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RSS-based Network Selection in Emerging Wireless Networks

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Abstract
Received signal strength (RSS)-based was proposed in this paper by adopting attribute handover decision algorithm to investigate network selection decision model based on lifetime connectivity that makes the mobile user equipment (MUEs) stay longer in a preferred network. Quality of service (QoS) as an important parameter is achieved by introducing Cost Function (CF) while connecting MUEs. Entropy and G1 methods were introduced in an interactive manner to attain deterministic network selection decision policy. However, since MUEs differ in the choice of QoS parameters, Markov Decision Process (MDP) is then formulated for the network selection (vertical handover) decision problem with the aim of maximizing the expected cost to avoid ping pong (unnecessary handover) effect caused by bad network selection. The simulated results are later compared to show the power of the proposed technique.

Keywords: Cost Function; Network Selection; MDP; Handover; Performance.

INTRODUCTION
In recent time, demand for data traffic by users especially the Mobile Internet usage has dramatically increased and is expected to steadily rise in the near future. However, the focus has been to improve communication links quality of service for better performance of networks [1, 2]. The heterogeneity of wireless networks (HWNs) comprises a variety of wireless access networks in which various access technologies, different data transmission rates and all other kinds of services are provided to users so as to satisfy users' requirements. Seamless and effective handover decision is one of the most important techniques in selecting the best preferred network. Handover process which involves switching of resources between same networks (Horizontal) could be termed "symmetric" process, while that handover that exchanges of resources between different networks (Vertical) is said to be "asymmetric". Therefore, mobility management has become challenging when providing support for vertical handover in multiple access networks.

The various schemes employed for vertical handover decision making are: received signal strength (RSS)-based decision method; cost function (available bandwidth and network cost) method; multi-attribute decision algorithms methods (MADM); Gray Relational Analysis (GRA), TOPSIS, etc. For vertical handover to trigger, a mobile terminal (MUE) could either move out of the connected access network to another network or switches to another network

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based on preferences or wireless network redistributes network load to improve system performance. In trying to make effective and efficient handover decisions, the MUE's quality of service (QoS) requirements are taken into account by jointly considering network performance and network cost (energy and bandwidth). A cellular network that provides universal coverage is considered in this work. One WLAN network, whose signal is provided by an access points (APs) is overlayed on a 4G network and mobility of the MUE adopts mobile IP for its mobility management as illustrated in Fig. 1.

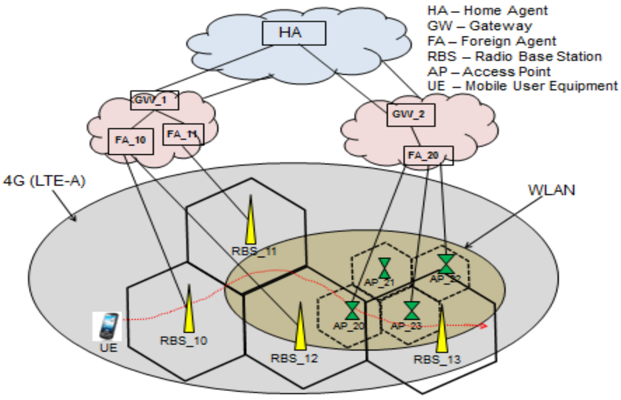

Fig. 1. System Model

The moment a mobile user moves away from the service coverage area of one network for another network, or a
mobile user connected to a specific network chooses to handover its resources to another network in fulfilling service requirement, a network-control handover strategy will result in a serious signaling overhead as a result of long time delay and increased complexity. On the other hand, poor operability is experienced when a terminal-control handover strategy is employed. Therefore, the need for a network selection strategy based on MDP that can receive not only messages from every network, but can also detect the behaviours of user terminals is necessary. The network selection strategy seeks to employ a combination of VHO and multi-attribute decision making (MADM) systems. The purpose of this paper is to provide user adaptable criteria for vertical handover decision making which selects the target network according to running application, user preferences and overall network condition.

The rest of the paper is organized as follows: Section two reviews some of the previous works done. Section three gave description of Markov decision process-based decision algorithm where latency, network load, cost, user preference and price are presented as the metrics for the network selection. Section four discusses the results of simulations as performance evaluation of the algorithm designed. Section five concludes the paper.

