Wireless Pers Commun (2015) 82:1665–1684
DOI 10.1007/s11277-015-2305-6

Cross Layer Based Dynamic Handover Decision in Heterogeneous Wireless Networks

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Published online: 28 January 2015
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Abstract Heterogeneous wireless networks encompass different radio access technologies to offer services as per the requirements of the users at anytime and anywhere. In such networks, mobile users have to undergo vertical and horizontal handovers to realize seamless communication with guaranteed quality of service. In this paper, we propose cross layer based dynamic handover decision algorithm to maximize resource utilization and to attain high QoS. The parameters measured at different layers are used through media independent handover functionality to estimate handover requirement and to select an appropriate target network. Based on user's preferences, different weights are assigned to handover decision parameters using fuzzy analytical hierarchical process. The weights, assigned to decision parameters, are made adaptive to call time, velocity of mobile user, type of application and remaining battery life of the mobile handset. A popular multiple attribute decision making technique, TOPSIS (technique for order preference by similarity to the ideal solution), is adopted to choose the most suitable target network. Numerical results are obtained through computer simulation for preference scores of different networks, security, end to end delay and available data rate, which show that QoS perceived by the end user is maintained consistently in varied conditions of the network and applications.

Keywords Heterogeneous wireless networks · MIH · TOPSIS · FAHP · Quality of service · Cross layer

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1 Introduction

In recent years, wireless technologies have experienced huge advancements to meet the growing demands of end users and to offer a variety of applications while moving across a diverse range of mobile access networks. Due to limited characteristics of individual networks such as coverage area, bandwidth and data rate; integration and coordination of different networks is required in heterogeneous wireless networks. These networks may be comprised of different radio access technologies including wireless local area network (WLAN), worldwide interoperability for microwave access (WiMAX), 3G ultra mobile telecommunication systems (UMTS) and long term evolution (LTE). To enjoy service continuity with a support for multimedia applications and to promise expected QoS, efficient handover algorithms are required to be incorporated. Depending upon the type of networks involved, handover can be classified as horizontal handover (HHO) and vertical handover (VHO) [1]. The handover between networks supporting same technologies refers to HHO while VHO is executed between access points supporting different network technologies. Both HHO and VHO processes consist of three steps: handover requirement estimation, target network selection and handover execution [2]. Firstly, the handover requirement is estimated before initiating the handover procedure to avoid unnecessary handovers. Handover may be mobile initiated or network initiated depending upon system requirements. In the second step, a decision is made regarding the selection of the new network, to which the Mobile Node (MN) will be transferred. In execution step, handover procedure is accomplished by forming new links between Base Station (BS) and MN. Conventionally, the link quality measured in terms of Received Signal Strength (RSS) is considered as the criteria to take a handover decision. However, due to its random nature, RSS seems to be an inadequate parameter while taking a decision about handover requirement and selection of target network in upcoming networks. Recent wireless networks are based on all-IP structure. Thus, it becomes essential to consider parameters from higher layers while designing handover algorithms. Also, the performance of one layer affects the other. Bad resource scheduling in MAC layer can lead to interference that affects the performance of the physical layer due to reduced signal to interference-plus-noise-ratio (SINR) and ultimately deteriorates the overall network performance [3]. It is, therefore required that there should be a provision for exchanging useful information between layers which can be utilized for enhanced system performance. This concept of exchanging information between layers is known as cross layer technique [3]. Handover decisions may be taken based on the information collected from various layers and coordinated through a well-designed cross layer interface manager.

The Media Independent Handover (MIH) defined by the IEEE 802.21 standard [4], enables the exchange of useful information among different layers by cooperative use of three types of MIH services named as MIH Event Service (MES), MIH Command Service (MCS), and MIH Information Service (MIS). Assuming the ability of MN to support multiple interfaces, the MIH facilitates a fast handover by exchanging event information among entities from different technologies.

To meet the end user QoS requirements, multiple parameters are to be taken into consideration while taking decisions about the handover. Various Multiple Attribute Decision Making (MADM) techniques [5] have been proposed in order to select the optimum target network, which would ensure the best possible services according to the demands of the user at any time. MADM algorithms are extensively used to find the most suitable option based on the score obtained for all possible alternatives. The parameters that can influence a decision are assigned different priorities which are converted into weights using analytical hierarchy process (AHP) method. In this paper, an effective MADM technique, TOPSIS (Technique for Order Preference by Similarity to the Ideal Solution) is used to select the optimum target network. The reason for choosing TOPSIS is its simplicity and requirement of limited subjective inputs from decision makers [6]. In recent years, fuzzy logic has received a great deal of attention from researchers in various disciplines for solving complicated problems. It is found to be very useful when combined with AHP to deal with imprecise and uncertain information associated with networks. The parameters measured at the physical layer, network layer and application layer are used not only for the selection of optimum target network but they are also responsible for estimating handover requirement. As a result of the increasing number of multimedia applications and number of users, there can be a problem of constrained network resources. This motivates us to give due attention towards the handover requirement estimation to avoid wastage of network resources. By considering the fact that the user preferences for various parameters get affected by type of application, user context and location; the weights assigned to parameters are made adaptive with respect to end user information.

The remainder of this paper is organized as follows: Sect. 2 reviews the related work in this field. Section 3 presents the proposed method for handover requirement estimation and target network selection. In Sect. 4 the numerical results are obtained and discussed. Finally, conclusions are drawn in Sect. 5 followed by the future scope of the work.

2 Related Work

Many researchers have proposed and evaluated mobility management techniques for improving the performance of wireless access networks in different aspects. A comprehensive survey of vertical mobility management schemes in wireless networks is presented in [7,8]. Various design challenges such as QoS, resource allocation for supporting service differentiation, pricing are highlighted and a context aware handover mechanism based on QoS requirement is proposed. The handover requirement estimation is implemented using fuzzy values of RSS, QoS, and BER and network coverage in [9]. The MIH triggers are generated in [10] to initiate handover, using QoS experienced by users for a particular application, resulting in improved handover time, end to end delay and throughput. The authors in [11] have introduced fuzzy logic for wireless networks to solve complicated problems. An immediate or dwell handover can be preferred based on fuzzy logic to reduce packet transfer delay [12]. A fuzzy MADM based solution is introduced for VHO decision in [13]. An enhanced MIH framework is introduced by authors in [14] by combining entropy weighting method with weighted Markov chain approach. Many handover strategies have utilized fuzzy logic in TOPSIS to take decision about target selection during handover as fuzzy logic has the ability to handle uncertain and conflicting decision matrices [15,16].

