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Research Article

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Development of Duration Based Call Admission Scheme for Cellular Network

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Abstract With the major challenges suffered by majority of the wireless communication network users and also the challenges being faced by the network providers in order to provide satisfactory quality of services that will meet the demand of their subscribers, there is a need for an implementation of a better call management scheme. With the knowledge of how disappointed or bad the mobile users feel whenever they experience network congestion that brings about poor quality of service; the researcher therefore proposes a new scheme for call management. This proposed scheme classified calls into two; short-calls and long-calls. Statistically, it has been found that over 65% of GSM users make calls that are less than or equal to 180s. Hence, this proposed scheme will give priority to short calls, and also adopt a relative probability factor (β) which will be used to allocate some percentage of the channels that were initially allocated to long calls whenever the long calls are minimal within the last interval being considered.

Keywords Short Calls, Long Calls, Call Drop, Call Admission Call, Signal Strength

Introduction

Telecommunications networks aim to provide integrated services such as voice, data, and multimedia via inexpensive low-powered mobile computing devices over wireless infrastructures [1]. As the demand for multimedia services over the air has been steadily increasing over the last few years, wireless multimedia networks have been a very active research area. To support various integrated services with a certain quality of service (QoS) requirement in these wireless networks, resource provisioning is a major issue [2-3]. With the rapid growth in the number of users of wireless communication networks, the network providers are therefore being demanded to provide better and reliable quality of services to their users [4]. In Cluster-Based Call Acceptance scheme, quality of service guarantee is provided to both the handoff calls and new calls by maximizing the utility of the BTS resources to accommodate handoff and new calls in order to improve the performance of the network [5].

In wireless networks, call dropping is possible due to the users' mobility. A good CAC scheme has to balance the call blocking and call dropping in order to provide the desired QoS requirements [6]. Admission control decision is made using a traffic descriptor that specifies traffic characteristics and QoS requirements. A new call request is accepted if there is free channel in the network resource, and also if the call meets the QoS requirements of new calls without disrupting the QoS for the already supported calls. Too many calls lead to a situation where the mutual interference between the connections degrades the QoS for the new call as well as for the ongoing calls. Therefore, admission control play a very important role in providing the user with the requested QoS as well as making an efficient use of the available capacity and preventing the system from an outage situation due to overloading [7].

An accepted call that has not completed in the current cell may have to be handed off to another Base Station (BS). During the process, the call may not be able to gain a channel in the new BS to continue its service due to the limited resource in wireless networks, which will lead to call dropping. Relatively, new calls and handoff calls can be treated differently in terms of resource allocation. Since dropping a call in progress is more annoying than blocking a new call request, handoff calls are typically given higher priority than new calls in access to the wireless resources. This preferential treatment of handoffs increases the blocking of new calls and hence degrades the bandwidth utilization [8].

Materials and Methods

Handoff calls (requests) are queued when all of the channels are occupied in a base station. Calls are then accepted whenever there are free channels. Queuing of handoff requests when there is no channel available can reduce the dropping probability at the expense of higher new call blocking. If any channel is released it is assigned to the next handoff waiting in the queue. If the handoff attempt finds all the channels in the target cell occupied it can be queued. According to [9], the scheme is based on the fact that adjacent calls in a mobile radio system are overlaid. This ensures that there is a reasonable handoff area where a call can be handled by base station in adjacent cell. If the BS finds all channels in the target cell occupied, a handoff request is put in the queue. The channel is assigned to request on the top of the queue usually on the event that a channel is released when the queue for handoff requests is not empty as shown in Figure 1.

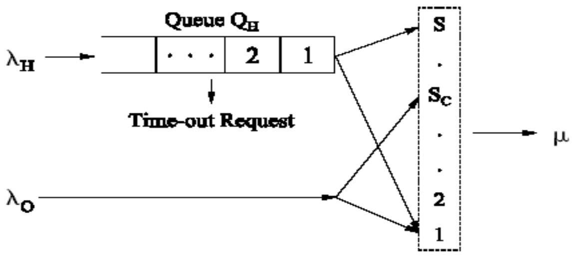

Figure 1: System model with priority and queue for handoff call [9]

A. M+G Scheme

In [10], a different handoff technique (M+G) was proposed by combining the mobile assisted handoff (MAHO) and guard Channel (GC) techniques. In the proposed technique, the mobile terminal (MT) reports back not only the relative signal strenght intensity (RSSI) and the bit error rate (BER) but the number of free channels that are available for the handoff traffic as well. This will ensure that a handed-off call has acceptable signal quality as well as a free available channel. The performance of this handoff technique is analysed using an analytical model whose solution gives the desired performance measures in terms of blocking and dropping probabilities.

