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A DISTRIBUTED CALL ADMISSION CONTROL IN CELLULAR MOBILE NETWORKS USING INTELLIGENT TECHNIQUES

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Abstract: *Quality of Service (QoS) provisioning in wireless mobile networks is quite a challenging task due to the scarcity of wireless resources. With the future wireless/mobile networks moving towards micro/pico cellular architecture, it would become all the more challenging owing to the frequent handoffs. Call admission control (CAC) is one of the key elements in ensuring QoS in mobile networks. The present paper focuses on distributed call admission control (DCAC) scheme, in which the call admission decision uses the information not only from the local cell but also from the neighboring base stations and the information is exchanged periodically. It has been shown by various researchers that a call admission scheme based on distributed approach can guarantee QoS requirements. In this regard, the paper presents fuzzy logic based distributed call admission control (FDCAC) scheme. Further, the scheme takes into consideration of diverse traffic types and also considers the priority of calls in order to provide higher connectivity to high priority users. In this paper, two variants of FDCAC distributed approach have been considered and their performance has been compared with that of the simple guard channel scheme in terms of various QoS parameters such as new call blocking probability and call dropping probability. Based on the results, the bandwidth efficiency of the proposed scheme has been verified and compared with the other models including guard channel scheme.*

Keywords: *Quality of service, distributed call admission control, call admission control, Fuzzy logic, cellular mobile networks.*

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1 INTRODUCTION

Recent years have witnessed explosive growth in the field of wireless mobile communication. The tremendous growth and usage of mobile network has enhanced the need for meeting better quality of service requirements. However, provisioning of QoS in wireless networks is complicated owing to the user mobility and limited network resources. Effective resource management is required to provide available resources during the call set up time as well as throughout the lifetime of connection. Call admission control (CAC) is a fundamental mechanism to ensure effective network resource management and to meet the QoS requirements of users. It involves making a decision for every new call request if there are enough idle resources to meet the QoS requirements without violating the QoS for already accepted calls.

Among various call admission control schemes, distributed call admission control (DCAC) consider both the local information (i.e. the amount of unused bandwidth in the cell where the user currently resides) and remote information (i.e. the amount of unused bandwidth in the neighboring cells) in order to determine whether to accept or reject the connection. It has been shown by various researchers that an admission control scheme that relies solely on local information cannot guarantee QoS requirements of a connection throughout its lifetime (Naghshineh and Schwartz, 1996; Wu *et al.*1998; Jiang *et al*, 2001;Kamble and Gupta, 2010).

Most of the researchers in distributed call admission control have dealt separately with the call admission control approaches in wireless networks. DCAC schemes proposed in the literature are mostly meant for only a single traffic type and the scheme may not work well if the network carries diverse types of traffic. In other schemes, call admission threshold is required to be estimated based on the assumption that all the admitted new calls are in progress at the beginning of control period. But in practice, some of the ongoing calls at the control period T may include the calls carried forward from the previous period and rest are new calls arriving at any time during the period. Other call admission control schemes for mobile networks are based on criterion like threshold level, handoff prioritization involving handoff, network status etc. (Yoon and Lee, 1999; Kim *et al.*2000). However these schemes involve the accurate measurement of threshold level.

In this study, an intelligent distributed call admission control scheme based on Fuzzy logic is proposed to ensure QoS for multimedia traffic applications. The proposed scheme is distributed in the sense that it takes into consideration of both local as well as remote information from neighboring cells and accordingly allocates bandwidth. The proposed scheme also takes into consideration of diverse traffic types and gives higher priority to real time calls compared to non-real time calls in order to provide higher connectivity to users. In addition to this, the performance of the proposed scheme is compared with that of simple guard channel scheme in terms of major QoS parameters such as new call blocking probability, call dropping probability and bandwidth utilization.

The paper is organized as follows. In section 2, related work in this area is described. Section 3 covers the proposed Fuzzy logic based distributed CAC (FDCAC) scheme in detail. In Section 4, simulation results are discussed and the performance of the proposed scheme is analyzed. Finally concluding remarks are presented in Section 5.

2 RELATED WORK

One of the earliest methods of ensuring call admission control in mobile networks is the guard channel scheme (Daigle and Jain, 1992; Oh and Tcha, 1992). In this scheme, each cell reserves a number of channels for exclusive use by handoff users. Various variants of this scheme exist based on the number of guard channels selected by the base station. Though the strategy is simple because there is no need for exchange of control information between the base stations, but wastage of scarce resources occur because of its poor adaptability to changing traffic load. In (Jiang *et al.*2001), a bandwidth reservation scheme is proposed, where a fixed number of channels are reserved exclusively for handoffs in each cell. The scheme also allows queuing of handoff requests when the reserved channels are not available in the cell. However, the proposed scheme does not consider information regarding the neighboring cells.

