American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-5, pp-136-146
www.ajer.org
Research Paper Open Access

Assessment/Analysis of Multi-Hop Relay-Enhanced Wimax Networks and the Reliability Concept of Long Term Evolution Advanced (LTE-A) In 4G Wireless Technology

Richmond Adebiaye[1], Taiwo Ajani[2], Theophilus Owusu[3]
[1]*Department of Informatics & Engineering Systems, College of Science & Technology/ University of South Carolina Upstate, USA*
[2]*Department of Computer Information Systems, Ferrum College, VA, USA*
[3]*Graduate Business School/Keiser University, Fort Lauderdale, FL USA*
Corresponding Author: Richmond Adebiaye

ABSTRACT :*Modern telecommunication companies have developed or installed high-speed data plan services to convey information in the form of a stream of networks that relay data or information faster than the typical data delivery. Multi-hop relay (MHR) enhanced WiMAX networks are conceivably the most promising Radio Access Technology set up to provide high-speed broadband connectivity to large geographical locations. This research provides an assessment of the challenges of enhanced WiMAX network concepts and its impact in offering reliability within the LTE-Advanced framework. The study identified common physical components, technologies, and wireless standards of enhanced WiMAX networks, establish the effectiveness of Quality of service (QoS) in enhanced WiMAX networks, interpret the challenges of enhanced WiMAX network concepts in LTE-Advanced framework, and analyze the determining factors thataffects enhanced WiMAX network in offering reliability within the LTE-Advanced framework. The study adopted a research survey design byusing a simple random sampling that focused on Collection of data through online questionnaires and analyzing the data to generate specific findings using descriptive statistics, Analysis of Variance (ANOVA), and Principal component analysis. The study found several challenges including; coverage holes due to 'shadowing' (r=-0.642), poor signal to interference and noise ratio (SINR) for the SSs' with respect to Base Stations, BS (r=919), cost of servicing few Subscribers Stations (SSs) or few users (r=-0.719), reliability problems still persist on in-band relaying with respect to out-of-band relaying (r=0.817) and technical and non-technical support services (r=0.854), werefound to be statistically significant in the enhancement of WiMAX networks. The study findings created framework for the implementation of policies on communication technology enhancements that would spearhead infrastructural development towards improvement in multi-hop relay enhanced networks on WiMAX and provide a reliable LTE-Advanced framework.*

KEYWORDS *-Multi-hop Relay (MHR) networks, high-speed data plan services, WiMAX technology, Load-Aware Routing Metric (LARM), Burst Profile (BP)*

Date of Submission: 27-04-2018 Date of acceptance: 12-05-2018

I INTRODUCTION

High-speed data relay represents data transfer in the form of quotes, requests, results,and yields that are transmitted in the shortest real time possible, without delays (Bhosale-&-Daruwala, 2013). Additionally, high-speed data relay will pass information in an open networked format rather than pass information or data in a pulsed format (Adhicandra, 2010).High-speed data relay can be achieved through Multi-hop relay (MHR) enhanced networks, which help in breaking long distance low-quality linksbetween Subscriber Stations (SS) and Relay Stations (RS)into two or more high-quality segments that enable faster data traffic and signaling to mobile users (Hammoshi, 2011). MHR also offers wider service network coverage,and as a result, it effectively overcomes the heavily shadowed areas and areas beyond the normal cell range (Yongxue, 2009).Khan et al. (2012) noted that the MHR also overcomes the shadowing and multipath issues that restrict the exceptional performance nature of high-speed data plan services. The MHR networks have concurrentlyintroduced the application of RS toimprove coverage and capacity of the network system. However, some issues that hinder the performance of the MHR like; path selection and locations of relay stations which affectquality of service, the path selection criterion based on Load-Aware Routing Metric (LARM), and the locality of relay stations with low flow of data based on Burst Profile (BP) (Singh & Sengupta,2011). This will be examinedin this research,to ascertain ways or methods on how to improve the quality of service (QoS) of the MHR networks.One of the common MHR networks is WiMAX technology. WiMAX implies “Worldwide Interoperability for Microwave Access,” and represents the fourth generation (4G), it is a technology which allows users to connect to the internet wirelessly. Therefore, WiMAX technology is similar to the**Wi-Fi**technology, because both technologies allow mobile phone users to connect to the Internet wirelessly.WiMAX technology is suitable for a long-range wireless networking between the service base stations and the relay stations,for both mobile and fixed connections (Grewal & Ajay, 2010). Kalpana et al. (2012) also acknowledge that WiMAX has been envisioned as the leading form of internet provision when compared to cable networking, but its adoption has been limited in most areas.

WiMAX technology is an essential part of Long Term Evolution (LTE); a wireless broadband technology developed by the Third Generation Partnership Project (3GPP) industry to significantly provide increased peak data rates, with the potential for high downstream and low upstreamscalable bandwidth capacity and backwards compatibility with the existing GSM and UMTS technology (Zhang & Chen, 2008). Joon et al. (2012)agree with Hammoshi (2011) that LTE provides for future developments that could result in the peak order of3G, 4G and eventually 5G.The upper layers of LTE are based upon improvements that will likely result in all internet provision networks like the current state of wired communications. According to the research conducted by Bapuji& Sharma (2011), it was suggested thatLTE will support mixed data systems, voice and video communication,and messaging traffic. In mobile phone communications, LTE is a system standard for high-speed communication without the use of wires for mobile gadgets which includes phones and digital devices. The LTE system increases the capacity and speed of communication using a different radio interface like GSM, together with core network improvements.

