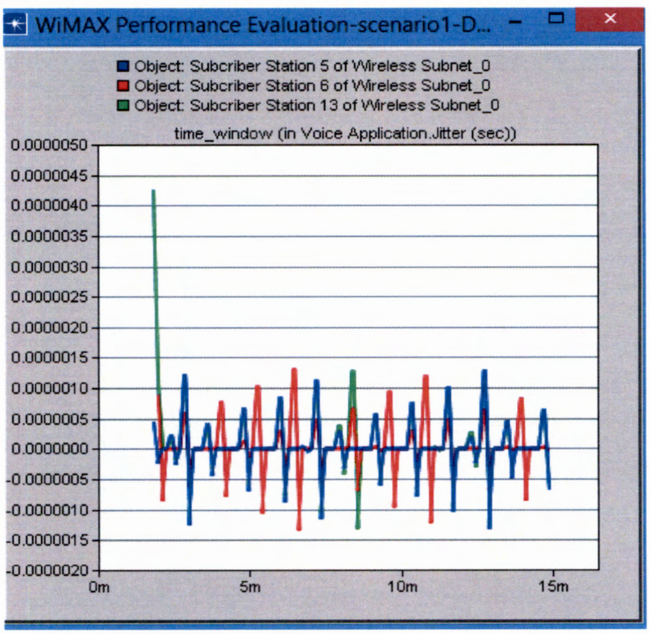

Figure 4:4 Average Time Jitter (sec)

Figure 4:4 presents the average time jitter results over the network at different subscriber stations. The stations blue (10km), red (20km) and green (30) were placed at various distance ranges to determine performance results.

4.2.3 Traffic Dropped

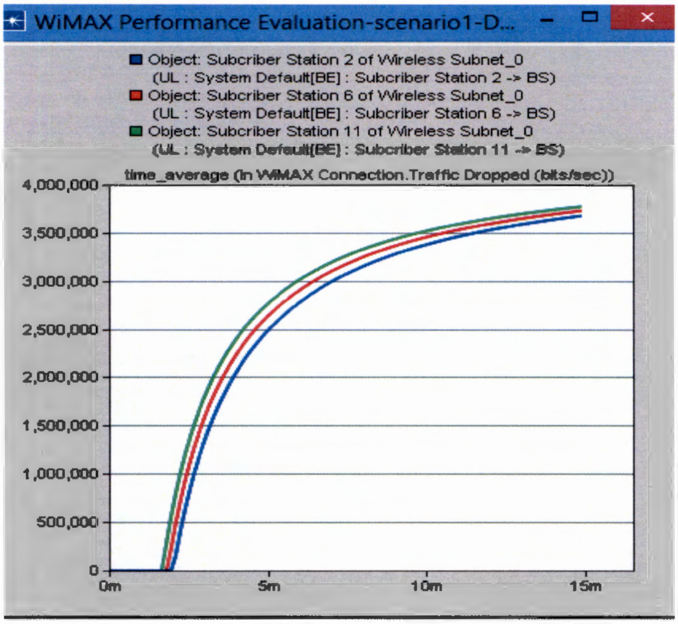

Figure 4:5 Traffic Dropped (bits/sec)

Figure 4:5 presents traffic dropped over the network at various subscriber stations. The subscriber stations are represented in the following order blue (10km), red (20km) and green (30km).

4.3 Discussion

Discussions of these results show the network performance after traffic had been sent from various subscriber stations at different distances from the base station. The distance is consistent with all the scenarios from Figure 4:1 to Figure 4:5. Also consistent throughout the simulation is the amount of traffic running through the network.

In Figure 4:1, the same amount of traffic, video, audio and file transfer were sent over the network from the base station, and evaluated at 10 km, 20km and last at 30km subscriber stations.

Traffic received in Figure 4:2 showed slight variations at three different subscriber stations. However, packets received at 10km and 20km had very slight variations, while packets received at 30km were satisfactorily within the study expected standard. This suggests that over 20km the rate of packets received increases, implying that distance affects the quality of the packets received. Noting that, the variations could as well be caused by signal blockage by either trees or anything blocking the line of sight. Variations could therefore be mitigated by increasing nodes and lowering the traffic.

