A Single Hidden Layered Fuzzy Back propagation Algorithm for Joint Radio Resource Management in Radio Access Systems

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Abstract— **In this paper, we propose a single hidden layered fuzzy neural algorithm, which is able to provide a better quality of service constraints in a multi-cell scenario with three different radio access technologies (RATs) namely the Universal Mobile Telecommunication Systems (UMTS), the Wireless Local Area Network (WLAN) and the Global System for Mobile Telecommunication (GSM) / Enhanced Data rate for GSM Evolution (EDGE) Radio access Network (GERAN). This proposed algorithm works in two steps; the first step is to select a suitable combination of cells among the three different RATs. The second step chooses the most appropriate RAT to which the users can be attached and to choose the suitable bandwidth to allocate for the users. The Joint Radio Resource Management (JRRM) makes use of fuzzy neural approach to manage dynamically the allocation and deallocation of the different radio resources among the different radio access systems for spectrum bands allocated to each of these systems. By simulation results, we have shown that the proposed algorithm selects the most appropriate RAT in a multi-cell scenario.**

Keywords- Joint Radio Resource Management (JRRM), fuzzy neural algorithm, Radio Access Technology (RAT) selection.

I. INTRODUCTION

First generation mobile communication systems (e.g. Nordic Mobile Telephony (NMT) and Advanced Mobile Phone System (AMPS)) are based on analog transmission techniques, whereas second generation systems (e.g. GSM and D-AMPS) are based on digital transmission. In digital systems, more efficient use of the available spectrum is achieved by digital encoding of the speech data. Due to the transition from 2G to 3G, a number of standards have been developed, which are categorized as 2.5G. These are add-ons to the 2G standards and mainly focus on deployment of efficient IP connectivity within the mobile networks.

Third generation systems which includes Universal Mobile Telecommunication System (UMTS) [1] are now providing services like wireless access to the Internet and high data rate applications like real time video transmission. To cope with these, high bandwidth services and the enormous increase in the number of users, a more efficient use of the radio spectrum is required.

In turn, the perspective of beyond 3G systems is that of heterogeneous networks, which provides wireless services independent of its location in a completely transparent way [2]. The user terminal should be able to pick the best access technology such as Wireless Local Area Network (WLAN), the Universal Mobile Telecommunication Systems (UMTS) and the Global System for Mobile Telecommunication (GSM) / Enhanced Data rate for GSM Evolution (EDGE) Radio access Network (GERAN) at its current location and use the access technology seamlessly for the provision of desired service. This leads to the introduction of new Radio Resource Management (RRM) techniques referred to as JRRM (Joint Radio Resource Management) algorithms which manages dynamically the allocation and deallocation of radio resources between different Radio Access Technologies (RATs). That is, instead of performing the management of radio resources independently for each RAT, some form of overall and global management of the pool of radio resources can be envisaged.

The JRRM approach works in a mobile, multiuser, multicell and multi-RAT scenario where a guaranteed QoS is offered to the users. It involves fuzzy set concept and learning capabilities of neural networks in order to make RAT selection and bit rate allocation among the available RATs.

This paper proposes a single layered fuzzy neural algorithm which suitably selects the most appropriate RAT among the multi-cell scenario. This work extends the previous work by considering a single layered back propagation neural network instead of 5 layered back propagation network as explained in [3].

This paper is organized as follows: section II the JRRM strategy is presented, section III provides the proposed fuzzy-Back-propagation algorithm, Section IV presents the real time environment and results and discussions are carried out in Section V and the conclusion and Future work is discussed in Section VI.

II. THE JRRM STRATEGY

The JRRM algorithm operates in a heterogeneous scenario with three available RATs namely WLAN, UMTS and GERAN.

The two main functions of JRRM scheme are

1. RAT Selection (users to choose the RAT to which it has to be attached)
2. Bit Rate Allocation (RAT decides the most suitable bandwidth to allocate for the users)