The success of the mobile phone usage has led to the growing demand for wireless services. To address this increasing demand, WiMAX networkshavebeen developed and deployed on a large scale. Similar systems have been deployed including; mobility-oriented technologies like GPRS, CDMA or UMTS,and Local Area Network-oriented technologies such as Wi-Fi (Jangra& Kavita, 2012). However, Ramjee et al. (2010) identified some of the WiMAX networks’ challenges like; quality of service (QoS), security, multiple input/multiple output antennas, mobility, radio resource management, planning, cost/revenue optimization, medium access control (MAC) layers, physical layers,and network layers.With the background information on high speed data plan services, multi-hop relay enhanced networks (MHR), WiMAX Networks,Long Term Evolution Advanced (LTE-A) wireless technology, WiMAX networks, and the reliability of concept of LTE-A in wireless technology, this study provides an in-depth analysis of the challenges of multi-hop relay enhanced WiMAX networkand the impact on its deployment within the LTE-Advanced framework.

II PURPOSE OF THE STUDY

The current developingLong-Term Evolution Advanced (LTE-A) standard, which is enhanced by the multi-hop relaying system is an essential feature in communication service delivery. However, the problem of reliability persists in thein-bandrelaying when compared to theout-of-band relaying, which decreases capacity due to the half-duplex feature. Therefore, this research provides an assessment of the challenges of multi-hop relay enhanced WiMAX network concept and its impact in offering reliability within the LTE-Advanced framework. The study will be guided by the following research objectives:

Research objectives

The research objectives of the study are;

i. To establish the socio-demographic factors of the engineers/technicians involved in multi-hop relay enhanced WiMAXnetworks.

ii. To identify the factors, components, technologies, and wireless standards that affect multi-hop relay enhanced WiMAXnetworks

iii. To ascertain the Quality of service (QoS) in multi-hop relay enhanced WiMAX networks

iv. To interpret the challenges encountered by the multi-hop relay enhanced WiMAX network concept inthe LTE-Advanced framework

2.2 Research Questions

The research questions derived from the research objectives of the study are:

i. What are the socio-demographic factors of the engineers/technicians involved in multi-hop relay enhanced WiMAXnetworks?

ii. What are the factors, components, technologies, and wireless standards that affect multi-hop relay enhanced WiMAXnetworks?
iii. What are the significant effective Qualities of service (QoS) in multi-hop relay enhanced WiMAX networks?
iv. How do the challengesinvolved in multi-hop relay enhanced WiMAX network concept affect the LTE-Advanced framework?

2.3 Significance of the study

The current study holds several significances for the telecommunication industry and businesses in general. For instance, it proposes methods that may improve both capacity enhancement and cost-effective coverage extension, by analyzing the Orthogonal Frequency Division Multiplexing (OFDM) and adaptive modulation used to enhance performance in both 3G and 4G technologies. The result findings also can be useful to various governments in designing and implementing policies relating to recent communication technology enhancements. Furthermore, it can help in spearheading infrastructural development by offering WiMAX that promises reliable LTE-Advanced framework.

2.4Research hypotheses

The null research hypotheses derived from both the research objectives and questions are;
H_0 (1): There are no significant differences between and within common physical components that typically affect multi-hop relay enhanced WiMAXnetworks.
H_0 (2): There are no significant differences in effective Quality of services (QoS) associated with multi-hop relay enhanced WiMAX networks.
H_0 (3): There are no significant associations between challenge factorsassociated with multi-hop relay enhanced WiMAX network concept.

III RESEARCH METHODOLOGY

The research methodology section presents the research design, the study variables, data collection process, and data analysis techniques used to obtain the study findings. The research methodology mainly focuses on the procedures and methods of obtaining and analyzing data to generate the conclusions of the study.

3.1 Research design

The study adopted a research survey design with a focus on data collection process through online questionnaires;thedatawas organized in spreadsheets/SPSS interfaceandanalyzedto generate the researchfindings. The research survey was designed to help in testing the hypotheses onthe significant challenges involved in multi-hop relay enhanced WiMAX network conceptaffectingthe LTE-Advanced framework and the significant impacts of enhanced WiMAX networks in offering reliability within the LTE-Advanced framework.

3.2 Study variables

The study variables are grouped into three broad categories: response variable, explanatory variables, and intervening variables. The response variables of the study are; the multi-hop relay enhanced WiMAX network conceptand the reliability concept ofLong Term Evolution Advanced (LTE-A) wireless technology.

The MHR enhanced WiMAX network is explainedby assessing the physical layer, Medium Access Control Layer, Quality of Service, and security sublayers of theWiMAX. The WiMAX components including Mobility Management Architecture for the networks, Radio Resource Management in the networks, Radio and Network Planning, System Capacity, Cost/revenue Optimization, Multiple Antenna Technology, and the Wireless Standards Index are considered as explanatory or independent variables.

The intervening factors will include;personal demographic attributes of thestudy participants such asage, gender, level of education, WiMAX network experience, and WiMAX network coverage.

3.3 Data collection

The data collection process targeted all telecommunication engineers/technicians involved with or working in multi-hop relay enhanced WiMAX networks in India. Due to lack of time and limited resources, a sample size of 180telecommunication engineers/technicianswas used for this research. An online survey-style questionnaire was administeredas a research tool for this study in seeking insights concerning the MHR enhanced WiMAX networks. Most of the responses were based on the 5-point scale with the following ratings: Very Low (VL=1), Low (L=2), Neutral (N=3), High (H=4), and Very High (VH=5). The 5-point scale ratings were to ensure that data collected had reliability, validity, and precision features for statistical analysis.

