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PRICE BASED TRAFFIC CONGESTION CONTROL IN THE UPCOMING 5G DEPLOYMENT

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ABSTRACT

The demand for data in the 4G (Fourth Generation networks) and 5G (Fifth Generation networks) is becoming excessively high and the solution is being investigated to effectively utilize the available spectrum at the physical layer across different protocols to speed-up access from 2.5 to 10 times. Furthermore, the current proposals for 5G systems is envisaged to increase spectrum efficiency which brings about customer satisfaction, network density and operational efficiency, using newly 3.5 GHz NCC auctioned spectrum bands. The CPU processing power and cloud computing are expected to be the key driving factors in the evolution of wireless Network from 1G to 5G. These support wide range of new technologies like IoT, smart cities and Cyber and information Security as well as broadband penetration using entirely new Network architectural concept as a total transformation. This paper presents 5G network tariff implementation strategies and proposes a model of revenue generation which would enable a market mechanism that would allow the customer to communicate with the 5G Network and negotiate a contract based on some QoS (Quality of Service) parameters like blocking probabilities of High Priority Users (HPUs) and Low Priority Users (LPUs) , delay, and price. The percentage Improvement in Cumulative Revenue (CR) generated by the proposed model over the existing models is 10. Recommendations were made on the way forward for the optimum 5G tariffs in the Nigerian context.

Keywords: 4G (Fourth Generation networks) and 5G (Fifth Generation networks), QoS (Quality of Service), blocking probability, High Priority Users (HPUs) and Low Priority Users (LPUs)

INTRODUCTION

As the world's demand for data is increasing at an amazing rate, there is a need for seamless and ubiquitous content rich interoperability between the Wireless Service Providers (WSPs). With current 4G and 5G customer devices consuming tremendous amount of data, the current network architecture needs major transformation to meet up with the subscribers' demand. The 5G network as a fifth generation mobile technology is expected to outperform earlier versions of wireless communication technology (Huawei, 2021). Fifth Generation (5G) wireless communication network development addresses the shortcomings of the current Fourth Generation (4G) LTE and WiMAX. The 5G networks for future applications in all domains support wide range of new technologies like IoT, smart cities and Cyber and information Security as well as broadband penetration. It would support the administration of new governance, enhancement of current business models, efficiency in the health care delivery, economic growth and insecurity reduction in the totality of human endeavor (Bakare et al, 2021). According to the International Telecommunication Union's IMT-2020 standard 5G is expected to offer a theoretical peak download speed of 20 gigabits per second and 10 gigabits per second upload speed, 99.999% reliability and less than 1 msec latency. The QoS parameters like speed, priority queuing and reliability need to be differentiated for optimal volume-based tiering tariff implementation so as to increase customers' WTP (Willing to Pay) for 5G services.

LITERATURE REVIEW

In Rong et al (2007), a utility and fairness constrained optimal revenue strategy for WiMAX downlink CAC (Call Admission Control) optimization is proposed in order to successfully deploy a commercial WiMAX (Wireless Interoperability for Microwave Access) system. In this work, there is a service differentiation and no priority scheme. Yaipairoj S, et al (2007) proposed a pricing model for General Packet Radio Service (GPRS) networks integrated with Wireless Fidelity (Wi-Fi), which applies to data users with high service demand ("heavy"). The proposed models identify how the integration can play a significant role in increasing operators' overall revenue and potentially improving the performance of the Mobile WiMAX networks. The research gap which motivated us to improve on Yaipairoj et al (2007) is the potential application of the proposed demand function in the development of an efficient price and utility based Congestion Control scheme that optimally shape users' traffic in terms of delay, service class partitioning, and prioritization for wireless users in Mobile WiMAX network. The Demand/Utility function yielded optimal revenue as a result of enhanced system utilization with guaranteed users' satisfaction. There is a priority scheme and no Service differentiation.