The JRRM uses fuzzy logic concept and learning capabilities of neural networks in order to make RAT selection and amount of bandwidth to be allocated for each user. Neuro-fuzzy hybrid systems combine the advantage of fuzzy systems which deal with explicit knowledge and neural networks which deal with implicit knowledge that can be acquired by learning. Fuzzy logic provides a simple way to arrive at a definite conclusion based on vague, ambiguous, imprecise, noisy or missing input information. Fuzzy logic based methodology is good at explaining how to reach suitable decisions from imprecise and dissimilar information. Fuzzy logic strategies have been widely proposed in the literature in many different fields of knowledge [4]-[8]. On the other hand, Neural networks are good at recognizing the patterns by means of learning procedures. Taking this into account, this paper introduces the combined use of two intelligent techniques, fuzzy logic based methodology and neural networks, thus proposing a fuzzy neural based approach. The other problems related to RRM are handoff decision (e.g., [9] and [10]), connection admission control (e.g., [11]), power control (e.g., [12]), and channel allocation (e.g., [13] and [14]). This innovative fuzzy neural-based JRRM approach significantly extends the preliminary work carried out by the authors in [15] and [16], where this approach was explored and assessed in simplified scenarios and without self-adaptive components. This section explains the basic fuzzy neuron model and fuzzy BP architecture.

A. Fuzzy Neuron

The Fuzzy neuron is the basic element of the fuzzy BP model [17]. Figure.1 shows the architecture of the fuzzy neuron. Given the input vector I= (I_0, I_1… Ii) and weights vector W= (W_0,W_1,…..,W_i), where I_0= (1,0,0) is the bias, the net input to the output neuron is calculated in (1) as

$$O=f(NET)=f\,[\,CE[net]\,] \qquad (1)$$

where net = $\sum W_i\ I_i$ the fuzzy weighted summation. The function CE is the centroid of the triangular fuzzy number and can be treated as defuzzification operation which maps fuzzy weighted summation value to a crisp value. Thus, if net=(net_m,net_α,net_β) is the fuzzy weighted summation then the function CE is given by

$$CE(net)=net_m+1/3(net_\alpha - net_\beta) = NET \qquad (2)$$

The function f is the sigmoidal function which is given in (3)

$$f(NET)=1/(1+exp(-NET) \qquad (3)$$

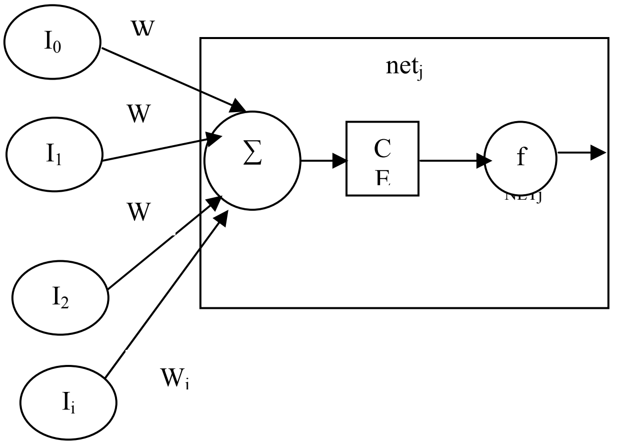

Figure.1 Fuzzy Neuron Architecture of Fuzzy BP model

B. Fuzzy BP Architecture

A fuzzy back-propagation neural network is a multilayer, Feed-Forward neural network consisting of an input layer, a hidden layer and an output layer. The functioning of fuzzy BP proceeds in two stages, namely

- Learning or Training and
- Inference

A linguistic variable is characterized by a term set. A total of seven linguistic variables are considered for RAT selection. The block diagram of JRRM Algorithm is given in figure. 2. The inputs to the JRRM algorithm are

1. SS_{UMTS} SS_{GERAN} SS_{WLAN} (Signal Strength of UMTS, GERAN, WLAN)
2. RA_{UMTS} RA_{GERAN} RA_{WLAN} (Resource Availability of UMTS, GERAN, WLAN)
3. MS (Mobile Speed)

Specifically, the term sets considered here for each linguistic variables are

$$X(\,SS_{UMTS}\,) = X(\,SS_{GERAN}\,) = X\,(SS_{WLAN}\,) = X\{\,L,H\,\} \qquad (4)$$

$$X\,(RA_{UMTS}\,) = X(\,RA_{GERAN}\,) = X(\,RA_{WLAN}\,) = X\{\,L,\,M,\,H\,\} \quad (5)$$

$$X(\,MS\,) = X\{\,L,\,H\,\} \qquad (6)$$

Here ‘H’ stands for High, ‘M’ stands for Medium and ‘L’ stands for Low. The signal strength of UMTS, GERAN and WLAN consists of two fuzzy sets: Low and High, whereas Resource availability of UMTS, GERAN and WLAN consists of three fuzzy sets: Low, Medium and High. The output of JRRM algorithm provides

