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Author(s): Mishra, J. L., Dahal, K. P. and Hossain, M. A.

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Call Admission Control using Cell Breathing Concept for Wideband CDMA

Jyoti Laxmi Mishra, Keshav. P. Dahal and M.A. Hossain
School of Informatics, University of Bradford BD7 1DP, UK
j.l.mishra; k.p.dahal; m.a.hossain1 (@bradford.ac.uk)

***Abstract*— This paper presents a Call Admission Control (CAC) algorithm based fuzzy logic to maintain the quality of service using cell breathing concept. When a new call is accepted by a cell, its current user is generally affected due to cell breathing. The proposed CAC algorithm accepts a new call only if the current users in the cell are not jeopardized. Performance evaluation is done for single-cell and multicell scenarios. In multicell scenario dynamic assignment of users to the neighboring cell, so called handoff, has been considered to achieve a lower blocking probability. Handoff and new call requests are assumed with handoff being given preference using a reserved channel scheme. CAC for different types of services are shown which depend upon the bandwidth requirement for voice, data and video. Distance, arrival rate, bandwidth and non-orthogonality factor of the signal are considered for making the call acceptance decision. The paper demonstrates that fuzzy logic with the cell breathing concept can be used to develop a CAC algorithm to achieve a better performance evaluation.**

***Index Terms*— Call Admission Control, Performance Evaluation, Blocking Probability, Fuzzy Logic, Cell Breathing.**

I. Introduction

IN Code Division Multiple Access (CDMA), radio resources are scarce quantities [1]. Each user is given a code which is spread out to the available frequency. The user is assigned a code which needs to be orthogonal to codes of other users. As the number of users goes up, interference between users' increases due to which the quality can deteriorate. Hence, a standard is to be maintained for providing a good service to the users. This standard is known as Quality of Service (QoS). Call Admission Control (CAC) is one of the techniques for radio resource management of wideband CDMA. According to Fang and Zhang [2], CAC can be defined as *'A provisioning strategy to limit the number of call connections into the networks in order to reduce the network congestion and call dropping.'*

CAC algorithm is developed in many ways by researchers. Signal to Noise and Interference Ratio (SINR) based CAC algorithms [1, 3 and 4] set a threshold value. If the SINR received is less than the threshold, the call is not accepted. In order to accommodate large number of mobile users; cells (area covered by one Base Station) have micro and pico cellular structure to facilitate the user movement from one cell to another cell. This requires handing over of ongoing call from one cell to another, which is called handoff. It is said that it is better not to have a call setup than to have it dropped. Fang and Zhang in [2] give priority to handoff calls by reserving some channels for them. This method is popularly known as reserved scheme or guard channel method. Ramjee et al. [5] used the guard channel method and proposed a fractional guard channel policy. Ghaderi and Boutaba in [6] presented a CAC algorithm for voice and data by enhancing the fractional guard channel scheme mentioned in [5]. Two acceptance ratios like in [7] for voice calls and data calls are used to maintain the QoS.

In CDMA, the uplink and downlink powers are not the same. Generally, uplink power, from mobile station (MS) to base station (BS), is considered for making the call admission decision [8]. Due to frequency reuse, cell size is continuously reducing which increases the handoff of MS from one cell to another.

New researches are reported in implementing CAC in IP based CDMA network [9]. Multimedia applications are considered in [10, 11]. Zhang et al. state that a fixed channel reservation scheme increases new call blocking probability and highlights the need of dynamic channel reservation [10]. In [12], Ayyagari and Ephremides have developed some optimal strategies to maximize the throughput for multimedia traffic and thereby improving the capacity of the system. A CAC algorithm has been proposed for multimedia services by assigning different CAC thresholds to different call classes in [13]. Kim and Han in [7] proposed a CAC algorithm for multiple types of services using total received power as threshold taking into account cell load and SINR. Higher priority is given to voice traffic by setting higher threshold compared to data traffic.

As the number of user goes up, interference increases as well, MS thus needs to increase the power transmission. Due to this reason, users at the boundary will be dropped and the cell size shrinks [14]. Reverse is the case when the number of user decreases that is, the cell size increases. This is termed as cell breathing.

