Prioritized Call Admission Control Schemes for Integrated Traffic in Wireless Mobile Networks

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Abstract

In this paper, we analyze the performance of Call Admission Control schemes for mixed traffic in integrated data/voice wireless mobile networks in which new and handoff data/voice calls are accepted based on prioritization of handoff requests. Three types of traffic is analyzed in this paper originating data/voice calls known as new calls, handoff data calls and handoff voice calls. A higher priority is given to the handoff voice calls than to handoff data calls. Guard channel and fractional guard channel policies are used to analyze the handoff performance of integrated traffic. A numerical analysis of the system performance is presented to evaluate the blocking probabilities of new calls and handoff data calls, forced termination probability of handoff voice calls

Keywords - Guard Channel, Fractional Guard Channel, Call Blocking Probability, Forced Termination Probability, Quality of Service (QoS).

Introduction

Over the last two decades there has been a tremendous increase in the demand for wireless mobile communications services. As the number of users grows, the system operators progressively deploy smaller cells (micro and pico cells) to increase system capacity. As the cell size reduces the cell boundary crossings increases exponentially and results in higher handoff rate. Handoff process enables a cellular system to provide such a facility by transferring an active call from one cell to another. Further, there is also a tremendous increase in variety of service types such as, multimedia, e-mail and general data services, in addition to traditional voice communication. The increase in the number of handoffs as well as the requirement for providing different types of services generates the new challenges for Call Admission Control (CAC) schemes.

In a wireless mobile communication system two critical Quality of Service metrics are used blocking probability and forced termination probability. Both of these QoS metrics are fraction of new and handoff calls that are blocked due to unavailability of channels. The new call blocking probability is the probability that a new call request is blocked. The forced call termination probability is the probability that an ongoing call is forced to terminate before it completes the service. Therefore, the CAC technique in use has to create equilibrium between the call blocking and forced termination to provide the desired

performance and quality of service (QoS) in a wireless mobile network.

In wireless mobile network a fixed number of channels are assigned to a given cell. If a channel is used by a call, no other call can use the channel again in the same cell at the same time. With the decrease in size of cell the handoff attempts are also increases. The handoff calls be given priority over new calls since handoff calls are more sensitive than new calls. Several call admission control schemes have been proposed and used to improve the handoff performance. One of these handoff schemes is the prioritized handoff procedures in which a number of channels in each cell are reserved for handoff calls in order to reduce the handoff failure probability at the cost of a small increase in the new call blocking probability. Guard channel schemes have been shown to be effective for providing the QoS guarantee in terms of both call termination and call blocking probabilities by Guerin (1988), Ramjee *et al*., (1996), Li *et al*., (1998) and Wu *et al*., (2002). The performance of non-prioritized and prioritized handoff procedures have been analyzed by Hong and Rappaport (1986). The queuing concept in the handoff process was introduced to reduce the forced termination probability by Tekinay and Jabbari (1992). Rappaport and Purzynski (1996) were developed analytical models for a cellular mobile environment consisting of mixed platform types with different classes of channel and resource requirements. Handoff calls are prioritized over new calls and quotas are incorporated for each type of resources.

The most of the researchers using guard channel and fractional guard channel techniques focused only on handoff voice calls. An analytic model for multiple handoff and analysis of single type of calls has been proposed by Rappaport (1991). Recursive formula, for the new call blocking and handoff failure probabilities using fractional guard channel policies in cellular networks are derived by Jose *et al*., (2006). Posner and Guerin (1985) presented traffic policies for minimizing the blocking of handoff calls. Performance of personal portable radio telephone systems with or without guard channels is analyzed by Yoon and Un (1993). A simple scheme to improve the performance of mobile cellular networks is presented by incorporating delay of voice end user to the new originating calls over handoff call in a two dimensional traffic model is proposed by Amin and Islan (2009). A dynamic threshold channel allocation scheme is proposed by Ojesanmi *et al*., (2009) for cellular networks. Chiranjeev and Rajeev (2009) presented a new preemptive handoff scheme in integrated mobile communication environment.