- Bandwidth allocation of UMTS and GERAN but the bandwidth allocation of WLAN is not considered since the current WLAN systems cannot guarantee the bandwidth allocation,

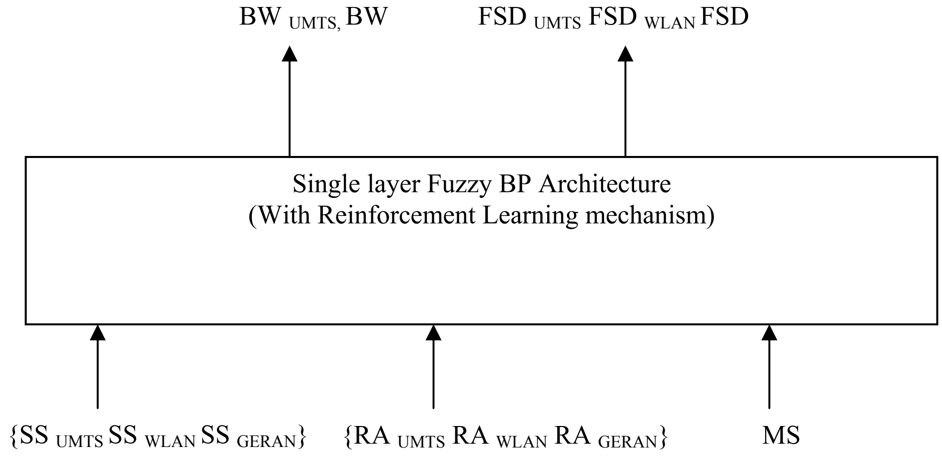

Figure 2 Block Diagram of JRRM algorithm

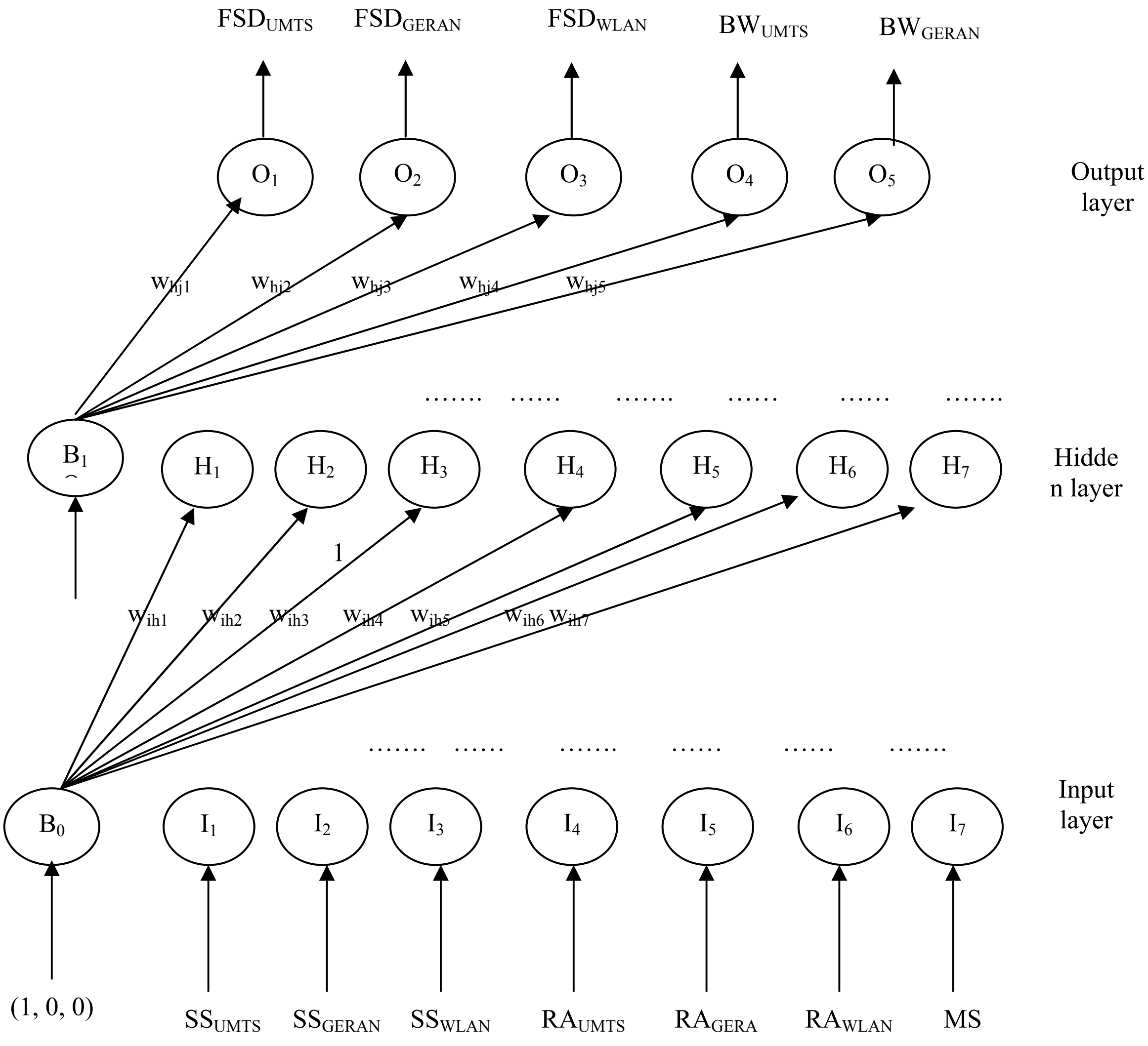

Figure 3 Architecture of proposed fuzzy BP

- Fuzzy Selected Decision of UMTS, GERAN and WLAN

The Figure.3 explains the architecture of proposed Fuzzy_BP. Let (SS_{UMTS} SS_{GERAN} SS_{WLAN} RA_{UMTS} RA_{GERAN} RA_{WLAN} MS) be the N input patterns that fuzzy BP needs to be trained, with (1,0,0) as bias.
Let FSD_{UMTS} FSD_{GERAN} FSD_{WLAN} BW_{UMTS} BW_{GERAN} can be obtained as output.
The term sets for output linguistic variables are

X(DUMTS) =X(DGERAN) = X(DWLAN) =X{Y,PY,PN,N} (7)

where *Y* stands for "yes," *PY* for "probably yes," *PN* for "probably not," and *N* for "not."
Similarly, there will be two output linguistic variables corresponding with the allocated bit rate *BW* (*BWUMTS, BWGERAN*), each with the following term sets:

X(BWUMTS) = X(BWGERAN) = X{H,M,L} (8)

where *H* stands for "high," *M* for "medium," and *L* for "low."
Fuzzy rules take the form IF (Conditions) and THEN (actions), where conditions and actions are linguistic variables, respectively. An example of Fuzzy IF-THEN rule is given below:
"IF A is high THEN B is low ELSE B is not low". The formulated inference rule for this paper is given in Table I.

III. PROPOSED FUZZY-BACKPROPAGATION ALGORITHM

The proposed fuzzy-Backpropagation algorithm is explained below:

ALGORITHM : FUZZY_BP

Step 1: Initialize some random values for weight sets of the Input-Hidden layer { W_{ih1} W_{ih2} W_{ih3} W_{ih4} W_{ih5} W_{ih6} W_{ih7}} where W_{ih1}=(W_{ih1a} W_{ih1b} W_{ih1c}) is an LR type fuzzy number. Initialize weights sets for Hidden-output layer { W_{hj1} W_{hj2} W_{hj3} W_{hj4} W_{hj5} } where W_{hj1}=(W_{hj1a} W_{hj1b} W_{hj1c}). Initialize learning rate (alpha) and momentum factor (mf)

Step 2: Let (X_i,Y_i) where i=1,2,…N be the input-output pattern set that fuzzy BP should be trained. Here X_i=(X_{UMTSi}, X_{GERANi}, X_{WLANi}, MS_i, B_{UMTSi}, B_{GERANi}) is an LR type fuzzy number where X_{UMTSi} = (X_{UMTSia} X_{UMTSib} X_{UMTSic}) and Y_i is the Crisp output.

Step 3: Perform steps 4-10 when stopping condition is false

Step 4: Perform steps 5-9 for each training pair

Step 5: Each input unit receives input signal Xi and sends it to the hidden unit (i=1 to n). Each hidden unit Z_{inj} sums its weighted input signals to calculate the net input.

