Queueing analysis of combined guard channel and mobile assisted handoff on prioritized channel assignment for cellular network

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ABSTRACT: In this paper we have considered a wireless mobile network with data/voice traffic. The paper, considered two type of channel assignment (1) with guard channel (2) without guard channel. In cellular mobile system, radio channels are very limited and mobility of mobile terminal occurs a phenomenon called handoff. Handoff is defined as process of transferring an ongoing call or data session from one channel connected to the core network to another. Due to the limited bandwidth available in various cells, there is a finite probability that an ongoing call, while being handed off, or it may get dropped. Minimizing the dropping of ongoing call during the handoff is the important issue for the mobile communication. In this paper we analyzed the channel assignment by the Queueing approach and compared the result of both the models in terms of dropping and blocking probability. We used the MAHO scheme, mobile assisted handoff, in which mobile terminal assists BSS and mobile switching center makes handoff decisions. In MAHO mobile terminal required to reports its RSSI (received signal strength indication) back to its serving BSS. In first case we reserved some channels for handoff calls. And in 2nd case we didn't use any guard channel; there is no priority in channel assignment for handoff.

Keyword: cellular wireless network, queuing theory, MAHO, guard channel, handoff.

I. INTRODUCTION

Wireless communication is exhibiting its fastest growth period in history; due to enabling technologies which permit a wide spread deployment. Now a day's cellular systems are the most popular system used in the telecommunication industries. The data services or voice speeches are conveyed very easily by the mobile terminal. Cellular wireless systems have a large number of users over a large geographical area, within a limited frequency spectrum [14] & [15]. So in cellular mobile networks, the large geographical coverage area or region is divided into small services area. They are called cells within its region. Before communication between two users in a network, the frequency band is divided into smaller bands [6]. These bands are reused in non-interfering cells and the group of frequency bands or channel should be assigned. When a mobile user or mobile terminal crosses the cell boundary or passes out of the range, the signal gets unacceptable. The transition and the process to make the transition are called handoff [3]. The term handoff does not mean a physical change in the assigned channel but rather that the different base station handles the radio communication task. Thus handoff is the process where the call transfers a mobile station from one base station to another base station or one cell boundary to another cell boundary or from one BSS to another. MT receives the signal strength regularly from the base station system (BSS) and reports to MSC (mobile switching centre). In wireless mobile communication, the wireless area divides in cells, each cell has a BSS or BTS that provides a radio link to each MT that is active in the cell. More than one BSSs or BTSs are in under the control of MSC. MSC has a function to manage the handover decision, if a MT moves ,the serving BSS may not able to provide good signal strength as compared to others BSS [10]. The signal strength get decrease as MT moves away from serving BSS and the signal strength from others BSS get increase as MT moves towards them. The serving MSC may decide handover the service to other better serving BSS. Several handoff techniques are proposed and implemented but the simplest technique is that the MT solely responsible for making handoff decision on the basis of RSSI (receive signal strength indicator). When received signal strength drops below an threshold signal, the MT may decide to choose another base station. We are very familiar with a handoff technique MAHO (mobile assisted handoff). In MAHO scheme, it assisted by MT, and handoff decision is completely responsible by MT. In this scheme, the serving BSS asking the MTs to periodically report their receive signal strength (RSSI) from the surrounding base station. There are considered two type of assignment one is with GC and other is without GC. We analyzed proposed scheme MAHO+GC [1].There are combined two schemes MAHO and GC (guard channel) and to form a scheme MAHO + GC, in this scheme the handoff assisted by MT and some channels are reserved for handoff calls. And the important is signal quality factor by which handoff process will initiate. We took a signal quality factor (α) in this approach and handoff may responsible on this factor [1].