The work of Mughele and Wole (2012) investigated the causes of congestion using a survey research design methodology, live data from MTN BTS and BSC, as well as customer feedback. The study showed that a major cause of MTN network congestion is lack of adequate network resources to cope with the demand of its teeming subscribers. Similarly, Ohaneme et al. (2012) simulated some traffic models in MATLAB environment for evaluating performance of GSM networks using Call Completion Ratio (CCR) and Answer Seizure Ratio (ASR) on four mobile network's BTS and BSC in Nigeria. The result showed that the QoS is not reliable as a result of network congestion. However, the work did not identify the cause or proffer solution to the congestion problem. Ozovehe1 et al (2011) addressed congestion during busy hour and analyzed real-time traffic user to predict the traffic demand pattern on network resources for proper prediction of network congestion so that resources can be provided to take care of rejected or diverted traffic.

In Thumar et al, (2011), the utility functions for both the entities of the Cognitive Radio network, i.e. the HPU and LPU, are formulated with two important considerations: the HPU is the priority user and has a soft rate demand to be satisfied; and the LPU's net utility involves a cost for relaying the HPU's traffic. Maximizing the utilities of the HPU and LPU are conflicting objectives. Symbiotic and Cognitive In this scheme there is no Priority scheme and no Service Differentiation. Nnamdi, Aneke and James (2017) have developed a control algorithm for the management of the congestion experienced in the GSM network in Nigeria. It explores the use of Erlang-B in determining the appropriate probability level for some range of subscribers, dynamic allocation with and without time slicing, coupled with signal sensing, frequently recent call allocation, and priority allocation algorithms were developed to manage the congestion. Furthermore, a hybrid algorithm was developed that integrates all the algorithms together, Galadanci and Abdullahi (2019) utilizes the log files data generated on three active GSM networks in Kano, and intensively evaluated statistically using the Minitab statistical software package. The traffic performances of three key teletraffic parameters of GSM network, during the seven months' duration including the festive periods, is evaluated using regression analysis. A traffic model over some key parameters was developed. Emuoyibofarhe and Ozchi (2015) recommended the need to restructure and re-plan the cells in particular geographical regions in the south west with high traffic intensity and is achieved by increasing the number of channels in those cells (stations) and also, by provision of more cell sites in order to ensure proper caution in the frequency re-use factor so as to prevent other transmission challenges that can affect the grade of service rendered to the Subscribers resulting into congestion in the traffic. In Mowafi, et al (2012), a scheme of management of the available bandwidth in a WiMAX system along with the QoS requirements of different traffic classes is proposed. WiMAX Dual Cognitive Radio Scheme (WDCRS) is proposed in order to obtain high bandwidth utilization, high throughput. The scheme achieves higher bandwidth utilization and lower blocking probability compared to existing schemes. Shuaibu D.S. (2012), presented partitioning resource based CAC service differentiation and link aware. The CAC algorithm that partitions traffics to constant bit rate (CBR) and variable bit rate (VBR) for service differentiation is proposed. The scheme did not develop a dynamic pricing algorithm for both the classes to enhance WSP (Wireless Service Providers) revenue and to maximize the users' total utilities. In this scheme, there no any Demand/Utility function. The Service Differentiation Improved overall service flow acceptance. The advantage of the proposed model shall be users' fairness as they would only be charged when they start to utilize the bandwidth. Considering the shortcomings of the above mention models, another model that considered an initial HPU bandwidth utilization and could be able to do congestion control by tuning the values of Price Leveling Factor PLFs has been proposed in this work according to the introduced concept of the proposed utility and acceptance probability models.

