A Fuzzy Call Admission Control Scheme in Cellular Multimedia Networks

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***Abstract*—Scarcity of the spectrum resource and mobility of users make Quality-of-Service (QoS) provision a critical issue in cellular mobile multimedia networks. This paper presents a fuzzy call admission control scheme to meet the requirement of the QoS while prioritizing handoff call requests over new call requests. It searches automatically the number of the guard channel in a base station to make an effective use of resource and guarantee the QoS provision. A performance measure is formed as a weighted linear function of new call and handoff call blocking probabilities of each service class. Simulation compares the proposed fuzzy scheme with some well-known policies. Simulation results show that fuzzy scheme has a better robust performance in terms of average blocking criterion.**

Keywords-call admission control; fuzzy; cellular multimedia networks; Quality of Service

I. INTRODUCTION

Next generation cellular mobile networks are expected to support multimedia services such as voice, video, data etc. and wide user mobility. Cellular system exploits frequency reuse to achieve high capacity by limiting the coverage of each base station within a small geographic area called a cell. When the users move from one cell to another, handoff operation will occur. Mobile users may be connected to different cells all the time during the lifetime of their connections. Since the user's itinerary and the availability of resources in various cells is hard to be predicted in advance, it makes QoS provision a critical issue in cellular radio systems.

Call Admission Control (CAC) is one of the important mechanisms in guarantying the QoS. It can be defined as the procedure of deciding whether or not to accept a new connection. If the network can not meet the connection need, the connection request will be denied. In cellular wireless networks, one important parameter of the QoS is call blocking probability (CBP), which indicates the likelihood of the new connection being denied. The other important parameter is call dropping probability (CDP), which expresses the likelihood of the existing connection being denied during handoff process due to insufficient resource in target cell. From the user's point of view, having a call abruptly terminated in the duration of the connection is more annoying than being blocked occasionally on a new call attempt. It is acceptable to give higher priority to handoff call. One well-known method for prioritizing handoff is the guard channel policy. A fraction of the total available channels in a cell is reserved exclusively for handoff requests. To reserve channel can reduce the CDP, but the CBP will increase accordingly. Hence, reduction of CBP and CDP are conflicting requirements, and optimization of both is extremely complex. To guarantee an acceptable CDP is one of the main goals of QoS provisioning in wireless networks.

There are many schemes about call admission control in wireless networks. Reference [1] consideres nonprioritized or complete sharing scheme which not differentiate between new call and handoff requests. Reference [2] distinguishs between new calls and handoff calls, and gives higher priority to handoff calls. Recently, intelligent techniques such as fuzzy logic, neural networks, and genetic algorithms have been widely applied to call admission control [3-6]. The advantages of intelligent techniques are numerous, most notably learning from experience and the scalability, adaptability, and ability to extract rules without the need for precise mathematical model. Fuzzy logic is used in [3-4], but they consider for a single traffic class in cellular networks.

In this paper, we propose an intelligent call admission control scheme based on fuzzy logic for cellular mobile multimedia networks. The scheme is built upon the concept of the guard channels. We design a fuzzy controller in terms of the important QoS target. The scheme adjusts the number of the guard channels on line according to the CDP of each multimedia traffic class and current number of the guard channel. It can keep the average blocking criterion low.

The remainder of this paper is organized as follows. Section II describes system model and analysis method. Section III gives the details of the proposed fuzzy call admission control scheme. Section IV runs simulation to compare the fuzzy scheme with the complete sharing and guard channel schemes. Then, it discusses the simulation results. Finally, section V gives conclusion of the paper.

II. SYSTEM DESCRIPTION

A. System Model

In our model, we consider a cellular network with a limited number of bandwidths or channels. There are K classes of call services. Different classes of calls may have different requirement of QoS. The arrival rates of new calls and handoff calls of class i, $i = 1,2,\dots K$, are assumed to form a Poisson

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process with mean λ_{ni} and λ_{hi} , respectively. The channel holding times of new calls of class i are assumed to follow an exponential distribution with mean $1/\mu_{ni}$. The cell residence time, i.e., the length of time that a user stays in a cell during a visit, is assumed to follow an exponential distribution with mean $1/\mu_{hi}$ and μ_{hi} denotes the call handoff rate. b_i denotes the number of channels required to accommodate the class i calls.