3.4 Data Analysis Procedure

The socio-demographic data was organized using descriptive statistics, frequency tables, and graphical methods. Data concerning research questions were analyzed using descriptive statistics, Analysis of Variance (ANOVA), and principal component analysis. The descriptive statistics employed µand σ values in the analysis while ANOVA used F and p-values. The principal component analysis used factor loadingsand eigenvalues toaddress the research questions. The results weresubsequentlysummarized and interpreted to generate the findings of the study.Data analysis was primarilyconductedusing social package for social scientists (SPSS version 22).

IV DATA ANALYSIS RESULTS

This section presents the data analysis on the socio-demographic factors of the study participants and the analysis concerning research questions.

4.1 Socio-demographic factors about the study respondents

Table 1: Frequency distribution and descriptive statistics

Variable	Attribute	Frequency	Percent	Mean	Standard deviation
Age in years	15-24	12	6.7	38.75	9.110
	25-34	40	22.2		
	35-44	71	39.4		
	45-54	49	27.2		
	55-64	8	4.4		
	Total	180	100.0		
Gender	Male	94	52.2	1.42	.494
	Female	75	41.7		
	Others/Partners	11	6.1		
	Total	180	100.0		
Level of Education	Undergraduate	75	41.7	2.60	.901
	Graduate	78	43.3		
	Advanced/Post-Graduate	27	15.0		
	Total	180	100.0		
WiMAX experience in years	0-4	16	8.9	14.75	.929
	5-9	34	18.9		
	10-14	73	40.6		
	15+	57	31.7		
	Total	180	100.0		

According to Table 1, the results indicated that majority of therespondents were 35-44 years old as at the time of the research with a relative frequency of 39.4%, followed by those who were 45-54 years and 25-34 years with relative frequencies of 27.2% and 22.2% respectively. Those aged 15-24 years and 55-64 years old were minor age groups with relative frequencies of 6.7% and 4.4% respectively. The results also indicated that the mean age of respondents was 38.75 years with a standard deviation of 9.11 (µ=36.75 and σ=9.11). The age factor displayed a normal curve as shown in the histogram below.

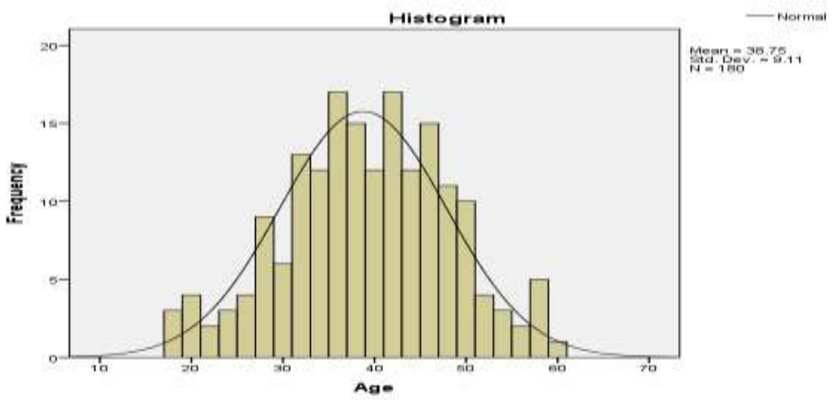

Figure1: Histogram of age distribution

Concerning the gender factor, the results in Table 1 show that 52.2% of respondents were males while 41.7% were females. Other respondents who were 6.1% identified themselves as others or partners in terms of gender. These results show more males than females among the networking engineers/engineers/techniciansare involved in the MHR enhanced WiMAX network as displayed in the pie chart below.

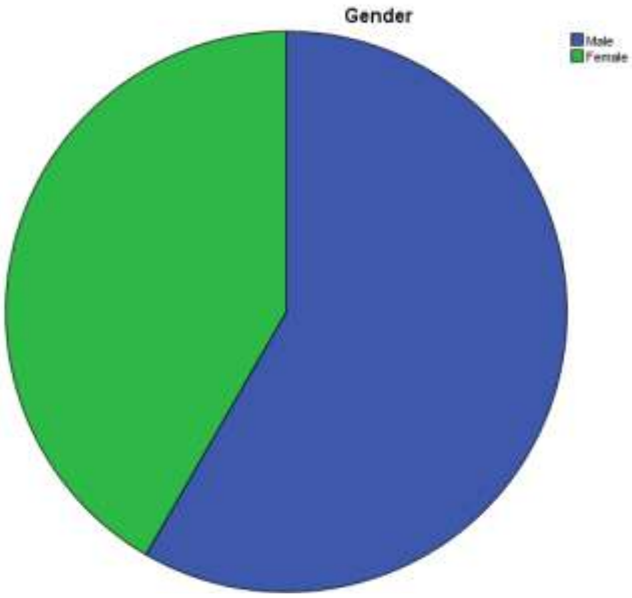

Figure2: Bar chart of gender distribution

On the respondents ‘level of education, results in Table 1 showed that 43.3% of the respondents had graduate degree level of education, 41.7% had undergraduate level of education and 15.0% had advanced graduate level education. These results indicate that most of networking engineers/engineers/technicians involved in the multi-hop relay enhanced WiMAX network concept concerning LTE-Advanced frameworkhave specialized levels of education as portrayed in the bar graph below.

