Comparison of Fuzzy Logic and Genetic Algorithm Based Admission Control Strategies for UMTS System

Petr KEJÍK, Stanislav HANUS

Dept. of Radio Electronics, Brno University of Technology, Purkyňova 118, 612 00 Brno, Czech Republic

xkejik00@stud.feec.vutbr.cz, hanus@feec.vutbr.cz

Abstract. *CDMA systems have so-called soft capacity, so the total number of possible sessions has not an exact value. The capacity of CDMA system depends on the interference level in the system. There are therefore RRM (Radio Resources Management) functions, which are responsible for supplying optimum coverage, ensuring efficient use of physical resources and providing the maximum planned capacity. This paper presents and compares several algorithms that are used for admission control purposes in UMTS system. Several versions of fuzzy logic based algorithms, load factor based algorithm and genetic based algorithm are mutually compared via simulations.*

Keywords

Admission control, CDMA, UMTS, fuzzy logic, genetic algorithm.

1. Introduction

The first version of UMTS (Universal Mobile Telecommunication System) was released in 1999 (Release 99). Its evolution is, however, still in progress. There is a demand for new and optimal versions of all RRM algorithms. Admission control algorithms have to deal with different types of multimedia traffic and their various QoS (Quality of Services) demands, for example, so the evolution of the system has not been finished yet.

In UMTS (generally in CDMA systems) all users operate on the same frequency at the same time. This causes multiple access interference (MAI), which is the key issue, because system capacity depends on the interference level.

Admission control (AC), which is a part of RRM, solves system load and it decides if a new session request will be accepted or rejected. It also decides in the case of handover sessions. The main goals are to keep interference below a tolerable limit, which is related with QoS of all accepted sessions, to maximize system capacity and to minimize the number of blocked and dropped sessions. A number of admission control algorithms and solutions have been developed and published in the literature. They use a variety of approaches, some examples follow. The number based algorithm, which was used especially in 2[nd] generation systems like GSM (Global System for Mobile communications), could be found in [1]. Mobility based algorithms try to predict future locations of users and even exploit their distribution in cell. An example could be found in [2]. A number of algorithms are interference based, for example [3]. They exploit interference level, load factor value or SIR (Signal to Interference Ratio) value. Another approach that uses macrodiversity and nonuniform modulation could be found in [4], for example. There are also some novel approaches that use fuzzy logic, [5], or they are based on genetic algorithms, [6]. They use these techniques in order to deal with traffic uncertainty.

The basics of fuzzy logic theory were presented by Prof. Lotfi A. Zadeh in 1965. An example of fuzzy AC could be found in [5]. A fuzzy logic admission control for multiclass traffic is presented here. In [7], there is a quite complex fuzzy logic based AC, which contains a fuzzy equivalent interference estimator and a pipeline recurrent neural network interference predictor. Other fuzzy logic based AC approaches could be found in the literature. Genetic algorithm based AC approaches are inspired by evolutionary biology. A number of approaches could be found in the literature. These algorithms could be used for AC in the particular system, for example [6]. Genetic algorithms are also often used for intersystem AC. An example could be found in [8].

This paper presents some admission control algorithms, which are based mainly on the fuzzy logic approach. These algorithms are mutually compared via simulations.

2. Load Factor Based AC

The first algorithm is a simple one, based on uplink load factor calculation. Uplink load factor, η_{UL}, is calculated, according to [1]:

$$\eta_{UL} = (1+j)\cdot\sum_{i=1}^{K}\frac{1}{1+\dfrac{W}{(E_b/N_0)_i\cdot R_i\cdot v_{f,i}}} \tag{1}$$

where j is the other cells to own cell interference ratio, K is the number of users in the cell, W is the chip rate

(3.84 Mchip/s in UMTS), $(E_b/N_0)_i$ is the energy per bit per noise power spectral density, R_i is the required bit rate, and $v_{f,i}$ is the voice activity factor of the i^{th} user. The η_{UL} value is compared with the decision threshold ($\eta_{UL\,max} = 0.5$). If it exceeds the threshold, the session will be rejected (dropped out). Slightly different threshold levels are used for voice, data and handover sessions so that voice and handover sessions have a higher priority.

