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Utility aware network selection in small cell

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Abstract

In fifth generation heterogeneous network, small cell is developed to compensate the growing demand for mobile data services. Due to the smaller size of cell, users have a short duration of connection, however, the user may also have the need of handoff frequently. At the time of handoff, different networks are available with different data rate and different other parameters. So, there is the need of frequent selection for the optimal network. In this paper, a utility-aware optimization algorithm has been proposed for network selection in a heterogeneous environment of Wi-Fi, WiMAX, WLAN, LTE, UMTS, and GPRS network. The weight factor is proposed for modified Jaya algorithm which is calculated by the analytical hierarchical process, standard deviation, and entropy method. Different applications are considered such as video, voice, web browsing and email transfer in which available bandwidth, packet jitter, packet loss, cost per byte are taken as dominant attributes, respectively. According to the dominant factor, different networks are selected for different applications because the requirement of all applications cannot be fulfilled by one network. Finally, the proposed algorithm is compared with multi-attribute decision making algorithms and game theory and accuracy of the proposed algorithm is calculated. The accuracy of proposed algorithm is higher as compared to the other algorithms and at the same time, this algorithm requires less computation which can further reduce the handoff latency and failure probability. Hence, the performance of handoff can be improved by using modified Jaya algorithm.

Keywords Fifth generation (5G) · Game theory · Heterogeneous wireless network (HWN) · Jaya algorithm · Network Selection and Small Cell

1 Introduction

The demand of mobile data is increasing during the last few years due to increasing numbers of applications. The user would like to be connected at anywhere and anytime regardless of their location [1]. The rapid demand of mobile data cannot be fulfilled by the fourth generation (4G) network so it moves the research towards the fifth generation (5G) [2]. The 5G network provides the better quality at every location and at every time [3]. It takes the advantage of different advance technologies i.e. millimeter wave (mm-Wave) communication, massive Multiple-Input Multiple-Output (MIMO), cognitive radio communication,

ultra-dense network, small cell technology, heterogeneous network etc. as well as different other provisioning technologies [4]. For efficient communication, two of the different technologies of 5G network may be combined. So, to increase both energy efficiency and spectral efficiency, the ultra-dense network is combined with mm-Wave technology [5] by considering the different factors such as load balancing, energy harvesting and cross-tier interference. A gradient association technique is proposed to solve this optimization problem which further improves the network utility and energy efficiency.

For increasing the coverage and system capacity, small cell i.e. femtocell, picocell and microcell is used with macrocell. The small cell relieves the burden of macrocell by providing the hotspot to the indoor and outdoor users. A lot of research has been done on the small cell because it helps in spectrum reuse with less power consumption and increases the coverage area with low infrastructure cost [6]. Despite their advantages, there are some problems arise in small cell network such as interference management,

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resource allocation, mobility management due to heterogeneous network [7]. The efficient energy resource allocation in heterogeneous small cell network is discussed in [8] with Wi-Fi spectrum sharing. Another, in orthogonal frequency division multiple access [9], the power allocation, backhaul bandwidth allocation, and efficient energy consumption are considered. It allocates the transmit power of small cell in such a manner so that it increases the energy efficiency.

Due to the smaller size of cell in a 5G network, there is always a need for mobility management especially vertical handoff [10]. The process of vertical handoff from one network to another network happens when the selected network does not provide the required service for the specific application [11]. The selection decision is made at the time of call initialization and then subsequently every time during the call as a part of handoff execution. The selection decision should be right for providing the uninterrupted service to users. Therefore, the network selection becomes necessary for every mobile user [12].

The selection of network is the complicated problem which can be solved by different methods. In cognitive radio, there is always a need of network selection for secondary user. Three different network selection strategies namely random, weighted and greedy are considered in collision constrained network selection [13]. The collision constrained method achieves an improved performance in terms of system throughput and collision probability. The probabilistic approach [14] decides the initial and target channel in cognitive radio for handoff procedure. The performance of this approach is determined in terms of average sojourn and extended service times.

The selection of network using probabilistic approach [15] considered the transition and steady state network selection probability in Code Division Multiple Access (CDMA) and Wireless Local Area Network (WLAN). Based on the steady-state probabilities, two network parameters such as call blocking probabilities and network throughput are evaluated. As the number of users increases, these two parameters start decreasing. So, this method does not give an optimal result for a larger number of users. A network-assisted approach [16] for selection of network in heterogeneous cellular networks jointly enhance network performance and user experience. In this approach, a semi-Markov decision process is used and it is solved by policy iteration algorithm. It has the advantage of requiring no prior parameterization but needs to pertinently set the tuning thresholds for the optimal solution. To predict the received signal strength indicator (RSSI) at every location, adaptive handoff trigger strategy [17] is used. The problem is formulated in terms of hidden markov models (HMM) which further improve the handoff probability and handoff success probability.

Multi-attribute decision making (MADM) algorithms are most commonly used method for network selection [18]. Different MADM algorithms include Simple Additive Weighting (SAW), Multiplicative Exponential Weighting (MEW), Grey Relational Analysis (GRA), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and VIKOR (VlseKriterijumska Optimizacijia I Kompromisno Resenje, in Serbian) are used for ranking of networks. In the literature [19], MADM algorithm is weighted by analytical hierarchical process (AHP) method. In the AHP method, the relative importance of different indexes should be accurate. If the number of the attribute is increased, then the complete comparison matrix is reconstructed. In the MADM algorithm, the selection is done on the basis of user's preferences [20] and the user always tries to maximize their utility so their decision may lead to an inefficient performance in terms of network utilization.

Game theory, a decision-making technique in case of a complex problem, is also used for selection of a network. It is a most useful tool for analyzing and modeling the problem of the 5G heterogeneous network as discussed in [21]. The author in [22] described the basic concept of game theory in network selection and different types of games. The main elements of a game are players, the strategy of each player and the payoff function associated with each strategy of each player in a game. A tutorial survey on game theoretic approach [23] in cognitive radio networks is given and it is used for dynamic spectrum sharing in cognitive radio networks. In reputation based network selection [24], the user–network interaction is modeled as a cooperative game. The network reputation factor is considered which reflects the network's previous behavior in assuring service guarantees to the user.

