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Network Selection in Wireless Heterogeneous Environment by C-P-F Hybrid Algorithm

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Abstract Numerous wireless communication technologies have been employed to manage mobile users anywhere, any time and anyhow. Additionally, users are more and more fascinated by multimedia applications such as voice, audio and video, which require Quality of Service (QoS) support. To retain the user with Always Best Connected network in such restrictions is a challenging issue. A contemporary approach for efficient network selection in wireless heterogeneous networks is conferred. The approach composed of two criteria: the first is the cost function comprising of received signal strength, available bit rate, signal to noise ratio, throughput and bit error rate metrics. The metrics' respective weights are being optimized by Particle Swarm Optimization (PSO). The second criterion consists of fuzzy logic system fed with similar metrics as inputs and targeted towards same output. The final decision of network selection is taken by the blend of these two criteria. Simulation results indicated that the proposed scheme based on Cost function, PSO and Fuzzy system (C-P-F) provided better performance in terms of minimizing the unnecessary handoffs (network selection rate), utility degree and load balancing. The proposed algorithm (C-P-F) significantly reduces the network selection rate by 50% as compared to existing algorithm based on cost function and PSO. This reduction indicated higher probability of guaranteed session continuity and good quality of the currently running service, which resulted in high user satisfaction levels. It enhances user satisfaction 55%

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and reduced network selection rate upto 75% in comparison of existing network selection techniques.

Keywords Network selection · LTE · WiMAX · Fuzzy system · RAT · PSO

1 Introduction

In order to provide ubiquitous wireless access in the heterogeneous environment of networks with complementary characteristics, it is essential to integrate different Radio Access Technologies (RATs) under one umbrella. Heterogeneous Wireless Networks' (HWNs) integration, their expansion and reliable network selection criteria are essential and challenging research problem to ensure seamless communication for multimedia applications while attaining acceptable QoS (Quality of Service) [1]. Numerous network selection algorithms are available dependent only on Received Signal Strength (RSS) and do not utilize the advantages of other physical layer parameters and their basic information in a wireless heterogeneous environment. In addition, while performing network selections; existing algorithms do not consider the QoS of ongoing session to satisfy the end-user that depends upon location, preferences, and applications. A single network selection criterion is unable to provide required QoS while selecting a network in a heterogeneous environment. Hybrid network selection techniques are required to realize simple, general, scalable, flexible and adaptable solution. The challenge is to design a network selection method which can enhance overall network performance and individual user experience, without excessively complicating the network. In this paper, hybridization of C-P-F (Cost function, PSO and Fuzzy system) is employed to get optimal network selection.

The outline of the paper is: Sect. 2 illustrates the survey and prime motivations to choose network in heterogeneous environment of LTE and WiMAX. Section 3 presents the system modeling. Section 4 represents a criterion to select an appropriate network. Section 5 discusses the performance evaluation of proposed approach. Section 6 presents conclusions drawn.

2 Literature Survey

Many network selection algorithms have been proposed in literature. In [2], handoff decision was combination of Multiple Attribute Decision Making (MADM) and FL. Where, FL was utilized to negotiate with the inexact data of various criteria and consumer inclination. For handoff decision, imprecise information was initially changed to crisp numbers, and then, conventional MADM methods TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) and SAW (Simple Additive Weight) were applied. Statistical results showed that TOPSIS was highly susceptible to user inclination and metric values, and SAW gave a comparatively conventional ranking result. Authors in [3] presented a movable terminal structural design for devices working in heterogeneous environments, and proposed a scheme that independently determined the attachment point and the best local interface while considering user preferences and network status, service requirements and resource availability. FL and GAs (Genetic Algorithms) have been employed to resolve the multi criteria Access Network Selection (ANS) issue in [4]. The method employed a general multi criterion of Software Assistant (SA) to facilitate user and operator for provisioning of required QoS, flexibility, scalability, and simplicity. Results showed that SA and proposed scheme yielded more robust and better performance than the random based selection. The fuzzy neural methodology framework in [5] considered different subjective criteria as well as different operator policies through a multiple choice making method, such as high priority provided to one RAT over another or balancing traffic between RATs.

A user centric network selection approach based on auction mechanism was carried out in [6], while considered negotiation between network operators and users. The truth telling behavior of network and consumption details of users are considered as service quality metrics along with genuine price offered by the network operators. FL approach was employed to reduce frequency of handovers. Autonomic Interface Selection Architecture (AISA) based on fuzzy control has been proposed in [7] to choose an interface automatically and dynamically. AISA selected an appropriate interface among numerous accessible interfaces for every requisition derived from diverse autonomic judgment rules. The design sensed and interpreted relative variations in the network, and adapted to incorporate varying network situations and customer requirements while choosing an interface. AISA utilized human experience in terms of fuzzy set to decide the most appropriate interface for an application in an autonomous way.

A User Preference oriented Network Selection algorithm (UPNS) was devised by merging Fuzzy Analytic Hierarchy Process algorithm (FAHP) and entropy theory in [8]. Its implementation resulted in improved efficiency in satisfying user's individuality and maintaining user satisfaction. A neuro-fuzzy multi-factor based Vertical Handoff Decision Algorithm (VHDA) was suggested in [9]. It considered six metrics and applied rule dependent system for vertical handover choice. The number of vertical handovers calculated in a scenario showed that overall number of handovers reduced and it offered improved QoS than existing vertical handovers techniques in terms of handoff quality indicator.

The proposed algorithm in [10] employed GAs, PSO and FL controllers for decision under certain input criteria such as user velocity, service costs, QoS, type of service and service parameters of mobile customer. Fuzzy with multiple decision-making attributes was introduced for network selection in [11]. It was observed that Network Selection Function (NSF) measured the capability of available radio resources individually. The network acquired the maximum NSF value was designated as the perfect network to handover from the existing access network.