The fuzzy membership functions are optimized using a genetic algorithm to select best target network and to reduce the number of handovers in [17]. A modified WPM method is proposed in [18] where quality of context (QoC) is utilized to penalize alternatives and weight distribution depends on a fuzzy measure of saliency of context information. The authors in [19] have elaborated the idea of gathering network context through MIS. Multiple decision makers are used to take a compromised decision in [19]. An energy efficient network selection method is proposed by Chamodrakas and Martakos [20] using parameterized utility functions to make it adaptable for different applications. The authors further use fuzzy representation of TOPSIS method to address issues of inconsistency related to conflicting decision criteria. The authors in [21] propose AHP for subjective and entropy method for objective weights to satisfy the QoS requirements of the user.

Most of the handover initiation algorithms have considered RSS or QoS to estimate requirement of the handover, which may lead to unnecessary handovers if there is a temporary failure due to fading or congestion. To avoid this problem, our algorithm, in addition to SIR and QoS, also considers the time required to reach the boundary of current cell while taking a decision about the necessity of handover. Moreover, the direction of movement of MN has significant impact on the selection of appropriate target network, which has been ignored in existing solutions. To the best of our knowledge, none of the existing multi-criteria algorithms consider the effect of end user information on the weight assigned to the corresponding parameters. It may thus lead to poor performance in some critical situations, which are explained in Sect. 3.2. Our proposed algorithm provides flexibility to weight assignment in order to maintain the desired QoS in varied conditions.

3 System Modeling

In this section, system modeling for proposed cross layer based dynamic handover algorithm is presented. We focus on two steps of handover process: handover requirement estimation and target network selection. The advanced mobile terminals are expected to have enough intelligence to take decision about handover requirement and network selection. To perform these functions, information about characteristics of serving access network, target access network is collected and utilized in combination with MN context. The system model aims to have an appropriate estimation of handover requirement and choose the most suitable target network, which would maximize the end user's satisfaction level by providing the best services with affordable cost. In order to achieve these goals, the MN should carefully identify the parameters responsible for handover decisions. The parameters measured at the physical layer, network layer and application layer are included in the proposed framework as shown in Fig. 1. The detailed discussion about these parameters is given in the next section.

3.1 Cross Layer Parameters

3.1.1 Handover Requirement

In this paper, the signal to interference ratio (SIR), location and velocity of MN, measured at physical layer and perceived QoS in terms of measurements taken at application layer are considered as criteria for finding requirement of handover. The handover requirement factor is solely dependent upon parameters measured at serving network and subsequently found to be responsible for triggering the handover.

Signal to interference ratio (SIR): The MN obtains SIR from serving BS to consider its influence on handover requirement. In the proposed algorithm, SIR refers to the ratio of desired signal to the total interference (power received from neighboring cells) [22]. The specification for SIR in order to meet the bit error rate requirements varies with type of network. For instance, in GSM, the minimum theoretical acceptable value for SIR is 9 dB. Practically, it lies in the range of 14–15 dB [23].

Time To reach boundary (TTR): The measurements about location/distance and velocity of MN at L2 layer are used to have an estimation of the time required to reach the boundary of the current cell. The information about the location of the MN can be provided by the 3GLoCation Services networks [24]. The MN, moving away from serving BS with high velocity, results in a small value of TTR, which indicates that MN is about to reach boundary

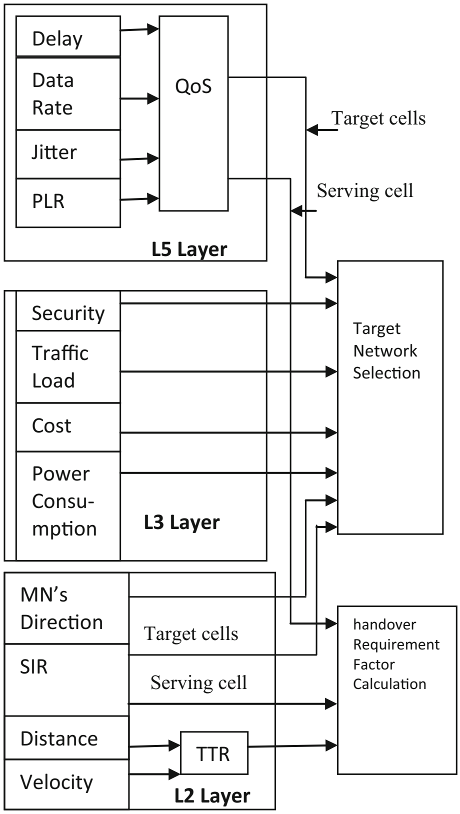


Fig. 1 System model for proposed dynamic handover

and handover is imminent. The boundary of the cell is assumed at a point where received signal strength goes below the threshold level to maintain a link.

Quality of service (QoS): A set of parameters including available data rate, end to end delay, jitter and packet loss rate (PLR), measured at the application (L5) layer [25] is responsible for QoS perceived by end users. For different applications like voice, data and multimedia, diverse QoS specifications are entailed by multimedia communications. An MN, bearing degrading QoS, is expected to send request for handover.

3.1.2 Target Network Selection

Once the handover requirement factor is found to be greater than a predefined threshold (considered as 0.75 [12]), the target network selection procedure is performed. The network context can be extracted through MIH server as mentioned in [19]. The following parameters, in addition to target cell's SIR and QoS parameters (discussed above), are considered to select the target network.

Movement direction of MN: The direction of movement of MN, predicted at physical layer using GPS, is utilized to select an appropriate network. A BS existing in the predicted direction of movement of MN is preferable.

Power consumption: To enhance the battery life of MN, a network having lesser power consumption is preferred. The power consumption depends on the type of associated networks. The list of candidate networks is obtained at the network layer.

Traffic Load: Traffic load information for candidate networks can be obtained at the network layer from network neighbor information received through MIH. The traffic load varies from network to network and from time to time. To reduce network congestion and call blocking probability [26], it becomes essential to consider traffic load as an important factor during the target network selection process. The reduced traffic congestion enhances the user satisfaction level by providing uninterrupted services.
Security and Cost: Security level provided by each network and cost per bit also play a significant role in order to select a secure and cost-effective network.