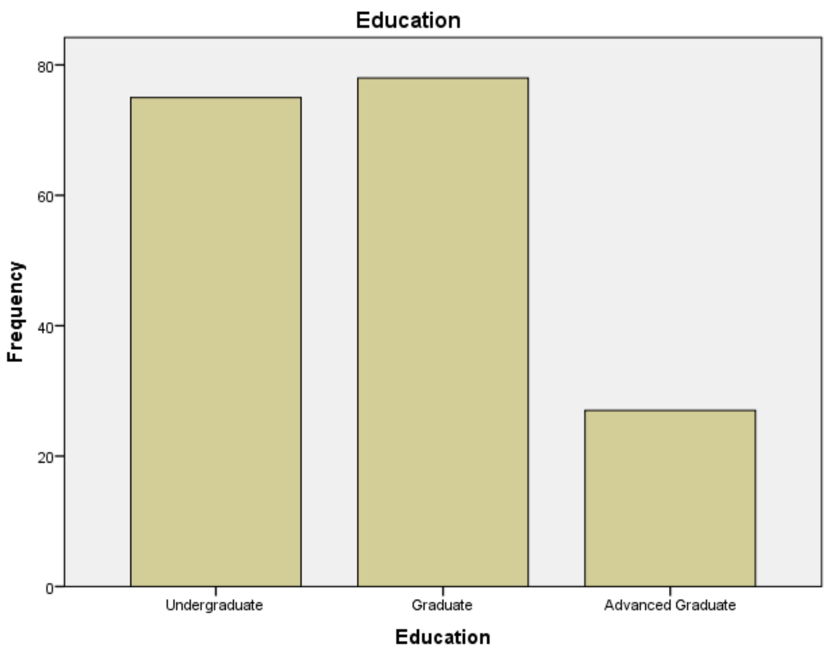

Figure3: Bar graph of education levels distribution

Finally, the results in Table 1 also indicated that most engineers/engineers/technicians involved in multi-hop relay enhanced WiMAX network concepts had 10-14 years' experience, which can be categorized as masterIT experience (40.6%) followed by those who had more than 15 years' experience,which can be categorized as excellent IT experience (31.7%). The remainingWiMAX network groups had 5-9 years' experience(intermediate experience) and 0-4 years' experience (basic experience) with relative frequencies of 18.9% and 8.9% respectively. The bar graph below shows that most of networking engineers/technicians involved in the multi-hop relay enhanced WiMAX network had either a master oran excellent level of experience as portrayed in the bar graph below. In the study, we attribute master level to represent the skillful level (with appropriate industry's certifications) while excellent level will represent expertise level.

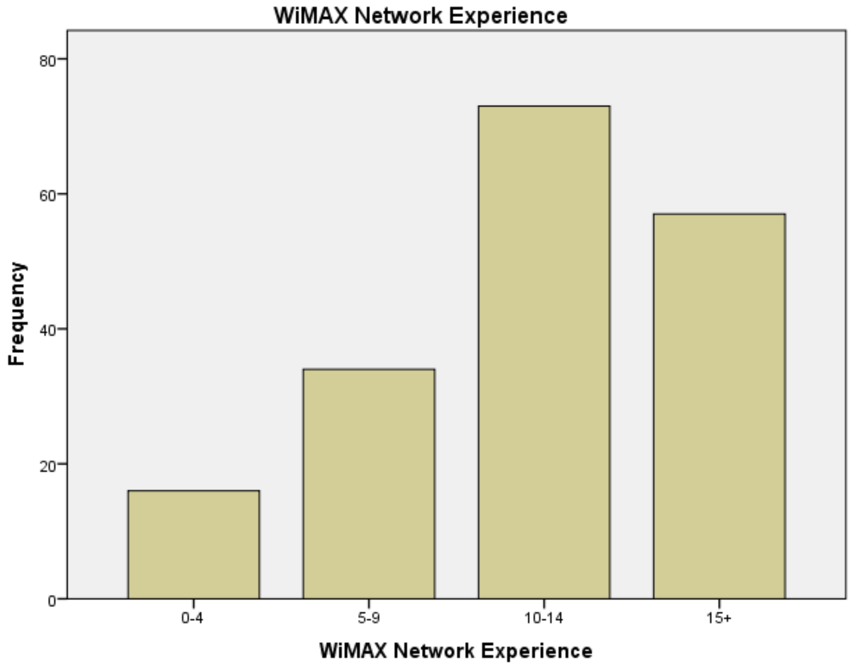

Figure4: Bar graph of WiMAX network Experience distribution

In summary, most networking engineers/engineers/technicians involved in the MHR enhanced WiMAX network had either a master (skillful) level of WiMAX network experience (40.6%) or excellent (expertise) level of WiMAX network experience (31.7%). Concurrently, the engineers/engineers/technicians also possess college education:Undergraduate degree level of education (43.3%), Graduate level of education (28.3%), and post-graduate level of education (15.0%). Therefore, the study concludes that the socio-demographic factors of the engineers/engineers/technicians like education and networking IT experience have significant enhancement of multi-hop relay WiMAXnetworks.