In literatures it has already been shown that for CAC fuzzy logic is useful in the decision making process [15]. Planning and optimization process can be automated with intelligent tools and network elements [16]. Ray-Guang mentioned in

[17] that fuzzy logic system is already proven to be robust. Shen [15] has presented a fuzzy CAC based upon the estimated effective bandwidth and has successfully shown that Fuzzy Logic lowers blocking probability as well as achieves high resource utilization. In [18], fuzzy traffic controller is designed for real time and non-real time services. In [15], [17], [18], [19] decision is made based on the effective bandwidth.

In this paper cell breathing concept using fuzzy logic is introduced for a CAC algorithm. This algorithm considers distance, arrival rate, bandwidth and non-orthogonality factor of the signal. The CAC algorithm is developed based on the mathematical model mentioned in [14] with added features of handoff and new calls as well as multiple services. CAC needs some data to make the decision to accept or reject a call to maintain a satisfying quality of service. Fuzzy CAC is developed considering the distance as one of its input variables to justify the cell breathing concept. If the user is very near to the base station then there is actually no need to consider distance and hence other parameters than distance should be considered**.** Similarly, if the MS is very far from the BS, the signal received will be very low and hence, a call request can be rejected without checking other conditions. Finally, if the MS is in the acceptable range then other parameters affecting the quality of the signal and interference, such as arrival rate, bandwidth required etc, should be considered along with the distance.

The model is presented in section II. Section III consists of fuzzy systems and fuzzy rules followed by experiments and results in section IV. Further modification to the CAC algorithm is done in section V. The paper is concluded in section VI with some future works.

II. SYSTEM MODEL

A. Mathematical model for single cell

The model is based upon following equations from [14]. A MS transmits signal with P_S power which will be received at the BS as P_R. Because of path loss P_R is less than P_S. Interference (I_i) caused by non-orthogonality between codes, at the BS to user i is given by

$$I_i = N_t + \psi_t + \sum_{\substack{j \neq i \\ j=1}}^{n} V_j . P_{Rj} . \varepsilon_{ji} \qquad (1)$$

where Ψ_t is the interference due to the neighboring cell, N_t is the thermal noise, ε_{ji} is the non-orthogonality factor, V_j is the activity factor and P_{Rj} is the received power of all other users *j* if there are *n* cells .

Maximum distance covered is then given by the following equation in which λ is the wavelength, P_{Smax} is the maximum power transmitted by the mobile station, L_{pce} is the path loss, F is the inter-cell interference factor, S is the service factor , n is the number of user at present in the cell, ε is the non-orthogonality factor, while V is the activity factor, g_b and g_m are base station and mobile station gain which is considered to be 1 for simplicity.

$$d_{\max} = \frac{\lambda}{4\Pi} \sqrt{\frac{P_{S\max} . L_{pce} . (S - (n-1) . \frac{\varepsilon V}{F})}{N_t} g_b . g_m} \qquad (2)$$

Equations (1) and (2) are used to make the decision to accept or reject a requested call within a CAC algorithm as shown by the flowchart in Fig 1.

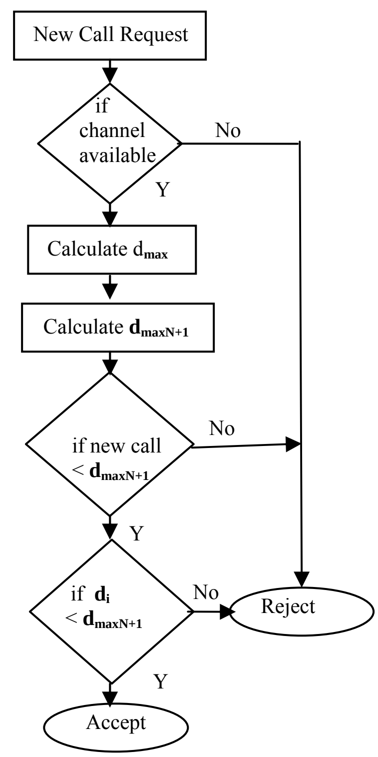

Fig.1 Flowchart for the CAC [7]

A new call will be accepted only if the number of channels available is less than the total capacity. Also, if a new user requests for a connection, the distance covered by the base station decreases. Due to this reason, the new distance covered if new user is to be accepted, is calculated as d_{maxN+1}. Again, the condition is checked if the new user is within that cell boundary. If this is the case then a check is made to find whether existing users still get the service by comparing distances of all existing users d_i with the new distance d_{maxN+1}. If the service is still available to all the existing users then the call is accepted else it will be rejected.

