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A location aware history-based approach for network selection in heterogeneous wireless networks

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Abstract: Efficient decision making in vertical handoff and network selection algorithms improves users' quality of service and helps users meet service requirements, anywhere and at any time. Hence, in this paper, a user-centric network selection algorithm is proposed, utilizing the estimated reputation of the available candidate networks based on user location and combined experienced users' utility. User utility is defined based on 1) quality of service, 2) monetary cost, and 3) energy consumption metrics. In the proposed history aware-based user location algorithm, the past experience of users for available networks is considered to estimate the future utility that a user can obtain from a candidate network. The reputation factor for networks is used based on knowledge of users from each other while receiving service. Simulation results indicate that the average obtained utility by users is improved and handoff criteria, i.e. handoff number and failed and unnecessary handoffs, decrease. It can be seen that users choose networks with good past operations and this can encourage operators to provide good quality services for increasing their revenue.

Key words: Reputation, network selection, performance, user-centric

1. Introduction

In next-generation networks (NGNs), multiple access networks exist with different simultaneous technologies such as EDGE, WLAN, and third-generation (3G) systems, such as the Universal Mobile Telecommunications System (UMTS). They provide different coverage, quality of service (QoS), and monetary costs for end users. WLAN can provide data rates of up to 54 Mbps with low coverage and high energy consumption in hot spot areas (e.g., business centers, airports, hotels, and campuses), while in the evolution of cellular networks within the UMTS standard, the data rates are limited from 384 kb/s to 2 Mb/s that support wireless Internet over a wide geographical area. In this environment, users with multiple interfaces can select a proper network, according to application type, user profile, and network conditions [1–3]. Different groups such as the 3GPP (Third Generation Partnership Project), 3GPP2 standardization groups [4], and the IEEE 802.21 Media Independent Handover (MIH) Working Group are working to facilitate interconnection between networks for users to use different service types in the integrated structure and provide drafts for seamless handover between different technologies [5].

Seamless access over heterogeneous networks is one of the most important challenges in NGNs [6]. In such an environment, mobility management can improve QoS and prevent service degradation. Mobility management includes location management and handoff management [7]. Location management enables the system to follow

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the locations of the MTs moving within different networks to deliver calls to the user by employing the optimal routing procedure.

Handoff management deals with active connection transferring from one BS/AP to another BS/AP or though the transfer channels (frequency, time, type of modulation) or changing interface [8]. In view of the different integration structures, network characteristics, user requirements, and environmental conditions, different handoff management aspects can be explored in Figure 1. All dimensions of handoff, such as its characteristics, technologies, and structures, are completely introduced.

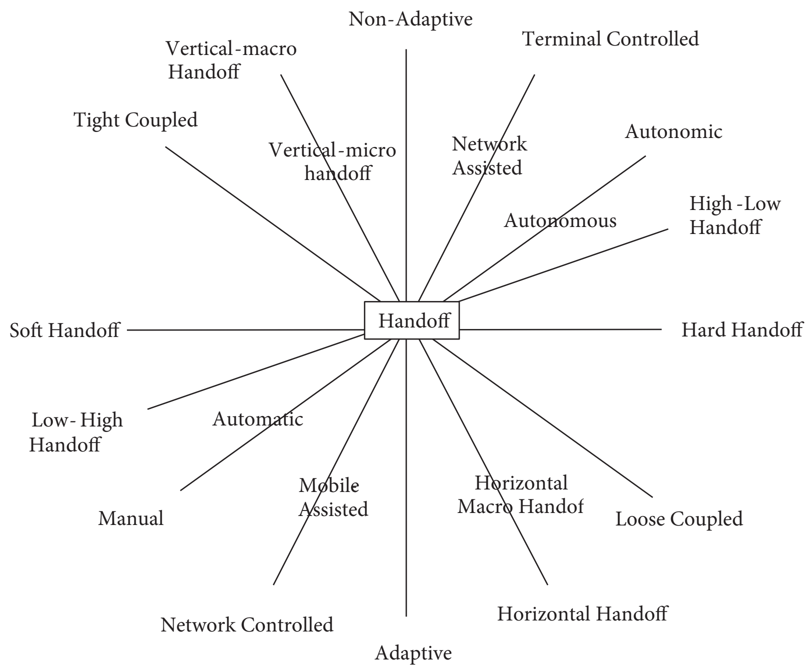

Figure 1. Handoff implementation from different perspectives.

Different works have been studied for handoff management during recent years. These methods can be categorized into five classes: RSS-based (received signal strength) algorithms, e.g., [9], where decisions are made based on RSS; cost function-based algorithms, e.g. [10], where cost function is determined in the best wireless system at any moment; policy-based algorithms [11,12], multicriteria decision making-based algorithms; and intelligent algorithms, e.g., [13–15].

Handoff has three phases: handoff triggering, network discovery and selection, and handoff execution. Network selection is a critical phase that has an effective role in the decision making phase and handoff execution procedure. Metrics used in network selection are based on QoS-related characteristics [16], energy-related characteristics [17], user preferences such as price [1], and terminal situation-related characteristics such as mobility parameters. Considering all metrics simultaneously is complex and a conflict between them may occur (e.g., it is difficult to find services with high quality and very low price). In this case, utility function can be used for decision making [2].

Various studies for network selection in wireless heterogeneous networks have been presented. In such cases that the decision is based on the multidecision criteria method (MDCM), the proper access network according to different attributes and user preferences is selected by using MDCM algorithms such as AHP (analytic hierarchy process), technique for order preference like an ideal solution (TOPSIS), and simple additive weighting (SAW) [1]. In some studies, fuzzy concepts are considered during decision making due to uncertainty in measurement of network parameters [3]. In cost-function methods, selection is done related to network ranking obtained from utility functions [18]. Other heuristic methods have been presented to improve the precision of the decision parameters by using learning and optimization algorithms [19].

Considering user and network behavior during interactions as reputation can improve system performance. Reputation with the concept of rating has been used in different network structures in recent years, e.g., ad hoc routing, peer-to-peer, and social networking [20]. This mechanism has benefits that can consider network parameters, user preference, and application requirements in the decision making. Reputation can also be used for network selection to improve inefficient, nonoptimal, or unstable decisions in the handoff process for network selection. In [21] a solution for fast decisions in VHO by using previous observed QoS and SCTP protocol based on binary trust was studied, and it was improved in [22]. In [23], network selection was modeled as using reputation in cooperative game theory and average received utility was used for ranking phase.

In all of these approaches, expected quality of received service by the user was not investigated for the network selection phase in handoff management. In our history aware-based user location algorithm, the past experience of users from available networks is considered to estimate the future utility that a user can receive from a candidate network. User location, network condition, and application requirements are considered for calculating future utility of available networks before selecting a network. The utility function based on decision metrics is defined to show the level of user agreement from a network in terms of QoS, energy consumption, and economic aspects. The presented approach, including user situation and network selection triggering conditions, can improve the number of vertical/horizontal handoffs, the performance of the networks, and the users' QoS.

The main functions of the proposed reputation-based method in the selection of an optimal network are:

- Presenting utility-based surplus considering power consumption aspects for network selection and handoff triggering.
- Using estimated reputation for service reception from each network by considering past experience of users related to the user's location, application requirements, and network behavior.

The remainder of the paper is organized as follows. In Section 2, the network model is presented. The handover algorithm and network selection mechanism based on reputation are specified in Section 3. In Section 4, the performance of the proposed algorithm is evaluated in several important regards. Finally, the conclusion and the future works are presented in Section 5.

