Performance Analysis of a Fuzzy Logic Based Adaptive Call Admission Control over Heterogeneous Wireless Networks

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Abstract: **This paper propose a novel call admission control (CAC) scheme that considers real-time and non-real-time nature of a call before allocating resources for its progress in a network. The scheme accumulates the benefits of different CAC schemes for best optimization of the available resources. It has combined the three major schemes- reserve guard channel, buffer based and prioritization. Application of fuzzy logic made the scheme adaptive by dynamic control of the threshold resource parameters using fuzzy logic. Simulation results show that the scheme outperforms the existing CAC schemes in terms of QoS.**

Key words: **CAC, Overlay networks, Guard channel, Fuzzy logic.**

I. Introduction

The next generation communication networks are expected to be composed of many heterogeneous networks enabling all-IP-based seamless interworking with the Internet backbone and provision of guaranteed quality of service (QoS) to all applications [1]. Call admission control (CAC) in a heterogeneous wireless domain is a key for efficient and optimized resource allocation to the call without compromising with the service agreement committed to the calls already in progress. Handoff latency, throughput, call blocking probability (CBP) and call dropping probability (CDP) are the performance metrics for the real-time and non-real-time traffic that require some bandwidth guarantee. Call blocking occurs at call initiation when there are not enough channels to serve a new call. Call dropping refers to the forced termination of an ongoing handoff call in absence of channels in the new cell. The future heterogeneous networks can be efficiently analysed with wireless overlay network (WON) model [19]. However, CAC in WON need to consider not only the local issues within a cell, but also the inter-layer issues and heterogeneity making it a very complex procedure. In particular, it becomes difficult for a CAC scheme to take an admission decision based on a multitude of conflicting parameters with discrete values. Under this situation, application of fuzzy logic in the CAC scheme simplifies the complexity and enables the CAC decisions to take under wide variety and range of parameters. An intelligent call admission controller adopts fuzzy techniques to make admission decision for a new call request by considering the QoS measures of all service types and predicted interference.

II. Background

Three major schemes- reserve guard channel, buffer based and prioritization are generally adopted in the existing CAC schemes. In guard channel scheme [2-5], some channels are exclusively reserved for high priority handoff calls so that they are allocated more channels than the low priority new calls. In buffer based CAC scheme, the call requests are queued in a buffer if channels are not available. Channels are provided from the buffer end as soon as free channels are available. Some relevant buffer-based schemes are presented in [6-7]. A guard channel based buffer management scheme integrating CAC, scheduling and traffic management is given in [8]. In priority queuing [9], a buffer queues the priority data packets and the scheduler schedules the traffic classes based on the occupancy of the higher priority buffers. CAC schemes for heterogeneous networks considering real-time and non-real time calls are given in [10-12]. Interference [1], Power [13] and signal-to-interference ratio (SIR) [14] based schemes are CDMA-oriented. Fuzzy logic control has been successfully applied for CDMA networks [15] [16]. In [17], fuzzy logic has been used for adaptive control of the inputs with feedback. In [18], three traffic classes, voice, video and data call with real time and elastic traffic were considered in the fuzzy logic based CAC scheme for WCDMA network. The scheme first estimates the effective bandwidth of the call request from a mobile station (MS) and its mobility information then makes a decision to accept or reject the connection request based on the estimation and system resource availability

All the existing CAC schemes consider the local issues within a cell, but do not consider the inter-layer issues in case of heterogeneous overlay networks. In particular, it becomes difficult for a CAC scheme to take an admission decision based on a multitude of conflicting parameters with discrete values. Under this situation, it is necessary to opt for an integrated approach that should take care of all the factors due to heterogeneity as well as multi-class services of voice, video and data. This paper considers heterogeneous wireless overlay networks and proposes a fuzzy logic based dynamically adaptive CAC scheme using the common techniques of reserve channel, buffer management and priority scheduling all together in order to achieve best utilization of the resources while providing guaranteed quality service to the users. The fuzzy logic application enables automatic tuning of the threshold parameters of the resources to make it most efficient.