B. Priority Level

The multimedia services such as voice, video, data etc. can be categorized into two classes: class 1(real time) and class 2(non-real time) according to the required QoS. Different multimedia services request different bandwidths and have different QoS requirements. We classify traffic service into three services type: handoff services (class 1), handoff services (class 2), and new calls services (class 1 and class 2). We assume that the priority level of handoff services is higher than new calls services and the priority level of handoff services (class 1) is higher than handoff services (class 2).

C. Average Blocking Criterion

We define a weighted linear function of CBP and CDP of each class as average blocking criterion.

$$P = \sum_{i=1}^{K} \left\{ \omega_{ni} \frac{\lambda_{ni}}{\lambda_{ni} + \lambda_{hi}} CBP_i + \omega_{hi} \frac{\lambda_{hi}}{\lambda_{ni} + \lambda_{hi}} CDP_i \right\}, \quad (1)$$

Where ω_{ni} and ω_{hi} represent the weighting factor of new call and handoff of class i. $\omega_{hi} > \omega_{ni}$, because handoff failure is considered less desirable to user compared with new call attempt failure.

III. FUZZY LOGIC CALL ADMISSION CONTROL SCHEME

A. Structure of Fuzzy Logic Controller (FLC)

The concept of fuzzy set is an extension of classical set. For a classical set X, an element may belong to set X or may not. But for a fuzzy set, an element is related to a set by a membership function μ . The membership function usually take on a value between 0 and 1. A FLC can provide algorithms which convert the linguistic control strategies based on intuition, heuristic learnings and export knowledge into an automatic control strategy. The FLC is made of fuzzifier, inference engine, Fuzzy Rule Base and defuzzifier. The structure of FLC is shown in Fig.1. The input linguistic parameters of the FLC are set as call dropping probability of class i (CDP_i) $i = 1,2,\ldots K$,and number of the guard channels (C_h). The output linguistic parameter is set as the tuning number of the guard channels (ΔC_h). We design a FLC of K+1 input parameters and one output parameter based on Mamdani fuzzy model. We assume two service classes: class 1(real time) and class 2(non-real time), $K = 2$.

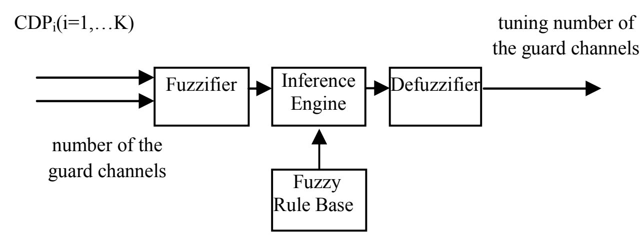

Fig.1. FLC structure

B. Membership Function

We choose thresholds for CDP_1, CDP_2, and number of the guard channels as 0.01, 0.02 and 12% of the total number of channels (denoted by C) in a cell, respectively. The tuning number of the guard channels is chosen to vary within the range from –12% to +12% of the total channel capacity of a cell.

The term sets of CDP_1, CDP_2, C_h, ΔC_h are defined as follows:

T (CDP_1)={ S, M, B}
T (CDP_2)={ S, M, B}
T (C_h)={VS, S, M, B, VB}
T (ΔC_h)={NB, NM, NS, NVS, Z, PVS, PS, PM, PB}

We choose triangular functions as membership functions because they are simple and practical. The membership functions for input and output linguistic parameters are shown in Fig.2, Fig.3, Fig.4, and Fig.5.

C. Fuzzy Rule Base

The Fuzzy Rule Base consists a series of 45 fuzzy rules, shown in Table 1. The control rules have the following form: IF "condition", THEN "action". For example, if the CDP_1 is Small, CDP_2 is Small, and number of the guard channels is Very Small, then it triggers the 1th rule and makes tuning number of the guard channels Zero.

Thus, fuzzy controller can compute the tuning number of the guard channels according to the CDP_1, CDP_2, and current number of the guard channels. The fuzzified output parameter can be converted to a crisp value by the maximum membership inference method.