2. Network model

In this paper, it is assumed that network heterogeneity is due to networks with different technologies, which are at the disposal of various operators providing different classes of services. The heterogeneous network environment with the coverage of "A" consists of M UMTS cellular networks and N wireless local area networks. They are managed by k different operators ($k \in \{1, 2, ..., K\}$). The UMTS and WLAN networks are represented by UMTS_m and WLAN_n, respectively, where m ($m \in \{1, 2, ..., M\}$) and n ($n \in \{1, 2, ..., N\}$) indicate the network indexes. It is assumed that the UMTS network with high coverage covers all areas including WLAN networks as shown in Figure 2. WLAN access points and Node-B of UMTS through the radio network controller (RNC) and serving GPRS support node (SGSN) are connected to the IP core network. Every user has multiple interfaces and can choose only one of them at a time to receive service.

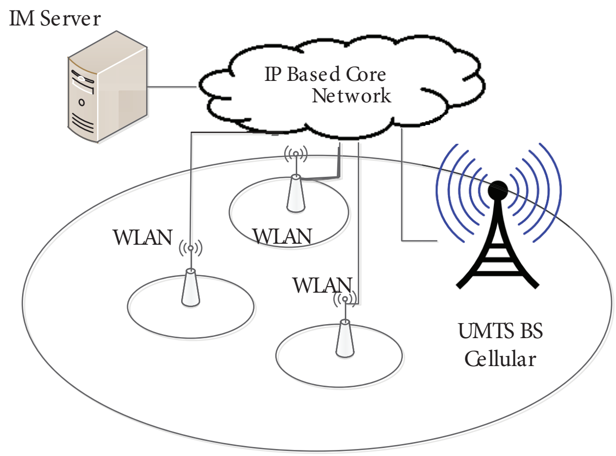

Figure 2. Used network model.

In our network model, the users can decide to handoff to a particular network based on reported experiences of other users and the process of handoff from network 'i' to network 'j' occurs for two reasons: 1) to prevent the user connection from disconnecting because of node mobility, and 2) to receive better service according to application requirements or the existence of a network with higher utility.

There is an information manager (IM) server residing in the network environment to provide required information from stored data of candidate networks. The requested information for IM server support includes network characteristics, e.g., coverage and resources related to the user location.

3. Reputation-based handover

Handover management is an important mechanism that can help users freely receive service while moving in the network coverage. It has three phases: handoff triggering, network selection, and handoff executions. Here, two phases, utility-based handoff triggering and location aware network selection, are investigated and handoff execution is out of this paper's scope.

Utility-based handoff triggering is initiated for two conditions: 1) to meet the user requirement or QoS improvement, and 2) to prevent active connection dropping. Location aware network selection is based on the location of the user and network reputation. A pseudocode and the flowchart of the proposed handoff algorithm are shown in Figure 3.

An example of handover scenario is shown in Figure 4. At first, when the terminal is initiated to trigger a handoff, it sends a proposal, including user profile, terminal characteristics, and requirements, to Old AP/BS. The Old AP/BS then sends the user proposal to the IM server residing in the enterprise network. The IM server restores information based on the terminal proposal from its database. The restored information includes service support and coverage of the network related to user location for candidate networks. Network information is sent to the user through Old AP/BS by the IM server. The terminal ranks candidate networks utilizing the network selection algorithm. It sends the handoff request to the selected network and then sends the last experience from the current network to the IM server through Old AP/BS. Finally, the handoff is executed for the new selected network.

Algorithm 1. Handoff Decision Algorithm

1: *New_ranking_list ← NULL;*
User_Utility ← 0;
2: *If RSS<RSS_{th} || Usr_Utility<$Usr\_Utility_{th}$*
handoff triggering
3: *Call func: Calculate_User_Utility;*
4: *Call func: Check_Utility;*
5: *If User_Utility < $User\_Utility_{Threshold}$*
6: *Call func: Filter_Net (App_type, Cov., Vel);*
7: *Call func: Estimate_Reputation ;*
8: *Call func: Rank_Network;*
9: *Rank_List ← Rank Result;*
10: *If Rank_List ≠ Φ*
11: *New_ Rank_List ← Rank_List * Rep;*
12: *Target_Net ← opt_Rank(New_ Rank_List);*
13: *Call Func: handover Execution;*
14: *Else*
15: *Call Function: Stay_Current_Net;*
16: *End*
17: *Else*
18: *Call Function: Stay_Current_Net;*
19: *End*

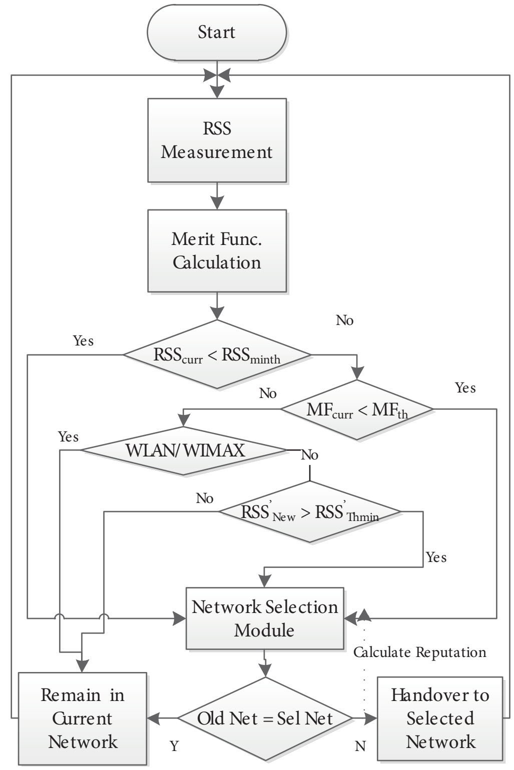

Figure 3. Handoff decision algorithm and its flowchart.

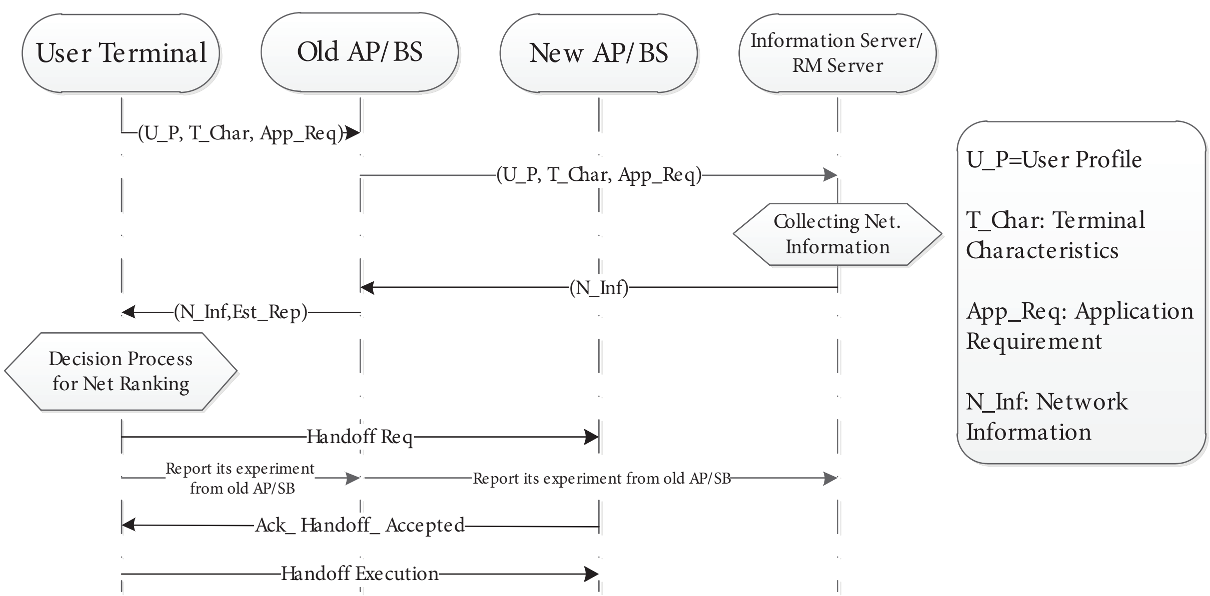

Figure 4. Handover scenario.

