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Comparison of Fuzzy Rule Based Vertical Handover with TOPSIS and Received Signal Strength Based Vertical Handover Algorithms

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Abstract

The tremendous development in the heterogeneous network has led to the fulfillment of service requirements of the users. To provide users with ubiquitous seamless connection between these architecturally different networks there has to be a reliable handoff between them. The process of vertical handover (handover among different access networks) requires consideration of various factors. Considering only the received signal strength (RSS) to decide when and where handover initiates is an inefficient approach to determine the target network. Multiple criteria has to be taken into account as not all the available networks have similar capacity, availability and services as that of users' requirement. The heterogeneous network environment taken for study consists of WiMAX, WCDMA and WLAN. The RSS method and multicriteria Technique for Order Preferences by Similarity to an Ideal Solution (TOPSIS) method of vertical handover decision algorithms are analyzed. A multicriteria fuzzy rule based vertical handover decision algorithm is developed. The possible number of rules for four inputs and three memberships function is 81 but the number of rules in the fuzzy system is reduced by using Iterative Dichotomizer 3 (ID3) method. RSS and TOPSIS method shows a comparable performance in terms of number of handoffs. Fuzzy rule based handover algorithm increased the number of handoffs than the other two algorithm but it improved the balanced index by 25% than RSS method and 41% than TOPSIS method.

Keywords

Heterogeneous Network – Vertical Handover – TOPSIS Method – Fuzzy Inference System – ID3 Method

1. Introduction

The concept of heterogeneous network is introduced to satisfy the demands of varied customers for varied network resources. It consists of multi-platform networks with various radio access technologies (RATs). A mobile user may roam within these networks and accomplish vertical handover (VHO) using single criteria, such as received signal strength (RSS). A single criteria vertical handover decision, however, is inclined to one parameter value and may not represent users' requirement. It may cause inefficient handoff, unbalanced network load, and service interruption.

The demand of data rate and traffic capacity of mobile communication is growing rapidly; thus the concept of heterogeneous network is introduced to meet this demand. In a heterogeneous network, mobility feature is essential because mobile stations must be able to roam throughout the network and be able to connect to various Radio Access Technologies (RATs)[1]. This switching from one station to another is based on discovered access technologies, quality of service (QoS) constraints, operator policies, user preferences and available system capacity and utilization. An emerging issue of research is on optimizing the VHO process so as to reduce the network signaling, reducing mobile station power loss, balancing the networks, improving the QoS and reducing the blocking probability of the networks.

The method to decide handover based on RSS is considered as the simplest method to decide handover but it may not have sufficient reliability because of the RSS fluctuation [2]. While the horizontal handover takes place between points of attachment in the same RAT in the border region of two cells (for example, between two neighboring base stations of a cellular network), the vertical handover occurs between points of attachment supporting different RATs (for example, between an IEEE 802.11 access point and a cellular network base station). VHO (also called intersystem handover) enables users to access several networks such as WLAN, WMAN, WPAN, and WWAN in parallel. It allows the applications even the real time application to be seamlessly transferred among different networks [2].

Two different kinds of wireless networks normally have incomparable signal strength metrics. Several issues should be taken into consideration such as environmental factors, handover metrics, handover decision algorithms and handover management in order to achieve better handover in vertical handover.The vertical handover is a complex process since it has to make the handover decision among networks that has different system properties, this way the decision cannot be based on one factor (like RSS) as in the horizontal handover.

In [1] Gita Mahardhika and et al. has performed TOPSIS method of vertical handoff decision for a heterogeneous network consisting of WLAN, WCDMA and WiMAX. In [3] K. Vasu and et al. has proposed a QOS aware fuzzy rule based vertical handover mechanism. The decision is performed using a non birth-death Markov chain. A hybrid approach of combining TOPSIS and Fuzzy Logic in parallel to deal with VHO issues by applying TOPSIS weightage approach to all the input parameter and parallely developing a subsystem for each parameter using fuzzy logic is performed in [2]. A vertical handover strategy in providing better QoS in WiMAX/WLAN interworking system has been proposed in [4]. TOPSIS MADM process is used to select the best network among a multiple wireless networks in [5] and some discussion on fuzzy TOPSIS method is done in [6].

