

An Intelligent Call Admission Control Scheme for Quality of Service Provisioning¹⁵² in a Multi-traffic CDMA network

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Abstract - In Code Division Multiple Access (CDMA) mobile cellular network, quality of service (QoS) provisioning of diverse user applications is a great challenge due to scarcity of wireless radio resources and the different QoS requirements demanded by the users. An effective call admission control (CAC) algorithm is needed for optimization of existing resources and better admission control to improve the overall performance of the cellular network system. Realizing that interference is caused by users in own-cell and other-cell which brings about the near-far effect causing some calls to be blocked/dropped, we set a signal-to-interference-noise ratio threshold (SINR) target for calls. For a multi-traffic wireless network, call blocking probability as a QoS metric should be reduced to the barest minimum. In this paper, an intelligent admission control model based on fuzzy logic is proposed to handle the imprecision and uncertainty surrounding the different classes of traffic for both real time and non-real time applications. Thus, the admission decision is expected to admit a higher number of service requests while at the same time guaranteeing the required QoS for every active connection. Three classes of traffic with different QoS requirements were considered in the proposed model. The accuracy of the model is validated through simulations in MATLAB and the results are satisfactory depicting the effectiveness of fuzzy logic in an intelligent call admission control scheme.

Keywords: Call Admission Control, Quality of Service, CDMA Network, Cell Load, Fuzzy Logic

1 INTRODUCTION

The global mobile communications market has expanded very rapidly. From analog phone systems in the 70's and 80's, cellular systems have progressed to digital cellular phone systems in their second generation (2G) with Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), and Code Division Multiple Access (CDMA), technologies in the 90's [1]. Society has seen the introduction of data services from 2.5G with short message service to third generation (3G) mobile phone system where mobile phone can access internet services, retrieving text, pictures, video, and other documents with a fast delivery speed [2]. The Next Generation Wireless Networks (NGWN) - fourth generation (4G) promotes an integration of emerging technologies for seamless connectivity. In such CDMA networks, radio resources such as power and bandwidth are scarce quantities [3]. Each user is given a code which is spread out to the available frequency.

The frequency reuse factor is one. The user is assigned a code which needs to be orthogonal to codes of other users. However, as the number of users increases, the quality of service in the network deteriorates. Hence, a standard is to be maintained for providing good services to the users. This standard is known as quality of service (QoS). Call Admission Control (CAC) is the technique used for radio resource management in CDMA networks ensuring that the challenge of distributing the available channel capacity among multiple traffics with different bandwidth requirements and QoS requirements are tackled.

Previous papers [3], [4] considered total interference into the system but did not assign a value for the threshold. Furthermore, the impact of user mobility was not captured in the fuzzy logic controller proposed. In this paper, we consider interference as noise rise in the system from mobiles in own-cell and (adjacent) other-cell and represent it in terms of effective cell load (own-cell load plus other-cell load) with a threshold of 0.8. In our model, if the effective cell load together with the load factor is

less than the threshold value, the call is accepted otherwise it is rejected. Generally, uplink power, from Mobile Station (MS) to Base Station (BS) is considered for making the call admission decision [6]. Therefore the focus of this work is to develop an intelligent call admission control algorithm based on fuzzy logic that can be used in the uplink direction of a well-established CDMA network for effective call admission into the system. This is expected to reduce call blocking to the barest minimum in the network.

The rest of the sections are arranged as follows. In section 2, we review related literature. Section 3 discusses the methodology and presents the fuzzy system model. In section 4, simulation results are discussed to validate the accuracy of the model and in section 5, we summarize and conclude the paper giving directions for future work.

2 REVIEW OF RELATED WORKS

CDMA is the fastest-growing digital wireless technology since its first commercialization in 1994. Its advantages over TDMA and FDMA technologies, such as voice signal quality, system security and reliability, power consumption and handset battery life, have created a multiple of research on CDMA systems. These result in gains such as increased capacity, immunity to multi-path fading, voice activity and soft handoff mechanism. Compared to exiting technologies such as FDMA and TDMA which uses different frequency sub-bands and time slots respectively to carry multiple calls, CDMA distinguishes different calls by unique codes, which are assigned individually to each call. Fig.1 depicts the differences between the three technologies.

