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Minimization of Call Blocking in a Wireless Mobile Communication System Using Adaptive Traffic Model

Arinze SN*, Onoh GN
Department of Electrical and Electronic Engineering Enugu State University of Science and Technology (ESUT) Enugu State, Nigeria

Original Research Article

***Corresponding author**
Arinze SN

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Abstract: Call blocking is the inability of mobile users to gain access to the network. Despite the strong signals displayed on the subscriber's phone, several attempts to make successful calls usually end in failures. This research work was focused on an adaptive traffic modeling for reducing call blocking probability in a wireless mobile communication system. It was aimed at developing a good traffic model that will enable the service providers to utilize the allocated channels as efficiently as possible so as to reduce call blocking probability. Etisalat Nigeria mobile network was used as the study field. Firstly, the traffic pattern of the network was determined. This was achieved by using the performance and monitoring tool to measure the system traffic volume. Then, the channel utilization of the network was obtained by measuring the busy hour attempted call, successful call during busy hour, busy hour blocked call, available traffic channels using the key performance indicator. Erlang B model was used to evaluate the system performance using the data obtained. This was done by varying the traffic load with increasing and decreasing number of channels. An adaptive traffic model using artificial neural network was then developed to minimize the call blocking probability. The developed model was simulated using artificial neural network fitting tool. Using a developed algorithm, the model was compared with the fixed channel allocation and dynamic channel allocation. The results obtained showed that the artificial neural network maintained the lowest call blocking probability. This model has an improved performance over the existing system.
Keywords: Call Blocking Probability, Key Performance Indicator, Traffic Model, Traffic Load, Channel Utilization, Channel Allocation, Artificial Neural Network, Multilayered Feed Forward Neural Network.

INTRODUCTION

Tremendous Worldwide increases in the demand for mobile communication application services and constant growth of the number of subscribers have made the mobile network to experience a significant increase in traffic. It tends to deteriorate network service quality which manifests most in call blocking. Despite the strong network signal displayed on subscriber's phones, several attempts to make successful calls usually end in failures. This situation usually frustrates mobile users especially when he or she wants to make an urgent call. This is caused by poor spectrum utilization particularly when the network does not have a good traffic scheme for managing its numerous loads or signal flows.

Thus a mobile communication network should have a scheme for efficient channel utilization to avoid call blocking. Without a proper solution to this problem, it will because the subscribers to migrate to other network providers thereby reducing the revenue that should be accrued to the former network provider.it may also cause subscribers to have two subscriber identity module (SIM) cards on one handset. Minimization of call blocking remains a critical issue and a high priority especially given the growing size and demand of the networks. Many researchers have proposed traffic models on reducing call blocking.The authors in [1] used queuing theory as a model technique which examines everycomponent waiting in line to be served, including the arrival process, service process, number of servers, and the number of customers. These were analyzed using the Markov chain to develop a blocking probability. It posed a significant role in determining the number of channels required to serve a certain traffic load in a particular geographical location but failed to minimize the blocked calls to a low value for a good QoS. A fuzzy based call admission control schemewas developed in [2] which overcame measurement errors, traffic model uncertainty and avoided the requirements of complex mathematical relations among various design parameters. Above all, it was able to achieve low call blocking probability but to a minimum extent. Another proposed scheme for reducing call blocking probability in cellular network using auxiliary station by providing channels to the originating calls was developed in [3]. The work was useful in reducing call blocking probability but it has a high expenditure. A work in [4] analyzedTraffic models for wireless communication networks" by using deterministic fluid and stochastic traffic model. The work was useful in examining various phenomena in wireless network such as blocking probability but it has no capacity constraints and hence not suitable to quantify the blocking probability for new call attempts, hand off calls and retries of blocked calls in real live network.In [5] Engset multi-rate loss model technique was used to reduce call blocking probability. Multiple service classes with quasi-random call arrival process, explicit distinction between new and hand off calls were considered and then preceded to the calculation of local and new call blocking probabilities. An efficient model for reducing soft blocking probability in wireless cellular network by extending the Kaufman – Robert's algorithm was presented in [6]. This algorithm allows an efficient approximation of the blocking probabilities but yields accurate result only for low user's activities. Therefore it cannot be used extensively for large networks.

The author in [7] presented models for minimization of call blocking which includes partnership between government and corporate organization with GSM Operators National roaming agreement Regionalization, merging of networks and dynamic half rate decoding. He concluded that service providers have to continuously monitor and optimize their network. In [8], the researchers used Xie and Kuek's traffic model (which assumes a uniform density of mobile users throughout an area of coverage and that a user is equally like to move in any direction with respect to cell boundary but it cannot serve a densely populated area. Another research by [9] combined dynamic load balancing technique with call admission control to re-route calls that would have been dropped to another less busy cell within the BSC area. Their scheme allowed mobile users to access idle radio channels in another wireless network. The network in focus was for homogenous network not heterogeneous networks. Their obtained results showed that cells were enabled to accommodate more calls thereby increasing the call carrying capacity of the network but not to a large extent. In [10], a load balancing scheme was proposed and used simultaneously in all the cells. The performance of their proposed scheme was presented in terms of call blocking probability and channel utilizations. It was found to reduce the call blocking but to a minimal level in a highly congested cell. A dynamic channel allocation algorithm was developed in [11] to reduce call blocking probability. Channels used were placed in a pool and assigned based on demand. Traffic load was distributed in the network instead of concentrating it in a particular cell. It minimized call blocking probability but there was computational complexity, exhaustive checking of channels and improper channel allocation in the pool system. In this research the proposed adaptive traffic model minimized call blocking probability by using the intelligent capability of artificial neural network to assign channels according to the current system conditions and channel usages without consuming time, exhaustive checking of channels, algorithmically complex and as well respond correctly to unseen input patterns based on the knowledge and features captured from the training set.