$Z_{inj}=W_{ib}+\sum_{k=1}^{7} W_{ihk} X_{ik}$. Apply the (1), (2), (3) to Z_{inj}

Step 6: For each output unit Y_i calculate the net input: Compute $Y_{inj} = \sum_{k=1}^{5} W_{hjk} Z_{injk}$. by applying (1), (2), (3) to Y_{inj} for the output neurons

Back-Propagation of error

Step 7: Each output unit Yi receives a target pattern 't' corresponding to the input training pattern and computes the error correction term: $\delta_{hj(k)}$ for the hidden-output layer as follow

$$\delta_{hj(k)} = -(t-y) * y * (1-y) * \mu \quad (9)$$

where k =1,2,3 and μ=1 for k=1
μ= (-1/3) for k=2
μ= (1/3) for k=3

Calculate the bias correction term $\delta_{bj(k)}$

$$\delta_{bj(k)} = -(t-y) * y * (1-y) * \mu \quad (10)$$

where k=1,2,3 and μ=1 for k=1
μ= (-1/3) for k=2
μ= (1/3) for k=3

On the basis of the calculated error correction term, update the change in weights of hidden-output layer

$$chw_{hj(k)} = -(alpha * \delta_{hj(k)} * z) + (mf * w_{hjold(k)}) \quad (11)$$

Here k=1,2,3

Calculate the change in weights of bias-output layer

$$chw_{bj(k)} = -(alpha * \delta_{bj(k)}) + (mf * w_{bjold(k)}) \quad (12)$$

Here k=1,2,3

Step 8: Compute error portion $\delta_{ih(k)}$ for the input-hidden layer as follows:

$$\delta_{ih(k)} = (\delta_{hj(k)} * z * (1-z) * \mu * x(k)) \quad (13)$$

where k=1,2,3 and μ=1 for k=1
μ=(-1/3) for k=2
μ=(1/3) for k=3

Calculate the error portion $\delta_{ib(k)}$ for the bias-hidden layer

$$\delta_{ib(k)} = (\delta_{bj(k)} * z * (1-z) * \mu * \beta) \quad (14)$$

Here k=1,2,3 and μ=1, β=1 for k=1
μ=(-1/3), β=0 for k=2
μ=(1/3), β=0 for k=3

On the basis of the calculated error correction term, update the change in weights of input-hidden layer

$$chw_{ih(k)} = -(alpha * \delta_{ih(k)}) + (mf * w_{ihold(k)}) \quad (15)$$

where k=1,2,3

Calculate the change in weights of bias –hidden layer

$$chw_{ib(k)} = -(alpha * \delta_{ib(k)}) + (mf * w_{ibold(k)}) \quad (16)$$

where k=1,2,3

Step 9: Update New weights of input-hidden layer and hidden-output layer

$$w_{ihnew(k)} = w_{ihold(k)} + chw_{ih(k)} \quad (17)$$

$$w_{hjnew(k)} = w_{hjold(k)} + chw_{hj(k)} \quad (18)$$

where k=1,2,3 and update the new weights of bias-hidden layer and bias-output layer

$$w_{ibnew(k)} = w_{ibold(k)} + chw_{ib(k)} \quad (19)$$

$$w_{bjnew(k)} = w_{bjold(k)} + chw_{bj(k)} \quad (20)$$

here k=1,2,3

Step 10: Check for the stopping condition. The stopping condition may be certain number of epochs reached or when the actual output equals the target output.

The above algorithm is implemented for selecting the most suitable RAT of Joint Resource Radio Management in Radio Systems. In this case, the value of learning rate is assumed to be 0.9 and momentum factor as 0.001. The initial weight values were randomly generated for the process.

IV. REAL TIME ENVIRONEMENT

A multi cell-scenario is selected with 7 cells deployment which includes 4 UMTS base stations, 2 GERAN base stations and one WLAN hot spot as shown in Figure.4 to evaluate the proposed fuzzy-backpropagation algorithm. In this scenario, both the RAT and the cell need to be selected for each user during the execution of the algorithm. The proposed Fuzzy-Back propagation algorithm is executed for each user for selecting a combination of cells from the available RATS namely (a UMTS cell, a GERAN cell and a WLAN access point).