"M + G" scheme is a further improvement over their previous guard-plus-rehandoff ("G + ReHo") scheme. The "M + G" scheme utilises MAHO in addition to the GCs. In this scheme, even if a channel is available at a candidate BSS, a poor-signal quality call is not handed over to it. Similarly, a good-signal quality call is also not handed over to a BSS with no available channels. Thus, the "M + G" scheme ensures that a handoff call is handed over to a BSS that is able to offer both good signal quality as well as an idle channel, thereby resulting in $\alpha \rightarrow 1$. The 'α' depicts signal strength factor. They modeled the scheme using the Markov reward model shown in Figure 2.

The dropping probability is now given by the steady-state expected reward rate, which can be written as

$$\pi_j = \pi_0 \begin{cases} \frac{\rho^j}{j!}, & j \leq c-g \\ \frac{\rho^{c-g}}{j!} {\rho_h}^{j-(c-g)}, & j \geq c-g \end{cases} \quad \ldots \ldots \ldots \ldots \quad (1)$$

Where $\mu = \mu_1 + \mu_2$, $\rho = (\lambda_n + \alpha\, \lambda_n)/\, \mu$, and $\rho = \alpha\, \lambda_n/\, \mu$, and

$$\pi_0 = \frac{1}{\sum_{j=0}^{c-g-1} \frac{\rho^j}{j!} + \sum_{j=c-g}^{c} \frac{\rho^{c-g}}{j!} \rho_h{}^{j-(c-g)}} \quad \text{……………………………………………….} \quad (2)$$

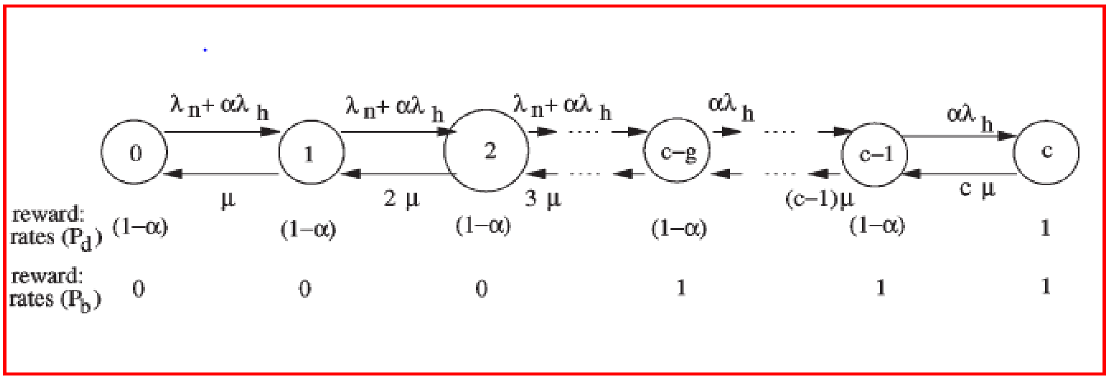

Figure 2: Markov reward model [9]

System Model Description

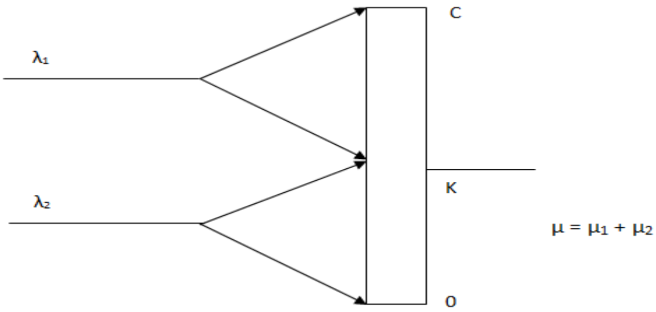

Figure 3: Simplified system model

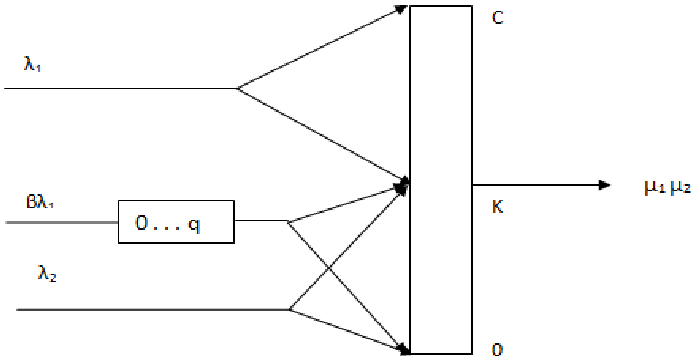

Figure 4: Modified queuing system model

The states of the communication cell are represented by 0 … 1 … k … C.

