2011 International Joint Conference of IEEE TrustCom-11/IEEE ICESS-11/FCST-11

Performance Modelling and Analysis of Dynamic Class-Based Call Admission Control Algorithm using Fuzzy Logic for Heterogeneous Wireless Networks

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Abstract—**In this paper, a fuzzy logic call admission control (CAC) mechanism is proposed for an integrated UMTS-WLAN network. This paper grounds a novel dynamic CAC algorithm on a class–based CAC method. It uses fuzzy logic theory to generate the optimal quantity of the channel thresholds so as to assign radio resource efficiently and guarantee the Quality-of-Service (QoS) requirement. The new fuzzy logic algorithm exhibits its superiority by comparing the handover dropping probability with that of threshold–based approach. The simulation results verify that the evolved threshold-based CAC with fuzzy logic provides a lower handover dropping probability.**

Keywords-heterogeneous wireless networks; fuzzy logic; call admission control; markov chain; handover dropping probability

I. INTRODUCTION

The evolution of telecommunication systems from the 3rd generation (3G) to the next generation networks delineates the development of an integrated environment including hybrid wireless networks, for instance Universal Mobile Telecommunication System (UMTS), Wireless Local Area Networks (WLANs), Worldwide Interoperability for Microwave Access (WiMAX), Digital Video Broadcasting (DVB) and satellite networks. Hence, the future generation mobile communication system is targeted to support integration and co-existence of multiple radio access technologies (RATs) in a common composite radio environment [1].

Due to the rapid growth in customers and user's mobility, subscribers shift among diverse wireless networks constantly while a service is processing [2]. Thus, an ongoing service may have to be handed over to other networks [3]. However, limited scarce radio resource in the destination network might lead to handover traffic dropping and new connection request blocking.

In order to guarantee the Quality of Service (QoS), the target network is required to provide a ubiquitous coverage and ensure good QoS for customers [4]. Efficient management of radio resources becomes a key factor in enhancing the network performance [5]. Hence, call admission control (CAC) is involved because it is such an important mechanism to balance the resource allocation for different services in order to meet the desired QoS requirements [6]. The CAC algorithm of the destination network limits the number of users and controls their admission requirements to prevent network congestion.

The designed CAC in [2] allocates radio resource to users according to user's priority. It uses Markov chain process (MCP) technique to evaluate the performance of the integrated UMTS-WLAN environment. However, for a heterogeneous telecommunication network, because of dynamic QoS requirements and varying channel conditions, the CAC technique has to make the decision based on the imprecision and uncertain measurements. Having the nature of coping with uncertainty and imprecision problems and providing a platform for handling uncertainty and imprecise knowledge, fuzzy logic theory is expected to give a good solution to the development of a CAC scheme [7].

Consequently, this paper is going to propose an evolutional class-based CAC approach coalescent with fuzzy logic theory. This novel algorithm furnishes optimal thresholds and tries to keep the handover dropping probability at a low level. The remainder of this paper is organized as follows: Section II outlets the principle of threshold-based CAC approach. Section III analyzes a developed model for CAC mechanism combining with fuzzy logic system. And then, the mathematical results and numerical analysis are demonstrated in Section IV, and it also reveals the performance of new fuzzy logic CAC approach. Finally, in Section V, the conclusion summarizes the major achievements and details the future work.

II. CLASS-BASED CALL ADMISSION CONTROL SCHEME

In [2], because of user's mobility, ongoing services are handed over in a hybrid UMTS-WLAN network. A threshold-based CAC scheme adopting a one-dimensional MCP technique is introduced. This scheme complies with a resource allocation priority policy and classifies users into different grades. According to user's class differentiation [8], the two-threshold CAC strategy prioritizes arriving admission requests. Meanwhile, [2] utilises MCP to visualize a mathematical analytic method to measure the performance of the class-based CAC method by evaluating the dropping probability of handover services.