RELATED WORKS

Many research works have been conducted in recent years on how to design algorithms for effective vertical handover decision. Among the design schemes is the RSS-based vertical handover decision method [3, 4], where inclusion of parameters like hysteresis are introduced to avoid ''Ping-Pong'' effect. Vertical handover occurs when the measure of RSS values between a target network and the connected network is exceeding a certain threshold level. However, RSS prediction suffers some difficulties when such strategy is adopted and therefore leads to decrease in the efficiency of the handover process. In this case, a combination of several parameters is necessary in order to conduct ubiquitous network selection.

One of the preferences is the cost of accessing networks where comparisons is made between the connected and target networks, before MUE decides to switch to the network with the least cost. This procedure is possible by adopting Cost function-based strategy as decision making process for network selection. However, while various methods are used to choose the best network depending on the choice of preference, another strategy to select a better access network is the choice of the maximum reward. The authors in [5–8] found the use of cost (or reward) model as a strategy to select the network with the minimum (or maximum) cost (or reward). The use of such algorithms provide a stabilization period for extending the decision making time thereby reducing the handover iterations. However, it should be noted that consideration is not given for adjusting the corresponding cost function according to the QoS parameters.

In [9], gray relational analysis (GRA)-based algorithm was applied in selecting an ideal network that provides the MUE with the best available QoS by dividing the available networks into different levels. Furthermore, authors in [10,11] proposed artificial intelligence based algorithms by combining fuzzy logic and neural network to select the network attributes and clients as inputs to fuzzy controller in which vertical handover was achieved in accordance with the predefined fuzzy reasoning judgment. Though the multi-attribute handover decision algorithms (MADM) considered so many factors, they are incapable, according to MUEs' preferences to handle problems with uncertain properties. During the handover decision stage, several network characteristics may impact the handover process in which they provide information about the next available access network. The majority of the handover mechanisms are based on link quality parameters such as RSSI, SINR and bandwidth to choose the optimal target network.

Kaid et al [12] in their work, considered Markov decision process to analyse RSS-based vertical handover decision using forecast polynomial problem. The algorithm considered by the researchers was found to impact significantly on the network by reducing the number of handovers and greatly improved the network resource utilization. In [13], Shen et al proposed a cost-function-based network selection strategy in integrated wireless mobile networks to execute handover decision. They combined cost function and other network parameters to achieve the network selection. Even though the parameters used increases the complexity of the process/environment, the network performance in the neural network stood out to be better.

In most methods adopted for vertical handover decisions, it is found to show only RSS as the judgment index; however, the RSS-based strategy is rather simple but produces ''Ping-Pong'' effect during switching. Therefore, in this work, RSS is considered as the primary judgment index, while some auxiliary decision factors such as the MUE velocity as well as the WLAN lifetime are taken into account for network performance improvement. This work proposes an RSS-based multi-attribute algorithms using Markov Decision Process (MDP) as handover decision strategy. The method is capable of extending the service time of the MUE in the preferred network and adjusts the handover threshold according to the velocity of the MUE. A cost function is first constructed, where the weights of QoS factors are computed by the G1 and entropy methods, before employing an iterative algorithm to obtain the deterministic policy for the MUE to switch to the preferred network of maximum reward.

MDP-based HANDOVER DECISION ALGORITHM

Network selection strategy comprises of handover information gathering, network selection decision making and handover execution. Using detection and signal measurement, handover information collects context information required for all handover strategies by detecting and measuring the local information such as coverage and location. The knowledge base is needed to be updated in real time. A series of strategies, which represent the decision making rule of controlling selection in the whole process, is stored in this knowledge base.

Network selection decision making determines whether handover should be operated by user terminal or by the network. The real-time applications would need a low latency, while jitter could be defined as the variation in end-to-end transmission delays which is commonly used as an indicator of the network consistency and stability. However, for determining network performance, jitter becomes a critical element. While the concept of data loss is classified as an independent factor that ensures quality of service, cost and the security can be considered to improve the quality of connection and is considered in handover decision making.

The proposed method of network ranking is computationally complex when trying to eliminate or add networks of any connectivity. The complexity leads to unnecessary computing process which could be minimised by eliminating those networks that cannot meet the required acceptable value of users' request. As such a threshold value of the required context in the networks ranking stage is introduced in order to achieve this goal.

