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Experiment-based Performance Investigation of Call Admission Control Schemes in Mobile Network Systems

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***Abstract*—Mobile networks are witnessing rapid advances in the number of the subscribers and the classes of services (voice, data and multimedia). In order to provide service with high capacity and quality, handoff and the mobility management schemes must be acceptably and optimally implemented. In this paper, various CAC schemes have been investigated and reviewed with mathematical models developed and experiments designed to assess and validate their performance. The analysis in this paper indicates that the majority of the schemes have poor resource utilization because resources are not fully used. Also, the experimental results show that new calls have a higher blocking probability in the non-prioritized scheme which gives more considering to handoff requests. The experience of high call blocking probability of new calls is due to prioritization used.**

Index Terms*—Handoff schemes, data services, call admission control, quality of service, network traffic.

I. Introduction

Recent trends in wireless networks are aimed at providing integrated services that include; voice, data, and multimedia with desirable quality of services (QoS). Considerations were made concerning the cost-power relationship of the infrastructure. The demand for multimedia services over the air has increased tremendously in recent times. Wireless networks have successfully evolved into versatile internet protocol (IP) - based wireless that can provide these multimedia services to the users while still maintaining a desirable QoS of voice and data. Successful support of the multimedia applications requires quality of service guarantees over the wireless lines [1]. In the 1980s, the advanced mobile phone system (AMPS) and European counterpart, Total Access Communication System (TACS) came into the scene with the expansion and implementation of the basic cellular concept. The idea of cellular was invoked in AMPS because the Area covered was divided into small cells and the process of frequency reuse was employed among cells so that the cells far enough apart (to avoid interference) can be assigned the same frequency. Another concept known as the handoff scheme was employed between neighboring cells. As the mobile user (mobile station) moves from one cell to another, and the call to or from the user has not finished, the first cell has to "handoff" the cell to the next cell at the cell boundary without users awareness and without experiencing degradation of the service quality. Handoff is a very important feature of a mobile system. It is the process of changing the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection while a call is in progress. Usually, this is initiated either by crossing a cell boundary or signal quality degradation in the current channel. Therefore, mobile station (MS) can move from one base station (BS) to another, without dropping the call or experiencing difficulties. There are basically two types of handoff principles – the soft handoff and the handoff. If a new BS has some unoccupied channels, then it assigns one of them to the handed off call. Nevertheless, if at the time of the hand off, all the channels are in use, two things could happen; the call could be dropped, or it is delayed for a while. The challenges in achieving optimum spectral efficiency and high data rate in wireless cellular communication networks is increased by the wireless communication environment, which is characterized by dynamic channels, high influence of interference, bandwith shortage and strong demand for quality of service support. In order to support various integrated services with certain quality of service requirements in these wireless networks, the study of radio resource management (RRM), radio resource provisioning (RRP), and mobility management is useful. Radio resource management is of interest because it is employed to utilize the limited radio spectrum and radio network infrastructure as efficiently as possible. The RRM involves strategies and algorithms for transmit power control, channel allocation, handoff criteria, modulation scheme, error coding schemes etc. RRM plays a vital role in cellular networks to efficiently utilize the limited radio resource while ensuring a required quality of service [2], [3], [4].

II. Background Information

In a wireless mobile network, a mobile user can move from cell to cell and engages call connection as he/she moves. Handoff probability, handoff rate, call dropping probability, and actual call holding times for complete calls and incomplete calls are often used as metrics to assess the network systems performance [2].

A. Handoff Probability

The probability that a call connection needs at least one more handoff during its remaining lifetime is known as Hand-off probability. These probabilities are referred to as handoff probability for a new call or the handoff probability for a handoff call, depending on whether a call connection is a new call or a handoff call. From observations, a new call needs at least one handoff if and only if the call holding time T_c is greater than the residual cell residence time R_c, i.e $T_c > R_c$.

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B. Call Dropping Probability

Call dropping probability also known as call incompletion probability, is the probability that a call connection is prematurely terminated due to an unsuccessful handoff during the call life. Mobile users are more sensitive to call dropping than to call blocking at call initiation. Wireless service providers have to design the network to minimize the call dropping probability for customer care. Call is dropped if there is no available channel in the targeted cell during a handoff, that is, a call is dropped when a handoff failure occurs during a call life. Assuming, Pb and Ph are the call blocking probability and handoff blocking probability, respectively. Also, P_c denotes the probability that a call is completed (without blocking and forced termination). Then the call dropping probability P_d can be expressed as;

$$P_d = 1 - P_b - P_c \tag{1}$$

$$P_d = 1 - (1 - P_h)^H \tag{2}$$

Where H itself is a random variable. Given the call blocking and dropping probabilities P_b and P_d, the call completion probability (P_c) is given by [1] as;

$$P_c = (1 - P_b)\ (1 - P_d) \tag{3}$$

Intuitively, call completion probability shows the percentage of those calls successfully completed in the network.