3.1. Utility-based handoff triggering

Handoff initiation works based on the utility function to meet the user satisfaction. If the average utility obtained by the user from the current network does not meet the threshold value, the network discovery module is activated to find new candidate networks with higher utilities. The utility function originates from utility theory, which describes the level of pleasure or satisfaction of a good from the view point of the customer, but does not specify by how much that alternative is better [24,25]. It can be used in the cases where various alternatives exist. The utility value of an alternative is different for users with different preferences.

Here, the utility concept is applied to the model satisfaction level of the user for the selected network. Utility function for a network is defined according to the monetary cost C, power consumption P, QoS-related factors, and the received signal strength as follows:

$$\text{Utility}_{User} = f(s) \ .(\theta_1.f(q) - \theta_2.\, f(c))^{q1} \,.\, f(e)^{q2}, \tag{1}$$

where functions $f(q), f(s), f(c)$, and $f(e)$ are the utilities of QoS parameters related to the class of application, RSS, monetary cost, and power consumption, respectively. The parameter θ_i is the preference weight for monetary cost and quality related to user type (quality user: quality is more important; mediate user: no importance between quality and price; economic user: the cost of service is more important that quality). Parameter q_i is related to user preferences between surplus and energy consumption and it is important when a constraint exists for the energy consumption.

The function $f(q)$ depends on application requirements related to service type (real-time (RT) services or non-real-time (NRT) services). NRT services, popularly known as data services (e.g., web downloads), have less strict delay requirements, but they are sensitive to transmission rate and quality of experience (QoE). In RT services such as streaming video, delay and transmission rate are important, but are less flexible than data services. The function $f(q)$ can be formulated from the unified quantitative model by using the sigmoid function [26] as a good approximation for user's satisfaction. In this quantitative model, the parameters that affect the QoE are considered by employing the weights for different preferences related to application type.

$$f(q) = \begin{cases} \frac{A}{1+\exp(-B\sum_{i=1}^{3} w_i\, \phi_i\,)} & BW > BW_{\min} \& \ D \leq D_{\max} \& \ Ploss \leq Ploss_{\max} \\ 0 & \text{Otherwise} \end{cases} \tag{2}$$

where,

$$\phi_i = \begin{cases} \frac{\upsilon_{req} - \upsilon_{\min}}{\upsilon_{\max} - \upsilon_{\min}} & \upsilon_{req} \leq \upsilon_{mac} \\ 1 & \upsilon_{req} > \upsilon_{mac} \end{cases} \qquad \text{for } i = 1,\ \upsilon : Bandwidth$$

$$\phi_i = \begin{cases} \frac{\omega_{\max} - \omega_{req}}{\omega_{\max} - \omega_{\min}} & \omega_{req} \geq \omega_{\min} \\ 1 & \omega_{req} < \omega_{\min} \end{cases} \qquad \text{for } i = 2, 3,\ \omega : Delay\ ,\ Ploss$$

Weight w_i is adjusted with regard to the service type and can be calculated by using the AHP method. Other methods such as intelligent learning mechanisms can be used to obtain user preferences and minimize user interactions. υ_{req}, $\upsilon_{\min}$, $\upsilon_{\max}$, ω_{req}, $\omega_{\min}$, and $\omega_{\max}$ in Eq. (2) denote the required, minimum required metric, and maximum required for the bandwidth, delay, and error rate, respectively. The A and B values are the scaling coefficients, which differ for the RT and NRT applications.

Function $f(s)$ models receive signal quality, which is used for choosing networks with a better signal quality and decreases the ping-pong effect. Since it is difficult to compare the received signals of networks with different technologies, due to different sensitivities and threshold values of their receiver devices, a normalized value is considered for RSS as follows:

$$f(s) = \begin{cases} RS & P_{recieved} > P_{th} \\ 0 & \text{Otherwise} \end{cases} \quad s.t.\ RS = \frac{P_{recieved} - P_{th}}{P_{\max} - P_{th}} \tag{3}$$

where P_{max} and P_{th} denote the maximum transmitted signal strength and threshold value for the network, respectively. If the received signal is lower than the threshold, the value of $f(s)$ decreases to zero and the utility function has minimum value in Eq. (2). In this case, the user will decide to change the current network, and a vertical/horizontal handoff will take place.

3.2. Location aware network selection

Network selection as an important part of handover management has a significant effect on the user's QoE. Here, a reputation-based algorithm according to the user's location for network ranking is used with the goal of providing service with an acceptable QoE level for users. In this regards, past experiences of users are considered to obtain network reputation for ranking the candidate networks. The network reputation is calculated, based on history, with respect to the utility value obtained from the network while receiving service.

The structure of the reputation-based network selection is illustrated in Figure 5. As shown, it has three units: the reputation estimation unit (REU), decision making unit (DMU), and execution handover unit (EHU). In the REU, the future reputation of a network is estimated by a neural network (NN) algorithm according to the user's knowledge about network conditions and the user profile (terminal condition and user preference). The estimated reputation is used in the DMU for decision making to select the proper network. The obtained policy in the DMU is forwarded to the EHU. In the EHU, if the chosen network is a new network to which the user is not currently connected, its interfaces are configured to set up a connection to the selected network.

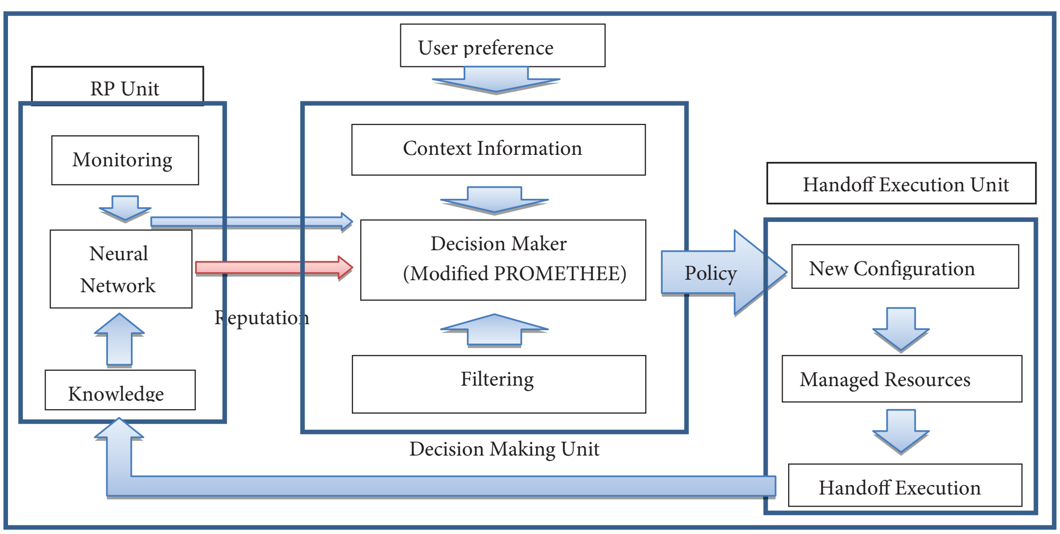

Figure 5. Proposed network selection flowchart.