The proposed network model fits well with the Markov decision process due to the transition probability existing between different systems that depend on the combination of multiple parameters. The formulated Markov process based vertical handover decision model comprise of five elements: decision epoch, state, action, transition probability and reward. During each decision epoch, the MUE decides whether to remain in the connected network or switch to other networks.

Formulation of Markov-based Handover Decision Model

It is assumed that the MUE chooses an action a based on its present state information and the state space is denoted by s. For each state $s \in S$, the state information includes the network ID number indicating which network the MUE is connected to, the available bandwidth and the average delay of each candidate network. X_t denotes the state at decision epoch t. Given the current state s and the chosen action a, the state transition probability function in the next state s' is denoted by $P[s' \mid s, a]$.

The reward function of the link $f(X_t, Y_t)$ denotes the reward value provided by the selected network within one time interval $(t, t + 1)$. The cost function $g(X_t, Y_t)$ presents the MUE's cost of the processing and signaling overhead when it switches from one network to the other, the cost becomes zero if the MUE is unable to switch to another network after the handover decision. The cost function can then be defined as,

$$r(X_t, Y_t) = f(X_t , Y_t) - g(X_t , Y_t) \tag{1}$$

A decision rule which explain/describes the procedure for selecting each state during a specified decision epoch is adopted. The deterministic Markov-based decision rule is given as $\delta_t : S \rightarrow A$, which specifies the action choice in a certain decision epoch t for each state. A policy $\pi = (\delta_1, \delta 2, \ldots \delta_N)$ denotes a sequence of the corresponding decision rules adopted during each decision epoch $v^{\pi}(s)$ is the expected total reward between the first decision epoch and the time when the connection break. During initial state ***s*** under policy π, the expected total reward can be expressed as,

$$R(\mathrm{s}) = \quad v^{\pi}(s) = \mathrm{E}_s^{\pi}\left[\mathrm{E}_N\left\{\sum_{t=1}^{N} r(X_t, Y_t)\right\}\right] \tag{2}$$

Where, E_s^{π} denotes the expectation with respect to policy π and initial state ***s***, and E_N is the expectation of random variable *N*. It should be noted that the chosen action ***a*** depends on the initial states, which changes under different policy π and may have different state transition probability function in E_s^{π}. The random variable *N*, which indicates the connection time of the MT, is considered to be geometrically distributed with mean value 1=1/(1 – λ). Therefore,

$$p(\mathrm{N} = n) = \lambda^{n-1}\ (1 - \lambda); \quad n = 1, 2, 3, \ldots \tag{3}$$

When equations (2) and (3) are added together and manipulate the summation order, we obtain;

$$v^{\pi}(s) = \mathrm{E}_s^{\pi}\left\{\sum_{t=1}^{\infty}\sum_{n=t}^{\infty} r(X_t, Y_t)\lambda^{n-1}(1-\lambda)\right\} = \mathrm{E}_s^{\pi}\left\{\sum_{t=1}^{\infty}\lambda^{t-1} r(X_t, Y_t)\right\} \tag{4}$$

It is obvious that the vertical handover decision issue could be seen as optimization problem with the goal of getting the maximum total reward value. To resolve the handover problem in another way, Markov decision process could be employed to utilize the iterative algorithm. The idea is for the MUEs to make decisions according to the information received from their neighboring BSs.

Reward Function

In order to evaluate the performance and choose a network that can maximize the total reward, a reward function is constructed. For state ***s*** and action ***a***, the total benefit function is given by,

$$f(s, a) = w_{\mathrm{b}} f_{\mathrm{b}}(s, a) + w_{\mathrm{d}} f_{\mathrm{d}}(s, a) + w_{\mathrm{ij}} f_{\mathrm{ij}}\ (s, a) + w_{\mathrm{tr}} f_{\mathrm{tr}}(s, a) \tag{5}$$

where $f_{\mathrm{b}}(s, a)$, $f_{\mathrm{d}}(s, a)$, $f_{\mathrm{ij}}(s, a)$ and $f_{\mathrm{tr}}(s, a)$ represent the benefit function of each QoS factor in the proposed algorithm, while the weighting factors satisfy $w_{\mathrm{b}} + w_{\mathrm{d}} + w_{\mathrm{ij}} + w_{\mathrm{tr}} = 1$.

