Advanced Fuzzy Logic Based Admission Control for UMTS System

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Abstract. *The capacity of CDMA (Code Division Multiple Access) systems is interference limited. Therefore radio resources management (RRM) functions are used. They are responsible for supplying optimum coverage, ensuring efficient use of physical resources, and providing the maximum planned capacity. This paper deals with admission control techniques for UMTS (Universal Mobile Telecommunication System). A UMTS system model and four fuzzy logic based admission control algorithms are presented in this paper. Two new versions of fuzzy logic based admission control algorithms are presented there. All algorithms are mutually compared via simulations. Simulations show that the novel advanced fuzzy algorithm outperforms the other simulated algorithms (in terms of blocking probability, dropping probability and the number of active UEs in cell).*

Keywords

UMTS, CDMA, admission control, fuzzy logic.

1. Introduction

Mobile systems, like GSM (Global System for Mobile communications) or UMTS (Universal Mobile Telecommunication System), have to deal with mobility of users, unpredictable traffic and also with varying radio channel conditions. These 2G (2nd Generation) and 3G (3rd Generation) systems are already installed and used at present. Their upgrades (like Evolved High Speed Packet Access, HSPA+) are able to partly cope with novel systems like LTE (Long Term Evolution) and thus these systems survive so far. UMTS is used below as a representative of CDMA (Code Division Multiple Access) systems. CDMA systems do not have a fixed capacity. Their capacity depends on the interference level in the system. A suitable version of an admission control (AC) algorithm therefore has to be implemented.

Admission control algorithm decides whether a new session request will be accepted, or rejected. It also decides (it partly overlaps with handover control) if an existing session will be kept or dropped. The main aims of AC are: to maximize the number of sessions in a cell (in the system), to minimize the number of blocked and dropped sessions, and to guarantee QoS (Quality of Service) and QoE (Quality of user Experience) of all existing sessions. The admission procedures have not been standardized, so the evolution and optimization of AC is still in progress.

A number of AC algorithms and approaches can be found in the literature. Note that some approaches overlap, so the classification of algorithms is not unique. An algorithms survey can be found in [1] or [2]. Some algorithms are number (capacity) based; an example can be found in [1]. There is another group of algorithms which try to predict movement trajectories of users, [3], [4], for example. Examples of interference based algorithms can be found in [5], [6]. There are also some novel approaches, which use fuzzy logic. They use this technique in order to deal with traffic uncertainty and user mobility. An example of fuzzy AC can be found in [7]. A fuzzy logic AC for multiclass traffic is presented here. A novel neural fuzzy based AC algorithm providing multirate services is presented in [8]. This algorithm outperforms the other algorithms (see [8]) by tens of percent. However, its complexity and computational demands are quite high. Other fuzzy logic based AC approaches can be found in the literature.

This paper presents new fuzzy logic based AC algorithms and compares them with another two fuzzy logic based algorithms. It would be useful to compare the above mentioned algorithms with other algorithms (already published). However, it is not a simple task. Chapter 2 is based on [7] and [8]. These publications present own proposed algorithms. However, some essential parameters are not specified in those papers (for example: threshold values of membership functions, session length, etc.). Therefore, these algorithms cannot be reproduced and compared with the algorithms that are introduced below.

The rest of the paper is organized as follows. Section 2 describes fuzzy logic based AC algorithms. Section 3 describes the proposed simulation program (model). Simulation results are presented in Section 4. Finally, Section 5 provides conclusions.

2. Fuzzy Logic Based Algorithms

Four versions of fuzzy logic based AC algorithms are described and simulated in this paper. These algorithms are based (in general) on [7] and [8]. Input variables are fuzzificated (processed with triangular membership functions, see Fig. 1 and Fig. 2). Fuzzy rules are then applied. Fuzzy rules 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)". At the end, there is a backward transformation which yields the final decision. Details (for example: a five-layer fuzzy controller structure and a description of individual layers) can be found in [9].