Radio Network Selection (RNS) solution was developed by the combination of parallel FL control and MCDM system to attain adaptable solution. The solution in [12] provided better and more robust option over previously discussed algorithms. A multi-criteria algorithm based on User Specific Intelligent Vertical Handoff (UIVH) and Adaptive Neuro Fuzzy Inference System (ANFIS) was employed to choose the optimal network for Vertical Handoff (VHO) [13]. UIVH always decided the most excellent available network while considered the specific requirements of users. Gradual rise in handover completion time has been noticed while continuation addition in number of handovers. QoS aware VHO mechanism applied fuzzy rule and multi criteria for selection in [14]. It effectively fulfilled the needs of various applications in a heterogeneous environment. An evaluation model applied a non-birth death Markov chain for VHO. It improved the performance in case of diverse traffic classes as compared to other VHO algorithms. Another multi criteria VHO algorithm in [15] employed numerous factors such as user preferences, traffic types and system metrics for decision while maintaining QoS requirements. Target network selection module and VHO Necessity Estimation (VHONE) module were utilized weighted user's and system's metrics. To enhance the strength of the procedure, the weighting scheme was planned with fuzzy linguistic variables.

A blend of FL technique with GRA and AHP decision making methods were proposed in [16, 17]. It was observed that to attain a goal of network selection, decision making methods are helpful in making arrangement of alternative order and by adding artificial intelligence techniques, the results become more accurate. In order to provide seamless communication to users, a ranking algorithm was proposed in [17, 18]. It combined Mahalanobis distance and MADM techniques. A categorization method applied to make classes with homogeneous criteria and the MADM, Fuzzy AHP methods employed to find out weights of intra-classes and inter-classes. Lastly, Mahalanobis distance applied to rank options. It effectively reduced ranking abnormality and the number of network selections.

Authors in [18, 19], proposed a Handover Decision System (HDS) modular design based on fuzzy to deal with the network selection problem. The performance was evaluated in terms of network selection and the execution time. The HDS design provided a significant improvement in terms of execution time. Other schemes for network selection were proposed in [19–22] for the vertical handoff in heterogeneous wireless network. As compared to existing approaches, these ensured the seamless mobility in the integration of WiMax, WiFi hotspots and cellular networks. As discussed previously, classical techniques, which are based on evaluation of imprecise metrics, fail to yield efficient network selection decisions. We propose a novel algorithm based on C-P-F (Cost function-PSO-Fuzzy system) to resolve this issue.

3 System Modeling

A wireless heterogeneous network has been formed as demonstrated in Fig. 1 with an aim to elect the most appropriate network as per user requirement.

In the above situation, it is considered that users are moving at a steady rate with an arbitrary mobility. Initially user moves from the cell connected to base station '$BSnet_1$', towards another base station '$BSnet_2$'. $BSnet_2$ is placed at distance 'D' from $BSnet_1$. The channel signal power at consistent distance is described as

$$d = k\mathrm{d_s} \tag{1}$$

k is an integer value varies from 0 to D/d_s [22, 23]. Where, d_s represented sampling distance and it is considered equal to 1 m. Here, D is equivalent to 1500 m. It is assumed

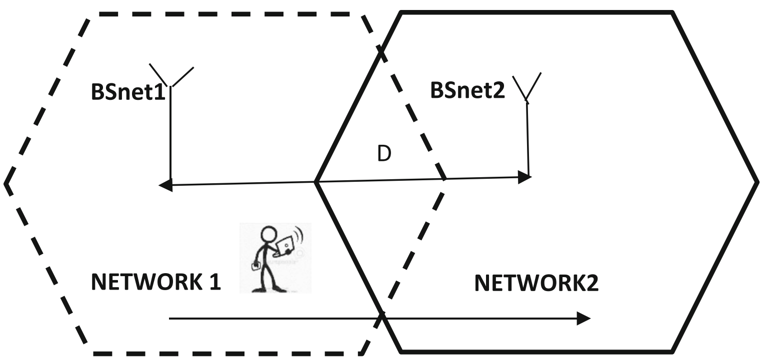

Fig. 1 A wireless heterogeneous environment comprising of networks

that the both base stations are situated and operated from the middle of the particular cells. ‘D’ defined the area in which the users have arbitrary movement. The physical layer metrics (RSS, Achievable throughput, SNR, ABR, and BER) of current wireless networks are calculated by Eqs. (2–7).

$$\mathrm{RSS_i} = -174 + (\mathrm{S_i}/\mathrm{N_i}) - 10 \times \log_{10}(\mathrm{d}) + 10 \times \log_{10}(\mathrm{FS_i} \times \mathrm{Nused_i}/\mathrm{Nfft_i}) + \mathrm{NF_i} \quad \mathrm{i} = 1, 2 \tag{2}$$

$$\mathrm{C} = \mathrm{BW} \times \log_2\left(1 + \left(\frac{\mathrm{S}}{\mathrm{N}}\right)\right) \tag{3}$$

$$\mathrm{ABR_i} = \mathrm{B_i} \times \log_2\left(1 + \left(\frac{\mathrm{S_i}}{\mathrm{N_i}}\right)\right) \quad \mathrm{i} = 1, 2 \tag{4}$$

$$\frac{\mathrm{S_i}}{\mathrm{N_i}} = \gamma_\mathrm{i} = \frac{\mathrm{E_b}}{\mathrm{N_0}} \quad \mathrm{i} = 1, 2 \tag{5}$$

$$\mathrm{T_i} = \frac{\mathrm{L} - \mathrm{C}}{\mathrm{L}} \times \mathrm{R_i} \times (1 - \mathrm{BER_i}(\gamma_\mathrm{i}))^\mathrm{L} \quad \mathrm{i} = 1, 2 \tag{6}$$

$$\mathrm{BER_i}(\gamma_\mathrm{i}) = \frac{1}{2} e^{-\frac{\gamma_i}{2}} \quad \mathrm{i} = 1, 2 \tag{7}$$

WiMAX and LTE networks are represented by i = 1, 2 respectively. Received signal strength of networks denoted by $\mathrm{RSS_i}$. Its value dependent upon the amount of sub-carrier utilized (Nused), frequency (Fs), range of FFT (Nfft), signal to noise ratio (S/N) and Noise Figure (NF) at any point of distance ‘d’. To determine available bit rate (ABR) for communication networks, the Shannon capacity theorem is applied. ABR is directly relative to S/N and bandwidth of network at every precedent. Here, S/N is formalized in Eq. (5). It relies upon power of bit with respect to noise there. Equation (6) is employed to calculate throughput of the networks and it is directly relative to data rate and BER of the wireless network. C signifies cyclic redundancy bits, whereas L represents the length of packets in bits. BER of available networks is calculated by S/N of their corresponding network. While keeping in view realistic implication, the distinctive values of system metrics preferred are tabulated in Table 1.