The switching cost between networks is driven as $g(s, a)$. Similarly, q(s, a) is the access cost services provided to the MUE. Consequently, the total penalty function is given by,

$$p(s, a) = w_{\mathrm{g}} g(s, a) + w_{\mathrm{q}} q(s, a) + w_{\mathrm{c}} c(s; a) \tag{6}$$

and the weighting factors satisfy $w_{\mathrm{g}} + w_{\mathrm{q}} + w_{\mathrm{c}} = 1$.
The reward function is defined as;

$$r(s, a) = f(s, a) - p(s, a) \tag{7}$$

The weights in reward function however, reflect the importance of corresponding attributes and therefore could influence the decision process of the vertical handover. Therefore, G1 method, which reflects the MUEs' preferences, is combined with the entropy method to calculate the weight of each QoS factor. The main superiority of G1 method lies in its simple computation complexity when compared with other methods.

SIMULATION RESULTS

A cellular network that capable of providing universal coverage as depicted in Fig. 2 is considered as the simulation model. One WLAN network, whose signal is provided by an access point (AP), is within the 4G network and mobile IP is adopted for mobility. The WLAN is selected as the preferred network due to its lower cost compared with the 4G network. Three scenarios are defined in the vertical handover methods: moving into (MI) the preferred network; moving out (MO) of the preferred network and passing (P) through the preferred network. In HWNs, the MUEs always want to connect with the preferred network as long as possible so as to satisfy its application requirements. There exist two mobility management methods; loose and tight couplings with the former being adopted, where the WLAN gateway connects with the 4G network in hotspot mode. The gateway represents the agent of mobile IP to support the different multimedia services requirements of [14, 21].

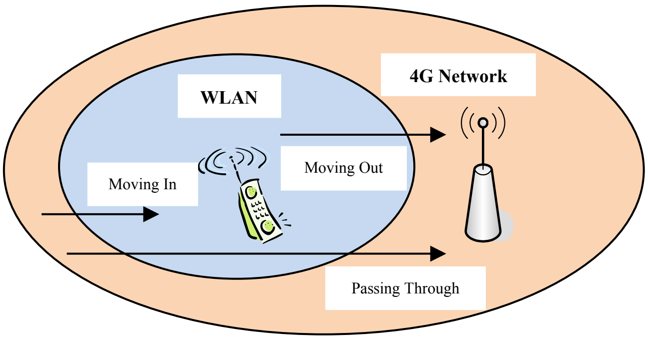

Fig. 2 Simulation Scenario [9]

Due to the physical constraint of MUE's velocity where its speed is not affected by the previous movement, we adopt Gauss-Markov model [15–17] to describe the mobility. However, in wireless environment, shadow fading and the MUE's mobility causes signal attenuation and so the RSS (dBm) could be driven from [18] as:

$$\mathrm{RSS}[t] = \mathrm{P_T} - \mathrm{L} - 10n \log(d) + \mathrm{N}[t] \qquad (8)$$

where t is the discrete time index, P_T is the transmission power of AP, L is the fixed pass loss, n is the pass loss factor, d is the distance between the MUE and the AP in the WLAN, and $N[t]$ is the shadow fading. The MT can communicate with the AP in the WLAN if the RSS value is above the threshold.

Different QoS levels are required for every executed application of the mobile user. Thus the context criteria considered in this include: Received signal strength (RSSI), Bandwidth, Latency, Jitter, Cost and Security. Measurement of these criteria are implemented during the simulation process of every candidate network at the access layers that which guarantees periodic reports detailing the transactions exchanged at the level of these layers. Two contextual categories of criteria are given as; static comprising of cost and security, while the dynamic varies according to the location and the state of the network (Table 2). The weight assignment of the sensitive context criteria is given by an application of Analytic Hierarchy Process [8, 17-20] method.

Table: 1 Simulation Parameters for VHO.

Para	Value	Parameter	Value
P_T	100 m Watt	T_j	0.01 s
n	3.3	T_{MO}	-85 dBm
d	7 dB	T_{MI}	-80 dBm
s	28.7 dB	T_{hando}	1 s
D_{av}	0.5 m	R_W	25 Mbps
D_S	5 m	R_C	0.4 Mbps

Table 2 Simulation parameters for MADM.

