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Seamless Vertical Handover in Heterogeneous Network Using Neural Network Based Smart Multi-Criteria Decision Making Algorithm

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Abstract: The heterogeneous nature of 3GPP-LTE network allows global roaming for a range of mobile access network by providing higher data rate and higher bandwidth services. To maintain seamless connectivity during frequent handover experienced by the roaming users and to provide seamless connectivity, an intelligent Vertical Handover Decision (VHD) algorithm is proposed which uses neural network based SMART (Simple Multi Attribute Rating Technique) algorithm for choosing the best network by calculating a set of criteria. It also aims at reducing delay by improving the Quality of Service (QoS) and also reduces unnecessary handovers by avoiding connection failure. To show the applicability the proposed scheme is applied to LTE (Long Term Evaluation) wireless network by integrating WiFi and WiMax networks. The simulation result shows that the proposed scheme reduces delay, number of packets lost, rate of failure and also improves the QoS by providing seamless connectivity when compared to SAW, TOPSIS and TOPSIS with knapsack algorithm existing in the literature.

Key words: LTE, WiFi, WiMax, SAW, TOPSIS, SMART, VHD

INTRODUCTION

Heterogeneous wireless network incorporate different radio access technologies such as GSM, GPRS, HSPA, UMTS, WiFi, WiMax and LTE (Long Term Evolution) for wireless communication (Zekri *et al*., 2012). The major challenge in the heterogeneous wireless network is to provide seamless connectivity and QoS. Hence vertical handover techniques are employed in heterogeneous wireless network. The standardization efforts undertaken by LTE focuses on realization of higher data rates, lower end-to-end delay, wider coverage and full internetworking with other access system (Kausar and Cheelu, 2013). During vertical handover process, the various steps to be taken are network discovery, handover decision and handover triggering. The handover decision phase is the core stage for making Vertical Handover Decision (VHD) (TalebiFard *et al*., 2010).

Multi Attribute Decision Making (MADM) is a method that is used to select the network that is available based on preferences. Some of the existing methods of MADM are SAW (Simple Additive Weighting), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), WPM (Weighting Product Model), etc., (Kausar and Cheelu, 2013).

The criteria available in vertical handover decision may be RSS based schemes, QoS based schemes, Decision function based schemes, Intelligence based schemes and context based schemes (Ahmed *et al*., 2014). Zhu and McNair (2006) has proposed a cost based function to judge target network based on a variety of user and network-valued metrics by maximizing the QoS experienced by each user. Balasubramaniam and Indulska (2004) developed a context-aware vertical handover scheme for pervasive environment. It uses a wide range of context information about networks, users, user devices and user applications and also adaptable to a variety of context changes such as device changes and network QoS changes.

Kassar *et al*. (2008) uses fuzzy logic based scheme by integrating AHP (Analytic Hierarchy Process) for decision making and classification by providing flexibility, efficiency, seamlessness, automation and performance optimization. Samaan and Karmouch (2009) and Bellavista *et al*. 2011) provide classification for context based approach to perform handover decision and management. The various vertical decision handover schemes are analyzed in Lin *et al*. (2008), Fernandes and Karmouch (2012) and Yan *et al*. (2010).

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Radhika and Reddy (2011) uses Game Theory to solve the handover problem by using Bayesian Nash-equilibrium point. Nasser *et al*. (2006) uses several parameters such as energy consumption, bandwidth, security and link quality in a normalized weight cost function is used to choose the best network. Ahuja *et al*. (2014) demonstrated an algorithm for network selection based on Received Signal Strength (RSS), outage probability and distance. The algorithm uses two stages, a distance parameter is used to select the best network for handover and the RSS and outage probability are used in the second stage for network selection. The major disadvantage of this work is complexity increases because of various decision making parameters (Hussein *et al*., 2016).

Hussein *et al*. (2016) uses Fuzzy logic Quantitative Decision (FQDA) algorithm by considering parameters such as bandwidth, end-to-end delay, jitter and Bit Error Rate (BER) to select the best network. Goudarzi *et al*., (2016) proposed an artificial bee colony algorithm for real-time vertical handover using different objective function for finding the optimal solution by considering both user and network. Wen and Hung (2015) uses three algorithms to find the most energy efficient networks in heterogeneous environment since the main constraint are memory and computational capability these algorithms are too complex for mobile devices. Stevens-Navarro and Wong (2006) compare several VHD schemes SAW and WPM are used to choose the best network from the available Visitor networks (VTs) for the continuous connection by the mobile terminal. Sheng-mei *et al*. (2010) proposed SINR (Signal to Interference plus Noise Ratio), AHP (Analytic Hierarchy Process) and information Entropy weight method based TOPSIS (SAE-TOPSIS) to perform vertical handoff decision.