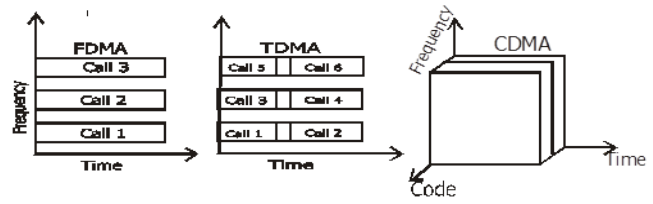


Fig. 1: Diagram illustrating FDMA, TDMA and CDMA technique [2]

At present, dissimilar wireless access networks including 2.5G, 3G cellular networks, Bluetooth, Wireless Local Area Networks (WLAN), and worldwide interoperability for microwave Access (Wi-max) co-exist in the mobile computing environment, where each of these offer complementary characteristics and features in terms of coverage area, data rate, resource utilization, power consumption, etc.[7]. The end user is expected to be able to connect to any of the different available access networks. In this heterogeneous environment, the effective utilization of the limited available resources is a challenge. The admission control is one of such challenge a network service provider faces to achieve better system utilization in handling this complex scenario to provide the best quality of service to the users of the network. Mobile users always look for best connected networks at anywhere and anytime among the complementary access technologies. According to [8], the traditional CAC schemes were based on the call level quality of service only and few of them have considered the physical layer quality of service like SINR as QoS criteria.

Call admission control limits and regulates the number of users admitted into the network under the constraints of network capacity and resource allocation strategies. CAC in CDMA cellular networks has been addressed as a means of managing interference to ensure efficient QoS support, as the capacity of CDMA systems is interference-bound. CAC directly controls the number of users in a cell in order to keep the interference under a tolerable limit so that an adequate radio link performance and required QoS for each user can be maintained.

Perros and Kim [9] dealt with Asynchronous Transfer Mode (ATM) in their CAC algorithm which has no direct application with mobile cellular networks with its problems of scarce radio resource and different QoS requirements for diverse user applications. In [10], the admission control based on thresholds were addressed for separate regions but determining the values of thresholds that separate those regions was a critical problem. Haas, Halpem and Wicher [11] used a decision-theoretic approach based on Markov Decision process but [5]

showed that large number of states in Markov model is unsuitable for real-life problems. In a wireless cellular system, a call admission controller makes a decision based on the imprecision and uncertainty measurements due to varying channel conditions, user mobility and QoS requirements, etc. The authors in [12] proposed CAC algorithms to serve single-class traffic such as real-time voice calls.

Kim and Han [13] analyzed the performance of the call admission control algorithm in CDMA system for multi rate traffic by taking the received power as the admission parameter. In effective bandwidth-based CAC scheme proposed in [14] for CDMA cellular networks, the effective bandwidth of each call is estimated based on the inter-cell and intra-cell interference and the admission decision is made based on comparing the existing bandwidth with the total effective bandwidth of all the calls including the new call. Research have shown that the intelligent techniques such as fuzzy logic, artificial neural network, genetic algorithm, etc. and their combinations exhibit better efficiency than the traditional CAC policies and leads to higher user satisfaction [6], [15]. In [5], fuzzy logic technique was adopted in the admission control mechanism but only network load and mobile node precedence were considered as input into their proposed admission control framework disregarding user mobility. The resource allocation is a challenging task in a multi-traffic heterogeneous wireless network. This paper proposed the development of an efficient and intelligent CAC scheme based on fuzzy logic that can handle the uncertainty and imprecision problems in this multi-traffic environment to optimize the resource utilization. The linguistic control capabilities of the fuzzy logic controller can achieve reduced call blocking probability, maximized utilization of system resources, guaranteed users QoS requirements and improved revenue for mobile operators. Our model considers type of service request by user, user mobility, total

interference (cell load), and loading factor into the system as inputs to the fuzzy call admission controller.