Received signal strength indicator: **-** In this paper, first we analyse the effect of poor signal quality on the GC-based handoff and without GC based handoff scheme [9] & [11]. There is an acceptable threshold of signal quality of handed-off calls; there may be a probability that such calls do not have adequate signal quality [10]. In such situations, a channel will be allocated to a handoff call, but such a call cannot be sustained by the new BSS due to poor signal quality (α_0 =1-α). Let α be the probability of good signal and bad signal quality, α=1 that may not be true because all BSSs are not going to provide the same quality [1]. If MT closer to the BSS, those may have higher received signal strength indicator (RSSI) compare to those MT that is away from the BSS. In second case we took without GC based scheme, there is no reserved channel for handoff calls, there is no prioritization for handoff calls. Only the received signal strength indicator (α) plays a important role in this scheme, if a MT interested to handed over to the another BSS, there are two necessary condition, there should be a vacant channel in the new BSS and have an adequate signal quality to MT for handed over one BSS to the another. The MT may be having a higher received signal strength indicator (RSSI) compare to those BSSs that are further away from this MT. In fact the MAHO makes the decision only on the basis of RSSI when the new BSS have a vacant channel [13]. It means that a given BSS may not have an higher RSSI for the some of the handoffs for which it may be a good candidate on the basis of channel availability. A poor quality handoff call may either be dropped or it may be rehanded off to another BSS.

II. MODEL DESCRIPTION

In this paper we analyzed two type of handoff techniques in which an MSC makes handoff decisions based on two parameters, RSSI and channel availability. In this scheme assumes that the controlling MSC assisted by the MT makes and implements the handoff decisions. It will depend on following assumptions [1].

1) Downlink (BSS to MT) RSSI measurements made by the MTs by measuring the signal strength of the Forward Control Channel (FCCH) from different BSSs;
2) Uplink (MT to BSS) channel information provided by the BSSs to the MSC periodically or when ordered to do so by the MSC.
3) Channel availability at different base stations [13].

In this scheme, the channel availability and the RSSI are the main factors which are responsible in handoff process. The downlink RSSI measurements are made by an MT either periodically or on specific orders sent by its serving MSC. There are two ways to evaluate the channel availability in the cell.

1) The BSS broadcasts the data about the free available channel regularly over its FCCH (i.e. BSS to MTs). The FCCH act as a broadcast channel, it carries the information about the free available channel currently in a particular BSS. MT receives the instructions from its serving MSC about the identity of the BSSs that are of interest to that MSC for eventually performing a handoff [14]. In response to these instructions, an MT prepares its MAHO report consisting of RSSI information and the channel availability information associated with the indicated BSSs.
2) Each BSS keeps its MSC informed of its channel status, i.e., how many channels are being used by the number of new calls, handoff calls, and free GCs over some infrastructure network. Typically, there is an infrastructure network that interconnects BSSs and MSCs that is used by the BSS to report its channel availability information [14]. The uplink RSSI and channel availability information is provided by the BSSs to MSCs using such an infrastructure network. MSCs themselves are networked together over this infrastructure network and it may communicate with each other .When a handoff involves more than one MSC, the MSCs exchange channel availability data sets in addition to the RSSI sets

The handoff scheme will ensure that the new BSS receiving a handoff call will be able to provide a free channel as well as good signal quality [1].

ANALYTICAL MODEL

The analytical model for calculating blocking probability of new calls and dropping probability of the system is developed by assuming that a handed-off call always has an acceptable signal quality.

As we discussed before, we have considered two models in this paper first is with GC and second is without GC.

In the models, we take states i (=0, 1, 2….c), it denotes the number of ongoing calls in a cell. The inter-arrival time between successive new calls is λ_n ("assumed to be a random variable with distribution exponential"), it denotes the arrival rate for new calls. The Inter arrival time for the handoff calls is λ_h ("also assumed to be distributed with exponential"). Since any poor signal quality handoff is immediately dropped, total incoming-call traffic rate is ($\lambda_n + \alpha\lambda_h$) [4]. Given that there is a total of *c* channels available in a cell for computing the dropping probability, states (0, 1 . . . c − 1) and there are 'G' number of channel reserved for handoff calls (G < C) only in first model. Guard channels are reserved in all cells for handoff calls. its allocation depends on the RSSI which has arrival rate of $\alpha\lambda_h$. In second model there are no GC reserved for handoff.

ASSUMPTIONS AND NOTATIONS

In this work we have developed a Queueing model to analyse the wireless mobile communication system. There are few assumptions and notations that we have considered: Consider a cellular systems cell that has allocated "c" channels and "g" channels are reserved for handoff calls known as Guard Channel in model 1. And in model 2 there are no guard channels are reserved for handoff.

1) **Arrival of calls**: **-** There are two type of calls, new calls and handoff calls.

   λ_n =arrival rate of new calls.

   λ_h =arrival rate of handoff calls.
2) **Service of calls**: **-** Cell allocate a channel for a service request calls and give the service, it is denoted by "μ".