Theory of work

These contain the available technologies, ideas and theories relevant to this work.

Channel allocation techniques

It is a means of allocating the available channels to mobile network. It is a scheme for increasing capacity. It stabilizes the fluctuations in the probability of call blockage over the entire coverage area of a network over time. It can be classified as fixed and dynamic. In fixed channel allocation, each cell is assigned a predetermined set of voice channels. Any call attempt within the cell can only be served by the unused channels in that particular cell. If all the channels in the cell are occupied, the call is blocked. The user does not get service. Although FCA is common in most existing cellular radio systems, it is not well suited for varying traffic conditions and the cost of increasing capacity can be high as more channels are needed to be acquired from the regulating agency. This seemingly impossible act makes FCA less attractive in the densely populated environment. In dynamic Channel allocation, voice channels are not allocated to different cells permanently. Channels are placed in a pool and assigned to a new cell according to the overall signal to interference pattern in all cells. Each channel can be used in any cell as long as it satisfies the signal to interference ratio requirements for the system. The channel is returned to the pool after the cellular cell is terminated [12].

Traffic Requirements

Traffic is the use of radio channels and when a user makes a phone call, the channel is seized for communication. To model a system and to analyze the change in traffic after designing, the static characteristics of an exchange should be studied. The incoming traffic undergoes variations in many ways. Due to peak hours, business hours, seasons, weekends, festival, tourism area, the traffic is unpredictable and random in nature. So the traffic pattern and traffic models should be analyzed for the system design. The grade of service, call setup success rate, channel utilization and the call blocking probability are also important parameters for the traffic study.

- Busy Hour–It is the sixty minutes interval in a day in which the traffic volume or the number of call attempts is greatest. It is the period when incoming calls are most likely to be blocked or turned away.
- Call Setup Successful Rate (CSSR)–It is the ratio of the number of successful calls to the number of call attempts.
- Grade of Service (GoS) – It refers to the proportion of unsuccessful calls relative to the total number of calls. GoS is defined as the ratio of lost traffic to the offered traffic.it is directly rated to the blocking probability
- Channel Utilization Rate (CUR) – It is the percentage of the total number of successful calls to the total available channel
- Call Blocking–Call blocking in telecommunication is when a circuit group is fully occupied and unable to accept further calls. Due to blocking, calls are either queued or lost. Call blocking probability is the probability of call losses for a group of traffic channels. It defines the chance that a customer will be denied service due to lack of resources. When all servers are busy, then the system cannot process incoming traffic and in this situation, incoming traffic are believed to experience blocking. It is mostly calculated during the busy hours.
- Traffic Load–Traffic load is the ratio of calls arrivals in a specified period of time to the average amount of time taken to service each call during that period. It is the number or volume of calls intensity (λ) and service time (mean holding time μ)
- Traffic models are used as the basis for the design of network application and for capacity planning of networking systems. The earliest models were largely Poisson based but the modern systems that account for complexities requires more accurate models that will greatly enhance the accuracy of network dimensioning, extending network investments and increasing the profit returns. The modern traffic model that have the widest adoption are Erlang B, Extended Erlang B, Erlang C and Engest [7].

Multilayered feed forward neural network

It is the most popular neural network architecture in use because of its simplicity and ease of its utilization in various applications. The structure of its network is shown in fig.1

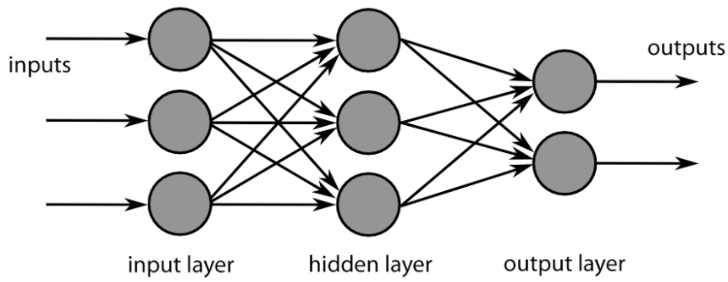

Fig-1: Multilayered feed forward Neural Network (MFNN)

It can be seen that it consists of several layers of interconnected processing elements known as neurons. The function of a neuron is to sum up all its weighted input values and generate an output via a transfer function. The neurons are linked together by means of excitatory and inhibitory connections called weights. These weights are adjustable and they represent the strength of the corresponding connections. As the weights are being modified, the correlation between successive layers of neurons is altered and the network is adapted collectively so as to capture the essential characteristics of the information presented to it. The process of weight adaptation is commonly known as training of a neural network. The training of the MFNN is usually accomplished using the back propagation algorithm, which is a form of supervised error-drives learning. During the training phase, the back propagation requires a full set of input stimuli and the corresponding set of output responses for each training input pattern, the output pattern of the network is compared to the output exemplar and any difference between them is considered as an error. This error is known as mean squared error (MSE) which is calculated as the mean square difference between the desired output and the actual response. The modification of the weight continues until the acceptable level of MSE is reached.