Figure 4:3 presents average time delays for the traffic to go through the network from the base station to the three subscriber stations. The delay taken by the traffic to go through the network to reach all the subscriber stations varied. The subscriber station at 10 km experienced lower delay time, and subscriber station at 20km experienced average delay time while the subscriber station at 30km experienced the highest delay time.

In figure 4:4, The average time jitter for traffic over the network when it reaches the three subscriber stations show that the subscriber station at 30 km experienced jitter though it was low. The subscriber stations at 10km and 20km also experienced jitter, though less than the subscriber station at 30km. Although jitter was expected at the subscriber station at 30km, the amount of jitter dropped significantly at the other intervals.

Figure 4:5 presented traffic that dropped over the network to the three different subscriber stations. It is expected that if the subscriber station is further from the base station, the network would drop more traffic due to interferences either because of obstacles or signal strength. However, the network consistently retained the packets. This could be attributed to the Wireless MAN – OFDMA for Orthogonal Frequency Division Multiple Access ability and the TCP/UDP at the transport layer level. The use of TCP/UDP ensures that no packets are lost or dropped by the network.

Concluding the simulation results, we observe that metrics balance network deficit with the traffic load to optimize efficiency. For example the further the subscriber station, continued simulation showed reduction in jitter. The consistency of the metrics within expected levels when performance measured is from the three subscriber stations distance points suggests that it performed as expected. The observation that it experienced delay the further the distance suggests that more nodes could be added to boost the signal. Also, the apparent characteristic of the rural areas of having a low population density means the network may optimize efficiency due to low traffic.

4.4 Study findings

The findings here involve the literature review and simulation results. Thus, they have been analysed and grouped into three areas which involved preferred technology from the backbone to the last mile level. The study also appreciates that rural connectivity would require policies inclined towards rural areas for universal access to broadband to reach rural areas. Also the findings noted the weak economic state of rural areas in terms of the prevailing infrastructure development deficit in Botswana developing countries and the general state of economic growth and development. Another phenomenon observed is the declining government capacity to implement service delivery. Where governments have played the role of implementing projects, either issues of quality arise or there are no maintenance plans in place to prolong the project life span.

On the other hand, developing countries have a broad base of skilled personnel, and policies to address development issues. This raises the concern that, despite developing countries evident capacity to deliver their development agenda, the general population especially in the rural settings continue to suffer high poverty incident rates. Then the question that arises is why there are high policy failure rates? Hopefully, this study presents some findings that could help explain the situation of developing countries. Above all, these study findings argue for rural broadband connectivity, deployment of hybrid technology for rural broadband connectivity, development of rural broadband policies or plans and encouragement for more players in the form of institutions to deliver rural based initiatives along with governments.

4.4.1 Technology

Since a significant proportion of about 15% of the overall population lives beyond 50 km of the backhaul network, and cannot be reached without inclusion of the satellite. The satellite access could be incorporated into the current optic fibre network ring line currently deployed around the country. Another option is the Rwanda[6] approach, which involved the private sector to use satellite to connect rural areas through VSAT, DTHi and other approaches. Also, the study proposes that since to run broadcasting requires less bandwidth coupled with current compression technologies, the government release the rest of the bandwidth to BOCRA for Broadband initiative and consider:

- The government keep 9GHz for broadcasting and other projects.
- The government optimize satellite and save on around BWP 200 000 000 lease fees for rural area initiatives.

The lack of the Maitlamo National ICT Policy of 2007 to review deployed technologies is not only passive, but also threatens to render the broadband strategy to fail. The government and private sector initiatives should consider deployment of the leading broadband technologies such as IEEE 802.16 WiMAX. Botswana investment on broadband infrastructure development so far exceeds the necessary threshold to attain universal access to broadband, however the challenge remains the lack of institutions to lobby for various interest groups.

4.4.2 Policy, Legal and Institutional Frameworks

Botswana Broadband Strategy of 2013 is yet to be adopted. The lack of government capacity to implement projects has a close relationship with the state policy development process. Although when complete, on average the policies address key means to achieve the intended goal, it is at development process level that interest groups are left out, leaving the government alone to deliver. This approach to policy development "fatigues" government and marginalises the general population which in most instances are the intended target.