μ_n =service rate of new calls.

μ_h =service rate of handoff calls. (4)

3) **Dropping probability**: - It is the probability that handoff calls receive the poor signal quality, such calls are immediately dropped, denoted by **Pd.**
4) **Blocking probability: -** It is the probability that a new user finds the all channels are busy in the cell, denoted by P_b
5) **Received signal strength indicator: -** It is the signal strength that MT receives from the cell and makes the handoff decision, denoted by "**α**". Probability of good signal quality denotes 'α' and poor signal quality denotes '1-α'.
6) **Traffic intensity: -** It is the average utilization, defined as the ratio of arrival rate to the service rate of call. Denoted by "**ρ**".
ρ = λ / μ;

State transition diagram

We have considered two type of model one is cellular network with guard channel and second is without guard channel (non prioritized), both model is described below with all the calculations, blocking probability and dropping probability of the system.

Model 1: - With guard channel (prioritized)

We consider a cellular system has c number of total channels and g numbers of guard channels. We calculated the steady state probability of all the channels is busy in the system [1].

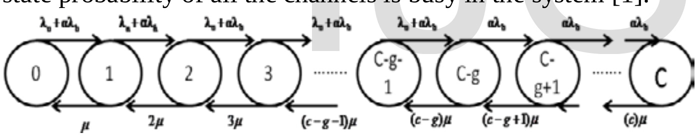


Figure 1: State Transition diagram (with guard channel)

$$P_c = \left(\frac{\lambda}{\mu}\right)^c Po \quad (1)$$

Steady state condition

$$\sum P_c = \sum Po * \rho^c \quad (2)$$

$$Po \sum \rho^c = 1 \qquad \left\{ \text{Steady state condition} \right\}$$

$$Po = \frac{1}{\sum \rho^c} \qquad Po = \frac{1}{\left(\frac{1-\rho^{c+1}}{1-\rho}\right)} \quad (3)$$

$$\lambda = \lambda n + a\lambda_h \quad , \mu \quad , \rho$$

$$\rho_1 = \frac{\lambda n + a\lambda_h}{\mu} \qquad \rho_2 = \frac{a\lambda_h}{\mu}$$

probability of busy of 0^{th} channel

$$P_0 = \frac{1}{\sum_{j=1}^{c-g-1} \frac{(\rho_1)^j}{j!} + \sum_{j=c-g}^{c} \frac{(\rho_1)^{c-g} (\rho_2)^{j-(c-g)}}{j!}}$$

The P_j is the steady state probability of the system where j=0, 1, 2…..c. This equation is solved by the balance equation which is a birth-death process studied in literature reviewed. Which is

$$P_j = \begin{cases} \left[\frac{(\rho_1)^j}{j!}\right] P_0 & , j \le c-g \\ \left[\frac{(\rho_1)^{c-g} (\rho_2)^{j-(c-g)}}{j!}\right] P_0 & , j \ge c-g \end{cases} \quad (5)$$

Performance Parameters of model 1

1. **Blocking probability:** The blocking probability is defined as all the channels are busy in the cell, the new incoming call will be blocked [9].

The new call blocking probability is given below [1].

$$P_b = \frac{\sum_{j=c-g}^{c} \frac{(\rho_1)^{c-g} (\rho_2)^{j-(c-g)}}{j!}}{\sum_{j=1}^{c-g-1} \frac{(\rho_1)^j}{j!} + \sum_{j=c-g}^{c} \frac{(\rho_1)^{c-g} (\rho_2)^{j-(c-g)}}{j!}} \quad (6)$$

2. **Dropping probability:** Call is dropped when signal strength is poor [9].

The dropping probability is computed [1].

$$P_d = P_c + (1-\alpha) \sum_{j=0}^{c-1} P_j \quad (7)$$

Model 2:- Without guard channel (non prioritized)

We consider a cellular system wherein each cell has C channels serving all types of requests. We can easily find the steady state probability of all c channels is busy in the system.