3.2 Proposed Adaptive Weight Assignment Technique

This work aims to develop a technique for adaptive weight assignment for handover decision parameters. This approach is expected to satisfy the requirements of the end users. The end users can specify their preferences by assigning priority weights in linguistic terms to each system parameter. We incorporate fuzzy logic into AHP [27], a weight assessment technique for MADM methods. It is capable of handling the fuzziness associated with end user's preferences efficiently as compared to conventionally used AHP process. The fuzzy linguistic terms are useful in solving complex problems involving uncertainty and can be modeled using fuzzy sets. In FAHP, nine judgment levels are used in the form of triangular fuzzy numbers (TFNs) to represent the relative importance among the pair of decision factors. The membership value of TFN is defined by three real numbers (l, m, u) where m is the most promising value, l and u are lower and upper bounds that limit the field of possible evaluation. The following steps are involved in FAHP process:

(1) Firstly, the user's relative preference for 'n' parameters is taken. Then a pair wise comparison matrix 'X' having 'n' elements for TFNs is prepared according to Table 1.

$$X = [x_{ij}]_{n\times n} = \begin{bmatrix} (1,1,1) & (l_{12}, m_{12}, u_{12}) & (l_{1n}, m_{1n}, u_{1n}) \\ \vdots & (1,1,1) & \vdots \\ (l_{n1}, m_{n1}, u_{n1}) & \cdots & (1,1,1) \end{bmatrix} \quad (1)$$

Where x_{ij} is the relative preference of ith parameter with respect to jth parameter and

$$[x_{ji}] = [x_{ij}]^{-1} = (l_{ij}, m_{ij}, u_{ij})^{-1} = \left(\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}\right) \quad (2)$$

(2) The fuzzy synthetic extent with respect to ith parameter F_i is calculated by

$$F_i = \sum\nolimits_{j=1}^{n} x_{ij} \times \left[\sum\nolimits_{i=1}^{n} \sum\nolimits_{j=1}^{n} x_{ij}\right]^{-1} \quad (3)$$

Table 1 Linguistic variable with triangular fuzzy numbers (TFNs)

User preference	TFN	1/ TFN
Equal (E)	(1, 1, 1)	(1, 1, 1)
Moderate (M)	(2/3, 1, 3/2)	(2/3, 1, 3/2)
Strong (S)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strong (VS)	(5/2, 3/7/2)	(2/7, 1/3, 2/5)
Extreme (Ex)	(7/2, 4, 9/2)	(2/9, 1/4, 2/7)

Table 2 Weight assignment for handover requirement factor

Parameters	SIR	QoS	TTR	Weight
SIR	E	M	S	0.4507
QoS	1/M	E	M	0.3237
TTR	1/S	1/M	E	0.2256

Where $\sum_{j=1}^{n} x_{ij} = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}\right)$ and

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij}\right] = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} u_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} m_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} l_{ij}}\right) \quad (4)$$

(3) The probability for a convex fuzzy number F_i to be greater than k convex fuzzy numbers F_j ($j = 1, 2, \ldots, k$; $i \neq j$) is calculated as follows:

$$P\left(F_i \geq F_j\right) = \begin{cases} 1 & m_i \geq m_j \\ 0 & l_j \geq u_j \\ \frac{l_j - u_i}{(m_i - u_i) - (m_j - l_j)} & \text{otherwise} \end{cases} \quad (5)$$

(4) Taking $d_i = \min\{P(F_i \geq F_j)\}$, the weight vector is given by $W' = (d_1, d_2, d_3, \ldots, d_n)$.
(5) Normalized weight vector is defined as

$$W = (W_1, W_2, \ldots, W_{n)} = \left(\frac{d_1}{\sum_{i=1}^{n} d_i}, \frac{d_2}{\sum_{i=1}^{n} d_i}, \ldots\ldots, \frac{d_n}{\sum_{i=1}^{n} d_i}\right) \quad \text{and}$$
$$\sum_{j=1}^{n} W_j = 1 \quad (6)$$

The preference levels are assigned to parameters SIR, QoS and TTR in linguistic terms as given in Table 1 which are converted in form of TFNs. The weights calculated using the above method, are found to be 0.4507, 0.3237 and 0.2256 for SIR, QoS and TTR respectively as shown in Table 2. These weights can be changed by modifying the preference level.

For target network selection, same steps for weight assignment are followed. However, a static approach for assigning weights may result in erroneous solution. By considering the fact that type of application and situation context influence the sensitivity of handover algorithms to certain parameters, we propose an adaptive weight assignment technique.

To implement this technique effectively, three phases are considered for the system parameters as shown in Fig. 2. The parameters for first phase criteria are given by: context dependent parameters (CDP), QoS, security, cost and SIR (Table 3). The CDP, termed as Phase 2 parameters, include movement direction, power consumption and traffic load. Depending upon context related to end user, such as call time (the time when the service request is being sent), remaining battery life and MN's velocity, six cases are defined for phase 2 (Table 4). The time of call can be during busy hours, normal hours or free hours. Also the remaining battery life and MN's velocity can attain any fuzzy value from low, high or medium. The six cases are distinguished on the basis of different levels of end user information. The priorities given to CDP are different for each case to ensure the best services irrespective of the situation. For example, a user moving with high velocity (case 2 and 6 in Table 4) will approach the boundary of serving cell earlier under the assumption that the probability of changing

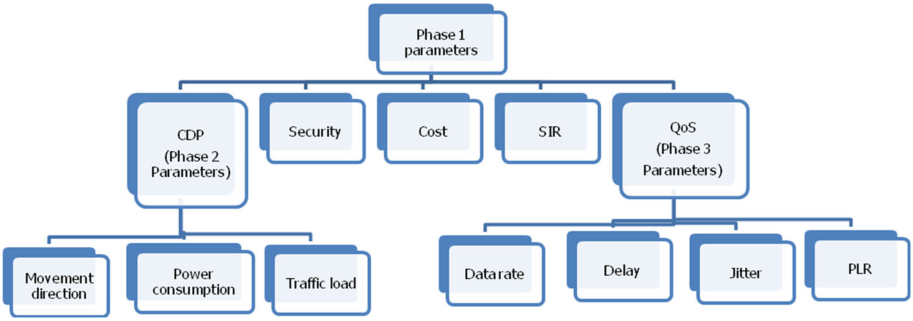


Fig. 2 Hierarchical structure for handover parameters

Table 3 Weight assignment for Phase 1 parameters

Parameters	CDP	QoS	Security	Cost	SIR	Weight	
						FAHP	AHP
CDP	E	E	S	VS	S	0.5240 (w_p)	0.4191
QoS	E	E	M	S	M	0.2654 (w_q)	0.3171
Security	1/S	1/M	E	E	1/M	0.0827 (w_s)	0.0700
Cost	1/VS	1/S	E	E	1/M	0.008 (w_c)	0.0572
SIR	1/S	1/M	M	M	E	0.1199 (w_{sir})	0.1367