3 SYSTEM MODEL

In fig.2, the CDMA network architecture is presented while fig.3 shows the system model of the CDMA soft blocking system where the near-far problem exists due to interference. When a call request arrives, the mobile switching centre uses the mobility information of all the mobiles in the cell and in the neighboring cells as well as their traffic characteristics to calculate the resource utilized by all the active calls. Then it estimates the resource requirement of the new call and finds the resource availability to accommodate the new call without degrading the QoS of accepted ongoing calls. So, the mobility information of the user, interference caused by the MSs at its home BS and from neighboring cells, the type of service request and load factor are the considered inputs into the system causing call blocking.

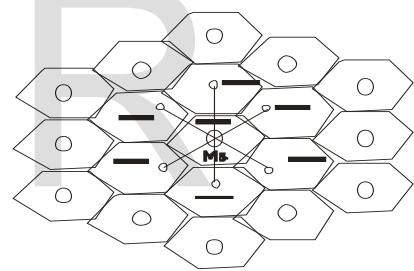


Fig. 2: CDMA network architecture

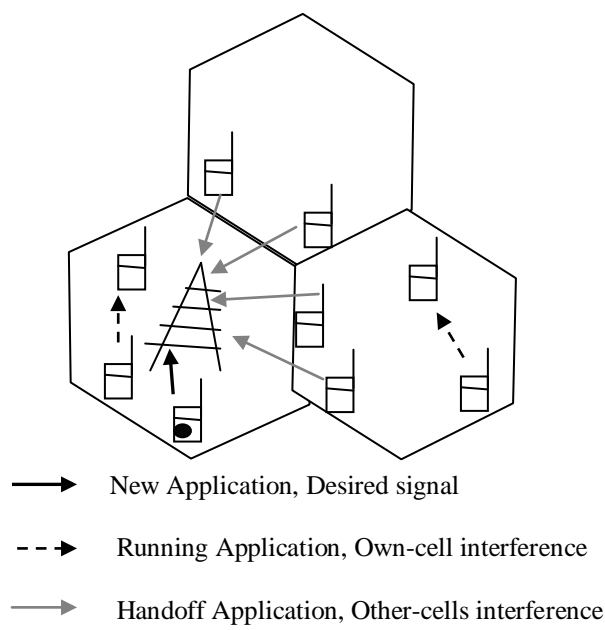


Fig. 3: CDMA Near-far effect due to interference

Since frequency reuse factor in CDMA systems is 1, all users both in own-cell and other-cells contribute to the total interference, thus influencing the link quality in terms of received bit-energy-to-noise spectral density ratio (E_b/N_o), which is required to provide the needed QoS. The more users are active at the BS, the larger is the multi-access interference at the BS and the higher are the transmit powers required by mobiles to fulfill their QoS requirements. Mobiles closer to the BS get stronger pilot signals and transmit less power than mobiles farther away from the BS. The SINR of each and every connection depends on the power emitted by the mobiles, own-cell and other-cell interference and thermal noise. The transmit power of the MS from the SINR requirement of a user of service class k is given as:

$$(E_b/N_o)_k = \frac{WP_k}{v_k R_k (I_{total} - P_k)} = \frac{GP_k}{v_k (I_{total} - P_k)} \quad (1)$$

Solving equation (1) for P_k , the received signal power from the user k gives:

$$P_k = \frac{I_{total} W}{1 + (E_b/N_o)_k v_k R_k} \quad (2)$$

Where $G (=W/R_k)$ is the processing gain and the target value of E_b/N_o depends on the type of service required by the user. W is the wideband CDMA chip rate, v_k is the voice activity factor, I_{total} is the total interference.