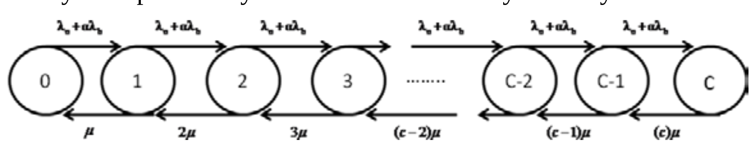


Figure 2: State Transition diagram (without guard channel)

$$\sum_c P_c = \sum Po * \rho^c$$

$$\sum_{n=0} P_n = 1 \qquad \{\text{Normalizing condition}\}$$

Compute P_0 by using normalizing condition

$$Po \sum \rho^c = 1$$

$$Po = \frac{1}{\sum \rho^c}$$

$$\rho = \frac{\lambda n + a\lambda_h}{\mu}$$

$$Po = \frac{1}{\sum_{j=0}^{c}\left(\frac{\lambda_n + \alpha\lambda_h}{\mu}\right)^j * \left(\frac{1}{j!}\right)} \quad (8)$$

$$P_c = \left(\frac{\rho^c}{c!}\right) * P_o \quad (9)$$

Performance parameter

The blocking and dropping probability are same in this model, if all channels are busy the dropping and blocking probability is computed below.

$$P_c = \frac{\left(\frac{\lambda_n + \alpha\lambda_h}{\mu}\right)^c * \left(\frac{1}{c!}\right)}{\sum_{j=0}^{c}\left(\frac{\lambda_n + \alpha\lambda_h}{\mu}\right)^j * \left(\frac{1}{j!}\right)} \quad (10)$$

If all C channels are busy the new calls as well as handoff calls request are dropped

$P_d=P_b=P_c$

III. NUMERICAL ANALYSIS

The analysis of both of the models is evaluated in terms of dropping *(P_d)* (equation no. 8, 10) and blocking probabilities (P_b) (equation no. 7, 10), respectively. For computation purpose we assume that the total number of channels c = 12 and the number of GCs is (g = 2). To evaluate the effect of poor-signal-quality handoff calls, we take α = 0.8 to 1. Depending on whether the "poor"-quality handoff calls are dropped. In the numerical computations, call completion rate μ_1 is taken to be 0.5 call/min, and μ_2, denoting the rate at which ongoing calls are handed off to some other BSS, is assumed to be 0.5 call/min [1]. This gives μ = 1.0. When a BSS receives a poor-signal-quality handoff call, such a call will be dropped immediately. We analyzed a case in which the arrival rate of new calls λ_n is varied from 5 to 40 call/min. Since μ = 1.0, λ_n also represents the new-call traffic load in erlangs. The only other remaining parameter is the handoff arrival rate λ_h is assumed to be varied from 5 to 40 call/min.

***MAHO**:* This scheme makes handoff decisions solely on the basis of signal quality (thus ensuring α=1) and does not take into account the availability of free channels or GCs for the handoff calls. From modeling and performance evaluation purposes, we can utilize the poor signal quality factor which α_0 , as shown in Fig. 1, For the MAHO case, states (0, 1, . . ., c − 1) are assigned to have poor signal quality ά (1-α) and state c is assigned to have good signal quality factor α=1. The dropping as well the blocking probabilities are evaluated.

***M + G**:* The "M + G" case refers to the handoff scheme based on the proposed handoff protocol [1]. The underlying handoff protocol ensures that, when a call is to be handed off, it is handed off to a cell that is able to provide a free channel as well as acceptable signal quality, thus ensuring $\alpha \rightarrow 1$.

Blocking Probability versus Signal Strength

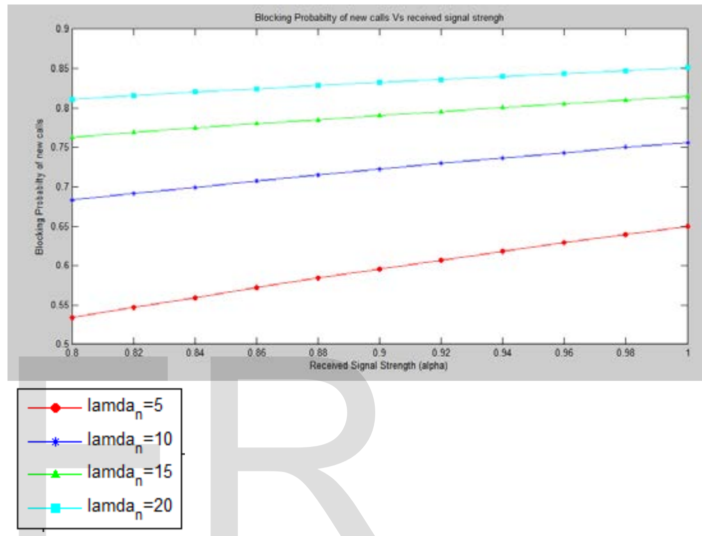
It shows the behaviour of P_b (new call blocking probability) (equation no. 6, 9) as the function of signal strength α. Mathematically P_b increases as α increase monotonically.