The study has established that the state of regulatory laws for broadband in Botswana is adequate and satisfactory to meet the delivery strategy. Efforts continue to develop to the service transaction area to protect service end users. However, similar efforts to establish funding for rural broadband initiatives lag behind. Another area related to the legal framework is the apparent lack of innovations and research funding and the introduction of unlicensed frequency parameters, for example commercial entities such as private and public companies should be encouraged by government to participate through funding and tapping into research by students and learning institutions. In South Africa students go on research attachments with companies such as Telecom, The Council for Scientific and Industrial Research (CSIR) and other companies for further studies. Therefore not regulating the whole frequency spectrum could encourage for scientific and technological breakthrough in innovations and research. Another area established by this study is the marginal presence of the broad spectrum of interest groups. Rural areas are affected by broad development issues outside government parameters. Advocacy, business and environment based are a few of the areas that require to be addressed by the broadband without direct government involvement. The study also established that not only an increase in institutions is important, but also growing their capacities to deliver, is crucial towards attaining rural broadband. The study propose that the Government:

- Relinquishes the chairing role of the Information Age Council to the private/public sector and remains with the secretariat role.
- Releases the chairing of the National Broadband Strategy to the private/public sector with the view to upsurge public participation.

4.4.3 Rural Areas Beyond 50km Reach of the Optic Fiber Ring.

Getting services to the rural areas is a challenge, but to service deep rural areas is a nightmare for developing countries. The situation is worsened by the general acute lack of broad infrastructure development to support rural development initiatives. The state of lack of infrastructure development in developing countries has fatigued governments to the extent that implementation of rural based projects has reached crisis point. Unemployment is on the increase, low employment opportunities, diminishing rural economic opportunities and increased rural to urban migrations of the labour force are a few of the factors that exacerbate poverty in the rural areas. This study proposes that the government together with other stakeholders, develop rural based strategies and policies to accelerate rural infrastructure development including ICT and Broadband infrastructure. The following is proposed;

- Rural Broadband Fund.
- Satellite – Optic fiber approach.
- Acceleration of the rural electrification project and other infrastructure developments.
- Development of Project Strategy forum to oversee national projects delivery along BoFiNet model.

4.5 Chapter Summary

This chapter presented results, discussions and the study findings. The chapter provided an overview of the metrics used to evaluate the simulation. Also, results obtained were covered in detail leading to the conclusions of the findings.

The findings presented here arose from both the reviewed literature and simulation results. Also, propositions are reflected to provide a framework for the proposed hybrid broadband network that proactively covers rural areas.

Chapter 5

SUMMARY, CONCLUSIONS AND FUTURE WORK

5.1 Summary

The grading of any country as "developing", "developed" or "middle income" is derived from the country's state of basic services and general quality of living standards, which in most cases are determined by a collection of variables such as economic status, political stability and rule of law, proper and acceptable fiscal policies and others. For purposes of this study we argue that, on the background of the state of lack of basic human services including broadband infrastructure development in developing countries, and their skewed commitment to meet universal access to broadband targets, Botswana may not attain results in terms of quality and broadband for all by the set date. Moreover, so far efforts to mitigate the consequences of the digital divide remain without clear policy position and commitment. A one size fits all solution for both urban and rural areas continue to dominate the broadband deployment. Either there is no rural connectivity or users experience poor quality of service. Although quality of services, speed and service affordability of the broadband services may determine access, in Botswana the contrary persists. However, this study has confirmed that, the deployment of hybrid satellite terrestrial systems could address the issue of broadband penetration, while quality could benefit from a capacity enhanced and broad segment regulatory approach. More institutions with converging broadband interest would help attain quality and penetrating services as compared with fewer institutions saddled with regulatory responsibilities, quality issues and licensing determinations.