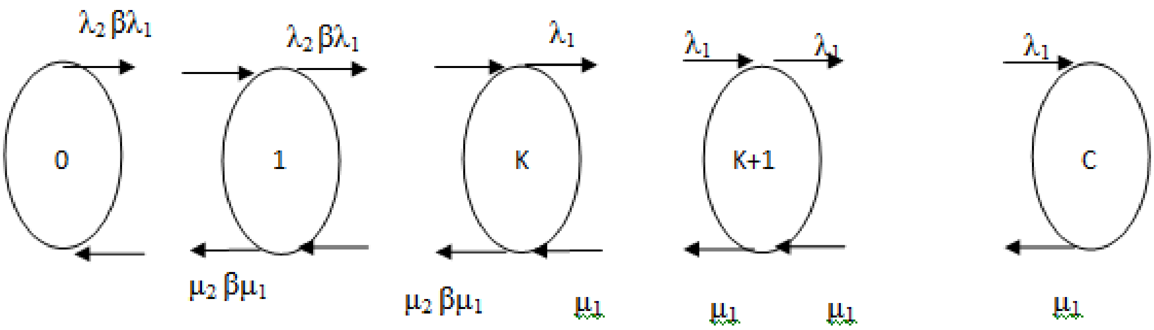

Figure 5: Transition state diagram

Figure 3 shows the simplified system model of the proposed scheme, while Figure 4 depicts the queuing model of the system. And Figure 5 shows the state transition diagram for the proposed model. This state transition diagram throws more insight on how different calls are being accepted within a particular range of channels. The symbols in Figures 4 and 5, and their representations are as follow;

(i) λ stands for arrival rate,

(ii) β stands for probability factor,

(iii) λ_1 stands for short call arrival rate,

(iv) λ_2 stands for long call arrival rate,

(v) $\beta\lambda_1$ stands for relative probability factor for short call arrival rate,

(vi) μ stands for service rate,

The following assumptions were made in order to ensure adequate implementation of this new call management scheme:

(i) This proposed model is designed to be implemented during the day especially at peak periods.

(ii) Any call that is less than three minutes is classified as short call otherwise is a long call.

(iii) This proposed model is designed to be flexible; the model keeps the records of all the users' call duration within the last six months, and it also has the ability to automatically change users' group in terms of either short-call user or long-call user with respect to the average number of minutes made in the last seven days.

(iv) Every new network user is initiated automatically as a short-call user for the first seven days in case of bonus and other benefits.

Through personal interaction and questionnaire, the set of data in Table 1 was obtained.

Table 1: Field survey showing call duration and percentage

Duration(s)	**Percentage (%)**
≤ 60	40
$60 \leq 120$	20
$120 \leq 180$	10
$180 \leq 240$	5.5
$240 \leq 300$	5
$300 \leq 360$	4.5
$360 \leq 420$	4
$420 \leq 480$	3.5
$480 \leq 540$	2.5
$540 \leq 600$	2

Analysis of the Proposed Model

Let the state of the cell as the number of calls in progress for the base station containing the call be denoted as "s".

Where ''s'' is defined as follows;

$s = 0, 1,2,3, ... k, (k+1), (k+2) … C$ …. …. ….. …. …… ….. ….. … …..(3)

The birth- death moves from its state k to k+1 (if birth occurs) and (k-1) if death occurs.

If we choose a time interval Δt so that they can only be;

(i) One state of transition in that interval

(ii) There can be only one arrival or termination but not both.

At this point we assume that the probability of arrival is directly proportional to the time interval Δt.