The scope of this paper is to develop a fuzzy rule based vertical handover decision algorithm. Fuzzy rule based VHO decision algorithm is compared with the conventional RSS based vertical handover algorithm and Technique for Order Preferences by Similarity to an Ideal Solution (TOPSIS) multicriteria vertical handover decision algorithm using random waypoint mobility model.

2. Related Theory

2.1 RSS Method

In the past, handoff decisions have been based on an evaluation of the RSS between the base station and the mobile node [7]. In the RSS method, handover is carried out only on the basis of received signal strength from different access networks. This method is efficient for horizontal handover which constitutes handover in the same network but for vertical handover it causes inefficient handoff and unbalanced network load. The general mechanism of RSS based handover is given in fig. 1.

2.2 TOPSIS

TOPSIS Multicriteria Decision requires subjective weightage value to each criterion to calculate the decision. It is a widely used Multi Criteria Decision Making (MADM) algorithm developed by Yoon and Hwang [2].

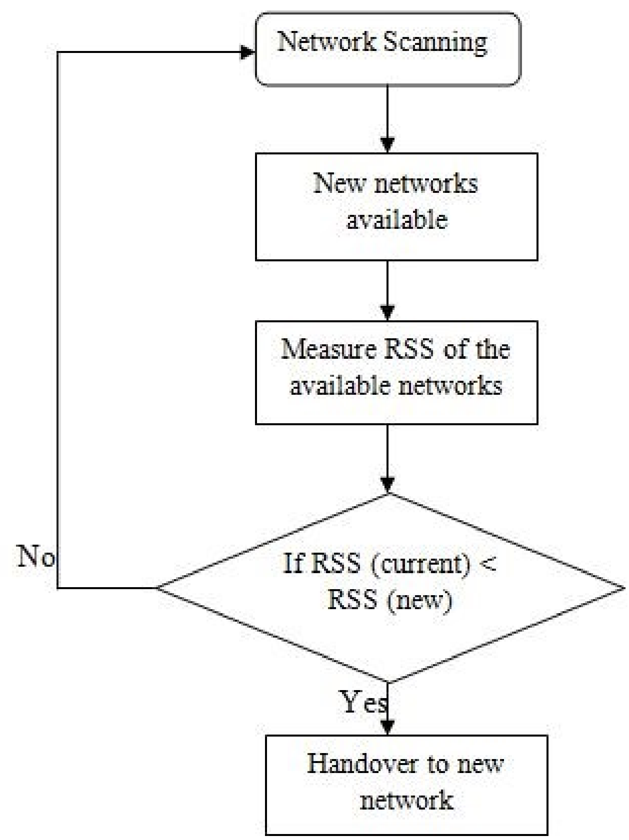

Figure 1: Generalized Mechanism of RSS based vertical handover

The algorithm calculates perceived positive and negative ideal solutions based on the range of attribute values available for the alternatives. The premise of the algorithm is that the best solution is the one with the shortest distance to the positive ideal solution and longest distance from the negative ideal solution, where distances are measured in Euclidean terms [2].

2.3 Fuzzy Logic

Fuzzy logic is a system of multivalued logic. The theory of fuzzy sets relates to classes of objects with unsharp boundaries in which membership is a matter of degree [3]. Fuzzy Logic Control (FLC) is a non-linear control method, which attempts to apply the expert knowledge of an experienced user to the design of a controller. Fuzzy control system contains four main parts, the fuzzifier, the fuzzy rule base, the fuzzy inference engine, and the defuzzifier. The fuzzifier maps the real valued numbers into a fuzzy set, which is the input to the fuzzy inference engine.

