DYNAMIC ADMISSION CONTROL AND RESOURCE RESERVATION FOR WCDMA

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ABSTRACT

Current and next generation wireless networks including 3rd generation (3G) and beyond are expected to provide a wide range of multimedia services with different QoS constraints. Call admission control (CAC) and resource reservation (RR) for mobile communication are of the most important issues that guarantee system efficiency and QoS required for different services in a very scarce resource as the radio spectrum. As forced call termination due to the handoff call dropping are generally less desirable than blocking a new one, handoff calls should have a higher priority than new calls. This paper investigates the concepts of sharing resources and reservation for WCDMA systems with the unique feature of soft capacity. Voice and data traffic are considered, and further classified into handoff and new requests. The reservation thresholds are dynamically adjusted according to the traffic pattern and mobility prediction in order to achieve maximum channel utilization while guaranteeing different QoS constraints. Blocking probability, dropping probability, and channel utilization are used as benchmarks for the proposed scheme.

Keywords: call admission control, resource reservation, WCDMA.

1 INTRODUCTION

The current and next generation wireless cellular networks are expected to provide multimedia services with different quality of service (QoS) requirements. A typical example is the universal mobile telecommunication system (UMTS) which is required to support a wide range of applications each with its specific QoS. There are four QoS classes defined in UMTS specifications; the conversational class, the streaming class, the interactive class, and the background class [1]. Since multimedia services have different traffic characteristics, their QoS requirements may differ in terms of bandwidth, delay, and dropping probabilities. The radio resource management unit is responsible for the fair and efficient allocation of network resources among different users. The large demand for high capacity has led to the use of micro and Pico –sized cells. As a consequence, the handoff rate significantly increases and the handoff procedure becomes a crucial issue to ensure seamless connectivity and satisfactory QoS. Also from the user's point of view, handoff attempt failure is less desirable than blocking a new call.

Due to the limited resources in wireless multimedia systems, efficient call admission control (CAC) and resource reservation (RR) schemes are needed to maintain the desired QoS. Up to now various solutions have been proposed for handoff control and channel reservation. One method is based on queuing handoff requests till a free network resource becomes available [2].However, this may cause QoS degradation for real time traffic which is delay-sensitive. Another solution is based on reserving a fixed amount of resources, permanently (guard channels, GCs) for handoff traffic [3]. However, such static approach is unable to handle the variable traffic load. So, it obviously causes low efficiency. A mixed traffic with different bandwidth requirements has been considered [4]. There have been a considerable amount of guard channel schemes supporting voice and data in integrated mobile networks [5,6] .Recently, Dynamic GC schemes have been discussed in the literature to improve the system utilization while providing QoS guarantees to higher priority calls [7-9]. However, these schemes have been studied for TDMA/FDMA systems and are not completely suitable for CDMA systems because CDMA systems are interference limited. Several uplink CAC's designed for CDMA have been proposed in literature. These CAC's can be classified to the following categories: power-based CAC, SIR-based CAC, and throughput-based CAC. A power-based admission control with multiple power-based thresholds for multiple services has been proposed [10]. By setting higher thresholds for voice traffic, voice traffic is given a higher priority compared to data traffic. SIR-based call admission control monitors the SIR experienced by each user [11]. A throughput-based admission control having four different load limits with four classes of traffic has been also proposed [12]. A comprehensive survey for these schemes can be found in [13].

In this paper, we focus on QoS-aware CAC and resource reservation. The concepts of guard channel and resource reservation are extended for operation in WCDMA. Calls are classified based on the traffic type (real time and non real time), to either new or handoff requests. Resource allocation to each traffic class can be dynamically adjusted according to the traffic load variations, mobility of users, and QoS requirements. Multiclass calls with different QoS requirements are considered. The proposed scheme achieves lower blocking and dropping probabilities while maximizing channel utilization.

The rest of the paper is organized as follows. In section (2), an overview of WCDMA capacity and load estimation is provided. The model of the proposed scheme is presented in section (3).Performance metrics such as new call blocking probability, handoff dropping probability, and resource utilization are used to evaluate the proposed scheme performance in section (4). Numerical results are presented in section (5) .Finally, concluding remarks are discussed in section (6).