Let $P_k(t)$ = probability that the system is in state k
that is. k servers are busy

λk = call arrival rate in state k

μk = call arrival rate in state k

Then we have the following probabilities in the time interval Δt

P (exactly one arrival) = $\lambda\Delta t$
P (exactly one termination) = $\mu\Delta t$
P (No arrival) = $1 - \lambda\Delta t$
P (No termination) = $1 - \mu\Delta t$

Then the probability of finding the system in state k at t+Δt is given by

$$P_k(t+\Delta t) = P_{(k-1)}(t)\,\lambda_{(k-1)}\Delta t + P_{(k+1)}(t)\,\mu_{(k+1)}\,\Delta t + (1-\lambda_k\Delta t)(1-\mu_k\Delta t)\,P_k \quad \ldots \quad (4)$$

The first term on the right hand side represent the possibility of finding the system in state K-1 at time t and a birth or call request occurring. The second term represents the possibility of finding the system in state k+1 at time t and a call termination occurring. The last term represents no arrival and no termination.

Expanding Equation (4) and ignoring the second order Δt term, we have:

$$P_k(t+\Delta t) = P_{(k-1)}(t)\,\lambda_{(k-1)}\Delta t + P_{(k+1)}(t)\,\mu_{(k+1)}\,\Delta t - (\lambda_k-\mu_k)\,P_k(t)\,\Delta t + P_{k(t)} \quad \ldots \quad (5)$$

Thus to get the change of probability P_k with time we have:

$$\frac{P_k(t+\Delta t) - P_k(t)}{\Delta t} = P_{k-1}(t)\,\lambda_{k-1} - (\lambda_k + \mu_k)P_{k(t)} \quad \ldots \quad (6)$$

As $\Delta t \Longrightarrow 0$, we have:

$$\frac{dP_k(t)}{dt} = P_{k-1}(t)\,\lambda_{k-1} + P_{k+1}(t)\,\mu_{k+1} - (\lambda_k + \mu_k)P_{k(t)} \quad \ldots \quad (7)$$

Equation (7) is the differential Equation that governs call arrival and calls termination process but while the above Equations give us the rate of change of state probability, we are concerned about the steady state operation. This is because at steady state condition, the probabilities reach the equilibrium value and do not change with time. However, if we assume a constant birth rate which is independent of the state of the system that is if a birth occurs it is impossible to find the system in state zero. Thus Equation (3.6) is for $k \geq 1$:

$$\frac{dp_k}{dt} = \lambda P_{k-1}(t) - \lambda P_k(t) \quad \ldots \quad (8)$$

And Equation (3.7) is for k=0

$$\frac{dp_0}{dt} = -\lambda P_0(t) \quad \ldots \quad (9)$$

In order to solve these equations, we have to assume certain boundary condition, for instance, at time t=0, the system is in state zero that is no birth has taken place

$$P_k(0) = \begin{cases} 1, & \text{for } k = 0 \\ 0, & \text{for } k \neq 0 \end{cases} \quad \ldots \quad (10)$$

With this condition we get solution for Equation (9) as:

$$P_0(t) = e^{-\lambda t} \quad \ldots \quad (11)$$

From Equation (8) and (11), putting k=1, the next equation is obtained as

$$\frac{dp_1(t)}{dt} = \lambda P_1(t) + \lambda e^{-\lambda t} \quad \ldots \quad (12)$$

Solving Equation 12, we have

$$p_1(t) = \lambda t e^{-\lambda t} \quad \ldots \quad (13)$$

For K = 2, the solution is

$$p_2(t) = \frac{(\lambda t)^2 e^{-\lambda t}}{2!} \quad \ldots \quad (14)$$

Thus by induction, we write the general solution as:

$$p_k(t) = \frac{(\lambda t)^k e^{-\lambda t}}{k!} \quad \ldots \quad (15)$$

From Equation (15), we see that the interstate transition time is exponentially distributed. Thus applying this to the transition diagram in Figure 5, then, the probability that the BTS is in state *i* is given as P(*i*), and can be solved using the birth-death process. The state balance Equations as derived from the states transition diagram are as follows:

The probability that the call is in any state within the cell is given thus;

$$S\mu P(s) = \frac{\lambda^i}{\mu^i S!} P_0 \qquad 0 \le S \le C \quad \ldots (16)$$