Several call admission algorithms using dynamic schemes have been proposed by various researchers (Zhang and Zhu, 2005; Kim *et al.*2000). The dynamic call admission schemes are based only on information gathered locally by each base station. In (Hou and Papavassiliou, 2001), a dynamic reservation based CAC scheme is proposed using the concept of influence curve. According to this scheme, a moving user exerts some influence on the channel allocation in neighboring cells. This is related to the mobility pattern (i.e. speed and direction) of each specific user. However, it may not be practical always to characterize the random moving pattern of the users in wireless networks. Though these schemes provide scalable solutions but can lead to overestimation of resource requirements, thus adversely affecting the bandwidth utilization. In order to overcome these drawbacks, distributed call admission control (DCAC) algorithms that takes into consideration of the information exchanged from the neighboring cells have been proposed (Iraqi and Boutaba, 2000; Jiang *et al.*2001). However, in (Iraqi and Boutaba, 2000), only a single traffic type is considered and the scheme is not adaptive to changes in network conditions and it may not work well if the network carries diverse types of traffic.

In (Kim *et al.*2000), a modified DCAC scheme is described that does not follow the assumption of Poisson admission process. However, the proposed scheme requires frequent measurement of probability that a call hands off to other cells and probability for a call to remain in the same cell. Further the proposed DCAC is not applicable to multimedia environment. A distributed call admission algorithm has been proposed by (Ramanathan *et al.*1999) that guarantees upper bound of the cell overload probability. Also the authors used bandwidth adaptation algorithm that seeks to minimize the cell overload probability. (Zhang and Zhu, 2005) proposed distributed intelligent CAC scheme for wide band multi service CDMA system. Their results indicated that the proposed algorithm can guarantee the QoS requirements of users in terms of dropping probability and call blocking probability.

In (Naghshineh and Schwartz, 1996), DCAC scheme with aggregate resource reservation using mobility prediction based on mobile positioning system location information has been proposed and it takes into account the expected bandwidth to be used by calls handing off to and from neighboring cells within a configurable estimation time window. However the use of global positioning system for predicting user mobility leads to signaling overheads. According to DCAC scheme proposed in (Levine *et al.*1997), number of active calls present in both the local cell and its neighboring cells need to be known in order to determine its new call admission threshold. In addition to this, call admission threshold is estimated based on the assumption that all the admitted new calls are in progress at the beginning of control period. However, this assumption may cause imprecision in the control and makes the implementation of scheme difficult and thus leading to over provisioning of resources for handoff calls. Further, in this scheme, only a single traffic type is considered because of which it may not work well if the network carries diverse type of traffic and is not adaptive to changes in network conditions.

Review of literature reveals that various DCAC schemes rely on unrealistic, simplifying approximations and assumptions, leading to imprecise control decisions. In addition to this, the computational complexity of the CAC algorithms based on Markov models becomes very high due to the number of states describing the system (Jayaram *et al.*2000). Fuzzy logic based control schemes have been investigated in various areas of traffic control such as CAC and congestion control (Naghshineh and Schwartz, 1996; Oliveira and Kim, 1998; Oh and Tcha, 1992) where they have demonstrated the ability to make intelligent control decisions successfully. Furthermore, Fuzzy logic can overcome most of the assumptions and complicated computations as the fuzzy if-then rules are based on linguistic variables that incorporate human-like knowledge representation of information.

3 PROPOSED FUZZY LOGIC BASED DCAC (FDCAC) MODEL

The objective of the proposed FDCAC scheme is to maximize the effective bandwidth utilization and to fulfill the QoS requirements in terms of achieving minimum handover dropping probability and new call blocking probability. Let us consider 2-D array of hexagonal cells as shown in Fig 1. Let λ_h be the handover call arrival rate into the cell, P_B be the probability that a newly arriving call will be blocked. Maximum number of calls that can be supported in the cell be N_{max}.

Consider any test mobile in a radio cell C_0 and let the number of calls in a cell at time t_o be k. It is assumed that the test mobile resides in the same cell with probability p_s and that it hands-off to the adjacent cell with the probability of $p_m/6$, as the current cell is surrounded by six neighboring cells and an existing call within a cell may handover to any of the six cells.