3.2.1. Decision making unit

Decision making as a multicriteria problem for selecting an optimal network among different candidate networks is a challenge. To address this challenge for which alternatives with different criteria exist, using multiattribute decision making methods can be useful. Different multiattribute methods have been studied in recent years, e.g., TOPSIS, AHP, and PROMETHEE. The TOPSIS method is a multicriteria method that aims to address solutions from a set of alternatives. The underlying logic of TOPSIS is to define both positive and negative ideal solutions. The basic principle is that the selected alternative from the ranking list has the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution [25]. In the AHP method, the decision is made based on the criteria that are normalized in accordance with the predefined scale of the relative importance.

In PROMETHEE as a multicriteria method [27], the candidate alternatives are evaluated based on different metrics in order to select the best network. The evaluation process is based on the preference function, the difference between two alternatives over each criterion, and the preference degree of this difference. It compares a pair of alternatives (networks) for each criterion.

Since it is not possible to select all the optimum criteria simultaneously, because there might be conflict between them, PROMETHEE is used for network selection where there are different criteria for alternatives in the selection phase. PROMETHEE is simple to process for a limited number of alternatives and can achieve unique advantages when important elements of the decision are difficult to quantify or compare. In this method, different types of criteria with different units can be compared. We have utilized the modified PROMETHEE (predicted reputation of candidate networks is considered in the selection phase of PROMETHEE) to compare alternatives with corresponding criteria in a pairwise comparison manner. In the modified PROMETHEE, the final selection phase of the PROMETHEE method is modified by the estimated reputation factor of alternatives (candidate networks). Subsequently, in the selection of a network by the user, the bandwidth, delay, and network load (as the QoS parameters) and also the power consumption and the distance from base station have been considered. This way, the inconsistency of two conflicting objects can be solved and the best network from the existing networks, which is closer to the ideal choice, can be selected. The implementation of this approach is presented in 5 steps as follows:

Step 1: Calculating the degree of preference for each of the alternative networks. For example, suppose that $\theta_i(x)$ is the value of criterion i for alternative x, and $\Delta_i(x,y)$ is the difference of criterion i for the two x and y decisions.

$$\Delta_i(x,y) = \theta_i(x) - \theta_i(y) \tag{4}$$

The preferred degree of criterion i between two decisions of x and y, indicated by preference function $P_i(x,y)$, will then be defined as follows:

$$P_i(x,y) = p(\Delta_i(x,y)) \qquad \forall x \in]-\infty, +\infty[\,, 0 \leq p(x) \leq 1 \tag{5}$$

where p_i is nondecreasing, and $p_i(\Delta) = 0 \; for \; \Delta \leq 0$ and $0 \leq p_i(\Delta) \leq 1 \; for \; \Delta > 0$. Different functions have been defined for the preference function, for which the Gaussian type has been considered in this article due to its practical application.

Step 2: Calculating multicriteria preference index $\pi(x,y)$, including all the weighted criteria for both networks x and y as follows:

$$\pi(x,y) = \sum\nolimits_{i=1}^{m} w_i \, P_i(x,y) \tag{6}$$

where w_i is the weight allocated to each criterion, and m is the total number of criteria used in the decision making. This index has values between 0 and 1, which indicates the global intensity of a preference between a pair of alternatives.

Step 3: Implementing outranking flow. For alternative x, the positive outranking flow $\varphi^{+}(x)$ and negative outranking flow $\varphi^{-}(x)$ are defined as follows:

$$Positive\,outranking\,flow:\varphi^{+}(x)=\frac{1}{n-1}\sum_{y=1}^{n}\pi(x,y) \tag{7}$$

$$\text{Negative outranking flow:}\varphi^{-}(x)=\frac{1}{n-1}\sum_{y=1}^{n}\pi(y,x) \tag{8}$$

where n is the number of possible alternatives. The positive outranking flow $\varphi^{+}(x)$ indicates how much each alternative outranks the other alternatives. The negative outranking flow $\varphi^{-}(x)$ shows the degree of weakness of an alternative relative to the other alternatives.

Step 4: Ranking the alternatives based on the outranking flows. In this regard, the net outranking flow is defined as follows:

$$\varphi(x)=\varphi^{+}(x)\;-\;\varphi^{-}(x) \tag{9}$$

Step 5: Selecting proper networks based on outranking flows and predicted network reputation by taking the user and network conditions. Suppose that $\Re_x$ is the predicted reputation value for network i. In this case, the modified net outranking flow is defined as follows:

$$\varphi^{'}(x)\;=\;\Re_x\;.\;\varphi(x) \tag{10}$$

Based on this relation, a higher modified net outranking flow means that that network is better than the other networks. In other words:

- x is preferred to y if $\varphi^{'}(x)\;>\;\varphi^{'}(y)$
- x is indifferent to y if $\varphi^{'}(x)\;=\;\varphi^{'}(y)$

3.2.2. Reputation estimation unit

As presented, users utilize the estimated reputation of networks for decision making in the network selection phase. Future reputation is estimated by using the past calculated reputation. Calculated reputation of a network is determined by three parameters: 1) QoS, 2) average power consumption, and 3) monetary cost by using Eq. (11). Network reputation is calculated by users when the user is disconnected from the network and shows how the provided service has been useful for the user.

$$\text{Reputation}=\;f(s)\;.(\theta_1.f(q)-\theta_2.\overline{k})^{q1}\,.\,f(\overline{e})^{q2} \tag{11}$$

Where:

$$\phi_i=\begin{cases}0 & \upsilon_{delivered}<\upsilon_{\min}\\ \frac{\overline{\upsilon_{delivered}}-\upsilon_{\min}}{\upsilon_{offered}-\upsilon_{\min}} & \upsilon_{\min}\leq\upsilon_{delivered}\leq\upsilon_{offered}\\ 1 & \upsilon_{delivered}>\upsilon_{mac}\end{cases}\qquad \text{for } i=1,\ \upsilon:\text{Bandwidth}$$

$$\phi_i = \begin{cases} 0 & \omega_{delivered} > \omega_{\max} \\ \frac{\omega_{\max} - \overline{\omega_{delivered}}}{\omega_{\max} - \omega_{offered}} & \omega_{offered} \le \upsilon_{delivered} \le \upsilon_{\max} \\ 1 & \upsilon_{delivered} < \upsilon_{offered} \end{cases} \quad \text{for } i = 1, 2, \ \omega : \text{Delay, Ploss}$$

Here, $\overline{x_{de}}$, $x_{offered}$: $x = BW,\ L,\ D$ denote the average parameter values delivered to the user during received service and the values offered to the user for service delivery. The function $f(\overline{e})$ indicates the average power consumption, and $\overline{k}$ is the normalized monetary cost.

3.2.2.1. Effective parameters in reputation estimation

Effective parameters in estimating reputation are related to important terms in the user's utility. Since the utility depends on user location, network conditions, and velocity, we consider these factors to estimate the reputation of a network.

User location is an effective factor in the quality of service (link quality, throughput), energy consumption, and packet loss in the wireless environment. As the distance of a user from a BS/AP increases, the RSS value and thus the effective received rate decrease as in Eq. (13).

$$R_{effective} = Rate * \log(1 + SINR) \tag{12}$$

When the quality of the received signal diminishes as a result, loss increases, which can affect the BER, as follows: $P_{recieved}(db) = P_{transmitt}(db)$- Loss(db) where (Loss αd). According to the term $P_{recieved}\,\alpha\,\frac{P_{transmit}}{d^n}$, $2 < d < 4$, by increasing the distance from the AP/BS, the user's terminal needs more power (important in the uplink mode, e.g., photo sharing).

