Abstract- The Long Term Evolution-Rural Wireless Architecture Model (LTE-RWAM) is a multiple of demarcated telecommunication cells each composed of a series of eNodeB’s, MIMO structures, Access Gateway’s (AGW) and connected at source and end to the Evolved Packet Cores (EPC). The EPC is connected to the communication cells through the eNodeB Interface (X2) and Core Network Interface (S1) and is built to support packet-switched traffic. EPCs are connected to eNodeBs that are enhanced base stations that provide air interface and perform radio resource management for the access systems, radio balancing and radio mobility control including handover decisions for mobile user equipment (UE). Within the eNodeB’s are MIMO structures employed to use multiple transmitters to send data from the source to the recipient. In fact, the whole system uses affordable but complex equipment that is capable of carrying signals over long distances. The LTE-RWAM enhances mobile connectivity in remote populated regions. The LTE-RWAM system is constructed across the rural sectors to ensure mobile network connectivity. Such a wireless architecture was designed to provide effective connectivity to rural sectors at a low cost as the infrastructure needs to cover a wider geographical areas.

Index Terms— Access gateway, evolved packet core, eNodeB, Long Term Evolution-Rural Wireless Architecture Model (LTE-RWAM), MIMO, telecommunications cell, X1 and S1 interfaces

I. INTRODUCTION

The Long Term Evolution-Rural Wireless Architecture Model (LTE-RWAM) is a multiple of demarcated telecommunication cells each composed of a series of eNodeB’s, Multiple Input/Multiple Output (MIMO) structures and an Access Gateway (AGW). At the ends of the infrastructure, the Evolved Packet Cores (EPC) are connected through the eNodeB Interface (X2) and Core Network Interface (S1). The EPC is built to support packet-switched traffic. The EPC component has the following nodes: Serving Gateway (SGW), Packet Data Network Gateway (PGW), Mobile Management Entity (MME) and Policy and Charging Rules Function (PCRF) that are discussed in detail in Section III.

Inside these telecommunications cells, there are series of eNodeBs that are an enhanced base stations that provide air interface and performs radio resource management for the access systems, radio balancing and radio mobility control including handover decisions for mobile user equipment (UE). In addition to eNodeBs, there are fixed MIMOs employed to use multiple transmitters to send data from the source to the recipient.

The LTE-RWAM system is constructed across the rural sectors to service mobile network connectivity. Such a wireless architecture was designed to provide effective connectivity to rural sectors at a low cost as the infrastructure needs to cover a wider geographical areas. This geographically dispersed infrastructure across poorly networked areas gives access to mobile services in rural communities.

A. Statement of the Problem

In the last decade the Global System for Mobile Communication (GSM) and Wideband Code Division Multiple Access (WCDMA) have been widely used in mobile communication particularly in Asia/Europe and America; being deployed in both rural and urban sectors. Such a wider coverage facilitated telecommunication growth within the areas. This of course facilitated development in the communication industry which saw these nations attain status of being considered developed nations. The utilization of GSM and WCDMA became one of the cornerstones to development in Europe and America. While these two continents were enjoying these two technologies, that
boosted communication, the deployment of such in the sub-Saharan regions was unfairly distributed, especially in the rural areas which remained undeveloped in regards to information technology. Most of the sub-Saharan states or countries only concentrated on the development of urban areas. These countries heavily invested in GSM and WCDMA technologies around the urban areas neglecting the country-side devoid of such facilities and services.

As the developed world realized that the two technologies GSM and WCDMA were not keeping up with evolution of wireless technologies urgently driven by the high demand of information usage, there was a move towards improving them. Therefore much research has been undertaken into ways of improving the existing technologies. These two technologies, GSM and WCDMA, are considered to have a number of drawbacks such as low speed, high latency, etc. In view of this, some advanced nations had vigorously begun researching ways of improving and managing these technologies. The improvements that were envisaged included low latency, efficiency, support for real time, flexible spectrum, high spectrum efficiency, re-use of existing cell infrastructure and lower cost per bit. It is in view of this that as the advanced countries were striving to improve the two technologies, the sub-Saharan region should have learnt to consider the rural sectors at the initial stages and develop them at the same pace. As the world is encouraging the two technologies to develop long term evolution strategies that will overcome the previously highlighted drawbacks the sub-Saharan region needs to prepare for the involvement of the rural sector. In this way they will be able to take the services to the vulnerable communities at the time when the services are required. After all, America and Europe have been classified as developed partially because they have taken the basic services to the rural sectors where such facilities are needed and scarce. It is in view of this that this work envisages the preparation and deployment of new LTE technologies to service the rural sectors and adequately connect them to urban areas.