For single cell time based simulation was done with the parameters as shown in Table I. MATLAB was used to implement this simulation framework.

TABLE I
SYSTEM PARAMETERS

Symbol	Parameters	Values
R	Radius of the cell	4000m
IR	Other cell to own cell interference ratio	55%

SNR	Signal to noise ratio	2,3 dB
P_{Smax}	Maximum transmission power	125mW
N_t	Thermal Noise	-80dBm
E	Non-orthogonality factor	0.10-0.80
λ/μ	Trafifc Intensity	1,2,3, 4…10 erlang
V	Voice activity factor	55%
Max_calls	Channel Capacity	25

B. *Multicell*

CDMA system follows soft handover. It means that at one time a MS is connected with 3 base stations. Hence, when a MS enters another cell, the change in frequency will not affect the quality of service. It will take into account the received signal for all three BS's but will communicate with only one. The same concept for single cell is used in multicell. However if calls are to be blocked in the first cell then the request is sent to the second cell. If requested call cannot be accepted in that cell, then it is sent to the third cell. If it is not accepted in the third cell, it is finally rejected or blocked.

III. Fuzzy System

Research results reported in [5, 6 and 8] have shown that CAC can be improved using an intelligent algorithm. Here we develop a CAC algorithm using fuzzy logic as shown in Fig. 2. Unlike the deterministic mathematical model presented in the previous section, fuzzy logic techniques can deal with imprecise and flexible features of CAC. The cell acceptance decisions are made based on parameters such as distance, arrival rate, bandwidth and the nature of the code (non-orthogonal factor ε). These parameters are not as rigid as they are in previous section.

In this section a flexible Fuzzy Logic based decision making algorithm using cell breathing concept with linguistic values for these parameters is proposed. The blocking probability is calculated for different scenarios.

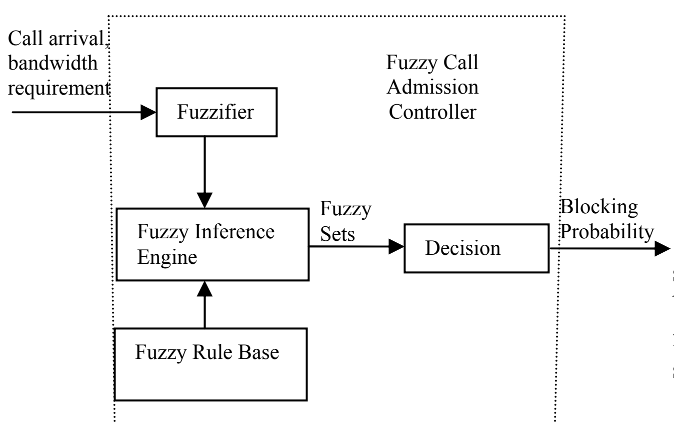

Fig.2 Block diagram for fuzzy system in CAC

From the simulation it is seen that the blocking probability is affected by the arrival rate, bandwidth and nature of code. Thus, universe of discourse for the proposed system consists of sets of linguistic variables such as Distance, Arrival, Bandwidth required and ε. The first linguistic variable is distance as distance plays an important role in the decision making for the acceptance or rejection of a call. The range may vary depending upon the MS position. One such example with worst condition of 4000m is taken as shown in Fig. 3.