C. Call Blocking Probability

The overall blocking probability is the weighted sum of the blocking probability of each region. New calls in the soft region are blocked only if both calls are found in the blocking condition. The overall blocking probability is given as;

$$P_b = P_{bH} + (1 - P)Pbs^2 \tag{4}$$

P_b is the overall probability, P_{bH} is the probability in the hard region and Pb_s is the probability in the soft region.

D. Probability of Assigning Channel Successfully

Base on fluid flow model used in [3], it can be concluded that the inter-cell handoff requests come from any direction in the range of $(0, 2\pi)$ with equal probability. Assuming the channels have already been assigned to the MUs when a new call or an inter-cell handoff call arrives, the BS must usually form a new beam with some busy physical channel. It is possible that the cell still has channels that can be reused, but none of them can be assigned to the new call, inter- cell handoff call or intra-cell handoff call because of beam area overlapping problem. The situation mentioned above happens when the number of active MUs in the cell, n, is greater than the number of channels N. When $n \geq N$, some free physical channel can always be found to be assigned to the new call or inter-handoff call.

Handoff Initiation and Techniques

Handoff (or handover) is the process of transferring an active call from one cell to another. The transfer of a current communication channel could be in terms of a time slot, frequency band, or a code word to a new base station (BS). Deciding when to request a handoff is known as handoff initiation. Handoff decision is based on the received signal strengths (RSS) from the current BS and neighboring BSs. The RSS is usually observed to be weaker as the MS moves away from the first Base station (BS1) and gets stronger as it gets closer to the next base station (BS2) as a result of signal propagation characteristics. The received signal is averaged over time using an averaging window to remove momentary fading due to geographical and environmental factors.

1) Relative Signal Strength Technique: This method selects the strongest received BS at all times. The decision is based on a mean measurement of the received signal. In relative signal strength, the RSSs are measured over time and the BS with strongest signal is chosen to handoff. This method is observed to provoke too many unnecessary handoffs, even when the signal of the current BS is still at an acceptable level. This is due to signal fluctuations. These unnecessary handoffs are known as the ping-pong effect. As the number of handoffs increase, forced termination probability and network load also increases. Therefore, handoff techniques should avoid unnecessary handoffs.

2) Relative Signal Strength with Threshold: This method allows a MS to hand off only if the current signal is sufficiently weak (less than threshold) and the other is the stronger of the two. The effect of the threshold depends on its relative value as compared to signal strengths of the two BSs at the point at which they are equal [5]. If the threshold is higher than this value, this scheme tends to behave in performance like the relative signal strength scheme, so the handoff occurs at position A. If the threshold is lower than this value, the handoff will be delayed, until the current signal level crosses the threshold at that position. If the delay is so long that the MS drifts too far into the new cell, it reduces the quality of the communication link from the first BS and may result in a dropped call. In addition, this results in additional interference to co-channel users. Consequently, this scheme may result in the creation of overlapping cell coverage areas. In actual practice, threshold is not used alone because its effectiveness depends on prior knowledge of the crossover signal strength between the current and candidate BSs. Relative signal strength with threshold introduces a threshold value to overcome the ping-pong effect. The handoff is initiated if the first BS's RSS is lower than the threshold value and the second BS's RSS is stronger than that of the first BS's.

3) Relative Signal Strength with Hysteresis: This scheme allows for handoff only if the new BS is sufficiently stronger (by a hysteresis Margin h), than the current one. Accordingly, the handoff would occur at that point. This technique also prevents the ping-pong effect, the repeated handoff between two BSs caused by rapid fluctuations in the received signal strengths from both BSs. The first handoff, however, may be unnecessary if the serving BS is sufficiently strong. This technique uses a hysteresis value to initiate handoff. Handoff is requested when the BS2's RSS exceeds the BS1's RSS by the hysteresis value h.