Levenberg-Marquardt Algorithm

The Levenberg-Marquardt algorithm is anideal method that gives a quantitative solution to the problem of reducing a non-linear function. It is one of the permutations of the multilayered feed-forward neural network. It involves a repetition refinement to parameter values in order to minimize the sum of the squares of the errors between the function and the calculated data points [13].

The Levenberg-Marquardt curve-fitting method is a fusion of two minimization methods namely the Gradient Descent and the Gauss-Newton method. The summation of the squared errors in the gradient descent method is minimized by amending or improving the parameters in the steepest descent direction while the summation of the squared errors in the Gauss-Newton method is reduced by locating the least of the quadratic.

This algorithm has an efficient implementation in MATLAB software since the solution of the matrix equation is a built in function, so its attributes become even more pronounced in a MATLAB environment. In the MATLAB environment, the algorithm trains the neural network by dividing the dataset (input and target) into train, test and validate. The division ratio 70%:15%:15% is used to control how the network parameters are adjusted during each epoch.

Training stops when the maximum number of epochs is reached, the maximum amount of time is exceeded, performance is minimized to the goal and performance gradient falls below a set minimum.

METHODOLOGY

The work was carried out in five steps. The first step was to determine the traffic pattern of the network under study.it involves using key performance and monitoring tool to query the traffic volume .Having obtained the busy hour traffic, the next step was to evaluate the channel utilization of the network. With the result obtained, the key performance indicator tool was used to determine the channel utilization of the network during the busy hour. The system performance was then analyzed in terms of call blocking using Erlang-B formula. An adaptive traffic model using artificial neural network was developed. The developed model was simulated using artificial neural network fitting tool. Finally an algorithm was used to compare the developed model with the existing model for accuracy.

Tool used for the work

Network Management Systemis a set of hardware and software tools that allow an IT professional to supervise the individual components of a network within a larger network management frame work. Its component assist with identifying what devices are present in a network, monitoring the network components and the extent to which their performance matches capacity plans and tracking performance indicators such as channel utilization. The platform receives and processes events from the network elements such as the mobile switching center in the network.

The network management system consist of the

- Network Element (NE): It consist of the mobile switching center which is the primary service node for GSM and responsible for routing voice calls.
- M2000 System: It consists of M2000 server, M2000 client and alarm. It works in client /server mode. It is responsible for monitoring, analyzing and controlling network performance.
- LAN Switch: It is a packet switching in which data packets are transferred from the M2000 server to the M2000 client in the network management system.

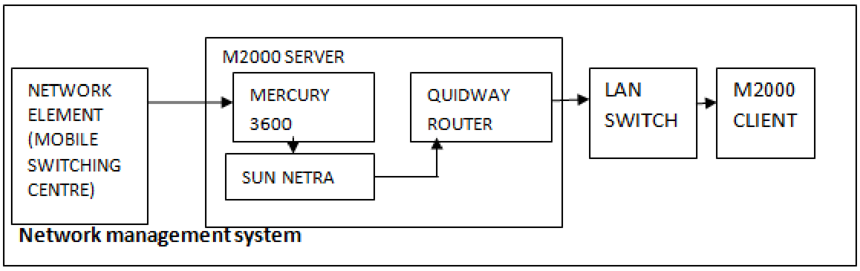

Fig-2: Network Management System

Determination of traffic pattern under study

Performance measurement for voice traffic pattern was carried out by logging into the M2000 Client. Using the performance and monitoring tool, twenty base stations transceivers were selected in the measurement object, traffic volume was selected in the measurement counter and 24hrs was selected in the measurement period. Fig. 3 shows the process of performance measurement involved in the M2000 system.

Determination of channel utilization

The twenty base transceiver stations were queried during the busy hour gotten from the traffic pattern by using the key performance indicator (KPI) on the M2000 client. Traffic parameters such as busy hour attempted calls, success calls during busy hour, busy hour calls blocked, available traffic channels as the measurement counters. With the result obtained, the Call Setup Successful Rate**,** Grade of Service and Channel Utilization Rate were calculated and compared with NCC recommended values for each.