In this paper, we proposed prioritized call admission control schemes for integrated traffic in wireless mobile network with dual threshold values. In wireless multimedia network the threshold scheme is known as upper limit (UL) scheme and it gives a very good performance, while the parameter forced termination is concerned, but it degrades the parameter new call blocking. In an integrated environment, there are both voice calls and data calls. Based on their nature, these two types of mobile traffic can be further subdivided into the following three categories:

- Originating (data/voice) calls i.e. new calls
- Handoff Data Calls
- Handoff Voice Calls

The performance of the CAC is analyzed by applying guard channel and fractional guard channel

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techniques on above three types of traffic. Furthermore, handoff voice calls must have priority over handoff data calls since, data traffic is delay-insensitive and voice traffic is stringent to access delay. Hence, an ongoing voice call is allowed to preempt over ongoing data call. In the proposed scheme, any kind of handoff calls have priority over all new calls and handoff voice calls have priority over handoff data calls. The performance of the CAC is evaluated on the following (QoS) metrics:

- Blocking probability of new calls
- Blocking probability of handoff data calls
- Forced termination probability of handoff voice calls

In section 2, description of the system model is given. Call admission control schemes and their performance analysis are presented in section 3 and the numerical results derived are discussed in section 4. At the last the conclusions of the paper is presented in section 5.

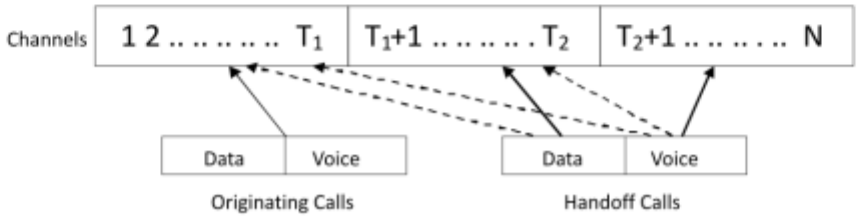

Figure 1: Systems model of proposed scheme

Call Admission Control Schemes

The call admission control schemes proposed in this paper is based on the Guard Channel and the fractional Guard Channel. Mainly, three types of traffics are assumed in these CAC algorithms, new calls, handoff data calls and handoff voice calls. The new (data/voice) calls are admitted traditionally. The handoff calls are admitted according to the proposed schemes.

The performance of the admission schemes is computed on the basis of the following assumptions:

- Let us consider a wireless mobile network with N channels in a given cell.
- The handoff data calls are assumed different from the handoff voice calls and priority is given to handoff voice calls over new calls and handoff data calls.
- In each cell the arrivals of originating calls, handoff data calls and handoff voice calls are Poisson distributed with arrival rates λ, λ_{hd} and λ_{hv} respectively.
- Call duration time or call holding time of all types of calls are exponentially distributed with the average call duration time for new calls, handoff data calls and handoff voice calls is denoted by $\frac{1}{\mu}$, $\frac{1}{\mu_{hd}}$, $\frac{1}{\mu_{hv}}$ respectively and traffic intensity is denoted by $\rho_{hv} = \frac{\lambda_{hv}}{\mu_{hv}}$ and $\rho = \frac{\lambda}{\mu}$, $\rho_{hd} = \frac{\lambda_{hd}}{\mu_{hd}}$, for new calls, handoff data calls and handoff voice calls respectively.

In this paper, we use the one dimensional Markov chain model to find the blocking probabilities of new calls and handoff data calls and forced termination probability of handoff voice calls. From the literature

it has been observed that as the traffic intensity of a particular type of calls increases the blocking probability of that type of calls is also increases. The average service time for all type of calls is normalized to unity and there is no effect of this normalizing process on the traffic intensity.

Guard channel policy

The Guard channel (GC) policy reserves a subset $N-T_1$ out of these N channels for handoff (data/voice) calls and another subset $N-T_2$ exclusively for handoff voice calls. Here, T_1 is the threshold value of the number of channels after which no new calls will be accepted and T_2 is the threshold value of the number of channels after which all the incoming handoff data calls will be rejected. When, the number of occupied channels are exceeds the threshold T_1, the guard channel policy rejects all new calls and accepts only handoff data and handoff voice calls. When, the number of occupied channels are exceeds the threshold T_2, the guard channel policy rejects all new calls as well as handoff data calls and accepts only handoff voice calls. When all the channels are occupied handoff voice calls are also rejected. The algorithm for the proposed policy is given below:

Algorithm: Guard Channel Policy with Dual threshold

```
if (incoming Call is a New Call) then
        if (the number of busy channels < T1) then
                admit call;
        else
                reject call;
 if (incoming call is a handoff data call) then
        if (the number of busy channel < T2) then
                admit call;
          else
                reject call;
if (incoming call is a handoff voice call) then
        if (the number of busy channel < N)
                admit call;
        else
                reject call;
```

Total number of occupied channels can define the state of a cell at any time . A continuous time Markov chain with N states is used to model the cell channel occupancy. The state transition diagram for Guard Channel policy applying on a cell with N channels with $N-T_1$ and $N-T_2$ Guard Channels is presented in fig 2.

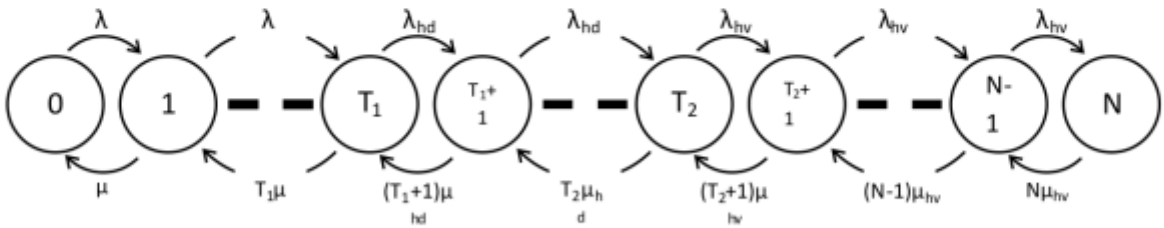

Figure 2: State transition diagram for guard channel scheme

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The steady state probabilities P_i for i (i = 0, 1, 2, ……., N) channels are occupied in a cell is given by:

$$P_i = \begin{cases} \frac{(\rho+\rho_{hd}+\rho_{hv})^i}{i!} P_0 & 0 \le i \le T_1 \\ \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_1}\rho_{hd}^{i-T_1}}{i!} P_0 & T_1+1 \le i \le T_2 \\ \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_2}\rho_{hv}^{i-T_2}}{i!} P_0 & T_2+1 \le i \le N \end{cases} \quad ...(1)$$

where,

$$P_0 = \frac{1}{\sum_{i=0}^{T_1} \frac{(\rho+\rho_{hd}+\rho_{hv})^i}{i!} + \sum_{i=T_1+1}^{T_2} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_1}\rho_{hd}^{i-T_1}}{i!} + \sum_{i=T_2+1}^{N} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_2}\rho_{hv}^{i-T_2}}{i!}} \quad ...(2)$$

From the stationary distribution given in equation (1), the blocking probability for new calls is obtained as follows:

$$P_{nb} = \frac{\sum_{i=T_2+1}^{T_2} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_1}\rho_{hd}^{i-T_1}}{i!} + \sum_{i=T_2+1}^{N} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_2}\rho_{hv}^{i-T_2}}{i!}}{\sum_{i=0}^{T_1} \frac{(\rho+\rho_{hd}+\rho_{hv})^i}{i!} + \sum_{i=T_1+1}^{T_2} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_1}\rho_{hd}^{i-T_1}}{i!} + \sum_{i=T_2+1}^{N} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_2}\rho_{hv}^{i-T_2}}{i!}} \quad ...(3)$$

The Blocking Probability of handoff data calls is

$$P_{hdb} = \frac{\sum_{i=T_2+1}^{N} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_2}\rho_{hv}^{i-T_2}}{i!}}{\sum_{i=0}^{T_1} \frac{(\rho+\rho_{hd}+\rho_{hv})^i}{i!} + \sum_{i=T_1+1}^{T_2} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_1}\rho_{hd}^{i-T_1}}{i!} + \sum_{i=T_2+1}^{N} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_2}\rho_{hv}^{i-T_2}}{i!}} \quad ...(4)$$