2 OVERVIEW ON WCDMA CAPACITY

The capacity of a WCDMA system is limited by the total interference it can tolerate, so it is called an interference-limited system. The maximum capacity is achieved when the cumulative interference becomes so great that the energy per bit to noise density ratio (E_b/N_0) requirement cannot be fulfilled for the class i traffic. As each class has different requirements, so the bit energy to noise density for class i is given by [1]:

$$(E_b / N_0)_i = \frac{W}{v_i . R_i} \cdot \frac{P_i}{I_{tot} - P_i} \qquad (1)$$

Where, W is the chip rate. P_i is the received signal power from class i. v_i is the activity factor of class i. R_i is the bit rate of class i. I_{tot} is the total received wideband power interference including the thermal noise power in the base station. Then:

$$P_i = \frac{1}{1 + \frac{W}{(E_b / N_0) . R_i . v_i}} . I_{tot} \qquad (2)$$

If we define the load factor L_i for each user as, [1];

$$L_i = \frac{1}{1 + \frac{W}{(E_b / N_0)_i . R_i . v_i}} \qquad (3)$$

The total load factor (η) is defined as the sum of the load factors for all active mobile users and it is given by:

$$\eta = \sum_i N_i . L_i \qquad (4)$$

where N_i is the number of active mobile stations of class i.

Other cells interference must be taken into account when calculating the load factor. Other cells interference is the interference caused by the mobile users of neighboring cells and is denoted by I_{oth}. Define l_i as the ratio of other cells interference to P_i , then Eq. (3) becomes:

$$L_i = \frac{(1 + l_i)}{1 + \frac{W}{E_b / N_0 . R_i . v_i}} \qquad (5)$$

Using the same idea of the Greatest Common Divisor (GCD) as in [14], the load factor of each class can be represented as an integer multiple i of $\Delta\eta$:

$$\frac{L_i}{\Delta \eta} = i \qquad (6)$$

Where i is a positive integer. By this mapping the concept of channel allocation in TDMA/FDMA systems can be easily extended to WCDMA .

3 THE PROPOSED SCHEME

3.1 System Model

In our proposed model two classes of traffic are considered: real-time (RT) such as conversational and streaming traffic and non real-time (NRT) such as interactive and background traffic. Furthermore, they are classified according to their request type to new and handoff calls. So we have 4 priority classes. These classes are class (1) RT handoff requests, class (2) NRT handoff requests, class (3) RT new requests, and class (4) NRT new requests as in Table (1). Assume that each traffic class has different bandwidth requirement, i.e. they have different multiples of the greatest common divisor described above. We assume that the arrival rates of the new and handoff calls are λ_{h1} ,λ_{h2} , λ_{n1},λ_{n2} for handoff voice, handoff data, new voice, and new data, respectively. Let η_{max}, η_1, η_2, and η_3 be the loading limit for classes 1, 2, 3, and 4, respectively as in Fig. 1.

Without loss of generality, let the voice call increases the load by the basic GCD ($\Delta\eta$) and the data call increases it by n.$\Delta\eta$ where n is an arbitrary integer. Only the uplink is considered in this scheme.

Class	Traffic type	Request type	class description
1	voice/RT	Handoff	conversational and streaming
2	data/NRT	Handoff	interactive and background
3	voice /RT	New	conversational and streaming
4	data/NRT	New	interactive and background

Table 1: Priority classes

It is assumed that whenever the uplink call has been assigned a channel, the downlink connection is established. Note from Fig. 1 that this sharing scheme with the predefined thresholds can be easily extended to a Full Sharing (FS) scheme by letting $\eta_1=\eta_2=\eta_3=\eta_{max}$.