IV. SIMULATION

A. Simulation Parameters

In order to evaluate the performance of our fuzzy scheme, we implement and simulate complete sharing and guard channel schemes for comparison. We assume total channel capacity of a cell is 50. We let K =2, b_1 =1, b_2 =2. We assume

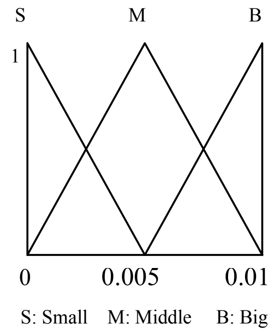

Fig.2 Membership functions for call dropping probability of class 1

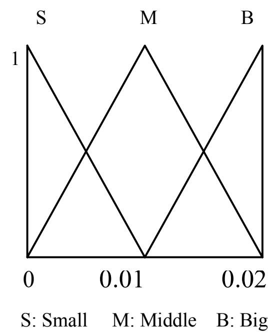

Fig.3 Membership functions for call dropping probability of class 2

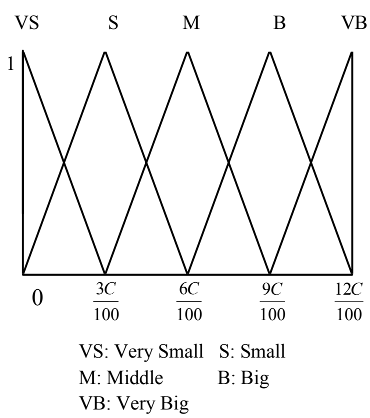

Fig.4 Membership functions for number of the guard channels

that the handoff call arrival rate is proportional to the new call arrival rate by $\lambda_{hi} = \alpha\lambda_{ni}$ for every class (i=1,2). Here α is set to 0.5. We set $\lambda_{n1} = 2\lambda_{n2}$, $\lambda_{h1} = 2\lambda_{h2}$. $1/\mu_{ni}$ and $1/\mu_{hi}$ is assumed to follow exponential distribution with mean 200 seconds and 100 seconds, respectively. We choose weighting factor $\omega_{ni} = 0.5$, $\omega_{hi} = 2$. The total simulation time is chosen to be 24 hours.

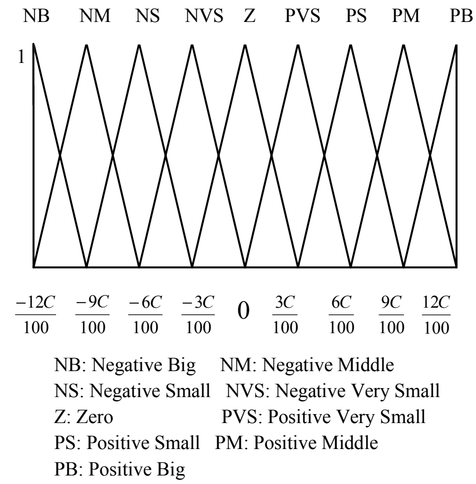

Fig.5 Membership functions for tuning number of the guard channels

Table 1 Fuzzy control rules

Rule Number	IF CDP_1	AND CDP_2	AND Number of the guard channels	THEN Tuning number of the guard channels
R1	Small	Small	Very Small	Zero
R2	Small	Small	Small	Negative Very Small
R3	Small	Small	Middle	Negative Small
R4	Small	Small	Big	Negative Middle
R5	Small	Small	Very Big	Negative Big
R6	Small	Middle	Very Small	Zero
R7	Small	Middle	Small	Zero
R8	Small	Middle	Middle	Negative Very Small
R9	Small	Middle	Big	Negative Small
R10	Small	Middle	Very Big	Negative Middle
R11	Small	Big	Very Small	Zero
R12	Small	Big	Small	Zero
R13	Small	Big	Middle	Negative Very Small
R14	Small	Big	Big	Negative Very Small
R15	Small	Big	Very Big	Negative Small
R16	Middle	Small	Very Small	Zero
R17	Middle	Small	Small	Zero
R18	Middle	Small	Middle	Zero
R19	Middle	Small	Big	Negative Very Small
R20	Middle	Small	Very Big	Negative Very Small
R21	Middle	Middle	Very Small	Positive Small
R22	Middle	Middle	Small	Positive Very Small
R23	Middle	Middle	Middle	Zero
R24	Middle	Middle	Big	Zero
R25	Middle	Middle	Very Big	Zero
R26	Middle	Big	Very Small	Positive Small
R27	Middle	Big	Small	Positive Very Small
R28	Middle	Big	Middle	Zero
R29	Middle	Big	Big	Zero
R30	Middle	Big	Very Big	Zero
R31	Big	Small	Very Small	Positive Middle
R32	Big	Small	Small	Positive Small
R33	Big	Small	Middle	Positive Very Small
R34	Big	Small	Big	Zero
R35	Big	Small	Very Big	Zero
R36	Big	Middle	Very Small	Positive Middle
R37	Big	Middle	Small	Positive Small
R38	Big	Middle	Middle	Positive Very Small
R39	Big	Middle	Big	Zero
R40	Big	Middle	Very Big	Zero
R41	Big	Big	Very Small	Positive Big
R42	Big	Big	Small	Positive Middle
R43	Big	Big	Middle	Positive Small
R44	Big	Big	Big	Positive Very Small
R45	Big	Big	Very Big	Zero

