

M-RATS: Mobile-based Radio Access Technology Selector for Heterogeneous Wireless Environment

Aleksandar Tudzarov and Toni Janevski, *Senior Member, IEEE*

Abstract — Wireless heterogeneous environments are a common reality today and will be so even more in the future. This paper is focused on providing a wireless access selection method for the future mobile terminals that will use naturally inspired algorithms for best network selection. The novel algorithm uses mobile terminal measurements from different radio access technologies within a given time window. The network selection is based on specified criteria, whose number can be increased as needed. Each criterion is modeled with a membership function associated with Fuzzy Logic controllers, which are optimized by using Particle Swarm Optimization. Each criterion is weighted, with the aim to assign the influence on the decision for a radio access network. Hence, our proposed algorithm implements past knowledge of the service performances of available wireless networks used by the mobile, to make a decision for network selection on given time intervals. The main contribution in the algorithm for wireless access network selection is in the usage of nature inspired algorithms, such as Particle Swarm Optimization – PSO, for optimization of Fuzzy Logic controllers, as well as usage of a Genetic Algorithm for optimization of decision making based on multi-criteria inputs. The simulation analysis has shown that the proposed algorithm gives a better probability of satisfied users compared to other existing wireless network selection algorithms.

Keywords — Fuzzy Logic, Genetic Algorithm, Optimization, Wireless Networks.

I. INTRODUCTION

NEXT generation of mobile networks will certainly include the presence of many wireless technologies, some of which exist nowadays, some will appear in the following years. In such heterogeneous environments it is very important to have intelligent mechanisms for access networks selection, and even more, for dynamic changing of wireless access networks. The chosen access network at a given time period should be able to satisfy user requirements for a certain service, as well as to be supported by wireless networks. Hence, radio network selection should incorporate the characteristics of the network. For example, it is different if we have a IEEE 802.11 wireless network or 3GPP mobile network (e.g., 3G, LTE etc.). New mobile terminals should have capabilities for alternative network selection or simultaneous network selection [1].

Aleksandar Tudzarov is with T-Mobile Macedonia, 1000 Skopje Macedonia, E-mail: aleksandar.tudzarov@telekom.mk.

Toni Janevski is a Full Professor at the Ss. Cyril and Methodius University, Faculty of Electrical Engineering and Information Technologies, Karpos 2 bb, 1000 Skopje, Macedonia, E-mail: tonij@feit.ukim.edu.mk.

One of the most important mechanisms for radio resources management in heterogeneous environment, regarding the Quality of Service (QoS), radio resource utilization and user satisfaction, is the mechanism for initial network access for a given connection. This mechanism is referred to as the initial choice of the radio access network and it consists of a procedure for radio resource management for an optimal choice of radio access network.

The main goal in this paper is to create a new mechanism for initial network access selection, which will provide statistically better results from other existing mechanism, by using intelligent decision making mechanisms. Better results mean better user satisfaction from a given service as well as QoS and operator demands. Certainly, the demands from the network operators, service providers and users can be contrary in certain scenarios. However, with the increasing processing power and memory of mobile terminals, they will become capable of doing much more data storage and processing, and hence this foreseen development of consumer equipment can be used for putting more intelligence in the radio access network selection. Such an approach is outlined in this paper.

The main contribution of this paper is the development of an algorithm that enhances the way the Fuzzy Logic Controllers are built in a manner that optimizes (FL) decision, generated and optimized by PSO (Particle Swarm Optimization) algorithms.

Access network selection based on Fuzzy Logic and Genetic Algorithms is proven to provide better results and to be more robust when compared to random-based selection algorithms [2]. Furthermore, the usage of nature inspired algorithms like Particle Swarm Optimization (PSO) for optimization of Fuzzy Logic Controllers is analyzed in [3], [4], [5] and Multi-Criteria Decision Making systems are used in order to incorporate the past knowledge of wireless networks behavior. All of these algorithms are generally based on learning capabilities provided from measured data, and therefore providing historical measurements of network related data is one of the main system elements, [6], [7], [8], and [9]. However, there is a need for analysis to determine the proper size of history data buffer.

The paper is organized as follows. In the next chapter we describe the network selection algorithm. Section III covers initial history buffer size analysis, while simulation results are given in Section IV. Finally, Section V concludes the paper.