Table 4 Weight assignment for Phase 2 parameters

Case	End user information			Weights assigned to handover parameters					
	Time of call	Remaining battery life	MN's velocity	MN's direction (w_{pd})		Power consumption (w_{pp})		Traffic load (w_{pt})	
				FAHP	AHP	FAHP	AHP	FAHP	AHP
1	Busy hours	Medium	Low	0.114	0.107	0.3227	0.2583	0.5628	0.6370
2	Free hours	Medium	High	0.5628	0.6370	0.3227	0.2583	0.114	0.107
3	Free hours	Low	Medium	0.3227	0.2583	0.5628	0.6370	0.114	0.107
4	Normal hours	Low	Low	0.114	0.107	0.5628	0.6370	0.3227	0.2583
5	Busy hours	High	Medium	0.3227	0.2583	0.114	0.107	0.5628	0.6370
6	Normal hours	High	High	0.5628	0.6370	0.114	0.107	0.3227	0.2583

the direction of movement of MN is very less for such a short period. In this situation, the maximum weight is assigned to movement direction of MN to select a target network existing in the same direction. Another situation is when the user is requesting a service during busy hours (case 1 and 5) then there is a very high probability of call drop due to congestion in contrast to normal or free hours. Here, the maximum weight is assigned to the traffic load parameter to choose a network bearing lesser load at that moment. In continuation to the above, the status of the remaining battery life of MN is also found to be responsible for making weights adaptive. A device with low battery life will prefer a network with minimum power consumption to continue its services and maximum weight will be assigned to power

Table 5 Weight assignment for Phase 3 parameters

Type of traffic	Weights assigned to handover parameters							
	Data rate (w_{qdr})		Delay (w_{qd})		Jitter (w_{qj})		PLR (w_{qp})	
	FAHP	AHP	FAHP	AHP	FAHP	AHP	FAHP	AHP
Conversational	0.4307	0.2966	0.0309	0.1018	0.5334	0.5485	0.0050	0.0532
Streaming	0.5164	0.5650	0.0014	0.0553	0.3351	0.2622	0.1471	0.1175
Interactive	0.4532	0.5558	0.3035	0.2589	0.2383	0.1364	0.005	0.0489
Background	0.4800	0.4094	0.0140	0.0356	0.3990	0.4852	0.1350	0.0698

Table 6 Final Weight assignment for all parameters

Parameters	Direction	Power consumption	Traffic load	Data rate	Delay	Jitter	PLR	Security	Cost	SIR
Weight	$(w_p) * (w_{pd})$	$(w_p) * (w_{pp})$	$(w_p) * (w_{pt})$	$(w_q) * (w_{qdr})$	$(w_q) * (w_{qd})$	$(w_q) * (w_{qj})$	$(w_q) * (w_{qp})$	(w_s)	(w_c)	(w_{sir})

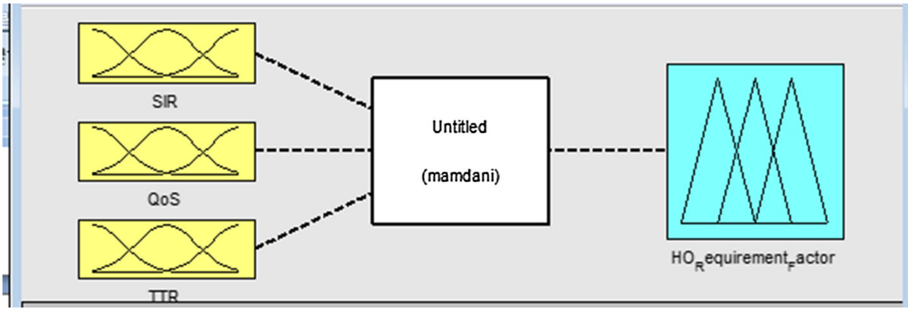


Fig. 3 Fuzzy logic controller for handover requirement factor

consumption. Phase 3 parameters are data rate, delay, jitter and PLR, collectively referred to as QoS. For each case of phase 2, four different traffic classes are considered named as conversational, streaming, interactive and background, with different characteristics and QoS demands as defined by 3GPP TS-23,107 [28]. The relative importance of phase 3 parameters varies with the type of traffic class as depicted in Table 5. The final weights for all parameters are calculated by multiplying the weights assigned to CDP and QoS at phase 1 with weights of phase 2 and phase 3 parameters respectively as shown in Table 6.

In this research work, phase 2 parameters are given more weight, to distinguish network selection in six cases. For the sake of comparison, weights calculated using AHP, are also mentioned along with FAHP.

3.3 Calculation of Handover Requirement Factor Using Fuzzy Logic

In this section, handover requirement factor is calculated using fuzzy inference system (FIS) of Mamdani type as shown in Fig. 3. The handover requirement factor is dependent upon current condition of serving BS which is measured in terms of SIR, QoS and TTR. The mobile terminal can give different priorities to these inputs to make them responsible for

Table 7 Fuzzified values of input parameter

Parameter	Crisp value	Fuzzy value	Crisp value	Fuzzy value	Crisp value	Fuzzy value
SIR	0–15	Less	5–35	Medium	25–40	High
QoS	0–0.4	Low	0.1–0.9	Medium	0.6–1	High
TTR	0–2	Low	0.5–4.5	Average	3–5	High