4.2 The factors, components, technologies,and standards that affect the MHR enhanced WiMAX networks

Table 2: Sample descriptive statistics

WiMAX Factors	N	Mean	Mean (%)	Std. Deviation
Internet traffic & Congestion	180	3.79	75.8	1.352
The Servers' speeds	180	2.51	50.2	1.053
Hardware-Software configuration	180	4.11	82.2	.915
Technical Support efficiency	180	3.93	78.6	1.091
LTE reliability concept	180	4.21	84.2	.769
Cost-Financing implications	180	2.44	48.8	1.132
WiMAX Overall ratings	**180**	**4.38**	**87.6**	**.400**

The results in Table 2 shows that the overall WiMAX networks averagerating by the networking engineers/technicianswere μ=4.38 and σ=0.400 that is, the overall WiMAX network efficiency has a mean rating of 4.38 out of possible 5. The results also indicated that WiMAX networks were highly rated by the networking engineers/technicians in theInternet traffic and Congestion factor (μ=3.79 and σ=1.352), Hardware-Software configuration (μ=4.11 and σ=0.915), Technical Support efficiency (μ=3.93 and σ=1.091), and the LTE reliability concept (μ=4.21 and σ=0.769). On the other hand, WiMAX networks were poorly rated by the networking engineers/techniciansonservers' speeds (μ=2.51 and σ=0.1.053) and in cost-financing implications (μ=2.44 and σ=0.1.132).

The results indicated that the overall WiMAX network efficiency has a mean rating of 4.38 out of possible 5, indicating that about 87.6% of the networking engineers/technicians feel that WiMAX network is efficient enough in offering its services. Similarly, the networking engineers/technicians felt that the WiMAX network is appropriate in internet traffic and congestion factor by 75.8%, hardware-software configuration by 82.2%, technical support efficiency by 78.6%, and the LTE reliability concept by 84.2%. Conversely, the networking engineers/technicians felt that the WiMAX network has not been effective in addressing the servers' speed by 50.2% and on cost-financing implications by 48.8%. These above results were further examined by carrying out an Analysis of Variance (ANOVA) test concerning the identification of the factors, components, technologies, and wireless standards that affectenhanced WiMAX networks. The research hypothesis test provided below can be useful.

H_0 (2): There are no significantcommon physical components, technologies, and wireless standards of multi-hop relay enhanced WiMAXnetworks.

Table 3: Analysis of Variance (ANOVA) test results

Factor	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Internet traffic & Congestion	Between Groups	5.979	1	5.979	5.525	020
	Within Groups	192.599	178	1.082		
	Total	198.578	179			
The Servers' speeds	Between Groups	4.219	1	4.219	2.324	129
	Within Groups	323.175	178	1.816		
	Total	327.394	179			
Hardware-Software configuration	Between Groups	22.188	1	22.188	30.954	000
	Within Groups	127.590	178	.717		
	Total	149.778	179			
Technical Support efficiency	Between Groups	30.863	1	30.863	30.128	000
	Within Groups	182.337	18	1.024		
	Total	213.200	19			
LTE reliability concept	Between Groups	37.037	1	37.037	95.626	000
	Within Groups	68.941	178	.387		
	Total	105.978	179			
Cost-Financing implications	Between Groups	.244	1	.24	90	664
	Within Groups	229.200	178	1.288		
	Total	229.444	179			

The ANOVA results in the table above indicate that internet traffic and congestion (F= & p=0.000), hardware-software configuration (F=5.525 & p=0.020), technical support efficiency (F=30.954 & p=0.000), and the LTE reliability concept (F=95.626 & p=0.000) were significant in influencing the WiMAX network services. Therefore, since the p-values for these factors are less than 0.05, we reject the null hypothesis and conclude that internet traffic and congestion, hardware-software configuration, technical support efficiency, and the LTE reliability concept are significantlycommon physical components, technologies, and wireless standards of the multi-hop relay enhanced WiMAXnetworks.The ANOVA results also aligned with those in Table 2 that the servers' speed (F=2.324 & p=0.129) and in cost-financing implications (F=0.190 & p=0.664) were not significant in affecting WiMAX network services.Therefore, since the p-values for these factors are more than 0.05, we accept the null hypothesis and conclude that: servers' speed and cost-financing implications are not significantcommon physical components, technologies, and wireless standards that boost the multi-hop relay WiMAXnetworks.

4.3 The effectiveness of Quality of service (QoS) in multi-hop relay enhanced WiMAX networks

Table 4: Sample descriptive statistics

QoS Scenario	N	Mean	Mean (%)	Std. Deviation
Free space model	180	3.92	78.4	1.072
Erceg's suburban fixed model	180	4.09	81.8	.867
Outdoor to indoor and pedestrian	180	4.03	80.6	1.000
Vehicular environment	180	3.25	65.0	1.143
Overall QoS	**180**	**4.30**	**86.0**	**.42725**

Note:

- *Free space model QoS scenario is an ideal environment wherein the transmitter and the receiver have a clear line of sight path between them; no other blocks exist.*
- *Erceg's suburban fixed model QoS scenario is based on extensive experimental data gathered at 1.9 GHz in 95 macros; the transmission power and antenna height of the BS are high.*
- *Outdoor to indoor and pedestrian QoS scenario is a small cell size; BS is placed outdoors with a low antenna height and a low transmission power; pedestrian users are placed on streets and inside buildings.*
- *Vehicular environment QoS scenario is characterized by a large number of cells and high transmission power.*

According to Khan et al. (2012) in the evaluation of parameters for improving handoff performance in mobile WiMAX networks, their research categorized the QoS scenarios into four groups asexplained above. The categories of QoS arefree space model,Erceg's suburban fixed model, Outdoor to indoor and pedestrian, and vehicular environment. Results in Table 4indicated that the overall QoSwas rated by the networking engineers/technicians at μ=4.11 and σ=0.915 with a mean of 4.11 out of 5possibilities. On the categories of QoS, the networking engineers/technicians rated them as free space model (μ=3.92 and σ=1.072),Erceg's suburban fixed model (μ=4.09 and σ=0.867), outdoor to indoor and pedestrian (μ=4.03 and σ=1.00), and vehicular environment (μ=3.25 and σ=1.143)

The results showed that the overall QoSof WiMAX network with a mean of 4.11 out of 5 possibilitiesis about 86.0% effective. Interestingly, all the four categories of QoS are rated highly by the networking engineers/technicians; thefree space model was rated at 78.4%, theErceg's suburban fixed model was rated at 81.8%, the outdoor to indoor and pedestrianscenariowas rated at 80.6%, and lastly, the vehicular environmentwas rated at 65.0%. These results were further scrutinized using the following research hypothesis and ANOVA test to check their significances.