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4) Relative Signal Strength with Hysteresis and Threshold: This scheme combines the performance of the Threshold and Hysteresis concepts to come up with a technique with minimum number of handoffs. The handoff occurs only if the current signal level in the current BS drops below a threshold and the target BS is stronger than the current one by a given hysteresis margin. The handoff is requested when the first BS1's RSS is below the threshold and the second BS2's RSS is stronger than BS1's by the hysteresis value h. Whenever the RSS drops below the receiver threshold, the ongoing call is then dropped instantly. The time interval between the handoff request and receiver threshold enable cellular systems to delay the handoff request until the receiver threshold time is reached when the neighboring cell does not have any empty channels. This technique is known as queuing handoff calls and it is very effective in handoff efficiency.

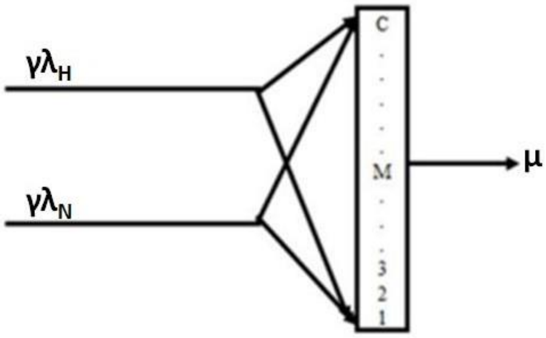

Fig. 1: Typical system model for non-prioritized scheme

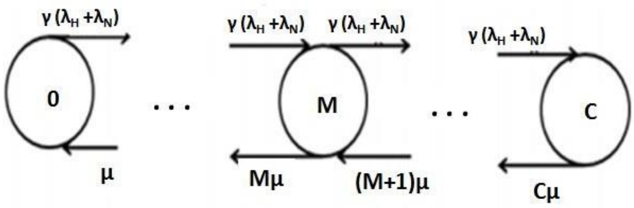

Fig. 2: State transition diagram for non-prioritized model

III. REVIEW OF RELATED WORKS

In [3], an efficient call admission control scheme was proposed to improve resource utilization and decrease the dropping probability. The scheme classifies calls into HC and NC. The scheme accept HCs based on latency and resource blocks availability. While NCs are also accepted based on latency and resource blocks availability and if the length of HC queues (lengHC) is less than the threshold size of its queue. The scheme performs well in terms of dropping probabilities and resource utilization ratio. However, the NCs suffer an increase in NCBP when threshold size of HC queue is large.

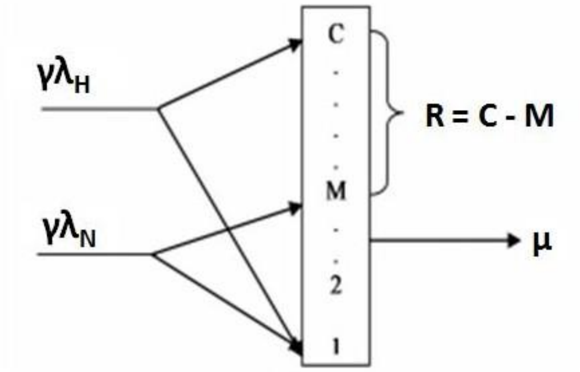

Fig. 3: Typical system model for prioritized scheme

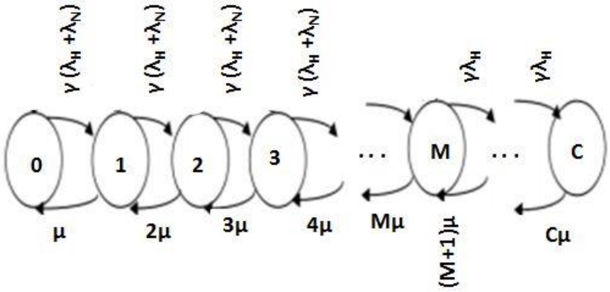

Fig. 4: State transition diagram for prioritized model

In the papers, [5] and [6], improved handoff scheme for minimizing handoff failure in mobile networks was developed and analyzed. Using analytical computation method, the authors demonstrated the impacts of various network parameters on the handoff failure and new call blocking probabilities. They also demonstrated that the use of the direction of the mobile station in the handoff scheme helped in further reducing handoff failure in mobile systems. The basic concept behind this new scheme is the idea that if the mobile terminal is approaching the base station, the poor signal handoff request can be accepted with probability that increases as the mobile terminal approaches the base station. The assumption is that the signal quality will improve as it nears the base station. In essence, this scheme ensures that the mobility factor (α) is always one (1). This ensures that the handoff request is handed-off to the BS with the best ability to handle the request. In a follow up to their works in [5] and [6], the authors went further in [4] to make comparative analysis of their works in and [6] by comparing its performance with other existing algorithms. The comparative performance of various handoff schemes in terms of handoff failure and success probabilities was carried out in this paper. They demonstrated through simulations that their proposed scheme performed better than the other schemes.