Basing CAC in CDMA systems on measured interference implies measuring the noise rise. According to [16], the noise rise NR is the ratio of total received interference power at the BS to the thermal noise. The thermal noise is the interference due to an empty system, thus:

$$NR = \frac{I_{total}}{N_o} = \frac{I_{own} + I_{other} + N_o}{N_o} \quad (3)$$

When a call arrives to the cell, the NR is estimated and if it exceeds a predefined threshold, the call is blocked. The cell load n , is the ratio of the received power from

all active users to the total received power and is given as:

$$n = \frac{I_{own} + I_{other}}{I_{own} + I_{other} + N_o} \quad (4)$$

From equations (3) and (4), we derive the relation between noise rise and cell load as:

$$n = \frac{NR - 1}{NR} \quad (5)$$

Hence instead of using noise rise for CAC, we can use cell load. The cell load threshold for new arriving call must not exceed the maximum value, n_{max} of 0.8 which is considered as the shared system resource. The resource requirement of a service class k known as the load factor is described as:

$$L_k = \frac{1}{1 + (E_b/N_o)_k v_k R_k} \quad (6)$$

The own-cell load and the other-cell load are expressed as:

$$n_{own} = \sum_{k=1}^K m_k L_k \quad (7)$$

$$n_{other} = (1 - n_{max}) \frac{I_{other}}{N_o} \quad (8)$$

$$n = n_{own} + n_{other} \quad (9)$$

Where m_k is the number of active users of service class k .

We compute the blocking probability of a new call arriving at an instance with own-cell load as,

$$\begin{aligned} P_{b(n_{own})} &= \\ \text{Prob. } (n_{own} + L_k + (1 - n_{max}) \frac{I_{other}}{N_o}) &> n_{max} \\ &= \text{Prob. } (n + L_k > n_{max}) \end{aligned} \quad (10)$$

According to [17], [18], and [19], the total interference at the BS receiver for a user is the interference from the users in own cell and neighboring cells. We model other-cell interference in equation (10) as a lognormal random variable with distribution function, $\Gamma(x)$ and parameters, mean and standard deviation as follows:

$$\begin{aligned} \mu\Gamma &= \mu + \log(1 - n_{max}) - \log(N_o) \quad \text{and} \\ \sigma\Gamma &= \sigma, \text{ respectively.} \end{aligned}$$

Therefore, we obtain for the local blocking probabilities as:

$$P_{b(n_{own})} = \begin{cases} 1 - \Gamma(n_{max} - (n_{own} + L_k)) & \text{if} \\ 1, & \text{else} \end{cases} \quad (11)$$

$$n_{max} - (n_{own} + L_k) \geq 0$$

3.1 FUZZY SYSTEM MODEL FOR CAC

Fuzzy logic configurations include pure fuzzy logic system (FLS), Takagi and Sugeno’s fuzzy system and Mamdani’s fuzzy system [20]. This work adopts the Mamdani’s FLS. As shown in fig.4, the major components of the proposed FLS for CAC are fuzzifier, fuzzy rule base, fuzzy inference engine, and defuzzifier. This configuration of the FLS has been widely used in industrial applications and consumer products.

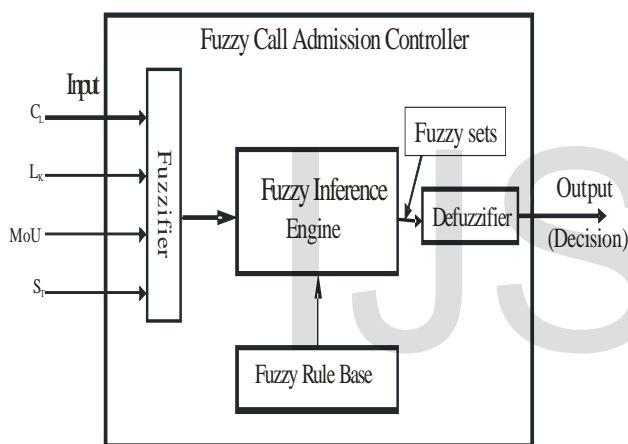


Fig. 4: Block diagram of the proposed fuzzy logic system for CAC

In the proposed FLS, the fuzzifier transforms the values of the input parameters into the fuzzy linguistic terms through a set of triangular membership functions. These fuzzy linguistic terms are the inputs of the inference engine, which will perform the inference according to the fuzzy rule base. The fuzzy rule base is constructed by the expert knowledge of the phenomenon (admission control). The defuzzifier converts the results of the inference into the usable value for admission decisions. The purpose of the fuzzy admission controller is to admit many mobiles with varying quality of service requirements. The universe of discourse (UoD) for the proposed system consists of linguistic variables in premises which are