978-0-7695-4600-1/11 $26.00 © 2011 IEEE
DOI 10.1109/TrustCom.2011.250

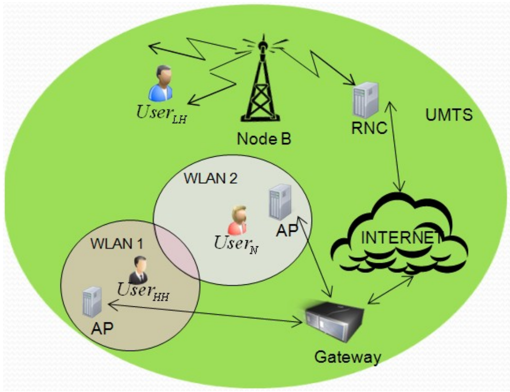

Figure 1. Integrated UMTS-WLAN network.

Fig. 1 shows the environment of a heterogeneous network in [2]. There are three classes of user: $User_{HH}$, $User_{LH}$ and $User_N$. $User_{HH}$ connects with *WLAN 1* and is going to move into *WLAN 2*'s coverage area; $User_{LH}$ has a connection with *UMTS* network and tends to establish a new connecting with *WLAN 2*. $User_N$ is a stable customer of *WLAN 2*. Reference [2] defines that $User_{HH}$ sends the high priority handover (HH) traffics; $User_{LH}$ sets up the low priority handover (LH) services and $User_N$ initials new connection (N) services.

In this two-threshold scenario, the total channel capacity of target network is assumed as C; C_N and C_H are the channel thresholds, where $C_N < C_H < C$. When a new channel request comes, if the occupied channels come up to C_N, the resource request for new connection will be restrained. While the amount of used channel is equal to or greater than C_H, the system will prevent the channel request from low priority handover traffics. Once the entire radio channels are possessed, the destination network will reject any admission request, even comes from $User_{HH}$.

On the assumption that λ_{HH} and λ_{LH} represent the channel request rates of $User_{HH}$ and $User_{LH}$ respectively, λ_N indicates channel request rate of new connection from $User_N$ which locates in destination network. λ_{HH}, λ_{LH} and λ_N conform to a Poisson arrival process. Setting the mean serving time is $1/\mu$ and follows a negative exponential distribution.

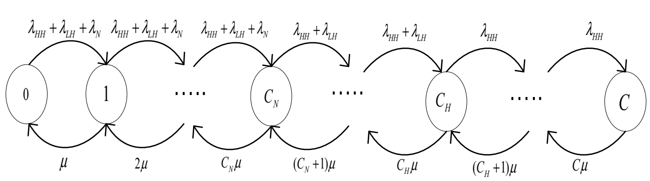

Figure 2. State transition diagram for two-threshold scenario.

The equations of steady-state probability P_k for each state of MCP are shown:

$$P_k = P_0 \frac{(\lambda_{HH}+\lambda_{LH}+\lambda_N)^k}{k!\mu^k}, where\ 0 < k \le C_N \tag{1}$$

$$P_k = P_0 \frac{(\lambda_{HH}+\lambda_{LH}+\lambda_N)^{C_N}}{k!\mu^{C_N}} \times \left(\frac{\lambda_{HH}+\lambda_{LH}}{\mu}\right)^{k-C_N}, where\ C_N < k \le C_H \tag{2}$$

$$P_k = P_0 \frac{(\lambda_{HH}+\lambda_{LH}+\lambda_N)^{C_N}}{k!\mu^{C_N}} \times \left(\frac{\lambda_{HH}+\lambda_{LH}}{\mu}\right)^{C_H-C_N} \times \left(\frac{\lambda_{HH}}{\mu}\right)^{k-C_H}, where\ C_H < k \le C \tag{3}$$

P_0 is the steady-state probability of the system being idle [9]. k is the quantity of used channels and also depicts kth state transition, $k=\{1, 2, 3\ldots, C\}$. The threshold-based CAC strategy estimates the system performance in the form of dropping probability. When all the channels are occupied, the high priority handover traffics will be refused, therefore the dropping probability of the high priority handover traffic is expressed as:

$$P_{HH} = P_C \tag{4}$$

While the amount of used channel is equal to or greater than C_H, the dropping probability formula of the low priority handover traffic is denoted as:

$$P_{LH} = \alpha \sum_{i=C_H+1}^{C} P_i \tag{5}$$

Where α is the channel request rate proportional for low priority handover traffics.

