Admission Control Techniques for UMTS System

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Abstract. *Universal mobile telecommunications system (UMTS) is one of the 3rd generation (3G) cell phone technologies. The capacity of UMTS is interference limited. Radio resources management (RRM) functions are therefore 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. An own UMTS simulation program and several versions of proposed admission control algorithms are presented in this paper. These algorithms are based on fuzzy logic and genetic algorithms. The performance of algorithms is verified via simulations.*

Keywords

UMTS, CDMA, admission control, fuzzy logic, genetic algorithms.

1. Introduction

Mobile systems, like GSM (Global System for Mobile communications) or UMTS (Universal Mobile Telecommunication System), have to deal with unpredictable traffic, varying radio channel conditions and also with mobility of users. CDMA (Code Division Multiple Access) systems (UMTS for example) do not have a fixed capacity (in contrast to GSM). Their capacity depends on the interference level in the system. It is denoted as soft capacity. A suitable version of admission control algorithm has to be therefore implemented. This algorithm has to deal with this varying capacity and has to ensure QoS (Quality of Service) of all sessions. The admission procedures have not been standardized, so the evolution and optimization or AC (Admission Control) is still in progress.

Admission control algorithm decides if 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 out. The main aims of admission control are: to maximize the number of sessions in cell (in the system), to minimize the number of blocked and dropped sessions, and to guarantee QoS of all existing sessions.

A number of admission control algorithms and approaches have been published in the literature. Some examples follow. There is an algorithms survey in [1]. Note that some approaches overlap, so the classification of algorithms is not unique. Some algorithms are number (capacity) based; see [1]. In this case, the overall system capacity is divided into several elements, which are handled by the algorithm. This method is, however, more suitable for 2nd generation systems like GSM. There is another group of algorithms which try to predict movement trajectories of users, [2], [3] for example. Examples of interference based algorithms can be found in [4], [5]. There are also some novel approaches, which use fuzzy logic or which are based on genetic algorithms. They use these techniques in order to deal with traffic uncertainty and user mobility. An example of fuzzy AC was introduced in [6]. 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 can be found in the literature. Genetic algorithm based AC approaches are inspired by evolutionary biology. These algorithms can be used for AC in a particular system, for example [8]. Genetic algorithms are also often used for intersystem AC, see [9], or they are used for other purposes, such as prediction, see [10].

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

2. Load Factor Based Algorithm

A simple load factor based algorithm (further denoted as **AC-L**) is simulated and compared with algorithms which are introduced below. This algorithm calculates the uplink load factor, η_{UL}, as defined in [1]:

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

where I is the interference ratio of other cells and own cell, K is the number of sessions in the cell, W is the chip rate (3.84 Mchip/s), $(E_b/N_0)_j$ is the energy per bit per noise power spectral density, R_j is the required bit rate, and $v_{f,j}$ is the voice activity factor of the j^{th} session. The η_{UL} value is compared with the decision thresholds. Slightly different thresholds levels are used for new/old and voice/data sessions in order to achieve a different priority for each session type. If the load factor value exceeds the threshold, the session will be dropped/rejected. The same principle is used in [11].

Note that this algorithm is used as a reference. Fuzzy logic based reference would be more suitable, but these algorithms (proposed in the literature below) are not specified in detail (some parameters and values are not specified). Therefore, it is not so easy (possible) to reproduce and to compare them. Chapter 3 can be used as an example. It is based on [6]. The paper [6] presents fuzzy rules and relative membership functions. However, many essential details are not specified in the article: the coefficients of membership functions (they have fundamental impact on the performance of the algorithm), mobility patterns of UEs (User Equipments), etc. Similar situation stands (for example) for [12].

3. Fuzzy Logic Based Algorithms

Fuzzy logic based algorithms (that are presented there) are partly (in general) based on [6]. There are three versions of fuzzy AC, which use different input variables. These variables are fuzzificated (processed with triangular membership functions). The input variables 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, N_{nu} – number of users in the neighborhood of the cell of interest, and $N_{nu\text{-}P}$ – predicted number of users, who will enter the cell of interest in 10 seconds. 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 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 term set for fuzzy rules: *strongly accepted* (SA), *accepted* (A), *weakly accepted* (WA), *weakly rejected* (WR), *rejected* (R) and *strongly rejected* (SR). In the end, there is a backward transformation which yields the final decision.