The information to the proposed scenario includes the signal strength at the user receiver which is measured in different ways according to the RAT considered. In case of UTRAN, the signal strength is measured by the received signal code power (RSCP) of the pilot channel [18]. For GERAN, this measure corresponds to the power received in the broadcast channel [19]. Finally, for WLAN, the beacon signal transmitted by the access point is measured [20]. In addition to this, the mobile speed is also given as input to the strategy. For mobile speed, several possibilities are there, for

TABLE I
Example of Inference Rules

Learned fuzzy Logic Rules												
	Preconditions							Consequence				
Rule	SS_{UMTS}	SS_{GERAN}	SS_{WLAN}	RA_{UMTS}	RA_{GERAN}	RA_{WLAN}	MS	D_{UMTS}	D_{GERAN}	D_{WLAN}	B_{UMTS}	B_{GERAN}
1	H	H	L	H	H	L,M,H	L	Y	Y	N	H	H
2	H	H	L	H	M	L,M,H	L	Y	PY	N	H	M
3	H	H	L	H	L	L,M,H	L	Y	PN	N	H	L
4	H	H	H	H	H	M	L	Y	Y	PY	H	H
5	H	H	H	H	M	M	L	Y	PY	PY	H	M
6	H	H	H	H	L	M	L	Y	PN	PY	H	L
7	H	H	H	H	H	L	L	Y	Y	PN	H	H
8	H	H	H	H	M	L	L	Y	PY	PN	H	M
9	H	H	H	H	L	L	L	Y	PN	PN	H	L
10	H	H	L,H	H	H	L,M,H	H	Y	Y	N	H	H
11	H	H	L,H	H	M	L,M,H	H	Y	PY	N	H	M
12	H	H	L,H	H	L	L,M,H	H	Y	PN	N	H	L
13	H	H	L	M	H	L,M,H	L	PY	Y	N	M	H
14	H	H	L	L	H	L,M,H	L	PN	Y	N	L	H
15	H	H	H	M	H	M	L	PY	Y	PY	M	H
16	H	H	H	L	H	M	L	PN	Y	PY	L	H
17	H	H	H	M	H	L	L	PY	Y	PN	M	H
18	H	H	H	L	H	L	L	PN	Y	PN	L	H
19	H	H	L,H	M	H	L,M,H	H	PY	Y	N	M	H
20	H	H	L,H	L	H	L,M,H	H	PN	Y	N	L	H
21	H	H	H	H,M,L	H,M,L	H	L	N	N	Y	L	L

example, based on Doppler frequency, positioning, cell reselection, handover rates, etc.

This proposed algorithm does not require a very accurate rate for mobile speed estimations, but it gives just an indication of inappropriateness of selecting some RATs (e.g., WLAN) in the case of high-speed users is required. The proposed fuzzy-backpropagation strategy has been first evaluated through simulations in the reference multicell scenario shown in Fig. 4 in order to analyze its behaviour and to tune and validate the parameters.

A mobility model with users moving according to a random walk model inside the coverage area is adopted with a randomly assigned mobile speed (MS) [0, 50 km/h] and a randomly chosen direction. The propagation model considered for UMTS and GERAN is given by L = 128, 1 + 37, 6 log d (km), which assumes that the frequency band is similar for both systems (i.e., GERAN: 1710–1785 MHz; UMTS: 1900–2025 MHz) [21]). For WLAN, since the conditions are different, the propagation losses inside the hot spot are modeled by L = 20 log d(m) + 40 [22]. An average call duration is 180 sec. The maximum bit rate available to the users in a UMTS and GERAN cell is 384 and 96 Kb/s, respectively. In addition, it is assumed that the user contractual bit rate is 192 Kb/s for UMTS and 40 Kb/s for GERAN.

Results are presented for the uplink direction, and the considered possible bit rates for the different RATs are as follows.

1) For UMTS, the results are 32, 48, 64, 80, 96, 112, 128, 192, 256, 320, and 384 kb/s. A single UTRAN FDD carrier is considered. The maximum allowed uplink load factor is 0.75.

2) For GERAN, the results are 32, 48, 64, 80, and 96 kb/s. It is assumed that four carriers are available in the GERAN cell for GPRS users, with coding scheme CS-4 [23], thus having a maximum bit rate in the cell of 640 kb/s.

3) For WLAN, it is considered that the total bandwidth available (11 Mb/s) is equally distributed among the WLAN users (i.e., the higher the number of users, the lower the bandwidth per user will be). It is also assumed that no more WLAN users are accepted when the bandwidth per user is less or equal than 384 kb/s. [24].