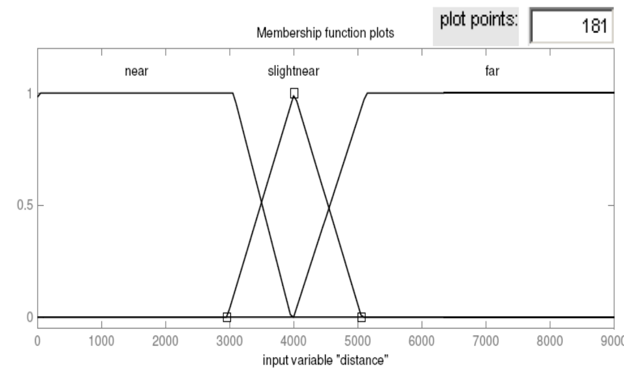

Fig.3 Distance as linguistic input variable

Second linguistic variable is arrival rate. It is a real number from 0.1calls/second to 0.99 calls/second as mentioned by [14]. Input linguistic variable arrival rate is defined on the term set U (Arr) = {Low, Medium, and High}. Membership function should always be defined with proper shape [18]. Gaussian curve is chosen for input linguistic variable as mentioned in [15] and is shown in Fig. 4. The reason behind choosing Gaussian curve is because arrivals are exponential random.

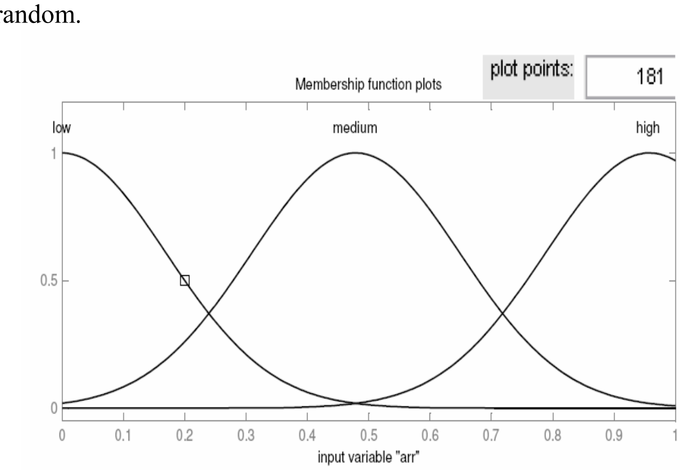

Fig.4 Membership function of arrival rate

Third input parameter is bandwidth. It can be seen from the simulation that for different types of services, different bandwidth is required. For voice, data and video as mentioned in [16], 12.2, 64 and 144 Kbps is required respectively. So, second input parameter is described with 3 sets U (BW) = {Low, Medium and High}. Trapezoidal function is chosen as shown in Fig. 4 and as described in [18].

Non-orthogonality factor is also one of the important factors in CDMA. Since, codes are not orthogonal in nature; there will be certain interference between codes. As the number of user increases, interference increases as well. In [14], the range of non-orthogonality is found to be in the range of 0.1 to 0.9. Higher value of non-orthogonality show higher interference between codes. As the non-orthogonality factor increases, quality of signal degrades. Fig. 6 shows the trapezoidal function with 3 sets low, medium and high used to describe the third linguistic variable non-orthogonality factor or ε.

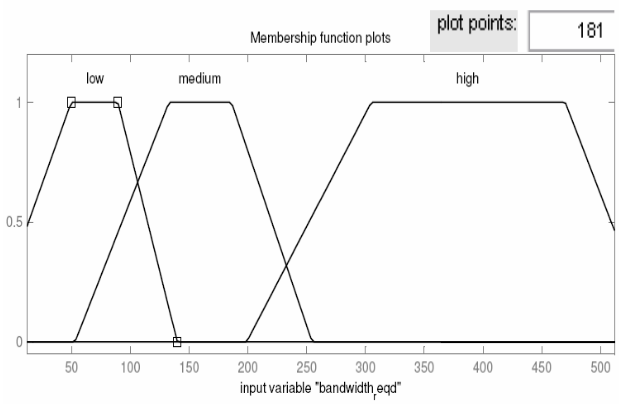

Fig.5 Membership function of bandwidth required

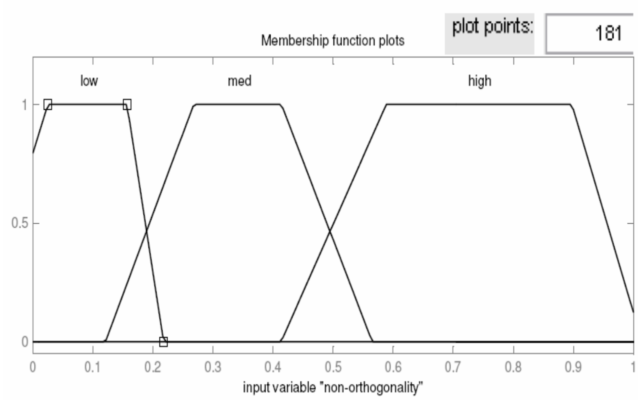

Fig.6 Membership function of non-orthogonality factor

Similarly the output linguistic variable is the blocking probability. For the performance evaluation of CDMA, blocking probability is one of the major factors. Instead of drawing a sharp line between low and high blocking probability, it is described using 7 sets. Blocking probability is defined on the term set

