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Intelligent Call Admission Control Using Fuzzy Logic in Wireless 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 wireless networks. This paper presents a fuzzy call admission control scheme to meet the requirement of the QoS. It searches automatically the optimal number of the guard channels in a base station to make an effective use of resource and guarantee the QoS provision. Simulation compares the proposed fuzzy scheme with an adaptive channel reservation scheme. Simulation results show that fuzzy scheme has a better robust performance in terms of call dropping probability, call blocking probability, and channel utilization.**

I. Introduction

IN the present and the next generation wireless networks, cellular system is still a major part in telecommunication infrastructure. 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 change cells many times during the lifetime of their connections. Specially, in future micro/pico-cellular architecture, handoff operation may occur more frequently than in present macro-cellular architecture. Since the user's itinerary and the availability of resources in various cells is not known 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. The methods for prioritizing handoff are the guard channel and queuing of handoff requests. With the guard channel method, a fraction of the total available channels in a cell is reserved exclusively for handoff requests from ongoing calls which may be handed off into the cell. The fixed reservation strategy wastes valuable spectrum resource while the dynamic reservation strategy can offer efficient spectrum utilization by minimizing number of the required guard channels.

In the present, there are many schemes about call admission control aiming at keeping the CDP and CBP low while maximizing the resource utilization to meet the system demand at the same time [1-6]. When the CDP decreases, the CBP will increase accordingly. So, it is hard to guarantee the minimum CDP and the minimum CBP at the same time. Minimizing the CDP is one of the main goals of QoS provisioning in wireless networks.

The main contribution of this paper is to propose an intelligent call admission control scheme based on fuzzy logic for cellular wireless 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 to its optimum in time according to the CDP and current number of the guard channel. It tries to make an effective use of resource and keep the CDP and CBP low at the same time.

The remainder of this paper is organized as follows. Section 2 analyzes the method and model for call admission control. Section 3 gives the details of the proposed fuzzy call

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admission control scheme. Section 4 runs simulation to compare the fuzzy scheme with an adaptive channel reservation scheme. Then, it discusses the simulation results. Finally, section 5 gives conclusion of the paper.

II. CAC METHOD AND MODEL ANALYSIS

The total number of available channels (denoted by C) in a cell consists of two parts. One part (denoted by C_h) is reserved exclusively for handoff calls. The remaining C- C_h channels are shared by both new calls and handoff calls. A new call will be admitted into the network if the number of busy channels in the cell is less than C- C_h when the call is originated. A handoff request will be admitted if the number of busy channels in the target cell is less than C.

We assume that the arrivals of new call and handoff call are independent Poisson processes. The new call arrival rate is λ_n and the handoff call arrival rate is λ_h. Channel holding times are assumed to follow a negative exponential distribution with mean $1/\mu$. For a cell capacity of C, queuing model is considered as M/M/C in which the C available channels in the cell represented as C servers. The system state space is a finite set E={0,1,2,…,C}. The state transition diagram is shown in Fig.1.

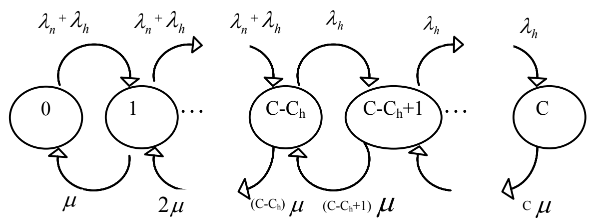


Fig.1. State-transition diagram

Let P_j represent the steady-state probability that the base station is in state j. During the analysis of birth-death process, the probability P_j can be obtained like that [1,4]:

$$P_0 = \left[\sum_{k=0}^{C-C_h} \frac{(\lambda_n+\lambda_h)^k}{k!\mu^k} + \sum_{k=C-C_h+1}^{C} \frac{(\lambda_n+\lambda_h)^{C-C_h}\lambda_h^{k-C+C_h}}{k!\mu^k}\right]^{-1} \quad (1)$$

$$P_j = \begin{cases} \frac{(\lambda_n+\lambda_h)^j}{j!\mu^j} P_0, 1 \le j \le C-C_h \\ \frac{(\lambda_n+\lambda_h)^{C-C_h}\lambda_h^{j-C+C_h}}{j!\mu^j} P_0, C-C_h+1 \le j \le C \end{cases} \quad (2)$$

The new call will be blocked if the number of busy channels is more than C- C_h. Hence

$$\text{CBP}= \sum_{j=C-C_h}^{C} P_j . \quad (3)$$

The handoff request will be denied if the number of busy channels is equal to C. Thus

$$\text{CDP}=P_C. \quad (4)$$

III. FUZZY LOGIC CALL ADMISSION CONTROL SCHEME

In the guard channel method, the number of the guard channels is important to the performance of wireless network. It affects the QoS and resource utilization of the network. The proposed fuzzy scheme tries to adjust dynamically the number of guard channels to its optimum to meet the requirements of the QoS and resource utilization.

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 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.2. This paper designs a FLC of two input parameters and one output parameter based on Mamdani fuzzy model. The input linguistic parameters of the FLC are set as call dropping probability (CDP) and number of the guard channels (C_h). The output linguistic parameter is set as the tuning number of the guard channels (ΔC_h).