cell load, load factor, user mobility information,¹⁵⁶ and type of service request. The fuzzy membership functions for the linguistic variables are as shown in fig.5a-5e with terms low, medium and high for cell load (C_L), load factor (L_k), user mobility (MoU) and type of service request (S_T). We formed the rules set based on the work in [21]. In this work we have $3^4 = 81$ rules. The code for each term is presented on table1. The output linguistic variable which is blocking probability denotes the admission acceptability of the new call into the system has terms, strongly rejected (SR), weakly rejected (WR), weakly accepted (WA) and strongly accepted (SA).

As shown in fig. 5a-5e , the parameters of Cell Load membership function are C_a, C_b, C_c, and C_d, while L_a, L_b, L_c and L_d represent Load Factor membership function values. M_a, M_b, M_c and M_d, are for User Mobility Membership function parameters. S_a, and S_b, depicts Service Type membership function values while the Admission Decision membership function values are D_a, D_b, D_c, D_d, D_e and D_f. From the fuzzy sets, the rule base is constructed as shown on table 2. Fuzzy AND operators are used to form firing strength that indicates the degree to which the antecedent part of the rule is satisfied (e.g. If antecedent... THEN conclusion).

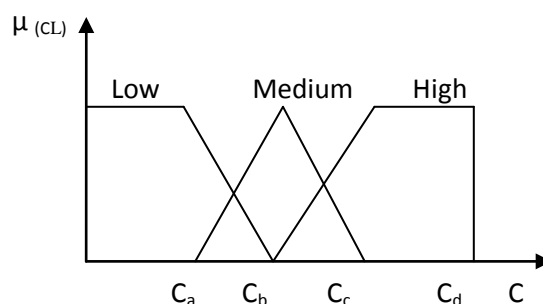


Fig. 5a: Linguistic Variable for Cell Load

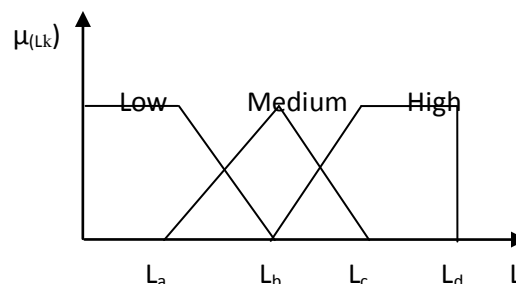


Fig. 5b: Linguistic Variable for Load Factor

$0 < L_{kij} \leq 0.06$; $0.06 < L_{kij} \leq 0.14$; $L_{kij} > 0.14$ for low, medium and high respectively.

TABLE 2

FUZZY RULE SET

Fuzz y Rule No	S _T	Mo U	L _k	C _L	D	Fuzz y Rule No	S _T	Mo U	L _k	C _L	D
1	1	1	1	1	SA	42	2	2	2	3	WR
2	1	1	1	2	SA	43	2	2	3	1	WA
3	1	1	1	3	WA	44	2	2	3	2	WR
4	1	1	2	1	SA	45	2	2	3	3	WR
5	1	1	2	2	WA	46	2	3	1	1	WA
6	1	1	2	3	WA	47	2	3	1	2	WA
7	1	1	3	1	WA	48	2	3	1	3	SR
8	1	1	3	2	WA	49	2	3	2	1	WA
9	1	1	3	3	WA	50	2	3	2	2	WR
10	1	2	1	1	SA	51	2	3	2	3	SR
11	1	2	1	2	WA	52	2	3	3	1	WA
12	1	2	1	3	WA	53	2	3	3	2	WA
13	1	2	2	1	SA	54	2	3	3	3	SR
14	1	2	2	2	SA	55	3	1	1	1	SA
15	1	2	2	3	WA	56	3	1	1	2	SA
16	1	2	3	1	WA	57	3	1	1	3	WA
17	1	2	3	2	WA	58	3	1	2	1	SA
18	1	2	3	3	WA	59	3	1	2	2	WA
19	1	3	1	1	WA	60	3	1	2	3	WR
20	1	3	1	2	WA	61	3	1	3	1	WA
21	1	3	1	3	SR	62	3	1	3	2	WA
22	1	3	2	1	WA	63	3	1	3	3	WR
23	1	3	2	2	WA	64	3	2	1	1	WA
24	1	3	2	3	WR	65	3	2	1	2	WA
25	1	3	3	1	WR	66	3	2	1	3	WR
26	1	3	3	2	WR	67	3	2	2	1	WA
27	1	3	3	3	SR	68	3	2	2	2	WA
28	2	1	1	1	SA	69	3	2	2	3	WR
29	2	1	1	2	SA	70	3	2	3	1	WA
30	2	1	1	3	WA	71	3	2	3	2	WA
31	2	1	2	1	SA	72	3	2	3	3	WR
32	2	1	2	2	WA	73	3	3	1	1	WA
33	2	1	2	3	WA	74	3	3	1	2	WA