The author in [25] used the dynamic evolutionary game for sharing of bandwidth in heterogeneous wireless networks. Evolutionary game model, a non-cooperative, user versus user game, is used for network selection where players are the user involved in the selection and their strategy is to select the network. The selection is done from three different networks and payoff function is used as a selection criterion. Network selection using bankruptcy game theory is described in [26]. Bankruptcy game model, a cooperative, network versus network game model is used, where players are the available network and the strategy is the coalition formation of the available network to provide resources to the user and payoff is calculated by using the characteristic function for each formed coalition [27]. Cloud-based network selection using coalition formation game [28] is used to balance system throughput and fairness with built-in utility division rule of the framework. The algorithm efficiency showed eight-time enhancement over a conventional coalition formation algorithm. The

main problem encountered with game theory is its complexity for a large number of users [29].

The authors in [30] propose an energy-aware utility function for user-centric network selection strategy and multimedia delivery in a heterogeneous wireless network. Based on the mobile device type, network conditions, application requirements and user preferences, the energy-aware utility function selects the best value network which satisfies the user needs. Multi-criteria optimization [31] has the advantage of network selection in an efficient way for both perspectives, i.e. the end user and the network operators. A multi-criteria utility function is proposed that satisfies all the properties to maximize the Quality of Experience (QoE) of the end user and acceptance probability for the network operator's radio resource management [32]. An important highlighted result is that this network selection not only benefits the end users but it also increases the revenues of network operators as well.

During the last few years, the optimization field has been grown rapidly [33]. Many optimization algorithms such as genetic algorithm (GA) [34], particle swarm optimization (PSO) [35, 36], artificial bee colony (ABC) [37] are used for solving the problem of network selection. GA is adaptive heuristic optimization algorithm which is based on the evolutionary natural selection. As compared to GA, PSO algorithm is easier to implement and achieve fast convergence. The main difficulty in PSO algorithm is its tuning of different parameters. In ABC algorithm, there is the need of objective function evaluations and it became slow for serial processing. To overcome the drawback of these algorithms, the teaching–learning-based optimization (TLBO) algorithm [38] is proposed. It is based on the fact that the teaching affects the learner output. In TLBO algorithm, there is the need of two-phase i.e. teaching and learning phase. The main drawback of TLBO algorithm is its convergence rate for higher dimension problems. To overcome the drawback of TLBO algorithm, Jaya algorithm is proposed [39]. The Jaya algorithm is the parameter-free algorithm and requires only control parameters. But Jaya algorithm cannot be used for a specific application because there is no concept of weight. So, there is the need for modification in Jaya algorithm. The main contributions of this paper are:

- The Jaya algorithm is modified and weight concept is proposed for the Jaya algorithm. Due to the addition of weight factor in Jaya algorithm, it can be used for any specific applications which can further increase the Quality of experience (QoE) of the user.
- The complex problem is converted into a simple optimization algorithm using the energy utility function. In literature [40, 41], the utility function is associated with the different game theory. The game

theory suffers the problem of complexity. So, the problem of complexity is removed in this paper.

- The justification towards the results of Jaya algorithm is done by comparing the results to the game theory and MADM algorithm. The results show the modified Jaya algorithm gives the correct results with less complexity.
- Finally, the performance of Jaya algorithm is shown in terms of accuracy. The Jaya algorithm performs the network selection in an accurate manner with less computation which can further reduce the handoff latency and handoff failure probability.

The remainder of this paper is organized as follows: Sect. 2 introduces the weight calculation methods. Section 3 discusses the modified Jaya algorithm. In Sect. 4, simulation results using different weight calculation and score calculation methods are discussed. Finally, in Sect. 5, the conclusion is given.

2 Weight calculation methods

2.1 Analytical hierarchical process (AHP)

AHP method is used to assign the weights to each attribute in the network selection strategy. It is the most commonly used method that is developed by Saaty [42]. It consists of different steps for weight calculation:

Step 1: Construct a hierarchy structure: First of all, the objective of the problem is defined in terms of different factors. Then the network selection problem is broken down into a hierarchical structure as shown in Fig. 1 where at the middle level, attributes are placed and at a lower level, networks are placed.

Step 2: Construct comparison matrix: The pair wise comparison matrix is given by $X = [x_{ij}]_{m \times m}$ where m denotes the total number of attributes and $x_{ii} = 1, x_{ij} = 1/x_{ji}, x_{ij} \neq 0$. The element x_{ij} is defined by Saaty's scale from 1 to 9 values as shown in Table 1. The scale number is given according to their importance of one attribute to another.
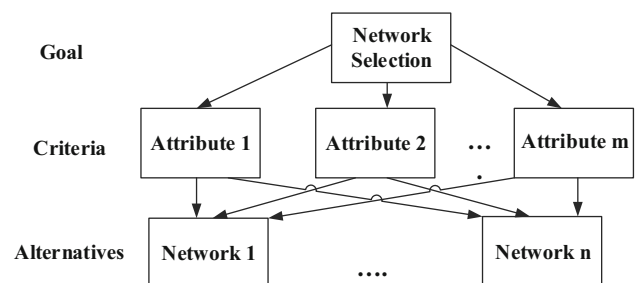

Fig. 1 Hierarchical structure model

Table 1 Saaty's scale of pairwise comparison

Saaty's scale	Relative importance of two sub-elements
1	Equally important
3	Moderately important with one over another
5	Strongly important
7	Very strongly important
9	Extremely important
2,4,6,8	Intermediate value

Step 3: Construct normalized matrix: The matrix is normalized by:

$$y_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{1}$$

Step 4: Calculation of relative weights: The weights of different attributes are calculated by:

$$w_i = \frac{\sum_{j=1}^{n} y_{ij}}{m} \text{ where } \sum_{i=1}^{m} w_i = 1 \tag{2}$$

where m denotes the number of attributes.