We compared the both the models in terms of blocking probability

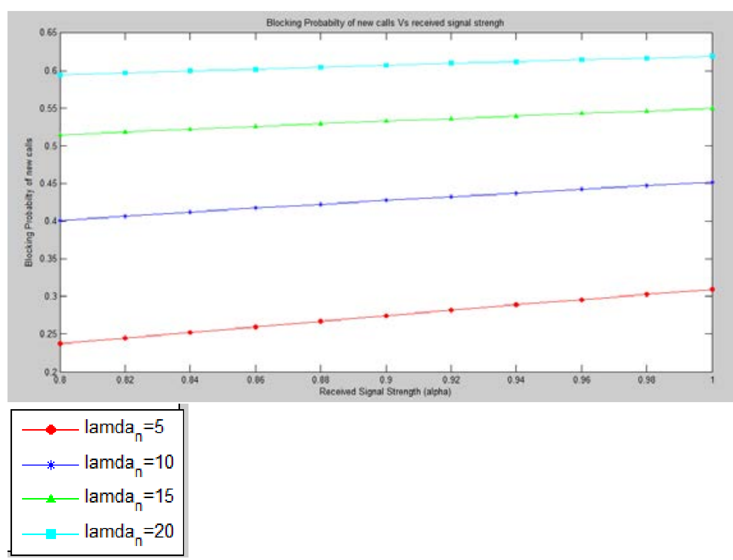
This plot assumes c=12 and g=2. To analyze the effect of signal quality factor α. α is set in a range of 0.8 to 1.

We have plotted the P_b (equation no. 6, 9) versus α at different value to new call arriving rate λ_n for both models

λ_n = 5 , 10 , 15 , 20 and μ =1 ;



Plot 1.1 blocking probability versus signal strength for cellular network with guard channel model.



Plot 1.2 blocking probability versus signal strength for cellular network without guard channel model (non prioritized).

From plot 1.1 and plot 1.2, we analysed that if the new call arriving rate is increases the blocking probability also increases as we studied.

We analysed that the blocking probability of new calls of the model with guard channel is larger than the model without guard channel.

We analysed that the new call blocking probability increases with signal strength, This is due to the fact that the increased value of *α* implies fewer handoff calls being dropped immediately, which leaves fewer channels available for accepting new calls, thus increasing P_b as *α* increases.

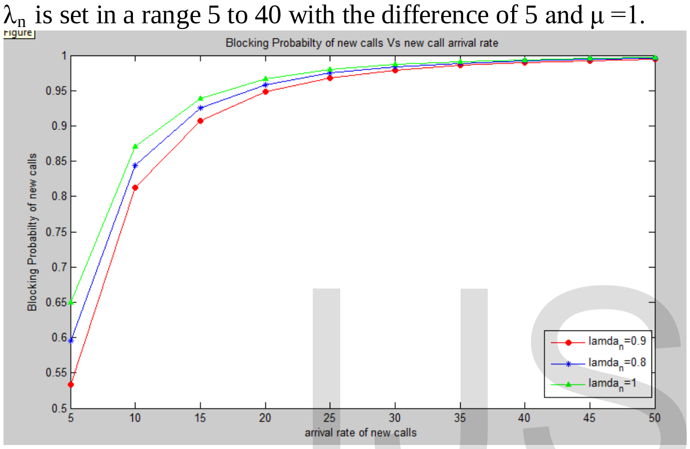
Blocking Probability versus New Call traffic load (Erlang)

It shows that the new call blocking probability as the function of new call arrival rate for c=12 and g=2. To analyze the effect of signal quality factor α is set to the value 0.8, 0.9 and 1.