Table 1 System metrics for simulation scenario [23, 24]

S. no.	System metrics	LTE	WiMAX
1.	Peak data rate	100 Mbps	75 Mbps
2.	Channel bandwidth (scalable)	1.4–20 MHz	3.5–10 MHz
3.	SNR	5–40 dB	5–21 dB
4.	Nfft	256	256
5.	Nused	1024	192
6.	NF	12 dB	12 dB
7.	$\mathrm{F_S}$	20 × 1e + 6	2.5 × 1e + 6

4 Proposed Network Selection Algorithm

The network selection algorithm based on C-P-F for choosing the optimal network in context of multimedia services is given in Fig. 2. There are multiple access technologies in heterogeneous wireless network and network selection can be made at any instance as per the quality of service and network conditions requirements for the applications and

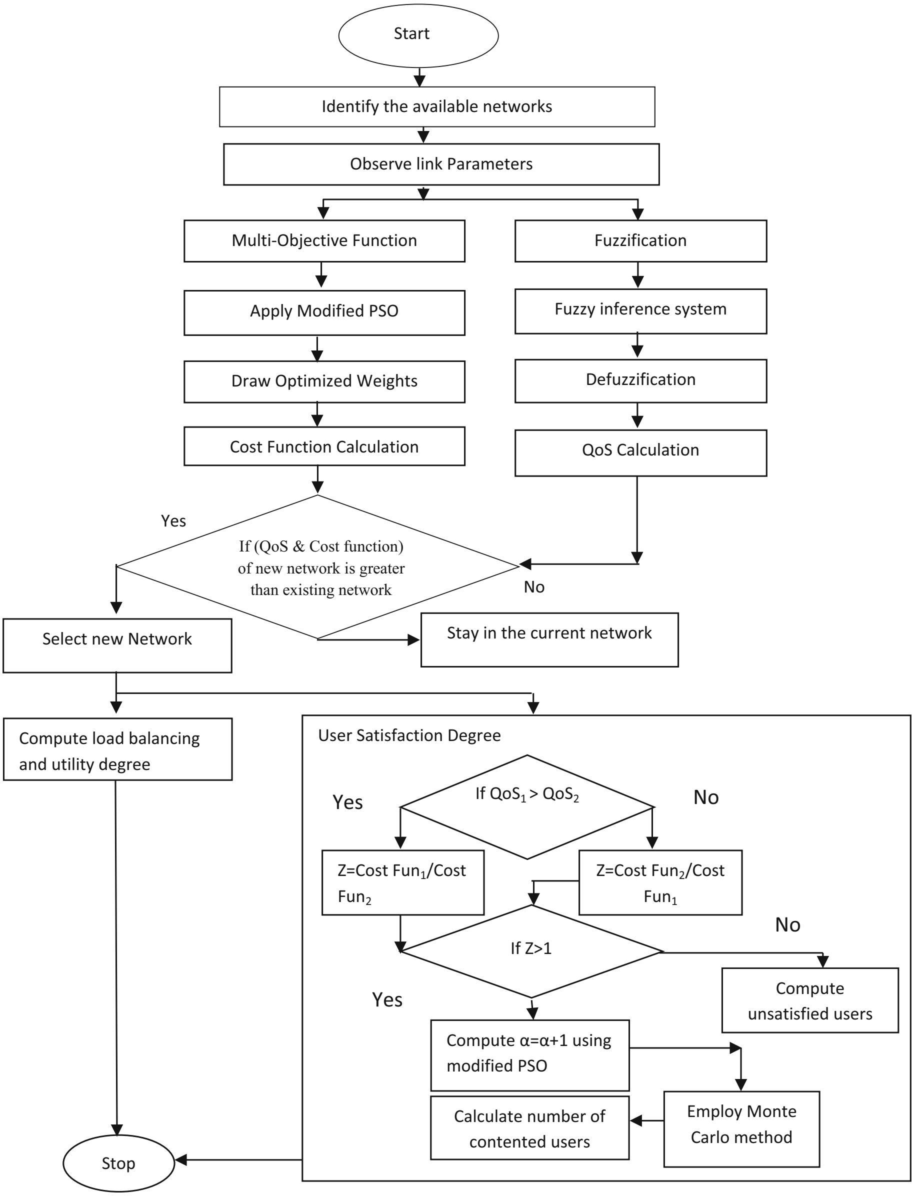

Fig. 2 Logic of proposed network selection model in heterogeneous wireless environment

customer preferences. In this paper, network conditions such as averaged RSS, SNR, Achievable throughput ABR, and BER are controlling the selection of network. Conditions of network fluctuate with respect to distance and time in a radio environment. Here, the coverage margins of the two networks is acted as an area of concern for network selection. Mobile handset units have multiple network access interfaces [24, 25]. Here, MS is able to access LTE and WiMAX networks.

Step 1 First of all, ensure the presence of wireless networks at multi-terminal MS in heterogeneous environment. MS is capable to trace and monitor the radio link quality parameters (averaged RSS, SNR, Achievable throughput, ABR and BER) and process link quality measurement. RSS is primarily used to sense the presence of a wireless network. Here, it is assumed that initially number of contented users is zero

Step 2 The proposed algorithm is applying blend of C-P-F to achieve a network selection decision among BS_{net1} and BS_{net2}. The link parameters of both the networks are calculated using Eqs. (2–7). Then apply these link parameters to calculate Multi Objective Function (MOF) of present wireless networks by employing Eq. (8)

$$\mathrm{MOF}(i) = W_{ij} \times \mathrm{RSS}_i + W_{ij} \times \mathrm{ABR}_i + W_{ij} \times \mathrm{SNR}_i + W_{ij} \times \mathrm{Throu}_i + W_{ij} \times \mathrm{BER}_i \quad (8)$$

W_{ij} indicates the relative weights of input metrics of present networks in heterogeneous environment. i represents the present networks and it varies from 1, 2,…, N. and here, N = 2 is considered. j represents the input metrics of present networks and it varies from 1,2,…,M. Here, it is assumed that M = 5. Every relative weight needs to assure Eq. (9).