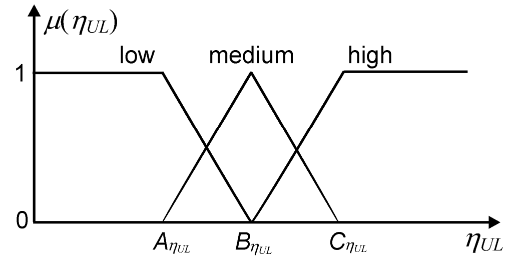

Fig. 1. Membership function for SP and η_{UL}.

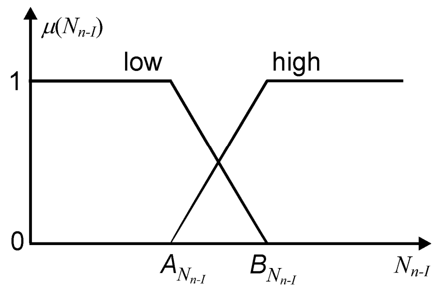

Fig. 2. Membership function for N_{n-I}, N_{n-P} and v_f.

2.1 Simple Algorithm (AC-F1)

This algorithm (further denoted as AC-F1) uses three input variables: activity factor v_f, which enables distinguishing between voice and data sessions, speed of user SP, and total uplink load factor η_{UL}. The corresponding linguistic term sets are: {low – L, medium – M, high – H} for SP and η_{UL}, and {low – L, high – H} for v_f. The threshold levels of membership functions (see Fig. 1 and Fig. 2): A_{SP} = 15 km/h, B_{SP} = 35 km/h, C_{SP} = 50 km/h, $A_{\eta ul}$ = 0.3, $B_{\eta ul}$ = 0.4, $C_{\eta ul}$ = 0.5, $A_{vf} = B_{vf}$ = 0.75. This algorithm has 18 fuzzy rules as defined in Tab. 1 (except the N_{n-I} and N_{n-P} columns). The corresponding linguistic term set for decision: {strongly accepted – SA, accepted – A, weakly accepted – WA, weakly rejected – WR, rejected – R}. This algorithm was presented in [9] and partly in [10]. It is assumed that speeds of UEs are known (estimated) by Node Bs (there are papers that deal with methods for estimation of speeds and positions of UEs).

Rule	N_{n-I}	N_{n-P}	v_f	SP	η_{UL}	Decision
1	L	L	L	L	L	SA
2	L	L	L	L	M	A
3	L	L	L	L	H	WA
4	L	L	L	M	L	SA
5	L	L	L	M	M	WA
6	L	L	L	M	H	WA
7	L	L	L	H	L	A
8	L	L	L	H	M	WA
9	L	L	L	H	H	WR
10	L	L	H	L	L	SA
11	L	L	H	L	M	A
12	L	L	H	L	H	WR
13	L	L	H	M	L	A
14	L	L	H	M	M	WA
15	L	L	H	M	H	WR
16	L	L	H	H	L	WA
17	L	L	H	H	M	WA
18	L	L	H	H	H	R

Tab. 1. Fuzzy rules, part 1.

Rule	N_{n-I}	N_{n-P}	v_f	SP	η_{UL}	Decision
19	L	H	L	L	L	A
20	L	H	L	L	M	WA
21	L	H	L	L	H	WR
22	L	H	L	M	L	A
23	L	H	L	M	M	WR
24	L	H	L	M	H	WR
25	L	H	L	H	L	WA
26	L	H	L	H	M	WR
27	L	H	L	H	H	R
28	L	H	H	L	L	A
29	L	H	H	L	M	WA
30	L	H	H	L	H	R
31	L	H	H	M	L	WA
32	L	H	H	M	M	WR
33	L	H	H	M	H	R
34	L	H	H	H	L	WR
35	L	H	H	H	M	WR
36	L	H	H	H	H	R

Tab. 2. Fuzzy rules, part 2.

2.2 Algorithm with Simple Prediction of UEs Positions (AC-F2)

This algorithm (further denoted as AC-F2) uses four input variables: activity factor v_f, which enables distinguishing between voice and data sessions, speed of user SP, total uplink load factor η_{UL}, and predicted number of UEs (User Equipments), N_{n-P}, that will enter the cell of interest in 20 seconds (this value was found optimal during several simulations). The threshold levels of membership functions: A_{SP} = 15 km/h, B_{SP} = 35 km/h, C_{SP} = 50 km/h, $A_{\eta ul}$ = 0.3, $B_{\eta ul}$ = 0.4, $C_{\eta ul}$ = 0.5, $A_{vf} = B_{vf}$ = 0.75, A_{Nn-P} = 2, B_{Nn-P} = 20. The movement prediction uses (according to UMTS system model movement possibilities) a simple linear method (the predicted position is calculated using present and past positions).