Step 5: Check consistency: For checking judgment error, consistency should be checked. Consistency Index (CI) is calculated by

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3}$$

where λ_{max} is the maximum eigen value and calculated by

$$\lambda_{max} \approx \sum_{j=1}^{m} \left[w_j \left(\sum_{i=1}^{n} x_{ij} \right) \right] \tag{4}$$

Now, Consistency Ratio (CR) is calculated by dividing the CI by the Random Index (RI) and is given by

$$CR = \frac{CI}{RI} \tag{5}$$

where RI value depends on the number of attributes and it is taken from Table 2 [19]. If the CR is smaller than or

Table 2 Value of RI

Number of attributes	RI
3	0.5
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

equal to 10%, the inconsistency is acceptable otherwise we need to revise the matrix.

2.2 Standard deviation (SD) method

The standard deviation method is used for weight calculation based on the principle of the degree of variation. Normally, the standard deviation is directly proportional to the variation of attributes range of a certain index. So, if the degree of variation in attributes range is large, then the standard deviation is also large. It means it offers more amount of information. The more information plays an important role in the evaluation work, so the weight becomes larger. Conversely, lower degree of variation contains small weight [43]. It consists of different steps:

Step 1: Construct decision matrix: The decision matrix is constructed by taking the *ith* network and *jth* attributes. The decision matrix is presented by $A = [a_{ij}]_{m \times n}$ where m denotes the number of networks and n denotes the number of attributes.

Step 2: Normalization: There are two types of normalization: benefit type and cost type. For benefit type, the normalization is done by

$$r_{ij} = \frac{a_{ij}}{a_{max}^j + a_{min}^j} \tag{6}$$

For cost type, the normalization is done by:

$$r_{ij} = \frac{a_{max}^j + a_{min}^j - a_{ij}}{a_{max}^j + a_{min}^j}, \tag{7}$$

where $a_{max}^j = max(a_{1j}, a_{2j}, ...a_{mj})$ and $a_{min}^j = min(a_{1j}, a_{2j}, \dots ,a_{mj})$.

Step 3: Calculate standard deviation: The standard deviation for *m* network is calculated by Shuo and Qi [43]:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m} (r_{ij} - \bar{r}_j)^2}{m}} \, for \, j = 1, 2, \dots, n \tag{8}$$

where

$$\bar{r}_j = \frac{\sum_{i=1}^{m} r_{ij}}{m} \, for \, j = 1, 2, \dots, n \tag{9}$$

Step 4: Calculate weight: The weight of different attributes is calculated by:

$$w_j^{SD} = \frac{\sigma_j}{\sum_{j=1}^{n} \sigma_j} \, for \, j = 1, 2, \dots, n \tag{10}$$

2.3 Entropy method

The entropy method is also used for weight calculation which is proposed by Shannon. In the communication system, the information entropy is related to the uncertainty of signals. Entropy method is also based on the variation degree of a certain index. If the information entropy is less, then the variation degree is more. It plays an important role because it contains more information so the larger weight should be assigned to that. Conversely, a large value of entropy indicates small variation and contains less information so it should be assigned smaller weight [44]. The different steps for weight calculation are:

Step 1: Construct decision matrix: The decision matrix is constructed by taking the *ith* network and *jth* attributes. The decision matrix is presented by $A = [a_{ij}]_{m \times n}$ where m denotes the number of networks and n denotes the number of attributes.

Step 2: Normalization: There are two types of normalization: benefit type and cost type. For benefit type, the normalization is done by

$$c_{ij} = \frac{a_{ij} - a_{min}^j}{a_{max}^j - a_{min}^j} \tag{11}$$

For cost type, the normalization is done by

$$c_{ij} = \frac{a_{max}^j - a_{ij}}{a_{max}^j - a_{min}^j} \tag{12}$$

Step 3: Calculate Entropy: The information entropy for each attribute is calculated by:

$$E_j = -(\ln m)^{-1} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{13}$$

where

$$p_{ij} = \frac{c_{ij}}{\sum_{i=1}^{m} c_{ij}} \tag{14}$$

when $p_{ij} = 0$,so $p_{ij} \ln p_{ij} = 0$

Step 4: Calculate weight: The weight for different attributes is calculated by Delgado and Romero [44]:

$$w_j^{en} = \frac{1 - E_j}{n - \sum_{j=1}^{n} E_j} for j = 1, 2, \ldots, n$$

$$0 \leq w_j^{en} \leq 1; \sum_{j=1}^{n} w_j^{en} = 1 \tag{15}$$

If the difference between attributes range is small, then the value of entropy is large and it contains small information. Therefore, the smaller weight is assigned to that attribute.

3 Modified Jaya algorithm

Jaya algorithm is an optimization algorithm which is applied to constraint and unconstrained optimization problem. This algorithm is the reduced form of Teaching–Learning-Based Optimization (TLBO) algorithm because in Jaya algorithm, fewer parameters are required and only one teacher phase is required whereas TLBO algorithm required two-phase i.e. teaching and learning phase [45]. The Jaya algorithm is based on the concept that the results are going in the direction of best solution and in the opposite direction of the worst solution [46]. In this paper, the Jaya algorithm is modified in terms of network selection which is defined in algorithm 1.

The decision matrix is constructed by taking the *ith* network and *jth* attributes. The attributes should be in the same scale so that the normalization becomes necessary. There are two types of normalizations i.e. benefit normalization and cost normalization. The benefit normalization is done for larger the better attributes e.g. bandwidth, security etc. while the cost normalization is done for the smaller the better attributes e.g. cost, delay [47]. The utility function is based on the principle of the larger the better criteria [48]. The one utility function is used for all parameters because here benefit and cost normalization is done for different benefit and cost parameters, so there is no need of cost function. The energy utility function is used where utility indicates the usefulness of network parameters. Here, the utility function relates to the service derived by the user from the networks. Every user has different preference so according to their preference, they have different utility function for the same network. The utility function $u(x)$ is defined as:

$$u_{i,j}(x) = \begin{cases} 0, & x < x_\alpha \\ \frac{x_{ij} - x_\alpha}{x_\beta - x_\alpha}, & x_\alpha < x < x_\beta \\ 1, & otherwise \end{cases} \tag{16}$$

where x is the defined attribute for the network, x_α is the minimum value of the attribute and x_β is the maximum value of the attribute.