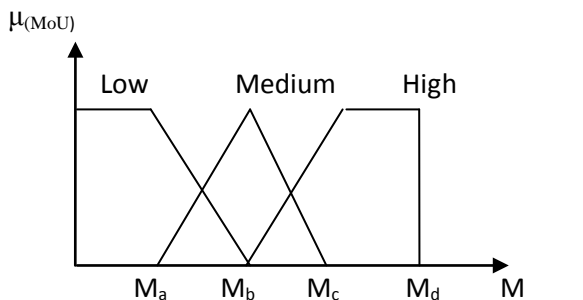


Fig. 5c: Linguistic Variable for User Mobility

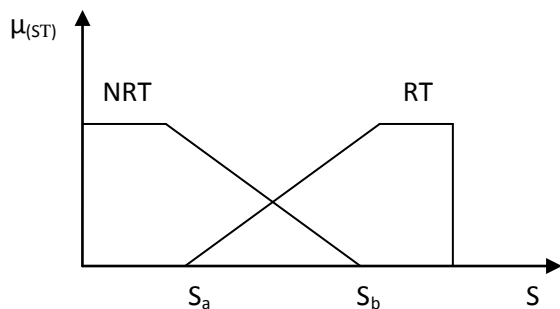


Fig. 5d: Type of Service Request

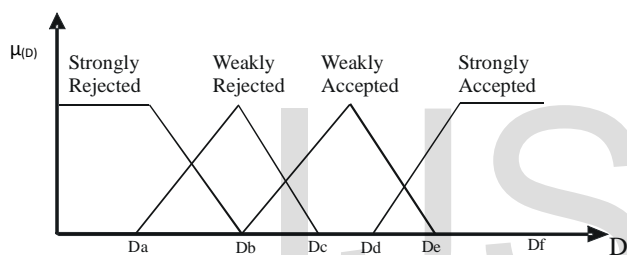


Fig. 5e: Linguistic Variables for Admission Decision

TABLE 1

CODES FOR TERMS USED IN EACH LINGUISTIC VARIABLE

Terms	Code
Low/Video	1
Medium/Data	2
High/Voice	3

Mathematically, table 1 is expressed as:

$$y_{ij} = \begin{cases} \text{low} & \text{if } 0 < y \leq 0.4 \\ \text{medium} & \text{if } 0.4 < y \leq 0.7 \\ \text{high} & \text{if } y > 0.7 \end{cases}$$

where y_{ij} is the value of the i_{th} linguistic term of the j_{th} linguistic variable for MoU and S_T. For cell load, we have $0 < C_{Lij} \leq 0.2$; $0.2 < C_{Lij} \leq 0.4$; $C_{Lij} > 0.4$ for low, medium and high respectively while load factor has

34	2	1	3	1	WA	75	3	3	1	3	SR
35	2	1	3	2	WA	76	3	3	2	1	WA
36	2	1	3	3	W R	77	3	3	2	2	W R
37	2	2	1	1	WA	78	3	3	2	3	SR
38	2	2	1	2	WA	79	3	3	3	1	WA
39	2	2	1	3	W R	80	3	3	3	2	W R
40	2	2	2	1	WA	81	3	3	3	3	SR
41	2	2	2	2	WA						

on-going connection cannot maintain its $SINR^{58}$ and eventually dropped. Since this paper considers new calls in target cell only and does not include handoff calls, only blocking probability is evaluated. This can help providers assess the impact of network load, interference and type of service request on the stability of the developed system when attempting to accept a new user. The simulation was done in MATLAB and the parameters are as shown on table 3.