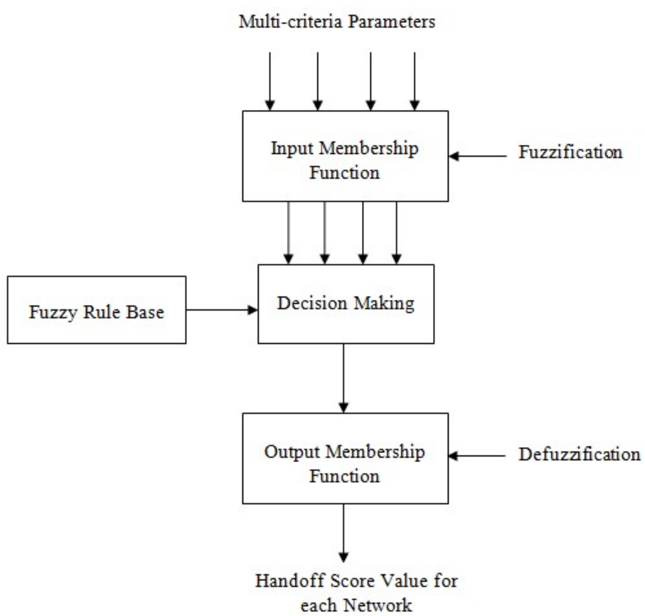

Figure 2: Fuzzy rule based handoff mechanism system

The fuzzification process includes the definition of the universe of discourse and the specification of the linguistic variables, the fuzzy sets for the linguistic variables, and the membership functions for the specified fuzzy sets. The fuzzy rules base consists of a collection of fuzzy IF-THEN rules to represent the human knowledge about the problem. The fuzzy inference engine maps the input fuzzy sets into output fuzzy sets and handles the way in which the rules are combined just as humans use many different types of inferential procedures. The defuzzifier task is the reverse operation to the fuzzifier. It maps the output fuzzy sets into real valued numbers [2]. The fuzzy inference system for handoff mechanism is shown in fig. 2.

2.4 ID3 Method

In decision tree learning, Iterative Dichotomizer 3 (ID3) is an algorithm developed by Ross Quinlan. It is a top-down greedy heuristic method that is used to generate a decision tree from a data set, S. ID3 algorithm iterates through every unused attribute of the set S and calculates the entropy H(S) (or information gain IG(A)) of that attribute and selects the attribute which has the smallest entropy (or largest information gain) value [8]. The set S is then split by the selected attribute to produce subsets of the data. The algorithm continues to recur on each subset, considering only attributes never selected before. ID3 attempts to make the shortest decision tree out of a set of learning data.

3. Methodology

3.1 Model Development

The model for the network overlay has been created in MATLAB with one WIMAX AP, four WCDMA APs and eight WLAN APs in an area of 100 km^2. The base station parameters used for these APs are given in table 1. The heterogeneous network overlay is shown in fig. 3. Multiple user mobility within the overlay using random waypoint mobility model is shown in fig. 4.

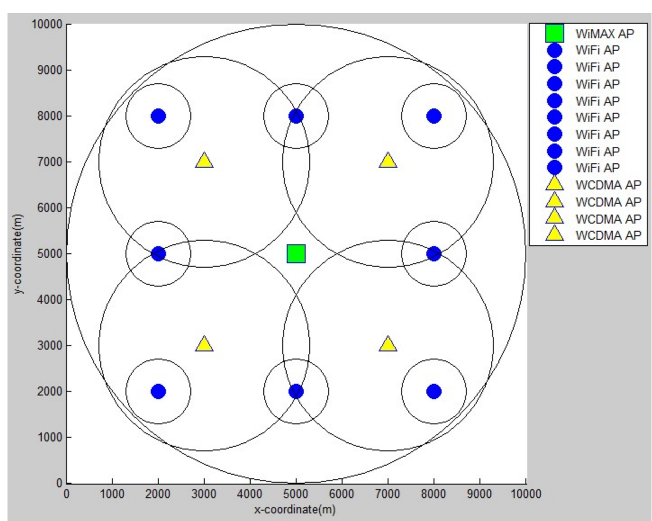

Figure 3: Heterogeneous Network Topology

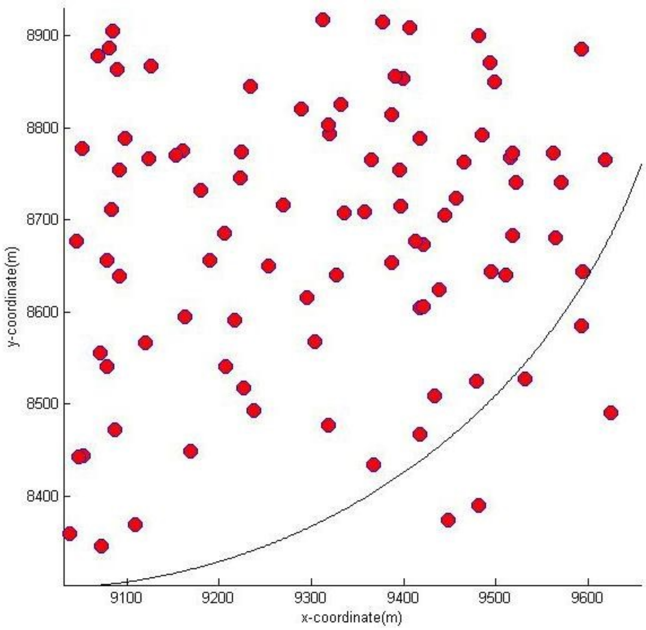

Figure 4: Mobility within the heterogeneous network overlay for multiple users

3.2 Propagation Model

The empirical loss model is selected for WiMAX and WLAN whereas COST 231 Walfish-Ikegami model is selected to account for the free space propagation loss of WCDMA.