After the calculation of utility function, the weight factor is considered. The weight is calculated by different weight calculation methods as discussed in the last section. Then identify the best and the worst network based on the concept of the utility function. The maximum utility function is identified as the best solution and minimum utility function is identified as the worst solution.

$$u_{best} \leftarrow max(u_w) \tag{17}$$

$$u_{worst} \leftarrow min(u_w) \tag{18}$$

The solution is modified based on the concept that the search is going in the direction of the best solution and

moves in the opposite direction of the worst solution. The solution is modified as

$$a'_{i,j} = u_{i,j} + \left[(u_{best,j}) - |(u_{i,j})| \right] - \left[(u_{worst,j}) - |(u_{i,j})| \right] \tag{19}$$

Then the normalization of all the parameters is done due to the same scaling of all attributes.

$$q_{ij} = \frac{a'_{i,j}}{a'_{i,max}} i = 1, 2, \ldots \ldots mj = 1, 2, \ldots \ldots n \tag{20}$$

Again, calculate utility function $u'_{i,j}$ of q_{ij} using the same utility function which is defined in (16) and evaluate the weight factor.

$$u'_w = \underset{i \in M}{argmax} \sum_{j=1}^{n} u'^{w_j}_{i,j} \tag{21}$$

If u'_w is better than u_w then $U_{i,j} = u'_{i,j}$ otherwise $U_{i,j} = u_{i,j}$ i.e. If the new solution is better than the previous solution, replace the previous solution with the new solution otherwise keep the old one. The complete procedure of modified Jaya algorithm is shown in Fig. 2. This proposed algorithm is different from the Jaya algorithm [46] because in this algorithm the weight factor is considered and selection is done on the basis of utility function.

4 Results and discussion

The simulation scenario consists of heterogeneous network i.e. Wi-Fi, WiMAX, WLAN, LTE, UMTS, and GPRS. WiMAX and LTE are the 4G network, UMTS is the 3G, GPRS is the 2.5G and Wi-Fi and WLAN can be the 3G or 4G network. WiMAX, LTE, UMTS, GPRS is the wide area network while Wi-Fi and WLAN is the local area network. The different attributes are considered i.e. Available Bandwidth (AB) in Mbps, Propagation Delay (PD) in millisecond, Packet Jitter (PJ) in millisecond, Cost per Byte (CB) in percent, Packet Loss (PL) per every 10^6 packets and network deployment (ND) factor. The framework of network selection in heterogeneous networks scenario is shown in Fig. 3. This scenario is designed for four different applications i.e. video, voice, web browsing and email transfer. The different networks are selected for different applications according to the user preference. Each network has different attributes range which is given in Table 3. The simulation is performed on MATLAB software. The weight is calculated by subjective and objective methods. AHP method is termed as subjective method because in this method user preference is considered. Standard deviation and entropy methods are termed as objective method because, in these methods, user preference is not considered. In the network selection results, the

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Algorithm 1.

1. Determine the decision matrix $A = \left[a_{ij} \right]_{m \times n}$ where m denotes the number of networks and n denotes the number of attributes.

2. For benefit attributes, the normalization is done by

$$x_{ij} = \frac{a_{ij}}{a_{i\,max}} \quad i = 1, 2, \ldots \ldots m \quad j = 1, 2, \ldots \ldots n$$

For cost attributes, the normalization is done by

$$x_{ij} = \frac{a_{i\,min}}{a_{ij}} \quad i = 1, 2, \ldots \ldots m \quad j = 1, 2, \ldots \ldots n$$

Where $a_{i\,max} = \max(a_{1j}, a_{2j} \ldots a_{mj})$ and $a_{i\,min} = \min(a_{1j}, a_{2j} \ldots a_{mj})$.

3. Calculate utility function using (16)

4. Evaluate weight w_j on the utility function using

$$u_w = \underset{i \in M}{arg\,max} \sum_{j=1}^{n} u_{ij}{}^{w_j}$$

5. Identify the best and worst network using (17) and (18)

6. Modify the solution based on best and worst network using (19)

7. Normalize and calculate the utility function using (20) and (16) respectively

8. If $u'_w > u_w$

$$U_{i,j} = u'_{i,j}$$

Else

$$U_{i,j} = u_{i,j}$$

End if loop

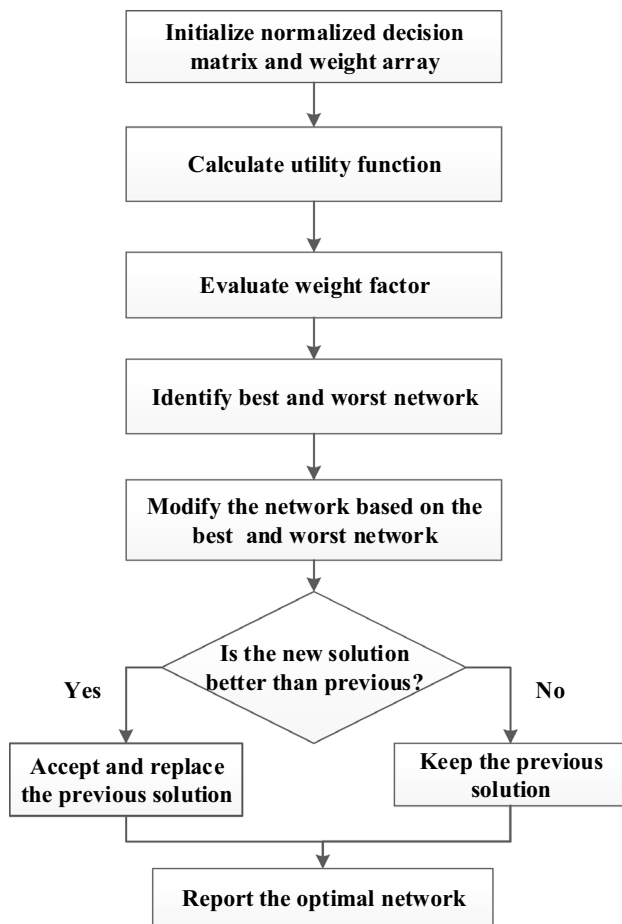9. Output: Best network is selected according to the different weights