U (BP) = {VL, L, M, MM, H, VH, EH} and the membership functions are as shown in Fig. 7.

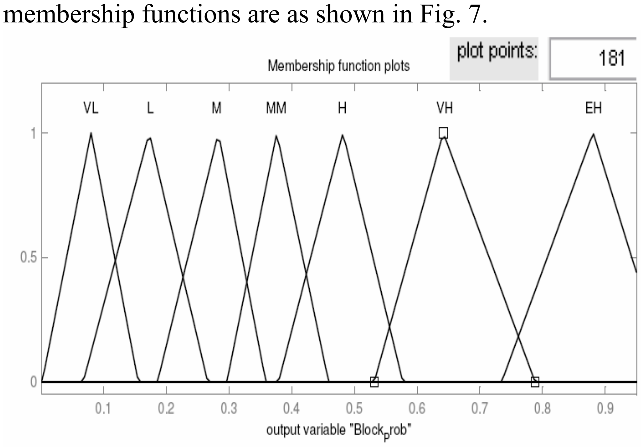

Fig.7 Blocking Probability as output variable

Fuzzy logic uses linguistic variables to map the input fuzzy variables to the output fuzzy variables. This is accomplished by using fuzzy if-then rules. Rules are generated in this paper based on the following considerations. If the distance of the MS is near to the base station then consider arrival rate, bandwidth required and non-orthogonality factor only. If the distance is far then Blocking Probability due to very low signal will be extremely high. Fuzzy rules are derived based upon the experience gained from simulation work in previous section. If Distance is Slight near and arrival is Low and Bandwidth required is Low and non-orthogonality factor is Low then Blocking Probability is L.

IV. Dynamic Assignment of Users

The CAC algorithm shown in Fig. 1, may not accept call request even though it is very near to the base station, due to the dropping of ongoing users. Modification is done as shown below in Fig. 8.

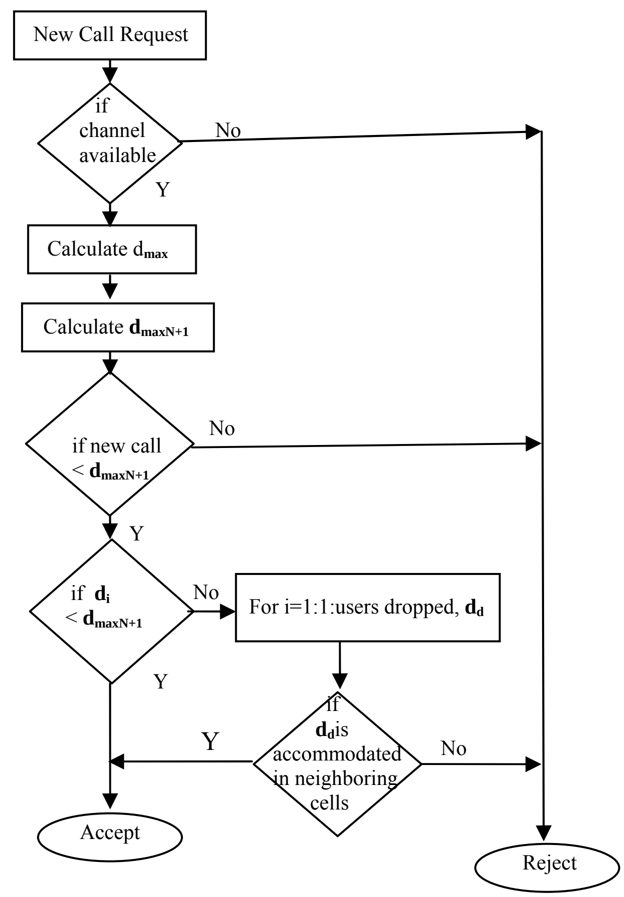

Fig.8 Flowchart for transferring old users to neighboring cells

V. Experiments and Results

Whenever a call is requested, the CAC algorithm checks whether that call is within the accepted distance or not. It is accepted if number of channels is less than the cell capacity and the MS is at the acceptable distance. Simulations are done in MATLAB for single cell and multiple cell scenarios.