Chinnappan and Balasubramanian (2016) proposed a fuzzy logic controller and Fuzzy analytic hierarchy process based VHD to estimate the necessity of HO and to determine the user satisfaction degree based on the critical parameters, such as mobile terminal speed, network load and service cost. Wang and Kuo (2013) compares the various algorithms such as SAW, GRA (Grey Relational Analysis) and ELECTRE (Elimination Et Choice Translating Reality) and uses different normalization and weight computation methods. Chamodrakas and Martakos (2012) propose an energy efficient utility function based fuzzy TOPSIS for network selection. Malathy and Vijayalakshmi (2015) propose a dynamic programming knapsack approach with TOPSIS for choosing the best network by reducing the handover failures.

Although many researchers uses several MADM methods with various strengths, still they suffer from lots of limitations like lack of accuracy in identifying the rank alternative, ranking abnormality problem, unreliable network score and rank, rank reversal problem. Thereby, to improve the MADM for seamless handover, the proposed approach introduces neural network based SMART algorithm in vertical handover by increasing the strengths of already existing schemes.

MATERIALS AND METHODS

Neural network based SMART algorithm: Neural network based SMART algorithm for VHD is proposed to solve the unreliable network selection for handover and rank reversal (abnormality) problem during the removal and insertion of the network in the network selection. The proposed architecture is shown in Fig. 1.

The gathering handover information phase collects network information such as availability of neighbour network link and mobile device state, network properties, mobile devices, access point and user preferences. The availability of neighbour network link consist information like cost, Signal to Noise Ratio (SNR), Bit Error Rate (BER), distance, Packet loss, throughput, Committed Information Rate (CIR), location and QoS parameters. The mobile device state information includes battery status and speed is collected to be stored in a repository for Handover Policies for making Handover Decision.

When the user moves from its own service access network to another access network, the repository for handover policies can be used for the preferences of network availability, preferences of user and corporate preferences.

To provide seamless communication, the decision phase is the core phase of vertical handover since it is used to evaluate and decide the best network for satisfying both system and user requirements. Under decision phase the parameter should be selected, processed and aggregated..

Selecting parameter: Context aware and location aware information are used for providing accurate information. The various parameters used are user trip information source, device service context source, communication context source, user preference context source, location and time context source. Once this information is selected, the processing parameter step is in charge.

Processing parameter: Neural network based back-propagation neural algorithm is used. A multilayer

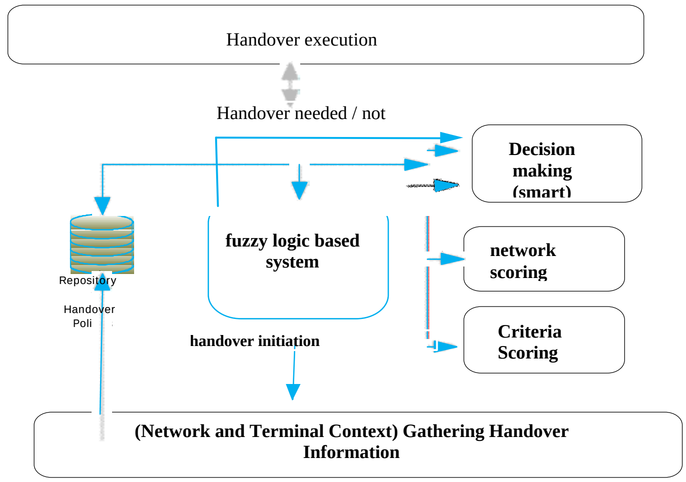

Fig. 1 Neural Network based SMART VHD algorithm

feed forward neural network with an input layer, a hidden layer, and an output layer is used. In the proposed work all neurons use sigmoid activation function. The weights are generated for all connections from input to hidden and from hidden to output layers. Biases are also assigned random values at the hidden nodes and the output node. The activation function at the hidden layer is calculated using Eq. 1 and the activation values at the output layer are calculated using Eq. 2.