II. WIRELESS NETWORK SELECTION ALGORITHM

In this section we provide a description of a novel algorithm for radio networks selection in heterogeneous environment, which is created using biologically inspired algorithms. The algorithm consists of four building components as shown in Fig.1. The first component or module is a set of parallel Fuzzy Logic (FL) controllers, which has as input the measurements data for different selection criteria, including user requirements, QoS requirements, service policies, as well as radio link conditions in different wireless technologies present in the user's area. The second module is a multi-criteria decision mechanism algorithm, which uses as inputs the outputs of the FL controllers from the first module. The third module is a Genetic Algorithm, which does optimization of weighting coefficients of different input criteria. That is, each criterion can have a different weight, which depends upon the assumption of its impact on the best network selection process (i.e. the decision). The fourth module is Particle Swarm Optimization (PSO) [5], [6], a mechanism which dynamically modifies the functions of FL controllers in the first module (shown in Fig. 1).

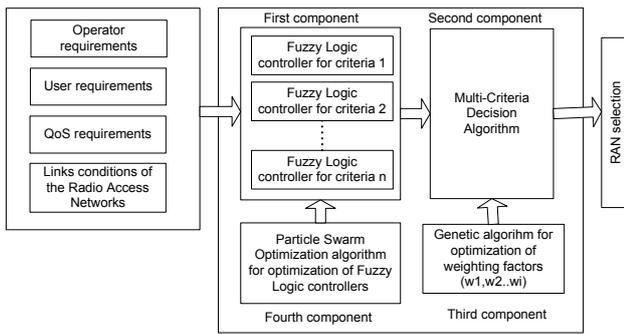


Fig. 1. Radio Access Network selection scheme.

This system is not limited only to access network selection, but it can also be used for solving other optimization problems as well. The proposed scheme in this paper is targeted for wireless networks selection in heterogeneous environment, so the decision as an outcome should select the best wireless network (among all present at the moment for a given user) or rank in a certain order all present radio access networks.

The initial phase of this scheme is data collection, by using measurement of the parameters of the Radio Access Networks (RAN). This process includes operator and user preferences. For instance, such measured parameters from each network are a received signal power and signal to noise ratio on a link layer. Then, additional preferences can be service cost over a given RAN, which depends upon Service Level Agreements (SLA) between the user and each of the wireless networks. i.e., depends upon service policies.

The proposed scheme assumes that a mobile terminal has enough processing power, memory capacity and battery support, so it can provide functionalities described above. Considering the Moore's law for computers, where

we can today place mobile terminals as well, one may assume that near the year 2020 mobile phones will have processing capabilities of today's power computers. So, the mobile phone can operate a database, do processing on given time intervals using measurements data from a given timeframe in the past.

III. INITIAL HISTORY BUFFER SIZE

A crucial part of selection mechanism in this terminal-controlled scenario is providing adequate data as an initial training sequence of Artificial Intelligence (AI) algorithms in the solving scheme. There are several possibilities to achieve this goal. Data can be provided by the network in a loosely-coupled scenario considering operator assisted terminal-controlled scenario, or by imposing a training period in the terminal itself considering a pure terminal-controlled scenario. Nevertheless, the quantity of historical data that have to be included in the initial phase of training of AI algorithms must be determined.

In order to define the initial buffer size, several simulations have been conducted with different sizes of initial buffer and a comparative analysis has been made. As can be seen in Fig. 2, the best buffer size can be defined in borders of 300- 400 historical intervals.

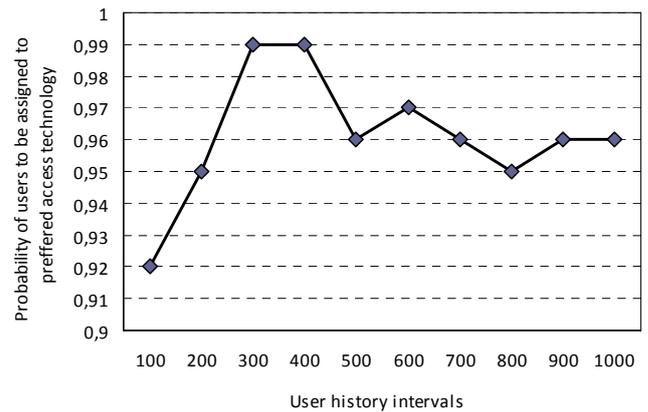


Fig 2. Initial buffer size dependency.

History intervals as shown in Fig. 2 are time periods between subsequent measurements of the RATs parameters of the mobile terminals as well as the snapshot of user and service network demands in that period of time. They present the most recent history of the user activity as well as user personal and user service demands from the network.