3. Fuzzy Logic Based AC

A fuzzy logic based algorithms (that are presented there) are based on [5]. There are three versions of fuzzy AC, which use different input parameters.

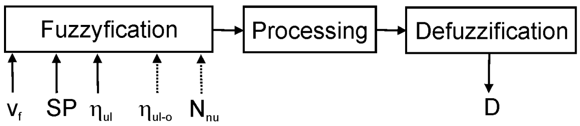

Fig. 1. Basic block scheme of fuzzy based algorithms.

Fig. 1 shows the basic block scheme of fuzzy logic based AC algorithms. The input parameters are fuzzificated (processed with triangular membership functions). The input parameters are the following: v_f – voice activity factor of the session of interest, SP – speed of user of interest, η_{UL} – total uplink load factor in the cell of interest, $\eta_{UL\text{-}0}$ – average total load factor of the 6 neighboring cells, and N_{nu} – number of users in the neighborhood of the cell of interest. The corresponding linguistic term sets are: {low - L, medium - M, high - H} for SP and η_{UL}; and {low - L, high - H} for the rest of input variables. Fuzzy rules are then applied. Fuzzy rules, partly defined in Tab. 1, express the "expert knowledge" of the problem. They correspond to the following form: IF "conditions (in the cell, session parameters)" THEN "control action (reject, for example)". The set of terms for fuzzy decision is {strongly accepted - SA, accepted - A, weakly accepted - WA, rejected - R, strongly rejected - SR}. In the end there is a backward transformation which forms the final decision D. More details could be found in [9].

Several versions of fuzzy logic based AC were simulated in this paper:

AC-F1 – this algorithm uses only three input variables: voice activity factor v_f, which enables distinguishing between voice and data sessions, speed of user SF, and total uplink load factor η_{UL}. This algorithm has 18 fuzzy rules (fuzzy rules 1-18 in Tab. 1, except the $\eta_{UL\text{-}0}$ column).

AC-F2 – this algorithm uses four input variables: three of them are the same as in the AC-F1 case, the fourth is the number of users in the neighborhood of the cell of interest. It is the number of users in neighboring cells close to the cell of interest (closer than 25 meters). This algorithm uses 36 fuzzy rules as partly defined in Tab. 1 (the second column has another variable). AC-F1 and AC-F2 were already partly presented in [10].

AC-F3 – this algorithm uses four input variables: three of them are the same as in the AC-F1 case, the fourth is the average total uplink load factor of the 6 neighbouring cells $\eta_{UL\text{-}0}$. This algorithm uses 36 fuzzy rules as partly defined in Tab. 1.

Fuzzy rule	$\eta_{UL\text{-}0}$	v_f	SP	η_{UL}	Fuzzy decision
1	L	L	L	L	SA
2	L	L	L	M	A
3	L	L	L	H	WA
4	L	L	M	L	SA
⋮	⋮	⋮	⋮	⋮	⋮
15	L	H	M	H	R
16	L	H	H	L	WA
17	L	H	H	M	WA
18	L	H	H	H	SR
19	H	L	L	L	A
20	H	L	L	M	WA
21	H	L	L	H	R
22	H	L	M	L	A
⋮	⋮	⋮	⋮	⋮	⋮
33	H	H	M	H	SR
34	H	H	H	L	R
35	H	H	H	M	R
36	H	H	H	H	SR

Tab. 1. Example of fuzzy rules.

4. Genetic Algorithm Based AC

A new genetic based algorithm, which is partly (in general) inspired with [6], is considered here. The AC problem is converted to genetic logic in such a way that sessions correspond to individual elements of the initial chromosome. This algorithm uses one generation of 50 offspring. This new generation consists of initial chromosome and new chromosomes that are generated by the mutation process (The individual elements of the initial chromosome are randomly mutated.). The best chromosome is chosen by using the fit function. The layout of accepted, rejected and dropped sessions corresponds with the structure of selected chromosome. The fit function has two parts. The algorithm chooses that chromosome for that F_{F1} is minimal and F_{F2} is maximal:

$$F_{F1,i} = LF_{thr} - LF_i\,, \tag{2}$$

$$F_{F2,i} = a_1 \cdot \sum_{j=1}^{N_{new,i}} 1 + 1/v_{f,j} + a_2 \cdot \sum_{j=1}^{N_{old,i}} v_{f,j} \cdot a_{3(v_{f,j})} \tag{3}$$

where $F_{F1,i}$ and $F_{F2,i}$ are the fitness function values for the i^{th} chromosome, LF_{thr} is the load factor threshold level ($LF_{thr} = 0.5$), $v_{f,j}$ is the voice activity factor of the j^{th} session. LF_i is the uplink load factor (see (1)), $N_{new,i}$ is the number of accepted sessions, $N_{old,i}$ is the number of kept old sessions for the i^{th} chromosome, a_1, a_2 and $a_{3(vf,i)}$ are constants: $a_1 = 50$, $a_2 = 1$, $a_{3(vf,i=0.5)} = 6$ and $a_{3(vf,i=1.0)} = 2$.

5. System Model

There are already some simulation programs for CDMA systems, for example [11-12]. These programs are, however, not free of charge and they focus mainly on the physical layer. A system model of UMTS has therefore been created in MATLAB. It is shown in Fig. 2. The movement trajectories of several users are also shown there. The system model consists of 19 hexagonal cells of equal size. Each UE (User Equipment) communicates with the closest Node B, which is located in the center of each cell. The 7 cells in the centre are used for the evaluation of algorithms. The other 12 cells (1st tier) simulate border conditions. The diameter of each cell is 1 km. Session requests are generated according to the Poisson process distribution with the arrival frequency from 150 up to 1200 session requests per hour (for each cell separately).

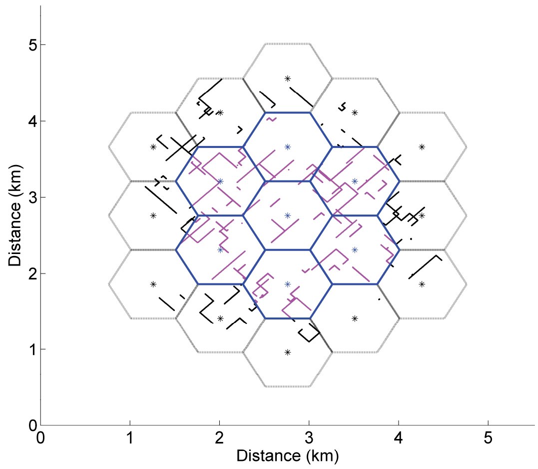

Fig. 2. System model with trajectories of movement of several users.

Duration of sessions varies between 60 and 180 seconds. All simulations take 60 minutes. The maximum allowed load factor is 0.5, $j = 0.55$, see (1). Two traffic classes, voice and data with voice activity factor 0.5 and 1 respectively, were considered in all simulations. These two classes assume the same input data. The only difference is the voice activity factor value. All users (sessions) have the same demands: $E_b/N_0 = 7.5$ dB and $R =$ 12.2 kbit/s. Users change their positions. Their speed varies between 0 and 50 km/hour.

6. Simulation Results

The algorithms introduced above were simulated in the system model, which was introduced in the previous section. All simulations take 60 minutes (from the UMTS point of view). The results presented are averages from 10 simulations and correspond to the 7 cells in the centre.

Figs. 3 and 4 show the relationship between blocking probability (BP - ratio of the number of rejected sessions to the number of session requests), dropping probability (DP - ratio of the number of dropped sessions to the number of session requests) and the arrival frequency of sessions (number of users).

Fig. 3 shows BP and DP for voice sessions. Fuzzy logic based algorithms enable decreasing the DP. This is important because dropping out an existing call is, from user's point of view, more disturbing than rejecting a new connection. Decrease of DP causes slight increase of BP (it is partly a trade-off).

