

SUPPORTING FLEXIBLE NETWORK OPERATOR POLICIES IN EGPRS THROUGH ADMISSION CONTROL

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Many of the admission control strategies for cellular data networks proposed in the literature allow the network operator to use different policies, depending on the network load, the number of users from each quality of service class, *etc.* Each policy is applied in a certain region, the regions being separated by thresholds. Those approaches suffer from a lack of flexibility: when the operating conditions change, the values for the thresholds have to be re-calculated. Our work supports flexible and adaptable network operator policies, overcoming the drawbacks of the existing algorithms through a fuzzy logic based solution.

1. Introduction

General Packet Radio Service, or GPRS^{1, 2} is a packetized service implemented over GSM in order to support data transfer applications like e-mail, FTP, WWW or audio and video streaming. EGPRS (Enhanced GPRS⁴) is using the EDGE (Enhanced Data Rates for Global Evolution) technology in order to ensure higher data rates. The users of an (E)GPRS network have different quality of service (QoS) requirements, and the network tries to fulfill their demands, using efficient resource allocation strategies. The problem of resource allocation in a GPRS or EGPRS network can be split into two subproblems: admission control (AC), which comprises the techniques used to decide if to admit or not an user (a Mobile Node or MN) into the network, and transmission control (TC), consisting of the algorithms used to share the network resources between the connected MNs. While we have addressed the transmission control problem in our previous works (e.g.¹⁰), in this work we focus on the admission control problem.

In this work we demonstrate the flexibility and adaptability of the fuzzy logic AC algorithm that we have proposed in ⁸ and ⁹. Dini and Guglielmi ³ have developed a fuzzy logic AC algorithm for WCDMA cellular networks, but, as far as we know, we are the firsts to develop a fuzzy logic AC algorithm for GPRS/EGPRS.

The paper is organized as follows. Next section describes our fuzzy logic admission control algorithm for GPRS/EGPRS, section 3 presents the advantages of our AC algorithm in terms of flexibility and adaptability, section 4 contains a set of simulation results, and the paper ends with a section of conclusions.

2. Fuzzy logic for admission control

In ⁹ we have defined the network load such that it is proportional with the *sending delay* of uses' data, given that the scheduling algorithm used for TC is Weighted Round Robin (WRR). Sending delay is the delay encountered by MN's data across the radio interface (RLC/MAC level) and it has a decisive influence on the *total delay* of the MN's data in the EGPRS network. Then, having the desired values for the delays of different QoS class MNs is equivalent with keeping the network load below or close to a target value, called *target network load*.

We use a Fuzzy Logic Controller (FLC) in order to keep the network load close to the target network load. The inputs of the FLC are the *network load* and *MN's precedence*. The precedence is assigned by the network operator to a MN based on its QoS class and on its mobility characteristics (if it is a *handoff* MN or not, which means, if the MN comes from another cell or not).

The fuzzy rules are in the form: "IF *network load* is Low AND *MN's precedence* is High THEN *admission decision* is Strong Admit". The linguistic variables *network load* and *MN's precedence* have the terms *Low (L)*, *Medium (M)*, and *High (H)* with linear shapes, while the linguistic variable admission decision has the terms *Strong Reject (SR)*, *Weak Reject (WR)*, *Weak Admit (WA)* and *Strong Admit (SA)*. The fuzzy rules are such that for low network load, all MNs are admitted, while for medium load, the low precedence MNs are marginally rejected, medium precedence MNs are marginally admitted, and high precedence MNs are strongly admitted. If the network load is high, MNs are rejected, except the high precedence MNs, which are marginally admitted. For more details about the linguistic terms and the set of rules, please report to ⁹.

3. The flexibility and adaptability of our fuzzy admission control algorithm

Here we will describe the features of our AC algorithm, that can support flexible and adaptable network operator policies.

No sharp thresholds that separate the AC policies. The admission control algorithms for cellular data networks proposed in ⁶, ⁷ and ⁵ allow the network operator to use different policies for different regions. The regions can be based on the network load, like in ⁶, ⁷, or on the number of users from each QoS class, like in ⁵. The regions are separated by thresholds, and the main problem of those approaches is to determine or to assign values for the thresholds. Such approaches suffer by the fact that, when the input conditions are changed, the values for the thresholds should be re-calculated or re-assigned.