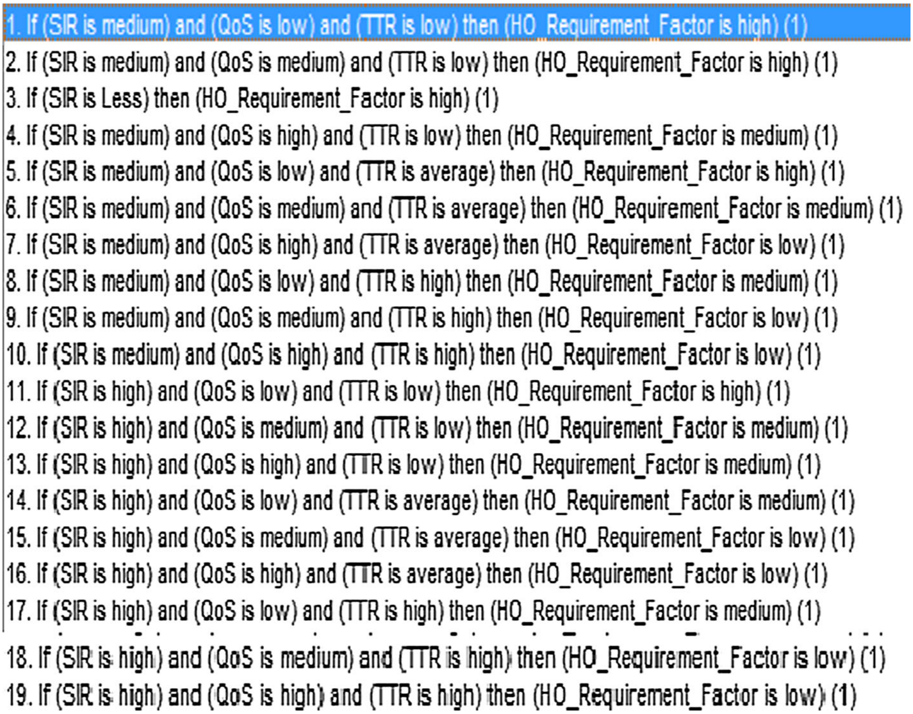


Fig. 4 Fuzzy rules

handover occurrence. The weights are assigned to these inputs according to FAHP method discussed in previous subsection. The QoS is calculated in the range of [0, 1] by performing a weighted sum of delay, jitter, PLR and data rate. The input parameters of weighted SIR, QoS and TTR are fuzzified using predefined membership function. Triangular membership functions have been used as they represent the real scenario in a wireless environment [29]. The fuzzy values corresponding to a range of crisp values of SIR, QoS and TTR are given in Table 7. These fuzzified input values are used to evaluate rules for obtaining fuzzy handover requirement factor. The number of fuzzy rules is reduced (19 instead of 27) because for a lesser value of SIR, handover requirement factor is kept high irrespective of the values of QoS and TTR (Fig. 4). In other words, SIR is considered as the most important criteria to decide handover. The degree of membership for fuzzy handover requirement factor output has been assigned low, medium and high corresponding to the set of inputs.

The output of FIS is shown in Fig. 5 which demonstrates the handover requirement factor value of 0.826 for a particular combination of input values (29.2, 0.221 and 0.971) of SIR, QoS and TTR. By using slider option, the value of handover requirement factor can be