User location from the view point of network operation is also important. In cellular networks some sectors may be congested and others may have low load. The user therefore not only considers network ID, but also considers user location in that cell to distinguish specific low load sectors to receive better service quality.

For example, the average user location in a WLAN cell depends on user arrival directions. As shown in Figure 6, different utilities can be obtained for users based on the terminal location and arriving directions θ_i. For example, the average distance of the terminal from the WLAN center will be more while receiving service for $\theta_1 > \theta_2$, and so power consumption increases and the link quality decrease. In other cases, if α_1 is equal to α_2, then traveling time in the network is the same for the same speed of movement through the network, and the average of user utility will be the same.

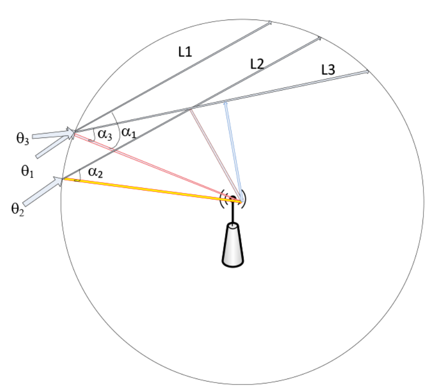

Figure 6. Movement of user at different arriving directions.

Velocity is another factor for which considering it in reputation estimation can improve the user's utility and handover performance (e.g., handoff number and unnecessary handoffs), because the utility that a user can obtain from a network varies for terminals with different speeds. For example, residence time of an MT (mobile terminal) with high speed in a microcell network is short, and therefore the probability of call dropping and loss of packets during handoff is higher.

Another important factor is the network condition, which should be considered in the reputation estimation. In WLAN networks due to no control mechanisms existing in resource management, the user's QoS is affected by user number and, due to retransmissions, power consumption increases. In CDMA-based networks such as the UMTS, the number of users has an inverse relationship with the available resources for users, according to $N = 1 + \frac{W/R}{E_b/N_0} - \frac{\eta}{S}$. Therefore, a user may receive different utilities from two cellular networks with similar characteristics, based on the behaviors of admin's network. For example, a cellular network complies with the offered quality to guarantee service quality, while another cellular network compromises the service quality of its current users by registering additional users. Thus, network behavior can be considered by the user during the network selection phase.

3.2.2.2. Estimating algorithm

To estimate the reputation of the candidate network, the NN algorithm is used. The calculated reputations by the users are employed as feedback to revise the estimated reputation. Let us suppose that in the epochs of $t_i, i = 1, 2, ...20$, user 'u' should select a new network. According to Figure 7, the times network 'n' has been selected by the user are marked by stars and the times the network has not been selected are marked by circles.

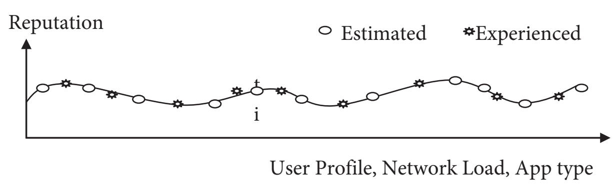

Figure 7. Reputation diagram for network n and user u. Circles: estimated reputations, stars: experienced by the user for network n.

If user i has 20 interactions with network j during this time interval, in each of the 'star' cases, the user will calculate the reputation of network 'n' in the end of service by using Eq. (11). However, the reputation of network 'n' in some cases where the user has not chosen the networks can be estimated by means of the neural network, based on the existing conditions and the past experience of users from network 'n'.

To estimate the reputation of available candidate networks, the feedforward NN with feedback is used. A NN is taught to resolve a problem simply by modifying its biases and weights and then backpropagating the difference between the current output of the NN and the desired response. Figure 8 is a view of the FFBP ANN used for reputation estimation.

The applied neural network has 3 layers and 4 inputs with regards to the user and terminal profile, network conditions, and application type. It is trained in the I-RM server by past experienced reputation reported by users during service reception. Training data are updated by aggregated information, which is reported by network users. When a user requests the reputation of a network, according to inputs of the network (user and terminal profile, network condition, and application type), estimated reputation is calculated by the I-RM server and it is sent to the user. Training data for estimating of network reputation are obtained from multiple users' experienced reports, according to user situation and network conditions.

The training approach of a feed forward neural network (FFNN) using the BP learning algorithm is described as follows:

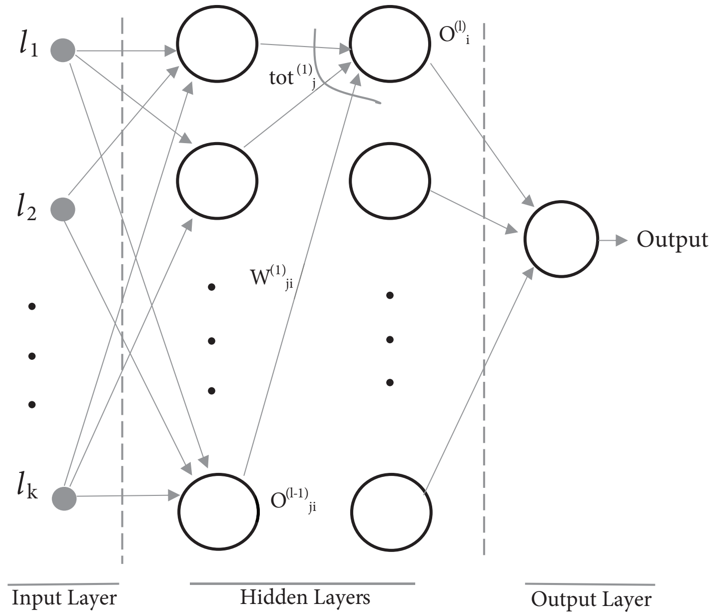

Figure 8. Typical feed forward backpropagating ANN used for reputation estimation.

Step 1: Using input and calculated reputation sets from the past experienced data $(i(k), C(k))$.

Step 2: Calculating the output values for all i neurons in each layer (l) by propagating the kth signal through the network by using:

$$o_i^l(k) = f(\sum_{p=0}^{n_{l-1}} w_{ip}^l i_p^{l-1}). \tag{13}$$

Step 3: Using $Er = Er(k) + Er$ to calculate total error and signal error $\delta_i^{(L)}$ as:

$$\delta_i^{(L)} = [C_i - o_i^L][f'(tot_i^{(L)})]. \tag{14}$$

Step 4: Update the weights $\Delta w_{ij}^{(l)} = -\eta \delta_i^{(l)} o_j^{(l-1)}, forl = 1, ..., L.$ and proceeding backwards: $\delta_i^{(l)} = o_i^{(l)}(1 - o_i^{(l)}) \sum_{p=1}^{n} \delta_p^{(l+1)} w_{pi}^{(l+1)}, forl < L.$

Step 5: Repeating all processes for other samples. After all, the system is in a state called one-epoch training. If the cumulative error Er in the output layer is less than a threshold level, the network is trained for estimating reputation [28].

Finally, this estimated reputation is used in the network selection phase to rank candidate networks.

4. Simulation results

The proposed algorithm is examined by studying simulation results. Simulation is done in the MATLAB environment by using practical parameters. It is assumed that handover is controlled by the user and different locations in the cell have various link qualities. Different behaviors for the network admin are considered such that a provider may not guarantee its offered service requirements.