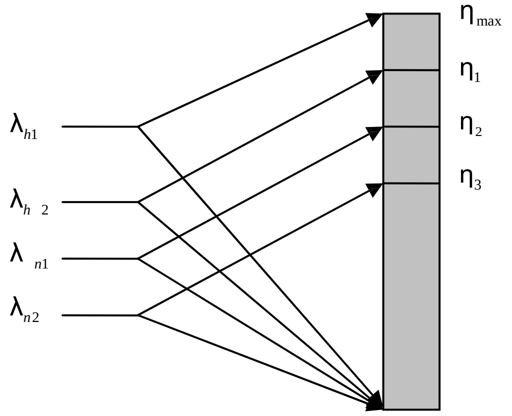

Figure 1: CAC scheme

However, in our proposed scheme, these thresholds are not static but they vary according to the traffic conditions and mobility of the users as explained in the following section. Complete Partitioning (CP) is not considered here because of its poor efficiency in terms of channel utilization [4] .

3.2 Reservation and Admission Strategy

The objective of using dynamic reservation channels (DCR) is to satisfy a desired dropping probability for handoff calls and at the same time reduce the blocking probability of a new call as much as possible. This improves the channel utilization significantly. The mobility of calls in a cell is defined as the ratio of the handoff call arrival rate to the new call arrival rate. Handoff predictive schemes can be classified into two types. One predicts handoff traffic according to mobility prediction. The other calculates the handoff probability according to call duration and call residence time. The acceptance probability P_{ac} defines the fraction of the reserved channels that can be occupied by new calls depending on the current status of the traffic and the mobility factor . P_{ac} is defined as follows [8]:

$$P_{ac,k} = \max\left\{0, \alpha_k\left[\frac{c_{max}-j}{c_{max}-\eta_{th}}\right] + (1-\alpha_k)\left[\cos\frac{2\pi(j-\eta_{th})}{4(c_{max}-\eta_{th})}\right]^{1/2}\right\} \quad (7)$$

Where c_{max} is the maximum load allowed for a particular class considering the acceptance probability, j is the current state of the system, η_{th} is the predefined threshold for the new class under consideration , $\alpha_k = \lambda_h / \lambda_n$ and k=1,2 is the mobility parameter for voice and data calls.

The admission criterion of the proposed scheme can be summarized as follows:

1- When a handoff voice call arrives with $\eta+\Delta\eta\leq\eta_{max}$, it will be accepted .Thus; a handoff voice call will only be dropped if there are no more channels.

2- When a handoff data call arrives, with $\eta+n\Delta\eta\leq\eta_1$, it will be accepted, otherwise it will be dropped.

3- When a new voice call arrives, with $\eta+\Delta\eta\leq\eta_2$, the call is accepted, otherwise, the base station checks for the arrival rates of the new and handoff traffic. If the acceptance probability defined in Eq. (7) is greater than zero, the channels reserved for the higher class (in this case handoff/data) are occupied by the new voice.

4- When a new data call arrives, with $\eta+\Delta\eta\leq\eta_3$, it will be accepted, otherwise, according to the mobility parameter of data traffic, (the acceptance probability) the channels reserved for the new voice traffic can be shared with the new data calls.

Note that although the handoff data has higher priority than new voice, a new voice call can occupy partly the channels reserved for handoff data even with high mobility of data traffic. This in turn improves the grade of service (GoS) for real time traffic.

4 PERFORMANCE ANALYSIS

4.1 Markov Model

We use a Markov model to validate the system performance. For performance measurement, we focus on the dropping probability of handoff calls and blocking probability of new calls. A cost function is formulated in terms of both measures giving the handoff call dropping a higher weight than blocking a new call.

The above system can be represented as multi-transition truncated $M/M/\eta_{max}/\eta_{max}$ loss model. Define $\lambda_d = \lambda_{h2}+\lambda_{n2}$, $\lambda_v= \lambda_{h1}+\lambda_{n1}$, $\lambda_{1-4}= \lambda_{h1}+ \lambda_{h2}+ \lambda_{n1}+ \lambda_{n2}$, $\lambda_{1-3}= \lambda_{h1}+ \lambda_{h2} +\lambda_{n1}$, $\lambda_{1-2}= \lambda_{h1}+ \lambda_{h2}$ with the markov chain diagram shown in Fig.2 from 0 up to the threshold of class 4 (η_3).