The forced termination probability of handoff voice calls

$$P_{hvb} = \frac{\frac{(\rho+\rho_{hd}+\rho_{hv})^{T_2}\rho_{hv}^{N-T_2}}{N!}}{\sum_{i=0}^{T_1} \frac{(\rho+\rho_{hd}+\rho_{hv})^i}{i!} + \sum_{i=T_1+1}^{T_2} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_1}\rho_{hd}^{i-T_1}}{i!} + \sum_{i=T_2+1}^{N} \frac{(\rho+\rho_{hd}+\rho_{hv})^{T_2}\rho_{hv}^{i-T_2}}{i!}} \quad ...(5)$$

Fractional guard channel policy

Fractional Guard Channel (FGC) policy is a general call admission control scheme in which an arriving new call will be admitted with probability β_{ni} when the number of busy channels is i (i = 0, 1, ….., T_1-1) and handoff data calls will be admitted with the probability β_{ndi} when the number of busy channels is i (i = 0, 1, ……., T_2-1). An arriving handoff voice call will always be admitted unless there is no channel available in the cell. FGC policy uses a vector $B_n = [\beta_{n0}, \beta_{n1}, \ldots\ldots\ldots, \beta_{n(T_1-1)}]$ to determine if a new call can be accepted and the component of that same vector determine the strategy. Similarly, to determine if a handoff data call can be accepted, FGC policy used another vector $B_{hd} = [\beta_{hd0}, \beta_{hd1}, \ldots\ldots\ldots, \beta_{hd(T_2-1)}]$.

Algorithm: Fractional Guard Channel Policy, random(0,1) returns a uniformly generated random number in the interval [0,1].

```
if (incoming Call is a New Call) then
        if (random(0,1) ≤ βni (the number of busy channels)) then
                admit call;
```

else
reject call;
if (incoming call is a handoff data call) then
if (random (0,1) ≤ β_{hdi} (the number of busy channels)) then
admit call;
else
reject call;
if (incoming call is a handoff voice call) then
if (the number of busy channel < N)
admit call;
else
reject call;

The state transition diagram for Fractional Guard Channel policy applying on a cell with N channels is presented in fig 3.

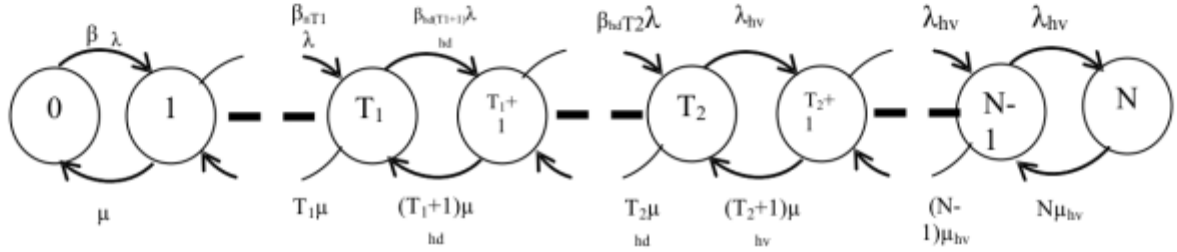

Figure 3: State transition diagram for fractional guard channel scheme

The steady state probability for i (i = 0, 1, 2, ……., N) channels are occupied in a cell is given by:

$$P_i = \frac{\Pi_{j=0}^{i-1}(\beta_{jn\rho} + \beta_{hdj\rho hd} + \rho_{hv})}{il} P_0, \qquad 1 \le i \le N \qquad \ldots(6)$$

where,

$$P_0 = \frac{1}{\sum_{i=0}^{N} \frac{\Pi_{j=0}^{i-1}(\beta_{jn\rho} + \beta_{hdj\rho hd} + \rho_{hv})}{il}} \qquad \ldots(7)$$

From this stationary distribution, we obtain the blocking probability of new calls is as follows:

$$P_{nb} = \sum_{i=0}^{N}(1 - \beta_{ni})P_i, \qquad \beta_N = 0 \qquad \ldots(8)$$

The blocking probability of handoff data calls is

$$P_{hdb} = \sum_{i=0}^{N}(1 - \beta_{hdi})P_i, \qquad \beta_N = 0 \qquad \ldots(9)$$

The forced termination probability of handoff voice calls is

$$P_{hvb} = P_N \qquad \ldots(10)$$

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Numerical Results and Discussions