A call request is modeled based upon the inverse transform technique i.e. if arrival rate is 2 calls/sec then an arrival will happen based upon

$$arr\_dur = [-\frac{1}{arr} * \log(1 - rand(1))] \quad (3)$$

Where, *arr_dur* gives the duration in time after which a new call request may happen. Similarly, 1/*arr* is the mean arrival in terms of time.

A. Results for single cell

In single cell scenario, whenever a call is requested, number of free channel is checked for that particular cell where the call request is originated. If the number of channels available are less than the capacity of the cell and distance of the user or MS is also within reasonable range then the call will be accepted.

Figure 9 shows the nature of the curve for blocking probability with respect to traffic intensity. It can be seen that when traffic intensity (ρ) is less, there is no blocking but as the traffic load increases, blocking probability increases as well. The nature of the curve can also be validated by Erlang B equation as shown in equation 4 where, P_B is the blocking probability, n is the number of channels and ρ is the traffic intensity given by λ/μ.

$$P_B = \frac{\frac{\rho^n}{n!}}{\sum_{i=1}^{n} \frac{\rho^i}{i!}} \quad (4)$$

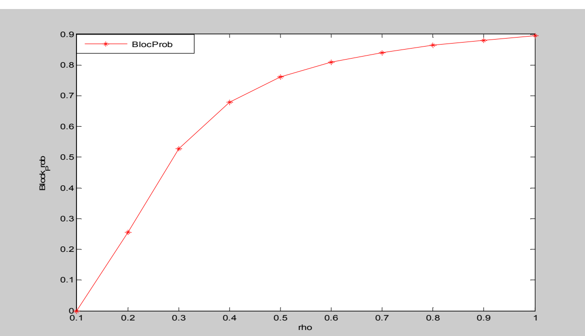

Fig. 9 Blocking Probability vs. Traffic Load

Calls requested can be categorized as handoff calls and new calls. Handoff calls are those calls which originate in different cell but due to mobility require service in the present cell. New calls will be originating in the cell considered. As, a call dropped is more annoying than a call blocked, handoff call should be given preference. Considering this fact, few channels are reserved for handoff calls.

Here, 4 channels are reserved for handoff calls. Hence, when a new call is requested, if the number of channels empty is more than 4 then new call is accepted else it is rejected. For, handoff calls, if the number of channel free is one or more then it will be accepted. Figure 10 demonstrates the nature of the curve for handoff call request and new call request. It can be seen that the blocking probability for handoff call is less than that for a new call.

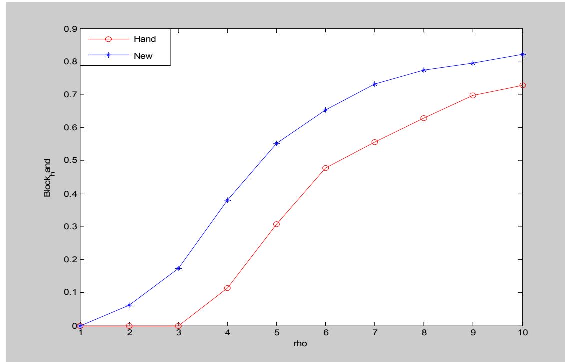

Fig.10 Blocking Probability vs. Traffic load with handoff and new call

Similarly, a call can also be broadly categorized into voice, data and video. Difference between these types lies in the fact that different types of service requires different bandwidth. As bandwidth is a fixed resource, channel capacity may vary in the cellular system. For this reason, the channel capacity varies for different services. In this case, for video call request the cell capacity reduces to 6, for data 15 and for voice it remains 25. As shown in figure 11 below, voice call request has the least blocking probability than data and video call requests. Thus, bandwidth required for video is the highest.