The fuzzy logic based AC solution that we have developed eliminates this drawback, by replacing the sharp values that separate the regions with fuzzy regions that overlap. In this way, *it is not necessary to determine or to assign precise values for the thresholds that separate the regions, giving more flexibility to the AC policies used by the network operators.* Moreover, the experience and expertise of the network operators can be directly transposed into fuzzy if-then rules, without the necessity to use complex mathematical models (e.g. Markov or queueing models). By its nature, fuzzy logic can tolerate imprecision, and hence it is more robust to changes in the inputs of the problem than other mathematical solutions.

On the fly changing of the target sending delay/network load. We use a function that maps the domain of the linguistic variable network load to the interval $[0, 63]$, which is its internal representation (in the FLC). In this way we obtain a very high flexibility and adaptability of our AC algorithm, because, if the network operator decides to change the value of the target network load, he has to change only the mapping function (which is a simple linear function), but the internal representation of the terms of the linguistic variables remains unchanged. This aspect can be crucial if a hardware implementation is used for the FLC, because the changing of the mapping function can be realized without interrupting the normal functioning of the FLC.

Low call dropping probability. The other input linguistic variable used in our AC algorithm, the MN's precedence, depends on the MN's QoS class and on the handoff status of the MN. If the MN is a handoff MN, the value of the precedence is higher than for a MN that starts its data transfer

session in the current cell. The high precedence MNs will be admitted even if the network load is high. Combined with the higher precedence assigned to handoff MNs, this means that the call dropping probability will be very low, or even zero. It is considered that for a user it is less desirable to interrupt a voice call or a data transfer in progress than to block a new call. Because of that, it is very important to obtain low values for the call dropping probability (the probability to drop a call or a data transfer session in progress).

On the fly change of admission strategy. The network operator can chose different AC strategies: for example, it can decide to admit all MNs that come from another cell, situation when the call dropping probability will be zero, or it can decide that, if the network load is high, to admit only the handoff MNs that belong to certain QoS classes, or even to admit the MNs from certain QoS classes no matter if they come from another cell or not. For example, if the QoS classes are based on users' subscription, the network operator can chose to admit always a call from a premium user. All those different strategies can be obtained without modifying the set of rules or the values of the linguistic variables, only by changing the function that assigns the value of the MN's precedence.

A general approach to ensure a proper balance between the values of call dropping and call blocking probability (probability to block a new call) is to use guard channels (to reserve resources in a cell for the MNs that come from the neighboring cells) and to combine resource reservation with an attempt to predict the cells that will be reached by the MN during its movement. Our approach could eliminate the necessity to reserve resources for the handoff MNs, treating in a unified way (through the precedence function) the handoff calls and the new calls. Nevertheless, the method that we propose can be used in combination with the guard channels method, maybe by keeping fewer channels in reserve for handoff MNs.

To conclude this section, we recall that the flexibility and adaptability of our fuzzy AC solutions relies on the following aspects:

- (1) the intrinsic flexibility and robustness offered by the fuzzy logic, its capability to tolerate changes in the inputs of the problem
- (2) the replacement of the sharp values of the thresholds that separate regions with different operator AC policies with overlapping fuzzy sets, eliminating in this way the necessity to determine precise values for the thresholds

- (3) the use of a mapping function between the values of the network load and the internal representation of the linguistic variable network load, which allows the change “on the fly” of the AC policy without interrupting the functioning of the FLC
- (4) the use of the MN’s precedence as the other input variable of the FLC. Being a conventional value, assigned by the network operator based on MN’s QoS class and on its mobility situation, it means that the network operator can easily change its admission control policy, realizing the desired balance between the importance of the QoS class of the MN and its mobility situation.

4. Simulation results

4.1. *The simulation model*

Our model was presented in ⁸ and it contains a module for each MN admitted in the cell. There is also a *user generator module*, which generates MNs at certain time intervals, each MN having a set of attributes, such as the QoS class, traffic characteristics, handoff, *etc.* After its creation, a MN attempts to enter into the system. The *admission controller* module decides if the MN is admitted or not, based on its QoS class, its handoff attribute, on the network load, *etc.* The admission controller models the PDP context activation process in a real GPRS cell. The data transfer is controlled, as in a real GPRS cell, by the *Packet Control Unit (PCU)*, that runs the scheduling algorithms used for resource allocation at the MAC/RLC level and it has a working period of 20 milliseconds, called block period.