Thus, the values of p_s and p_m can be expressed as (Naghshineh and Schwartz, 1996, Baldo *et al.*1999)

$$p_m = [1-e^{-hT}] \text{ and } p_s = e^{-(h+\mu)T}$$

where T indicates the estimated time during which the call performs only one handover. According to this model, handover dropping probability is approximated to be equal to overload probability and is given as

$$P_{HD} \approx P_O = \sum_{i=N+1}^{\infty} Pi$$

where Pi is the probability that there are i active calls in a cell. Overload probability is the probability that the cell cannot support any more calls after all the channels available are used up.

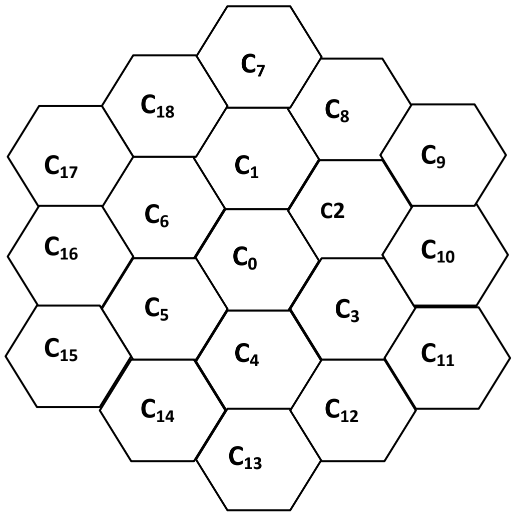

Fig. 1 Two dimensional cellular configuration

Therefore, from this approximation, handover dropping probability P_{HD} can be evaluated as

$$P_{HD} \approx P_O = \sum_{i=N+1}^{n_1+n_2+n_3+n_4+n_5+n_6} P^{0}_{t+T}(i)$$

$$\approx Q\{N-m)/\ \sigma\}$$

t^2

Where $m = n_1 ps + (n_1+n_2+n_3+n_4+n_5+n_6)\ p_m/6$

$\sigma^2 = n_1 ps\ (1-ps) + (n_1+n_2+n_3+n_4+n_5+n_6) \bullet (1-p_m/6) \bullet p_m/6$

and $Q(x) = (1/\sqrt{2}\Pi \int e^{-\ t2/2}\ dt$, $x \geq 0$, Q(x) is an integral of tail distribution of standard normal distribution function.

Further, P_B can be calculated by considering steady state probabilities of seven cells (i.e. the current cell and six neighboring cells) and it is given as

$$P_B = \sum_{n0=0}^{N_{max}} \sum_{n1=0}^{N_{max}} \sum_{n2=0}^{N_{max}} \sum_{n3=0}^{N_{max}} \sum_{n4=0}^{N_{max}} \sum_{n5=0}^{N_{max}} \sum_{n6=0}^{N_{max}} P(n_0)P(n_1)\ P(n_2)\ P(n_3)\ P(n_4)\ P(n_5)\ P(n_6)$$

where n_i denotes the number of existing calls at instant t and let $P(n_1)$, $P(n_2)$, $P(n_3)$, $P(n_4)$, $P(n_5)$, $P(n_6)$ be the steady state probabilities in the neighboring cell and N_{max} is the maximum possible number of calls in a cell.

In the proposed DCAC scheme, cells exchange their status information which is limited to nearest or next nearest neighboring cells. Thus in the present scheme, average handover dropping probability of the current cell and its adjacent neighboring cell (P_{ah}) is exchanged periodically. Furthermore, multiple channels can be allocated to a single user to satisfy higher bandwidth requirements of the user. It is assumed that when a new call or handoff call request is received at the base station, it provides the information regarding the type of the traffic class and the average bandwidth required for the connection. In the proposed model, different call admission criteria would be used for different class of traffic types and details are provided in the Table 1.

Table 1 Different categories of Traffic Classes considered in the study

Type of Traffic Class	Average Bandwidth requirement	Average connection duration (secs)	Examples
Class 2 (Real time) High*	30 Kbps	180	Voice and audio phone
	256 Kbps	300	Video phone and video conferencing
	3Mbps	600	Multimedia and video on demand
Class 1 (Non real time) Medium*	256 Kbps	180	Remote log in; data on demand
	5 Mbps	120	File transfer
Class 0 (Non real time) Low*	10 Kbps	30	Email and Fax, internet browsing

Source: Oliveira et al.,[20].

** This is as per the membership function shown in Figure 3.*

Call admission control algorithm is designed for both new call request and handoff calls. In the proposed algorithm, higher priority is assigned to real time handoff traffic (i.e. real time handoff and new call request).