B. Simulation Results

The measures obtained through the simulation are CBP and CDP of every service class and average blocking criterion. We simulate when new call arrival rate changes from 0.06 calls per second to 0.15 calls per second. The measures are plotted as a function of the new call arrival rate.

Simulation curves of the CBP_1 and CBP_2 of the three schemes are shown in Fig.6 and Fig.7. The curves of the CDP_1 and CDP_2 of the three schemes are shown in Fig.8 and Fig.9. We can notice that the values of the CBP_i increase as the traffic load increases for three schemes. The CBP_i of the CS scheme is lowest in all schemes. The reason is that it does not reserve any channel for handoff requests. But the CDP_i of CS scheme is highest in three schemes. They are far higher than thresholds for $CDP_1(0.01)$ and $CDP_2(0.02)$ respectively. The CS scheme can not meet the requirement of QoS. The CDP_i of fuzzy scheme and GC scheme are lower than their thresholds respectively. The CBP_i of fuzzy scheme is lower than GC scheme.

Simulation curves of average blocking criterion are shown in Fig.10. We can see from the figure, the average blocking criterion of fuzzy scheme is lowest. It indicates that the fuzzy scheme has a better robust performance. It can adjust dynamically number of the guard channels to adapt to changes in the network load.

V. CONCLUSION

The paper presents an intelligent call admission control scheme based on fuzzy logic in wireless networks. It searches automatically the optimal number of the guard channels. Simulation results show the proposed scheme has a better robust performance. It outperforms the complete sharing and guard channel schemes.

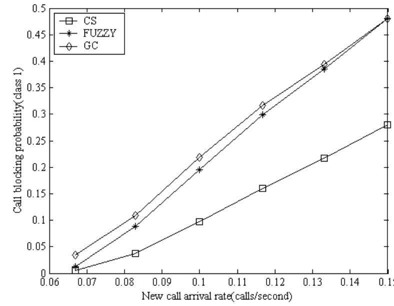

Fig.6 Call blocking probability(class 1)

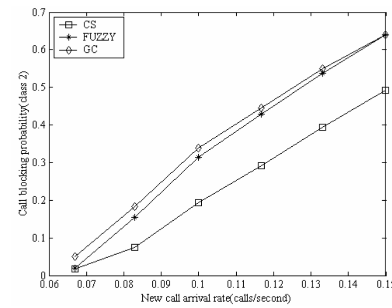

Fig.7 Call blocking probability(class 2)

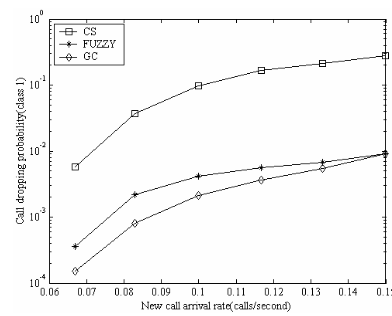

Fig.8 Call dropping probability(class 1)

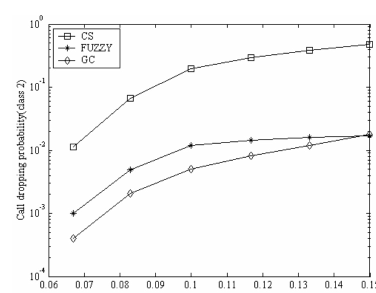

Fig.9 Call dropping probability(class 2)

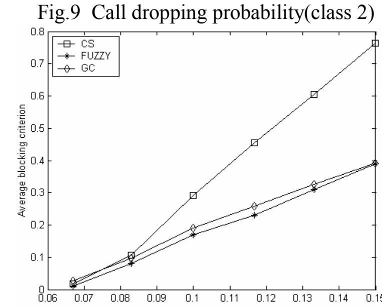

Fig.10 Average blocking criterion

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