4.2. *Simulation conditions*

In this work there are three QoS classes of MNs, based on their subscription: 10% of the MNs belong to QoS 3 class (premium), 80% to QoS 2 class (standard) and the remaining 10% belong to class QoS 1 (economy). The weights for MNs in the WRR algorithm used for TC are: $W_1 = 1$ for economy class MNs, $W_2 = 2$ for standard MNs and $W_3 = 4$ for premium MNs. Each MN generate 5 files in a session, each file having a length of 20 radio blocks. The file generation mode is interactive: a new file is generated only after the previous one has been sent. The user generation period is an exponentially distributed random variable having a mean value of 180ms. From the MNs generated during the simulation, 25% are handoff MNs, the rest of 75% starts a new data transfer session in the current cell. The

simulation stops after the creation of 4000 MNs. All the network resources are allocated for data transfer.

In this work we modify the target value for the average sending delay of premium users from 300 ms to 700 ms and we measure the call blocking probability for all classes of MNs, and the sending delay and the total delay for the QoS 3 class MNs.

MN's precedence is not changed here, being assigned such that all hand-off MNs will be accepted (hence, the call dropping probability for all the 3 QoS classes is zero). The precedence value is low to medium for QoS 1 MNs, medium for QoS 2 MNs and medium to high for QoS 3 MNs.

4.3. The results

Figure 1 presents the measured values for the average sending delay of QoS 3 class MNs when the desired sending delay has different values. It can be observed that the values of the sending delays oscillates around the target value.

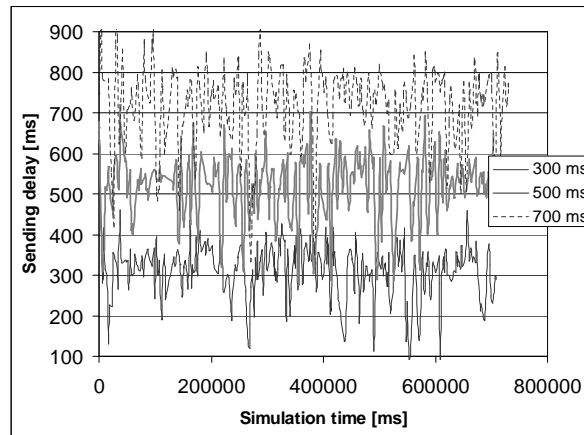


Figure 1. Measured sending delays for QoS 3 class MNs for target sending delays of 300 ms, 500 ms, and 700 ms.

Table 1 contains the mean values for the average sending delay and for the average total delay of all MNs from the QoS 3 class for the mentioned values of the target delay. It can be noticed that the mean value of the sending delay slightly exceeds the desired value in all situations, but the difference is small. For example, for a target sending delay of 500ms, the measured mean value of 534 ms is only 7% higher than the proposed value.

Table 1. Measured mean values for average delays for QoS 3 class users.

Target sending delay	Measured sending delay	Measured total delay
300	323	364
400	432	479
500	534	586
600	631	694
700	735	807

Table 2 shows the call blocking probabilities for all classes of MNs. It is important to note the QoS differentiation: QoS 3 class users have much smaller values for call blocking probability than QoS 2 users, the values for QoS 2 users being also smaller than for QoS 1 users. Only when the proposed network load is very low, compared to the user generation rate, the call blocking probability of QoS 3 class users is unacceptably high: the 0.12 value and even 0.6 value, but when the target delay is reasonable, the blocking probabilities have very good values (3% or less).

Table 2. Blocking probabilities for different target delays.

	QoS 1	QoS 2	QoS 3
300	0.61	0.27	0.12
400	0.64	0.28	0.06
500	0.71	0.27	0.03
600	0.73	0.24	0.01
700	0.68	0.23	0.01

In ⁹ we have compared the performance of the fuzzy AC algorithm (in terms of call blocking probabilities and delays for premium users) with non-fuzzy AC algorithms, based on thresholds, demonstrating the superiority of the fuzzy solution on those aspects too.

5. Conclusions

This paper demonstrates the flexibility and adaptability offered to the network operator by our admission control algorithm, compared to other solutions existing in the literature. The flexibility resides in the fact that the network operator can change very easy the desired values for the sending delay of the users from the most demanding QoS class. Also, the network operator can balance between the importance given to the QoS class versus

the mobility status of the user. In this way, it can be obtained the desired trade-off between the call dropping and call blocking probabilities of the AC algorithm. All those changes can be realized without interrupting the functioning of the fuzzy logic controller that implements the admission control algorithm.

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