$$W_{i1} + W_{i2} + W_{i3} + W_{i4} + W_{i5} = 1 \quad (9)$$

The analogous input metrics weights (RSS, SNR, Achievable Throughput, ABR, and BER) are employing Modified Particle Swarm Optimization (MPSO) and optimized [25, 26] with the objective function in Eq. (10)

$$\text{Objective Function} = \text{Maximize}(w_1(i) \times \mathrm{RSS}(i) + w_2(i) \times \mathrm{ABR}(i) + w_3(i) \times \mathrm{SNR}(i) + w_4(i).\times \mathrm{throu}(i)) + \text{ Minimize}(w_5(i) \times \mathrm{BER}(i)) \quad (10)$$

The cost functions of available networks are calculated by input metrics and optimized weights are enumerated by applying Eqs. (11) and (12). Here, optimized weights are indicated by ‘o’ of relevant wireless networks.

$$\text{Cost Fun1} = w_{11o} \times \mathrm{RSS}_1 + w_{12o} \times \mathrm{ABR}_1 + w_{13o} \times \mathrm{SNR}_1 + w_{14o} \times \mathrm{throu}_1 + w_{15o} \times \mathrm{BER}_1 \quad (11)$$

$$\text{Cost Fun2} = w_{21o} \times \mathrm{RSS}_2 + w_{22o} \times \mathrm{ABR}_2 + w_{23o} \times \mathrm{SNR}_2 + w_{24o} \times \mathrm{throu}_2 + w_{25o} \times \mathrm{BER}_2 \quad (12)$$

Cost functions of present wireless networks have been compared for optimal network selection. A network with high cost function value has been preferred for user connectivity.

Step 3 The calculated link parameters in step2 of the available networks are applied to fuzzy system for QoS calculation. The membership functions and range of the inputs and output are specified and then rules are formulated. Membership functions are assumed to be triangular in shape that depends on three scalar parameters i.e., a, b, c [26] and it is a function of a vector x

$$f(x;a,b,c) = \begin{Bmatrix} 0, & x \leq a \\ \frac{x-a}{b-a}, & a \leq x \leq b \\ \frac{c-x}{c-b}, & b \leq x \leq c \\ 0, & c \leq x \end{Bmatrix} \quad (13)$$

The rules designed link inputs and outputs which support the real scenario behind network selection behaviors. Mamdani fuzzy inference system is designed based on two hundred forty-three rules. These rules have been composed for a crisp solution required for inference process. This process involved the defuzzification of the solution set. A crisp value is withdrawn from a fuzzy set as a representation value, termed as defuzzification. Here, centroid of area strategy for defuzzification is applied. The network having high QoS crisp value is preferable for selection.

Step 4 An optimal network in the heterogeneous environment is selected by the combined decision of cost function and QoS calculation, shown in Fig. 2. The network with high cost function and QoS is selected as the most suitable network which leads to further reduction in the unnecessary network selection rate. If user is already connected to network having higher cost function and QoS then it remains connected to the current network

Contented users are calculated in accordance with the accomplishment of their particular requirement from the chosen network. Throughput and available bit rate are desirable needs for users those are running multimedia applications. SNR and RSS are considered as required parameters for non-line of sight region or users away from the source area. Here, ABR, achievable throughput, averaged RSS, SNR and BER are the key parameters for QoS that are provided by available wireless networks. Cost functions as well as QoS of available wireless networks are employed to calculate user satisfaction. It depends upon user's application prerequisite.

The number of contented users is computed by pseudo code as follows:

```
{
If (QoS1> QoS2)
then (calculate Z = Cost Fun1/Cost Fun2)
else (Z = Cost Fun2/Cost Fun1)
if (Z>1)
then compute contented users (α)
by modified PSO optimize contented users (α)
}
```

If the network conditions are not in favor of user as per its requirement then it is considered as an unsatisfied user.

5 Performance Evaluation

Network selection rate, load balancing, utility degree and contented users' metrics are calculated to evaluate the proposed network decision making algorithm performance in heterogeneous environment of LTE and WiMAX networks. Mobile user can randomly move with constant speed between BSs. Figures 3a–f and 4a–f show the membership