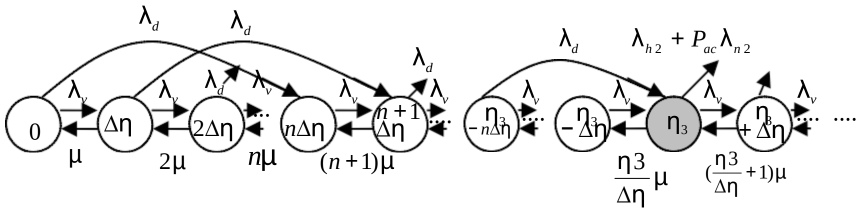

Figure 2: Multitransition $M/M/\eta_{max}/\eta_{max}$ loss Markov model

The closed form solution for steady state probabilities is not easily obtainable for this model because of the eigenvalue problem of the transition matrix.

An approximation for the above model is used according to [12] for which a closed-form solution can be obtained.

Let $\overline{\Delta\eta}$ denote the average loading required for data and voice calls.

$$\overline{\Delta\eta} = \frac{\lambda_v}{\lambda_v + \lambda_d}.\Delta\eta + \frac{\lambda_d}{\lambda_v + \lambda_d}.(n.\Delta\eta) \qquad (8)$$

By using average loading increment $\overline{\Delta\eta}$, the system can be represented by a birth–death process as shown in Fig. 3 .The load is normalized to be a multiple of average loading as follows:

$$\theta = \eta_{max} / \overline{\Delta\eta} \qquad \theta_1 = \eta_1 / \overline{\Delta\eta}$$

$$\theta_2 = \eta_2 / \overline{\Delta\eta} \qquad \theta_3 = \eta_3 / \overline{\Delta\eta} \qquad (9)$$

Now, we can easily obtain the local balance equation and, then, evaluate the performance of the proposed system as follows:

$$\lambda_{1-4} P_0 = \mu.P_1 \Rightarrow P_1 = \frac{\lambda_{1-4}}{\mu}.P_0$$

$$P_2 = \frac{(\lambda_{1-4})^j}{j!.\mu^j}.P_0 \qquad (10)$$

Similarly, the total balance equations can be derived as follows;

$$P_j = \frac{(\lambda_{1-4})^j}{j!.\mu^j}.P_0 \qquad 0 < j \le \theta_3$$

$$P_j = \frac{(\lambda_{1-4})^{\theta_3}.\prod_{i=1}^{j-\theta_3}(\lambda_{1-3} + \lambda_{n2}.P_{ac}(j-i))}{j!.\mu^j}.P_0 \qquad \theta_3 < j \le \theta_2$$

$$P_j = \frac{(\lambda_{1-4})^{\theta_3}.m_1.\prod_{i=1}^{j-\theta_2}(\lambda_{1-2} + \lambda_{n1}.P_{ac}(j-i))}{j!.\mu^j}.P_0 \qquad \theta_2 < j \le \theta_1$$

$$P_j = \frac{(\lambda_{1-4})^{\theta_3}.m_1.m_2.\lambda_{h1}^{(j-\theta_1)}}{j!.\mu^j}.P_0 \qquad \theta_1 < j \le \theta$$

(11)

Where:
$$m_1 = \prod_{i=1}^{\theta_2-\theta_3}(\lambda_{1-3} + \lambda_{n2}.P_{ac}(\theta_2 - i))$$

$$m_2 = \prod_{i=1}^{\theta_1-\theta_2}(\lambda_{1-2} + \lambda_{n1}.P_{ac}(\theta_1 - i)) \qquad (12)$$

P_o can be calculated with the help of the following equation:

$$\sum_{j=1}^{\theta} P_j = 1 \qquad (13)$$

The rationale behind our scheme is that the new call is blocked when the cutoff threshold for accepting new calls is reached and the acceptance probability does not permit further sharing for the reserved load for the higher priority class.