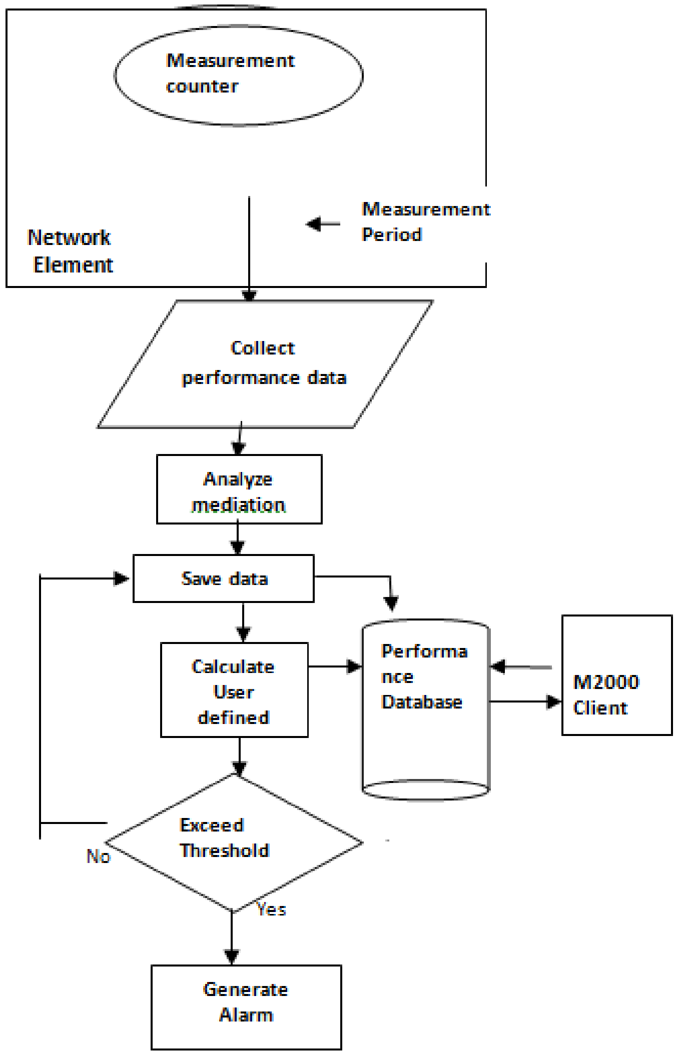

Fig-3: Process of performance measurement of the M2000system

Analysis of system performance in terms of call blocking using erlang b formula

The behavior of the network was observed by varying the traffic load with constant number of channels and varying the number of traffic load with increasing number of channels using Erlang B formula.

Development of a model for Dynamic Channel Allocation using Artificial Neural Network

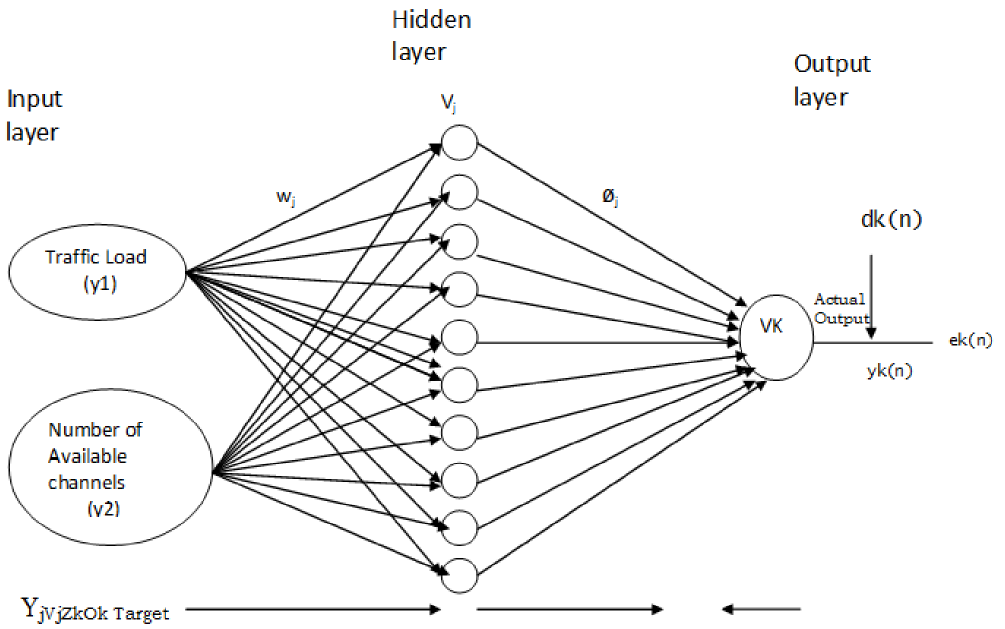

Fig-4: Traffic model structure using ANN

Yi = input = traffic load and no of available channels

At the hidden neuron, feed forward for each

$v_{j(n)} = \sum_{i=0}^{m} W_{ij(n)}\, y_{i(n)} + \theta_j$ ……………………………………… 1

$W_{i(n)}$ = weighted values = channel constraints

$\begin{pmatrix} = W_{10}W_{11}W_{12} \ldots\ldots W_{19} \\ W_{20}W_{21}W_{22} \ldots\ldots W_{29} \end{pmatrix} = \sum_{i=0}^{m} a_{ij}\, b_{ij}$

θ = bias term

$\omega_{ij} = weighted\ values = channel\ constraints = \sum_{i=0}^{m} a_{ij}\, b_{ij}$