This study has established that there is a serious lack of terrestrial infrastructure development in developing countries to support rural broadband connectivity initiatives. Also, it is evident that in some instances rural areas characteristics increase infrastructure and service deployment costs. The massive body of literature reviewed has unequivocally extrapolated that rural areas' economic potential is big and ready for national use, and these opportunities should be pursued vigorously and exploited to achieve a higher rate of rural commercialisation. For example, in South Africa the movement of people between farms and markets in urban areas has led to significantly improved broadband services. This has brought improvements in the lives of the South African farming communities and created links for rural communities to access previously difficult-to-access services such as banking, social media connectivity and education platforms.

The literature review has also shown that the current broadband access technologies cover rural areas to a limited extent due to lack of infrastructure and effective network topologies. Hence this study proposed inclusion of WiMAX technology to connect rural areas, due to its relevance to developing countries infrastructure quandary. Also, the study ran a model simulation to evaluate the performance of the WiMAX over various subscriber stations each 10 km from another and presented results and findings. Also the study has proposed a detailed deployment model (Figure 2:2).

5.2 Conclusions

It is apparent that rural and remote areas are affected by acute lack of infrastructure development to support various development initiatives. These include power (electricity), tarred road networks, telecommunications towers and other infrastructure to leverage rural development. Despite adequate capital and human resources, rural areas continue to experience a high incidence of poverty and underdevelopment.

Although wired technologies provide connectivity reliability through point to point connection, they require massive and expensive infrastructure deployment exercises. They also have limited bandwidth and range of coverage. In contrast, wireless technologies have adequate bandwidth and wide coverage ranges that could answer sparse areas connectivity challenges. WiMAX characteristics of relying on fewer infrastructure, wide coverage range (line of sight- 50km) and wider bandwidth puts it amongst leading wireless and mobile broadband access technologies.

Furthermore, wireless technologies require less infrastructure compared to wired technologies for deployment. This view balances the prevalent lack of telecommunication infrastructure in developing countries and by extension rural areas. We conclude that to tackle rural connectivity challenges, which amongst other issues is affected by a serious lack of infrastructure and inferior service quality, we propose deployment of Hybrid Satellite Terrestrial Systems (HSTS), and IEEE802.16 WiMAX at last mile level.

Furthermore, this study has established that, around 15% of Botswana population cannot be reached by optic fiber network ring line laid. These include beef producing communities in the various districts, tourism facilities in most national parks and game reserves and agro-farming ventures. In conclusion this study has observed that though Botswana government is the lead partner in the provision of the telecommunication broadband network, satellite services are not regulated by BROCRA. The implication is that unlike the terrestrial infrastructure regulated by BROCRA, satellite is not yet ready to generate viable economic returns despite government 36GHz of bandwidth subscription which currently is leased at around USD 2 000 000. This study also argues that since HD television broadcasting requires 4.5 MHZ and other spectrum needs puts the total country satellite needs at approximately 9GHz leaving 27GHz economically unaccounted. The inclusion of the satellite under BOCRA would facilitate the inclusion of all rural areas within reach of the broadband network. Conclusively this study proposes a satellite terrestrial hybrid system model network as shown in figure 2:2 to inform broadband deployment.

5.3 Future Work

The wireless technology is set to revolutionise the telecommunication industry, but people remain sceptical of the safety measures in place against harmful radioactive material. Equally while the telecommunication industry community has consistently been concerned to develop broadband access technology that addresses distance, bandwidth and speed, the rapid WiMAX evolution is yet to expand its wireless MAN boundaries to include sparse geographic areas. However, safety and health issue against harmful microwave and radioactive material remain a source of mistrust and conflict between industry players, telecommunication companies and the general public. Thus, it is important that when humanity endeavours to break into new areas or push further the telecommunication boundaries, priority and efforts are also equally invested to secure lives.