After obtaining all the steady state probabilities, the voice call blocking proability P_{bv} ; the handoff voice dropping proability P_{dv}; the data call blocking probability P_{bd} and the data call dropping probability P_{dd} can be expressed as follws:

$$P_{bd} = \sum_{j=\theta_3}^{\theta_{2-1}}[(1 - P_{ac}(j)).P(j)] + \sum_{j=\theta_2}^{\theta} P(j),$$

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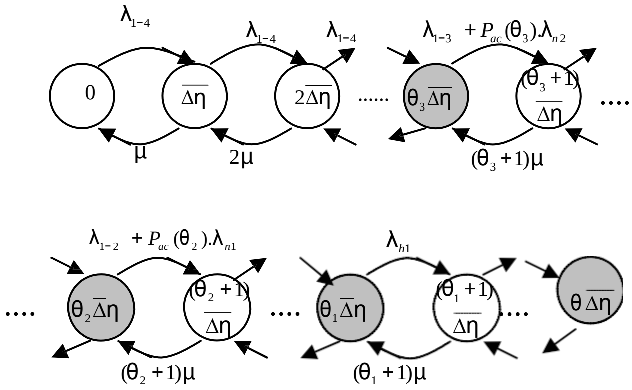

Figure 3: Simplified birth-death process

$$P_{bv} = \sum_{j=\theta_2}^{\theta_1 - 1} [(1 - P_{ac}(j)).P(j)] + \sum_{j=\theta_1}^{\theta} P(j) \quad ,$$

$$P_{dd} = \sum_{j=\theta_1}^{\theta} P(j) \quad ,$$

$$P_{dv} = P_{\theta} \qquad (14)$$

4.2 Resource Utilization

The resource utilization is defined as the ratio of occupied resources to the total system resources. Since the number of occupied resources is a random variable depending on the system state, we use the average number of occupied resources. So the resorce utilization is defined as :

$$U = \frac{1}{\theta} . \sum_{j=0}^{\theta} j.P_j \qquad (15)$$

4.3 Grade of Service(GoS)

The grade of service metric is used to evaluate the algorithm . It is defined as follows:

$$GoS_j = \beta .P_{dj} + P_{bj} \qquad (16)$$

where P_{dj} is the handoff dropping probability, and P_{bj} is the new call blocking probability ; j=1,2 stands for voice and data traffic, respectively. β=10 indicates the penalty weight for dropping a handoff call relative to blocking a new one.

5 NUMERICAL RESULTS

In this section we analyze the proposed scheme. A comparison study is made between our proposed Dynamic Channel Reservation (DCR) scheme and the Fixed Channel Reservation (FCR) and Full Sharing (FS) schemes. It should be noted that the FS scheme gives the minimal blocking probability of new calls and the FCR scheme gives the minimal dropping probability of handoff calls.The performances of these schemes are compared in heavily loaded systems.

The parameters used in our analysis are as follows:

-The greatest common divisor considered is taken as $\Delta\eta$=0.01. So we have 100 logical channels in the system.

-The percentage of each arrival rate out of the total offered traffic is: $\lambda_{h1}=0.2\lambda$, $\lambda_{h2}=0.2\lambda$, $\lambda_{n1}=0.3\lambda$ and $\lambda_{n2}=0.3\lambda$.

- The average call holding time is 180 sec .

-The loading limit percentages used are :100%, 90%, 80%, and 70% for classes 1, 2, 3 and 4, respectively.

- The mobility is varied through the analysis by varying the parameter α. High mobility is considered at α=1.5. Unless stated we consider low mobility with α=0.6.

Figure 4 illustrates the variation of voice call blocking probability with offered traffic.