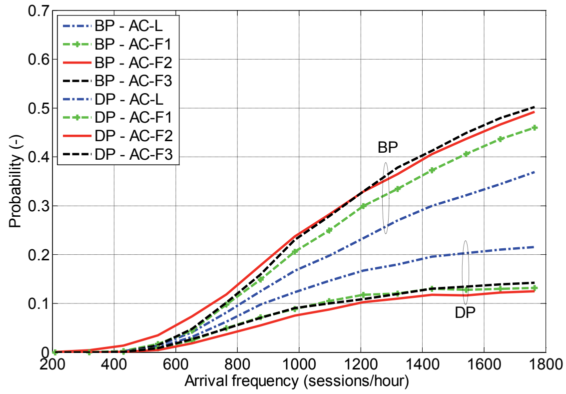

Fig. 3. Comparison of AC algorithms for voice sessions.

Fig. 4 shows BP and DP for data sessions. All curves partly correspond with Fig. 3. Voice sessions in Fig. 3 have a higher priority, so BP and DP in Fig. 4 reach slightly higher values.

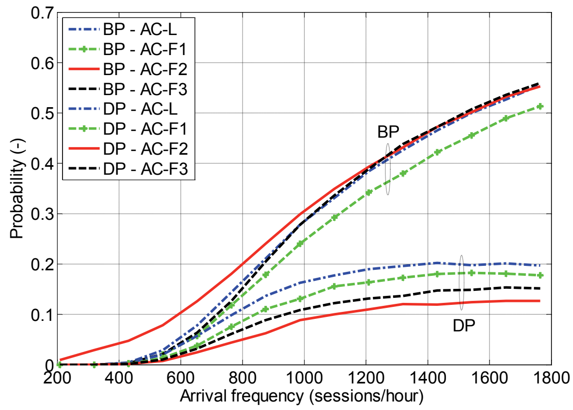

Fig. 4. Comparison of AC algorithms for data sessions.

Fig. 5 shows the average load factor (calculated for 7 cells in the centre) per cell for each algorithm. Note that the 0.5 value was set as the load factor maximum threshold. Fig. 5 shows that average load factors are comparable for all algorithms. The load factor for AC-F1 achieves slightly higher values than for the other algorithms.

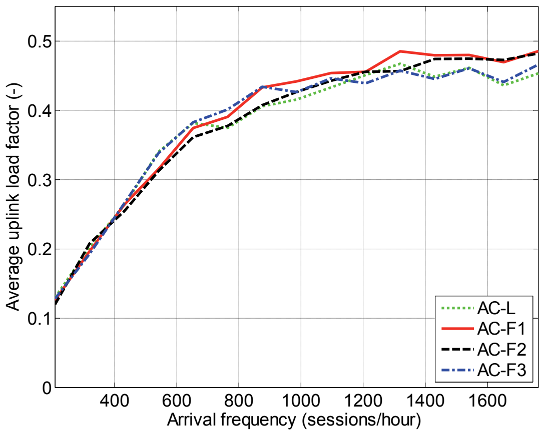

Fig. 5. Average uplink load factor in 7 cells in the centre.

Fig. 6 shows the average number of active sessions in the cell. It corresponds with results in Fig. 5. All algorithms achieve a comparable performance.

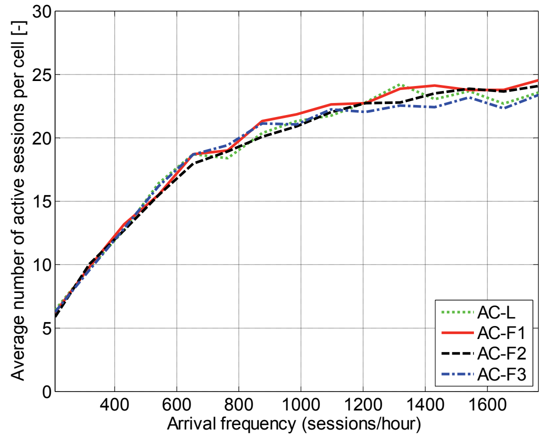

Fig. 6. Average number of active sessions per cell.

Fig. 7 shows the average bit rates that are achieved in one cell (voice and data sessions together). All algorithms achieve a comparable performance (differences are quite small). AC-F1 achieves the highest bit rate.

