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- SADAŠNJOST I BUDUĆNOST -

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P R E D G O V O R

Poštovani učesnici i čitaoci,

Iza nas je jedna od uspješnijih konferencija "INFORMACIONE TEHNOLOGIJE – sadašnjost i budućnost" (IT'17) održana od 27. februara do 04. marta 2017. godine na Žabljaku, a ovo je zbornik radova. Programski odbor i recenzentski tim je izvršio selekciju kvalitetnih radova koji su prezentovani na konferenciji i publikovani ovdje, a najbolji će biti prošireni i objavljeni u časopisu Elektrotehničkog fakulteta Univerziteta Crne Gore u Podgorici ("ETF Journal of Electrical Engineering"). Zahvaljujući vama, dragi autori, iz godine u godinu podižemo kvalitet radova koji su sadržani u ovom zborniku, a prvi put smo sponizorisni i od strane IEEE asocijacije.

Pred vama su 72 autorska rada, prezentovana u 11 sekcija, i sažeci 5 predavanja po pozivu koja su realizovana u plenarnom dijelu programa. Radovi, teme i predavači su birani po kvalitetu kao i tematici sadržaja kako bi konferencija razmatrala aktuelne momente u razvoju ICT-a, a šira stručna javnost i svi zainteresovani su bili u prilici da prate dešavanja na Skupu preko videolinka.

Organizator je registrovao oko 170 učesnika širom regiona i Evrope, 100 studenata sa sva 3 crnogorska univerziteta i veliki broj prisutnih i online posjetilaca (po našoj procjeni oko 100). Konferencija je bila dobro medijski ispraćena i podržana od državnih institucija, lokalne samouprave i velikog broja ICT kompanija.

Konačno, i Durmitor je svojim čarima i vremenskim uslovima omogućio svim učesnicima da u potpunosti uživaju u njegovim ljepotama i pružio nezoboravne utiske prirode ovog kraja. Ono što se moglo osjetiti je jedan zajednički duh i sinergija koje su nas vezivali svih 5 dana i nadahnuli novom snagom i voljom za radom i budućim druženjima. Organizator se nada da svi učesnici dijele naše mišljenje da je ovo jedan od najboljih (ako ne najbolji) IT u posljednjih 10 godina. To nas obavezuje da sljedeći IT bude bar kao ovaj, uz dodatni kvalitet, nove teme, nove ljude, nove akcije i isti duh konferencije.

Sve detalje o ovom, prošlim i narednom skupu možete naći na web adresi konferencoije www.it.ac.me.

Prof. dr Božo Krstajić

SADRŽAJ

PREDAVANJA PO POZIVU

AUTORSKI RADOVI

Client based selection algorithm for Hybrid Wireless Networks

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***Abstract* — This paper is focused on development of algorithm for network selection in Hybrid wireless environment based on user-side perspective. Client terminal in the proposed hybrid access design has possibility to change the Radio Access Technology - RAT based on different criteria. The selection of the RAT is performed by the wireless terminal using the user agent algorithm for decision making based on the experience from the performance measurements of RATs conducted by the client terminal in the past. We present results of simulation analysis of the proposed intelligent wireless RAT selection algorithm on the client-side for scenario with basic RAT technologies, WWAN and WLAN. The results showed that the presented algorithm gives better results compared to the traditional RAT selection algorithms and as such can play valuable role in designing of RAT selection algorithms for Next Generation Networks.**

***Keywords* — Hybrid wireless networks, Quality of Service (QoS), Fuzzy Logic, Particle Swarm Optimization, MCDM.**

I. INTRODUCTION

In this paper we provide complete functional overview of selection based algorithms in Hybrid wireless networks. The main assumption in our approach is that the user terminal will have the possibility to access different RATs (Radio Access Technologies) from single mobile device at the same time, which is reality even today. Then, we propose adding of new network nodes for policy-based routing between IP tunnels to mobile user via different RATs, which are placed in service stratum of the network. The focus in this paper is placed on designing of network selection algorithm that will offer the best selection mechanism for appropriate wireless network according to user preferences, network conditions and other input parameters.

Usually access network selection algorithms that can be found in literature are concentrated on single selection criteria with focus on radio signal strength (RSS) thresholds for each RAT as criteria upon which selection of RAT is based. Mobile terminal compares the RSS of analyzed RAT with the signal thresholds and decides if it should start handoff procedure. The ways that these algorithms operate have certain limitation regarding its reaction to the changing environment conditions.