II. LITERATURE REVIEW

Many concerns have been raised about the low connectivity in rural environments, especially in the third world nations. In [1] a comparison of regional connectivity was given among North America (69.7%), Asia (10.7%) and Africa (3.6%). The Internet connectivity in Asia and Africa was primarily restricted to urban areas. In [2, 3, 4] the authors emphasised that the fundamental difficulties in connecting rural areas were caused by economic constraints.

Other researchers such as [5, 6, 7] pointed out that in recent years, many developing countries have undergone a cellular revolution with a significant penetration of cellular networks in rural areas. However, despite this evolution, there still remain challenges in rural regions that are mainly due to cost. Also [8, 5, 9] reported that, while a sizable portion of the rural population owns cellphones in Africa and Asia, the network usage was limited due to exorbitantly high usage costs, roughly ranging from 10 cents to $1/min.

In [10, 11] they observed that for any connectivity solution to be economically viable in rural regions with low-user densities, it is essential to have small per-user setup costs and minimal recurring costs. They also highlighted that networks with a base-station model, such as WiMAX and cellular networks like GPRS and WCDMA, had an asymmetric design philosophy where expensive base stations, costing roughly $100000 – 100000 depending on range and capacity are amortized by large numbers of cheap client-devices over many users. They further illustrated that operational costs of these networks in rural areas were also high due to: significant power consumption to cover large areas, the need for backup power due to a lack of reliable grid power and a high cost of physical security for expensive equipment. They concluded that, these costs made existing cellular and wireless broadband services unfeasible in regions with low user densities.

Adding to this, [12] pointed out that a lot of rural set ups do not have good connectivity solutions that are economically viable. They further emphasized that the rural areas remain disconnected from both the rest of the world and from progress in general. It is in light of this that they introduced the WiFi-based Rural Extension (WIRE), which is a new wireless network architecture that could provide connectivity to rural regions at extremely low costs. They tailored the WIRE architecture specifically for rural terrain and especially in many third world nations, less than 1-2 sq kms within 100-200 kms of the city. They also highlighted that WIRE was designed to be a wireless distribution network that extended connectivity from city to each village. In view of this, WIRE was seen to make use of wireless technology to reach the rural sectors in terms of communication development. In fact WIRE had wider advantages as compared to the cellular network philosophy of providing broad network coverage. It [12] was reported that WIRE provided focused coverage within rural regions with little coverage outside. They went on to state that the network structure of a WIRE deployment was optimized based on the topography and the spread of rural regions. It was further reported that to efficiently reach out to sparsely spread out rural regions, WIRE used a combinational network structure with four important components, namely: point-to-point networks links, point-to-multipoint networks links, local distribution mesh networks and cellphones as end-devices in addition to PCs and kiosks.

Going even further, [12] described the WIRE architecture to be composed of: wireless nodes which are low-power single board computers that have capability to support multiple wireless cards for different network links; point-to-point links using highly directional antennas, point-to-multipoint links using sector antennas, multi-radio mesh links using omni-directional links, cellphones or low cost computing devices with WiFi-enabled interfaces and large local storage of at least a few GB at each local wireless node to perform in-network optimizations.
Then [12] stated the challenges of building the rural wireless networks, namely high loss rates, tower costs, unreliable power, and network management. For the high loss rate, they suggested that the Media Access Control (MAC) protocols had to be designed to handle high loss-rates.

III. THE LTE-RURAL WIRELESS ARCHITECTURE MODEL SETUP

As rural setup is scattered, it is very expensive to deploy the ICT/telecommunications infrastructure in between or among sites. Taking in cognizance that telecommunications equipment is very expensive, certainly covering wider areas would be a lot more demanding. However, utilizing the upcoming LTE technologies, a set of equipment that would suit the geographical rural environment is envisaged. The so-called nearly 4G LTE-Rural Mobile Infrastructure Model (LTE-RMIM) demonstrated in Figure 1, is a multiple of demarcated telecommunication cells each composed of a series of eNodeB’s (a smart base station), MIMO structures (which uses multiple antennas at both the transmitter and receiver to improve communication performance), Access Gateway (AGW), Serving Gateway (SGW) and Evolved Packet Core (EPC), X2 (interface function) and S1(paging function) interfaces.