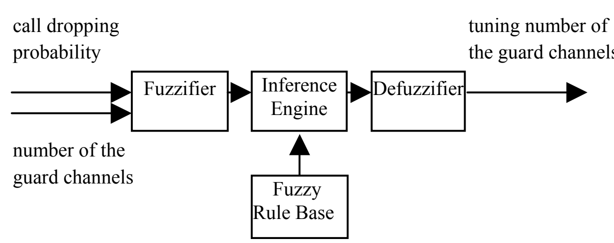


Fig.2. FLC structure

B. Membership Functions

We choose thresholds for CDP and number of the guard channels as 0.01 and 12% of the total number of channels 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.

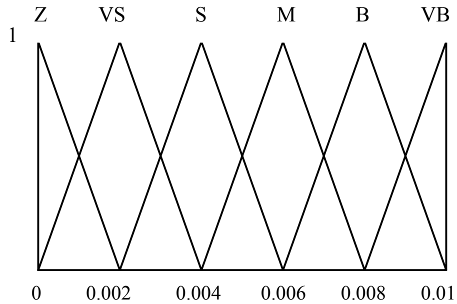
The term sets of CDP, C_h, and ΔC_h are defined as follows:

T (CDP)={Z, VS, S, M, B, VB}

T (C_h)={VS, S, M, B, VB}

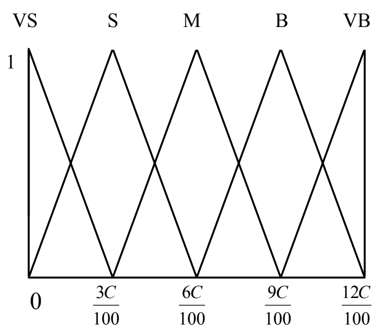
T (ΔC_h)={NB, NM, NS, NVS, Z, PVS, PS, PM, PB}

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.3, Fig.4, and Fig.5.



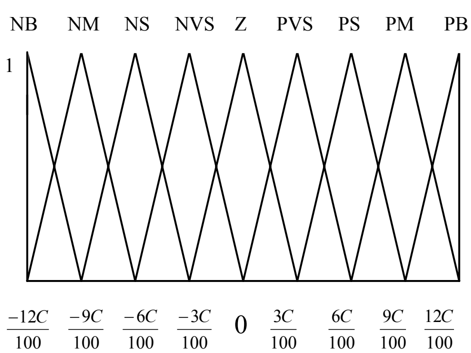
Z: Zero VS: Very Small
S: Small M: Middle
B: Big VB: Very Big

Fig.3. Membership functions for call dropping probability



VS: Very Small S: Small
M: Middle B: Big
VB: Very Big

Fig.4. Membership functions for number of the guard channels



NB: Negative Big NM: Negative Middle
NS: Negative Small NVS: Negative Very Small
Z: Zero PVS: Positive Very Small
PS: Positive Small PM: Positive Middle
PB: Positive Big

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

C. Fuzzy Rule Base

The Fuzzy Rule Base consists a series of 30 fuzzy rules, shown in Table 1. The control rules have the following form: IF "conditions", THEN "action". For example, if the CDP is Small, and number of the guard channels is Very Small, then it triggers the 11th rule and makes tuning number of the guard channels Positive Small.

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

Table 1 Fuzzy control rules

Rule Number	IF Call dropping probability	AND Number of the guard channels	THEN Tuning number of the guard channels
R1	Zero	Very Small	Zero
R2	Zero	Small	Negative Very Small
R3	Zero	Middle	Negative Small
R4	Zero	Big	Negative Middle
R5	Zero	Very Big	Negative Big
R6	Very Small	Very Small	Zero
R7	Very Small	Small	Zero
R8	Very Small	Middle	Zero
R9	Very Small	Big	Zero
R10	Very Small	Very Big	Zero
R11	Small	Very Small	Positive Small
R12	Small	Small	Positive Very Small
R13	Small	Middle	Zero
R14	Small	Big	Zero
R15	Small	Very Big	Zero
R16	Middle	Very Small	Positive Middle
R17	Middle	Small	Positive Small
R18	Middle	Middle	Positive Very Small
R19	Middle	Big	Positive Very Small
R20	Middle	Very Big	Zero
R21	Big	Very Small	Positive Big
R22	Big	Small	Positive Middle
R23	Big	Middle	Positive Small
R24	Big	Big	Positive Very Small
R25	Big	Very Big	Zero
R26	Very Big	Very Small	Positive Big
R27	Very Big	Small	Positive Middle
R28	Very Big	Middle	Positive Small
R29	Very Big	Big	Positive Very Small
R30	Very Big	Very Big	Zero

IV. SIMULATION

A. Simulation Parameters

In order to evaluate the performance of our fuzzy scheme, we implement and simulate an adaptive channel reservation scheme [3] for comparison. To fairly contrast our scheme to the adaptive algorithm, we used the traffic model and parameters given in [3]. We assume total channel capacity of a cell is 50. We also assume that the arrival processes of new call and handoff call are Poisson with mean arrival rates of λ_n and λ_h respectively. Channel holding times of both types of calls are assumed to follow a negative exponential distribution with mean $1/\mu$. In the simulation, we set that

$\lambda_n / \lambda_h = 5/1$ and $1/\mu$ =180 seconds. The total simulation time is chosen to be 24 hours.