An efficient non-prioritized call admission control model (ENCAC) for low traffic setting for minimizing call failure was proposed in [7]. This non-prioritized scheme is very useful for light traffic scenario like remote or residential areas. The model considers the signal quality, channel availability and the direction of the mobile terminal to the base station, before making decision on whether or not the call can be admitted. The continuous-time single dimensional birth–death process (Markov chain) was adopted to develop the proposed model. MatLab software was used to simulate and analyze the

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performance of the proposed schemes in terms of call failure probabilities. Based on the results, it was concluded that the proposed scheme is useful for the wireless systems. Consequently, it was recommended that mobile network providers should implement a scheme that best suits the location in terms of traffic expectations and equipment spacing. This will bring about mobile users' satisfaction

Similarly, in [8] a delay aware and user categorizations adaptive resource reservation-based call admission control (DAUCARR- CAC) is proposed to increase the network's resource utilization. The DA-UCARR- CAC classifies users into Gold and Silver and flows to RT and NRT, which translates to four types of bearers namely: Golden users with real- time flows (G-RT), Silver users with real time flows (S-RT), Golden users with non-real time flows (G-NRT) and Silver users with non-real time flows (SNRT) bearers and reserves virtually predefined RBs for each class. It accepts request if the resources required are less than the available RBs otherwise it admits the requests into a queue if resources are insufficient. The queued requests are accepted according to their computed AP when RBs are available. The scheme utilizes available RBs, delay tolerance, user categorization and flow type to compute the AP of a request. The scheme achieves a better balance between system utilization and QoS provisioning but calls with highest AP experience a high blocking probability. In [9], a call completion was analysed with the aid of a time diagram showing the block and drop probabilities with respect to the cell dwell time (CDT) and call holding time (CHT). A simple expression was derived which is a close approximation of the call completion probability in the GSM network. This derivation was made under exponentially distributed cell dwell time and call holding time with arbitrary distribution. This study showed that call completion probability can be measured in terms of some failed operations in the system.

A hybrid call admission control (HCAC) Scheme to reduce the handoff dropping probability was proposed in [10]. The HCAC employs the resource block strategy to allocate resources based on call type. The scheme determines the maximum number of RBs required (RBmax), minimum number of RBs required (RBmin), number of required RBs (RBreq) and tolerable maximum delay ($Dmax_i$). The new and handoff RT calls are accepted based on RBreq and its latency otherwise the calls are rejected if they exceed $Dmax_i$. Similarly, the new NRT call is accepted based on its RBreq while the handoff NRT is accepted based on its RBmin else the call is rejected if it exceeds its $Dmax_i$. The scheme reduces the call dropping probability. However, it has a high new call blocking probability under large number of users.

In [11], an existing shortest path algorithm used in EIGRP routing protocol was studied, problems were identified and a new shortest path algorithm was developed to address the identified problems. Specifically, the problem addressed in this paper was on the end-to-end delay in the existing shortest path algorithm used in EIGRP routing protocol. Mathematical expressions were developed to quantitatively represent the performance of the existing shortest path algorithm used in EIGRP routing protocol. Then, a new shortest path algorithm was developed for EIGRP routing protocol. Mathematical expressions were developed to quantitatively represent the performance of the new algorithm. In all, the proposed algorithm has a smaller end-to-end delay when compared to that of the existing shortest path algorithm used in EIGRP routing protocol.

In a follow up to [11], where the researchers proposed an improved shortest path first algorithm (ISPFA) used in enhanced interior gateway routing protocol, the authors carried comprehensive analysis of the proposed protocol and assessed its comparative performance with existing protocol in [12]. The analysis showed an average improvement of 36% by the proposed protocol over the existing.