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III. PROPOSED SCHEME

Our proposed CAC scheme CARETON (Call Admission control for Real time and Elastic Traffic on Overlay Networks) is applicable for optimized resource allocation in the next generation heterogeneous wireless overlay networks. The scheme is guard channel based but also considers traffic and buffer management collectively for efficient resource utilization, higher throughput and enhanced system performance for multi-class services such as voice, video and data. A priority for handoff voice traffic ensures that its performance of real-time traffic is not affected. It is implemented with fuzzy logic for automatic control of the resource allocation so that the desired QoS may remain constant under all traffic situations. The scheme is shown in Fig.1.

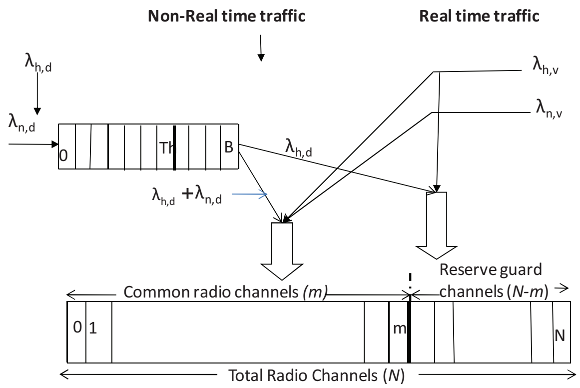


Fig.1: Channel allocation scheme for fuzzy based system

Reserved guard channels implement priority for the handoff call requests. The handoff calls are allowed to access all the N radio channels as per priority scheme. The real time handoff traffic access the channels directly, whereas, the non-real time handoff traffic access through the buffer. The new calls can access only the common m channels ($m < N$); real time calls directly and non-real time through the buffer. According to service class, the scheme provides highest call admission priority to real time voice followed by video and data calls and higher priority to the handoff calls over any new call attempts. We also provide higher priority of vertical (inter-layer) voice calls over horizontal (intra-layer) voice calls with overall highest priority to the real-time vertical handoff (VHO) calls in the WON's.

IV. FUZZY LOGIC CONTROL

The scheme uses fuzzy logic to control dynamically both the guard channels as well as the buffer size required for the desired QoS and resource utilization. On the other hand, use of buffer increases throughput as well as service provider's revenue. Since call arrival rate, mean dwell time, buffer length and also the number of guard channels that are in use are known to the system, it can easily calculate the dropping or blocking probability for each class for each sector. After calculating the probabilities, the system will read the priority table from the database of the base station. The system will feed all these input data such as blocking and dropping probabilities, priority factors, available guard channels etc. in to the fuzzy block which yields the desired value, number of guard channels to be tuned.

A. *Fuzzy Logic Controller*

The Fuzzy Logic Controller (FLC) converts the linguistic control strategies based on intuition, heuristic leanings and export knowledge into an automatic control strategy. It consists of fuzzifier, inference engine, fuzzy rule base and defuzzifier as shown in Fig.2. The input linguistic parameters are set as call dropping probability (*CDP*) of real time and elastic handoff calls, call blocking probability (*CBP*) of real time and elastic new calls, priority factor, buffer length and number of the guard channels ($N - m = g$).

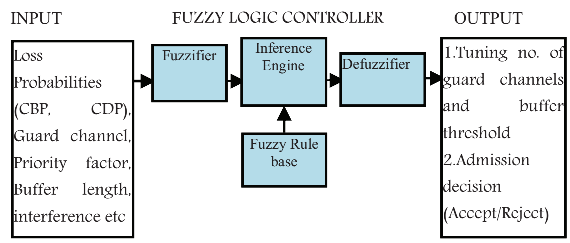


Fig. 2: Fuzzy-logic controller

B. *Membership Functions*

Membership function values for all input parameters are calculated during the fuzzification process for the corresponding terms sets as: *low* and *high*; or *low*, *medium* and *high*, and also set for decisions *strongly accepted* (SA), *accepted* (A), *weakly accepted* (WA), *weakly rejected* (WR) and *rejected* (R). The application of fuzzy rules follows in Table 1.