MATERIALS AND METHODS

The rising demand for mobile communication services is increasing, hence the importance of efficient use of the limited bandwidth and frequency spectrum. In recent years, considerable efforts have focused on the channel allocation and Call Admission Control (CAC) problems (Shuaibu, 2012). CAC is the process that attempts to control the number of connections in the network in order to make feasible the allocation of the available resources to meet the users' QoS requirements. In the Queuing Priority Schemes (QPS), when all channels are occupied, either new calls are queued while handoff calls are blocked or new calls are blocked while handoff calls are queued (Yaipairoj et al, 2007). If the overload lasts for a long period, the QPS cannot achieve a better performance either. When one user is admitted into the network, it will cause QoS degradation to other users. In term of the economic perspective, this phenomenon is recognized as "Externality" (Danbatta, 2015). In general, we can observe that the most serious QoS violation (Externality) occurs when the system is congested. However, the current CAC schemes cannot optimally avoid congestion because they do not provide incentives for users to use the channel resources effectively. Radio resource management is mainly on the MAC layer and Physical Layer (Vuong, 2008). Figure 1 represents the proposed pricing schemes at different congestion levels.

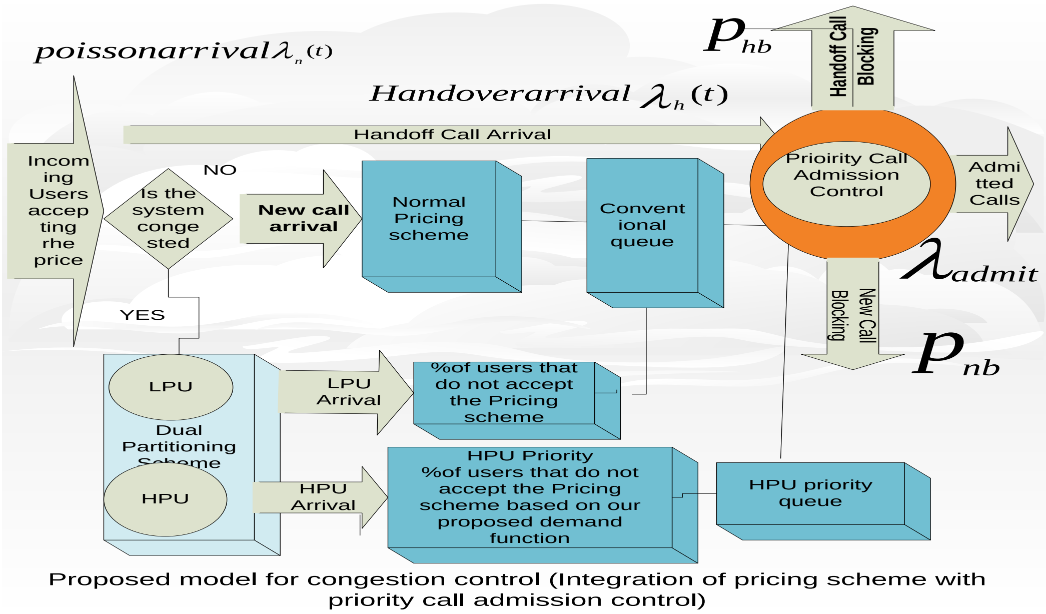

Figure 1: Proposed model for congestion control

The QoS of both types of queues can be identified by the user delay in the queues. That means the time that their call requests spend in the queue can be seen as the tail of a delay distribution.

$$P[W > t_h) = C(N_h, a_h) * e^{-N_h\mu(1-\rho_h)t_h} \qquad (1)$$

$$P[W > t_h) = C(N_h, a_h) * e^{-N_l\mu(1-\rho_l)t_l} \qquad (2)$$

$P[W > t_l) = C(N_h, a_l) * e^{-N_l\mu(1-\rho_l)t_l}$ Where $C(N_h, a_h)$, $C(N_l, a_l)$ is Erlang C formula for High Priority Users and Low Priority Users respectively, W is user delay (time in queue), a_p and a_c are the loads from High Priority Users and Low Priority Users, N_h and N_l is the number of channels logically assigned to High Priority Users and Low Priority Users, μ is the average departure rate of users ($1/T_{avg}$), ρ_h and ρ_l are the load per server for High Priority Users and Low Priority Users respectively, t_h and t_l are QoS requirement for priority queue and Low Priority queue respectively. The system will guarantee the time that mobile user's call request would not exceed amount of time. The t_h would be a lot less than t_l. when the system enters into congestion. Utilization of the system is given by (Yaipairoj et al, 2007) as