IV. SIMULATION ANALYSIS

For the purpose of simulation analysis we have used the following mobility model, which provides randomness for user mobility. Each mobile terminal has a velocity calculated according to the following:

$$v_i = v_{i-1} * C_v + \sqrt{1 - C_v^2} * v_{mean} * N ; \quad (1)$$

where v_i is the user speed [m/s]. C_v is the correlation of the velocity between time steps. It depends on both a_{mean} that is the mean acceleration of the mobile user and v_{mean}

which is the mean velocity of mobile user. C_v is calculated as:

$$C_v = \left(\frac{-dt * a_{mean}}{v_{mean}} \right) \quad (2)$$

where N is a Rayleigh distributed magnitude with mean 1 and a random direction. v_{mean} is the mean speed of mobiles. v_{mean} has been set to 10 km/h and a_{mean} has been set to 1 km/h², which are typical values for urban environment. Fig. 3 shows the users, in marked spots, over the simulated environment. Four types of services are considered in the simulation and they are equally distributed among the users, the voice calls, the low bit rate real-time video telephony, the high bit rate video, and the non-real-time data traffic.

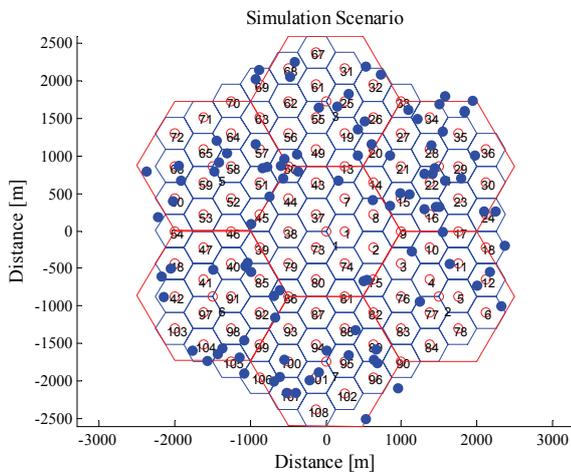


Fig.3. Simulation Scenario.

Further, we need to model the four types of services used in the simulation analysis in the following part of this paper. Each of the four service types is described and defined by a requested bandwidth (in bps) and latency (in ms). The first service type is defined with a lower bandwidth (data rate) and lower latency, because it includes telephony services. The second service type is defined with a higher average data rate and relatively small latency, and it is targeted to video conferencing service. The third service type is video streaming, which requires a higher bandwidth per connection, but can accommodate higher latencies compared to telephony. The last one, the fourth service type, models non-real time services, such as web and email, and it is defined with fairly higher data rates (since these services use TCP, which consumes all the available bandwidth end to end). All four service types, for the purpose of simulation analysis, are defined with the following pairs of values (bandwidth, latency), respectively:

$$[service_latency (ms), service_bandwidth (kbps)] \\ \{[100, 64]; [200, 128]; [400, 256]; [800, 512]\} \quad (3)$$

During the simulation for a given number of active users N , each user is randomly assigned to one of the four types of services defined above. For each service, the

connection duration is modeled with the Poisson process. The mean holding time is set to 50 seconds, based on comparative measurements. For the purpose of simulation, Fuzzy logic controllers were designed to fit the FL controller parallel scheme given in Fig.1. During this design process a Particle Swarm Optimization (PSO) algorithm is used in order to optimize FLC, where membership functions are tuned to the measured signal strengths and wanted user behavior. Considering that two RAT technologies (3G network and WLAN) are analyzed in the scenario, we have two outputs from each FL controller. Outputs from the FL controller present the so-called degree of membership of each RAT scaled to input variables regarding Fuzzy Logic rules.

In our simulations the PSO algorithm uses a swarm size of 50 particles, while the maximum number of iterations is set to 50. Evaluation function is based on minimizing the mean square error (MSE) while comparing it to the expected predefined values. Expected values are defined as values taken from a human decision that would be made if access network selection were done by a human for every point in time and separately for each analyzed criterion [5]. Considering the evaluation done in section III, for Initial data buffer in the simulations we use a range of 300 historical intervals. This means that in the scenario a training period of 300 time slots (intervals) is imposed and initial data gathered during this period are stored. These data are then used in GA for acquiring the first set of weights that will be imposed in the decision done using the multi-criteria approach. After this initial moment, in every other step, data from the buffer are constantly refreshed with new measured data. This is done in a FIFO manner, the first input data from a training period are replaced and pushed out from the buffer, all other data are moved one place backwards and newly measured data are placed on the last place. During this process a buffer data size remains the same 300 historical measured data, so we have a certain time window for data collection in the mobile terminal, obtained from different present RATs (in this case, there are two RATs, i.e., 3G and WLAN).

A Genetic Algorithm (GA) is used as the optimization method for determination of appropriate values for the weights of different criteria in a multi-criteria decision making approach. The goal of the GA is to optimize the weights upon locations of the users and their demands to the network (which is dependent upon service type initiated by each user). With this approach, the GA can assign a weighting coefficient to provide the best user satisfaction. In our analysis we use 200 iterations, which is based on the fact that there is no improvement after successive 100 generations in most cases.