The interpretation of some of the rules is as follows:

Rule 1: If service type is **Low** AND user mobility is **Low** AND Load Factor is **Low** AND cell load is **low** then **Strongly Accept**

Rule 6: If service type is **low** AND user mobility is **low** AND load factor is **Medium** AND cell load is **High** then We **akly Accept**

Rule 15: If service type is **Low** AND user mobility is **Medium** AND load factor is **Medium** AND cell load is **High** then **Weakly Accept**

Rule 27: If service type is **Low** AND user mobility is **High** AND load factor is **High** AND cell load is **High** then **Strongly Reject**

Rule 55: If service type is **High** AND user mobility is **Low** AND load factor is **Low** AND cell load is **low** then **Strongly Accept**

Rule 67: If service type is **High** AND user mobility is **Medium** AND load factor is **Medium** AND cell load is **low** then **Weakly Accept**

Rule 77: If service type is **High** AND user mobility is **High** AND load factor is **Medium** AND cell load is **Medium** then **Weakly Reject**

4 SIMULATION AND RESULTS

The performance measures of the system used in the simulation include the blocking probability which is the probability of the new call being blocked and the dropping probability which is the probability that an

TABLE 3
TRAFFIC PARAMETERS USED FOR
SIMULATION

Parameters	Value
Bit rate, R_k	144Kbps, 384Kbps
Voice activity factor, v_k	0.65, 1.0
BER, E_b/N_o	6dB, 5dB, 3dB
Max. cell load, n_{max}	0.8
Maximum transmitted power	125mW
Thermal Noise, N_o	-174dBm
Offered traffic load	0.2 – 2.0 Erlang
Chip rate, W	3.84Mcps
Load factor, L_k	0.02 - 0.2
Mean value for the function $\Gamma(x)$	1

When a call request arrives, the fuzzy CAC scheme checks whether it is real-time or non-real time request. The real-time service request has a higher priority over the non-real type service request due to scarcity of radio resources (bandwidth). In fig.6 and fig.7, we relate the blocking probability with offered load and obtained that with growing offered load, the high requirements of the high-speed service class lead to increased blocking probabilities in comparison to the other class. This indicates that the high speed services are more sensitive to higher cell loads than the lower bit rate services. This is attributed to the heterogeneous nature of CDMA networks with multimedia traffic and interference. With 384Kbps data rate, the system

experienced a blocking probability of about 0.025 while at 144Kbps, the blocking probability is reduced below 0.01, the threshold. The accuracy of the model is satisfactory because the simulated results are very close to the analytical results in literature.