III. Analytical Model of the Evolved Fuzzy Logic Call Admission Control System

To address the technical challenges in CAC for next generation wireless communications, the fuzzy logic approach is investigated based on real-time measurements. In the real mobile communication system, it is important to measure the quantity of the channel thresholds. Also it is difficult to make accurate appraisal and to obtain the complete statistics of input traffic. Fuzzy logic provides an approximate but effective means of describing the behavior of the systems that are too complex to tackle mathematically [7].

Up to now, several fuzzy logic CAC algorithms have been presented for homogeneous network. Reference [10] uses a fuzzy logic scheme to generate channel allocation handoff traffic for Personal Communications Service; in [11], a fuzzy logic admission control is introduced for a GPRS-EGPRS network, especially focusing on data and voice services; Reference [7] suggests a fuzzy logic CAC for UMTS cellular networks based on the measurements of the pilot signal power. And [12] compares the performances of a fuzzy logic based and a load factor based CAC for a WCDMA system. In [13], a fuzzy logic partition-based CAC is presented for Mobile WiMAX.

All of these approaches are concerned for homogeneous networks. This paper implements a threshold-based CAC algorithm combined with a fuzzy logic policy for a heterogeneous network.

A. *Fuzzy Logic Controller System*

A Fuzzy logic controller (FLC) system consists of a Fuzzifier, an Inference Engine, a Fuzzy Rule Base and a Defuzzifier. A FLC can provide algorithms which convert the linguistic control strategies based on intuition, heuristic learnings and export knowledge into an automatic control strategy [7]. The procedure is shown in Fig. 3. The function of the Fuzzifier is to transform the input parameters into the fuzzy language. The Inference Engine will perform the logic inference based on the Fuzzy Rule Base, which contains the expert knowledge of the admission control. Finally, the Defuzzifier transforms the outputs of the Inference Engine into usable values for admission decisions.

In this paper, FLC is responsible for the threshold assessment of channel resource. When a new channel request comes, the fuzzy CAC scheme estimates an effective bandwidth for the target network and the existing handover dropping probability, which facilitates the CAC decision and resource allocation for the radio resource request. Then, the fuzzy CAC strategy will dynamically tune the channel threshold to accept or deny the arriving resource request.

B. *Membership Function*

This paper profiles a Mamdani fuzzy model with three input parameters and one output parameter. The three inputs are set as the high priority handover service dropping probability, the low priority handover service dropping probability and the number of reserved channels, which is guarded by thresholds (C_N and C_H). The output is named as the amount of the adjusting channel.

A membership function (MF) usually takes on a value between *0* and *1*, where *1* is for full membership, *0* for the null-membership, while values in between give the degree of membership [10]. The triangular sharp is chosen as the MF for this paper, because it's higher resolution and sensitivity comparing with Gaussian MF, Trapezoidal MF and Generalized Bell MF. In order to analyze the performance of two-threshold fuzzy logic CAC, the adjusting channels of C_N and C_H will be discussed respectively.

1) Membership functions for counting the adjusting channels of C_H.

Assuming the observed high priority handover dropping probabilities (HDP) and low priority handover dropping probabilities (LDP) have the same value of *0.01*, hence, HDP and LDP are considered as having the same MF; the amount of reserved resource has the value of $\Gamma C=C-C_H$; so the range of adjusted channels is configured from $-\Gamma C$ to ΓC.

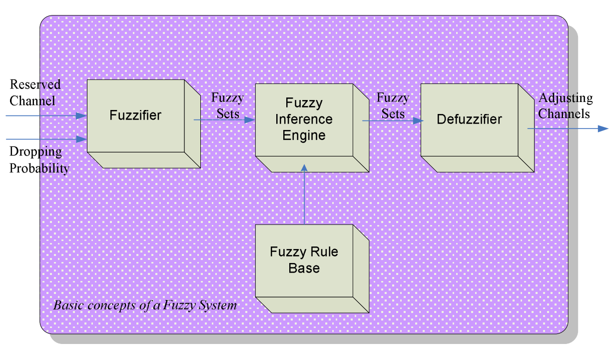

Figure 3. Basic concepts of a fuzzy logic system.