Usually this algorithm does not take in consideration different viewpoints and goals of the operators, users, and QoS requirements which make them inefficient for a multicriteria problem such as access network selection problem.

Access network selection based on Fuzzy Logic is proven to provide better results and to be more robust when compared to random-based selection algorithms. Furthermore usage of artificial intelligence algorithms inspired by nature for optimization of Fuzzy Logic Controllers (FLC) and Multi-Criteria Decision Making systems (MCDM) are used in order to incorporate past knowledge of wireless networks behavior. All of these algorithms are generally based on learning capabilities provided from measured data. The main contribution of this paper is the developments of algorithm that enhances the way the Fuzzy Logic Controllers are build in a manner that optimizes Fuzzy Logic (FL) decision, generated and optimized by PSO (Particle Swarm Optimization) nature inspired algorithms.

The remainder of this article is structured as follows. Section 2 provides overview of defined radio selector architecture in the Hybrid architecture. Section 3 provides simulation results of proposed selector architecture. Finally, Section 4 concludes the paper.

II. RADIO ACCESS TECHNOLOGY SELECTOR

In following part of the text we provide description of a novel algorithm for radio networks selection in hybrid wireless environment, which is created using artificial intelligence inspired algorithms.

The algorithm consists of three building components as shown in Figure 1. First component or module is a set of parallel Fuzzy Logic (FL) controllers that are using input data gathered from the measurements for different selection criteria, including: user requirements, QoS requirements, service policies, as well as radio link conditions in different wireless technologies.

The second module is multi-criteria decision mechanism algorithm, which uses as inputs the outputs of the FL controllers form the first module. That is, each criterion can have different weight, which depends upon the assumption of its impact on the best network selection process (i.e. the decision).

The Third module is Particle Swarm Optimization (PSO) [1], [2], [3] mechanism which dynamically modifies the functions of Fuzzy Logic controllers in the first module (shown in Figure 1). This algorithm is used to develop adaptive, flexible, and scalable Network Selection system that can utilize hybrid parallel FL decision-making systems and MCDM systems. FL systems are used in this algorithm in order to introduce flexibility and to deal with

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uncertainty that arises from constant changes of radio conditions that impacts radio technologies as well as to be able to use selection mechanism based on different types of inputs that are normally incomparable due to their incompatibility by the nature and behavior. By introducing FL in the selection algorithm possibility for using of different input parameters by their nature arises and increases flexibility and overall usability of the algorithm.

Considering this fact, input variables are in practice normalized in dimensionless values which magnitude represents their impact in selection criteria for each RAT. All of the outputs are normalized and receive values from [0 to 1] interval. In order to simplify implementation of FL and to give some clearance parallel FLC are used. Implementation of Parallel FLC reduces the complexity of inference rules used in the fuzzy-based solutions. Furthermore use of nature inspired algorithms like PSO – "Particle Swarm Optimization" for optimization of FLC and MCDM systems in order to incorporate past knowledge of network behaviors in these systems.

Proposed scheme to solve the network selection problem as well as Software assistant (SA) based on the proposed scheme in coexisted WWAN (Wireless Broadband Technologies 3G/4G) – WLAN (802.11 b/g/n/ac) based systems is described in Simulation bellow. [5], [6], [7], [8]

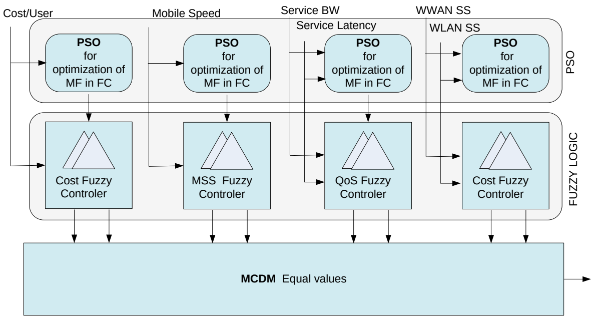

Fig.1. Network selection scheme

The selection procedure can be divided into three phases, initiation phase, decision phase, and execution phase. The objective of the initiation phase is to recognize the need for selection change and subsequently initiate it and find out the required information and measurements for the decision phase. In the decision phase, a comparison of the information and the measurements calculated from a variety of sources including networks measurements, QoS requirements, user preferences, and operator policies is done. This comparison leads to the identification of the best available Wireless Network according to the defined performance evaluation metrics. The scheme decision phase can be described in more detail as follows:

(i) The heterogeneous wireless environment contains up to n RATs (RAT1, RAT2... RATn) and the framework has to select the most promising one or to rank the RATs according to their suitability.