$$L(d) = L_0 + 10 * \gamma * \log \frac{d}{d_0} \quad (1)$$
$$L(d) = L_0 + 10 * \gamma * \log d \quad (2)$$
$$L(d) = 42.6 + 26 * \log d + 20 * \log f \quad (3)$$

Equation 1 represents empirical WiMAX model where L_0 is 105.45dB measured at $d_0 = 200m$ and $\gamma = 3.911$. Equation 2 represents empirical WLAN model where L_0 is 40dB referenced at 1m and $\gamma = 3.5$. Similarly equation 3 represents COST 231 Walfish-Ikegami model for WCDMA where d is distance from base station to mobile user in km and f is operating frequency in MHz.

Table 1: Base Station Parameters

Properties	WLAN	WCDMA	WiMAX
Cell Radius (m)	700	2300	10000
EIRP (dBm)	20	18	60
Receiver Sensitivity (dBm)	-119	-100	-100
Cell Edge Receiving Level (dBm)	-119.58	-100.45	-100.12

3.3 RSS Handover Decision Algorithm

This algorithm considers only the received signal strength (RSS) from various access networks to decide when the handover should be carried out or not.

Algorithm

1. Measure RSS from each available AP to the user
2. Find if the RSS from current network is less than newly measured RSS from other available AP
   (a) If Yes, handover to a new network that provides the maximum RSS
   (b) If No, stay in the current network
3. Repeat steps 1 and 2 after a fixed interval

3.4 TOPSIS Multicriteria Handover Decision Algorithm

The four input criteria used for TOPSIS analysis are the RSS, mobile speed, traffic class and network occupancy.

Algorithm

1. Find if the RSS from current network is less than the receiver sensitivity of the user
   (a) If Yes,
      i. Find the value of the input parameters from available access networks: RSS, user speed, traffic class user is requesting and the percentage of network occupancy
      ii. Calculate the weighted sum of these parameters for each available network
      iii. Handover to the network with the highest weighted sum
   (b) If No, stay in the current network
2. Repeat step 1 after a fixed interval