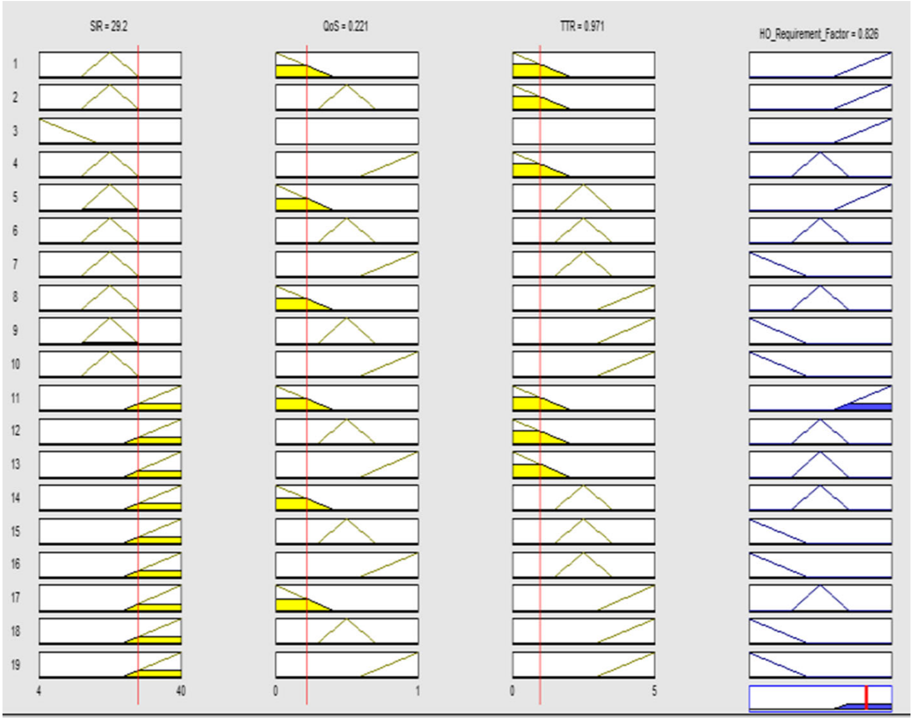


Fig. 5 Output of fuzzy inference system

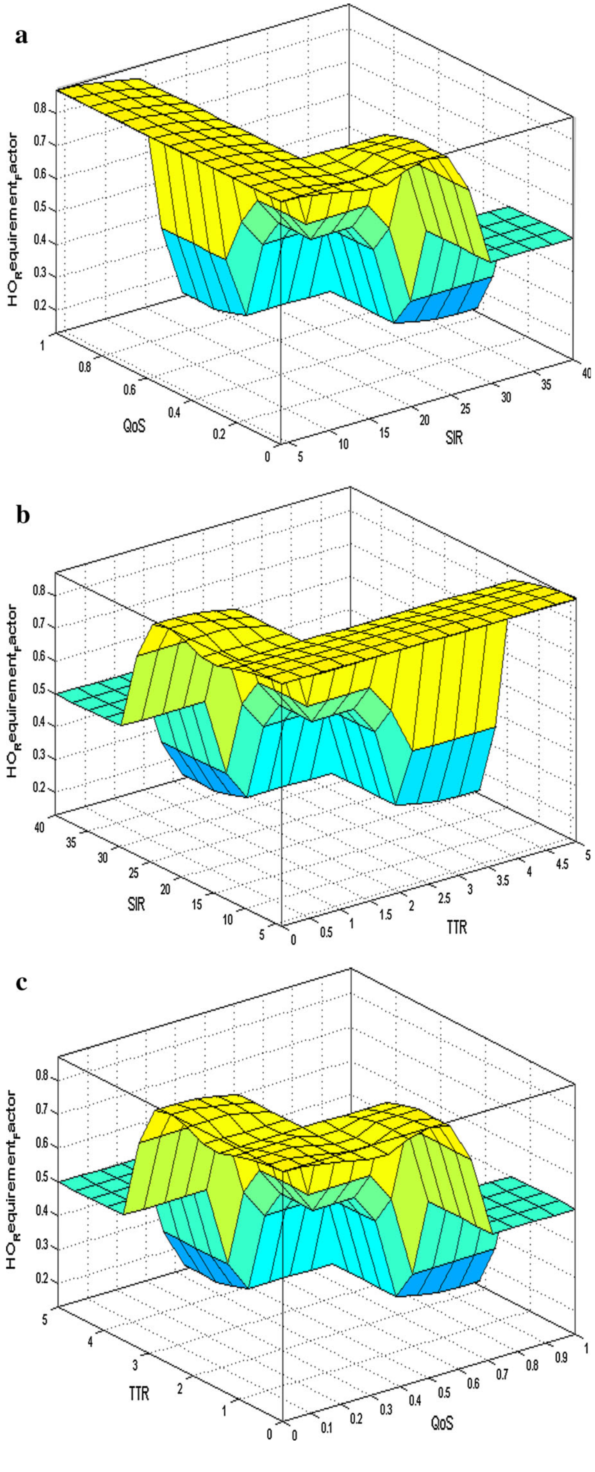
observed for any combination of inputs. The graphical analysis of handover requirement factor for different combinations of SIR, QoS and TTR can be done through Fig. 6a–c. The handover requirement factor decreases as SIR and QoS go from low to high as depicted in Fig. 6a and increases as TTR and SIR decreases as shown in Fig. 6b. When TTR and QoS goes from low to high, handover requirement factor decreases from high to low (Fig. 6c). These outputs validate the correctness of algorithm because handover is required when MN has reached near boundary with low values of SIR and QoS.

3.4 Selection of Target Network Using TOPSIS

Once the mobile node has collected enough information about the surrounding networks from different layers, a decision matrix can be generated to select the target network. In this paper, TOPSIS ranking algorithm is used to measure the relative efficiency of the available alternatives based on user's demand. The chosen alternative should be in the vicinity of an ideal solution, which is a composite of the best performance values amongst all alternatives. The negative ideal solution is the composite of worst performance values. It is to mention that this distance is affected by decision maker's subjective preferences for each criterion. The following steps have been followed for TOPSIS ranking algorithm.

1. Construction of decision matrix: suppose there are 'm' networks available and 'n' parameters are considered, a 'm $\times$ n' decision matrix containing the rating of all 'm' alternative networks with respect to all 'n' parameters is created as:

Fig. 6 Handover Requirement Factor for different combinations of **a** QoS and SIR. **b** TTR and SIR. **c** QoS and TTR



$$DM_{m\times n} = \begin{bmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & & \vdots \\ d_{m1} & \cdots & d_{mn} \end{bmatrix} \tag{7}$$

Each element d_{ij} in Eq. 7 represents the handover parameter j provided by the ith available network.

2. Decision matrix normalization: The vector method for normalization is the most suitable method for TOPSIS in terms of weight sensitivity, ranking consistency for various problem sizes and for different data ranges [30]. Each element of normalized decision matrix (NDM) is obtained by

$$r_{ij} = \frac{d_{ij}}{\sqrt{\sum_{i=1}^{m} d_{ij}}}$$
$$i = 1, 2, \ldots\ldots, m \text{ and } j = 1, 2, \ldots\ldots\ldots, n \tag{8}$$

Where r_{ij} is the normalized value of element d_{ij}.

3. Weighted normalized decision matrix (WNDM): This matrix is formed by multiplying each element r_{ij} of NDM with its associated weight (w_j) as calculated in Sect. 3.2. The elements of WNDM are calculated according to Eq. 9.

$$Z_{ij} = r_{ij} \times w_j \tag{9}$$

4. The positive (I^+) and negative (I^-) ideal solutions are calculated using Eqs. 10 and 11 respectively.

$$I^+ = (Z_1^+, Z_2^+, \ldots Z_n^+) = \{(\max_i Z_{ij} | j \in C_F), (\min_i Z_{ij} | j \in C_U)\} \tag{10}$$
$$I^- = (Z_1^-, Z_2^-, \ldots Z_n^-) = \{(\min_i Z_{ij} | j \in C_F), (\max_i Z_{ij} | j \in C_U)\} \tag{11}$$

Where C_F and C_U denote the sets with favorable and non-favorable criteria respectively.

5. The distance between each alternative from positive ideal and negative ideal solution is calculated as

$$D_i^+ = \sqrt{\left(Z_{ij} - Z_i^+\right)^2} \tag{12}$$
$$D_i^- = \sqrt{\left(Z_{ij} - Z_i^-\right)^2} \tag{13}$$

6. Preference score of ith network is calculated using Eq. 14.

$$S_i = \frac{D_i^-}{D_i^- + D_i^+} \quad i = 1, 2, \ldots\ldots\ldots, m \tag{14}$$

7. The preference order of the alternatives: The preference order of the alternative networks is calculated by sorting preference scores in descending order. The best alternative has the highest value of S_i.

4 Result Analysis and Performance Evaluation

In this study, a simple network configuration, shown in Fig. 7 is considered in order to investigate the performance of the handover algorithm utilizing the framework developed in sect. 3. The network incorporates an MN that integrates six access network interfaces: WLAN1