(ii) The selection depends on multiple criteria up to i (c1, c2, . . . , ci). Different type of criteria can be measured from different sources to cover the different viewpoints of the users, the operators, the applications, and the network conditions. Each criterion is measured then passed to its FL-based control subsystem in the first component.

(iii) Using the PSO system FLC optimization of Fuzzy MF is conducted based on measured inputs and wanted output behavior in order to create most suitable FLC that corresponds to input variable ranges and values. Optimization is conducted by minimizing of MSE between wanted and calculated outputs from Fuzzy Controller that is being optimized.

(iv) Every FL-based subsystem produced by PSO gives an initial score for each RAT that reflects the suitability of that RAT according the FL subsystem criterion. The different sets of scores (d_1, d_2. . . d_i) are sent to the MCDM in the third component.

(v) Using the initial scores coming from the first component and the weights that are assigned manually (they are equal for each FLC input) the MCDM will select the most promising access network or will rank the available RATs according to their suitability.

Proposed algorithm utilizes the advantages of parallel FL control, PSO optimization and MCDM, scheme is presented on Figure1.

The idea of the parallel FLC reduces the complexity of the inference rules used in the fuzzy-based solutions. Parameters of FLC that have to be considered while constructing the fuzzy logic are shape of Membership Functions (MF) and type of fuzzy inference system (FIS). In general there are two types of FIS which main difference are in aggregation and defuzzification process (Sugeno & Mamadani). In this work after short analyzes it is determined that it would be best if FLC are based on Mamadani FIS and triangular MF.

Particle swarm optimization (PSO) is a population based stochastic optimization technique inspired by social behavior of bird flocking or fish schooling. The system is initialized with a population of random solutions and searches for optima by updating generations.

Network selection problem is a multicriteria problem by nature, therefore flexible and complementary network selection multicriteria mechanism have to be used in order to provide a solution that can cope with the different viewpoints and goals. [4] Network selection MCDM solution enhanced version of simple multiattribute rating technique (SMART) has been used. SMART is one of the simplest and most efficient MCDM methods. The ranking value xj of alternative Aj is obtained simply as the weighted algebraic mean of the utility values associated with it, that is, a_{ij} according to (1):

$$X_j = \frac{\sum_{i=1}^{m} w_i a_{ij}}{\sum_{i=1}^{m} w_{ij}}, \quad j = 1,2,\ldots,n \qquad (1)$$

SMART employs relatively uncomplicated and straightforward manipulation method, which makes it stronger and easier to use in a hybrid and more complex models such as the proposed one in this paper. In proposed algorithm, there are two alternatives for the MCDM, one is a WWAN based network and the other is a WLAN based network. The input criteria of the MCDM are the outputs of the FL-based control subsystems in the first component. Weights W_i for criteria i are assigned to reflect their relative importance. The criteria with more importance to the operator and user can be assigned higher weight. Since all the outputs of FL subsystems are in the range [0, 1], there is no need to scale the criteria performance against alternatives, and there for all weights in this case are set to equal values. The ranking value of WWAN network X_{wwan} and the ranking value of WLAN network X_{wlan} can be calculated as follows:

$$x_{wwan} = \frac{MSS_{c1}*W_v + RSS_{c1}*W_s + STT_{c1}*W_t + UPP_{c1}*W_u}{TW}$$

$$x_{wlan} = \frac{MSS_{c2}*W_v + RSS_{c2}*W_s + STT_{c2}*W_t + UPP_{c2}*W_u}{TW} \quad (2)$$

where Wv is the assigned weight for the mobile station speed criteria. Ws is the assigned weight for the received signal strength criteria. Wt is the assigned weight for the service type criteria. Wu is the assigned weight for the user preferred price criteria. TW is the total weight and is calculated using:

$$TW = Wv + Ws + Wt + Wu. \quad (3)$$

The weights of the input criteria {Wv, Ws, Wt, Wu} as previously mentioned are set to equal values (0,25)

III. Simulation of Selector Model

Proposed selection algorithm is evaluated using the simulation approach. MATLAB mathematical software and a set of functions called RUNE [9] "RUdimentary Network Emulator" have been used for the simulation.