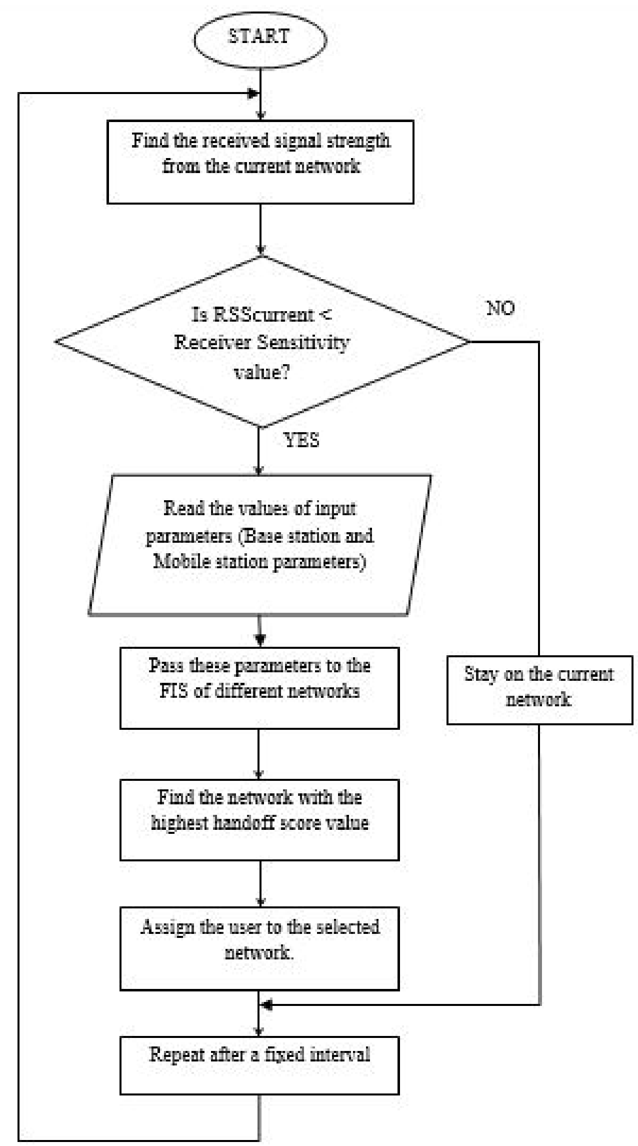

Figure 5: Multi-criteria Vertical Handover Decision Algorithm using Fuzzy Rule Based System

3.5 Fuzzy Rule Based Vertical Handover Decision Algorithm

The four input criteria used for fuzzy inference system are the RSS, mobile speed, traffic class and network occupancy. The universe of discourse for each of the inputs is given in table 2. The membership functions for the input parameters are linguistically represented as Low, Medium, and High. Whenever a handoff is required the value of the input parameters at that instant are given as input to the fuzzy system. The output is a handoff score value drawn from the fuzzy rule base and ranges from 0 to 1. The centroid method is implemented for defuzzification. A high value of handoff score value indicates a potential network to which the user may be handed over. The proposed system fuzzy rule based handover mechanism is shown in fig. 5.In order to reduce the number of rules required to define the rule base, ID3 algorithm is used which forms a decision tree at its output. These rules are consecutively applied to each input set to determine the output handoff score value. The ID3 method begins with a set of examples and ends with a set of rules in the form of a decision tree which then can be applied to unknown cases. 81 rules can be made for each network (four input parameters and 3 membership functions), which is recursively split by the ID3 and a decision tree is created using Shannon Entropy formula. The total numbers of ID3 derived fuzzy rule are narrowed down to a total of 45. For the case with 3 membership function whose linguistic representation is low, medium and high, the entropy equation for each input parameter is given in equation 4.

$$
\begin{aligned}
H = -\sum_{i=1}^{n} & N_L \log_3 \frac{N_L}{N_L+N_M+N_H} \\
& + N_M \log_3 \frac{N_M}{N_L+N_M+N_H} \\
& + N_M \log_3 \frac{N_M}{N_L+N_M+N_H}
\end{aligned} \tag{4}
$$

Where N_L, N_M and N_H represent the total instances of low, medium and high cases for each input parameter i.

Table 2: Universe of Discourse for Input Parameters

Parameters	WLAN	WCDMA	WiMAX
RSS (dBm)	(-120)–90	(-120)–40	(-120)–50
Mobile Speed(m/s)	0–12	0–12	0–12
Traffic Class(kbps)	0 – 720	0 – 720	0 – 720
Network Occupancy	0 - 50	0 - 100	0 - 200

Algorithm

1. Find if the RSS from current network is less than the receiver sensitivity of the user
   (a) If Yes,
      i. Find the value of the input parameters from available access networks: RSS, user speed, traffic class user is requesting and the percentage of network occupancy

ii. Find the handoff score value for the networks using fuzzy interference system
iii. Handover to the network with the highest handoff score

(b) If No, stay on the current network

2. Repeat step 1 after a fixed interval

3.6 Performance Evaluation

The implemented methods of vertical handover are compared on the basis of total number of handover that takes place and the load balance each algorithm provides as the time progresses. The simulation is performed for 200 users for 1000 sec at a single pass. The result has been analyzed by taking the average of 50 simulation passes.

Number of handoffs is a factor that determines system performance as it is correlated with signaling load and use of network resources. Thus higher value of handoff causes the efficiency of the wireless system to be deteriorated. The value of balance index indicates the traffic load balance between different types of network (WLAN, WCDMA, and WiMAX). Load balance index indicates how well the users are distributed in an environment containing multiple RATs. By creating a balanced network; more mobile users may be served. The formula for the load balanced index is given in equation 5.

$$D = (\delta \text{load}_{\text{WLAN-WCDMA}} + \delta \text{load}_{\text{WLAN-WiMAX}} + \delta \text{load}_{\text{WCDMA-WiMAX}}) \times 3^{-1} \quad (5)$$

$$B = 1 - \text{Normalized}(D) \quad (6)$$

where, B = balanced index and D = the difference in load densities between different RATs.