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Appendix 1

PUBLIC NOTICE

BOCRA

BOTSWANA COMMUNICATIONS REGULATORY AUTHORITY **(BOCRA)**
ADSL INTERNET CHARGES BY VALUE ADDED NETWORK SERVICE (VANS) PROVIDERS

BOTSNET

Package	Internet Speed	ADSL Bandwidth Charge	ADSL Access Charge by BTC	4 Port Ethernet Wireless Modem	Total of ADSL Bandwidth, Access Charge & Modem
Residential ADSL 256/192 kbps	256/192 kbps	BWP 75.64	BWP 91.00	BWP 32.36	BWP 199.00
Business and Residential ADSL 512/128 kbps	512/128 kbps	BWP 150.00	BWP 159.30	BWP 32.36	BWP 341.66
Business and Residential ADSL 1024/192 kbps	1024/192 kbps	BWP 217.50	BWP 206.85	BWP 32.36	BWP 456.71
Business and Residential ADSL 2048/256 kbps	2048/256 kbps	BWP 206.50	BWP 270.91	BWP 32.36	BWP 509.77

VAT exclusive.
Contact Telephone: [illegible]

Cres 684 (BBI)

Package	Ratio : Base level / Burst Level	ADSL Line Speed	ADSL Access Charge by BTC	ADSL Bandwidth Charge	Total of ADSL Bandwidth and Access Charge
Home	192/512	512/128 kbps	BWP 178.00	BWP 341.00	BWP 519.00
Power	192/640	512/128 kbps	BWP 178.00	BWP 691.00	BWP 869.00
Business	320/896	1024/192 kbps	BWP 230.72	BWP 1,024.00	BWP 1,254.72
Business Plus +	320/1024	1024/192 kbps	BWP 230.72	BWP 1,694.00	BWP 1,924.72
Corporate	512/1280	2048/256 kbps	BWP 303.52	BWP 2,279.00	BWP 2,582.52
Large Corporate	512/1408	2048/256 kbps	BWP 303.52	BWP 3,304.00	BWP 3,607.52
Pristine	512/1536	2048/256 kbps	BWP 303.52	BWP 4,229.00	BWP 4,532.52
Silver	768/1664	2048/384 kbps	BWP 372.96	BWP 5,517.00	BWP 5,889.96
Gold	768/1792	2048/384 kbps	BWP 372.96	BWP 7,557.00	BWP 7,929.96
Platinum	768/1920	2048/384 kbps	BWP 372.96	BWP 8,737.00	BWP 9,109.96
Diamond	1024/2048	2048/384 kbps	BWP 372.96	BWP 10,097.00	BWP 10,469.96

Internet Packages (ADSL) all include Wireless Router which remain the property of BBI
VAT inclusive.
Contact Telephone: [illegible]

MICROTECK

Package Residential ADSL-Shaped	Internet Speed	ADSL Bandwidth Charge	ADSL Access Charge by BTC	Total of ADSL Bandwidth and Access Charge
ADSL Starter	256 kbps	BWP 108.00	BWP 91.00	BWP 199.00
ADSL 512	512 kbps	BWP 180.00	BWP 159.30	BWP 339.30
ADSL 1024	1024 kbps	BWP 280.00	BWP 206.85	BWP 486.85
ADSL 2048	2048 kbps	BWP 380.00	BWP 270.91	BWP 650.91

Residential ADSL-Unlimited	Internet Speed	ADSL Bandwidth Charge	ADSL Access Charge by BTC	Total of ADSL Bandwidth and Access Charge
ADSL Lite	512kbps	BWP 230.00	BWP 159.30	BWP 389.30
ADSL Express	1024kbps	BWP 530.88	BWP 206.85	BWP 737.73
ADSL Turbo	2048kbps	BWP 733.60	BWP 270.91	BWP 1,004.51

Business ADSL Unlimited	Internet Speed	ADSL Bandwidth Charge	ADSL Access Charge by BTC	Total of ADSL Bandwidth and Access Charge
ADSL Lite Plus*	512 kbps	BWP 532.63	BWP 159.30	BWP 691.93
ADSL Premium*	1024 kbps	BWP 850.71	BWP 206.85	BWP 1,057.56
ADSL Enterprise*	2048 kbps	BWP 1,146.88	BWP 270.91	BWP 1,417.79

VAT exclusive.
Contact Telephone: [illegible]

* [illegible]