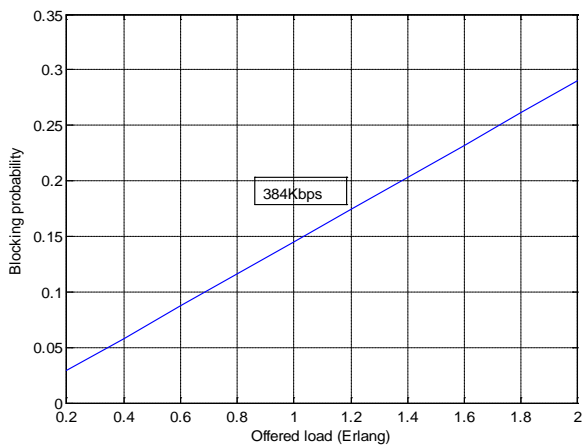


Fig. 6: Blocking probability Vs Offered traffic at 384Kbps

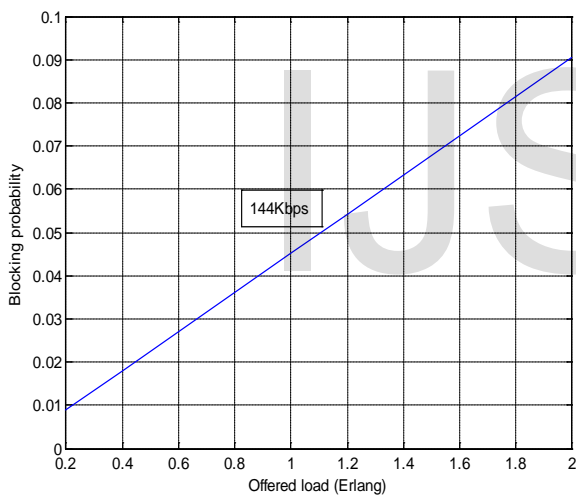


Fig.7: Blocking probability Vs Offered traffic at 144Kbps

It is noted that E_b/N_o is required to meet each user's QoS. Since the fuzzy CAC scheme is aimed at accepting more call requests than rejecting, we use a constant data rate of 144Kbps and varied E_b/N_o values in the simulation for video, data, and voice applications, i.e., 3dB, 5dB, 6dB. At higher signal energy per bit to noise spectral density, the blocking probability reduces indicating a significant improvement in the system. It therefore affirms that mobiles closer to the base station receive more signal

strength than those farther away. This near-far problem in CDMA network can be mitigated by increasing coverage through cell division. Fig.8 indicates that as the load increases, voice call request has the least blocking probability than the data and video call requests and also shows that bandwidth required for video is the highest.

From the graphs, it can be shown that the performance of the fuzzy based CAC for all the traffic classes is improved significantly especially under high loads.

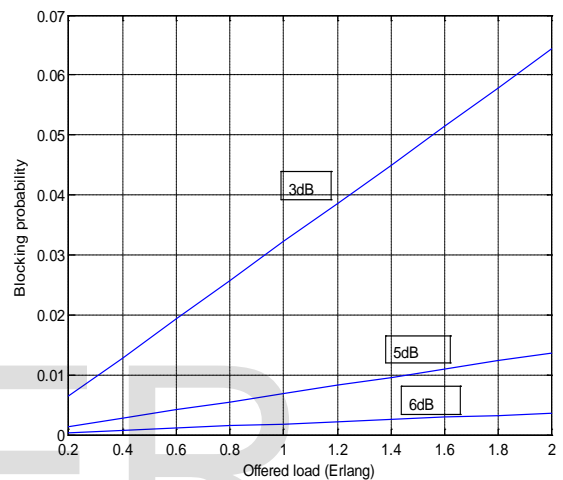


Fig.8: Blocking probability Vs Offered traffic for different types of service request

5 CONCLUSION AND FUTURE WORK

CDMA network is interference-limited system. The radio resources are scarce. When the system operates at nearly full capacity, admitting another user may affect the stability of the system. Therefore, proper call admission control is crucial and should balance between QoS requirements for the new user and existing users while at the same time keeping the accepted traffic at tolerable level. An investigation of this tradeoff in the uplink direction was done using fuzzy based call admission control technique. Different traffic classes were considered with priorities attached to real-time service request. The performance evaluation results show that fuzzy logic concept can be used to achieve better resource utilization in CDMA network.

In this work, an intelligent CAC scheme based on fuzzy logic for a CDMA network is proposed. The results

obtained by simulating the system's parameters in Matrix Laboratory (MATLAB) software version R2007b were analyzed. The fuzzy logic system provides a more human like reasoning (intelligence) to the call admission process thereby enhancing the system's decision in accepting or rejecting any call thus keeping the blocking probability to minimum. In the next generation wireless system, it is desirable to uphold guaranteed QoS to all types of users and optimize resource utilization in the system. In order to provide superior quality of service to the users, it is required to maintain the call blocking probability at minimal level. Since fuzzy logic does not have learning capability, future work is to adopt other soft computing techniques such as fuzzy-neural network, genetic algorithm, Markov decision process or game theory, etc. to the CAC scheme to obtain better efficiency in resource utilization.

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