Notation	Parameter definition	Value in Network_1	Value in Network_2
$bi_{\max}$	Maximum Available Bandwidth in Network i	25 units	10 units
di_{max}	Maximum a Delay in Network i	8 units	8 units
ji_{max}	Maximum Jitter in Network i	4 units	2 units
tr^i_{max}	Maximum Traffic in Network i	5 units	10 units
n_1	Switching Cost (network_1 – network_2)	0.3	–
n_2	Switching Cost (network_2 – network_1)	–	0.3
c_1	Access Cost for Network 1	1	–
c_2	Access Cost for Network 2	–	3

The network performance of the algorithm, TOPSIS [12] and VHO [17] in the case of multi-attribute handover decision were compared. Also considered is the scenario where two networks co-exist in a system. The parameters of MADM and VHO are shown in Tables 1 and 2. The average time between successive decision epochs is set to 15*s* and jitter set to 2.5*ms*. The bandwidth is set to 16 kb/s, while the traffic is set to 0.5 *erl*. The maximum and minimum velocities are set to 5 units and 1 unit, respectively. The area of the cellular is three times that of WLAN, while the spatial density of MUEs in the cellular network is eight times larger than that in the WLAN.

The interpretation of Fig. 3 indicates that the VHO algorithm help in reducing unnecessary number of HOs, since average value of RSS is being considered. The proposed algorithm dynamically adjusts the handover thresholds in accordance with the velocity of the MUE. This method keeps the connection between MUEs and WLAN long enough to guarantee the satisfying available bandwidth.

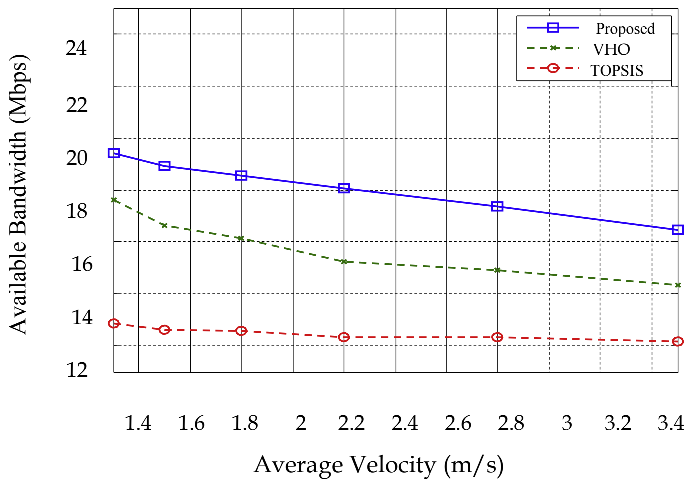

Fig. 3. Comparison of Available Bandwidth with Different MUE's Velocities (c = 90 dBm).

The proposed MADM was compared with other schemes in total reward, average number of handovers, etc., and Figs. 4–9 demonstrate the network performance in multi-attribute handover situation. In the case of constant bit rate (CBR) voice traffic, the expected total reward under different average connection durations is shown in Fig. 4. It is observed that the MADM algorithm achieves the highest expected total reward, because it takes the MUE's different requirements into account and considers the velocity during the vertical handover procedure by combining entropy methods to determine the importance of the QoS factors. Therefore, the proposed algorithm gave a good performs that was better than the other two schemes.

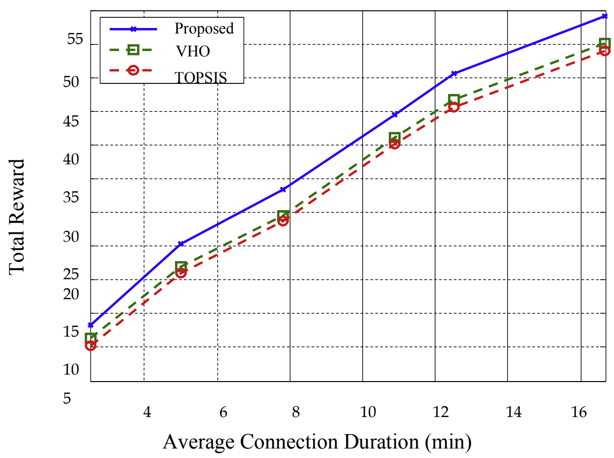

Fig. 4. Total Reward for MUE under different Connections durations.