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Fig. 2 Flow diagram of modified Jaya algorithm

method is used for assigning the weights. In the AHP method, the user can give the weight according to their requirement and applications which increase the Quality of Experience (QoE) of the user. In another two methods of weight i.e. standard deviation and entropy method, the assigned weights depend upon the attributes range. In the standard deviation method, the weight assigned to the attribute is directly proportional to the variation of its range. If the variation degree is small, then the standard deviation is also small and less weight is assigned to that attribute and vice versa. So, AB attribute is assigned maximum weight and PJ attribute is assigned minimum weight and so on. In the entropy weight calculation method, the weight is directly proportional to the information. If the difference between the attribute range is large, then it contains more information and larger weight is assigned to that attribute. So, in the entropy method, the AB attribute is assigned maximum weight. In the standard deviation and entropy weight calculation method, no user precedence is considered and weight depends upon the attribute range. So, this method cannot be used for any specific application. In the AHP method, the user can give importance according to their requirement as in this paper, it is used for different applications.

4.2 Network selection results

In this paper, the performance of modified Jaya algorithm is shown in terms of AHP, entropy and standard deviation weights.

The scores of different networks obtained by modified Jaya algorithm using utility function is shown in Fig. 5. For video application, the most precedence is given to AB, the second precedence is given to ND, the third precedence is given to PD and forth precedence is given to PJ attribute as shown in Fig. 4. The WiMAX and LTE network has the same range of AB, PD and PJ attribute but the different value of ND attribute. So, in that case, the second attribute is considered because it has different attribute value. As the WiMAX network is not widely deployed while LTE network is most common in use. So, due to consideration of all weight, LTE network is selected. As WiMAX network also provides maximum bandwidth but deployment factor of LTE network is large as compared to WiMAX network. So, WiMAX network is not selected for video application. In the case of the voice application, WiMAX network is selected although WiMAX, LTE, UMTS, and GPRS all these networks have minimum PJ. In this case, second and third precedence is considered. The second precedence is given to PD and the third precedence is given to PL. Although UMTS network has minimum PD but it has maximum PL so it is not selected for the voice application. Then after UMTS, the LTE and WiMAX network has
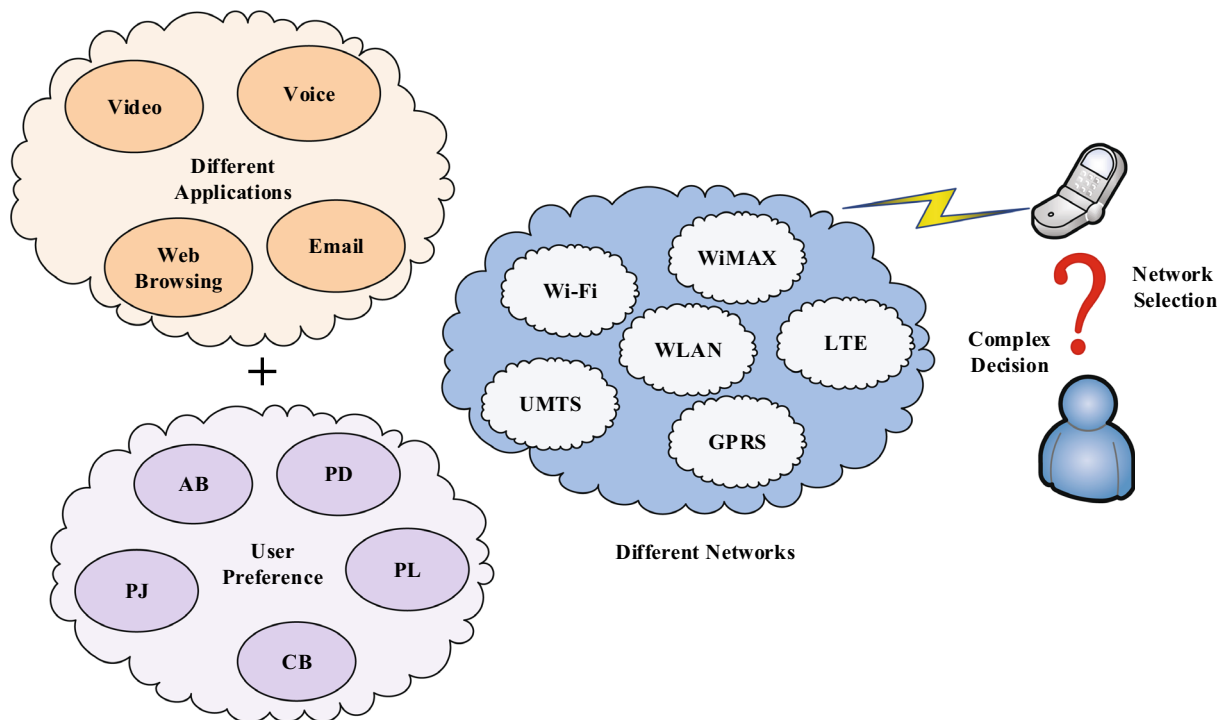
attributes are combined to their weights by different network selection methods i.e. modified Jaya algorithm, game theory [49] and MADM algorithm [50].

4.1 Weight calculation results

The four applications i.e. video, voice, web and email transfer are examined and every application is corresponding to the six different attributes. The weight calculated by the AHP, standard deviation and entropy method is shown in Fig. 4.