$$Utilization = \frac{call\ arival\ rate * T_{avg}}{N} \qquad (3)$$

The Revenue Generated by High Priority Users (Danbatta, 2015)

$$R(p)^{HPU} = \sum_{i=1}^{N_{HPU}} \mathbf{p}_i^{HPU}(t) * \lambda_{max}^{HPU} * \left(\left(1 - \left(\frac{p_i^{HPU}(t) - p_{min}^{HPU}}{p_{max}^{HPU} - p_{min}^{HPU}}\right)^{\alpha}\right)\right)\left(1 - C(N_p, a_p) * e^{-N_p\mu(1-\rho_p)t_p}\right) \qquad (4)$$

For $\alpha > 1$, the Revenue Generated by Low Priority Users (Danbatta, 2015)

$$R(p)^{LPU} = \sum_{j=1}^{N_{LPU}} \mathbf{p}_j^{LPU}(t) * \lambda_{max}^{LPU} * \left(\left(1 - \left(\frac{p_k^{LPU}(t) - p_{min}^{LPU}}{p_{max}^{LPU} - p_{min}^{LPU}}\right)^{\alpha}\right)\right)\left(1 - C(N_l, a_l) * e^{-N_c\mu(1-\rho_l)t_l}\right) \qquad (5)$$

For $\alpha < 1$, the Total Revenue Generated by High Priority Users and Low Priority Users (Danbatta, 2015)

$$R(p) = \sum_{i=1}^{N_{HPU}} \mathbf{p}_i^{HPU}(t) * \lambda_{max}^{HPU} * \left(\left(1 - \left(\frac{p_i^{HPU}(t) - p_{min}^{HPU}}{p_{max}^{HPU} - p_{min}^{HPU}}\right)^{\alpha}\right)\right)\left(1 - C(N_p, a_p) * e^{-N_p\mu(1-\rho_p)t_p}\right) + \sum_{j=1}^{N_{LPU}} \mathbf{p}_j^{LPU}(t) * \lambda_{max}^{LPU} * \left(\left(1 - \left(\frac{p_k^{LPU}(t) - p_{min}^{LPU}}{p_{max}^{LPU} - p_{min}^{LPU}}\right)^{\alpha}\right)\right)\left(1 - C(N_c, a_c) * e^{-N_c\mu(1-\rho_c)t_c}\right) \qquad (6)$$

Where, $(\mathbf{p}_i^{HPU}(t), \mathbf{p}_j^{LPU}(t),)$ is a vector of a price paid by High Priority Users and Low Priority Users respectively.

RESULTS AND DISCUSSION

Mat Lab simulation software was utilized to evaluate the performance of the proposed integrated pricing and call admission control in terms of congestion prevention, achievable total user utility, and obtained revenue. The achieved performance of different variations of the proposed integrated approach has been compared with the existing model. The variations model the potential behavior of users with regard to pricing and call blocking, with the corresponding results of conventional systems where pricing is not taken into consideration in the call admission control process. The Erlang B and C models were utilized for the blocking and waiting probability of the traffic respectively. The total number of channels has been maintained at 30. The average holding time for both the priority and conventional users is 200msec. The maximum and minimum acceptable prices are $8 and $22 per unit respectively. The proposed efficient demand functions were developed to cater for the shortcomings of the existing demand functions that are not taking the price and bandwidth ranges and charge infinite congestion price. The priority factor of 0.8 implies that 80% of the channels are allocated to the HPUs during congestion. Other values greater than 80% could be used. Table 1 presents the simulation parameters for the proposed model and Yaipairoj, et al. model.

In the simulation, the graphs of Revenue and Cumulative Revenue (CR) generated by the proposed model and Yaipairoj, model are plotted against the QoS parameters.