The definitions of linguistic sets for the high/low priority handover dropping probability (DP), the quantity of the reserved channel (RC) and the number of the adjusting channel (AC) for threshold C_H are deployed as below:

S (DP) = {Z (Zero), VL (Very Low), L (Low),
M (Medium), H (High)};
S (RC) = {VS (Very Small), S (Small), M (Medium),
B (Big), VB (Very Big)};
S (AC) = {NB (Negative Big),
NLB (Negative Little Big),
NM (Negative Medium),
NS (Negative Small),
NVS (Negative Very Small), Z (Zero),
PVS (Positive Very Small),
PS (Positive Small),
PM (Positive Medium),
PLB (Positive Little Big), PB (Positive Big)}.

The MFs of three inputs and one output are displayed in Fig. 4, Fig. 5 and Fig. 6.

2) Membership functions for calculating the adjusting channels of C_N.

The first and second inputs are still HDP and LDP, which has the same MFs as Fig. 4; the third input, the number of guarded channel, equals to $\Theta C=C_H-C_N$, its MF is denoted in Fig. 7; Fig. 8 exposes that the amount of adjusted channels for threshold C_N varies within the range from $-\Theta C$ to ΘC.

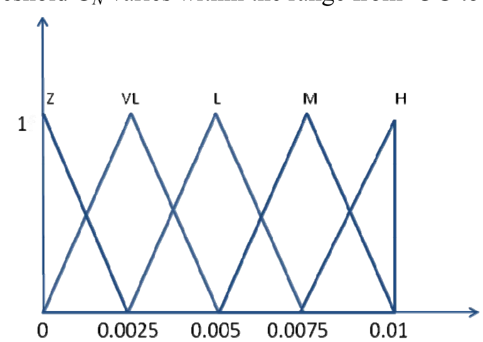

Figure 4. Membership function for high/low priority handover dropping probability.

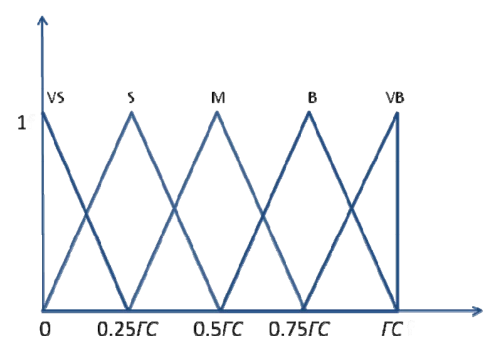

Figure 5. Membership function for the quantity of the reserved channels by C_H.

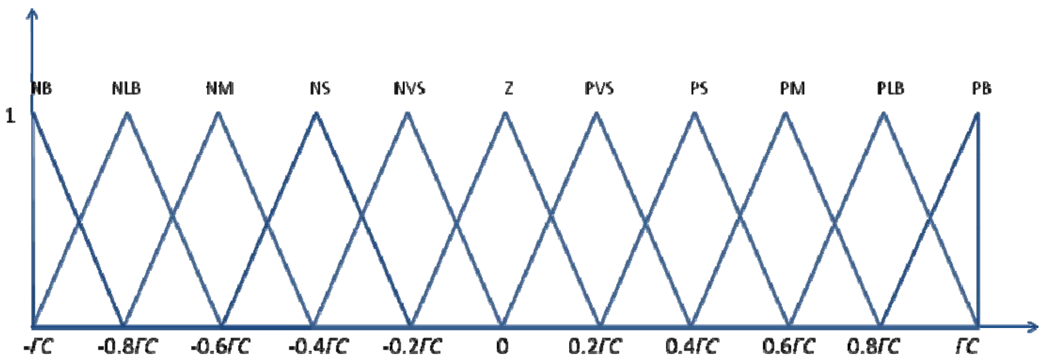

Figure 6. Membership function for the number of the adjusting channel of C_H.