For the video application, the highest weight is given to the AB attribute because video application has the requirement for maximum bandwidth. So, for this application, the first precedence is given to AB and second precedence is given to ND attribute. For voice application, the flow of information should be continuous, so PJ and PD should be minimal. So, for this application, the first precedence is given to PJ and second precedence is given to PD. For third and fourth application, i.e. web browsing and email transfer, importance is given to PL and CB attribute respectively. For all these applications, AHP

Fig. 3 Heterogeneous wireless network

Table 3 Different network attributes

Network	AB (Mbps)	PD (ms)	PJ (ms)	CB (%)	PL (per 10^6)	ND (in rank)
Wi-Fi	10	115	15	7	80	2
WiMAX	60	100	10	40	15	1
WLAN	11	150	20	10	20	2
LTE	60	100	10	50	80	3
UMTS	2	50	10	80	100	1
GPRS	1	300	10	90	50	1

minimum PD but LTE network has larger range of PL and WiMAX network has lower range of PL, so WiMAX network is selected for the voice application. WLAN network is selected for web application because for this application first precedence is given to PL attribute and the second precedence is given to PD attribute. Although WiMAX network has minimum range of PL but WiMAX network is not widely deployed so WLAN network is selected for web application due to lower PL and higher PD. Also, the WLAN network is selected for email application because for this application, the first precedence is given to CB and second precedence is given to PL attribute. In the standard deviation and entropy weight calculation result, the first precedence is given to AB and second precedence is given to CB. So, by taking consideration of AB and CB, WiMAX network is selected for both applications. Jaya algorithm is easy to implement and it can

accommodate multiple criteria for selection with less complexity.

The network scores obtained by game theory, TOPSIS, GRA are shown in Figs. 6, 7 and 8 respectively. The game theory [49], TOPSIS [51, 52] and GRA [53] algorithm is applied to the network attribute Table 3 and same weight calculation results are considered which is applied in the modified Jaya algorithm. The concept of TOPSIS method is simple and comprehensive. It gives the selection result with high efficiency and flexibility. GRA method can handle many parameters and give a precise solution. But it is very complicated because as the number of level increases, length of the process also increases. In this game theory, the network provides resources to the mobile user. As mutual cooperation occurred among different networks, so it provides more resources to the users. In the game theory, all preference is considered and after that network selection is done. For video application, first preference is
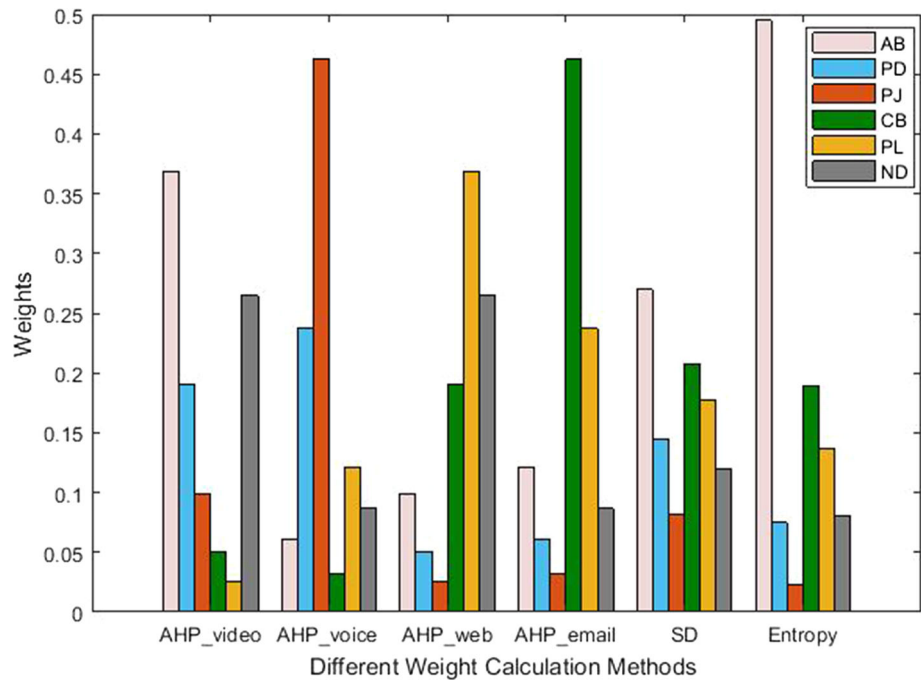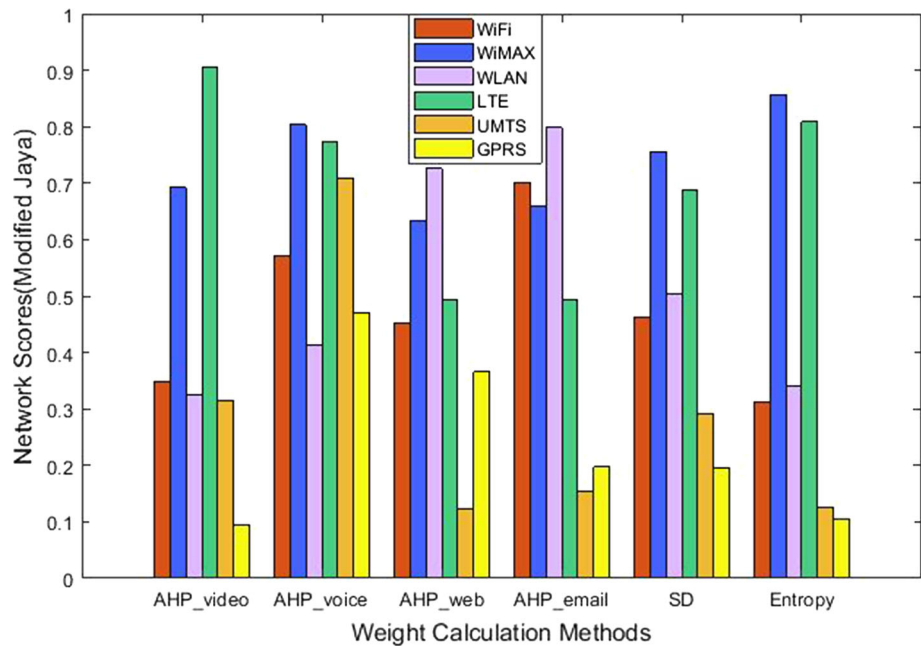
Fig. 4 Weight of different
attributes

Fig. 5 Network score using
modified Jaya algorithm

given to AB, second preference is given to ND, third preference is given to PD and forth preference is given to PJ parameter. By considering all these parameters, LTE network is selected. Although WiMAX and LTE network both have equal AB, PD, and PJ but ND attribute of LTE network is more as compared to WiMAX. Similarly, by considering all weights factors, for voice application, WiMAX network is selected. Similarly, for web and email application, WLAN network is selected by considering all

weight factors. For standard deviation and entropy weight, WiMAX network is selected due to the same reason.