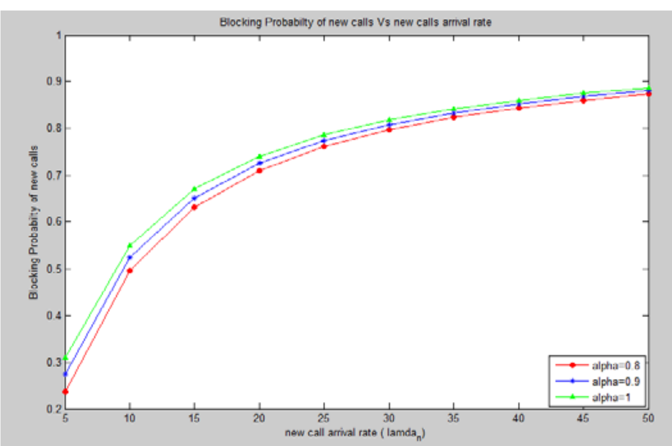
P_b is to be a monotonically increasing function of new calls arrival rate

We plot the P_b versus λ_n at different value to signal strength for both models

λ_n is set in a range 5 to 40 with the difference of 5 and μ =1.



Plot 2.1 blocking probability versus arrival rate in the model with guard channel



Plot 2.2 blocking probability versus arrival rate in the model without guard channel

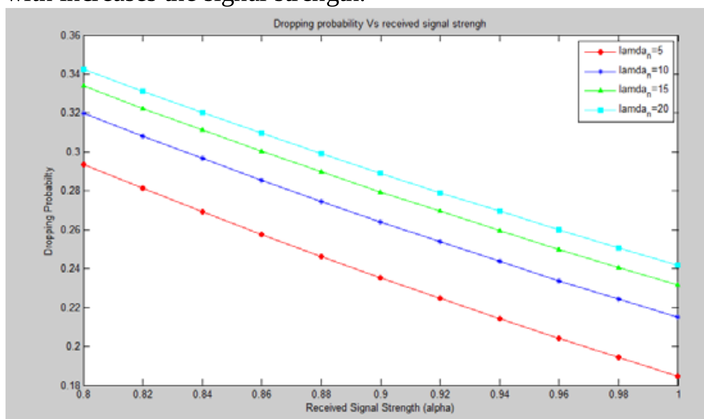
From the plot 2.1 and 2.2, we analysed that the blocking probability monotonically increasing with the new calls arrival rate. And also increasing with signal strength.

We analysed that the new call blocking probability is larger in the model 1 (prioritized) than model2 (non prioritized). This is due the number of channels for new calls are less in model 1 (fig. 1) than non prioritized model 2 (fig. 2).

Dropping Probability

1) *Dropping probability (equation no. 8) variation of model with guard channel (fig.1)*

This plot assumed that the total number of channels is c=12 and the guard channels=2 and we set the signal strength α is 0.8 to 1. We plotted dropping probability versus signal strength at different value of new call arrival rate λ_n = 5, 10, 15 and 20 as shown in the graph. Mathematically the dropping probability (equation no. 8) increases monotonically as ά (1-α) increases. It means the dropping probability will decreases with increases the signal strength.



Plot 3.1 Dropping probability versus signal strength for model with guard channel

From the plot 3.1, we assumed that dropping probability is decreases with increases with signal strength in the first model. And the dropping probability increases with increases the new calls arrival rate

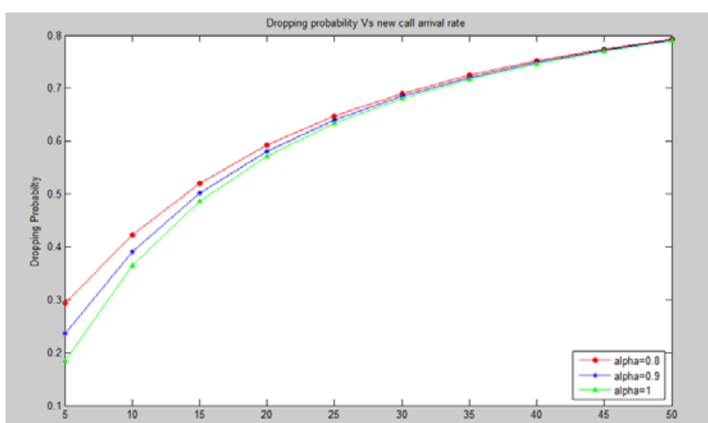
2) *Dropping probability (equation no. 10) variations arrival call rate for the model with guard channel (fig.5.1)*

It shows that the dropping probability as the function of new call arrival rate for c=12 and g=2. To analyze the effect of signal quality factor α is set to the value 0.8, 0.9 and 1.

P_d is to be a monotonically increasing function of new calls arrival rate.