We have compared in Fig.4 the proposed algorithm with almost all other relevant algorithms. The worst results are obtained with mobility based Radio Resource Management (RRM), while the best results are obtained with our proposed algorithm which includes FL optimized with PSO and GA for Multi-Criteria Decision Making (MCDM).

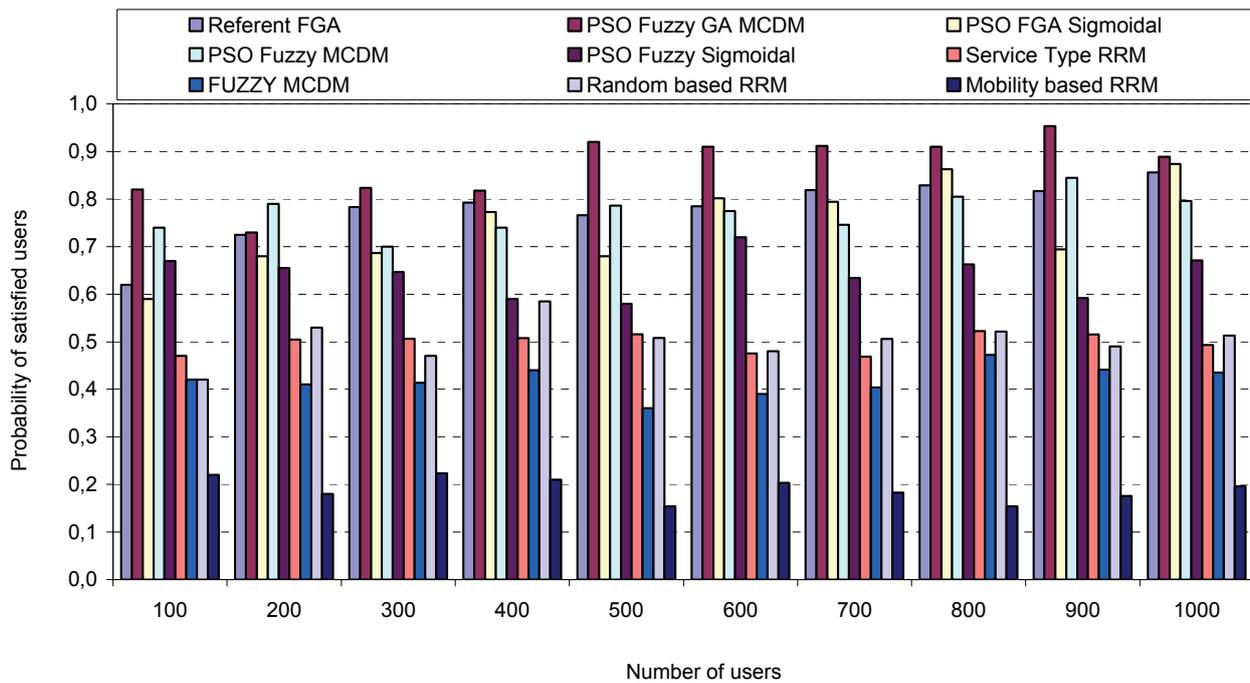


Fig.4. Probability of satisfied users.

In Fig.4, FGA stands for Fuzzy-logic Genetic Algorithm, while Sigmoidal refers to membership functions for FL controllers, which are trapezoidal or triangular in other cases. Several runs of simulation have been carried out for different numbers of users in simulation scenario (from 100 to 1000 users), and the results show the probability that a user is attached to RAT which provides the best user satisfaction regarding the bandwidth and latency requirement for each service type. The proposed wireless access selection algorithm in this paper achieves around 40% enhancement compared to service-based and random-based selection algorithms. Also, it also shows better results than all other wireless network selection algorithms, which is more noticeable when the number of data samples (users) is higher.

V. CONCLUSION

In this paper we have introduced a novel intelligent algorithm M-RATS, which works on the mobile terminal side and provides best Radio Access Technology Selection by using naturally inspired algorithms. In particular, it is based on different criteria, which are controlled by using Fuzzy Logic Controllers (FLC), optimized with Particle Swarm Optimization (PSO) algorithm. The outputs of FLCs (different FLCs are used for different wireless networks) are inputs to Multi-Criteria Decision Making module, which is controlled by Genetic Algorithm with different weights assigned to different criteria. In fact, M-RATS algorithm uses artificial intelligence mechanisms by learning the behavior of the user and the RATs. The scenario analyzed in this paper uses network-assisted M-RATS. It has been compared to 8 other RAT selection algorithms in the same heterogeneous environment and has shown the best results regarding the user satisfaction from the RAT selection.

Finally, it is also possible to maintain a database within the mobile terminal, which will keep records of RATs, services and user behavior, and use such data for making RAT selection or a change on given time intervals, where such intervals are also a subject to debate in the future.

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