For the present study, two variations of the proposed model are considered. For the first scheme, no bandwidth is reserved exclusively for high priority calls in the current or neighboring cells. For both the schemes, let the available bandwidth in the current cell be B_A. When the network load in the cell is normal, the proposed scheme tries to allocate the average required bandwidth to every incoming call in the cell and let this bandwidth be denoted as $b_{avg.}$ When a high priority real time handoff call comes, if the average required bandwidth is available in the current cell and average handover dropping probability in the neighboring cells and current cell (P_{ah}) is below the threshold level, i.e. P_{QoS}, then the call is strongly accepted. If these conditions are not met, then the available bandwidth is compared with minimum required bandwidth. Thus if the available bandwidth at least satisfies the minimum required bandwidth and (P_{ah}) is below the P_{QoS} level, then the call is accepted otherwise it is rejected. Similarly when real time new call request, non real time handoff call request or non real time new call request is received, if the available bandwidth exceeds the average bandwidth and average handover dropping probability is less than the P_{QoS}, then the call is accepted, otherwise it is rejected. The pseudocode for this scheme is summarized as follows,

Pseudocode for FDCAC scheme A (without reservation)

If the incoming call is real time handoff request,

If ($B_A \geq b_{avg}$) and ($P_{ah} \leq P_{QoS}$), **then**

strongly accept the call request and assign average required bandwidth.

else if ($B_A \geq b_{min}$) and ($P_{ah} \leq P_{QoS}$), **then**

strongly accept the call and allocate the minimum required bandwidth.

else reject the call request

If the incoming call is one of the following cases:

(i) real time new call request

(ii) non real time handoff call request, or

(iii) non real time new call request , then the pseudocode is summarized as below,

If ($B_A \geq b_{avg}$) and ($P_{ah} \leq P_{QoS}$), **then**

strongly accept the call request and assign average required bandwidth.

else reject the call request.

In the second scheme, the user movement pattern is assumed to be unknown and some amount of bandwidth is reserved for high priority handoff real time calls in the current and all neighboring cells. The amount of bandwidth to reserve would depend on the number of existing high priority real time calls in the current cell and the minimum required bandwidth. Let this reserved bandwidth be represented as B_R, then the total available bandwidth would be B_{TA} (= $B_A + B_R$). When real time handoff call is received, if the total available bandwidth is greater than the average required bandwidth and also average handover dropping probability is below the maximum defined value $P_{QoS,}$ then the call is strongly accepted else the minimum required bandwidth is compared with available bandwidth as in previous case. When the real time new call request, non real time new call or non real time handoff call is received, and if the total available bandwidth is greater than the average required bandwidth and also average handover dropping probability is less than the P_{QoS}, then the call is accepted. However if this condition is not true, if the total available bandwidth exceeds the minimum required bandwidth and average handover dropping probability is less than the $P_{QoS,}$ then the call is accepted else it is rejected. The details of this pseudocode is summarized as follows,

Pseudocode for FDCAC scheme B (with reservation)

If the incoming call is real time handoff request,

If ($B_{TA} \geq b_{avg}$) and ($P_{ah} \leq P_{QoS}$), **then**

strongly accept the call request and assign average required bandwidth.

else if ($B_{TA} \geq b_{min}$) and ($P_{ah} \leq P_{QoS}$), **then**

strongly accept the call and allocate the minimum required bandwidth.

else reject the call request

If the incoming call is one of the following cases:

(iv) real time new call request

(v) non real time handoff call request, or

(vi) non real time new call request , then the pseudocode is summarized as below,

If ($B_{TA} \geq b_{avg}$) and ($P_{ah} \leq P_{QoS}$), **then**

strongly accept the call request and assign average required bandwidth.

else reject the call request.