Where $a_{ij} = 1, if\ the\ ith\ is\ in\ \ jth\ cell\ can\ use\ co\ channels$

0, otherwise

Where b_{ij} =1, *if the ith and jth cells can use adjacent channels*

0, otherwise

The cells must be separated by a greater distance .the lesser the acceptable interference threshold, the higher the value of distance

$(V_J(n) = hidden\ layers$

Next layer

$y_j = \sigma\,(y_j)$

Output layer

$y_k = \sum_{i=0}^{m} W_{jk}\, y_j + \theta_k$……………………………………..2

The cost function for a local minimum

C = ½ $\sum\ (d_k - y_{k(n)})$………………………………………………….3

Calculating the final output layer and propagating backward.

$$\frac{\delta c}{\delta v_i} = \delta_j,\quad \frac{\delta c}{\delta v_k} = \delta k$$

Using chain rule for partial derivations

$$\frac{\delta c}{\delta v_j} = \delta_j,\ \frac{\delta c}{\delta_{v_{j(n)}}}\frac{\delta_{v_{j(n)}}}{\delta_{v_{j(n)}}} = y_{k(n)}(d_{kn-}\ y_{kn})\ .yj$$

$= \delta_{k(n)}.y_{k(n)}\sigma v_j$ ………………………………………………4

ΔWeight change

Generalize partial derivation

$\delta_{(kn)}$ For the last layer delta

$\delta_k = \frac{\delta c}{\delta v_k}$

Using chain rule

$= \frac{\delta c}{\delta v_k} \cdot \frac{\delta v_k}{\delta v_k}$

$= \sum_k W_{jk}\delta_k \sigma^1\ (y_k)$…………………………………………………5

The model structure in fig 5 showed the procedure for allocating a channel to a call. The artificial neural network initialized all counters and checks the number of call request. When the numbers of new call requested are less than the available channels, channels are assigned and system status is as well updated. When the numbers of call requested are greater than the available channels, a forced channel assignment allows a channel to be allocated by adjusting its weight connection. Even though channel constraints are violated, it doesn't degrade the system performance. When forced channel assignment fails, BSC are requested to locate free channels or otherwise request MSC to locate free channels. Channels are assigned when there are free available channels otherwise unsatisfied calls are blocked and recorded.

Simulation of the developed model and its comparison with existing network model

The developed model was simulated using artificial neural network fitting tool. Fig 3.6 showed the process involved in artificial neural network training