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

AC-F – this algorithm uses only three input variables: voice activity factor v_f, which enables distinguishing between voice and data sessions, speed of user SP, and total uplink load factor η_{UL}. This algorithm has 18 fuzzy rules as defined in Tab. 1 (except the "N_{nu} or $N_{nu\text{-}P}$" column).

AC-F2 – this algorithm uses four input variables: three of them are the same as in the AC-F case, the fourth is N_{nu} – the number of users (approaching the cell of interest) 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 defined in Tab. 1 and Tab. 2.

Rule	N_{nu} or $N_{nu\text{-}P}$	v_f	SP	η_{UL}	Decision
1	low	low	low	low	SA
2	low	low	low	medium	A
3	low	low	low	high	WA
4	low	low	medium	low	SA
5	low	low	medium	medium	WA
6	low	low	medium	high	WA
7	low	low	high	low	A
8	low	low	high	medium	WA
9	low	low	high	high	WR
10	low	high	low	low	SA
11	low	high	low	medium	A
12	low	high	low	high	WR
13	low	high	medium	low	A
14	low	high	medium	medium	WA
15	low	high	medium	high	WR
16	low	high	high	low	WA
17	low	high	high	medium	WA
18	low	high	high	high	R

Tab. 1. Fuzzy rules, part 1.

Rule	N_{nu} or $N_{nu\text{-}P}$	v_f	SP	η_{UL}	Decision
19	high	low	low	low	A
20	high	low	low	medium	WA
21	high	low	low	high	R
22	high	low	medium	low	A
23	high	low	medium	medium	R
24	high	low	medium	high	R
25	high	low	high	low	WA
26	high	low	high	medium	R
27	high	low	high	high	SR
28	high	high	low	low	A
29	high	high	low	medium	WA
30	high	high	low	high	SR
31	high	high	medium	low	WA
32	high	high	medium	medium	R
33	high	high	medium	high	SR
34	high	high	high	low	R
35	high	high	high	medium	R
36	high	high	high	high	SR

Tab. 2. Fuzzy rules, part 2.

AC-F3 – this algorithm uses four input variables: three of them are the same as in the AC-F case, the fourth is $N_{nu\text{-}P}$ – the weighted sum of two predicted numbers: the predicted number of users that will enter the cell of interest in 10 seconds without a change of movement trajectory, and the predicted number of users that will enter the cell of interest with a change of movement trajectory. The movement prediction uses a simple linear method (according to UMTS system model movement possibilities). This algorithm uses 36 fuzzy rules as defined in Tab. 1 and Tab. 2.

4. Genetic Algorithms

The AC problem is converted to genetic logic in such a way that sessions correspond to individual elements of the initial chromosome. The new generation consists of the initial chromosome and new chromosomes, which are generated by the mutation process (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 the selected chromosome.

Two AC algorithms were designed and simulated. They both have a similar structure, which is shown in Fig. 1. The current system state (number of new and old sessions) is transformed into the initial chromosome structure. A new generation is then generated and the best chromosome is chosen by using the fit function. The properties of this best chromosome are verified and if it exceeds some thresholds (it would cause overload situation, for example) it is replaced by the initial chromosome. This repeats for several times (generations). The final chosen chromosome structure is transformed into admission control decisions for the particular sessions.

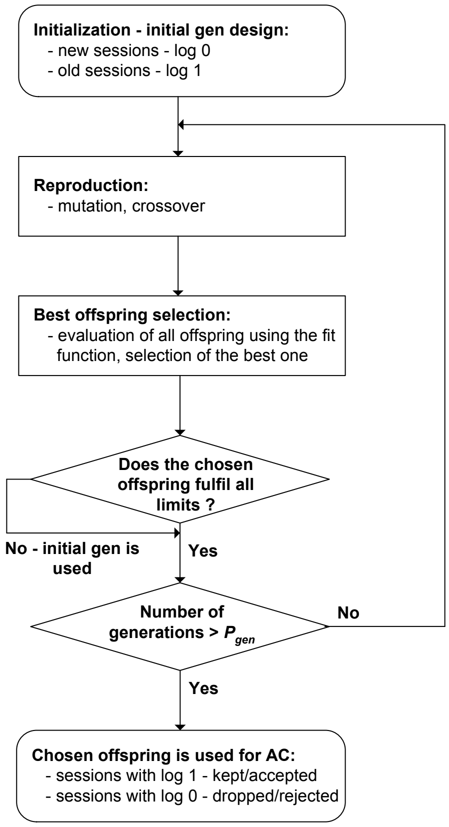

Fig. 1. Genetics based algorithm for admission control.