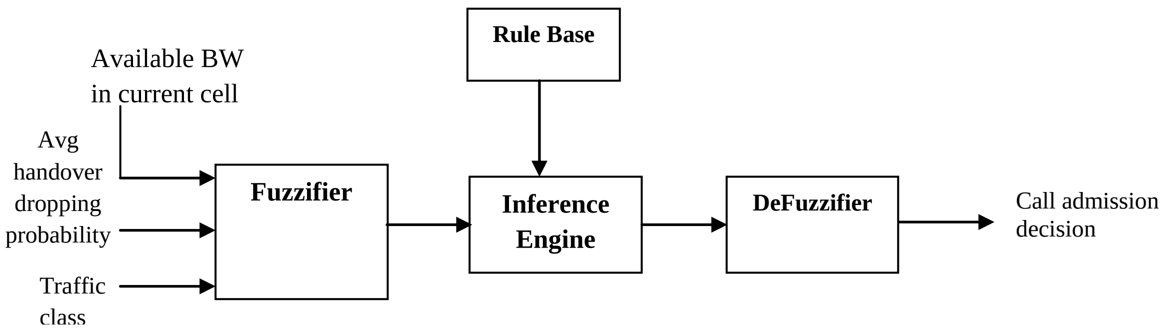

Fig.2 Fuzzy based Distributed call admission control Scheme

As can be seen, the controller comprises of Fuzzifier, Inference engine, Fuzzy rule base and Defuzzifier. All the real valued inputs are converted into corresponding linguistic variable values by Fuzzifier. The input parameters to the Fuzzifier unit include type of the traffic class that may be real time or non real time call requests; available bandwidth in current cell and average handover dropping probability in current and neighboring cells. Different types of traffic class are elaborated in Table 1. Real time services include voice and video services that are time and delay sensitive as well as loss sensitive. While services like data applications, email etc. that can tolerate large delays are classified as non real time applications. Real time handoff call requests have been given higher priority since in a multimedia networking environment; priority must be given to real time users because of limited resources (Baldo at al., 1999; Jayaram *et al*.,2000).

As can be seen from the Table 1, real time services have been classified as Class 2 (High) traffic services, similarly non real time traffic as Class 1 (medium) and Class 0 (low) for the Fuzzy rules. According to this, the membership function is depicted in Fig. 3. The most commonly used membership functions include Gaussian, triangle and trapezoid. For the present work, triangle functions are used. Membership functions for other inputs and outputs are depicted in Figs 3 to 6.

The membership function for average handover dropping probability (Baldo at al., 1999) is shown in Fig 5.

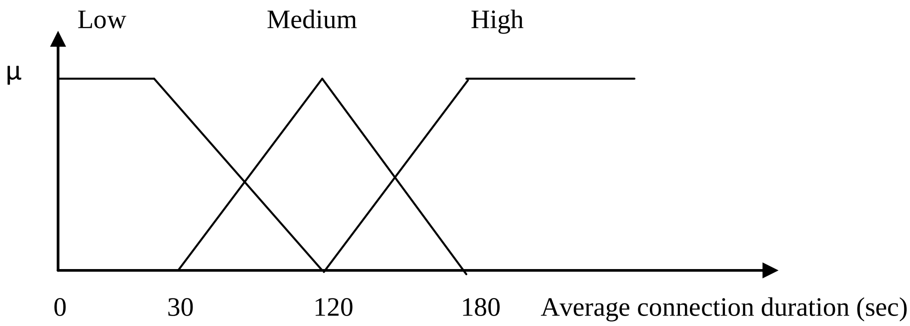

Fig. 3 Membership function for Traffic class

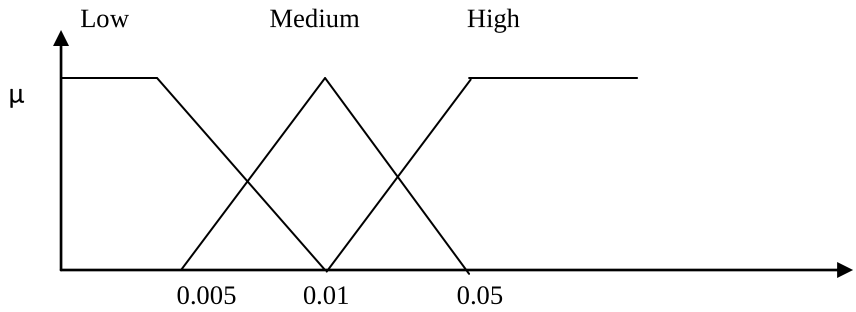

Fig. 4 Membership function for average HO dropping probability in current and neighboring cells

It is assumed that the maximum bandwidth capacity of a cell to be B Kbps.