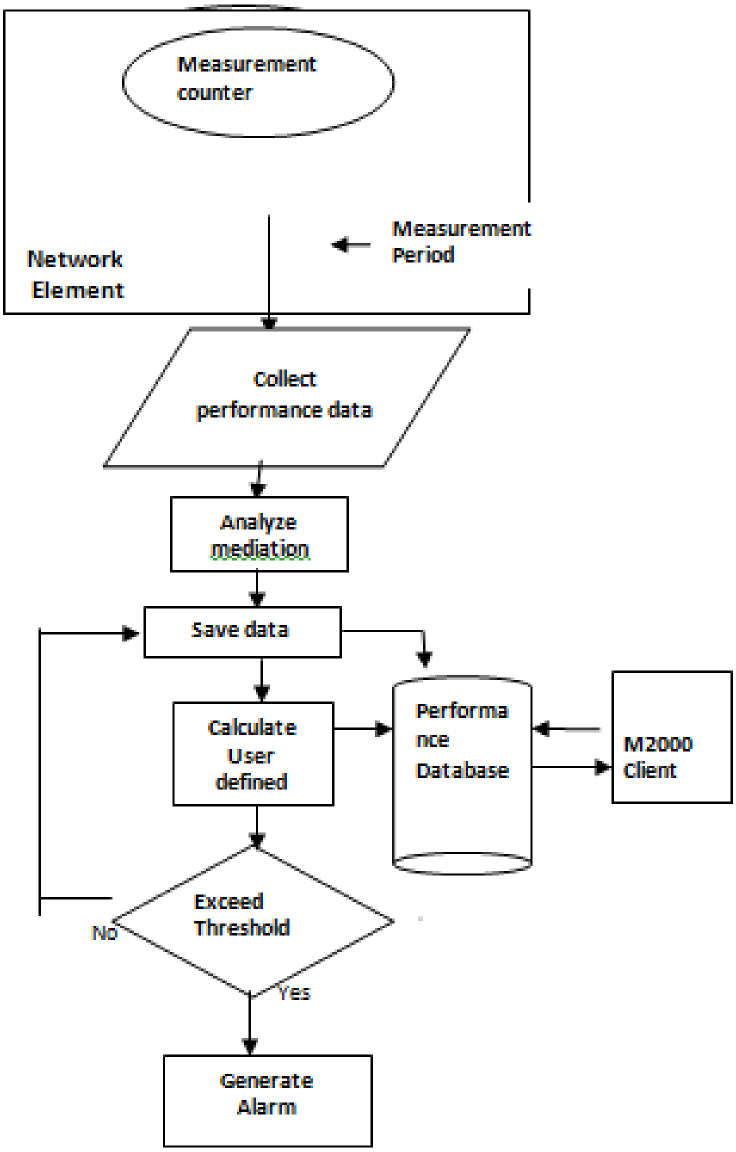

Fig-5: ANN model structure for Dynamic Channel Allocation

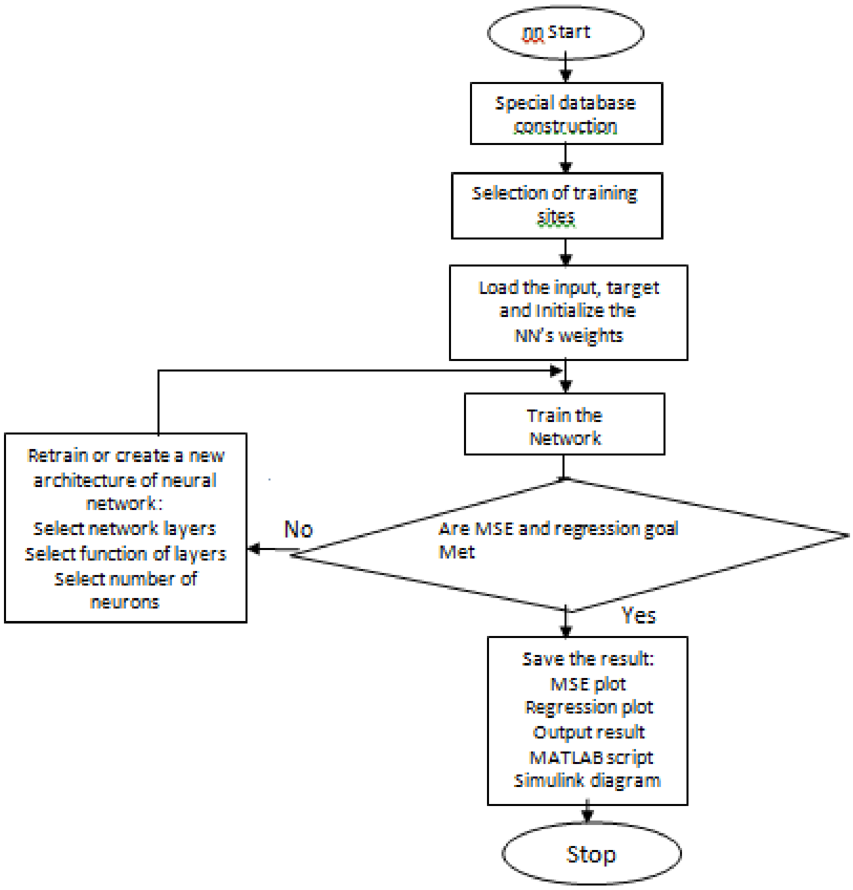

Fig-6: Process involved in artificial neural network training

An algorithm was developed and used to compare the existing fixed channel allocation, dynamic channel allocation and artificial neural network.

RESULTS

The traffic pattern in Fig. 7 showed that there are lesser call attempts between periods of 0-8 and 16 to 23 hours. The busy hour was between 10.00 – 11.00am because of more traffic load.

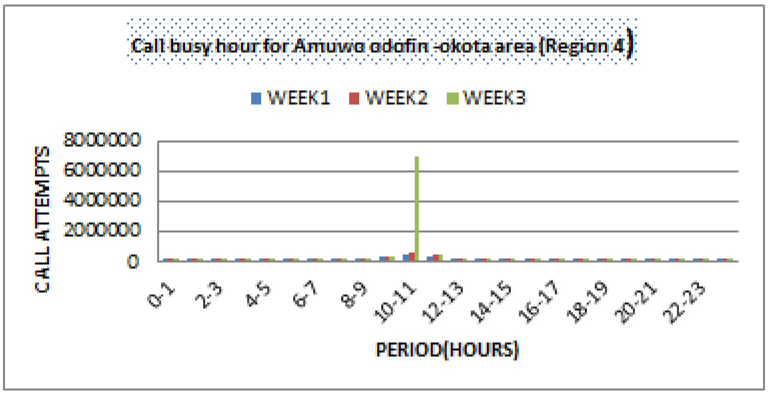

Fig-7: Traffic Pattern

The Average Key Performance Indicator in Fig.8showed that there are more call attempts, less successful calls during busy hour and more calls blocked.

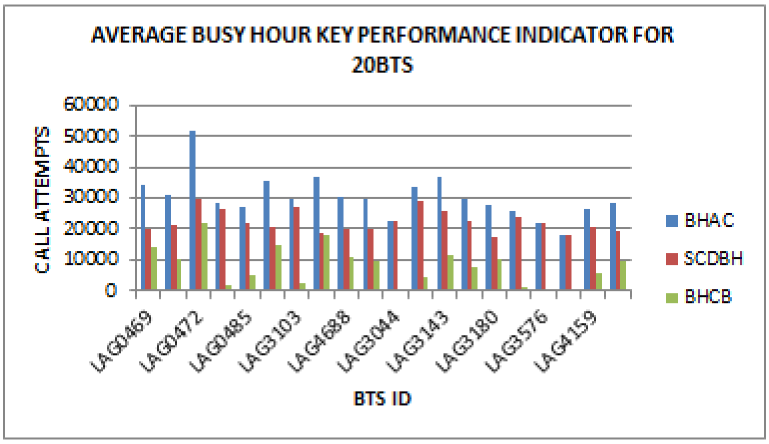

Fig-8: Average busy hour KPI chart

The Go S, CSSR and CUR chart in Fig.9 showed that the majority of the BTS in Region 4 are operating below the Nigerian Communications Commission (NCC) recommended values and therefore need for improvement so as to accommodate more calls and less blocking.