Therefore, the Equations for the two different parts of the model are as follows; For states "0" to "k"

$$S\mu P(s) = \lambda_2 P(s-1) \qquad 0 \le S \le K \quad \ldots (17)$$

For states "(k + 1)" to "C"

$$S\mu P(s) = \lambda_1 P(S-1) \qquad (K+1) \le S \le C \quad \ldots (18)$$

Hence, in the normalisation condition,

$$\sum_{s=0}^{c} P(s) = 1 \quad \ldots (19)$$

Then, the steady state probability, P(s), is found to be:

$$\begin{cases} \frac{1}{S_1!}\left(\frac{\lambda_1}{\mu_1}\right)^{s_1} P(0)_1 & (k+1) \le s \le c \\ \frac{1}{S_2!}\left(\frac{\lambda_2}{\mu_2}\right)^{s_2} P(0)_2 & 0 \le s \le k \end{cases} \quad \ldots (20)$$

$$P(0)_1 = \left[\sum_{s=(k+1)}^{c} \frac{1}{S_1!}\left[\frac{\lambda_1}{\mu_1}\right]^{s_1}\right]^{-1} \quad \ldots (21)$$

Let assume that:

$$\rho = \frac{\lambda}{\mu} \quad \ldots (22)$$

where ρ represents traffic intensity.

Substituting for ρ in equation (21),

$$P(0)_1 = \left[\sum_{s=(k+1)}^{c} \frac{1}{S_1!}\rho_1^{s_1}\right]^{-1} \quad \ldots (23)$$

Then,

$$P(0)_2 = \left[\sum_{s=(k+1)}^{c} \frac{1}{S_2!}\left(\frac{\lambda_2}{\mu_2}\right)^{s_2}\right]^{-1} \quad \ldots (24)$$

$$P(0)_2 = \left[\sum_{s=(k+1)}^{c} \frac{1}{S_2!}\rho_2^{s_2}\right]^{-1} \quad \ldots (25)$$

Then, the rejection probability of the first set is denoted as follows;

$$P_{g1} = \frac{\rho_1^{s_1}}{S_1!}\left[\sum_{S_1=(k+1)}^{c} \frac{\rho_1^{s_1}}{S_1!}\right]^{-1} \quad \ldots (26)$$

And that of the second set is denoted as:

$$P_{g2} = \frac{\rho_2^{s_2}}{S_2!}\left[\sum_{S_2=0}^{k} \frac{\rho_2^{s_2}}{S_2!}\right]^{-1} \quad \ldots (27)$$