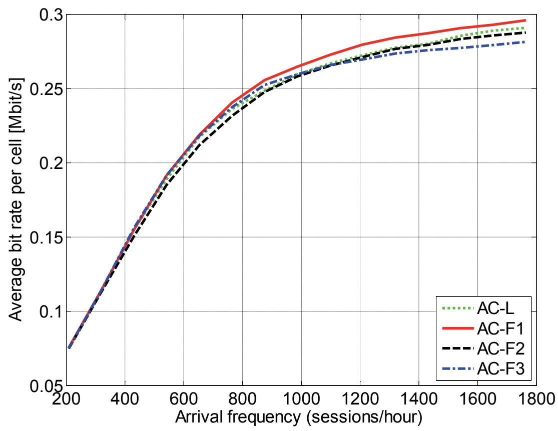

Fig. 7. Average bit rate per cell.

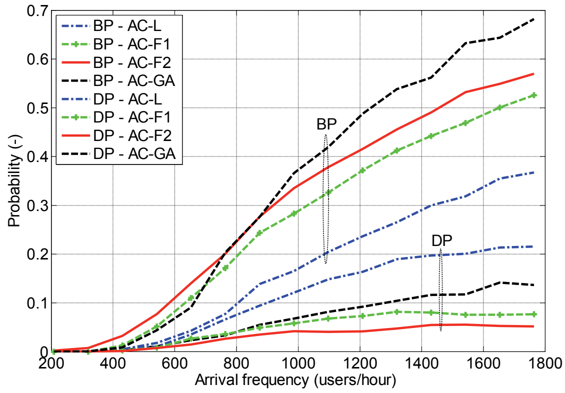

Fig. 8. Comparison of AC algorithms for voice sessions.

Figs. 8 and 9 correspond with Figs. 3 and 4. Genetic based AC (AC-GA) instead of AC-F3 is considered there. Simulation shows that AC-GA is able to perform admission control, but the performance of the fuzzy AC algorithms is better. The average load factor, number of active sessions, and average bit rate correspond with Figs 5-7 (they are not shown here).

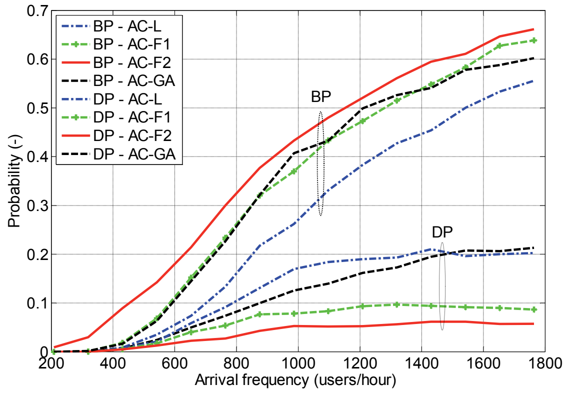

Fig. 9. Comparison of AC algorithms for data sessions.

Genetic algorithms (in general) have quite high computational demands and perform slowly. However, the simulated algorithm is quite simple. It uses only one generation of offspring and therefore it is able to work in real time.

7. Conclusion

Admission control algorithms for CDMA systems were presented in this paper. Fuzzy logic based, load factor based and genetic based algorithms were simulated in the UMTS simulation program, which was designed for this purpose. The proposed fuzzy based algorithms appear to have a better performance than the proposed genetic based algorithm. Three versions of fuzzy logic algorithms were simulated. The AC-F2 version appears to have the best performance (it corresponds with the fact that it uses a lot of exact information about the system). Future work will consider more complex versions of fuzzy logic based algorithms and genetic based algorithms with other fit functions.

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About Authors ...

Petr KEJÍK received the BSc degree in 2005 and the MSc degree in 2007 from the Brno University of Technology, Department of Radio Electronics, Brno, Czech Republic. In 2007, he started studies towards a PhD degree at the same university. His research interests include capacity and access optimization in CDMA systems.

Stanislav HANUS was born in Brno, Czech Republic, in 1950. He received the MSc and PhD degrees from the Brno University of Technology. He is Professor at the Department of Radio Electronics, Faculty of Electrical Engineering and Communication in Brno. His research is concentrated on Mobile Communications and Television Technology.