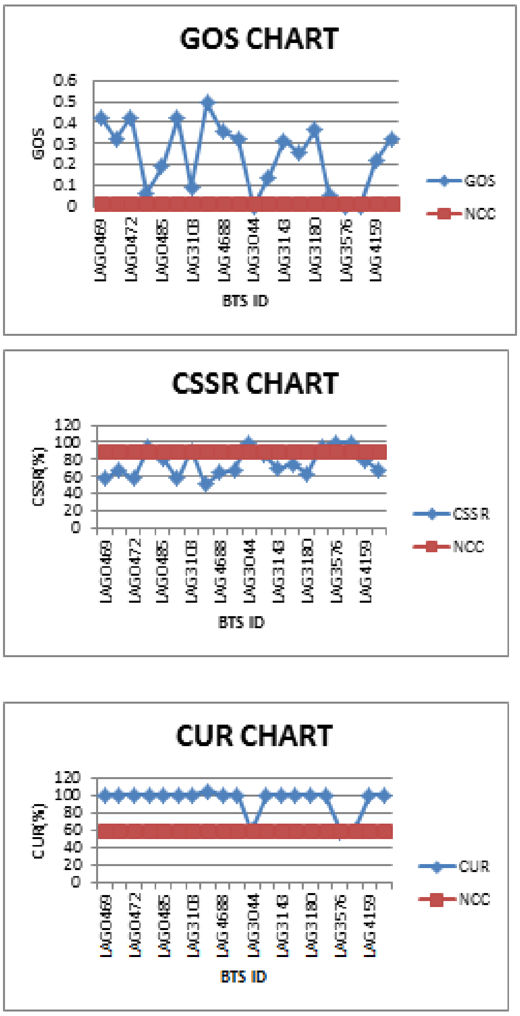

Fig-9: GOS, CSSR and CUR Chart

In Analyzing the Network performance in Fig.10 and Fig.11 by varying the traffic loads over a fixed or increasing number of channels increases and decreases the call blocking probability respectively. This showed that the blocking probability depended on the number of channels and traffic load.

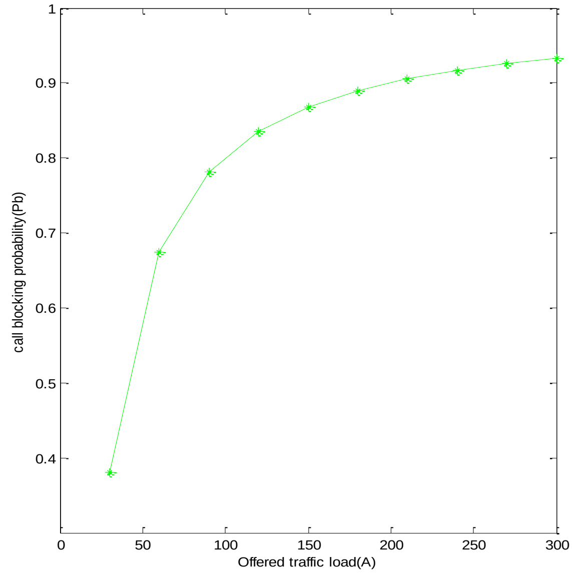

Fig-10: network performance with fixed number of channels

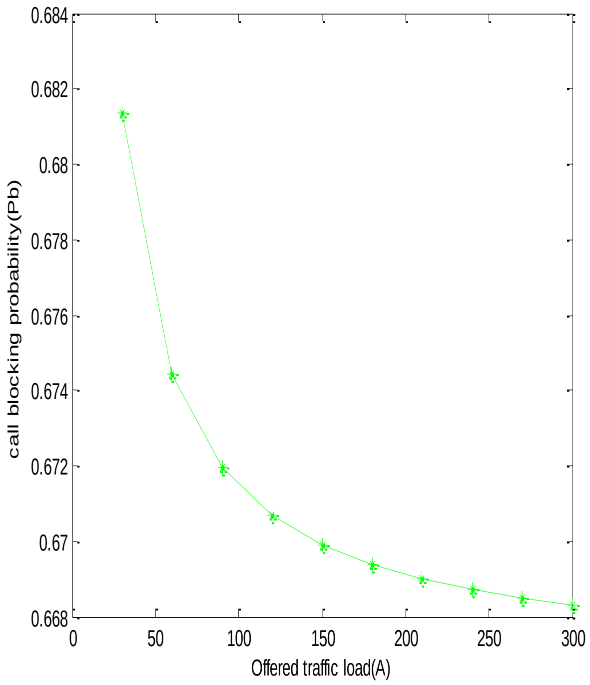

Fig-11: Network performance with increasing number of channels

In simulating the developed model using artificial neural network fitting tool, it was found in Fig.12 that the validation and test curves are very similar and the test curve had not increased significantly before the validation curve increased showing that there was no over fitting. The regression values were close to 1 which showed that artificial neural network was well trained and the outputs of the call blocking probability were very low.