Two AC algorithms with slightly different fit functions were designed and simulated. These algorithms are inspired by [8] and [9]. Comparison of the original and the proposed algorithms is not a simple task again. Admission control algorithm, defined in [9], performs admission control between several network technologies: 3G (3rd Generation), WLAN (Wireless Local Area Network). However, the system model that is used in this paper simulates only UMTS (3G) system.

4.1 Multiple Fit Function Algorithm

The first algorithm (further denoted as **AC-G1**) has a fit function which consists of two parts. The algorithm calculates the fit function values $F_{F1,i}$ and $F_{F2,i}$ for all chromosomes (offspring):

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

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

where LF_{thr} is the load factor threshold level, $F_{F1,i}$ and $F_{F2,i}$ are the fit function values, $N_{new,i}$ is the number of accepted sessions, $N_{old,i}$ is the number of kept old sessions, LF_i is the uplink load factor value for i^{th} chromosome, $v_{f,j}$ is the voice activity factor of the j^{th} session, and a_1 and a_2 are constants. The algorithm chooses the chromosome for which $F_{F1,i}$ is minimal and $F_{F2,i}$ is maximal. This algorithm uses one generation of 30 offspring.

4.2 Simple Fit Function Algorithm

The second algorithm (further denoted as **AC-G2**, new version) has only one fit function. The algorithm calculates the fit function values $F_{c,i}$ for all chromosomes (offspring):

$$\begin{aligned} F_{c,i} = (&a_1 \cdot N_{n\_v,i} + a_2 \cdot N_{o\_v,i} \\ &+ a_3 \cdot N_{n\_d,i} + a_4 \cdot N_{o\_d,i}) \\ &\times f(LF_{thr}\text{-}LF_i) \end{aligned} \tag{4}$$

where $F_{c,i}$ is the fit function value, $N_{n\_v,i}$ is the number of accepted new voice sessions, $N_{o\_v,i}$ is the number of kept old voice sessions, $N_{n\_d,i}$ is the number of accepted new data sessions, $N_{o\_d,i}$ is the number of kept old data sessions for i^{th} chromosome. The f function processes the difference between LF_{thr} and LF_i. The other variables (a_1 - a_4) are constants. This algorithm uses two generations of 30 offspring.

5. System Model

There are already some simulation programs for CDMA systems. An example can be found in [13]. These programs are, however, often not free of charge, they are focused on the physical layer simulations or they are simply unavailable.

An own UMTS system model has therefore been created in MATLAB. The system model consists of 19 hexagonal cells of an 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. Session 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 types of session (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. Suburban scenario is considered. Walfish-Ikegami channel model is used. The UMTS model is shown in Fig. 2. The movement trajectories of several users are also shown there. The 7 cells in the center are used for the evaluation of algorithms. The other 12 cells (1st tier) simulate border conditions. All users (sessions) have the same demands: $E_b/N_0 = 7.5$ dB and $R = 12.2$ kbit/s. Two traffic classes, voice and data, with voice activity factors 0.5 or 1, were considered in all simulations. These two classes assume the same input data. The only difference is the voice activity factor value. Duration of sessions varies between 60 and 180 seconds. The maximum allowed load factor is 0.5, $I = 0.55$, see (1).

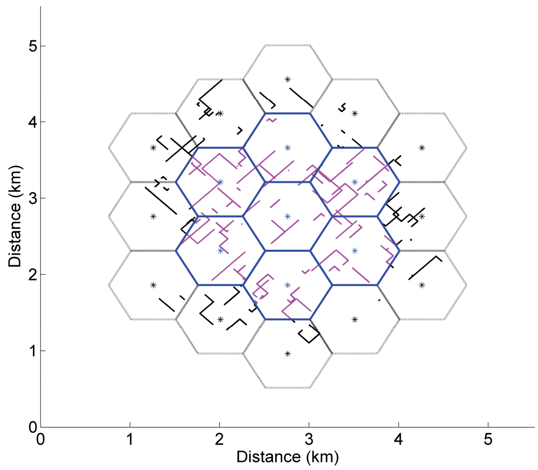

Fig. 2. System model.

6. 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 30 or 60 minutes (from the UMTS point of view). The results presented are averages from 5 to 10 simulations and correspond to the 7 cells in the center. The following figures show the relationship between the 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). These values are often used to compare the algorithms (see [8], [6] or [14]). Arrival frequency is considered for each cell separately.