From Figure 1, it can be seen that the cumulative revenue generated by both the two models are at the highest point when there is no congestion, that is the blocking probability is 0%. At this point the proposed model generated a CR (Cumulative Revenue) of $1100, and the least is a CR of $1000 generated by Yaipairoj model. As the blocking probability increases from 0 to 0.045, the CR drops down from the highest values to $100.

Table 1: The Simulation Parameters for the Proposed Models P&U-CC is Price and Utility based Congestion Control and Yaipairoj model

Parameters	**Proposed models parameters**	**Yaipairoj model parameters**
Blocking Probability model	Erlang B model	Erlang B model
Waiting Probability model	Erlang C model	Erlang C model
Minimum acceptable Price	$8	$8
Average Holding Time for priority users	200sec	200sec
Average Holding Time for conventional users	200sec	200sec
HPU maximum Congestion Price	$22	Infinity
Demand function Used	**Proposed Model P&U-CC**	**Odlyzko, A. (2001)**
Total Number channels	30	30
Priority factor	0.8	0.8
Gamma	1.5820	1.5820

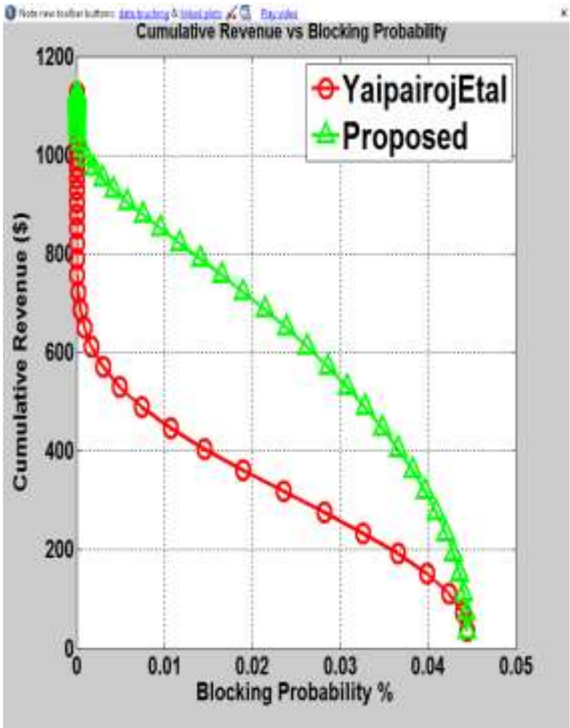

Figure 1: Cumulative Revenue vs. Blocking Probability

The plot of revenue against the probability of a priority user waiting for more than 1 minute is shown in Figure 2. It can be seen that the revenue generated by the proposed model at the zero probability of a priority user waiting for more than 1 minute ranges from 0 to $50. The revenue generated by the Yaipairoj model at the zero probability of a priority user waiting for more than 1 minute ranges from 0 to $38. The % improvement of the revenue generated by the proposed model at the 0.06 probability of a priority user waiting for more than 1 minute over the revenue generated by the Yaipairoj model at the same probability of a priority user waiting for more than 1 minute is 3.5%. All the two models generated the same revenue of $38 when the maximum acceptable probability of a priority user waiting for more than 1 minute is 0.17.

From Figure 3, it can be seen that the cumulative revenue generated by all the two models are at the highest point when there is no congestion, that is the probability of a priority user waiting for more than 1 minute is 0%. At this point the proposed model generated a CR of $1800, and the least is a CR of $1200 generated by Yaipairoj model. As the probability of a priority user waiting for more than 1 minute increases from 0 to 0.165, the CR drops down from the highest values to $100.