H_0 (3): There are no significant effective Quality of services (QoS) in MHR enhanced WiMAX networks, against;

H_1 (3): There is significant effective Quality of services (QoS) in MHR enhanced WiMAX networks.

Table 5: Analysis of Variance (ANOVA) test results

QoS Category	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Free space model,	Between Groups	8.841	1	8.841	7.755	.002
	Within Groups	202.909	18	1.140		
	Total	205.750	179			
Erceg's suburban fixed model,	Between Groups	8.379	1	8.379	1.818	.001
	Within Groups	126.199	178	.709		
	Total	134.578	179			
Outdoor to indoor and pedestrian	Between Groups	19.840	1	19.840	22.208	.000
	Within Groups	159.021	178	.893		
	Total	178.861	179			
Vehicular environment	Between Groups	.198	1	.198	.151	.698
	Within Groups	233.552	178	1.312		
	Total	233.750	179			
Overall QoS	Between Groups	7.567	1	7.567	53.641	.000
	Within Groups	25.108	178	.141		
	Total	32.675	179			

The results in Table 5shows that all the four categories of QoS except the vehicular environment were significantly effective in multi-hop relay enhanced WiMAX networks. Their F-ratio values and respective p-values are: Free space model (F=7.755 & p=0.000),Erceg's suburban fixed model(F=11.818 & p=0.000),outdoor to indoor and pedestrian(F=22.208 & p=0.000), and overall QoS (F=53.641 & p=0.000). The vehicular environment(F=0.151 & p=0.698) was insignificant.

The results show that; the overall QoS and three of its categories, namely; free space model,Erceg's suburban fixed model, andoutdoor to indoorpedestrianhad p-values that were less than 0.05. Therefore, the study rejects the null hypothesis and concludes that the free space model,Erceg's suburban fixed model, and the outdoor to indoor and pedestrianmodels are significantly effective QoS in enhancing multi-hop relay WiMAX networks. It is also worth noting that the vehicular environment(F=0.151 & p=0.698) didnot significantly enhance the WiMAX networks.

4.4 The challenges of multi-hop relay enhanced WiMAX network concept

RQ4: How do the challenge factorsassociated with multi-hop relay enhanced WiMAX affect its networking?

Table 6: Principal Component Analysis (PCA) results

Challenge/Factor		Component		
		1	**2**	**3**
Coverage holes due to 'shadowing'	F1	-.642	.121	.468
Poor signal to interference and noise ratio (SINR) for the SSs' Base Stations (BS).	F2	.919	-.039	-.002
Cost of serving few Subscribers Stations (SSs) or few users.	F3	-.719	-.039	-.002
Cost of deployments of Relay Stations (RSs) to increase cell capacity.	F4	-.320	.681	.476
The challenges of using RSS on both capacity and coverage enhancement.	F5	.048	.764	-.205
The reliability problems persist on the in-band relaying out-of-band relaying.	F6	.817	-.039	-.002
General quality of Service rating	F7	.371	.226	.398
Technical & Non-technical support services	F8	.854	-.039	-.002
Initial Eigenvalues		**4.861**	**2.115**	**1.097**
% of Variance		**54.013**	**23.498**	**12.184**
Cumulative %		**54.013**	**77.512**	**89.696**

The results in Table 6 indicate that the principal component analysis indicate three components; component1, component 2, and component 3 in describing the challenges involved in MHR enhanced WiMAX network concepts that affect LTE-Advanced framework. To interpret the challenges of MHR enhanced WiMAX network concepts and its impact in offering reliability within the LTE-Advanced framework, these three principal components were addressed. Hair et al. (1998) and Kothari (2004) agree that a factor loading which is greater than 0.7 describes a strong effect, a factor loading between 0.4 and 0.6 shows a moderate effect, while a factor loading equal or less than 0.3 is said to exhibita weak effect.

In principal component 1, the results indicate that: the factors F1, F2, F3, F6, and F8 strongly challenge the outcome of the MHR enhanced WiMAX network. These factors are coverage holes due to 'shadowing' (F1: r=-0.642), poor signal to interference and noise ratio (SINR) for the SSs' Base Stations(BS) (F2: r=919), cost of serving a few Subscribers Stations (SSs) or few users (F3: r=-0.719), reliability problems still persist on the in-band relaying out-of-band relaying (F6: r=0.817), and technical and non-technical support services (F8: r=0.854). The other factors namely, (F4; r=-0.320), (F5; r=0.048), and F7; r=0.371) had neither strong nor significant challengesin the enhancement of the MHR WiMAX network.