LENONG

Package	Internet Speed	ADSL Bandwidth Charge	ADSL Access Charge by BTC	Total of ADSL Bandwidth and Access Charge
Bronze	512/128 kbps	BWP 189.00	BWP 159.30	BWP 348.30
Silver	1024/192 kbps	BWP 265.00	BWP 206.00	BWP 471.00
Gold	2048/256 kbps	BWP 375.00	BWP 271.00	BWP 646.00

VAT exclusive.
Contact Telephone: [illegible]

GLOBAL BROADBAND SOLUTIONS (GBS)

Package	Internet Speed	ADSL Bandwidth Charge	ADSL Access Charge by BTC	Total of ADSL Bandwidth and Access Charge
ADSL Bronze	512 kbps	BWP 223.00	BWP 178.42	BWP 401.42
ADSL Silver	1024 kbps	BWP 503.00	BWP 231.47	BWP 734.47
ADSL Gold	2048 kbps	BWP 727.00	BWP 303.42	BWP 1030.42

VAT inclusive.
Contact Telephone: [illegible]

VIRTUAL BUSINESS NETWORKS (VBN)

Package	ADSL Bandwidth Charge	ADSL Access Charge by BTC	Total of ADSL Bandwidth and Access Charge
Residential ADSL			
128/512 kbps - 6Gig	BWP 170.00	BWP 159.30	BWP 329.30
192/2048 kbps - 8Gig	BWP 290.00	BWP 270.91	BWP 560.91
256/2048 kbps - 10 Gig	BWP 390.00	BWP 270.91	BWP 660.91
Business ADSL			
128/512 kbps - 5 gig	BWP 260.00	BWP 159.30	BWP 419.30
192/1024 kbps - 7Gig	BWP 360.00	BWP 206.85	BWP 566.85
256/2048 kbps - 10 Gig	BWP 480.00	BWP 270.91	BWP 750.91

VAT exclusive.
Contact Telephone: [illegible]

INTERNET OPTIONS BOTSWANA (IOB)

Package	Internet Speed	ADSL Bandwidth Charge	ADSL Access Charge by BTC	Total of ADSL Bandwidth and Access Charge
Bronze	512/128 kbps	BWP 190.00	BWP 159.30	BWP 349.30
Silver	1024/192 kbps	BWP 267.00	BWP 206.00	BWP 473.00
Gold	2048/256 kbps	BWP 375.00	BWP 271.00	BWP 646.00

VAT exclusive.
Contact Telephone: [illegible]

I BMX

Package	Internet Speed	ADSL Bandwidth Charge	ADSL Access Charge by BTC	Total of ADSL Bandwidth and Access Charge
Residential ADSL	512/128 kbps	BWP 210.70	BWP159.30	BWP370.00
Business ADSL	512/128 kbps	BWP 210.70	BWP159.30	BWP 370.00

VAT exclusive.
Contact Telephone: [illegible]

1 Value Added Network Service (VANS) only charge for the internet and other value added services while BTC bills the customer directly for the access charge and the telephone line rental.
2. VANS provide other services and fixed wireless internet solutions which are not part of the above presentation.
3 The above charges have not included the BTC telephone line rental which is normally required for connection to ADSL. The telephone line rental charges are P75.00 for residential line and P125.00 for business line.
4 There maybe additional charges for modem rental or purchase that has not been reflected above.
5 Save for inclusion of information on ADSL Access Charges by BTC, the BOCRA has ensured that information submitted by VANS for publishing is not altered.
6. For further information on other services and Terms and Conditions of Services please contact the respective service providers.
7 The tariff information is also avalabale in the BOCRA website (www.bocra.org.bw)
8 Source for all of the above is BOCRA.