This simple method was used in order to show that even a simple low complexity prediction method is able to achieve improvement. 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. This algorithm has 36 fuzzy rules as defined in Tab. 1 and Tab. 2 (except the N_{n-I} column). This algorithm was presented in [11].

2.3 Algorithm with Capacity Reservation (AC-F3)

This new algorithm (further denoted as AC-F3) uses four input variables: activity factor v_f, which enables distinguishing between voice and data sessions, speed of user SP, total uplink load factor η_{UL}, and the number of new sessions in the current cell for the last 20 seconds, N_{n-I}. 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. The threshold levels of membership functions: A_{SP}= 15 km/h, B_{SP}= 35 km/h, C_{SP}= 50 km/h, $A_{\eta ul}$ = 0.3, $B_{\eta ul}$ = 0.4, $C_{\eta ul}$ = 0.5, $A_{vf} = B_{vf}$ = 0.75, A_{Nn-I} = 2, B_{Nn-I} = 20. This algorithm has 36 fuzzy rules as defined in Tab. 1 and Tab. 2 (except the N_{n-I} column; N_{n-P} column is used for N_{n-I} in this case).

2.4 Advanced Algorithm (AC-F4)

This new proposed algorithm (further denoted as AC-F4) uses five input variables: activity factor v_f, which enables distinguishing between voice and data sessions, speed of user SP, total uplink load factor η_{UL}, the number of new sessions in the current cell for the last 20 seconds N_{n-I}, and predicted number of new UEs that will enter the cell of interest in 20 seconds (these values were found optimal during several simulations), N_{n-P}. It is a combination of three above mentioned algorithms.

Rule	N_{n-I}	N_{n-P}	v_f	SP	η_{UL}	Decision
37	H	L	L	L	L	A
38	H	L	L	L	M	A
39	H	L	L	L	H	WA
40	H	L	L	M	L	A
41	H	L	L	M	M	WA
42	H	L	L	M	H	WA
43	H	L	L	H	L	A
44	H	L	L	H	M	WA
45	H	L	L	H	H	R
46	H	L	H	L	L	A
47	H	L	H	L	M	A
48	H	L	H	L	H	R
49	H	L	H	M	L	A
50	H	L	H	M	M	WA
51	H	L	H	M	H	R
52	H	L	H	H	L	WA
53	H	L	H	H	M	WA
54	H	L	H	H	H	R

Tab. 3. Fuzzy rules, part 3.

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. The threshold levels of membership functions: A_{SP} = 15 km/h, B_{SP} = 35 km/h, C_{SP} = 50 km/h, $A_{\eta ul}$ = 0.3, $B_{\eta ul}$ = 0.4, $C_{\eta ul}$ = 0.5, $A_{vf} = B_{vf}$ = 0.75, A_{Nn-I} = 2, B_{Nn-I} = 20, A_{Nn-P} = 2, B_{Nn-P} = 20. This algorithm has 72 fuzzy rules as defined in Tab. 1 up to Tab. 4.

Rule	N_{n-I}	N_{n-P}	v_f	SP	η_{UL}	Decision
55	H	H	L	L	L	A
56	H	H	L	L	M	WA
57	H	H	L	L	H	WR
58	H	H	L	M	L	A
59	H	H	L	M	M	R
60	H	H	L	M	H	R
61	H	H	L	H	L	WA
62	H	H	L	H	M	R
63	H	H	L	H	H	R
64	H	H	H	L	L	A
65	H	H	H	L	M	WA
66	H	H	H	L	H	R
67	H	H	H	M	L	WA
68	H	H	H	M	M	R
69	H	H	H	M	H	R
70	H	H	H	H	L	R
71	H	H	H	H	M	R
72	H	H	H	H	H	R

Tab. 4. Fuzzy rules, part 4.