In principal component 2, the analysis indicated that factors F4 and F5 are strongly related to MHR WiMAX network. These factors are the cost of deployments of RS to increase cell capacity(F4; r=0.681) and the challenges of using RSS on both capacity and coverage enhancement (F5; r=0.764). Hair et al. (1998) cite that the first and second principal components are orthogonal to one another and hence, represent the highest variability within the data structure. Therefore, we will only consider the two components in this analysis.Finally, the results in Table 6 showed that the first component can explain the variability ofchallenges involved in the enhanced WiMAX network concept that affect LTE-Advanced framework by an Eigenvalue of 4.861 with thepercentage variance of 54.01. This indicates that among the challenges influencing MHR enhanced WiMAX networks through a linear combination of factors F1, F2, F3, F6,and F8 is about 54.01%.

The results also indicatedthat the second component can explain the variability of challenges involved in theMHR enhanced WiMAX network by an Eigenvalue of 2.115 with the percentage variance of 23.498. This proves that among the challenges influencing the MHR enhanced WiMAX network through a linear combination of factors F4 and F5 is about 23.498%. Lastly, the third component can explain the variability of challenges involved in MHR enhanced WiMAX network by an Eigenvalue of 1.097 with the percentage variance of 12.184. This proves that among the challenges influencing the MHR enhanced WiMAX network through a linear combination of factors F1; (r=0.468), F4; (r=0.476), and F7; (r=0.398) is about 12.184%.

Cumulatively, the first two components in explaining the variability of challenges involved in theMHR enhanced WiMAX network concept that affects the LTE-Advanced framework is about 77.512 while thefirst three components in explaining the variability of challenges involved in MHR enhanced WiMAX network is 89.696%. This translates to the fact that a linear combination of F1, F2, F3, F6, and F8 in principal component 1, will challenge the multi-hop relay enhanced WiMAX network by 54.013%, while a linear combination of principal component 1 and principal component 2, with respect to factors; F1, F2, F3, F6, and F8 on the one hand, and factors; F4 and F5, on the other hand, will challenge the MHR enhanced WiMAX network by 77.512%. Lastly, a linear combination of principal component 1, principal component 2, and principal component 3 concerning factors; F1, F2, F3, F6, and F8 (firstly), and factorsF4 and F5 (secondly), and factors F1, F4, and F7 (lastly),will challenge the MHR enhanced WiMAX network by 89.696%.

V FINDINGS AND CONCLUSIONS OF THE STUDY

Thestudy has conclusions based on data analysis results of thefour research objectives.

5.1 Socio-demographic factors about the study respondents

The study as evaluatedfinds out thatmost networking engineers/engineers/technicians involved in the multi-hop relay enhanced WiMAX network had either a master level of WiMAX network experience (40.6%) or excellent level of WiMAX network experience (31.7%). Concurrently, the networking engineers/technicians also possess specialized levels of educationwhich includes;undergraduate degree level of education (43.3%),graduate degree level of education (28.3%), and post-graduate level of education (15.0%). Therefore, the study evidently concludes that the socio-demographic factors of the engineers/technicians like education and networking IT experience are significant in the enhancement of MHR WiMAX networks. These findings concur with those of Jeffrey et al. (2007) who in their study on the fundamentals of *WiMAX: understanding broadband wireless networking*, concluded that a well-educated and highly experienced IT workforce was necessary for the enhancement of WiMAX networking.

5.2 The factors, components, technologies,and standards that affect MHR enhanced WiMAX networks

The study found that the p-values for most of the factors, components, technologies,and standards were less than 0.05. As a result, the null hypothesis was rejected,and the study concluded that internet traffic and congestion, hardware-software configuration, technical support efficiency, and LTE reliability conceptsaresignificantlycommon physical components, technologies, and wireless standards of themulti-hop relay enhanced WiMAXnetworks. Conversely, the study also indicatedthatsomefactors, components, technologies, and standards of WiMAX had p-values that were more than 0.05. Therefore, the study concluded that server speed and cost-financing implications are not significantlycommon physical components, technologies, and wireless standards that enhance themulti-hop relay WiMAXnetworks.

5.3 The effectiveness of Quality of service (QoS) in multi-hop relay enhanced WiMAX networks

The study determined that the overall QoSof WiMAX networkhad a mean value of 4.11 out of 5 possibilitieswhich was about 86.0% effective. Interestingly, all the four categories of QoS were rated highly by the networking engineers/technicians; thefree space model was rated at 78.4%, theErceg’s suburban fixed model was rated at 81.8%, the outdoor to indoor and pedestrianscenariowas rated at 80.6%, and lastly the vehicular environmentwas rated at 65.0%. results also show the overall QoS and three of its categories, namely; free space model,Erceg’s suburban fixed model, and the outdoor to indoor and pedestrianhad p-values that were less than 0.05. Therefore, the study rejected the null hypothesis and concluded that thefree space model,Erceg’s suburban fixed model, and the outdoor to the indoor and pedestrianmodel were significantly effective Quality of services (QoS) scenarios in enhancing the MHR WiMAX networks. It is worth mentioning that the studynotedthatthe vehicular environment(F=0.151 & p=0.698) was not significantly enhancing the multi-hop relay WiMAX networks.

5.4 The challenges of multi-hop relay enhanced WiMAX network concept

In principal component 1, the study found that the following factors were significant and strong challenges in the MHR WiMAX network coverage holes due to ‘shadowing’ (r=-0.642), poor signal to interference and noise ratio (SINR) for the SSs’ with respect to Base Stations(BS) (r=919), cost of serving few Subscribers Stations (SSs) or few users (r=-0.719), the reliability problems still persists on the in-band relaying with respect to out-of band relaying (r=0.817), and technical andnon-technical support services (r=0.854).Concerning principal component 2, the study found that the following factors such as the use ofcost of deployments of Relay Stations (RSs) to increase cell capacity (r=0.681) and the challenges of using RSS on both capacity and coverage enhancement (r=0.764)were significant and strong challenges in the enhancement of the MHR WiMAX network. These findings agreedwith the study by Vaidehi and Poorani (2010),who studied the handoff performance in a Mobile WiMAX network concerning “Control Automation Robotics and Vision” realizing the deployments of Relay Stations (RSs) to increase cell capacity, whichalsoimproved the WiMAX coverage enhancement.Lastly, on the third principal component,thestudy found that the factors;coverage holes due to ‘shadowing’ (r=468), cost of deployments of Relay Stations (RSs) to increase cell capacity (r=476),andgeneral quality of service rating (r=398) moderately challenged the enhancement of multi-hop relay WiMAX network.