$$H_i = f\left(\sum_{i-1}^{n} a_h \times V_{hi} + \theta_i\right) \qquad (1)$$

$$O_j = \left(\Sigma_{(i=1)}^{n} \cong a_h \times W_{ij} + \tau_j\right) \qquad (2)$$

Where H_i is the activation function of the hidden layer and V_{hi} is the weight assigned from input to hidden and W_{ij} is the weight assigned from hidden to output layers. The hidden nodes are represented as θ_i and the output nodes are represented as asτ_i. In both equation f(x) denotes the logistic sigmoid threshold function $f(x) = \frac{1}{(1+e^{-x})}$,. The backpropogation neural network has been trained with moderate values for the learning rate (α) and momemtum (μ). The weights are recalculated every time a training vector is presented to the network. Based upon the weight the decision can be made whether need handover or not.

Criteria scoring: The goal of criteria scoring is to map the decision criteria into scores based on user preferences. In this work both real time (voice, video, etc.,) and non-real time (web browsing, file transfer, etc.,) are taken. For each type of services, priority is assigned among the available network (WiFi and WiMax). WiMax is set as higher priority when a video application is active and WiFi is set as higher priority when a voice application is active. Equal spaced integers are called scored. It is the difference between highest score and the lowest score with respect to number of parameters. The scores can be in the range from 1-9 where 9 specify highest and 1 specifies lowest. The gap between the two successive score G called interface score is represented in Eq. 3.

$$G = SCO_H - \frac{SCO_L}{N_p} \qquad (3)$$

Where SCO_H is the highest possible score, SCO_L is the lowest possible score and N_p is the number of parameters chosen. In the proposed work the N_p value is 6.

Network scoring: The goal of this step is to perform real-time calculations for each type of running application. Based on user preferences the score have to be assigned. The same interface score is assigned to the available network. The two important scores calculated under this step are power score and cost score. Here also the scores can be in the range from 1-9 in (1) but taken in reverse fashion where the score 1 specifies the cheapest network. Four quality parameters are used such as bandwidth, delay, jitter and Bit Error Rate(BER). The bandwidth parameter Bw_i score and delay parameter score D_i is given in Eq. 4 and 5:

$$BW_i = \begin{Bmatrix} \left(1 - \frac{P_i - L_i}{U_i - L_i} \times 10\right) & L_i < P_i < U_i \\ 1 & P_i \geq U_i \\ 9 & P_i \leq U_i \end{Bmatrix} \qquad (4)$$

$$D_i = \begin{cases} \left(\frac{P_i - L_i}{U_i - L_i}\right) \times 10 & L_i < P_i < U_i \\ 1 & P_i \geq U_i \\ 9 & P_i \leq L_i \end{cases} \quad (5)$$

where, U_i is the upper limit for QoS parameter and L_i is the lower limit for QoS parameter. Equation 4 is specifically for bandwidth parameter whose result should be as high as possible and the Eq. 5 is for delay, jitter and BER whose result should be as low as possible.

Aggregating parameter: Since the vertical handover mechanism considers diverse metrics and parameters to evaluate the best candidate network, there is a need for an algorithm that should handle multiple parameters and metrics.. At the next step, Multiple Criteria Decision Making (MCDM) based SMART algorithm is used to choose the best network.

SMART for vertical handover: The Simple Multi Attribute Rating Technique (SMART) is one of the MCDM approach used for selecting the best network from a set of alternative against multiple criteria. In this method, overall value of a given alternative is calculated as the total sum of the performance score (value) of each criterion (attribute) multiplied with the weight of the attribute. The following stages describe the SMART approach:

Constitute a group of 3 decision makers D_1 , D_2, D_3 and 4 alternative base stations such as two WiFi base stations ($WiFi_1$,WiFi)and two WiMax Base stations ($WiMax_1$,$WiMax_2$) with six quality criteria such as

- C_1 : Low cost
- C_2 : Good RSS
- C_3 : High reliability
- C_4 : Optimum Bandwidth
- C_5 : Less delay
- C_6 : Long life battery

Assign values for each criteria. A threshold value is set based on the value assigned and also based on ranking the values are assigned in W_j for j=1,….n

Determine the weight of each criteria if W_j>0, the weights reflecting the relative importance of the ranges of the criteria values is shown in Eq. 6:

$$\sum_{j=1}^{n} W_j = 1 \quad (6)$$

Where:
n = is the number of criteria in the problem and
i = specifies the rank of the criteria ranges from 1-n

Determine the Rank Order Centroid (ROC) Weights using Eq. 7:

$$W_i(ROC) = \frac{1}{n}\sum_{j=1}^{n}\frac{1}{j}, i = 1,...n \quad (7)$$

Calculate the Weight average called as raw weights ($Wi^{*)}$ assigned to each alternative. This step allows normalization of the relative importance into weights summing to 1. Assume that all criteria have some importance, this means the ranges of possible raw weights will be W_i^*=100, 0< W_2^*≤100, 0< W_3^*= W_2^* In general, 0< W_i^*= W_{i-1}^* where I≠1. Make a decision by comparing the weights.