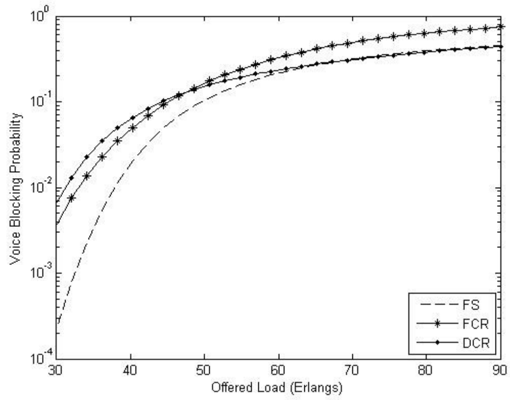

Figure 4: Effect of load variation on voice blocking probability .

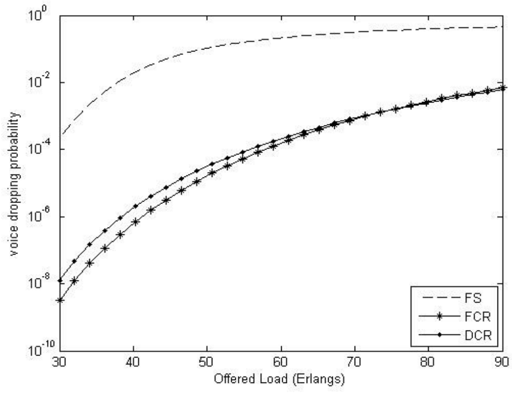

Figure 5: Effect of load variation on voice dropping Probability.

It is clear that the FCR scheme has the highest blocking probability at high loads . Our DCR has almost the same performance as the FC for the high loads.

Figure 5 demonstrate the effect of traffic load variation on handoff dropping probability of voice traffic under high mobility. Here we can see that our scheme gives the minimum dropping probability at high loads as the FCR whereas the FS scheme gives the worst performance. At low traffic load, the FCR scheme has better performance in terms of the dropping probability but this difference dimineshes at high loads.

Figure 6 shows the blocking proability of new data calls. We can see that FS method has the best performance. The DCR still outperforms the FCR .

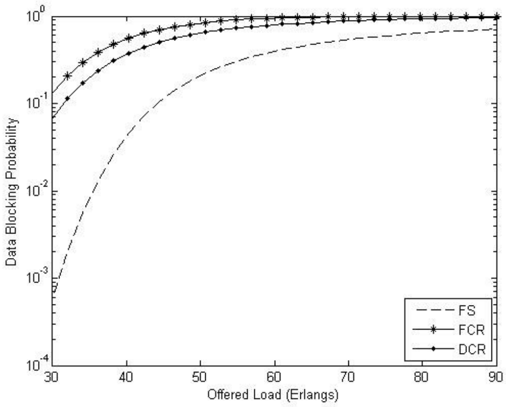

Figure 6: Effect of load variation on data blocking probability

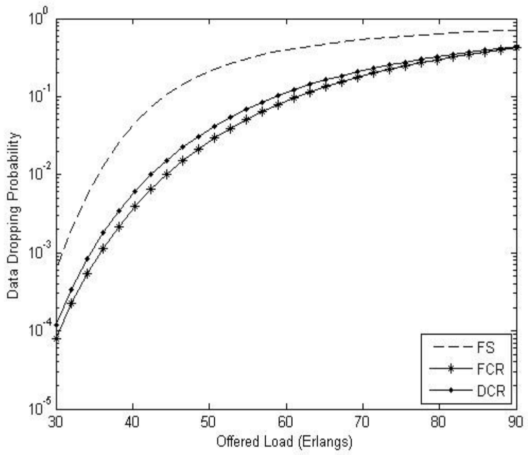

Figure 7: Effect of load variation on data dropping probability

Regarding dropping probability of handoff data calls,under high mobility of both types, Fig. 7 shows that the FCR has the best performance because new voice traffic occupies the load margin reserved for handoff data calls even with low mobility of voice traffic. So, this scheme may be considered as a special case of the scheme presented in [5] in which mixed data (new and handoff) have the same threshold. The GoS of voice and data as a function of the total offered load is shown in Fig. 8 and Fig. 9, respectively.

We observe from Fig. 8 that DCR scheme has the best performance at high loads because a high threshold is reserved for class 1 and that class 3 can share the channels reserved for class 2 even with low mobility of voice traffic.