The system model considers the coexistence of WWAN network with seven macro cells with omnidirectional antenna and cell radius = 1000 m and a WLAN network with hundred and eight microcells with omnidirectional antenna and cell radius = 250 m. In the system environment, each mobile has a velocity and is moved with a random distance and a random direction at defined time steps. The velocity is a vector quantity with magnitude and direction. The velocity of the i-th mobile is updated according to (4);

$$v_i = v_{i-1} * P + \sqrt{1-P^2} * v_{mean} * X \quad (4)$$

Where v_i is the complex speed [m/s]. P 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 mean velocity of mobile user. P is calculated according equation (5):

$$P = \left(\frac{-dt * a_{mean}}{v_{mean}} \right) \quad (5)$$

X is Rayleigh distributed magnitude with mean 1 and a random direction. v_{mean} is the mean speed of mobiles. v_{mean}, was set to 10 km/h and a_{mean} has been set to 1 km/h2.

Four types of services are considered in the simulation and they are equally distributed among the users: voice calls, low bit rate real-time video telephony, high bit rate video and the nonreal-time data traffic. N mobile users are created and they are randomly distributed among the defined service types.

In general their requirements from the wireless network are simulated as pair of values defined as: **[Latency, Bandwidth]**. In that sense following 4 pairs were considered {[100,64]; [200,128]; [400,256]; [800,512]}.

The traffic is modeled according to Poisson process. The main holding time is assumed to be 50 seconds. For the purpose of simulation FLC where designed that fits the FLC parallel scheme. Considering that two RAT technologies are analyzed in the scenario two outputs from every FLC are taken. Outputs from the FLC present degree of membership of each RAT scaled to input variables regarding FL rules. Taking into account that most of ANS algorithm are based on Radio Signal Strength and that this parameter has the biggest impact on final decision in ANS, special Particle Swarm Optimization (PSO) algorithm described above is used in order to produce FLC which membership function are tuned to measured signal strengths from simulation.

PSO algorithms uses Swarm size of 50 particles and maximum number of iteration = 50. Evaluation function is based on minimizing the mean square error (MSE) comparing to expected predefined values. Expected values are defined as values taken from humanly decision that would be made if access network selection is done by human for every point in time and separately for each analyzed criteria.

This subsection shows some simulation results and compares the performance of proposed solution to two different reference ANS (Access network selection) algorithms.

The first algorithm is a service-type based selection algorithm where high bit services with low propagation delay requirements are sent to the WLAN and the low bit rate services with the high propagation delay requirements are sent to the WWAN. The second algorithm is a random-based selection algorithm where the users are assigned randomly to the two networks. All solutions have been simulated, evaluated, and compared for the same objective optimization and that is to maximize the percentage of assigned to the networks with stronger signal strength (Pq). Several runs of simulation have been carried out for different number of users in simulation scenario (from 100 to 1000 with step of 100). Results are given on Figure2 and in Table 1.

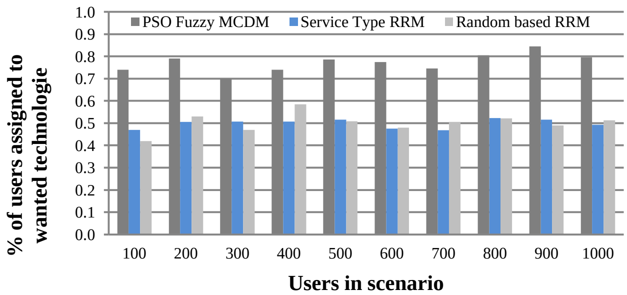

Fig. 2. Percentage of satisfied users

TABLE 1: PERCENTAG OF SATISFIED USERS

Nr. Users	PSO-Fuzzy MCDM ANS	Service Type based ANS	Random based ANS
100	0,740	0,470	0,420
200	0,790	0,505	0,530
300	0,700	0,507	0,470
400	0,740	0,508	0,585
500	0,786	0,516	0,508
600	0,775	0,475	0,480
700	0,746	0,469	0,506
800	0,805	0,523	0,521
900	0,844	0,516	0,490
1000	0,796	0,493	0,513

For example, with 900 users in the scenario Pq for proposed algorithm is 0,844 that means that 84% of the users are assigned to RAT with better signal strength and by that means with better QoS, while in that same scenario reference algorithms can achieve Pq factor of around 50%. In average, proposed solution achieves around 27% enhancement over the random-based selection algorithm.

IV. CONCLUSION

A novel scheme to solve the network selection problem has been presented in this paper. The scheme can cope with the different and contrast view points and goals of the operator and users. The proposed scheme has been used to present and design a multicriteria network selection solution that considered the user, the QoS, and the operator view points. The simulation results show that the proposed solution has a better and more robust performance over the reference solutions.

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