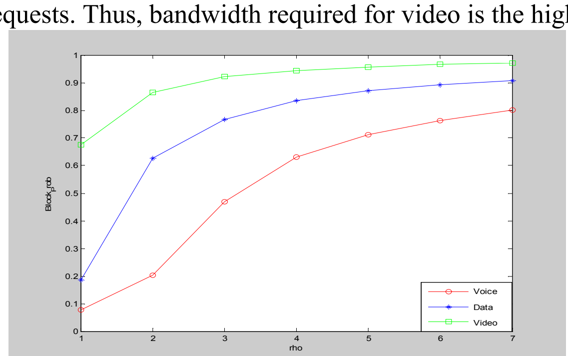

Fig.11 Blocking Probability vs. Traffic load for different type of service

B Results for multiple cell

In WCDMA, one MS is connected to 3 BTS at one time. So, depending upon the best receive power, service will be requested to one of the BS. If it satisfies all the criteria as mentioned in the algorithm, then the call will be accepted else it will be forwarded to the second cell and to the third cell. A call will be blocked finally if it cannot be accepted in the third cell as well.

Result in figure 12 shows that calls will be blocked only after the traffic load increases to certain level. The nature of the curve can be justified according to Erlang B equation shown in equation (4).

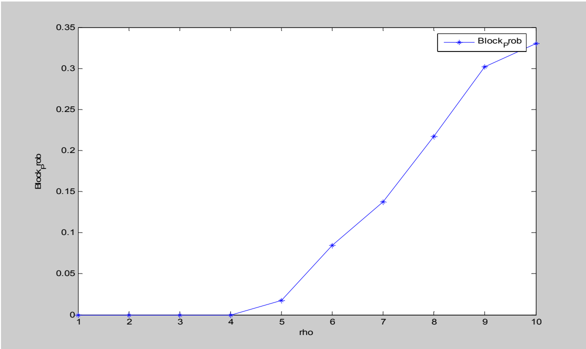

Fig.12 Blocking Probability vs. Traffic Load for multi-cell scenario

As mentioned above, some of the channels are reserved for the handover call giving it more priority as compared to the new call arrival. Result in figure 13 demonstrates that dropping rate for handover is less than the blocking rate for new call.

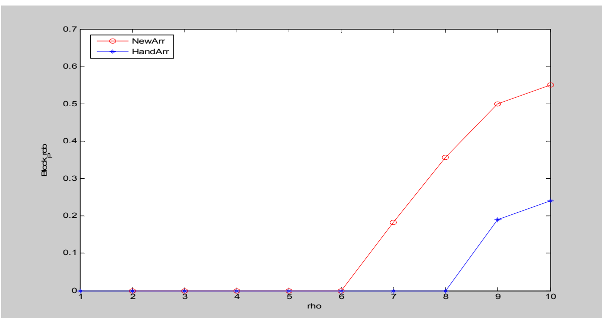

Fig.13 Blocking Probability vs. Traffic Load for handoff and new call arrival in multi-cell scenario

Figure 14 shows the nature of the curve for different types of services like voice, data and video. Blocking probability for voice is the least among the three.

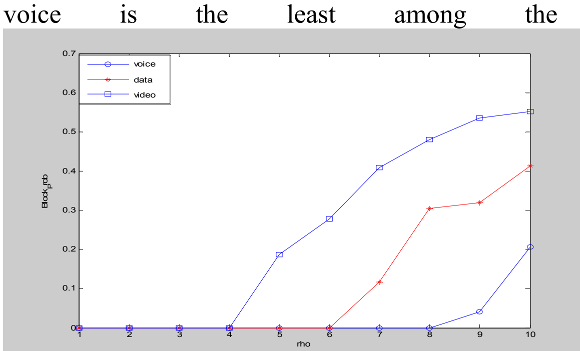

Fig.14 Blocking Probability vs. Traffic Load for multi-cell with different types of services

Analyzing all three results for multiple cell, it can be seen that the blocking probability for handover call request, new call request, voice, data and video service all resemble the nature of the curve given by Erlang B.

The performance of a cellular system drastically improves when multiple cell is considered as compared to the single cell.