Perform sensitivity analysis. This is done mathematically by decision maker by means of a value function. The simplest and most widely used form of a value function method is the additive model which is the simplest case and it can be applied using linear scale ranges from 0-100.

RESULTS AND DISCUSSION

The neural network based SMART approach is evaluated using NS2 simulator. The deployed network is composed of 10 mobile nodes in the simulation area of 1000×1000 m. This area is covered by two WiFi Access Point (AP) and two WiMax AP. Simulations are performed in order to validate the effectiveness of the fuzzy based SMART algorithm, in comparison with the existing algorithm analyzed in the literature.

At first UE Start the coverage in WiFi network and on mobility the UE move towards WiMax network. The velocity of the UE varied from 10-20 km h^{-1}. When performing handover, to quick route set up Adhoc On-demand Distance Vector (AODV) routing protocol is used. The simulation study was done by simulating 10 mobile terminals called as User Equipments are attached to WiFi network. This work measures the performance of delay, throughput and number of handovers occur by using AODV routing Protocol. The simulation process was taken place with repeated number of times and the resultant value is obtained by taking the average value. The simulation parameters are listed in Table 1. Using these parameters the test was taken place between the access network WiMax and WiFi.

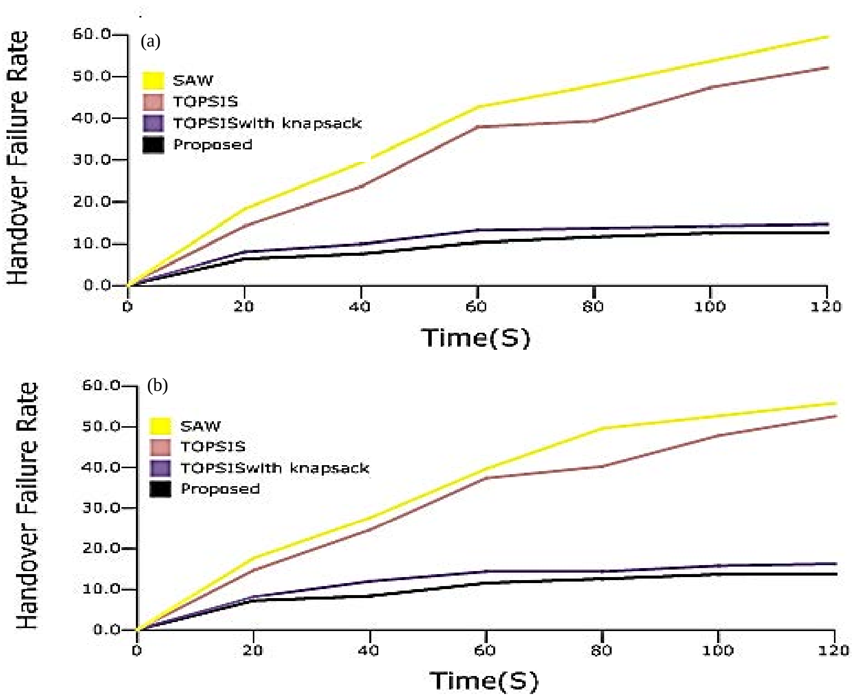

Fig. 2: Handover Failure rate with velocity: a) 10 km h^{-1}; 20 km h^{-1}

Table 1: Simulation parameters

Parameter name	Parameter value
Simulation range	1000 m 1000 m
Simulation duration	250 sec
Number of nodes	10
Number of base station	4
Routing protocol	AODV
Wireless standard	802.16, 802.11
Packet size	500-2000 kbps

Handover failure rate evaluation: A handover failure may occur when the handover is initiated but the target network does not have sufficient resources to complete it or when the handover is initiated and disrupted before the process is finalized handling over to another target network. The handover failure rate is mainly depends on the mobile node's location and speed. If the speed is low the connection time is longer that means the failure rate is less. However, if the speed is high, the delay is shorter and the probability of handover failure rate is higher. Hence in this scenario the handover failure rate is evaluated in terms of time.