The comparison of ranking scores of Jaya algorithm to another method of network selection i.e. game theory, TOPSIS, GRA is given in Table 4.

4.3 Accuracy

The accuracy of the ranking scores is calculated by subtracting of the minimum ranking score from the maximum
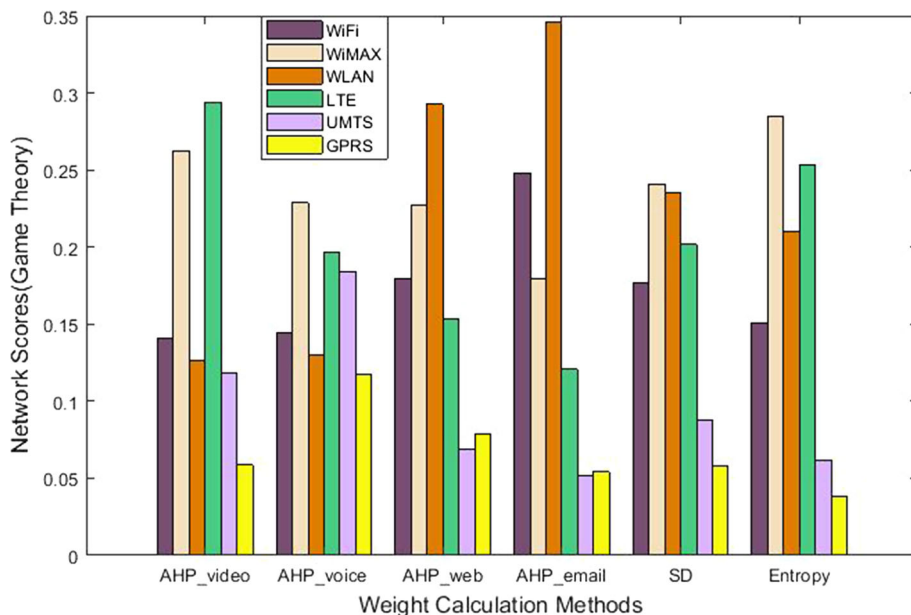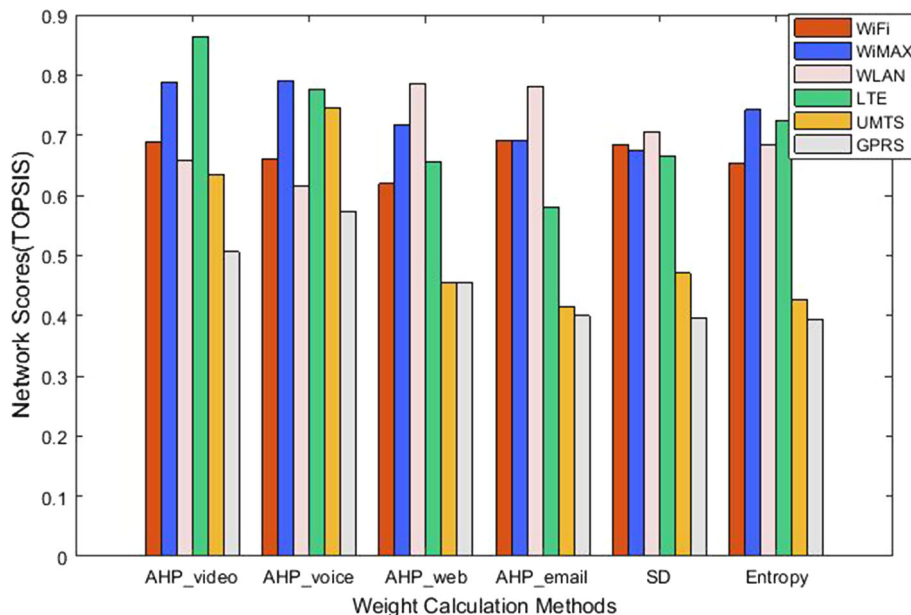
Fig. 6 Network score using game theory

Fig. 7 Network score using TOPSIS method

ranking score. In the ranking range, the difference between the minimum and maximum is determined. If the difference between the ranking scores is small, then identification of best alternative becomes difficult. Sometimes, this type of situation may lead to confusion in recognizing the best alternative. So, to avoid such situation, the difference between the maximum and minimum ranking values should be large. The modified Jaya algorithm is compared with another method in terms of accuracy by applying the different weight calculation methods.