At first, the proposed algorithm is evaluated with experimental results based on the experimental setup in [29]. In the scenario, the user walks through a lab area along a path of about 200 m receiving service for about 350 s with a bandwidth requirement of 100 kbps. There is a UMTS network with 1 km of coverage and a Wi-Fi network in the lab with coverage of 100 m. Both the UMTS and Wi-Fi networks have bandwidth of 7.2 Mbps with RSS threshold of –80 dBm. Practical parameters are considered for signal propagation in the simulation.

In Figure 9, the comparison result is presented for experimental and simulated received signal strength index (RSSI) of the Wi-Fi network while receiving service. As is seen, a good approximation results between simulated and experimental RSSI results that can model user behavior in the wireless networks appropriately. The building area of the lab is covered by walls, which attenuate signal strength. As shown in Figure 9, there are some peaks between times of 100–150 s and 200–300 s in the RSSI value. It is due to the user receiving the signal directly or through the window, without any attenuation caused by walls. Simulation results show the same behavior and experimental results have good approximation for the RSSI value.

The proposed history aware location-based algorithm is studied and compared with the RSS-based handoff algorithm implemented in [29]. Simulation parameters are listed in Table 1. In this scenario, the user walks around the lab for about 200 m. According to Figure 9, the user is in the range of the Wi-Fi network between times 100 s and 170 s and times 180 s and 300 s. The result of the proposed algorithm in terms of user's utility is shown in Figure 10, which has better results. Between times 100 and 170 s, the quality of the network is not good and after time 200 to 300 s, the quality of Wi-Fi is better than that of the UMTS network. The RSS-based algorithm decides only based on signal strength and selects Wi-Fi when it detects the Wi-Fi signal. Because in the RSS-based method the Wi-Fi network has low quality between 100–170 s and 190–215 s, the user obtains lower utility. However, our proposed algorithm considers user location and past experience from the Wi-Fi network and selects the UMTS network before time 215 to 300 s and Wi-Fi from time 215 to 300 s. As a result, compared with an RSS-based algorithm, our algorithm improves user quality.

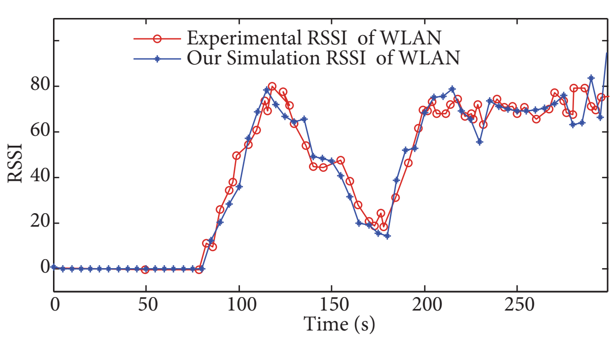

Figure 9. Comparing of simulation results of RSSI with experimental results.

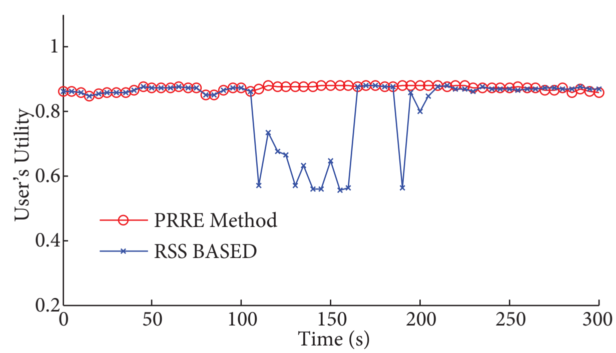

Figure 10. User's utility during service reception.

In scenario two, obtained utility by user versus its location and entrance into the network cell is studied. It is assumed that the user enters the WLAN cell with fixed velocity and constrained bandwidth. Two applications, audio streaming and video streaming, are considered. As shown, generally, by changing the user entrance angle, the average residence time of the user changes such that closer to the center of cell, QoS parameters and received signal become better and reputation of the WLAN increases. By comparing Figures 11 and 12, it can be seen that when the entrance angle increases, the utility of a user running a video application decreases faster compared with a user running an audio application. This is due to video applications requiring more bitrate and lower delay, but when the user travels far from the access network, because of the competitive environment of WLAN and the decreasing signal quality, power consumption and retransmission in the WLAN cell increase. Thus, delay increase and effective bitrate decreases. Since reputation is calculated based on obtained utility, when the user's utility decreases faster, the reputation related to user location decreases more in the case of video streaming applications.

Table 1. Network parameters used in the simulation.

	Data rate (kbps)	Delay (ms)	Packet loss	Power consumption	Monetary cost
UMTS	384	100	10^{-4}	1	5
WLAN1	2000	200	10^{-3}	3	3
WLAN2	1000	400	10^{-2}	2	2
WLAN3	1500	700	10^{-3}	3	2

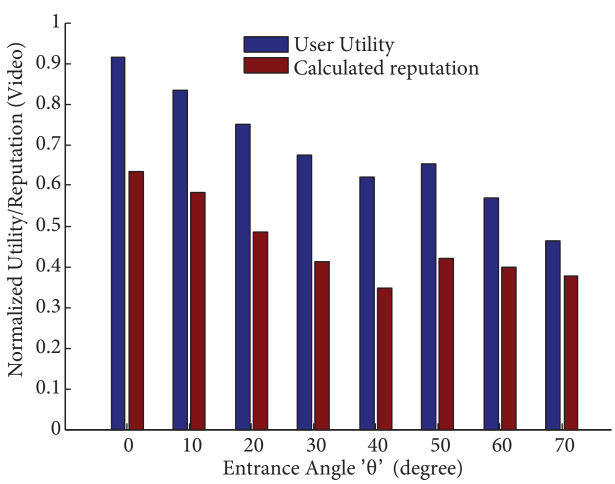

Figure 11. User utility for video streaming for different user entrance angles.

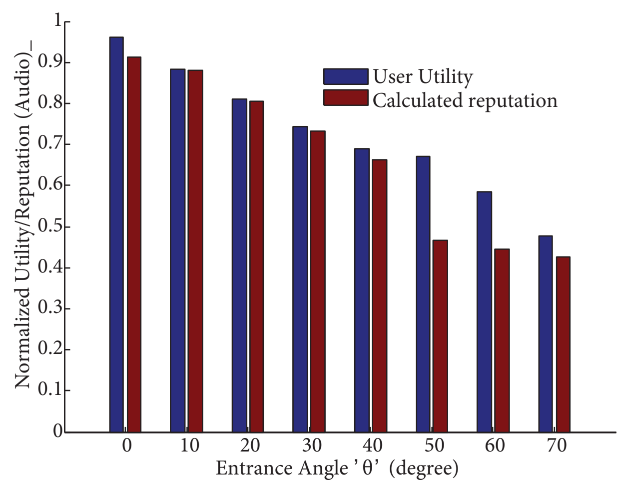

Figure 12. User utility for audio streaming for different user entrance angles.

In the next scenario, obtained utility by user related to bandwidth requirements for different user preferences is investigated for the proposed history aware network selection algorithm. We consider a 700 x 700 m^2 area, where three WLAN with diameter of 100 m are covered by a UMTS cell with diameter of 1000 m as shown in Table 1. The UMTS network allocates a maximum of 384 kbps of bandwidth to each user and the WLAN networks divide total bandwidth among all requests. We simulate users in a MATLAB (MathWorks Inc., Natick, MA, USA) implementation that requests from 100 to 1000 kb/s bandwidth. An access point is one of the available candidate networks if the user is placed in the coverage area of that access point. In all simulations, it is assumed that RSS is calculated related to environmental factors, distance, and the propagation Haau model in [30]. The network characteristics and application requirements are listed in Tables 1 and 2.