Fig. 5 shows MUE's total reward under different velocities. As can be observed, the total reward of the proposed method gets improved as the velocity increases and maintain stability within a certain range of velocity, while the network performances in another two algorithms decline significantly. This phenomenon is as a result of the VHO and TOPSIS do not consider the MUE's velocity, which causes the connection to be broken during the handover process. Additionally, QoS degradation, extra vertical handover signalling and processing costs also decrease the reward.

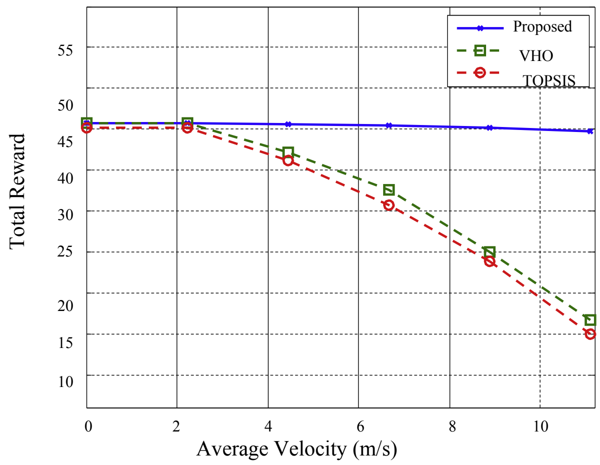

Fig. 5 Comparisons of MUE's total Reward under different Velocities.

Fig. 6 illustrates the simulation results of total reward under different handover signalling loads. The total reward de creases as the handover signalling load increases due to the signalling load rising during each connection. This results in the decline of the actual reward. The proposed algorithm however, lowers the probability of call dropping. Together with the cost of signalling and processing, it takes the MUE's velocity into consideration thereby reducing the total reward to less than what is obtainable in the other two algorithms.

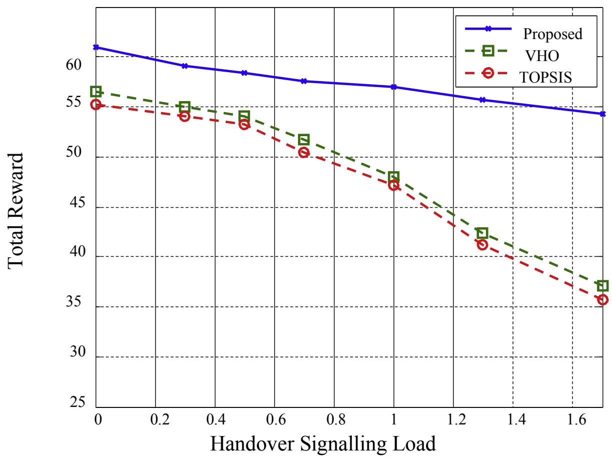

Fig. 6. Comparisons of Total Reward under different Handover Signaling Loads

For the Fig. 7, it shows the average number of handovers under different signalling loads. A critical observation indicates that as the handover signalling load increases, the average number of handovers decreases. The increasing handover signalling load makes the actual total reward of the candidate network lower than the current one in which the MUE resides. Therefore, the proposed algorithm can avoid a number of unnecessary handovers.

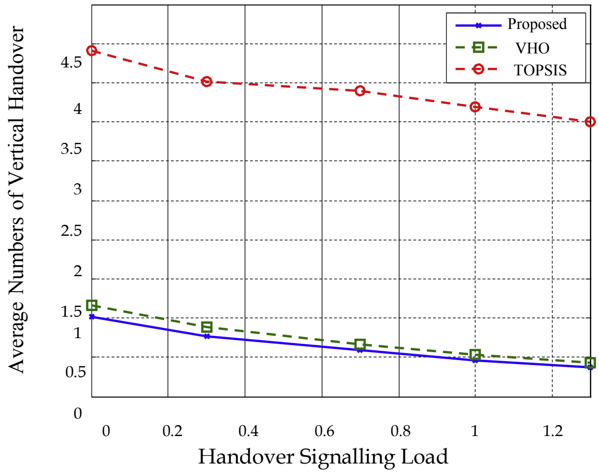

Fig. 7. Comparisons of Average Numbers of HOs under different Signalling Loads.

The Fig. 8 however demonstrates the relationship between total reward and connection duration under the File Transfer Protocol (FTP) data traffic situation. The performance trends observed in CBR voice and FTP traffic are almost the same, except that the reward value of the former is larger than that of the latter. This is because the MUEs are more prone to the WLAN with high transmission rate, and the required bandwidth together with its corresponding weight in FTP are larger than those in the CBR voice situation.