3. System Model

There are already some simulation programs for CDMA systems. An example can be found in [12] or [13]. However, these programs are often not free of charge, they are focused on the physical layer simulations, or they are simply unavailable. A UMTS system model has therefore been created in MATLAB. The system model consists of 19 hexagonal cells of equal size. Each cell contains a centrally located Node B with omni-directional antenna. The diameter of each cell is 1 km. Each UE (User Equipment) communicates with the closest Node B. Ses-sion requests are generated according to the Poisson process distribution with an arrival frequency of 150 to 1200 session requests per hour (for each cell separately). Two session types (voice and data) are distinguished. The UE positions and trajectories are generated randomly within the area. Users change their positions with speeds up to 50 km/h. Trajectories of UEs are linear with random change of direction every 20 seconds. Suburban scenario is considered. Walfish-Ikegami channel model is used. The UMTS model is shown in Fig. 3. The movement trajectories of several users are also shown there. The 7 cells in the centre are used for the evaluation of algorithms. The other 12 cells (1st tier) simulate border conditions. All users (sessions) have the same energy demands: E_b/N_0 = 7.5 dB. Two traffic classes, voice and data, with activity factors 0.5 or 1, and bit rates R_{bit} = 12.2 kbit/s (for both session types) were considered in all simulations. These two classes assume the same input data. Duration of sessions varies between 60 and 180 seconds. These values were set according to [7] and [14]. In addition, only few UEs would be in cell for higher bit rates. Simulation results would be more fluctuating.

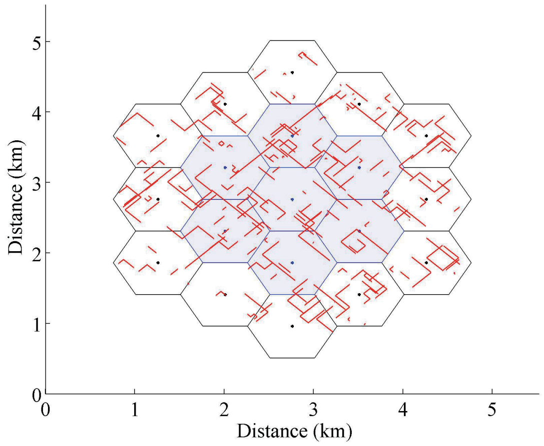

Fig. 3. System model.

4. Simulation Results

The algorithms introduced above were simulated and mutually compared in the system model that was introduced in the previous section. All simulations take 60 minutes (from the UMTS point of view). The length of simulation step is 200 ms (radio resource indication period (RRI), which is the time needed to receive in the RNC power measurements from the base stations, [14]).

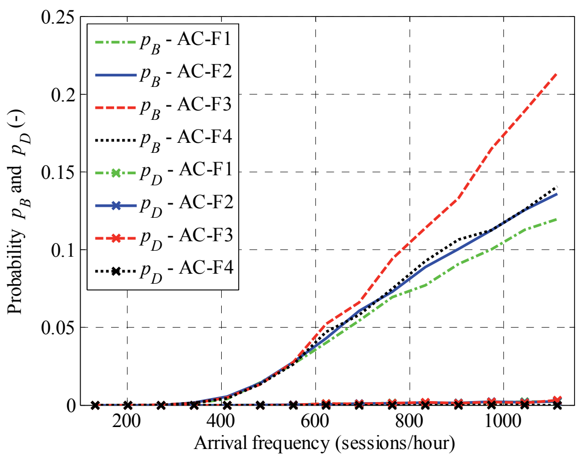

Fig. 4. Comparison of fuzzy AC algorithms for voice sessions.

The presented results are averages from 10 simulations and correspond to the 7 cells in the centre. The following figures show the relationship between the blocking probability p_B (ratio of the number of rejected sessions to the number of session requests), the dropping probability p_D (ratio of the number of dropped sessions to the number of session requests) and the arrival frequency of sessions (number of users). Arrival frequency is considered for each cell separately.