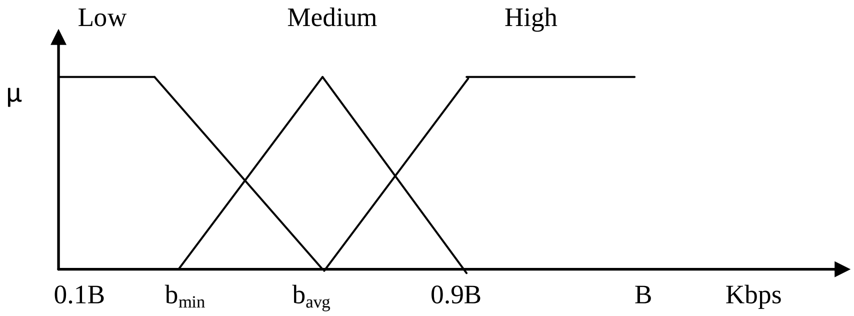

Fig. 5 Membership function for available bandwidth in current cell

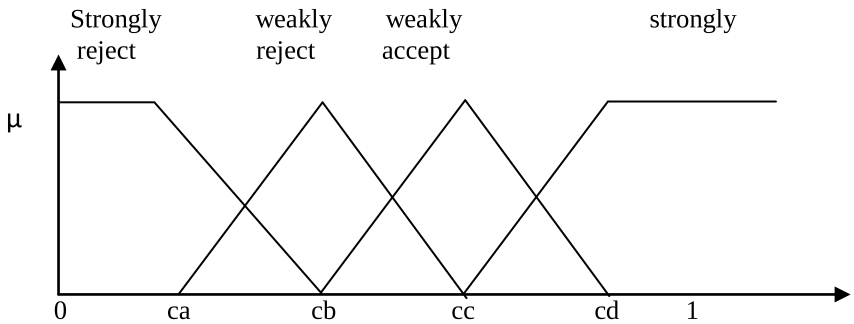

Fig. 6 Membership function for Call admission decision

The inputs to the FDCAC scheme are the mean values and are represented by their corresponding membership functions. Input fuzzy sets are labeled by their linguistic terms as low, medium and high. Fuzzy inference engine evaluates the set of If-Then rules which defines the system behavior. The result of this process is again a linguistic value, thus de-fuzzifiction step is required to set the output in discrete format. For this, centre of gravity method has been used as defuzzification method. The output i.e. the call admission decision for new call requests or handover calls is represented by the fuzzy sets as weakly accept (WA), strongly accept (SA), weakly reject (WR), strongly reject (SR). Some of the select Fuzzy rules for call admission control for handoff as well as new call requests are described in Table 2 and Table 3 respectively.

Table 2 Select Fuzzy rules for Handoff call request

IF			**Then**
Traffic class	**Average handover dropping probability in current and neighboring cell**	**Available BW in current cell**	**HO call admission decision**
Low	Low	Low	SR
Low	High	High	SR
Low	High	Medium	SR
Medium	Low	Medium	SA
Medium	High	High	SR
Medium	Medium	High	WA
High	Low	Medium	SA
High	Medium	Low	SR
High	High	Medium	SR

Table 3 Select Fuzzy rules for New call request

IF			**Then**
Traffic class	**Average handover dropping probability in current and neighboring cell**	**Available BW in current cell**	**call admission decision**
Low	Low	Low	WA
Low	High	High	SR
Low	High	Medium	WA
Medium	Low	Medium	SA
Medium	Medium	High	WA
Medium	High	High	SR
High	Medium	Low	SR
High	Low	Medium	WA
High	High	High	SR

The performances of the two proposed schemes have been compared with fixed reservation guard channel scheme in which fixed amount of guard channels are reserved exclusively for hand off calls only. The rest of the base station bandwidth is available for both new and handoff calls requests and priority is given to handoff calls. The details of the simulation are described in the following section.

4 SIMULATION RESULTS AND DISCUSSION

The simulation model comprises of cellular mobile network in which each hexagonal cell is assumed to be surrounded by six neighboring cells. A 2-D model of cellular system is considered that consists of 18 cells arranged in a circular pattern as shown in Figure 1. Each connection is assumed to experience multiple handoffs in its lifetime. It is assumed that each cell has a base station at the centre, which sets up and releases the connection (handoff and new call) and fixed channel allocation scheme is considered. It is assumed that the user while establishing the call also specifies the requirement profile in terms of average bandwidth required and specifies whether the call is real time or non real time. In addition to this, the new connections of various classes of traffic are generated with equal probability.

For the simulation purpose, the maximum bandwidth capacity of a cell is assumed to be 30 Mbps. For the present case, the performance of the proposed algorithm is compared with guard channel reservation model, thus fixed amount (5%) of the total bandwidth is reserved in the current cell exclusively for handoff calls in case of guard channel scheme. Each cell is offered same new originating traffic load, and the offered load to each cell is changed continuously. The above model was simulated in QualNet environment which is a discrete event network simulator and includes wide set of detailed models for wireless networking (QualNet user's manual). All simulations were repeated 20 times so that an averaged overall performance could be obtained and confidence interval was chosen to be 95%. The performance of two variants of Fuzzy logic based DCAC scheme is evaluated in terms of QoS parameters like blocking probability of new call requests, call dropping probability and bandwidth utilization. Fig. 7 compares the new call blocking probability for both the versions of FDCAC scheme and the guard channel scheme for class 2 traffic type.