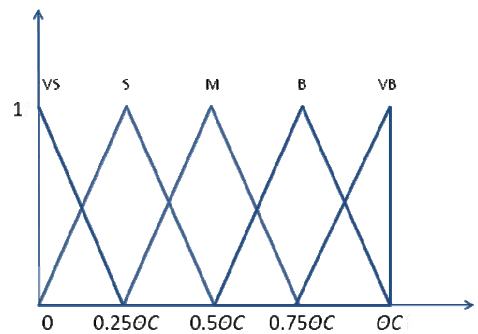

Figure 7. Membership function for the amount of the reserved channels by C_N and C_H.

C. *IF-THEN Rule*

The fuzzy logic system uses linguistic variables to map the input fuzzy variables to the output fuzzy variable [10], which is achieved under conditions prescribed by *IF-THEN* rule. FLC reckons the adjusting amount of channels in accordance with handover dropping probabilities and current number of reserved channels. In this scenario, each input of controller has *5* MFs. Fuzzy rule forms a series of *25 IF-THEN* rules to manage *25* different combinations, which is illustrated in Table I.

TABLE I. IF-THEN RULE

Rule No.	Dropping Probability	Reserved Channels	Adjusting Channels
1	Zero	Very small	Zero
2	Zero	Small	Negative Very Small
3	Zero	Medium	Negative Small
4	Zero	Big	Negative Medium
5	Zero	Very big	Negative Big
6	Very low	Very small	Positive Very Small
7	Very low	Small	Negative Very Small
8	Very low	Medium	Negative Small
9	Very low	Big	Negative Medium
10	Very low	Very big	Negative Big
11	Low	Very small	Positive Very Small
12	Low	Small	Positive Very Small
13	Low	Medium	Positive Very Small
14	Low	Big	Negative Very Small
15	Low	Very Big	Negative Small
16	Medium	Very Small	Positive Medium
17	Medium	Small	Positive Small
18	Medium	Medium	Zero
19	Medium	Big	Negative Very Small
20	Medium	Very Big	Negative Small
21	High	Very Small	Positive Big
22	High	Small	Positive Medium
23	High	Medium	Positive Small
24	High	Big	Positive Very Small
25	High	Very big	Zero

IV. MATHEMATICAL RESULTS

In this section, the performance of the novel CAC with fuzzy logic is illuminated by comparing with the class-based CAC method being mentioned in [2].

A. *Adjusting Channels for Thresholds*

Fig. 9 shows a plot of the output surface according to the input variables (the dropping probability and the number of reserved channels) and one output variable (the amount of the adjusting channels). The grid is a three element vectors. The horizontal two vectors depict DP and RC inputs; the vertical vector portrays AC output. The output surface specifies the number of sample points on which to express the membership functions in the input or output range [15].

B. *Performance Analysis of Fuzzy Logic Call Admission Control*

For the comparison purpose, mathematical results are indicated in this segment. The dropping probabilities of high/low priority handover services in two-threshold scheme are contrasted with those of two-threshold fuzzy logic CAC method.

Assuming that the entire available channels of UMTS-WLAN network are $C=100$; the ranges of the mean channel request rate λ_{HH}, λ_{LH} and λ_N for each kind of user are assumed to be $0.2 \le \lambda_{HH} \le 0.6$ *channels/s*, $0.2 \le \lambda_{LH} \le 0.8$ *channels/s* and $0.25 \le \lambda_N \le 1.2$ *channels/s*; the mean service time $1/\mu$ is set to be a constant value of *0.005s*.

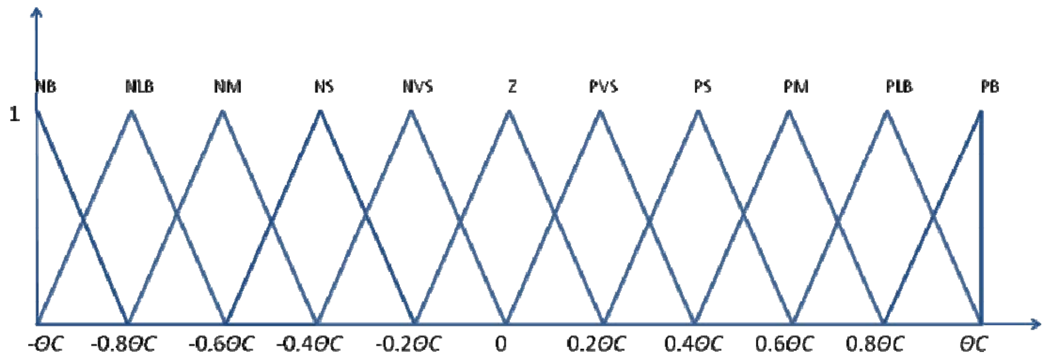

Figure 8. Membership function for the quantity of the tuning channels of C_N.