In [13], a Connection Admission Control and RBs reservation scheme is proposed to reduce call dropping probability. The scheme employs RB reservation algorithm to allocate the maximum number of RBs to all calls when possible. And if the cell is over-loaded, some of the calls in the cell might receive RBs lower than the requested RBs. It degrades NC with largest allocated resources allocated resources and lower priority (NRT) calls to minimum RB required to admit HC when resources are insufficient. Similarly, the scheme admits NC which has not exceeds its latency by degrading NRT calls. The scheme rejects both HC and NC if resources obtained from degradation are insufficient. The scheme reduces handoff dropping probability, maintains low new call blocking probabilities and ensures efficient resource utilization. However, the scheme unfair due to NRT call degradation.

A fair intelligent admission control scheme (FIAC) was proposed to ensure fair bandwidth allocation among different priority classes and among the flows at the same priority level in [14]. The LTE-FIAC scheme employs complete sharing to share the common pool of available resources to multiclass users. It uses virtual portioning to differentiate among multiclass users. It utilizes a stepwise degradation technique to degrade calls of lower priority to GBR using the Allocation and Retention Priority (ARP) index when resources are insufficient. The scheme achieves a lower call blocking probability and guarantees fair share of bandwidth. However, the scheme increases blocking probability. In addition, it may experience QoS degradation during call when channel fluctuate. In [15], a call admission control with reservation scheme is proposed to avoid call QoS degradation. The scheme considers two types of traffic namely narrow band and wide band applications. It reserves extra needed resources at the time of admission to maintain call QoS in case of channel condition change due to mobility. The scheme enhances QoS but wastes resources when the reserved resources are unused.

In [15] an efficient scheme to mitigate multimedia call failure in a network was proposed. To achieve this, the incoming calls (multimedia) were divided into real time and non-real time calls. Priority was given to the real time multimedia calls. Statistical approach using the continuous-time single dimensional birth–death process (Markov chain) was adopted to model the system. Consequently, a mathematical model known as success probability model of multimedia calls (SPMMC) was developed and simulation environment built to assess the performance of the proposed scheme The proposed scheme provides a quality of service guarantee to the multimedia calls and at the same time the exploitation of priority resources to accommodate blocked real time multimedia in order to improve the performance of the network. In this paper, it was predicted that by integrating the concept of real time multimedia calls priority to the M+G, the real time call failure probability has been considerably reduced. Statistical approach using the continuous-time single dimensional birth–death process (Markov chain) was helpful in developing the mathematical model (SPMMC). This model when implemented helps to assess the performance of the proposed scheme.

In [16], an analytical approach was adopted to model and analyze the performance of global system for mobile phones. This scheme integrates the handoff queue into the M+G scheme. This helps to further minimize handoff failure. Using simulation in MatLab, the proposed Scheme was evaluated in terms of handoff failure probability. This approach was applied in the analysis of mobility management and connection performance with emphasis on the prioritized. The arrival rate of originating and handoff calls were assumed to be Poisson while time variables such as call holding time, cell residence time, channel holding time, registration area (RA) residence time, and inter-service time are assumed to be exponentially distributed. The proposed scheme provides a quality of service guarantee to the handoff calls and at the same time the exploitation of buffer resources to accommodate blocked handoff in order to improve the performance of the network. In this research, it was shown that by integrating the concept of buffering (queue) to the M+G, the handoff call dropping probability was considerably reduced. The performance of this new scheme in terms of dropping probabilities was carried out using MatLab. It has been shown that the use of the buffer in the in the proposed handoff scheme helps in further reducing handoff failure in mobile systems.

IV. System Models

Almost all the reviewed CAC schemes adopted the $M/M/C/C$ queuing approach in [17] to model the mobile system. This system usually is considered to be made of many cells. These cells are assumed to be homogeneous. This implies that the cells are identical in capacity, performance and characteristics. For easy analysis, usually, only one of the cells is modeled. The results of this cell (marked cell) are applicable to other cells. Also, the schemes consider two traffic requests in the modeling and analysis: The new calls (NC) and handoff call (HC) requests. Furthermore, the model adopted is considered to be multiclass model.

A. Assumptions

The following assumptions are usually adopted in this system model.

Assumption 1: In a typical mobile network, both the new call and Handoff arrival rates in the cell form a Poisson process with mean values which can be represented as λ_H and λ_N respectively. Therefore, total arrival rate is the sum of the mean values shown in equation 5.

$$\lambda = \lambda_H + \lambda_N \tag{5}$$

Assumption 2: New call and handoff completion time are exponentially distributed with mean rates which can be represented as μ_H and μ_N respectively. Therefore, the effective service rate is usually the sum of the mean of the new call and handoff completion rates as represented in 6.

$$\mu = \mu_H + \mu_N \tag{6}$$

Assumption 3: The change in arrival rates is moderate in that the network reaches steady state between any two changes in the arrival rate. Therefore, the incoming traffic rate (call arrival rate) is the sum of new call and handoff arrival rates.