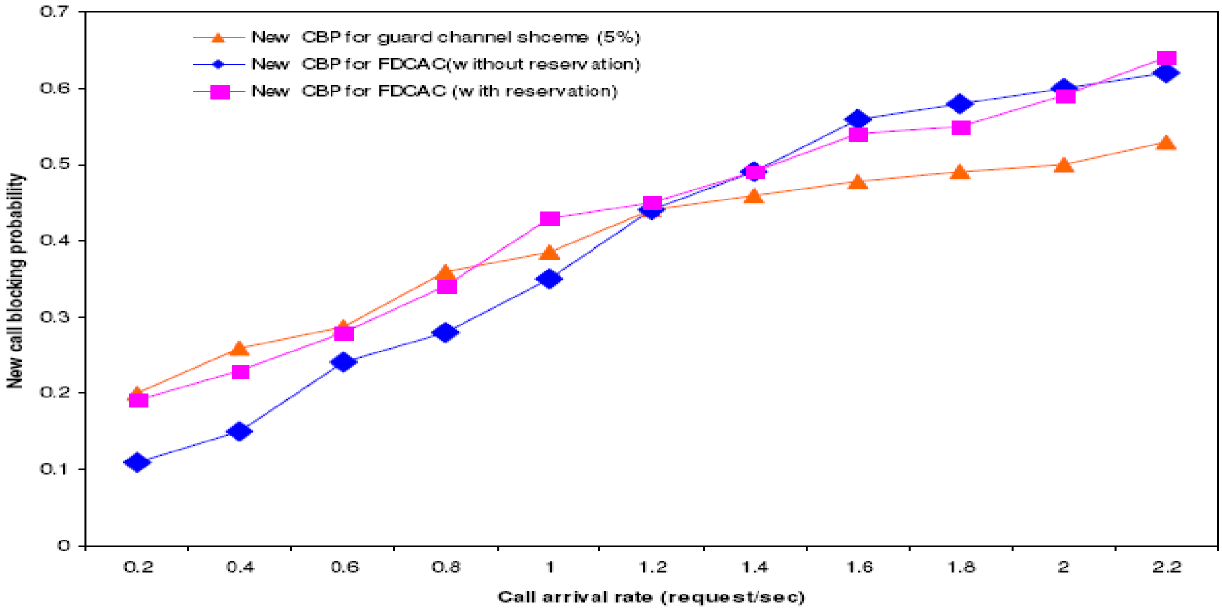

Fig. 7. New call blocking probability for Class 2 Traffic type

It can be seen that new call blocking probability for the guard channel scheme is lower compared to the FDCAC scheme, except under low load conditions. But with the further increase in the load, FDCAC without reservation scheme provides higher call blocking probability. Similarly, call dropping probability of both the FDCAC schemes is compared with the guard channel scheme for class 2 traffic type as depicted in Fig. 8.

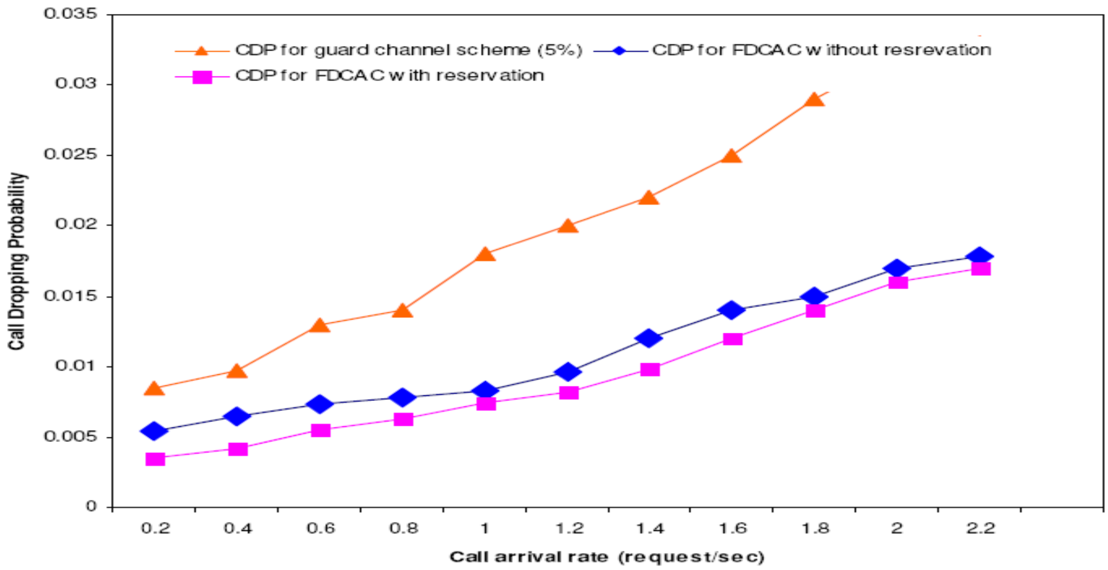

Fig. 8. Call dropping probability for Class 2 Traffic type

Fig. 8 shows that call dropping probability in case of FDCAC with reservation is less compared to the guard channel or FDCAC without reservation scheme. However as can be seen that the difference in CDP values for these two versions of FDCAC is not very significant.