We plot the P_d versus λ_n at different value to signal strength for both models

λ_n is set in a range 5 to 40 with the difference of 5 and μ =1.



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Plot 3.2 dropping probability versus arrival call rate for the model with guard channel.

From the plot 3.2, we analysed that the dropping probability is monotonically increases with new calls arrival rate. And it shows that the dropping probability decreases as increases the signal strength.

IV. TABLES

Table 1: - All parameters and assumptions and notations are follows given in the table for model 1 (prioritized)

S. No.	Assumptions, Notations and Parameters of the model	Model 1 (prioritized)
1	Total number of channel in the models (c)	12
2	Total number of guard channels (g)	2
3	Call arrival rate (λ_n , λ_h) (λ_n= new call arrival rate, λ_h= handoff arrival rate)	λ_n =5 to 40 call/min λ_h =5 to 40 call/min
4	Received signal strength indicator (α)	α = 0.8 to 1
5	Call service rate (μ)	μ = 1.0
6	Traffic intensity (ρ)	$\rho_1 = \frac{\lambda n + a\lambda_h}{\mu}$ For c-g channels $\rho_2 = \frac{a\lambda_h}{\mu}$ For g channels
7	P_0 (probability of busy of 0^{th} state)	$P_0 = \frac{1}{\sum_{j=1}^{c-g-1} \frac{(\rho_1)^j}{j!} + \sum_{j=c-g}^{c} \frac{(\rho_1)^{c-g}(\rho_2)^{j-(c-g)}}{j!}}$
8	P_b (blocking probability)	$P_b = \frac{\sum_{j=c-g}^{c} \frac{(\rho_1)^{c-g}(\rho_2)^{j-(c-g)}}{j!}}{\sum_{j=1}^{c-g-1} \frac{(\rho_1)^j}{j!} + \sum_{j=c-g}^{c} \frac{(\rho_1)^{c-g}(\rho_2)^{j-(c-g)}}{j!}}$
9	P_d (dropping probability)	$P_d = P_c + (1-\alpha)\sum_{j=0}^{c-1} P_j$

Table 2: - All parameters and assumptions and notations are follows given in the table for model 2 (non prioritized)

S. No.	Assumptions, Notations and Parameters of the model	Model 2 (non prioritized)
1	Total number of channel in the models (c)	12
2	Total number of guard channels (g)	0
3	Call arrival rate (λ_n , λ_h) (λ_n= new call arrival rate, λ_h= handoff arrival rate)	λ_n =5 to 40 call/min λ_h =5 to 40 call/min
4	Received signal strength indicator (α)	α = 0.8 to 1
5	Call service rate (μ)	μ = 1.0
6	Traffic intensity (ρ)	$\rho = \frac{\lambda n + a\lambda_h}{\mu}$ For all channels
7	P_0 (probability of busy of 0^{th} state)	$Po = \frac{1}{\sum_{j=0}^{c} \left(\frac{\lambda_n + \alpha\lambda_h}{\mu}\right)^j * \left(\frac{1}{j!}\right)}$
8	P_b (blocking probability)	$P_c = \left(\frac{\rho^c}{c!}\right) * P_o$
9	P_d (dropping probability)	$P_c = \left(\frac{\rho^c}{c!}\right) * P_o$

V. CONCLUSION

In this paper we have analysed the issue of handoff of wireless mobile communication, keeping in the mind a scenario in which the BSSs also have to deal with handoff calls having poor signal quality [1]. We have taken two model in this work the first is prioritized model in this we reserved some channels (GCs) (fig. 1) for handoff calls and second is non prioritized (fig. 2) and we see the variations in blocking probability (equation no. 7, 10) this is concluded that the blocking probability of non prioritized model is lesser than the prioritized model. We analysed a handoff scheme M+G to handle the poor signal quality handoff calls. This scheme combines the MAHO and GCs approaches that ensure α→1 [1]. In this we determined the performance parameter (table 1 & table 2) for the both model in terms of blocking and dropping probabilities as the function of signal strength and new calls arrival rate.

This paper shows that the comparison between two models with guard channel and without guard channel. In addition to this paper, deals with the difference between the models that which model could be use in the future and which is better with its parameter blocking probability and call dropping should be minimize. We have analysed that the dropping probability variation with the new call arrival rate is better in model1 (prioritized fig.1) than the model 2 (non prioritized fig.2).

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