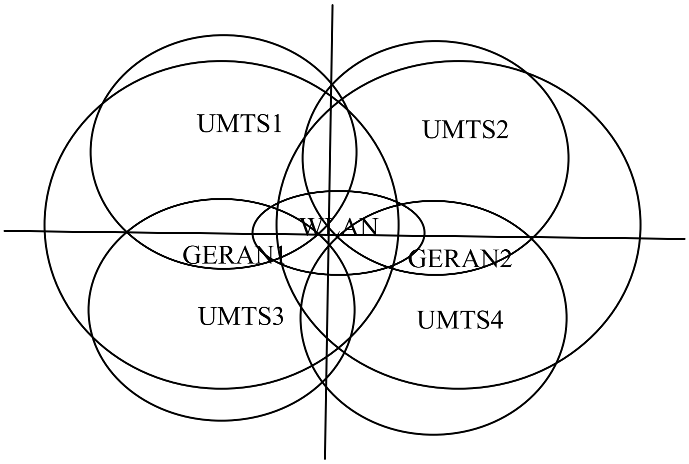

Figure.4 Multi Cell Scenario

The cell combination selection function is in charge of selecting for a given subscriber one cell for each of the considered RATs (i.e., UMTS, GERAN, and WLAN). The considered scenario consists of eight combinations of cells: C1 (WLAN, UMTS1, GERAN1), C2 (WLAN, UMTS2, GERAN1), C3 (WLAN, UMTS3, GERAN1), C4 (WLAN, UMTS4, GERAN1), C5 (WLAN, UMTS1, GERAN2), C6 (WLAN, UMTS2, GERAN2), C7 (WLAN, UMTS3, GERAN2), and C8 (WLAN, UMTS4, GERAN2). Cell radii of 150 m for WLAN, 650 m for UMTS, and 1 km for GERAN are retained. The fuzzy neural algorithm is activated every 100 ms for the simulation purposes in order to reallocate bandwidths and/or RATs to the currently admitted users as well as to include new users so that the allocated resources can be changed dynamically.

The resource availability (RA) is a RAT-dependent concept and, for the different RATs used in the fuzzy neural JRRM algorithm, is defined as follows.

1) For UMTS, RA = 1− ηUL, where ηUL is the uplink cell load factor.

2) For GERAN, RA = 640 kb/s − ρ, where ρ is the current amount of kb/s already allocated in the corresponding cell.

3) For WLAN, RA = maximum number of users–number of users allocated in WLAN cell, where the maximum number of users is the number of users that could be allocated in WLAN considering a rate of 384 kb/s per user.

V. RESULTS AND DISCUSSIONS

The set of considered membership functions for the seven input linguistic variables are depicted in Figure. 6. The work was implemented in MATLAB 7.9.0 and graph is presented to represent the minimization of error in future iterations. The proposed algorithm uses only single hidden layer fuzzy-back propagation network, whereas the previous work uses five-layered fuzzy neural structure. Figure.5 shows the curve of mean error with respect to number of epochs. The results clearly show the benefits offered by the proposed fuzzy neural JRRM are better than the other algorithms. In the first generation, the error value obtained was 5.3862 and in the second generation, the error value was reduced to 3.1339 and so on. In the 50th generation, the mean error was 1.2291. This shows that the mean error has been reduced in the further iterations.

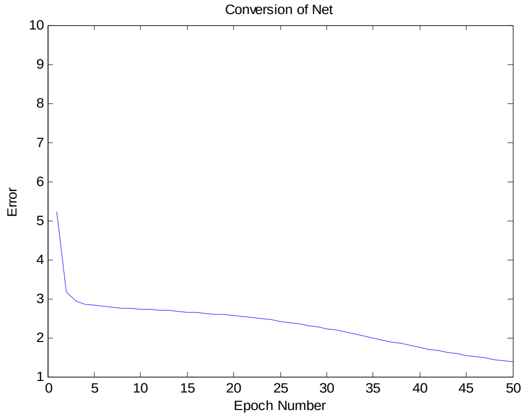

Figure.5 Performance of Neural Network

This graph shows that the proposed single hidden layered fuzzy neural algorithm was found satisfactory. Table II shows the output of proposed JRRM algorithm, where the most appropriate RAT which has higher bandwidth among other RATs can be selected for the user. The maximum FSD value among the ones corresponding to the UMTS, GERAN, and WLAN cells belonging to each combination is taken as the indicator of the appropriateness of selecting one of them.