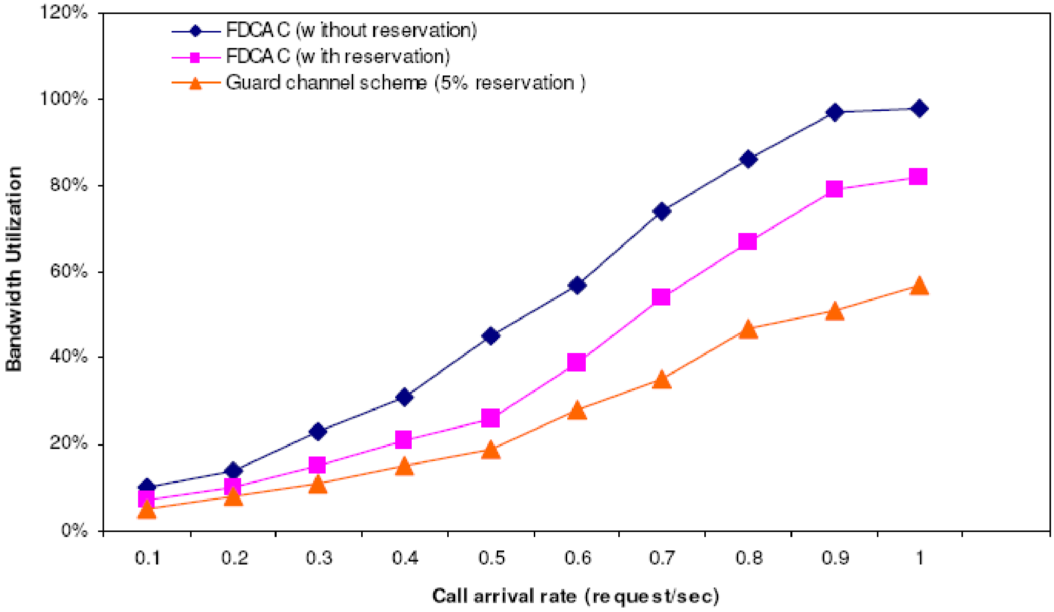

Fig. 9. Comparison of Bandwidth Utilization for the schemes

Fig. 9 depicts the bandwidth utilization for the guard channel and both the FDCAC schemes under study as a function of call arrival rate. The Figure indicates that the bandwidth utilization of both the variants of FDCAC scheme gradually increases with call arrival rate and is higher compared to guard channel scheme. However, FDCAC without reservation provides better utilization of bandwidth. From these results, it is evident that proposed FDCAC scheme without reservation fulfils most of the QoS requirements. The difference in the performance in terms of both the new call blocking probability and call dropping probability between the two variants is less bandwidth utilization of FDCAC without reservation is better. So it would be quite useful to focus on FDCAC without reservation and the cost of QoS guarantees need to be identified for the scheme B.

5 CONCLUSIONS AND FUTURE WORK

In this study, an intelligent distributed call admission control scheme using Fuzzy logic has been proposed to ensure QoS in multimedia environment. Two variations of fuzzy logic based FDCAC scheme have been considered. In the first scheme, no bandwidth is reserved exclusively for high priority calls in the current or neighboring cells. In the second scheme, the user movement pattern is assumed to be unknown and some amount of bandwidth is reserved for high priority handoff real time calls in the current and all neighboring cells. The performance of these two fuzzy logic based schemes has been compared with guard channel scheme.

It is shown through simulations that the performance of both FDCAC schemes is better compared to guard channel scheme in terms of QoS parameters considered. Further, the call dropping probability for FDCAC with reservation (scheme B) is not showing significant improvement compared to FDCAC without reservation (scheme A) scheme. It is also revealed that FDCAC scheme without reservation achieves better bandwidth utilization compared to other two schemes. This indicates that the performance of FDCAC scheme without reservation is better than the other two schemes. The work can be extended to take into account of different channel assignment techniques and also non-uniform traffic pattern can be considered in future work.

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