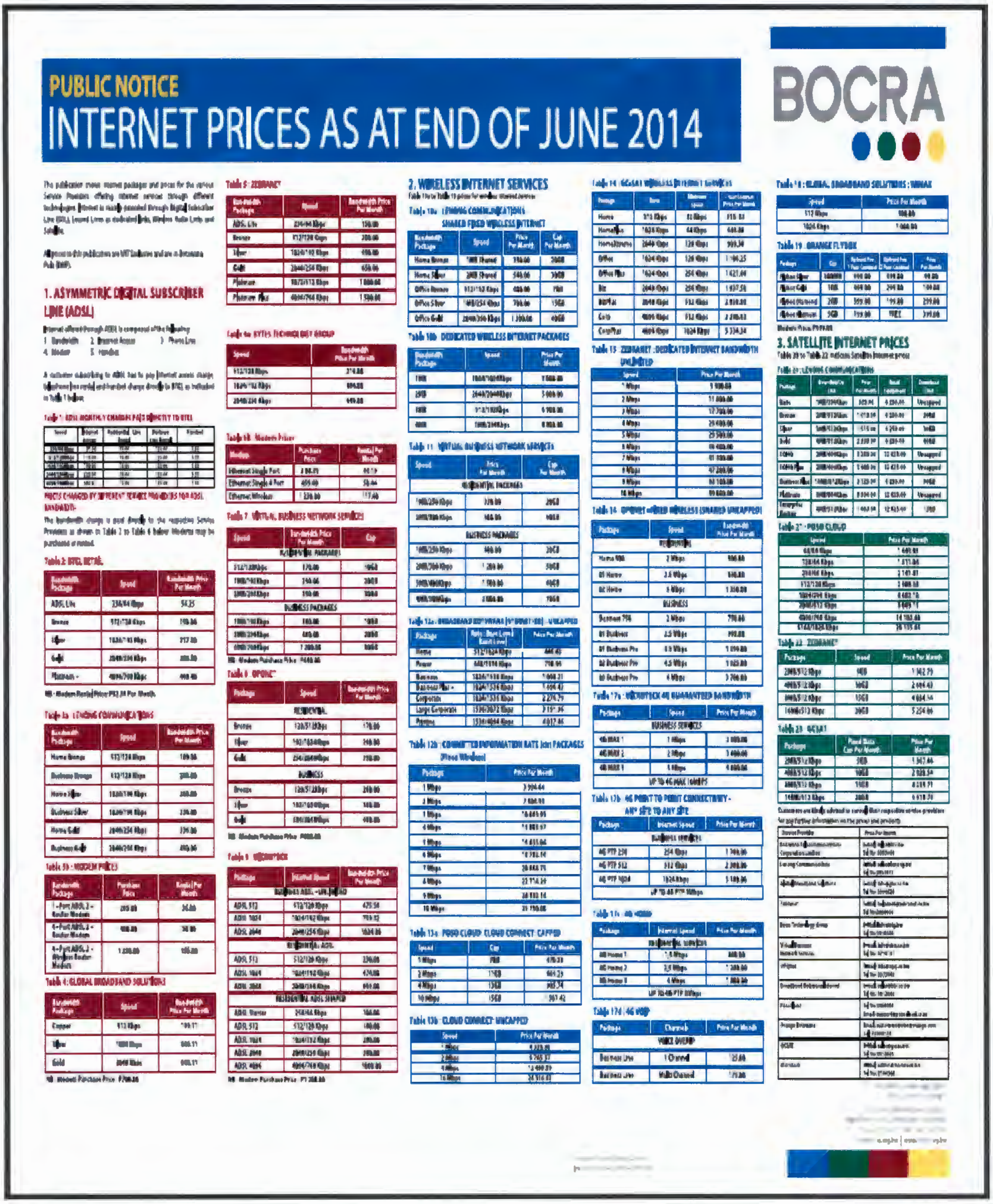
Imagine the world without order
Imagine Botswana without BOCRA

BOTSWANA COMMUNICATIONS
REGULATORY AUTHORITY

PLOT 206/207 INDEPENDENCE AVENUE
PRIVATE BAG 00495, GABORONE, BOTSWANA
TEL: +267 3957755 FAX. +267 3957976
info@bocra.org.bw | www.bocra.org.bw