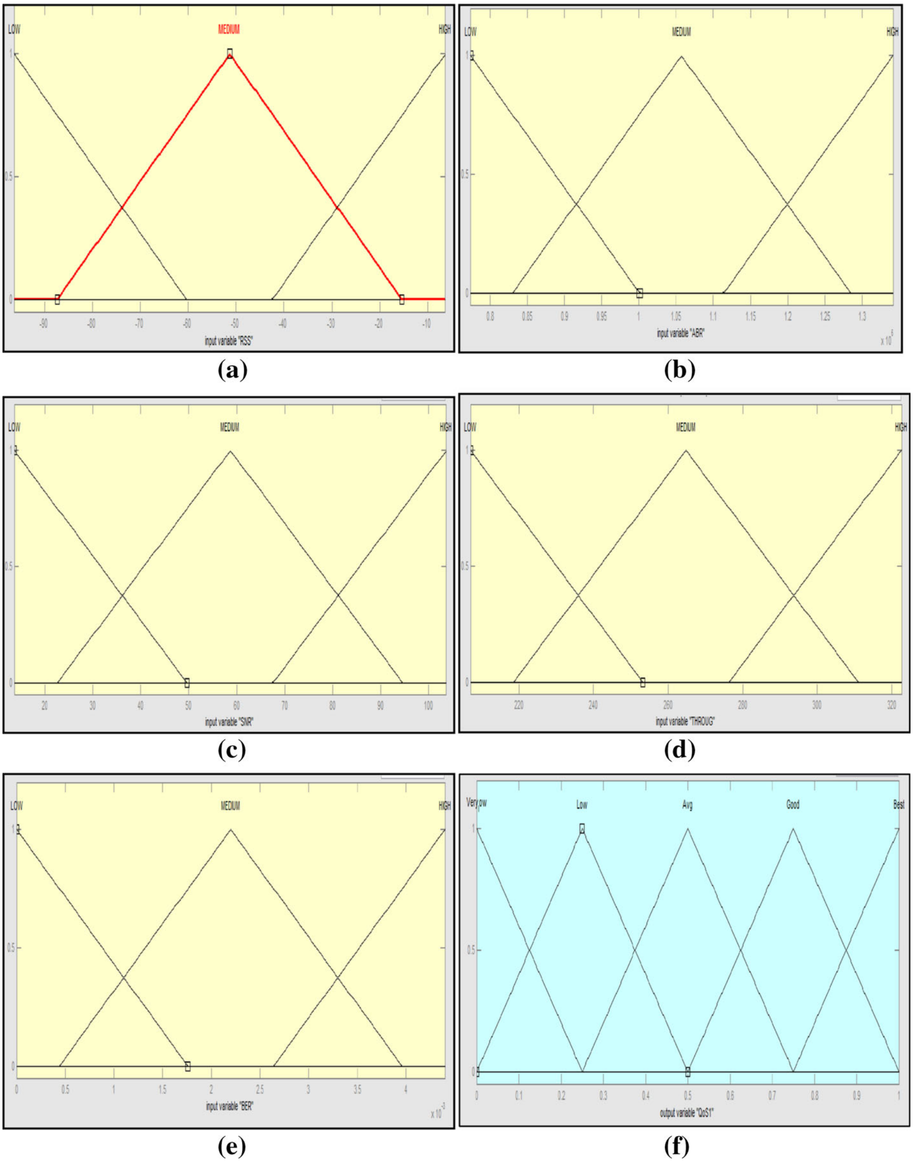

Fig. 3 **a–e** Degree of membership w.r.t link parameters, **f** degree of membership w.r.t QoS of WiMAX network

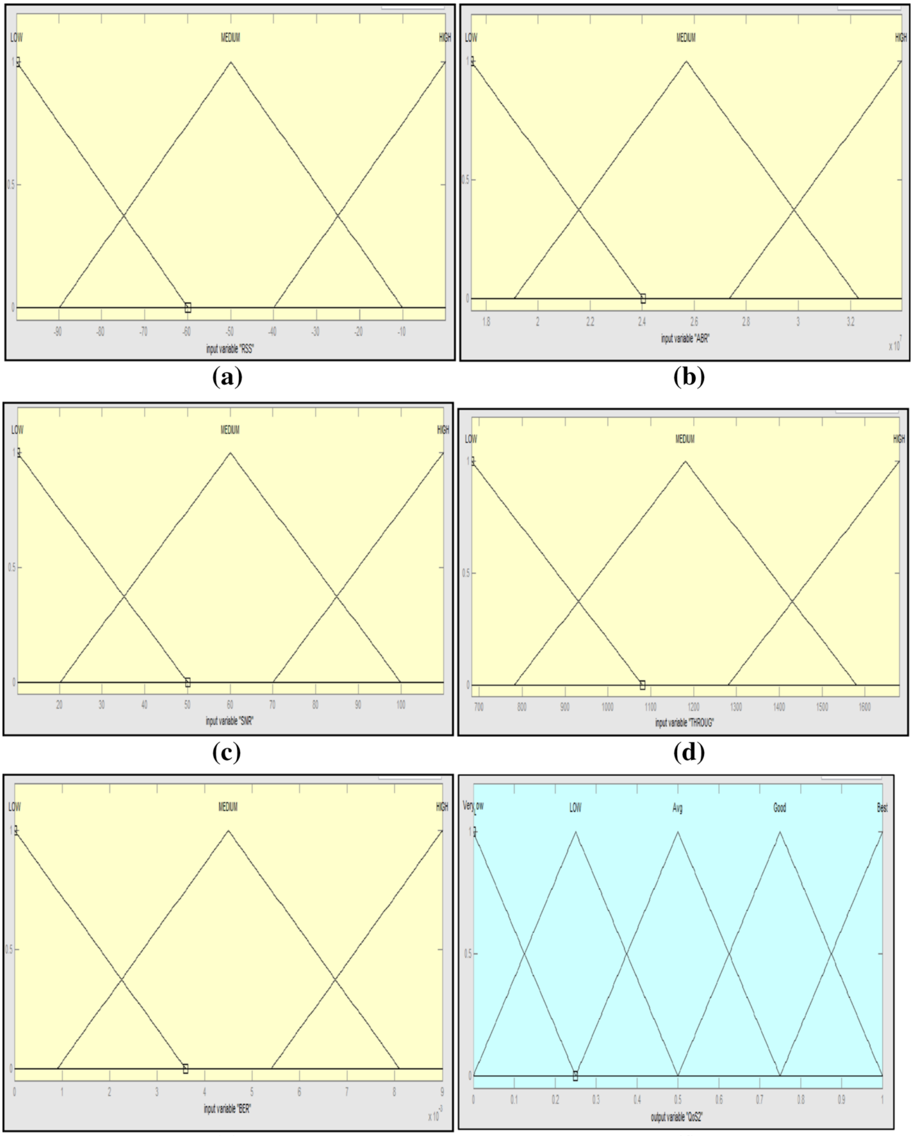

Fig. 4 **a–e** Degree of membership w.r.t link parameters, **f** degree of membership w.r.t QoS of LTE network

functions with respect to link parameters and QoS of WiMAX and LTE networks respectively.

Typical operating ranges of the attributes for different types of networks, utilized in fuzzy system are given in Table 2. The degree of QoS is calculated in the range of [0, 1] by performing a weighted sum of the membership values of averaged RSS, ABR, SNR, achievable Throughput and BER.

Inference rules, as shown in Figs. 5 and 6, are designed with the objective of calculating QoS of available wireless network i.e. WiMAX and LTE respectively.

Table 2 Parameters ranges of different types of available networks

S. no.	Parameters	WiMAX	LTE
1.	RSS (dB)	− 96.41 to − 6.3758	− 99.8082 to − 0.0982
2.	ABR (bps)	773,220–1341800	17,422,000–33,966,000
3.	SNR (dB)	13.5817–103.62	10.1918–109.9018
4.	Throughput (Kbps)	206.97–322.56	681.66–1680
5.	BER (dB)	0–0.0044	0–0.009