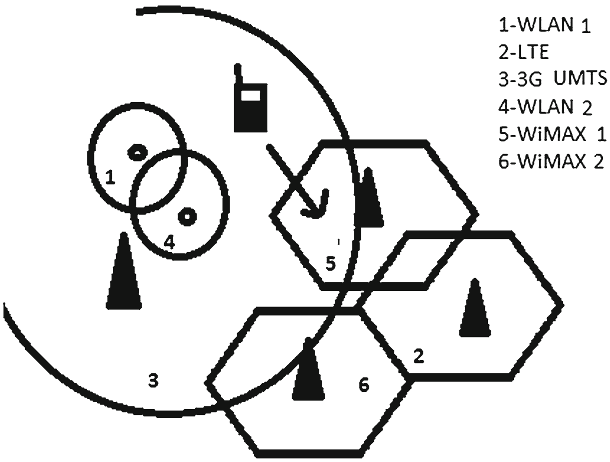


Fig. 7 Network configuration

Table 8 System parameters for computer simulation

Parameters	Network					
	WLAN1 (1)	LTE (2)	3G UMTS (3)	WLAN2 (4)	WiMAX1 (5)	WiMAX2 (6)
Data rate (Mbps)	54	70	3	11	45	40
Delay (ms)	80–90	30–50	20–30	40–50	70–80	55–60
Jitter (ms)	10–12	7–8	6–7	7–9	7–8	6–7
PLR (per 10^6 bytes)	40–50	40–50	20–30	20–25	30–40	40–50
Cost/bit	0.10	0.80	0.60	0.10	0.50	0.60
Traffic load (%/no. of users)	10–20	80–90	70–80	35–40	30–40	60–70
Power consumption (w) [20]	2.4	3	1	2.5	4.5	4.0
Direction (degree)	40	2	20	35	13	4
SIR (dBm)	8–10	10–12	9–10	14–16	8–10	11–13
Security (1–10)	1–2	5–6	4–5	2–3	5–6	6–7

(IEEE 802.11b), LTE, 3G UMTS, WLAN2 (IEEE 802.11g), WiMAX1 and WiMAX2 (IEEE 802.16e). For the performance evaluation, a single user scenario is considered, where the MN is assumed to be moving in the direction of network 5 with variable velocity. The simulation results are obtained using typical values of simulation parameters from Table 8. The preference scores are calculated for different cases (case 1–6) and four types of traffic classes as shown in Fig. 8a–d.The impact of user preferences on network selection can be extracted and interpreted for different cases. The scores vary in accordance with user priorities given through linguistic terms.

Based on the calculated scores, the preference order is found for all networks and the network with the highest score is designated as the best target for that particular case. The networks selected for different cases and traffic classes are mentioned in Table 9. It is evident

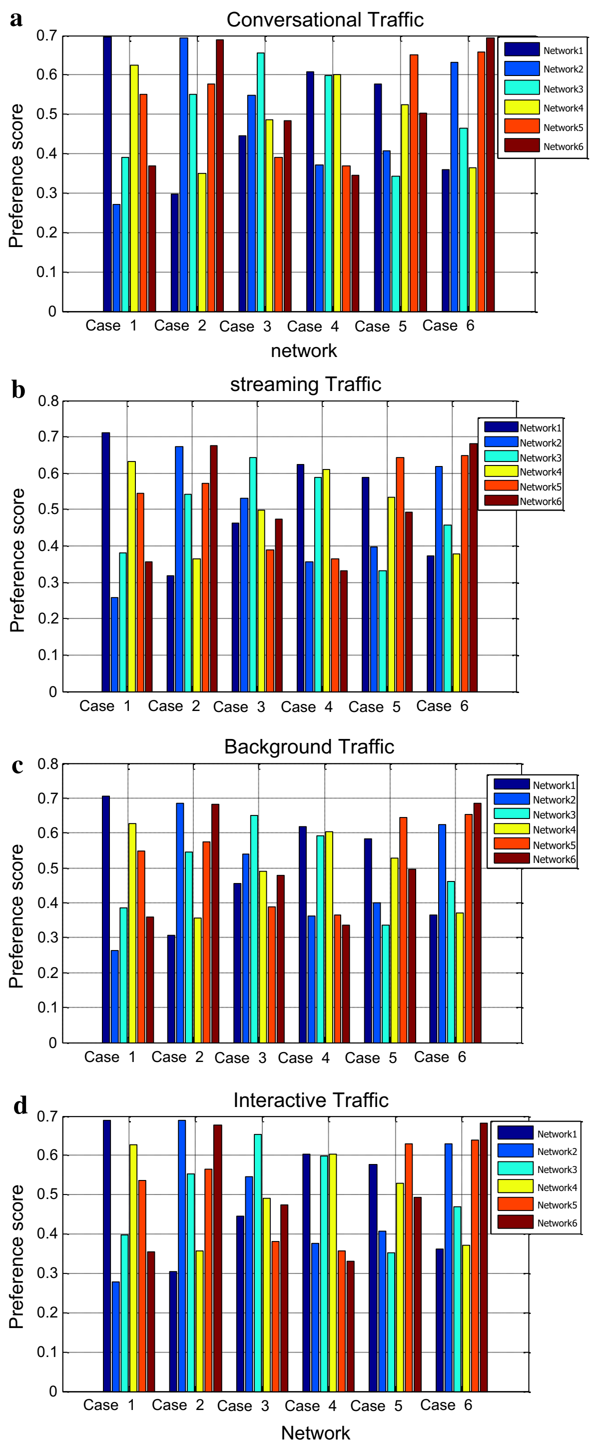


Fig. 8 **a** Preference scores for conversational traffic based on the proposed method. **b** Preference scores for streaming traffic for different cases based on the proposed method. **c** Preference scores for background traffic for different cases based on the proposed method. **d** Preference scores for interactive traffic for different cases based on the proposed method

Table 9 Network selected for different cases

Case	Critical parameter	Network selected			
		Conversational	Streaming	Interactive	Background
Case 1	Time of call	1	1	1	1
Case 2	MN's velocity	2	6	2	2
Case 3	Remaining battery life	3	3	3	3
Case 4	Remaining battery life	1	1	1	4
Case 5	Time of call	5	5	5	5
Case 6	MN's velocity	6	6	6	6

from Table 9 that the target network is selected according to the user situation context in different cases. While in conventional methods the target network is not adaptive to user situation and it is chosen based upon weight assigned to handover parameters irrespective of the end user information thus same network is selected in all cases. As a result the QoS may not be maintained in busy hours, high velocity and low remaining battery life. The following observations are made through Matlab simulation results:

1. When the MN is moving with low velocity and a request is made during busy hours (case 1), network 1 with minimum traffic load is having the highest preference score. Thus, it will be selected as the most suitable target network by the proposed handover algorithm.
2. A mobile user moving with high velocity will reach the boundary of the cell earlier as compared to a slow moving mobile user. In such a case, there is less probability of changing its direction within a short period of time, thus more weight is given to the direction. In case 2, a fast moving mobile user wants to access network during free hours, traffic congestion is not an issue. Thus, a network adequate for higher mobility scenario and existing in a direction close to the predicted direction of MN (network 2) is selected.
3. Case 3 considers that remaining battery life of MN is low. Therefore a low power consuming network (network 3) is selected as the best target.
4. Case 4 considers the same situation as in case 3 but call is not made at free hours. Thus, the score of networks 1, 3 and 4 is approximately same. But WLAN solves the purpose at a lower cost than UMTS, WLAN1 or WLAN2 can be opted according to the type of application.
5. Now the mobile user is trying to access the network in busy hours and normal hours in case 5 and case 6 respectively. The WiMAX1 (network 5) is preferred for low velocity and WiMAX2 (network 6) is selected for high velocity of the user because network 5 is in a direction opposite to the user's direction of movement.