Fig. 4 shows the comparison of several algorithms for voice sessions. It can be observed that increasing arrival frequency of sessions increases both probabilities (the number of UEs in the system and the number of session requests are increasing). The dropping probabilities for all algorithms are almost equal to zero. This is quite important, because dropping out of an existing session is (from the user's perspective) much more disturbing than rejection of a new session request. The blocking probabilities are quite low (in comparison with Fig. 5). Algorithm AC-F1 reaches the lowest values of p_B. Algorithm AC-F3 reaches the highest values of p_B.

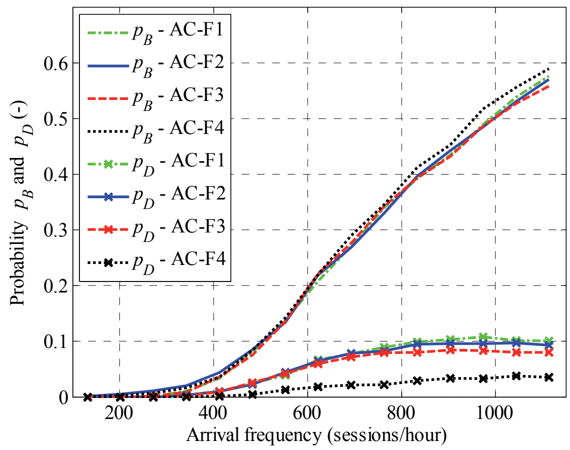

Fig. 5. Comparison of fuzzy AC algorithms for data sessions.

Fig. 5 shows the comparison of several algorithms for data sessions. Note that voice sessions have a higher priority, so p_B and p_D of voice sessions reach lower values (Fig. 4). The dropping probabilities (for data sessions) for all algorithms are kept low. Algorithm AC-F4 reaches the lowest values of p_D. The blocking probabilities are higher in this case (in comparison with Fig. 4). All algorithms reach similar values of p_B.

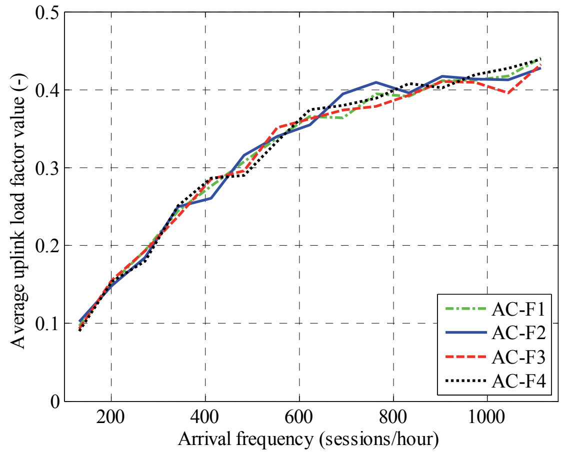

Fig. 6. Comparison of uplink load factors.

Fig. 6 shows the average (calculated from 7 cells in the centre) uplink load factor values in one cell. This figure shows how the cell occupancy develops according to the number of session requests. All algorithms reach similar values. This means that cell occupancies are similar for all algorithms (algorithms are compared under similar conditions).

Fig. 7 shows the development of average number of sessions in one cell according to the number of session requests. All algorithms reach similar values (algorithms are compared under similar conditions).

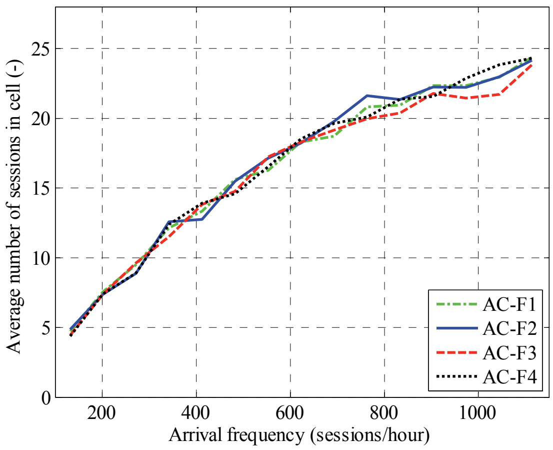

Fig. 7. Average number of sessions in cell.