C Fuzzified Results

MATLAB Fuzzy Toolbox has been used for developing Fuzzy CAC. Linguistic variables for input and output are as mentioned in section III of the fuzzy system. It can be seen in figure 15 that with the increase in bandwidth and arrival rate, blocking probability increases too.

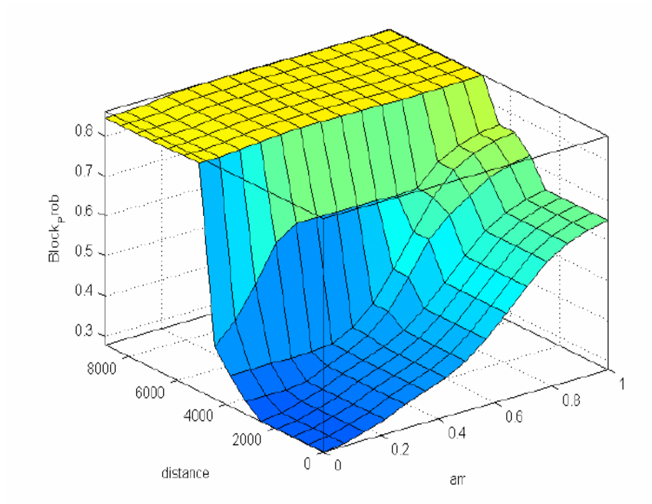

Fig.15 Surface view for fuzzified output

Comparison was done between results obtained for CAC using mathematical model and the fuzzified CAC. It can be seen from Fig. 8 that the blocking probability starts increasing with very low arrival rate in single cell whereas it starts only at 0.15 Erlang in case of fuzzified CAC as shown in fig. 14. Also, blocking probability reduces from 0.89 to 0.62. This shows the increase of performance using fuzzy CAC compared to the model for single cell.

D Dynamic assignment of users

Even though a call request is very near to the base station, it might not be accepted because of call dropping. An improvement can be by transferring some old users which might be out of service to the neighboring cells as shown in Figure 16.

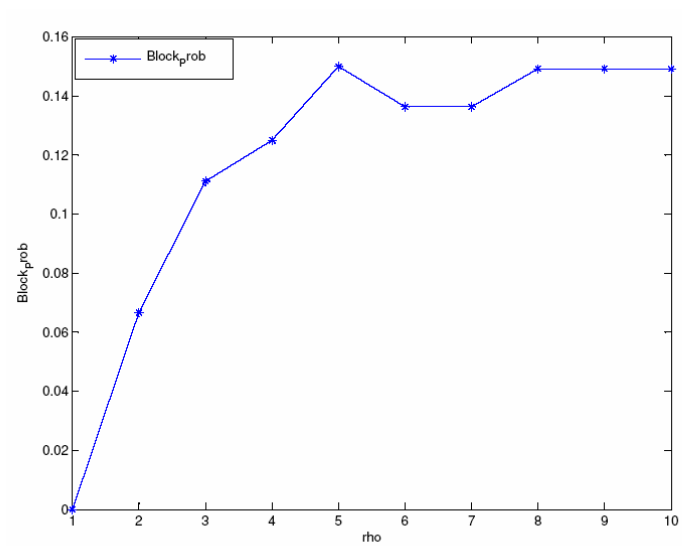

Fig.16 Blocking Probability vs. Traffic Load for multicell with dynamic user assignment

Comparing Figure 12 with Figure 16, it is seen that the blocking probability decreases from 0.32 to 0.15, thus increasing the performance of the system.

VI. Conclusion and Future Work

Cell breathing concept is considered in this paper unlike most of the existing CAC algorithms. The proposed CAC algorithm was deployed in single cell and multicell scenarios. CAC algorithm performs better if multicell is assumed with 0.33 P_B as compared to 0.9 of single cell at 10 Erlang. Fuzzy system was implemented in cellular system to make the decision of accepting or rejecting a call. The CAC with fuzzy implementation yields better result in terms of blocking probability if distance is considered reducing the blocking probability from 0.32 to 0.15. Furthermore, CAC with dynamic users is implemented with improved results.

Future work consists of including mobility of a user, path loss and implementation of neural network for intelligent CAC algorithm**.**

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