In addition to these points, decrease in score of WLANs can be observed as the velocity of MN increases while WiMAX2 and LTE networks are having higher scores for high velocities.

Figure 8b–d show that there are variations in preference scores of different networks with the change in type of traffic class. Though the network selected is found to be independent of the type of traffic for individual case due to the lesser weight given to QoS in present scenario but it can be changed according to the system requirements. For the sake of comparison of the proposed algorithm with handover algorithms based on a single criteria, graphs obtained from conversational traffic in case 2 are shown in Figs. 9, 10, 11. It is evident from Fig. 9 that the data rate offered by the target network selected using proposed algorithm is increased by 43 % when compared with the best data rate provided by conventional single criteria algorithms.

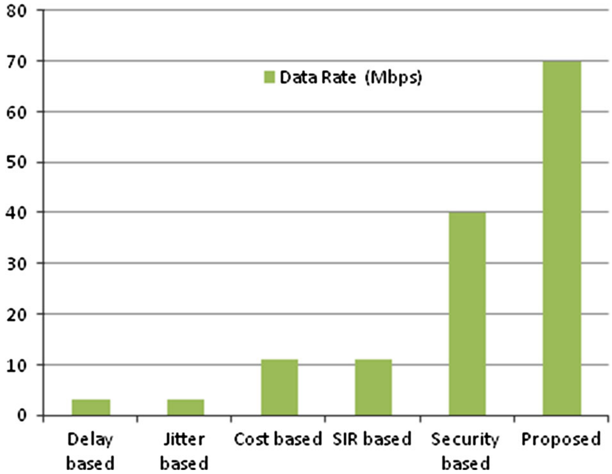


Fig. 9 Comparison of data rate for different algorithms

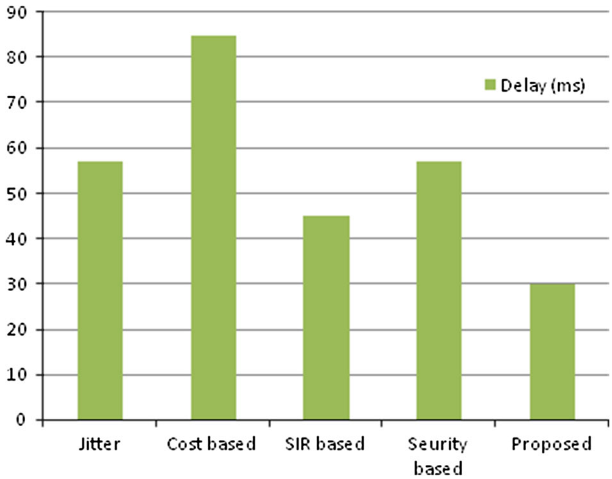


Fig. 10 Comparison of delay for different algorithms

Figure 10 exhibits that the performance of the handover algorithm has been improved in the proposed method by 35 % in terms of delay as compared to the best score of conventional algorithms. Furthermore, the proposed algorithm provides a security level enhanced by up to 17 % when compared with single criteria algorithms.

5 Conclusion and Future Scope

In this paper, we have proposed cross layer based dynamic handover algorithm for handover requirement factor estimation and target network selection for handover in heterogeneous wireless networks. Handover requirement factor determines whether a handover is required or not and reduces the signaling overhead as well as service interruption by eliminating

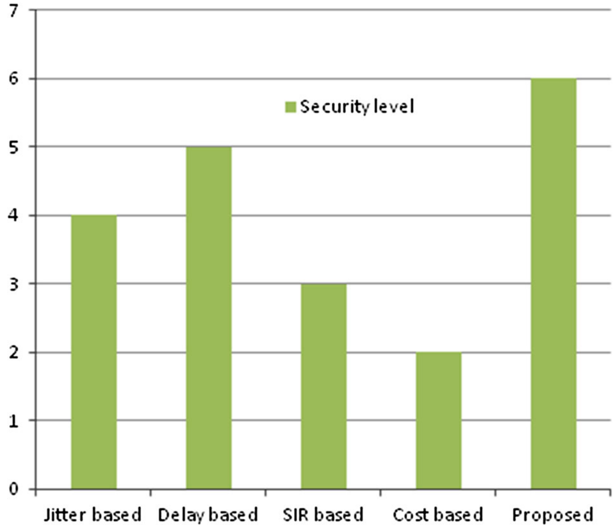


Fig. 11 Comparison of security level provided by different algorithms

unnecessary handovers. This algorithm uses FAHP to assign priorities to the parameters responsible for handover decision. The information from different layers is exploited to take a handover decision. The sensitivity of proposed target network selection algorithm to movement of MN, traffic load and power consumption varies with situational context. The situational context includes information about the velocity of mobile user, time of call and remaining battery life of MN. The weight assignment is made dynamic with the situation and type of traffic (conversational, streaming, interactive and background). The User's QoS demands for different traffic types and in different situations have been reflected in network selection. Unlike static algorithms, the proposed adaptive cross layer mechanism is capable of maintaining QoS in diverse conditions. The proposed mechanism can easily respond to the expected changes in network conditions by tuning the weights used for implementing TOPSIS. The performance of the handover algorithm is improved by the proposed method up to 43, 35 and 17 % in terms of data rate, delay and security respectively as compared to the conventional algorithms. In future other performance metrics like end to end latency, signaling load etc. can be explored. The implementation of the efficient algorithms in handover execution using mobility protocols like FMIPv6 is also an open issue.

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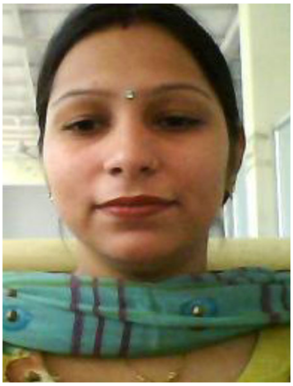

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