Figure 2 shows that in all cases the handover failure rate increases when increasing the mobile speed. Furthermore, it can be observed that SAW, TOPSIS and TOPSIS with knapsack has higher probability of handover failure because of the complexity in calculating weights and also all these algorithms have some limitations in the speed. The handover procedure will not be successfully completed by including a call drop or decreasing the QoS. By using the proposed algorithm which uses fuzzy based SMART algorithm which considers multiple context and location information, network history, user preferences the call remains connected to the network and guarantees the QoS even though a new network is discovered.

Throughput: An efficient handover approach is that which ensures high throughput. Figure 3 shows the packet loss for SAW, TOPSIS, TOPSIS with knapsack with respect to simulation time with velocity of 10 and 20 km h^{-1}. The simulation result shows that the proposed algorithm obtained throughput is higher and packet loss is lower than that of SAW, TOPSIS, TOPSIS with knapsack. The proposed algorithm is able to remain connected to the same network as long as possible, since its network selection is tuned according to various QoS and user preference parameters. Therefore, it is proved that proposed algorithm reduces the packet loss.

Number of handover evaluation: The ping-pong effect should be reduced and also the number of handover is an important metric to prove the effectiveness of neural network based SMART algorithm. We have represented the Access Point of WiFi as AP1 and AP2 and the Access Point of WiMax as AP3 and AP4. Therefore, Fig. 4 shows the average number of handover occurs per hour in Neural network based SMART, SAW, TOPSIS, TOPSIS