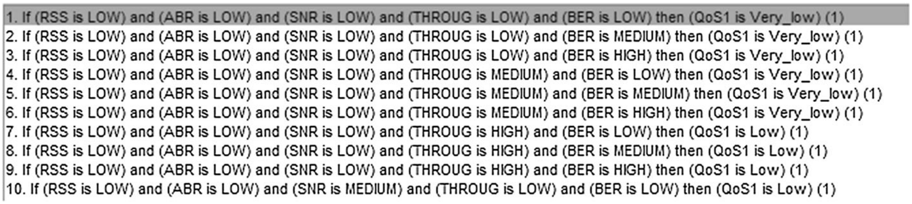
1. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is LOW) and (BER is LOW) then (QoS1 is Very_low) (1)
2. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is LOW) and (BER is MEDIUM) then (QoS1 is Very_low) (1)
3. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is LOW) and (BER is HIGH) then (QoS1 is Very_low) (1)
4. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is MEDIUM) and (BER is LOW) then (QoS1 is Very_low) (1)
5. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is MEDIUM) and (BER is MEDIUM) then (QoS1 is Very_low) (1)
6. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is MEDIUM) and (BER is HIGH) then (QoS1 is Very_low) (1)
7. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is HIGH) and (BER is LOW) then (QoS1 is Low) (1)
8. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is HIGH) and (BER is MEDIUM) then (QoS1 is Low) (1)
9. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is HIGH) and (BER is HIGH) then (QoS1 is Low) (1)
10. If (RSS is LOW) and (ABR is LOW) and (SNR is MEDIUM) and (THROUG is LOW) and (BER is LOW) then (QoS1 is Low) (1)

Fig. 5 Few inference rules for WiMAX network

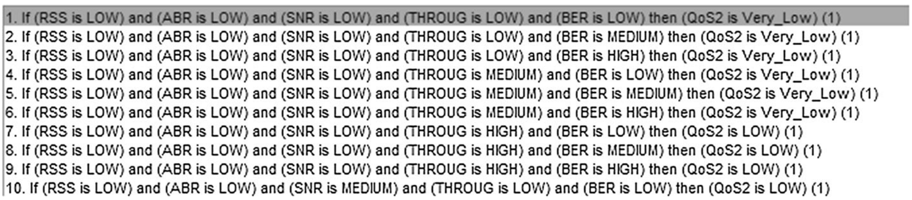
1. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is LOW) and (BER is LOW) then (QoS2 is Very_Low) (1)
2. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is LOW) and (BER is MEDIUM) then (QoS2 is Very_Low) (1)
3. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is LOW) and (BER is HIGH) then (QoS2 is Very_Low) (1)
4. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is MEDIUM) and (BER is LOW) then (QoS2 is Very_Low) (1)
5. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is MEDIUM) and (BER is MEDIUM) then (QoS2 is Very_Low) (1)
6. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is MEDIUM) and (BER is HIGH) then (QoS2 is Very_Low) (1)
7. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is HIGH) and (BER is LOW) then (QoS2 is LOW) (1)
8. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is HIGH) and (BER is MEDIUM) then (QoS2 is LOW) (1)
9. If (RSS is LOW) and (ABR is LOW) and (SNR is LOW) and (THROUG is HIGH) and (BER is HIGH) then (QoS2 is LOW) (1)
10. If (RSS is LOW) and (ABR is LOW) and (SNR is MEDIUM) and (THROUG is LOW) and (BER is LOW) then (QoS2 is LOW) (1)

Fig. 6 Few inference rules for LTE network

User interface of fuzzy system in Fig. 7 shows the calculated QoS of available wireless networks (WiMAX and LTE) in heterogeneous environment and this value is applied as input along with cost function for final decision of network selection.

Performance comparison between proposed algorithm (C-P-F) and existing algorithm in terms of number of network selections w.r.t distance is clearly depicted in Fig. 8. It is observed here that MS experiences less number of network selections in case of proposed algorithm (C-P-F) as compared to existing algorithm [27], while traversing a random trajectory. Thus, it reduces the switching load incorporated with the network selection process.

To ensure better accuracy, calculation based on maximum network selection rate has been performed using Monte Carlo method for proposed and existing algorithms in same heterogeneous environments. Comparison between network selection rate of proposed and existing algorithm is tabularized in Table 3. It is evident from the results that network selection rate is significantly reduced 75% by applying proposed C-P-F algorithm.

Load balancing (LB_0) among networks while achieving user satisfaction is considered to evaluate the performance of proposed algorithm. It is measured by calculating percentage among number of users in available wireless networks [4]. Here load balancing is highly influenced by QoS of network.