As depicted in Fig. 9, the relationship between average number of VHOs and average connection durations are presented. Here, the observed scenario is that the average numbers of handovers in the MADM and the VHO are almost the same, which are much less than that in the TOPSIS algorithm. It should be noted that, the computed variance of MADM algorithm in the CBR case is 0.0313, while it is 0.0031 in the FTP case. It demonstrates that although the average connection duration increases with the average number of handovers, the time duration increases more slowly in the case of FTP traffic. This is as a result of the transmission rate in WLAN network is higher and MUEs tend to switch to the network with high data transmission rate. In order to keep load balancing, the network threshold should be increased in which the new access requests can be denied when the load of the WLAN become high. In Table 3, from the numbers of algorithm iterations in different algorithm, we can observe that the MADM algorithm has better network performance in total reward and average number of handovers than the VHO algorithm, at the cost of computation complexity.

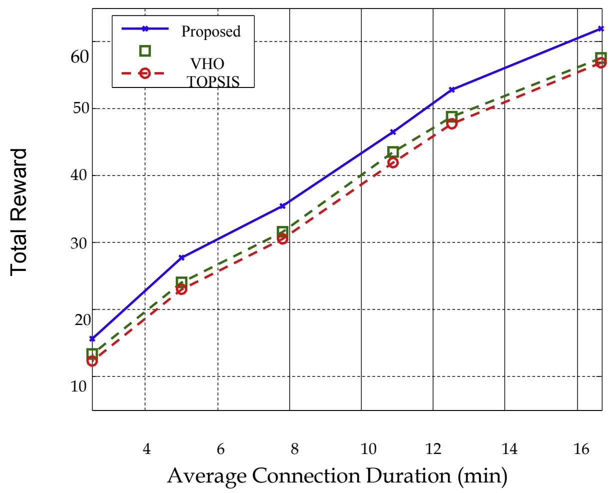

Fig. 8. Comparisons of Reward under different Average Connection Durations

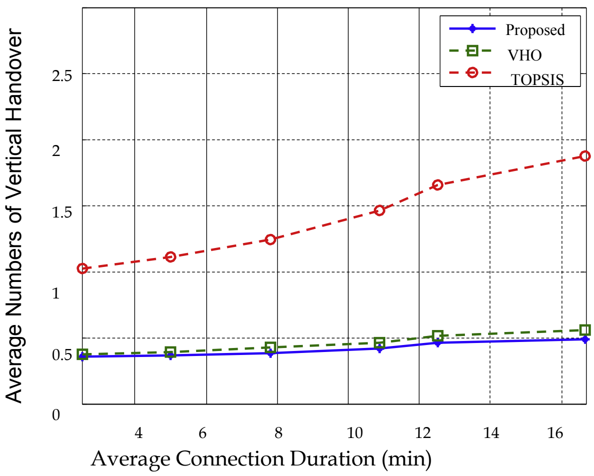

Fig. 9. Comparisons of Average Numbers of HOs under different Connection Durations.

Table 3 Comparisons of iteration times between MADM and VHO.

Average connection time (min)	Iterations of MADM algorithm	Iterations of VHO algorithm
2.5	80	45
5	110	76
7.8125	166	101
10.8675	201	130
12.5	269	183

CONCLUSION

There is still room for future wireless communication system to accommodate new kinds of wireless access networks and seamless vertical handover between different networks will pose a lot of challenges. Though so many decision algorithms have been discussed for vertical handover, most of them however did not pay attention to the impact of call dropping during the vertical handover process.

Furthermore, most of the multi-attribute decision making vertical handover algorithms falls short of dynamically predicting mobile users' circumstances. For guaranteeing the QoS of different MUEs, RSS and MDP-based vertical handoff decision algorithms is here proposed for multi-attribute situations, aimed at maximizing the expected total cost and minimizing the ping pong effects. In addition, G1 and entropy methods have been applied to calculate the weight of each QoS factor in the cost function and adopted the iterative algorithm under Markov decision process to obtain the maximum total cost value and its corresponding optimal policy. Comparisons were made between the proposed method with other existing algorithms in evaluating the network performance in which simulation results demonstrate that the proposed multi-attribute algorithm has higher expected total cost and lower average number of handover than the existing methods.

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