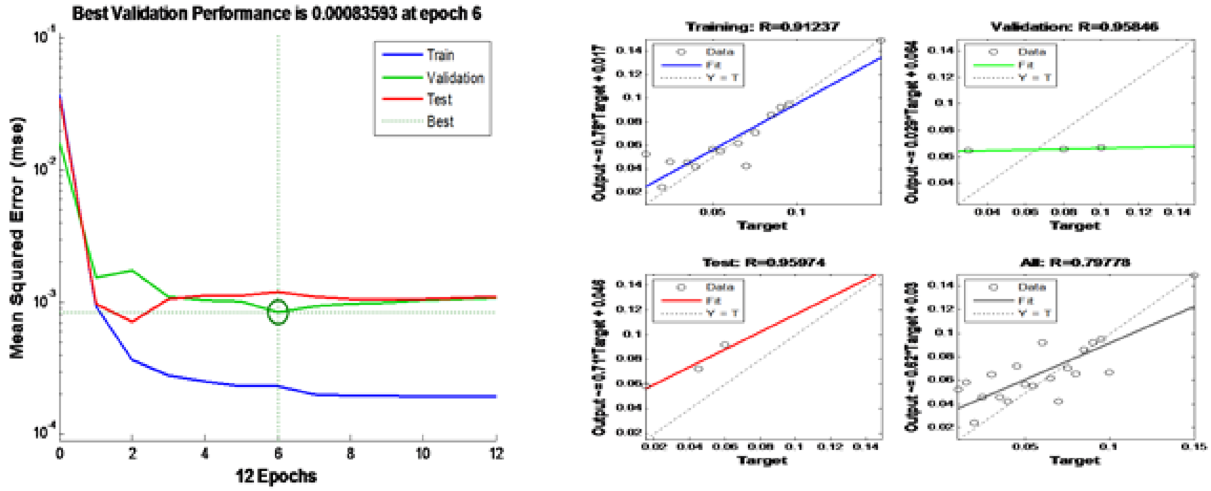

Fig-12: Simulation of the developed model

A developed algorithm was used to compare other techniques used in minimization of call blocking probability and it showed in Fig.13 that Artificial Neural Network maintained the lowest call blocking probability.

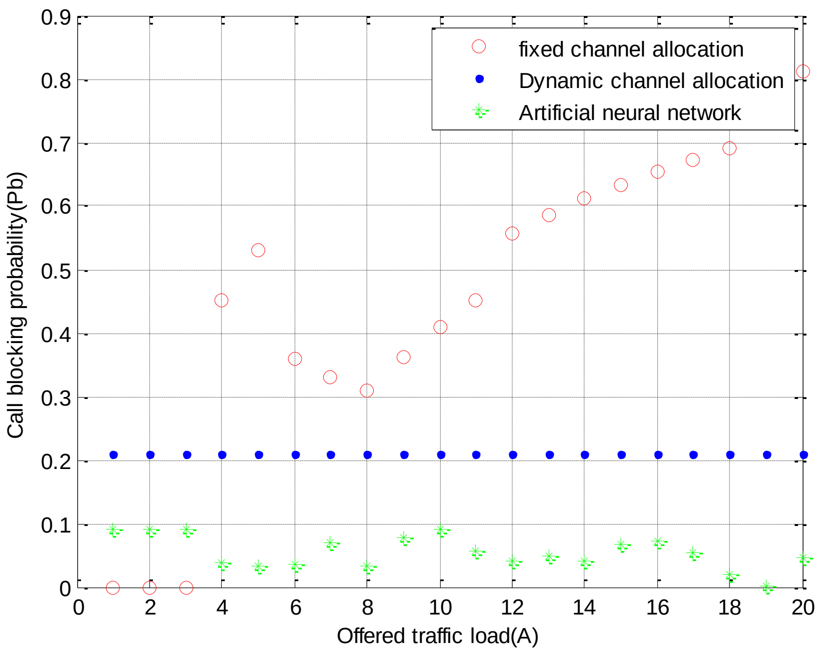

Fig-13: comparison of fixed channel allocation, Dynamic channel allocation and artificial neural network

CONCLUSION

Mobile Communication Network has been rapidly growing all over the world. In contrast with this rapid growth, inefficiency of channel utilization has degraded the network performance due to call blocking. A developed adaptive traffic model using artificial neural network presented in this paper minimized call blocking with much reduced complexity and without exhaustive checking of channels, thereby having efficient channel utilization. Its result showed that it maintained the lowest call blocking probability when compared with the fixed channel allocation and dynamic channel allocation.The future research on this work should focus on the combination of genetic algorithm with artificial neural network for a more reduced call blocking probability.

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