Fig. 3 shows a comparison of several algorithms (fuzzy based, in particular) for voice sessions. The dropping probabilities for all algorithms (except AC-L) are almost equal to zero. The blocking probabilities of fuzzy logic based algorithms are lower (or slightly higher – in the case of AC-F3) than the blocking probability of AC-L.

Fig. 4 shows a comparison of several algorithms for data sessions. Voice sessions in Fig. 3 have a higher priority, so BP and DP in Fig. 4 reach slightly higher values. The dropping probabilities (in Fig. 4) for all algorithms are lower than DP for AC-L. This is quite important, because from the user's perspective, dropping out of an existing session is much more disturbing than rejection of a new session. The blocking probabilities of fuzzy logic based algorithms are higher than the blocking probability of AC-L (finding the trade-off is the key issue). The AC-F3 algorithm (with mobility prediction) enables achieving a slightly lower dropping probability than other fuzzy logic based algorithms. At the same time, it achieves a slightly higher blocking probability.

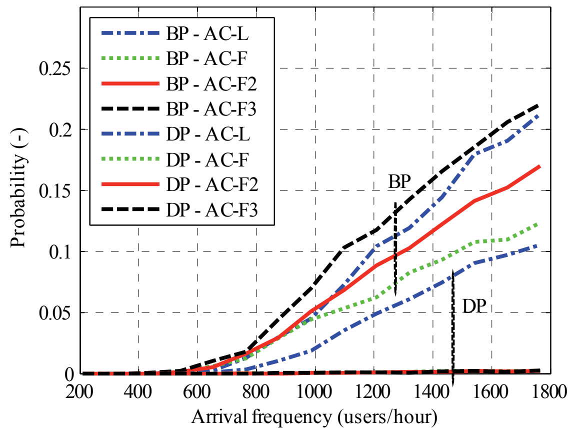

Fig. 3. Comparison of fuzzy AC algorithms for voice sessions.

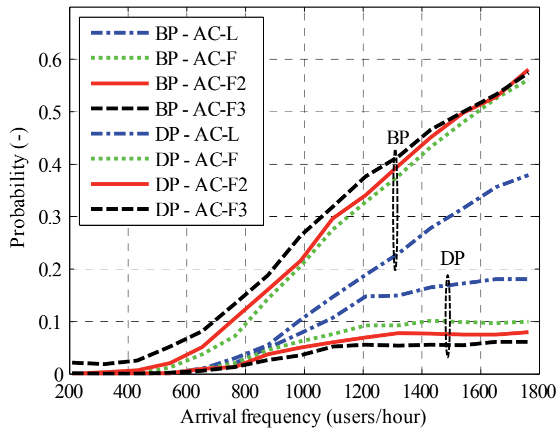

Fig. 4. Comparison of fuzzy AC algorithms for data sessions.

Fig. 5 shows a comparison of average (calculated from 7 cells in the center) load factor values for all algorithms. Note that the 0.5 value was set as the load factor maximum threshold. All fuzzy logic algorithms reach similar values of load factor. Since the load factor expresses the cell occupancy (network congestion), the number of users (cell occupancy) is comparable for all algorithms.

Fig. 6 shows a comparison of several algorithms for voice sessions. It compares (among others) both genetic based algorithms. The dropping probabilities for all algorithms (except AC-L) are almost equal to zero. The blocking probabilities of genetic algorithms are much higher than for AC-F.

Fig. 7 shows a comparison of several algorithms for data sessions. The dropping probabilities for genetic based algorithms are almost equal to zero. The blocking probabilities of genetic algorithms are lower than for AC-F. Blocking and dropping probabilities of genetic algorithms reach the similar values for voice and data sessions. AC-G2 algorithm reaches slightly lower blocking probability than AC-G1.

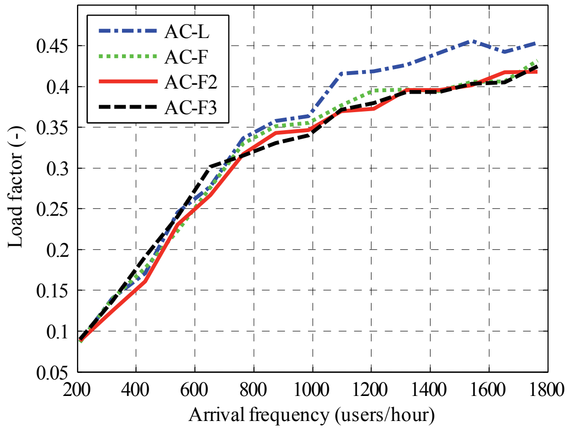

Fig. 5. Comparison of load factor values.