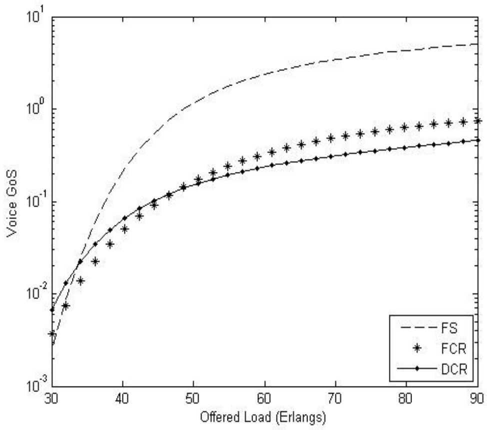

Figure 8: GoS for voice traffic

The GoS for data traffic is shown in Fig. 9 . Note that FCR has better performance. However, at high moility, almost the DCR and the FCR have the same performance. Another important parameter is the resource utilization. The resource utilization is dipicted in Fig. 10. This diagram shows that the FS scheme is the most efficient in resource utilization. DCR is more efficient than FCR in a wide range of traffic and mobility variations.Under high mobility of both types of traffic, the performance of DCR is still better than FCR as shown in Fig. 11.

6 CONCLUSION

In this paper, a new dynamic channel reservation (DCR) scheme with multi-thresholds is proposed. It can be considered as an extension of the well known guard channel (GC) scheme. We extend the scheme to WCDMA by using the dynamic loading limits η_1 ,η_2 and η_3 to give priority to handoff data calls, new voice calls, and new data calls, respectively. Thresholds are changing according to the predictive mobility and traffic patterns. Detailed results obtained from the analysis show that giving higher threshold for handoff voice reduces the voice dropping probability and at the same time high channel utilization is achieved. As a result, this scheme is able to guarantee a high QoS for different applications. It is also able to utilize the network resources efficiently.

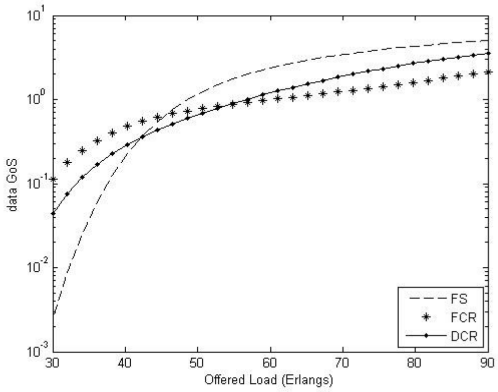

Figure 9: GoS for data traffic

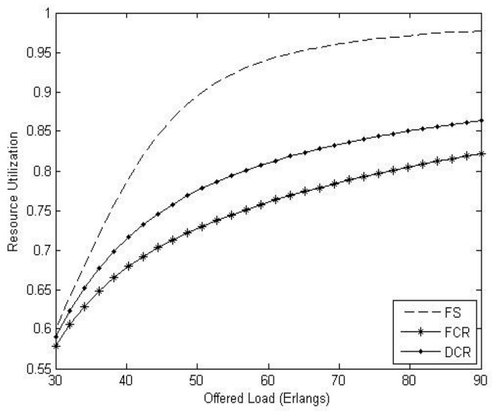

Figure 10: Resource utilization

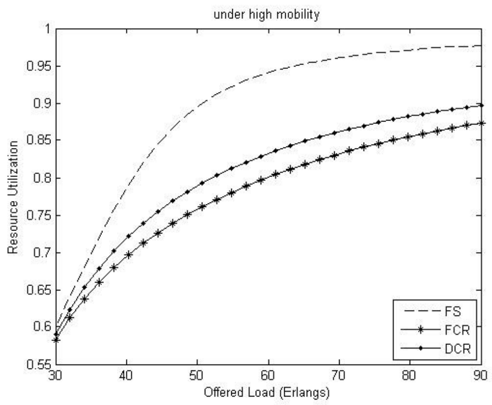

Figure 11: Resource utilization under high mobility

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