TABLE 1
FUZZY CONTROL RULES FOR GUARD CHANNELS

Rule No	*IF* pr	*AND* CDP	*AND* g is	*THEN* Δg
R1	H	H	S	+ve
R2	H	H	A	+ve
R3	H	H	Mo	+ve
R4	H	M	S	-ve
R5	H	M	A	-ve
R6	H	M	Mo	+ve
R7	H	L	S	-ve
R8	H	L	A	-ve
R9	H	L	Mo	+ve
R10	L	H	S	-ve
R11	L	H	A	-ve
R12	L	H	Mo	+ve
R13	L	M	S	-ve
R14	L	M	A	-ve
R15	L	M	Mo	+ve
R16	L	L	S	-ve
R17	L	L	A	-ve
R18	L	L	Mo	-ve

The final values are defuzzified to form the final decisions (accepted or rejected, number of reserve channels and buffer length). The output linguistic parameters are set as the tuning number of the guard channels (r) and buffer length (T_h). The term sets of call dropping probability (CDP), call blocking probability (CBP), priority, number

of guard channels $g(=N-m)$, and tuneable number of guard channels Δg ,are defined as follows:
Term set for loss probability T (Loss)={ S, M, H}, Term set call dropping probability T (CDP)={ L, M, H}, Term set call blocking probability T (CBP)={ L, M, H }, Term set reserve channel T (r)={S,A,Mo}, Term set Priority T(P)={L,H}, T (Δr)={N,P}, where L= Low, M= Medium, H= High, S=Small, A=Average, Mo=Moderate. We choose triangular functions as membership functions because they are simple and practical.

C. Fuzzy Rule Base

Table 1 shows the fuzzy rule base for the control of guard channels consisting of a series of 18 fuzzy rules. 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 tuned 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.

V. SIMULATION AND RESULTS

In order to evaluate the performance of our fuzzy logic based scheme CARETON, we implement and simulate an adaptive channel reservation scheme. System model of the scheme has been simulated in MATLAB v7. We consider total number of channels (N) in a cell as 120.The tuning number of the guard channels are allowed to vary within ±12% of N. We have considered $E_b/N_0 = 7.5\ dB$ (energy per bit per noise spectral density), the desired bit rate R = 2.2 kbit/s; and user mobility between 0 and 50 km/hour. We 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 $1/\mu$. We set $\lambda_n/\lambda_h=1/3$ and $\mu_1+\mu_2=1$sec. In the fuzzifier, we have inserted three blocks of inputs- guard channel block, buffer block and priority block.
We obtain the performance measures of CDP, CBP and throughput through the simulation. Simulation curves of the CBP of the two schemes (Fuzzy and Non Fuzzy) are shown in Fig.3. This shows how loss due to traffic load changes with priority factor for the data packets. The values of the CBP for the high priority data packets are small than low priority data packets. When the traffic load is low (e.g., new call arrival rate equals to 120 calls/minute), the values of the CBP for high priority and low priority data packets equal. As the traffic load increases, the CBP of the fuzzy scheme for higher priority data packets are 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.3. shows the variation of call blocking probability for the number of channels between 25 and 42. The plot shows the blocking effect for both with and without fuzzification. Although, fuzzification has reduced the effect of blocking probability, its curve is not smooth as of without fuzzification. This is perhaps due to the initial set up for the feedback control mechanism of the fuzzy controller. However, the fuzzified curve has become smooth when the number of channels was increased up to 60. This has been shown in Fig.4 where the blocking probability has been shown in a linear scale.