Table II Outputs of Proposed Fuzzy-BP Algorithm

FSD_{UMTS}	FSD_{geran}	FSD_{wlan}	BW_{umts}	BW_{geran}
0.9511	0.8047	0.1755	0.9279	0.7914
0.9495	0.5386	0.2131	0.9436	0.2128
0.9616	0.7665	0.1931	0.9393	0.7347
0.9546	0.7591	0.1985	0.9328	0.7164
0.9525	0.4811	0.2333	0.9475	0.1624
0.9446	0.769	0.1874	0.9289	0.7214
0.9498	0.8107	0.1726	0.9274	0.8020

VI. CONCLUSION AND FUTURE WORK

In this paper, a fuzzy- Backpropagation algorithm is proposed for a multi-cell scenario which includes UMTS , GERAN and WLAN radio access technologies. This algorithm operates in two steps in order to select the most suitable RAT and the cell to which the mobile to be attached. The first step selects a combination of 3 cells built around the 3 considered RAT. During the second step, the proposed algorithm selects the most appropriate RAT among the three considered and also selects amount of bandwidth allocated to each user. Finally, the results are obtained through the execution of the proposed algorithm for 50 generations. Further research will focus on incorporating multiple decision making techniques into our model to optimize the outputs further.

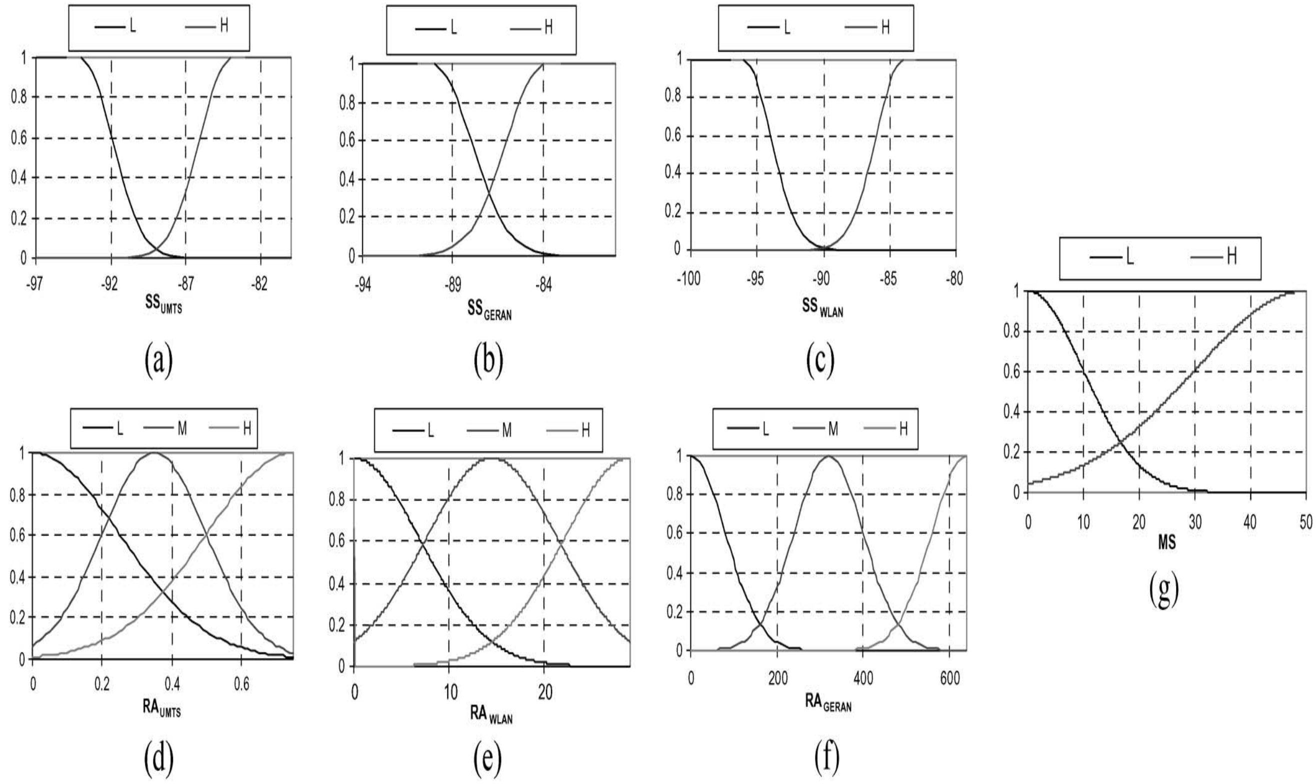

Figure. 6 Membership function for UMTS, GERAN and WLAN

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