In this section, we demonstrate the numerical results by various parameters to get the performance of Guard Channel (GC) and Fractional Guard Channel call admission control strategies with dual threshold values for handoff data calls and handoff voice calls. In the numerical analysis, it is assumed that each cell has N=30 channels, for guard channel policy the threshold value $T_1 = 15$ and $T_2 = 25$, arrival rate of new calls $\lambda = \frac{1}{20}$ and service rate μ for new calls varies from $\frac{1}{100}$ to $\frac{1}{1600}$ min., then the traffic intensity of new calls is given by $\rho = \frac{\lambda}{\mu}$. It is also assumed that both (data/voice) types of handoff calls are arrived at a constant rate i.e. $\lambda_{hd} = \lambda_{hv} = \frac{1}{30}$ and observe constant service time $\mu_{hd} = \mu_{hv} = \frac{1}{300}$ min., the traffic intensity $\rho_{hd} = \rho_{hv} = 10$. In fig.4, the blocking probability of new calls according to both the policies is drawn against the traffic intensity of new calls in the cell.

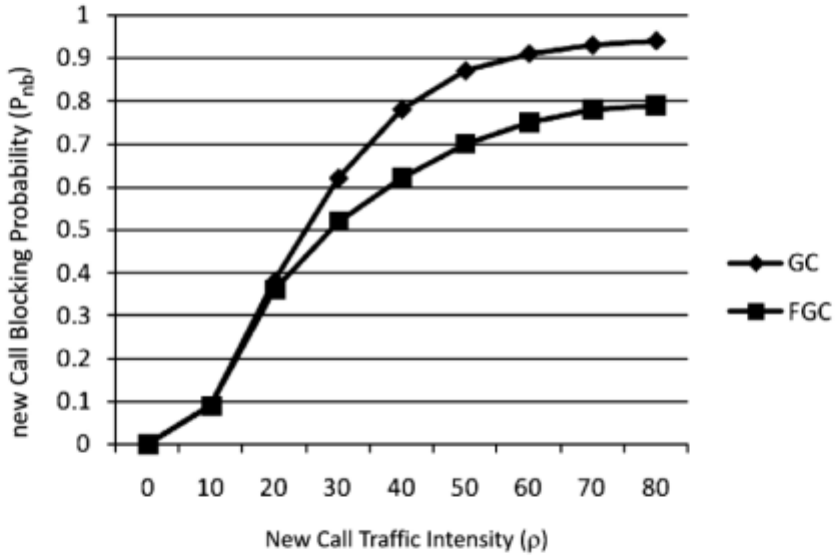

Figure 4: Variation of blocking probability of new calls against traffic intensity

In the fig.5, the blocking probability of handoff data calls is plotted against the traffic intensity of handoff data calls. Here, we choose the following set of parameters, total number of channels in the cell N=30, the threshold values T_1=15 and T_2=20, arrival rate of handoff data calls $\lambda_{hd} = \frac{1}{40}$ and service rate μ_{hd} for handoff data calls varies from $\frac{1}{100}$ to $\frac{1}{1600}$ min., then the traffic intensity of handoff data calls is given by $\rho_{hd} = \frac{\lambda_{hd}}{\mu_{hd}}$. It is also assumed that new calls and handoff voice calls are arrived at constant rate i.e. arrival rate of new calls and handoff voice calls is given as $\lambda = \frac{1}{20}$ and $\lambda_{hv} = \frac{1}{30}$ respectively. The service rate of new calls and handoff voice calls is given by $\mu = \frac{1}{300}$ min. and $\mu_{hv} = \frac{1}{600}$ respectively. Therefore, the traffic intensity of new calls is $\rho = 15$ and that for handoff voice calls is $\rho_{hv} = 20$.