Terminal situation, network characteristics, and user preference as well as traffic conditions of networks are assumed as metrics in the decision making process. The decision process is done according to required QoS parameters for each application, energy consumption, and service monetary cost. The simulation is run 1000 times, randomly, for three types of users with different preferences (QoS, energy importance, and economic user: $(\theta_1 = 0.8, \theta_2 = 0.2, q_1 = 0.8, q_2 = 0.2)$, $(\theta_1 = 0.8, \theta_2 = 0.2,\ q_1 = 0.4, q_2 = 0.6)$, and $(\theta_1 = 0.6, \theta_2 = 0.4, q_1 = 0.8, q_2 = 0.2))$ and average results are presented.

Figures 13a–13c show the user utility regarding different user preferences. For the proposed history aware network selection PRRE (PROMETHEE reputation-based method) is compared with the TOPSIS method. As shown, the user, by using PRRE, can obtain more average user utility during 1000 times. This is due to the fact that, in the decision making phase for network selection, the estimated reputation of networks related to user location, network condition, and application requirements is considered in PRRE, but the TOPSIS algorithm only considers multiple criteria without considering future conditions of network. In the decision making phase, PRRE also considers special cases: 1) some locations of a network cannot provide required service quality due to bad link quality or congestion; 2) a network cannot provide proper quality of service for some applications. In our algorithm, inappropriate conditions are thus eliminated during the network selection and a network with good operation in the past user's experience is selected. For example, in some situations where the user could not receive good service, the estimated reputation related to the user's utility can help for better decision making. Since the RSS is considered in the utility function, the mobile terminal tries to choose a network with higher RSS by considering other metrics, and so higher utility can also be obtained. It can be mentioned that by increasing bandwidth requests, obtained utility decreases faster for Figure 13a and 13c compared with Figure 13b. In these figures, surplus in utility function (Eq. (1)) is more important than power consumption. Comparing Figures 13a and 13b, it can be seen that in the same conditions, price is more important for the

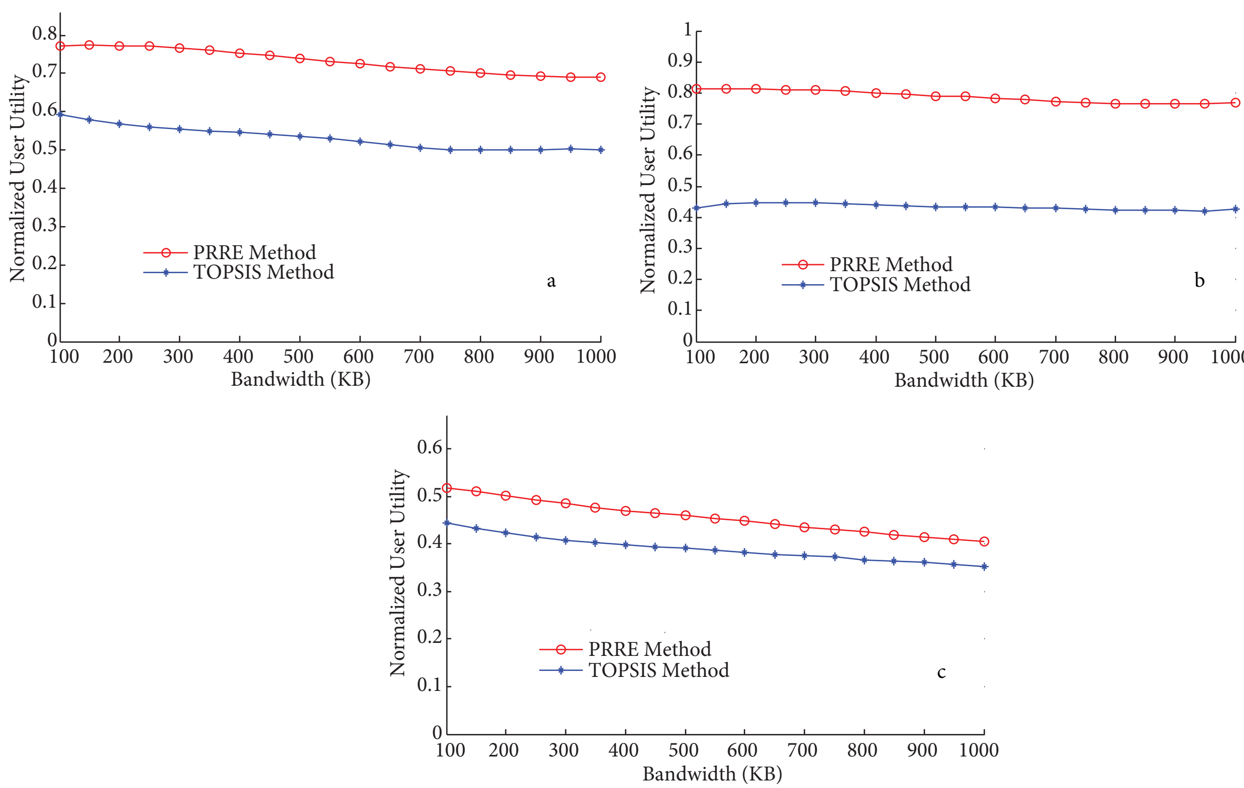

Figure 13. User utility for different preferred bandwidths in different user preferences: (a) QoS user $(\theta_2 = 0.2, q_1 = 0.8, q_2 = 0.2)$, (b) energy-important user $(\theta_1 = 0.8, \theta_2 = 0.2,\ q_1 = 0.4, q_2 = 0.6)$, and (c) economic user $(\theta_1 = 0.6, \theta_2 = 0.4, q_1 = 0.8, q_2 = 0.2)$.

economic user compared with the QoS user, and so according to the utility function of Eq. (1), the surplus economic user is lower than the economic user and that results in the utility of the QoS user becoming greater than that of the economic user. After service is finished, the user calculates the reputation of the current network and reports to be used as training data in the artificial neural network for estimating reputation.

In the last scenario, handover performance including the number of handovers, unnecessary and failed handovers, and packet drops is examined. A simulation is done with three WLAN and one UMTS network. Network characteristics and simulation environments are reported in Tables 1–3. The cellular network covers the entire simulation environment area of 1000 x 1000 m^2. User preferences and application requirements are listed in Table 2. User arrival rate is considered randomly with Poisson distribution and mean λ changing from 1 to 15. Average holding time is exponential with normalized mean μ to 1. Simulation is done for 1000 times randomly and average results are presented.

Table 2. Application requirements and user preferences.

	Data rate (kbps)	Delay (ms)	Packet loss	Power consumption	Monetary cost
Application requirement	200	400	10^{-2}	7	4
User preferences	0.7	0.15	0.15	0.2	0.15
	QoS weight: 0.65				

Table 3. Simulation parameters.

Mean user arrival rate (λ)	Poisson distribution, 1–15
Mean service duration time (μ)	Exponential distribution, 1
Path loss model	Standard model Haau, path loss constant = 4
Network coverage	UMTS = 1000 m, $WLAN_i$ = 120 m, i = 1,2,3
Topology size	1000 × 1000 m^2

Figures 14a–14c show the number of handovers and unnecessary and failed handovers versus arrival rate varying from 1 to 15. As shown in Figure 14a, the PRRE method returns better results in comparison with the RSS-based TOPSIS method in terms of handoff number. PRRE considers the user's utility in handoff triggering and so reduces ping-pong effects during handoff.