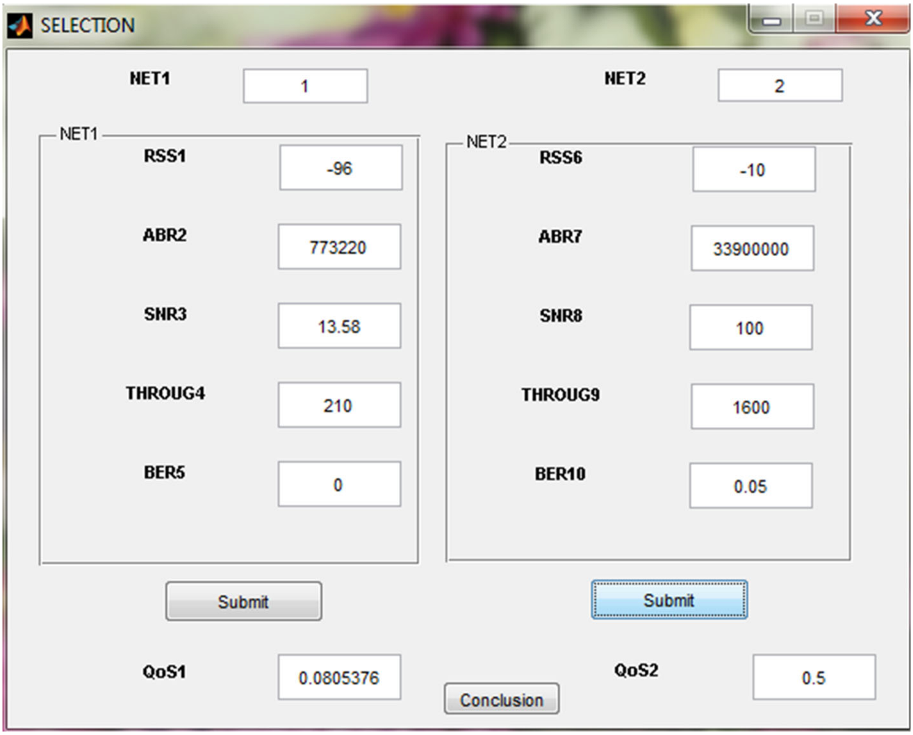

Fig. 7 User interface of QoS calculation using FL

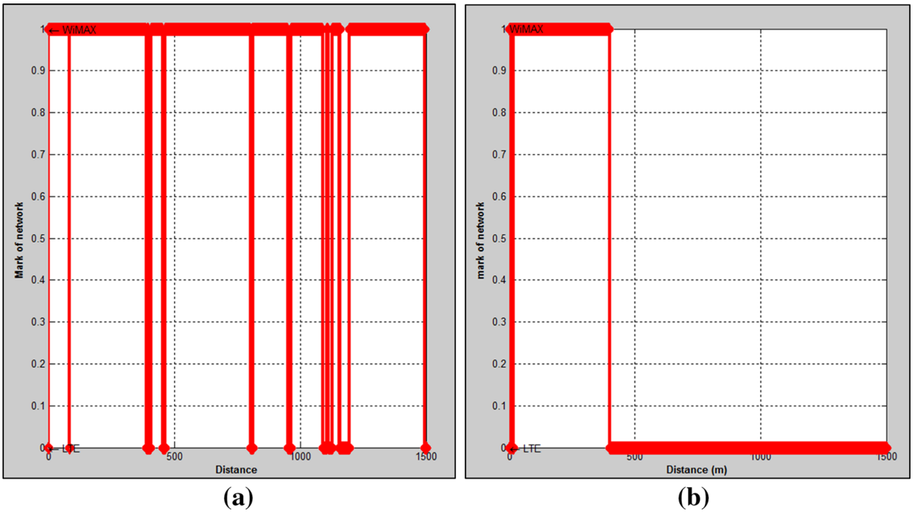

Fig. 8 Number of network selections w.r.t distance while user has random mobility **a** cost function and modified PSO [27], **b** C-P-F algorithm

Table 3 Comparison of network selection rate

	Cost and modified PSO algorithm [27]	C-P-F algorithm
Network selection rate	15–20	4–5

The following pseudo code has been applied to calculate load balancing.

```
{
If (QoS1>QoS2)
then net1=net1+1;
else
net2=net2+1;
}
```

QoS1 and QoS2 are calculated by fuzzy system. Where, net1 and net2 signifies the number of customers in their individual network i.e. LTE and WiMAX. In random movement case of MSs, the load balancing factor LB_0 fluctuates from 1.12 to 6.68.

Another performance evaluation criterion for the proposed algorithm is utility degree. It is calculated by modified sigmoid utility function [28]. It computes two independent variables i.e. achievable throughput ($Throu_i$) and available bit rate (ABR_i), as given in Eqs. (14) and (15).

$$AT_i = Throu_i + ABR_i \tag{14}$$

$$u_i(AT_i) = \begin{cases} 1 & AT_i > \eta_i \\ \dfrac{\left(\frac{AT_i - \eta_i^{min}}{0.5\eta_i - \eta_i^{min}}\right)^{\xi}}{1 + \left(\frac{AT_i - \eta_i^{min}}{0.5\eta_i - \eta_i^{min}}\right)^{\xi}} & \eta_i \geq AT_i \geq \eta_i^{min} \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

where AT_i is summation of achievable throughput and ABR of respective available wireless network, ξ is a tuned steepness parameter and its value must be greater than equal to 2. For multimedia services, η_i^{min} is minimal admissible bandwidth threshold value of mobile user. A mobile user will be considered fully gratified if u_i equal to 1 or if user's available bit rate and achievable throughput is more than or equivalent to user's requirement i.e., $AT_i \geq \eta_i$. User will be semi satisfied if u_i equal to 0.5 or if mobile user receives only a half of bitrate/throughput than user requirements i.e., $AT_i = 0.5\eta_i$. Here, we suppose that $\eta_i^{min} = 64$Kbps, $\eta_i = 6000$ Kbps and $\xi = 3$ for web browsing, multimedia messaging, interactive geographical mapping [29]. Figure 9 depicts the utility degree in terms of achievable throughput and available bitrate of mobile user w.r.t distance in heterogeneous environment.

It is apparent from Fig. 9 that utility equal to 1 for the both networks. Theoretically, data rate up to 75–100 Mbps is provided by both networks. The guaranteed bitrate prerequisite of multimedia applications such as video conferencing/streaming varies from 64 Kbps–4 Mbps as given in Table 4.

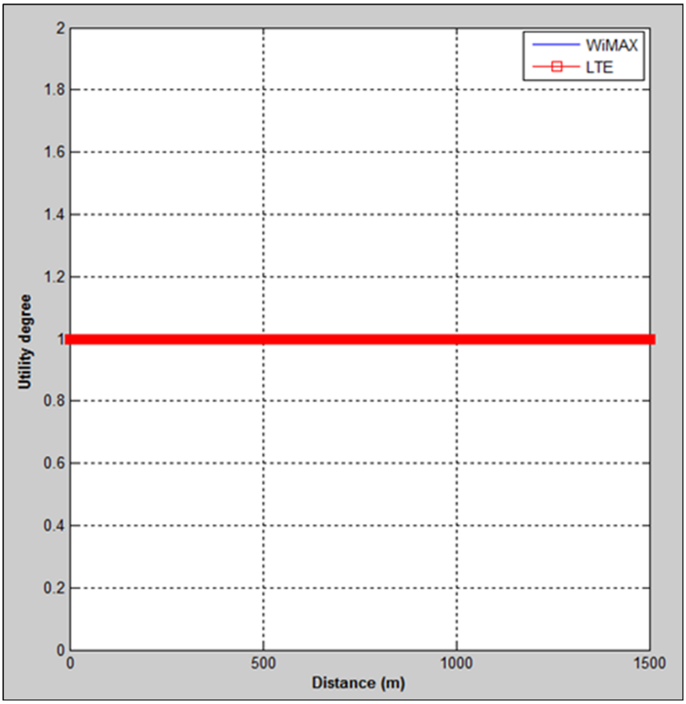

Fig. 9 Utility degree versus distance of LTE and WiMAX in heterogeneous wireless environment

Table 4 Different services employed by users [30–32]

S. no.	Service type	Metric (s)	Range
1.	Telephony services	RSS	− 75 dB
2.	Online radio	SNR	10 dB
3.	Video conferencing	Available bit rate	64 Kbps–4 Mbps
4.	Video streaming	Throughput	1 Mbps–1.5 Mbps

Best QoS can be attained when utility degree is equal to 1 or achievable throughput and available bit rate is more than guaranteed bitrate. When users are on random move and trying to select best network in heterogeneous environment then proposed algorithm retains QoS by maintaining utility degree equal to 1.