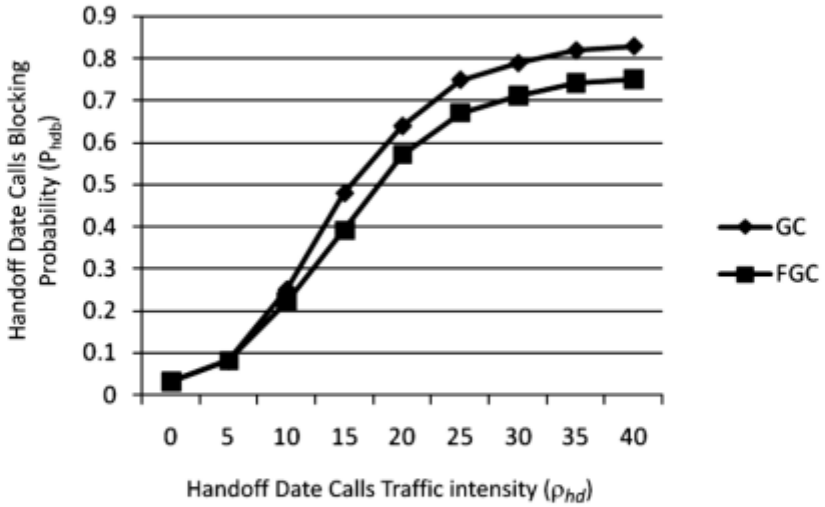

Figure 5: Variation of blocking probability of handoff data calls against traffic intensity

It has been observed that, as the traffic intensity of the handoff voice calls increases the forced termination probability of handoff voice calls is also increases. Fig.6, represent the variations in the forced termination probability of handoff voice calls against the traffic intensity of handoff voice calls. Here, we choose the following set of parameters, total number of channels in the cell N=30, the threshold values T_1=15 and T_2=25, arrival rate of handoff voice calls $\lambda_{hv} = \frac{1}{30}$ and service rate λ_{hv} for handoff voice calls varies from $\frac{1}{100}$ to $\frac{1}{1200}$ min., hence the traffic intensity of handoff voice calls is given by $\rho_{hv} = \frac{\lambda_{hv}}{\mu_{hv}}$. It is also assumed that new calls and handoff data calls are arrived at constant rate i.e. arrival rate of new calls and handoff data calls is given as $\lambda = \frac{1}{20}$ and $\lambda_{hd} = \frac{1}{40}$ respectively. The service rate of new calls and handoff data calls is given by $\mu = \frac{1}{200}$ min. and $\mu_{hd} = \frac{1}{400}$ respectively. Therefore, the traffic intensity of new calls is $\rho = 10$ and that for handoff voice calls is $\rho_{hd} = 10$.

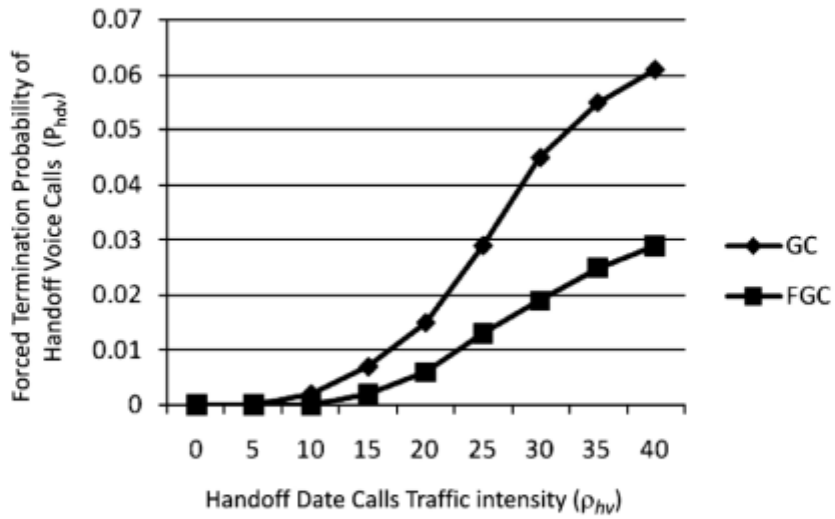

Figure 6: Variation of forced termination probability of handoff voice calls against traffic intensity

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Conclusion

This paper presents new algorithms for call admission control schemes using guard channel and fractional guard channel with dual thresholds for new calls and handoff data calls. It is observed that the proposed system offered a degree of protection to handoff data calls from preemption unlike previous preemptive schemes but gives priority to the handoff voice calls over handoff data calls. The fractional guard channel policy gives good performance as far as the forced termination of handoff voice calls is concerned. However, there is a need of proper tradeoff between the ratio of handoff data calls and handoff voice calls reservation to optimize the performance of the system and to obtain a good Quality of Service (QoS).

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