The PRRE method also considers the future network conditions and past experience of users in different locations of the network and, by selecting the proper network, with which it can provide acceptable service, it tries to reduce handoff number. However, in the RSS-TOPSIS algorithm, user location and the future of network conditions are not considered, and so after handoff using this method, the obtained utility may be reduced and another handoff is required to the old network. Figures 14b and 14c show failed and unnecessary handoffs.

In the proposed algorithm necessary handoffs are lower because the user avoids handover networks that provide low utility based on estimated network reputation. Since the location of the user is considered in the reputation estimation used in the decision making of the PRRE algorithm, handoff is not triggered in the situations where the user travels in cell borders and so unnecessary and failed handoffs causing delay and packet loss are reduced compared with the RSS-TOPSIS-based algorithm.

To evaluate the number of dropped packets, simulation is done by considering a user that runs an application with requirements and preferences according to Tables 4 and 5 with session time of 500 s. Its velocity changes from 1 m/s to 15 m/s. Packet size is assumed as 512 bytes. It is considered that the average

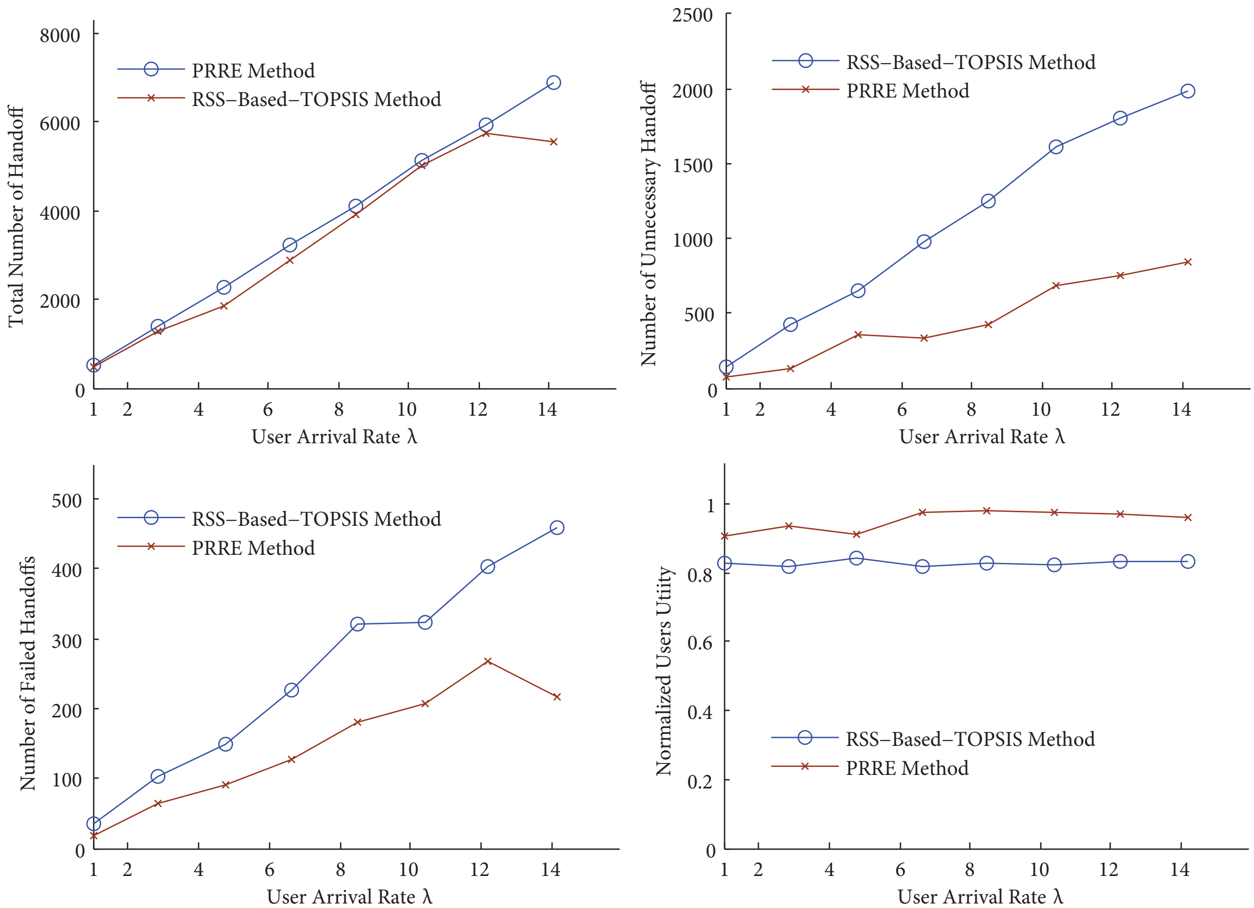

Figure 14. Number of handoffs, unnecessary handoffs, and dropped handoffs and user's utility for two PRRE and RSS-based+TOPSIS methods versus user arrival rate.

Table 4. Application requirement and user preferences.

	Data rate (kbps)	Delay (ms)	Packet loss	Power consumption	Monetary cost
Application requirement	100	400	10^{-2}	7	4
User preferences	0.7	0.15	0.15	0.2	0.3
	QoS weight				

Table 5. Simulation parameters.

Path loss model	Standard model Haau, path loss constant = 4
Network coverage	UMTS = 1000 m, WLAN_i = 100 m, i = 1,2,3
Topology size	1000 ×1000 m^2
Packet size	512 bytes, CBR
Session time	500 s

of handoff delay from the WLAN-UMTS is 180 ms and from UMTS-WLAN is 98 ms [31]. As seen in Figure 15, with increasing user velocity, the packet drops increase. This is due to increase in the handoff numbers and handoff delay. During handoff, incoming packets are dropped. The PRRE method has better results in terms of packet drops. This is due to PRRE considering user location and network behavior during handoff by using past experience and so avoiding unnecessary handoffs. Thus, the amount of packet loss is less in the PRRE than the RSS-TOPSIS-based handoff algorithm.

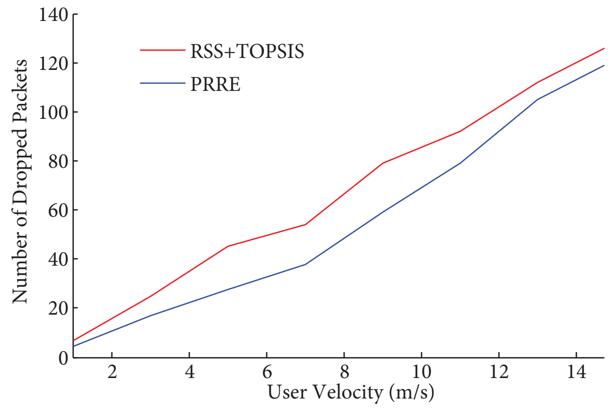

Figure 15. Number of dropped packets during handoff for two PRRE and RSS-Based + TOPSIS methods versus user velocity.

5. Conclusion

In this paper, a user-centric decision based on user location is proposed to find the best available network and maximize users' utility. In the proposed algorithm, users' utility is defined based on combinational metrics including quality of service, monetary cost, and energy consumption by considering the user and network preferences. For better decisions, we also utilize the estimated reputation factor of networks based on knowledge of users according to their past experience from each network while receiving service. Network reputation estimation is done with regards to the user location and network conditions and application type. Through this algorithm, if one network does not meet the required user utility, its reputation factor decreases according to the user, and so the chance of selecting that network decreases. The presented approach, including situation and network selection triggering conditions, can improve the number of vertical/horizontal handoffs, the performance of the networks, and the users' quality of service.

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