The accuracy of different ranking scores obtained by different methods is shown in the Table 5. The result

shows that the modified Jaya algorithm has maximum difference in ranking values so it is the most accurate selection technique. The modified Jaya algorithm is 35 and 50% more accurate as compared to the GRA and TOPSIS method and 67% more accurate as compared to the game theory. The accuracy of game theory is least because of its cooperative nature. As all the networks cooperatively provide resources to the users so the performance of all the networks are almost equal. Due to the least difference in ranking scores, the accuracy of game theory is less. So, in terms of accuracy, modified Jaya algorithm is best from all other methods.
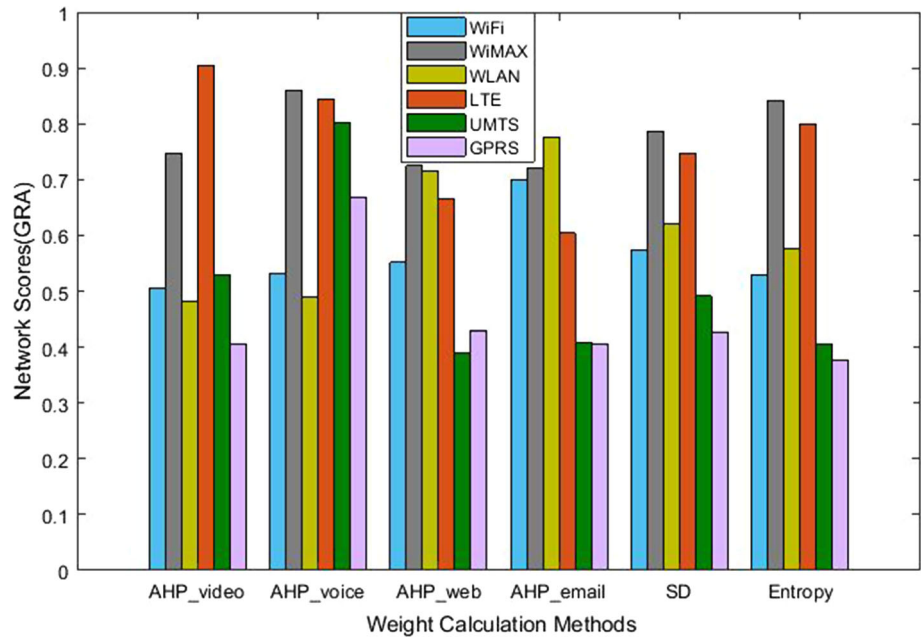
Fig. 8 Network score using GRA method

Table 4 Comparison of modified Jaya ranking scores to other methods

Applications	Network selection methods	Wi-Fi	WiMAX	WLAN	LTE	UMTS	GPRS
AHP video	Modified Jaya	0.3492	0.6923	0.3260	0.9051	0.3160	0.0948
	Game theory	0.1409	0.2622	0.1263	0.2938	0.1183	0.0586
	TOPSIS	0.6877	0.7873	0.6587	0.8632	0.6350	0.5056
	GRA	0.5052	0.7465	0.4804	0.9041	0.5296	0.4052
AHP voice	Modified Jaya	0.5712	0.8037	0.4126	0.7723	0.7084	0.4711
	Game theory	0.1442	0.2288	0.1298	0.1965	0.1838	0.1170
	TOPSIS	0.6614	0.7913	0.7913	0.7768	0.7447	0.5732
	GRA	0.5328	0.8604	0.4901	0.8428	0.8009	0.6676
AHP web	Modified Jaya	0.4514	0.6327	0.7263	0.4944	0.1241	0.3659
	Game theory	0.1798	0.2268	0.2926	0.1530	0.0690	0.0787
	TOPSIS	0.6196	0.7174	0.7865	0.6556	0.4551	0.4551
	GRA	0.5519	0.7245	0.7140	0.6658	0.3903	0.4299
AHP email	Modified Jaya	0.7015	0.6590	0.7982	0.4927	0.1541	0.1977
	Game theory	0.2479	0.1798	0.3459	0.1207	0.0514	0.0542
	TOPSIS	0.6903	0.6913	0.7814	0.5808	0.4148	0.4002
	GRA	0.7003	0.7201	0.7767	0.6038	0.4090	0.4055
SD	Modified Jaya	0.4616	0.7563	0.5047	0.6882	0.2923	0.1944
	Game theory	0.1765	0.2411	0.2356	0.2016	0.0875	0.0577
	TOPSIS	0.6844	0.6743	0.7061	0.6640	0.4701	0.3950
	GRA	0.5734	0.7872	0.6208	0.7458	0.4911	0.4257
Entropy	Modified Jaya	0.3126	0.8575	0.3408	0.8095	0.1255	0.1060
	Game theory	0.1510	0.2852	0.2102	0.2535	0.0619	0.0382
	TOPSIS	0.6543	0.7421	0.6850	0.7241	0.4265	0.3938
	GRA	0.5284	0.8406	0.5751	0.7992	0.4055	0.3777

Table 5 Accuracy of ranking scores

Protocol	Modified Jaya	Game theory	TOPSIS	GRA
AHP video	0.8103	0.2351	0.3576	0.4989
AHP voice	0.3911	0.1118	0.2180	0.3703
AHP web	0.8103	0.2351	0.3326	0.4989
AHP email	0.6440	0.2944	0.3812	0.3712
SD	0.5619	0.1833	0.3112	0.3614
Entropy	0.7515	0.2471	0.3483	0.4629

5 Conclusion

The selection of an optimal network plays an important role in the ongoing session of call at the time of handoff. The decision of network selection is influenced by the different factors. In this paper, a utility-based optimization algorithm is proposed for the network selection. The Jaya algorithm has been modified by including weight factor as user preference plays an important role in the selection criteria for increasing QoE of the user. The weight is calculated by AHP, standard deviation, and entropy method. The heterogeneous environment of Wi-Fi, WiMAX, WLAN, LTE, UMTS, and GPRS network is considered in which different networks are selected for different applications because for every application there are different requirements. For video application, LTE network has been selected due to higher deployment factor and for voice application, WiMAX network is selected as it has the less jitter and highest bandwidth and for web and email application, WLAN network is selected due to lower loss and cost. The selection results are compared with the MADM algorithm and game theory and finally accuracy of the modified Jaya algorithm is calculated. The modified Jaya algorithm is 35 and 50% more accurate as compared to the GRA and TOPSIS method and 67% more accurate as compared to the game theory. The proposed optimization algorithm is simple and requires less computation because it needs fewer control parameters. Due to its simplicity and better accuracy, the decision of network selection is fast which may decrease handoff failure probability and handoff latency. Due to the fast operation of the algorithm, it can be used in the smaller cells for frequent handoff. It is the powerful optimization algorithm which can be used for selection of secondary users in cognitive radio.

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