The selection of network depends upon the ongoing application at that time. If multimedia oriented application is running, then the primary concern is more on ABR, SNR and Achievable throughput, but less on BER to decrease data loss in secure/critical usage viz. online transactions. Inclusively, network selection depends upon user preferences and network conditions such as high averaged RSS, ABR, SNR, Achievable throughput and low BER. Number of contented users according to QoS prerequisite of service type, while user is on random movement is presented in Fig. 10. Here four types of services (telephony, online radio, video conferencing and video streaming) according to QoS (RSS, SNR, available bit rate, Throughput) requirement have been considered to evaluate the impact of network selection on multimedia customers in term of contented users. Every

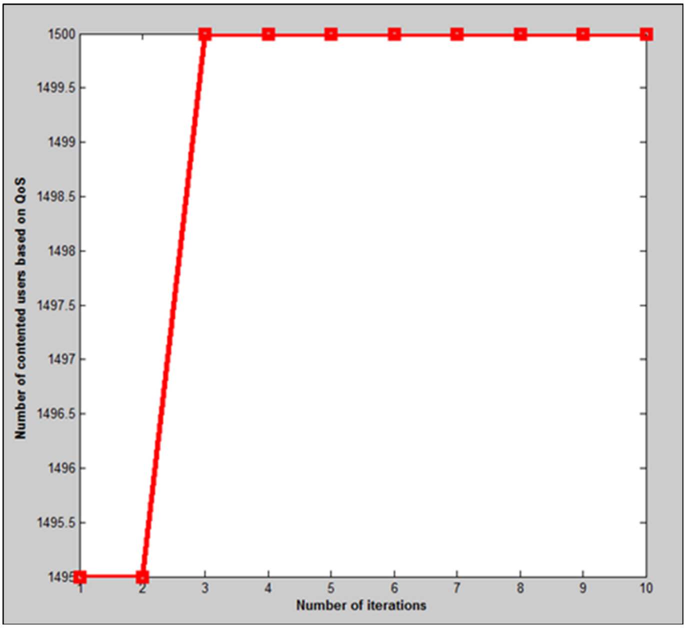

Fig. 10 Number of contented users with desired QoS while user on random move

service type has a specified QoS attribute requirement. The service type needs lesser data rate and higher RSS will be considered more suitable for telephony services. Video streaming service can be considered as high throughput requirement service. The service type requires higher available bit rate is suitable for video conferencing. The service type requires high SNR is more suitable for online radio service. Services with their specific attribute requirement are presented in Table 4. QoS considered here consists of all attributes as per requirement. The network having high QoS will have more contented users.

The proposed C-P-F algorithm performance with other existing algorithms is compared on the basis of probability of contented users as presented in Fig. 11. The user's

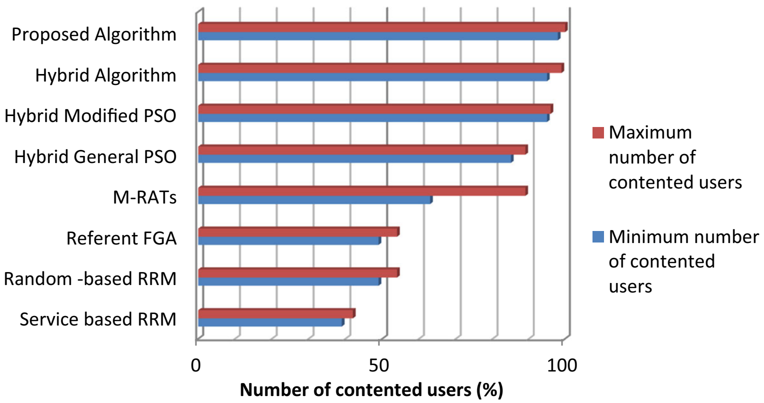

Fig. 11 Comparison of probability of contented users of proposed and existing methods

satisfaction level is dependent on services provided as per conditions and requisites fixed prior in service based RRM [33]. The accessible networks are arbitrarily assigned to users in random based RRM (Radio Resource Management). In third algorithm, i.e. referent FGA (Fuzzy Genetic Algorithm) [4] merges Genetic Algorithm (GA) and Fuzzy Logic (FL) for Radio Access Technology (RAT) selection. Multi criteria decision making algorithm, GA and PSO have been applied for the selection of RAT in Mobile based Radio Access Technology Selection (M-RATS) [34]. In Hybrid General PSO, multi objective decision-making algorithm has been hybridized with General PSO [35]. A multi objective decision-making algorithm with a fuzzy controller was developed in [12]. Hybrid modified PSO is employed for RAT selection. Optimized relative weights of selection making metrics, cost function and modified PSO were hybridized for network selection in [27].

It is realized that the proposed selection algorithm (C-P-F) attains around 55% performance improvement in comparison to random based selection and service based algorithms. Whereas, 15% performance improvement in case of hybrid general PSO, 10% in hybrid modified PSO and 5% in proposed with reference to probability of contented users, as reported in [27].

6 Conclusion

Due to the ever-increasing demand of always best connectivity and seamless mobility, network selection has constantly been an area of intense research. It is likely to continue in future too due to diversification and integration of heterogeneous wireless networks. In this work, we considered LTE and WiMAX networks in heterogeneous environment. A network selection scheme (C-P-F) has been developed by considering the practical constraints such as unnecessary network selections, utility degree, load balancing and user satisfaction. Weight optimization of cost function by modified PSO and QoS calculation by fuzzy system is carried out in C-P-F. Unnecessary network selection rate is reduced, while improving the user's QoS level and satisfaction. The simulation result shows that network selection rate is reduced with combined effect of cost function and fuzzy system. Proposed criterion has been assessed by network selection rate, utility degree, and load balancing and contented users. It is shown that proposed algorithm outturns 55% performance improvement in terms of contented users and 75% reduction in network selection rate as compared to existing techniques.

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