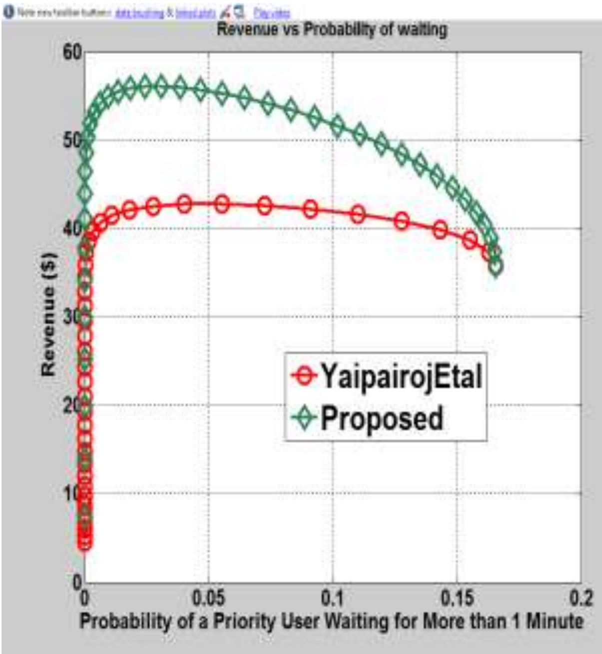

Figure 2: Revenue vs. Probability of Waiting

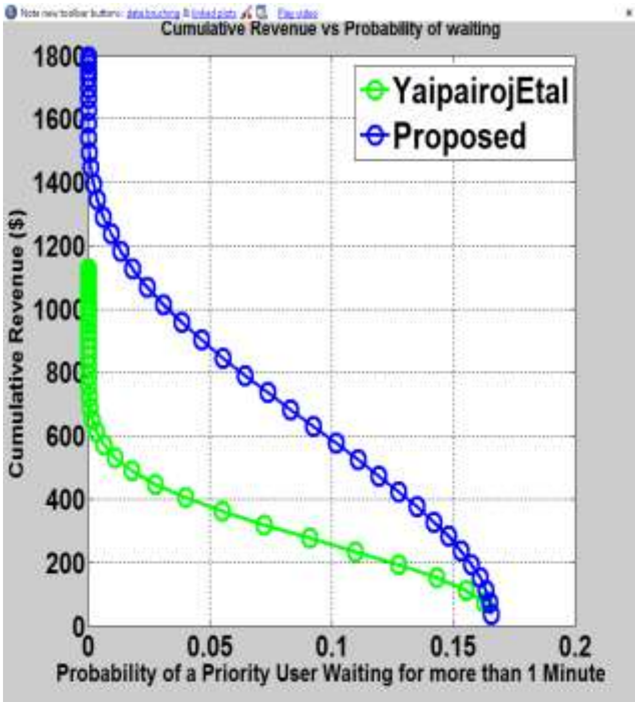

Figure 3: Cumulative Revenue vs. Probability of Waitin

Table 2: SUMMARY OF RESULTS

QoS Parameters	Revenue generated by **Proposed P&U-CC**	Revenue generated by **Yaipairoj model**	Cumulative revenue generated by **Proposed P&U-CC**	Cumulative revenue generated by **Yaipairoj model**	REMARKS
Blocking probability=0			$1100	$1000	% Improvement in CR is 10 As the blocking probability increases from 0 to 0.045, the CR drops down from the highest values to $100.
Probability of priority user waiting for more than 1 minute=0	$0-$50	$0- $38			% Improvement in Revenue ranges from 0 to 24%. All the two models generated the same revenue of $38 when the maximum acceptable probability of a priority user waiting for more than 1 minute is 0.17.
Probability of priority user waiting for more than 1 minute=0			$1800	$1200	% Improvement 33.3%
Probability of priority user waiting for more than 1 minute (0 - 0.165			CR drops down from the highest values to $100.	CR drops down from the highest values to $100.	For both the models the CR drops down from the highest values to $100.