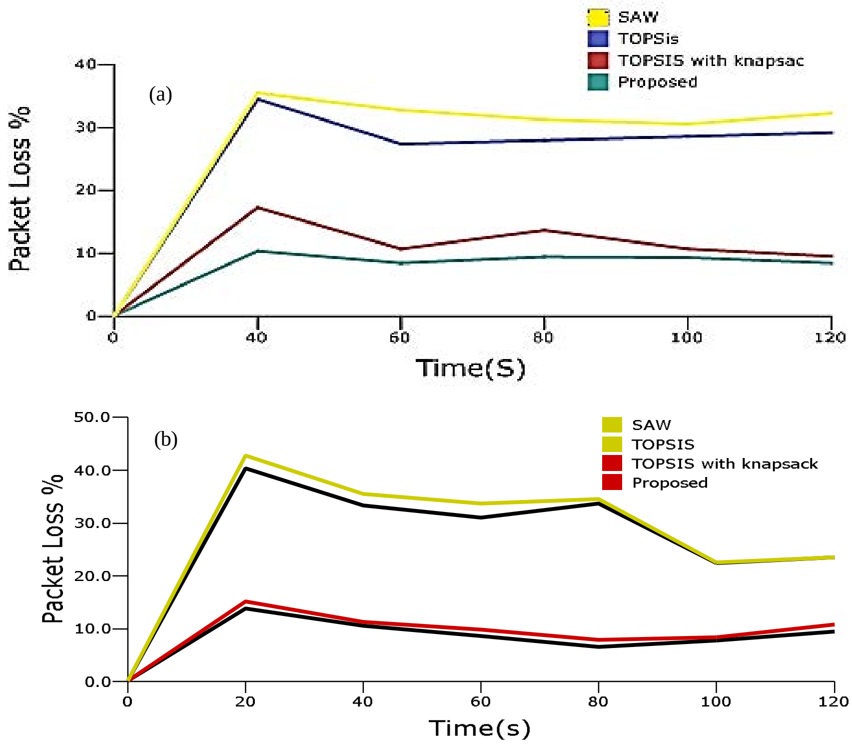

Fig. 3: Packet Loss rate with velocity: a) 10 km h^{-1}; b) 20 km h^{-1}

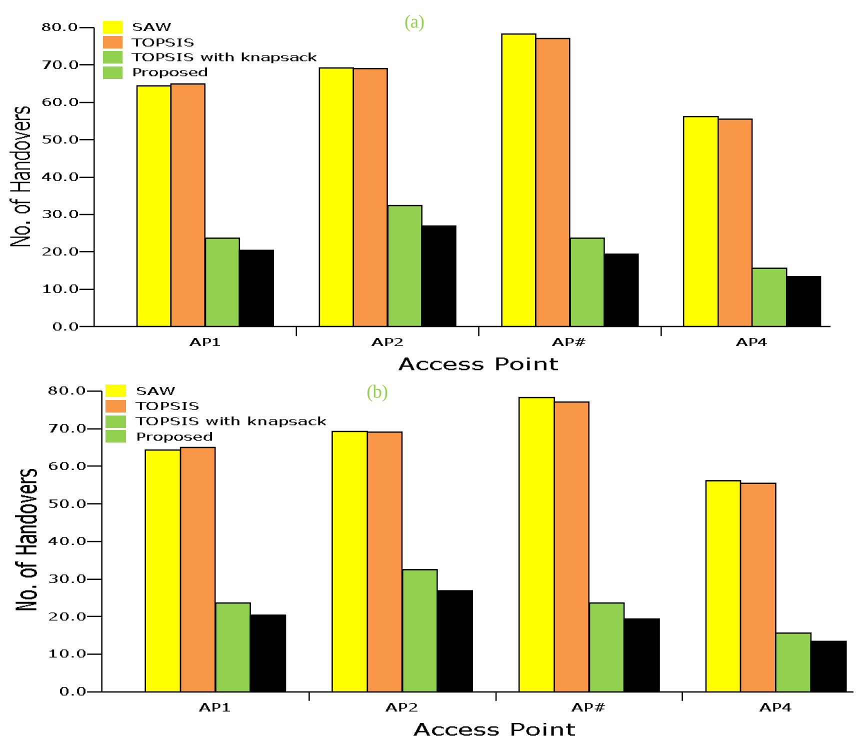

Fig. 4: Number of handover between WiFi and WiMax with velocity: a) 10 km h^{-1}; b) 20 km h^{-1}

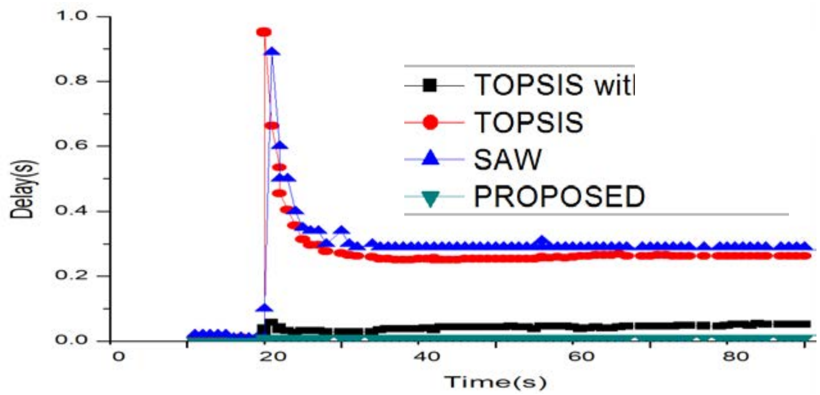

Fig. 5: Delay measurement when handover between Wifi and WiMax with velocity 10 km h^{-1}

with knapsack.Numerical result proved that the proposed one performs well compared to SAW, TOPSIS and TOPSIS with knapsack and also it limits ping pong effects. This is due to the fact that the proposed algorithm is based on a combination of different QoScriteria, user preferences and network history parameters. Moreover, the handover is executed only if needed. The result shows that the new proposed algorithm produces better result compared with SAW, TOPSIS, and TOPSIS with knapsack with velocity 10 and 20 km h^{-1}.

Average end to end delay: For real-time application the End to End Delay (EED), should be less for better application performance. Therefore, in this scenario the average EED for SAW, TOPSIS, TOPSIS with knapsack and proposed approaches the simulation results are presented in Fig. 5. It shows that the proposed approach performs the smallest EED. This is because, the packet delay depends on the number of handover and network reliability. In fact, frequent handovers leads collisions, interference and packet retransmissions.

CONCLUSION

In the proposed work, the vertical handover issues between WiFi and WiMax is addressed. In particular a sophisticated handover management scheme which uses neural network based SMART algorithm is proposed, which ensures seamless connectivity for mobile users throughout their roaming. Thorough numerical analysis of the proposed algorithm, showing that the proposed approach achieves very good results in terms of number of handover experienced by user, efficiency, seamlessness, performance optimization and reliability. Further, it reduces end-to-end delay and failure rate. The application of our vertical handover scheme can he extended to other interworking cases such as 3G-WMAN and WLAN-WMAN.

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