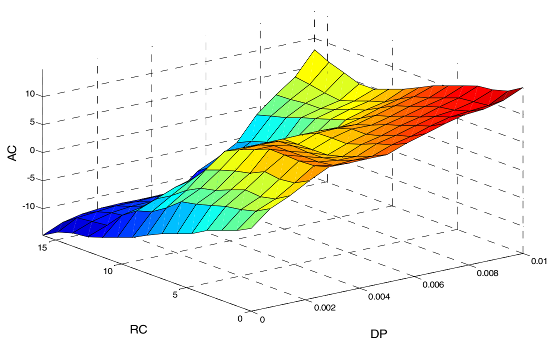

Figure 9. Tuning channels for the thersholds.

Simulation curves of the different handover dropping probabilities for class-base CAC and fuzzy logic CAC are exhibited in Fig. 10 and Fig. 11.

Fig. 10 displays the dropping probabilities of high priority handover traffic in class-based CAC and fuzzy logic CAC schemes, respectively. As the channel request rate increases, the dropping probabilities are raising for both schemes. The fuzzy logic approach gives an almost same handover dropping probability as in threshold-based strategy.

Fig. 11 indicates the handover dropping probabilities of $User_{LH}$ for both class-based CAC and fuzzy logic CAC schemes. Due to tuning channels, the positions of two thresholds are modified. The fuzzy logic technique provides an appropriate measurement to adjust thresholds and reduces the dropping probability of low priority handover traffics. To sum up, the fuzzy logic CAC method appears to give a lower dropping probability for overall handover traffic than the method described in [2].

Reviewing the numerical results of two figures, it can be seen that two thresholds altered by the fuzzy logic approach perform much better in the matter of achieving low handover dropping probability and improving the quality of handover services. Therefore, the fuzzy CAC strategy successfully satisfies the performance of entire handover dropping probability.

V. Conclusion

The paper demonstrates an intelligent threshold-based CAC using fuzzy logic theory strategy for the next generation telecommunication network. This new scheme dynamically modulates an optimum value for thresholds to meet the requirement of the QoS and keep the whole handover traffic in a low level.

For the future work, basing on fuzzy logic CAC, the concept of capacity planning will be considered as the mechanism to manage the entire radio resource of the target wireless network and improve the channel utilization of the hybrid network.

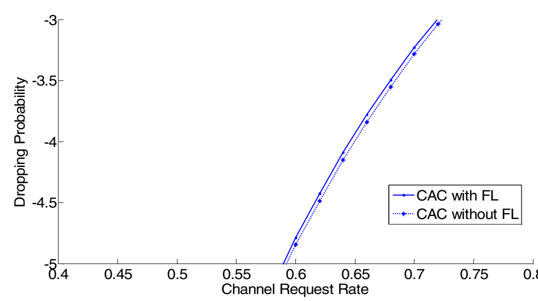

Figure 10. $User_{HH}$'s handover dropping probabilities of two-threshold call admission control with and without fuzzy logic schemes.

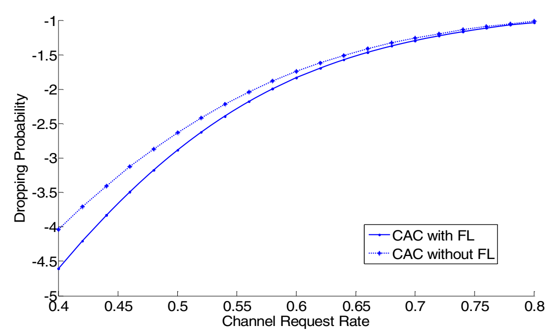

Figure 11. Dropping probabilities of low priority handover traffic in class-based call admission control with and without fuzzy logic strategies.

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