CONCLUSION

The proposed dynamic pricing is capable of preventing network congestion by reducing the arrival rate, if the users are prioritized. Interoperability, data generosity, QoS, and new 5G applications and services are expected to increase customers' WTP for 5G services and aim for an increase in an ARPU (Average Revenue per User). There has to be a trade-off between device costs and market competition during 5G commercial launch. In the proposed model, the 5G network was designed based on economic concepts and user behavior to provide an overall call admission strategy that simultaneously alleviates the network congestion, meets the QoS requirements of users, increases the network operator revenue and uses the network resources efficiently. Marketing strategies within the ecosystem would enable the NSPs to introduce speed, latency, and reliability based tariff plans. There is a need to conduct technical and economic feasibility studies before 5G Implementation. The research in 5G should be sponsored by 2G/3G/4G licensed Telecoms Operators in Nigeria. The NCC should provide take up research grants to various academic research institutions in Nigeria.

REFERENCES

Bakare KA, Lawal I.B Nafisah M.M and Abdulsalam A.J (2021) A, Review On 5G Wireless Network Implementation Strategies In Nigeria *FUDMA Journal of Sciences (FJS)I SSN online: 2616-1370 ISSN print: 2645 – 2944 Vol. 5 No. 2, June, 2021, pp 419-427*

Danbatta, K.B. (2015). *The Development of Price and Utility based Congestion Control Model in Mobile WiMAX*. A Thesis Submitted in partial fulfillment of the requirements of ***Bayero University Kano*** for the Degree of Doctor of Philosophy.

https://carrier.huawei.com/en/products/service-and-software/5G-Services (2021)

Yaipairoj, S. (2006). *Enhancing Performance of Mobile Services through Pricing Mechanisms.* A Thesis Submitted in partial fulfillment of the requirements of Stevens Institute of Technology for the Degree of Doctor of Philosophy.

Fishburn, P.C. and Odlyzko, A.M. (1998). *Dynamic Behavior of Differential Pricing and Quality of Service options for the Internet,* in IC E '98, pp. 128-139.

www.ncc.gov.ng/documents/918 2020. *Consultation Document on Plan for 5G Deployment in Nigeria.* Retrieved on 7th March, 2021

Yaipairoj, S., Harmantzis, F. and Gunasekaran, V. (2005). *A pricing model of GPRS networks with Wi-Fi integration for ''heavy'' data users,* In Proceedings of

IEEE second international conference on E-business and telecommunication networks (ICETE 2005). Reading, UK, October 3–7, 2005.

Rong B, Qian Y. and Kejia, L. (2007). *Downlink Call Admission Control in Multiservice WiMAX Network* IEEE Communication Society International Conference on Communication ICC proceedings, 5082-5087.

Mowafi, M. Y., Al-Mistarihi, M. F. and Marei, M. S (2012). *A Dual Usage of Cognitive Radio in Managing the WiMAX Band width* MIPRO /CTI

Aliyu Ozovehe, Okpo U. Okereke and Anene E. *Literature Survey of Traffic Analysis and Congestion Modeling In Mobile Network* IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 10, Issue 6, Ver. I (Nov - Dec .2015), PP 31-35 www.iosrjournals.org

G.S.M Galadanci, S. B. Abdullahi **(2019)** *'Modeling the Traffic Load of Selected Key Parameters for GSM Networks in Nigeria'* International Journal of Digital Information and Wireless Communications 2019.

Emuoyibofarhe, Ozchi, (2015) *Performance Analysis of Traffic Control Congestion Management in Mobile Wireless Communication in South West Of Nigeria.* Journal of Multidisciplinary Engineering Science and Technology (JMEST) ISSN: 3159-0040 Vol. 2 Issue 7, 2015

Ahuchaogu Nnamdi, Ezekiel Nnamere Aneke, Eke James (2017) *'Improving Quality of Service in GSM By Reducing Probability of Call Blocking Through Network Dimensioning Using Erlang B Model and Congestion Control Algorithm'* International journal of scientific and technical research in engineering (IJSTRE) www.ijstre.com Volume 2 Issue 6 ǁ June 2017.