REFERENCES

Journal Papers:

[1]. Adhicandra, I. (2010). "Measuring Data and VoIP Traffic in WiMAX Networks. Journalof Telecommunications, 2 (1) 156-89

[2]. Adebiaye, R (2017) Analysis on Mitigation of Intelli-drive Communication Congestion: Broadcasted Signal Phase in Vehicle-to-Vehicle (V2V) Safety Features Using DSRC IEEE 802.11p Standard: American Journal of Computing Research Repository. 2017, 5(1), 1-13. ISSN (Print): 2377-4606 ISSN (Online): 2377-4266. DOI: 10.12691/ajcrr-5-1-1 http://www.sciepub.com/ajcrr/content/5/1

[3]. Bapuji, V. and Sharma, S.S.V.N. (2011). "Quality of service for mobile Ad-Hoc wireless networks, "International Journal of Computer Science and Engineering, 3(4), 1573-1577.

[4]. Bhosale, S. &Daruwala, R.D. (2013). "Performance Evaluation of QoS Parameters during WiMAX to WiMAX Handoff using NS2 and QualNet", International Journal of Computer Applications (0975–8887) 64(9) 121-36

[5]. Grewal, V. & Ajay, K.S. (2010). "On Performance Evaluation of Different QoS Mechanisms and AMC scheme for an IEEE 802.16 based WiMAX Network". International Journal of Computer Applications. 6(7), 452-468.

[6]. Hammoshi, M. (2011). "WiMAX Simulation Model to Investigate Performance actors. Journal of Convergence Information Technology. 6(1) pp.

[7]. Jangra, K. & Kavita, D. (2012). "Comparison and analysis of wireless networks for healthcare telemonitoring systems. "International Journal of Research in Computer Application & Management. 12(2):125-130.

[8]. Joon, R., Manveen S. & Chadha S. (2012). "Analysis of WiMAXhandover. International journal of soft computing and engineering (IJSCE). 2(2): 476-479.

[9]. Kalpana, C., Upena, D. &Dalal, R. J. (2012). "Mobile Governance based on WiMAX Connectivity for Rural Development in India,"I. J. Computer Network and Information Security. 5(4), 49-55. in MECS: http://www.mecs-press.org/

[10]. Khan, S., Ji-Hyun L. & Golam, R. K. (2012). "Evaluation of parameters for improving handoff performance in mobile WiMAX networks."International journal of distributed and parallel systems. 12(3): 85-98.

[11]. Singh W. & Sengupta, J. (2011). "Performance Evaluation of a Cell site in Cellular Networks Using WiMAX technology," GESJ: Computer Science and Telecommunications Journal. 2(31), 1212-1232

[12]. Vaidehi, V., &Poorani, M. (2010). "Study of handoff performance in a Mobile WiMAX network." In: Control Automation Robotics & Vision (ICARCV) 11th International conference; Singapore:IEEE. pp. 2319-2324.

Books:

[13]. Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998), Multivariate Data Analysis, 5th ed., Prentice-Hall, Englewood Cliffs, NJ.

[14]. Hrudey, W. &Trajkovic, L. J. (2008). "Streaming video content over IEEE 802.16/WiMAX broadband access," OPNETWORK, Washington, DC.

[15]. Jeffrey, G. A., Arunabha, G. & Riaz, M. (2007). Fundamentals of WiMAX: understanding broadband wireless networking. Prentice Hall Communications Engineering and Emerging Technologies Series.

[16]. Kothari, C.R. (2004). Research methodology and techniques; 2ndedition.NewDelhi.New York. New Age InternationalPublishers.

[17]. Krueger, A. and Casey,M.A. (2000). Focus Groups: A Practical Guide for Applied Research 3rded.Thousand Oaks, C.A, and Sage.

[18]. Mugenda,O.M.&Mugenda,A.G.(2003).Researchmethods. Qualitativeand quantitative approaches. Nairobi: Acts Press.

[19]. Ramjee, P., Fernando J. & Velez, F. (2010). WiMAX Networks: Techno-Economic Vision and Challenges, Springer, 2010.

[20]. Yongxue, Y. (2009). Handover performance in the mobile WiMAX networks. MSE, University of South Florida, Tampa, Florida.

[21]. Zakhia, A., Yanlin P., & Chang, J. M. (2006). WiMAX: The Emergence of Wireless Broadband, IT Pro magazine IEEE computer society.

[22]. Zhang Y. & Chen, H. (2008). Mobile WiMAX: Toward Broadband Wireless Metropolitan Area Networks, edited, New York: CRC Press.

Richmond Adebiaye. " Assessment/Analysis of Multi-Hop Relay-Enhanced Wimax Networks and the Reliability Concept of Long Term Evolution Advanced (LTE-A) In 4G Wireless Technology"American Journal of Engineering Research (AJER), vol. 7, no. 5, 2018, pp.136-146.