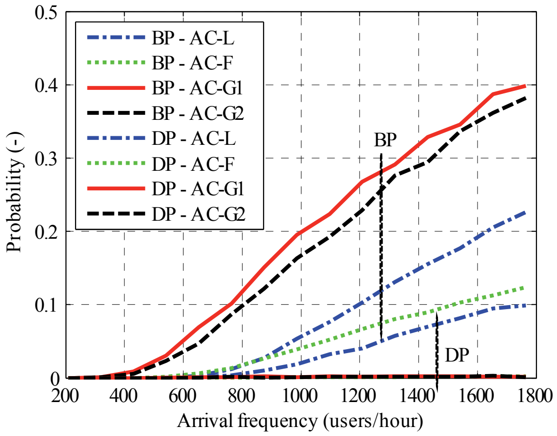

Fig. 6. Comparison of genetic AC algorithms for voice sessions.

Fig. 8 shows a comparison of average (calculated from 7 cells in the center) load factor values for all algorithms. All algorithms reach similar load factor values. It can be seen, that genetic algorithms have higher fluctuations of the load factor value than AC-L and AC-F. This causes fluctuations in the number of users in the system. Both genetic algorithms have a problematic and insensitive adjustment of performance. For example, it is not so easy to decrease the BP for voice sessions (Fig. 6).

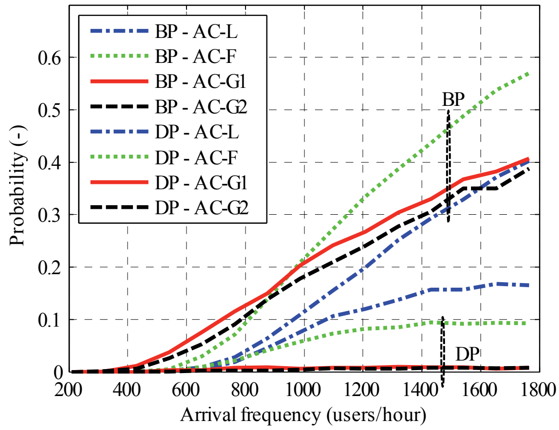

Fig. 7. Comparison of genetic AC algorithms for data sessions.

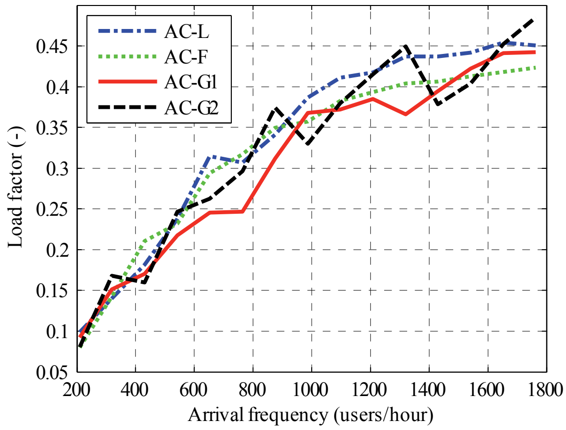

Fig. 8. Comparison of load factor values.

7. Conclusion

Admission control algorithms for CDMA systems were presented in this paper. Fuzzy logic based, load factor based and genetic algorithms were simulated in the UMTS simulation program, which was designed for this purpose. Fuzzy logic based and genetic algorithms have a better performance than load factor based algorithm that was used as a reference.

The genetic algorithms introduced are able to perform admission control, but they have some problematic properties, for example: high fluctuation of load factor value, fluctuations of the number of sessions in the cell or difficult setting of required values of blocking and dropping probabilities. The load factor fluctuations might increase interference level. If a congestion control was used, it would increase blocking and dropping probabilities. Both algorithms have high computational demands (simulations take a long time) Therefore, the proposed and simulated algorithms are not very suitable for admission control purposes.

The proposed fuzzy based algorithms appear to have a better performance than the proposed genetic algorithms. Three versions of fuzzy logic algorithms were simulated. The AC-F3 version appears to have the best performance (this corresponds with the fact that it uses a lot of exact information about the system). This algorithm is able to achieve the lowest values of dropping probability and it achieves only slightly higher values of blocking probability at the same time. Therefore, the AC-F3 algorithm can be regarded as the best one.

Future work will consider more complex versions of fuzzy logic based algorithms and genetic algorithms with other fit functions. The attention will be focused mainly on the fuzzy logic based algorithms with movement prediction of UEs.

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