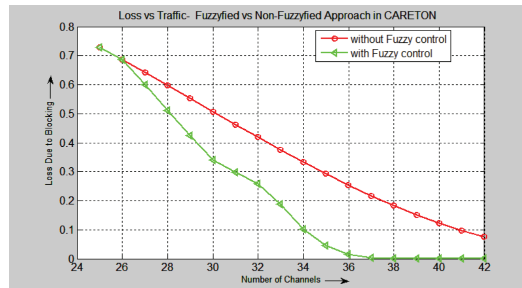


Fig. 3: Effect of CBP with lower number of channels.

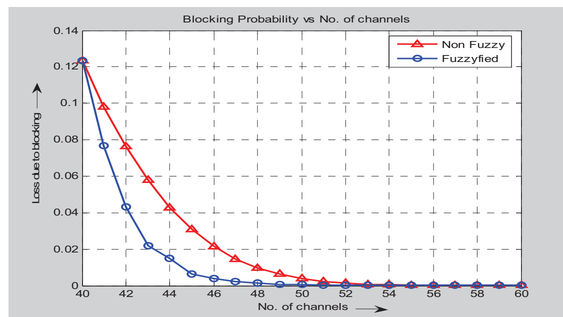


Fig. 4: CBP with higher number of channels

Simulation curves of the call dropping probability (CDP) are shown in Fig.5. We can notice that the values of the CDP increase as the traffic load increases for both fuzzification and non-fuzzification. When the traffic load is low (e.g., new call arrival rate equals to 60 calls/minute), the values of the CDP of both high priority and low priority data packets are equal. As the traffic load increases, the CDP of the fuzzy scheme for higher priority data packets is lower than the lower priority data packets. It indicates that our proposed algorithm can adjust guard channel better to reduce the CDP than the adaptive algorithm.

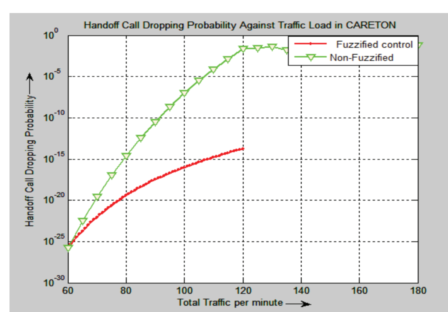


Fig. 5: CDP with traffic load

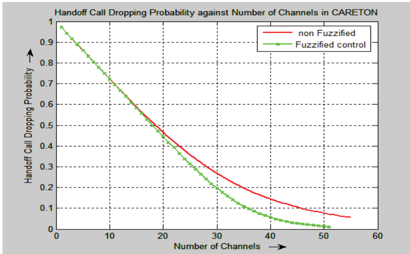
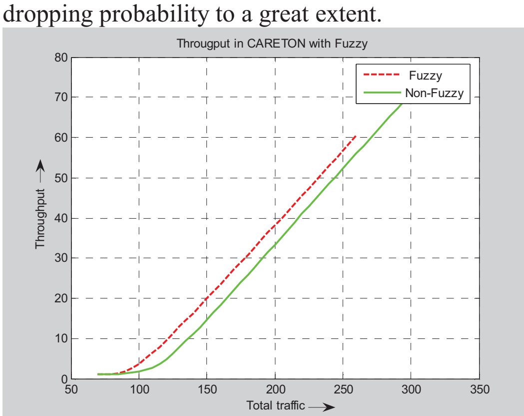


Fig. 6: CDP with number of channels

Fig. 6 shows the dropping probability against the number of channels. It is seen that up to 20 channels, fuzzification has no effect on the dropping probability. But as the number of channels increases, fuzzy control reduces the dropping probability to a great extent.



VI. CONCLUSION

The simulation results show that the proposed scheme outperforms other existing CAC schemes in terms of all the performance metrics mentioned earlier. Fuzzy logic application further improves the performance in heterogeneous wireless overlay networks. It is apparent from the results that the tuning capacity for the guard channels and buffer is significant when the number of channels in a cell is above 60. In this simulation, the maximum number of guard channels was taken as 15 out of 120 channels. Further increase of guard channel will not have any significant effect on the blocking probability, but will show much better performance against handoff call dropping.

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