$$\begin{aligned}\delta \text{load}_{\text{WLAN-WCDMA}} &= |\text{load}_{\text{WLAN}} - \text{load}_{\text{WCDMA}}| \\ \delta \text{load}_{\text{WLAN-WiMAX}} &= |\text{load}_{\text{WLAN}} - \text{load}_{\text{WiMAX}}| \\ \delta \text{load}_{\text{WCDMA-WiMAX}} &= |\text{load}_{\text{WCDMA}} - \text{load}_{\text{WiMAX}}|\end{aligned} \quad (7)$$

4. Result and Discussion

The number of handoffs executed for the three algorithms using random waypoint mobility model as the time progresses is shown in fig. 6. It can be seen from the figure that the total number of handoff in the fuzzy system is the highest. Fuzzy system gives a total handover of 239 while handoff in the TOPSIS method is 98 and the value is 117 using RSS method.

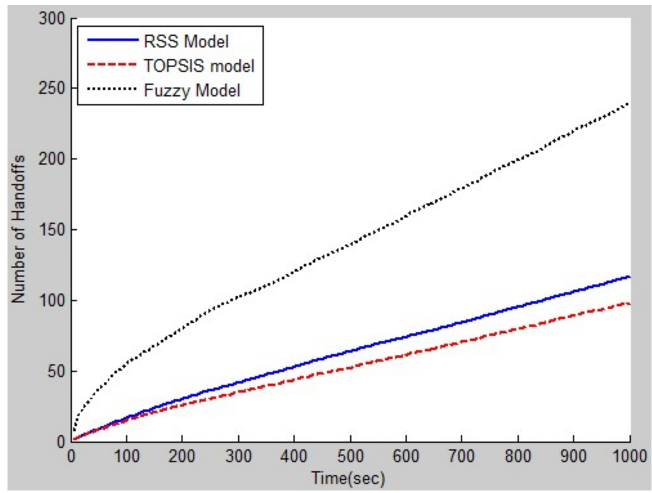

Figure 6: Cumulative number of handoffs with respect to time

The RSS method for handover decision tends to have less number of handover; this can be explained from the fact that in this method the mobile user solely determines the best signal strength AP and associates itself with that AP until the user moves out of the influence region of that AP. The TOPSIS and fuzzy rule based methods has to consider four factors before deciding where to handoff, this tend to give more frequent handovers than the RSS method.

The comparison of the three algorithms on the basis of load balanced index is shown in fig. 7. The balanced index for fuzzy based algorithm is the best with an average value of 0.86, hence it utilizes more access nodes in a balanced way. The RSS based vertical handover system has a medium value of balanced index of 0.61 and the TOPSIS method has the least value which is 0.45. Hence the Fuzzy algorithm balances load 25% better than RSS algorithm and 41% better than TOPSIS method. The load index value tends to be stable as the time progresses for all the algorithms.

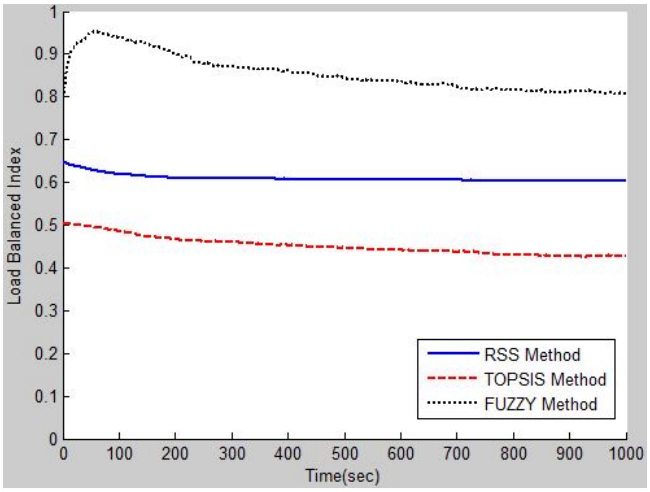

Figure 7: Balanced Index with respect to time for random waypoint mobility

5. Conclusion

The proposed fuzzy rule based algorithm when compared with RSS based vertical handover algorithm and TOPSIS multicriteria vertical handover decision algorithm showed a better performance in terms of load balanced index. In terms of number of handoffs RSS and TOPSIS method showed a better performance than fuzzy rule base algorithm.

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