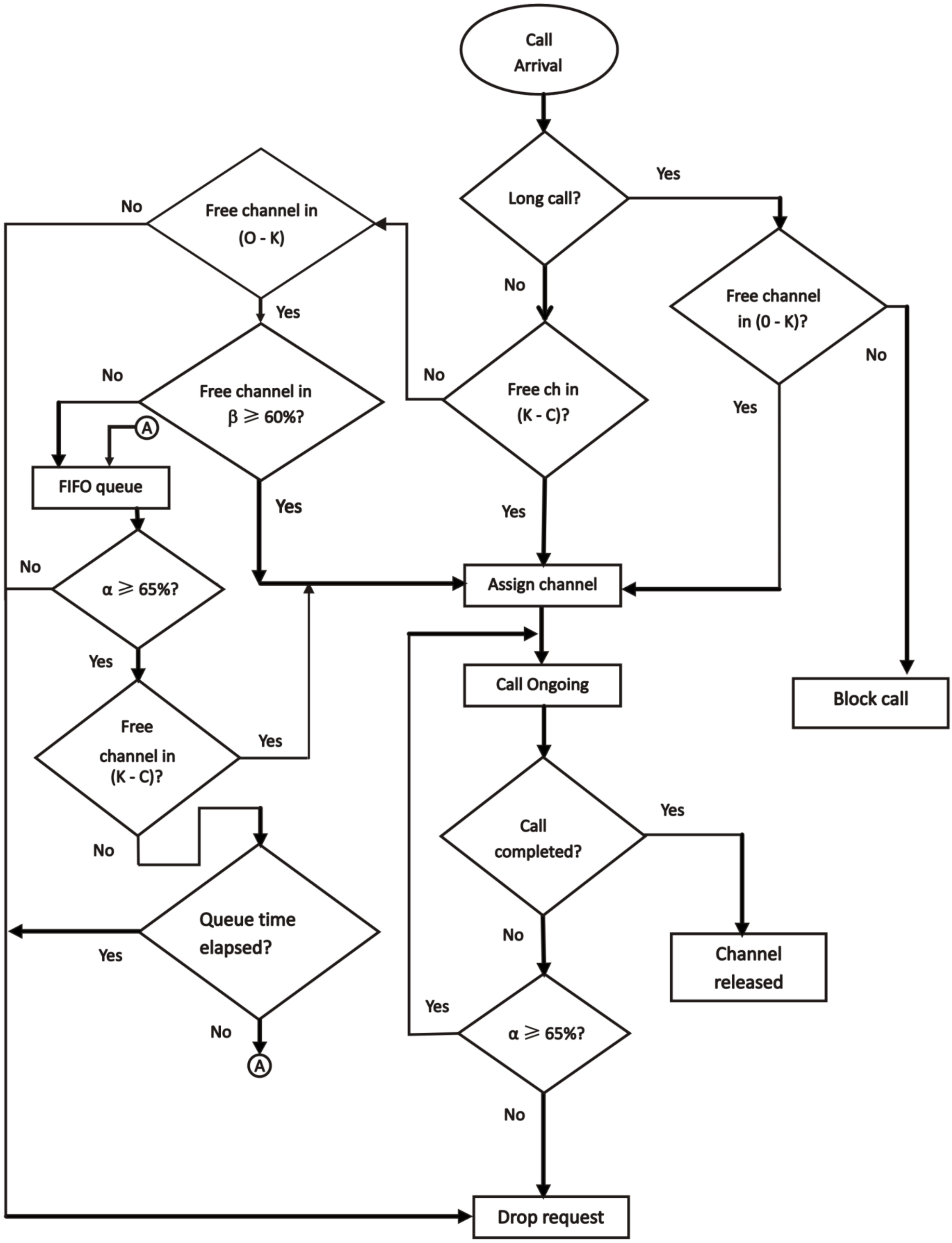

Figure 6: Scheme flowchart

Result and Discussion

With the implementation of the proposed scheme, a result illustrative graph shall be obtained through MATLAB simulation as shown in Figure 7 below. This Figure 7 showcases the effect of channel borrowing in reducing call failure probability.

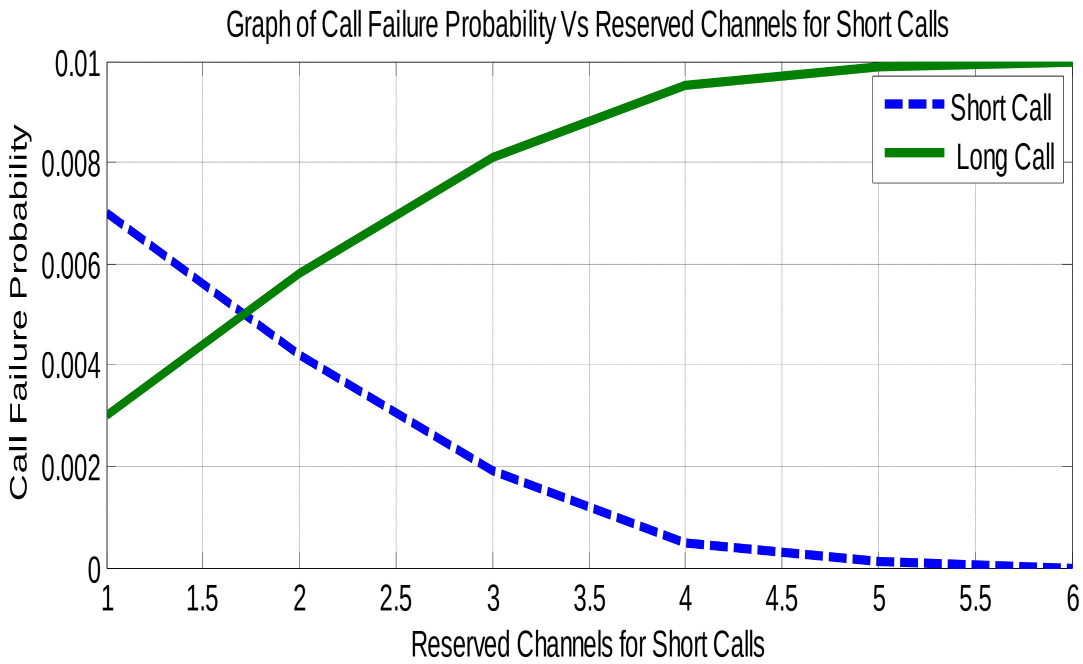

Figure 7: Graphical Result for Simulation I using MATLAB

Conclusion

With the results obtained through simulation, it can be seen that this proposed scheme performs excellently with respect to quality of service. The separation of calls within this research paper helps to provide one of the best channel management within a given BTS. Meanwhile, the scheme applied here is simply a priority-based one that ensures efficiency in BTS utilization in order to minimize call dropping challenges to the barest minimum.

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