Appendix 1 BOCRA ADSL Internet Charges

Appendix 2


PUBLIC NOTICE

INTERNET PRICES AS AT END OF JUNE 2014

BOCRA

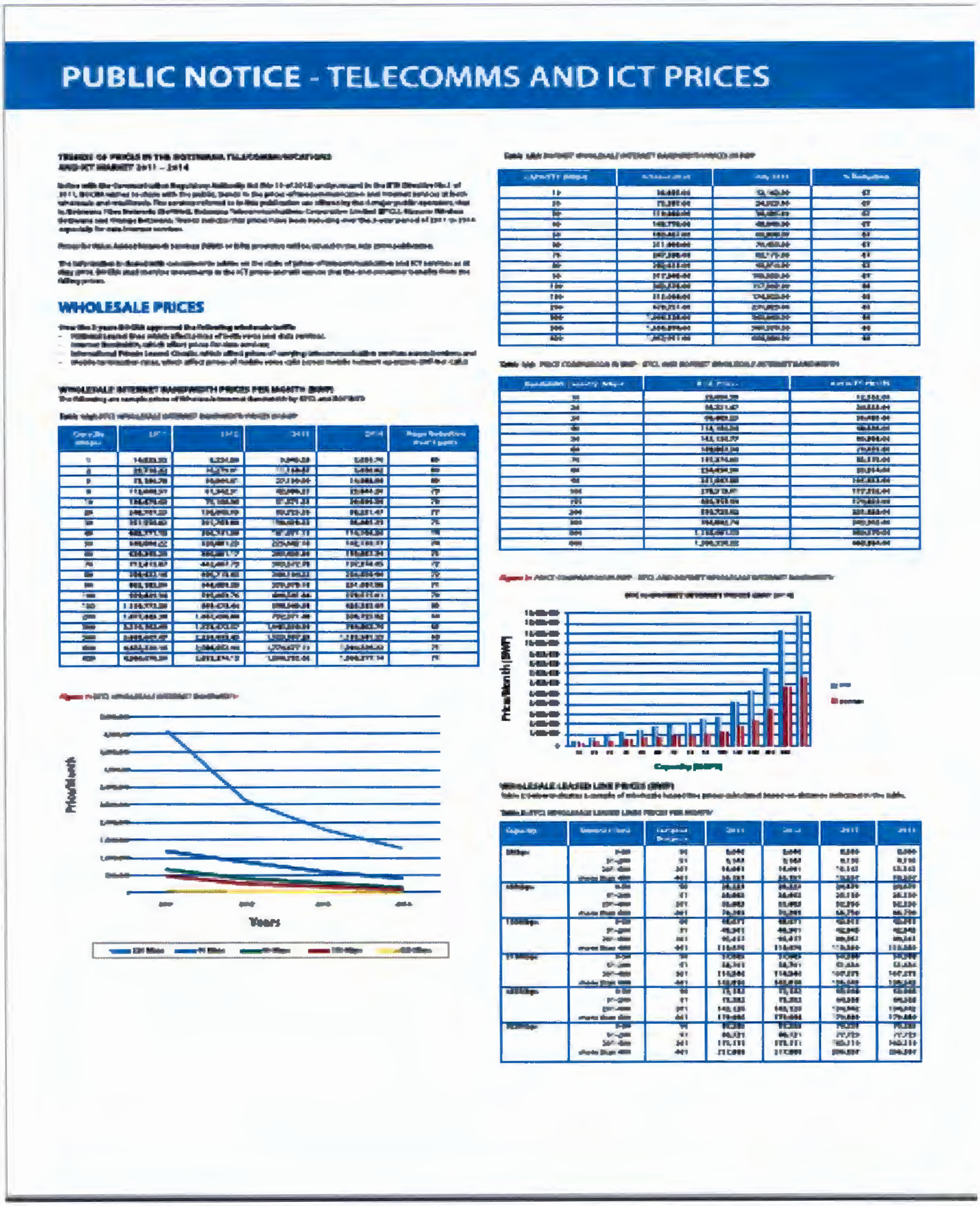
1. ASYMMETRIC DIGITAL SUBSCRIBER LINE (ADSL)

2. WIRELESS INTERNET SERVICES

3. SATELLITE INTERNET PRICES

Appendix 2 Internet Prices

Appendix 3



PUBLIC NOTICE - TELECOMMS AND ICT PRICES

WHOLESALE PRICES

Appendix 3 Telecoms and ICT Prices