B. Descriptions

A typical network cell is considered to be made of C channels. The CAC schemes are usually divided into two depending on the priority: Prioritized and non-prioritized. The non-prioritized scheme gives priority to no request. The assignment of the available channel is strictly on first in first out (FIFO) policy. Though this is very unpopular, it is usually employed in low traffic setting as demonstrated in [7]. In this method, all the system resources (channels) are shared equally by both the new calls and handoff requests. This is implemented using the FIFO protocol. A typical $M/M/C/C$ system model for the non-prioritized scheme is shown in figure 1 and corresponding transition diagram in figure 2.

In the prioritized scheme, priority is given to the handoff request ahead of the new call requests. What this means is that if both handoff and new call requests arrive at the same time, the available channel will be assigned to the handoff request. The famous means of implementing the prioritized scheme is the guard channel (GC) method. In the GC method, the channels in the cell are divided in two parts. One part is used by both the new and handoff requests while the other part referred to as reserved or guard channels are reserved strictly for handoff requests. The argument here is that it is better to continue with an ongoing call. It has been shown by research that mobile users show greater resentment to call drop than call blocking, the later depicting the inadmissibility of new calls. A typical $M/M/C/C$ system model for the prioritized scheme is shown in figure 3 and corresponding transition diagram in figure 4.

C. Mathematical Models

1) Non-Prioritized Scheme: In developing the mathematical expressions for the non-prioritized scheme, we will make reference to figures 1 and 2. The behaviour of non-prioritized cell can be described by Markov process as described in [19] and [20]. If C represents the total number of channels in the cell, there are (C+1) states in the Markov process. We represent the number of states as X_s. If we assume the probability that the system is in state any state, x_j, as P(x_j), we can determine P(x_j) using the birth- death process expressed in equation 7;

$$P(x_j) = \frac{\lambda_H+\lambda_N}{x_j\mu} P(x_j - 1); 0 \le x_j \le X_s \tag{7}$$

The normalization condition is as expressed in equation (8).

$$\textstyle\sum_{x_j=0}^{X_s} P(x_j) = 0 \tag{8}$$

From equations 7 and 8 recursively, we determine the steady-state probability *P(j)* as shown in equation 9;

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$$P(x_j) = \frac{(\lambda_H+\lambda_N)^{x_j}}{x_j!\mu^{x_j}} P(0): 0 \le x_j \le X_s \tag{9}$$

$P\ (0)$ is known as the probability at state 0 and can be expressed in equation 10;

$$P(0) = \frac{1}{\sum_{x_j=0}^{X_S} \frac{(\lambda_H+\lambda_N)^{x_j}}{x_j!\mu^{x_j}}} \tag{10}$$

Let us represent B_N and B_H as the new call blocking and Handoff call blocking probabilities respectively. Recall that, we are dealing with a non-prioritized scheme.
Therefore,

$$B_N = B_H \tag{11}$$

The blocking probability is the probability of the final state X_s i.e. $P\,(X_s)$ and can be derived by substituting $P\ (0)$ equations 10 in equation 9 with x_i replaced with X_s in equation 9. This is expressed in equation 12.

$$P\left(x_j\right) = \frac{(\lambda_H+\lambda_N)^{X_S}}{X_S!\mu^{X_S}} \frac{1}{\sum_{x_j=0}^{X_S} \frac{(\lambda_H+\lambda_N)^{x_j}}{x_j!\mu^{x_j}}} \tag{12}$$

Equation (12) is re-arranged and expressed in equation (13).

$$B_N = B_H = P(X_s) = \frac{\frac{(\lambda_H+\lambda_N)^{X_S}}{X_S!\mu^{X_S}}}{\sum_{x_j=0}^{X_S} \frac{(\lambda_H+\lambda_N)^{x_j}}{x_j!\mu^{x_j}}} \tag{13}$$