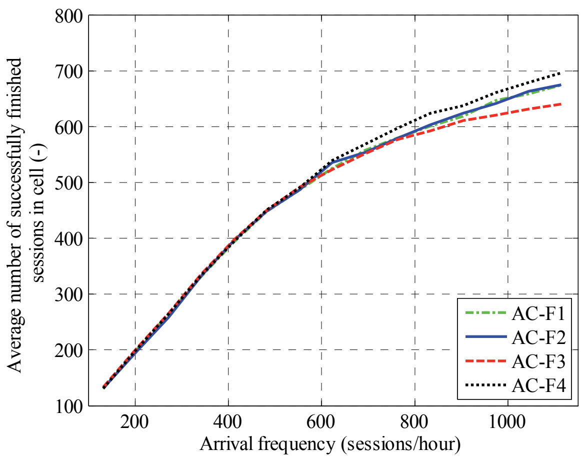

Fig. 8. Average number of successfully finished sessions.

Fig. 8 shows the average number of successfully finished sessions in one cell for the whole simulation (60 minutes). Algorithm AC-F4 reaches the highest numbers of finished sessions. Algorithm AC-F3 reaches the lowest numbers of finished sessions. AC-F1 and AC-F2 algorithms reach similar results.

Fig. 9 shows the average number of successfully finished voice sessions in one cell for the whole simulation (60 minutes). Algorithm AC-F3 reaches the lowest numbers of finished sessions. The other algorithms reach similar numbers of voice sessions.

Fig. 10 shows the average number of successfully finished data sessions in one cell for the whole simulation (60 minutes). Algorithm AC-F4 reaches the highest numbers of finished data sessions. The other algorithms reach similar numbers of sessions. Note that the number of successfully finished data sessions decreases for the high arrival frequency of sessions. This is because of the different session priorities. Data sessions are blocked (for high arrival frequency of sessions) more often in order to ensure low p_B and p_D for voice sessions.

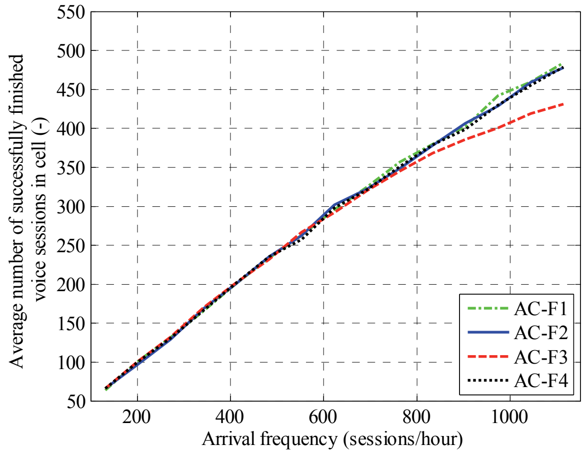

Fig. 9. Average number of successfully finished voice sessions.

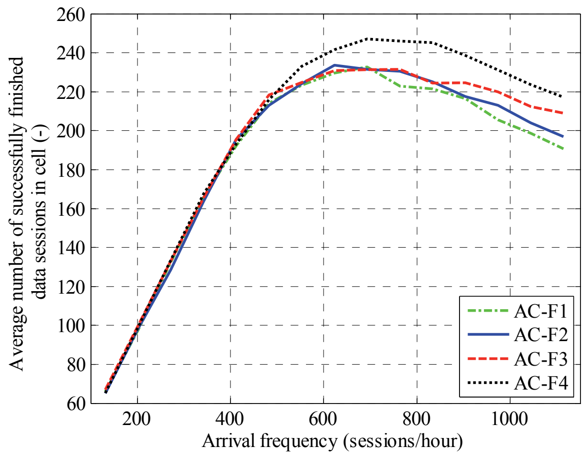

Fig. 10. Average number of successfully finished data sessions.

5. Conclusion

Admission control algorithms for CDMA systems are presented in this paper. Fuzzy logic based algorithms are simulated in the UMTS simulation program, which was designed for this purpose.

The proposed AC-F3 and AC-F4 algorithms are compared with AC-F1 and AC-F2 algorithms that were already published in [9], [10] and [11].

The proposed fuzzy based algorithm AC-F4 appears to have a better performance than the other algorithms. Algorithm AC-F4 is able to reach low values of p_D and comparable values of p_B at the same time. It is also able to reach slightly higher or comparable numbers of successfully finished sessions in a cell.