A. Evolved Packet Core (EPC)

The EPC is connected to these communication cells through the X2 interface as earlier stated. It is designed and built to support packet-switched traffic. The EPC is a component which is composed of four main nodes and these are: Serving Gateway (SGW), Packet Data Network Gateway (PGW), Mobile Management Entity (MME) and Policy and Charging Rules Function (PCRF). The SGW performs the switching and routing services for user plane traffic and it also acts as the main border between the radio access network and the core network. It terminates user plane access for the eNodeB, routes user plane traffic, performs accounting and monitoring of user data and acts as a local mobility anchor point for handover. Other functions of SGW are: uplink and downlink charging per UE, PDN and QCI, setting end-marker to the transmission to assist in eNodeB reordering function and lawful intercept. The next node of the EPC is the PGW. The PGW provides connectivity to the UE to external packet networks by being the point of exit and entry of traffic for the UE. It performs policy enforcement, packet filtering for each user, charging support and packet screening. It is also for access to the internet. The third node is the MME. Its function serves as the main control node for the LTE system architecture evolution (SAE) access network. It has a number of operations such as provide temporary identities for UEs, choice of SGW for a UE, bearer activation/de-activation, idle mode UE tracking, intra-LTE handover involving core network node location, etc. Whilst the forth node, the PCRF detects the service flow and enforces charging policy.

B. Access Gateway (AGW)

The AGW serves as a mobility anchor point for the user plane. It also provides termination of the LTE bearer. It implements key logical functions including that of MME for the control plane and the System Architecture Evolution Packet Data Network Gateway (SAE PDN GW) for the user plane.

C. eNodeB

The eNodeB is one of the most significant parts of LTE, in fact it is viewed as where the evolution comes in. It is comprised of all the communications architecture that makes LTE possible, including communications between the towers, the SGW and MIMO antennas. The eNodeB is an enhanced base station which provides the LTE air interface and performs radio resource management for the access systems, radio balancing and radio mobility control including handover decisions for mobile user equipment (UE). It interfaces with UE and hosts the physical, medium access control (MAC), radio link control (RLC) and packet data control protocol (PDCP) layers. In addition, the eNodeB hosts radio resource control (RRC) functionality corresponding to the control plane. It has more functions for example the radio resource management, admission control, scheduling, enforcement of negotiation UL QoS, cell information broadcast, ciphering/deciphering of user and control plane data and compression/decompression of

Figure 1. LTE-Rural Wireless Architecture Model (LTE-RWAM) System
DL/UL user plane packet headers. As discussed earlier, the EPCs are connected to the outer telecommunication cell through the S1 interface through the eNodeB, whereas, the eNodeBs are connected to one another through the X2 interface.

D. MIMO Structure

The LTE-RAWM employs the MIMO technique to send the data. It is the main signaling node that deals with registration and the technique of sending the data throughout the whole system. It uses multiple antennas to communicate the data. The way it operates is as follows: the multiple transmitters first convert serial bit stream into multiple parallel sub streams. The transmitters send the bit streams via different transmit antennas using the same time slot and the same frequency band. The multiple antennas receive the data and then separate out the original sub streams from the mixed signals, using the non-correlation of signals on multiple received antennas caused by multipath in the transmission. Therefore, this leads to significant increases in achievable data rates and throughput.

IV. CONCLUSION

The emerging LTE technology should be deployed to improve the telecommunication services particularly in the urban areas where there is already existing mobile infrastructure. While this technology is employed to improve the telecommunication services, the rural sector especially in the Sub-Saharan region remain under developed. It is in light of this, that the LTE-RWAM was considered. The LTE-RWAM is designed to be installed with multiples of sophisticated equipments along the system to manage and carry the signals covering a very large geographical areas and at a low cost. This kind of system is developed to suit the rural environment which can not afford expensive telecommunication infrastructure. In this way, such an infrastructure would render the mobile services to the rural communities.

REFERENCES


Jameson Mbale received his PhD in Computer Science from Harbin Institute of Technology, China, in 2003. He obtained M.Sc in Computer Science from Shanghai University in 1996 and B.A in Mathematics and Computer Science at the University of Zambia in 1993 in Zambia. Currently, he is a Senior Lecturer of Computer Science in the Department of Computer Science at the University of Namibia. He is the Head of the Department and the Coordinator of Centre of Excellence for Telecommunications and Information Technology (IT). His Research interest is in telecommunications, wireless networking and network security.

Victor Hamutenya is a senior manager ICT infrastructure Telecom Namibia.