2) Prioritized Scheme: In deriving the mathematical expressions for the prioritized scheme, references will be made to figures 2 and 3. The behaviour of non-prioritized cell can be described by Markov process as described in [19] and [20]. In this method, priority is given to handoff requests by assigning reserved channels exclusively for handoff calls. The common channels i.e. M channels are used for both new and handoff calls, while the remaining R (= C-M) channels are reserved for handoff requests only. An originating call is blocked if the number of available channels in the cell is less than or equal to M. A handoff request is blocked if no channel is available in the target cell. In determining the call blocking probabilities, a similar approach from the non-prioritized scheme will be adopted. Again, let C represents the total number of channels in the cell, and (C + 1) the total states in the Markov process. We represent the number of states as X_s. If we assume the probability that the system is in state any state, x_j, as P(x_j), we can determine P(x_j) using the birth-death process, the balanced equations for the two partitions shown in transition diagram of figure 4 can be obtained as in equation 14.

$$\begin{cases} x_j P(x_j) = (\lambda_H + \lambda_N) P(x_j - 1): 0 \le x_j \le M \\ x_j P(x_j) = \lambda_H P(x_j - 1): M + 1 \le x_j \le X_s \end{cases} \tag{14}$$

Applying equation 14 recursively with the normalization condition in equation 8, the steady state probability $P(x_j)$ results in equation 15;

$$P(x_j) = \begin{cases} \frac{(\lambda_H+\lambda_N)^{x_j}}{x_j!\mu^{x_j}} P(0): 0 \le x_j \le M \\ \frac{(\lambda_H+\lambda_N)^{M} \lambda_H{}^{x_j-M}}{x_j!\mu^{x_j}} P(0): M + 1 \le x_j \le X_s \end{cases} \tag{15}$$

As usual, P (0) can be expressed in this case as;

$$P(0) = \frac{1}{\sum_{x_j=0}^{X_S} \frac{(\lambda_H+\lambda_N)^{x_j}}{x_j!\mu^{x_j}} + \sum_{x_j=0}^{X_S} \frac{(\lambda_H+\lambda_N)^{M} \lambda_H{}^{x_j-M}}{x_j!\mu^{x_j}}} \tag{16}$$

From equations 15 and 16, the blocking probability of new calls can be derived as B_N in equation 17;

$$B_N = \sum_{x_j=0}^{X_S} P(x_j) \tag{17}$$

In a similar way, the blocking probability of handoff request can be derived as B_H in equation 18;

$$B_H = \frac{(\lambda_H+\lambda_N)^{X_S-M}}{X_S!\mu^{X_S}} P(0) \tag{18}$$

Substituting equation (16) in equation (18) results in;

$$B_H = \left[\frac{(\lambda_H+\lambda_N)^{X_S-M}}{X_S!\mu^{X_S}}\right] \left[\frac{1}{\sum_{x_j=0}^{X_S} \frac{(\lambda_H+\lambda_N)^{x_j}}{x_j!\mu^{x_j}} + \sum_{x_j=0}^{X_S} \frac{(\lambda_H+\lambda_N)^{M} \lambda_H{}^{x_j-M}}{x_j!\mu^{x_j}}}\right] \tag{19}$$

Here, a blocked handoff request call can still maintain the communication via current BS until the received signal strength goes below the receiver threshold or the conversation is completed before the received signal strength goes below the receiver threshold.

V. Comparative Analysis

In this section, some experiments and simulations of various CAC algorithms are presented. The aim of this is to validate the claims on the performance of the CAC techniques.

A. Experimental Setup

In order to achieve the purpose of this study, synthetic datasets with problems or characteristics of the mobile network system were created. The use of the synthetic datasets is necessary and important because they allow for a full assessment and evaluation of the selected algorithms on how well they perform, what data problem can be solved by them, and expose where they may encounter difficulties if any. Also, the simulation experiments were built in MatLab and validated scripts in Python. Basically, mathematical representation of the prioritized and non-prioritized handoff models were also simulated with changing channels, reserved channels, call duration, traffic situations etc.

B. Results

Numerical analysis and results for the experiments are presented and discussed in this section. The effects and impacts of the various network parameters on the various

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system performance metrics are assessed. This is achieved by taking the numerical examples and developing computations and simulations for the system performance in terms of the metrices.