The proposed fuzzy based algorithm AC-F3 has comparable (or slightly worse) performance than the other algorithms.

Future work will consider more complex versions of fuzzy logic based algorithms. It would be also convenient to investigate the impact of inaccurate estimate of some parameters (for example: speed of UEs, cell load, etc.).

Acknowledgment

This contribution has been supported by the research program No. MSM 0021630513 "Advanced Electronic Communication Systems and Technologies" (ELCOM) and by the project of the GA CR No. 102/08/H027 "Advanced Methods, Structures and Components of Electronic Wireless Communication".

References

[1] ROMERO, J., SALLENT, O., AGUSTÍ, R., DÍAZ-GUERRA, M. *Radio Resources Management Strategies in UMTS.* New York: Wiley, 2005.

[2] AGUSTI, R., SALLENT, O., PEREZ, J., GORIA, P., MANGANI, N., VAILLANT, A. *First Report on the Evaluation of RRM Algorithms by Simulation*. [Online] 2002, Cited 2008-11-24. Available at: http://www.arrows-ist.upc.es/ .

[3] ELAYOUBI, S., CHAHED, T. Admission control in the downlink of WCDMA/UMTS. Wireless Systems and Mobility in Next Generation Internet. *Lecture Notes in Computer Science*, 2005, vol. 3427/2005, p. 136 – 151.

[4] LEVINE, D., AKYILDIZ, I., NAGHSHINEH, M. A resource estimation and call admission algorithm for wireless multimedia networks using the shadow cluster concept. In *IEEE/ACM Transactions on Networking*, 1997, vol. 5, no. 1.

[5] CAPONE, A., REDANA, S. I3E: A novel call admission control scheme for W-CDMA systems. *Wireless Personal Communication*, 2006, vol. 39, no. 1, p. 81 – 97.

[6] LIU, D., ZHANG, Y., HU, S. Call admission policies based on calculated power control setpoints in SIR-based power-controlled DS-CDMA cellular networks. *Wireless Networks,* July 2004, vol. 10, no. 4, p. 473 – 483.

[7] MALARKKAN, S., RAVICHANDRAN, V. Performance analysis of call admission control in WCDMA systems with adaptive multi class traffic based on fuzzy logic. In *IJCSNS International Journal of Computer Science and Network Security,* 2006, vol. 6, no. 11.

[8] CHANG, C.-J., KUO, L., CHEN, Y., SCHEN, S. Neural fuzzy call admission and rate controller for WCDMA cellular systems providing multirate services. In *Proceedings of the 2006 International Conference on Wireless Communications and Mobile Computing*. Vancouver (Canada), 2006, p. 383 – 388.

[9] KEJÍK, P., HANUS, S. Fuzzy logic based call admission control in UMTS system. In *CD: Proceedings of the 2009 1st International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic System Technology.* Aalborg (Denmark), 2009. p. 375 - 378.

[10] KEJÍK, P., HANUS, S. Comparison of fuzzy logic and genetic algorithm based admission control strategies for UMTS system. *Radioengineering,* 2010, vol. 19, no. 1, p. 6 – 10.

[11] KEJÍK, P., HANUS, S. Fuzzy logic based call admission control with user movement prediction for UMTS system. In *Proceedings of the 20th International Conference Radioelektronika 2010.* Brno (Czech Republic), 2010, p. 67 – 70.

[12] LO, J., BRITO, A., CORREIA, L., CORREIA, A. Simulation of call admission control, load control, handover and power control algorithms for enhanced UMTS. *SEACORN Project* [Online], Cited 2009-11-19. Available at http://seacorn.cs.ucy.ac.cy/-eumtssim/.

[13] KHOJA, J., AL-SHALASH, M., PRABHU, V. Dynamic system simulator for the modelling of CDMA systems. In *Proceedings of the International Mobility and Wireless Access Workshop*. Fort Worth (USA), 2002, p. 50 – 58.

[14] SOLDANI, D. *QoS Management in UMTS Terrestrial Radio Access FDD Networks*. Dissertation for the degree of Doctor of Science in Technology, Helsinki University of Technology, 2005.

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