B. Simulation Results

The performance measures obtained through the simulation are the CDP, the CBP and channel utilization. We simulation when new call arrival rate changes from 10 calls per minute to 35 calls per minute. These performance measures are plotted as a function of the new call arrival rate.

Simulation curves of the CDP of the two schemes are shown in Fig.6. From the figure, we can see when traffic load changes, the values of the CDP of two schemes are lower than threshold 0.01. When the traffic load is low (e.g., new call arrival rate equals to 10 calls/minute), the values of the CDP of two schemes are equal. As the traffic load increases, the CDP of the fuzzy scheme is lower than the adaptive scheme obviously. It indicates that the fuzzy scheme has a better robust performance. It can adapt to changes in the network load.

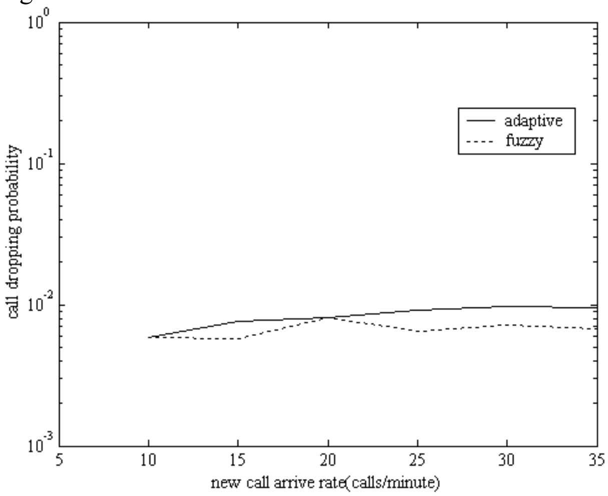


Fig.6. Call dropping probability

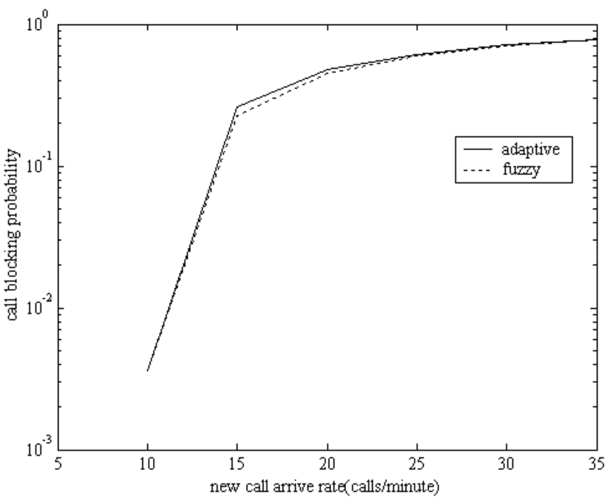


Fig.7. Call blocking probability

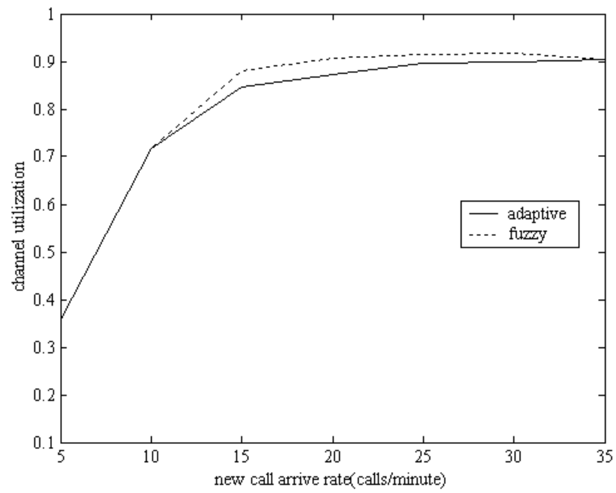


Fig.8. Channel utilization

Simulation curves of the CBP are shown in Fig.7. We can notice that the values of the CBP increase as the traffic load increases for both schemes. When the traffic load is low (e.g., new call arrival rate equals to 10 calls/minute), the values of the CBP of both schemes are equal. They both adjust C_h to the minimum 0 to reduce the CBP. As the traffic load increases, the CBP of the fuzzy scheme is lower than the adaptive scheme. It indicates that our proposed algorithm can adjust C_h better to reduce the CBP than the adaptive algorithm.

Simulation curves of the channel utilization are shown in Fig.8. We can see from the figure, channel utilization of the fuzzy scheme is higher than the adaptive scheme. It shows that the fuzzy scheme can utilize the resource more efficiently.

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 outperforms the adaptive channel reservation scheme. The fuzzy scheme has a better robust performance. It keeps the CDP and CBP low at the same time. It guarantees the QoS provision and increases the resource utilization of the network.

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