1) Non-Prioritized Scheme: This section presents the results of the experiment for the non-prioritized scheme. The results of effect of number of free channels on call blocking probabilities at different traffic loads of 35, 40 and 45 Erlangs for the non-prioritized scheme is shown is shown in figure 5. Similarly, figure 6 shows the effect of traffic on call blocking probabilities for the prioritized scheme at different number of free channels. It is observed from figure 5 that the blocking probabilities reduced with increase in the number of free channels. This is as expected because, as the number of free channels increases, more calls can be accepted and assigned the free channels. In essence, the more the system capacity, the more call requests the system can handle therefore, the less the number of calls will be lost. In similar vein, it is observed that, as the traffic increases, the blocking probabilities of new and handoff requests also increase as shown in figure 6. This can be explained from the theory that, as more call requests arrive, the channels will be congested resulting in some calls being rejected and consequently lost. As it was mentioned earlier, the non-prioritized scheme is best suited for low traffic scenes like the rural areas and remote areas where heavy traffic is not expected.

2) Prioritized Scheme: In this section, the results for the prioritized scheme is presented and shown in figure 7. This shows the effect of number of reserved channels on blocking probabilities. It can be observed that, as the reserved channels increase, the failure probability of new calls increases while that of handoff decrease. This is quite as expected because, as the reserved channels increase, more channels are assigned to handoff requests while the new call contests for the common channel. This results in most new calls being denied access.

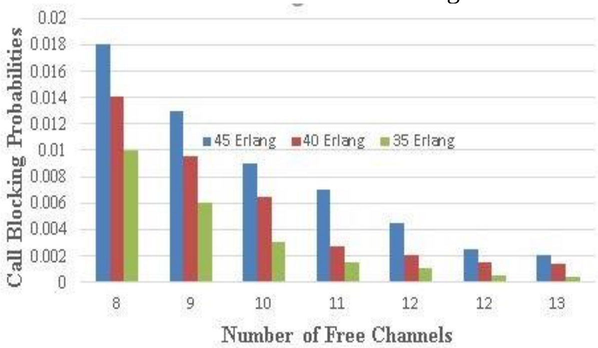

Fig. 5: Effect of free Channel on call failure probabilities at different traffic in Erlangs

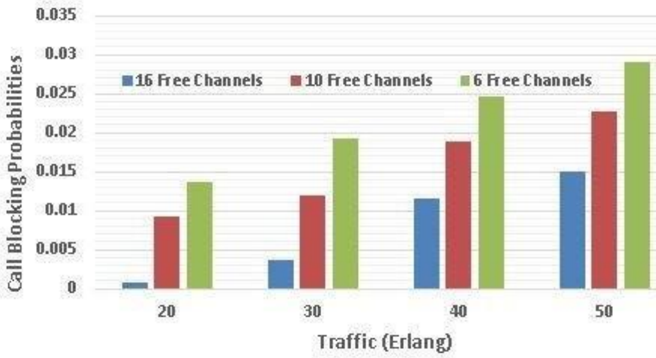

Fig. 6: Effect of traffic on call failure probabilities at different free channels

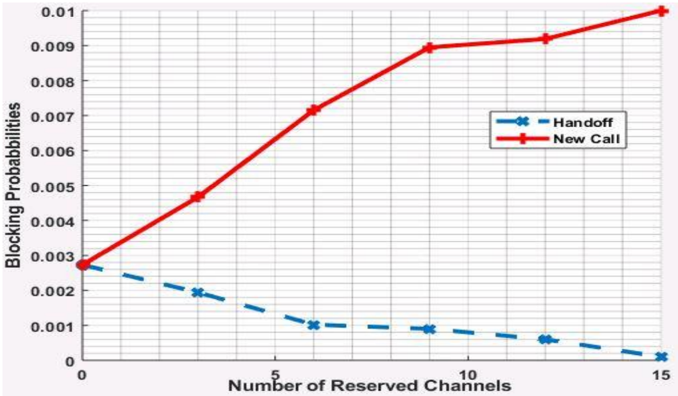

Fig. 7: Effect of number of reserved channels on blocking probabilities

VI. Conclusion

In wireless mobile networks, the size of the cell determines how frequent handoffs occur. In response to this, CAC schemes must be carefully designed to provide seamless connection and QoS guarantees to the mobile users. In this paper, we have investigated and reviewed some CAC schemes with mathematical and experimental models to assess and validate their performance. The schemes were categorized into two: prioritized and non-prioritized schemes. The analysis in this paper indicates that the majority of the schemes have poor resource utilization because resources are not fully used. Also, the experimental results show that new calls have a higher blocking probability in the non-prioritized scheme which gives more considering to handoff requests. The experience of high call blocking probability of new calls is due to prioritization used.

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