



A Fuzzy-Based AHP Approach to Handover Decision For Mobility Management in Heterogeneous Wireless Network

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Abstract

Handover decision is one of the enhancement mechanisms that plays vital role in heterogeneous wireless networks. It has become necessary therefore, to consider mobility issues and Quality of Service (QoS) provisioning to users when designing handover algorithm for heterogeneous wireless networks. The proposal is an approach for selecting a network based fuzzy logic and derived by Analytic Hierarchy Process (AHP) method. The work considered Power Level, Cost and Bandwidth as metrics for reducing the handoff execution, while prolonging the battery life span of the mobile equipment. Consequently, a Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method was used in ranking the networks availability, the result of which demonstrates improved system performance. It was evident that the method proposed when compared to other methods has demonstrated an edge over other methods with the highest relative standard deviation in terms of handoff priority and probability of minimizing handoff failure.

Keywords: Vertical Handover; Fuzzy; Power Level; Bandwidth, Cost.

1. Introduction

Recent developments in wireless technology has increased the pressure on network operators in providing new services while maintaining quality of service (QoS). The newly introduced services which includes video and voice streaming, high bit rates as well as capacity, require heterogeneity of technologies to allow users have access seamlessly at all times. Hence, mobility management is needed for network interoperability in order to provide users with better Quality of service and ubiquitous coverage. While trying to resolve mobility instances, handover is a significant aspect that ought to be observed. According to Serchi, et al (2017), handover challenges include mobility scenarios, metrics, decision algorithms and procedures. In heterogeneous networks, vertical handovers on the other hand can be initiated for convenience. However, vertical handover requires accurate and precise decisions about the availability of networks and resources for connection. The actual trend is to integrate complementary wireless technologies with overlapping coverage to provide the expected ubiquitous coverage and to achieve always best connected (ABC) advantage. The ABC concept is to enable users choose among a host of networks that best suits their needs and to change when something better avails. Mobility management focuses on tracking and tracing location of mobile device(s) for best quality service delivery. So many researches have been conducted in this area to handle the issues associated with handover, however, fuzzy logic-based decision making process is here proposed to solve mobility management issues in heterogeneous wireless network.

The purpose of this paper is to safeguard the integrity and confidentiality of mobile communication users from loss of data, Fuzzy logic based handover decision model is considered to seamlessly handover resources of users' preferences and increase availability while maintaining Quality of service (QoS) at affordable rate. The representation of the Fuzzy-based decision making is represented in Fig. 1 below.

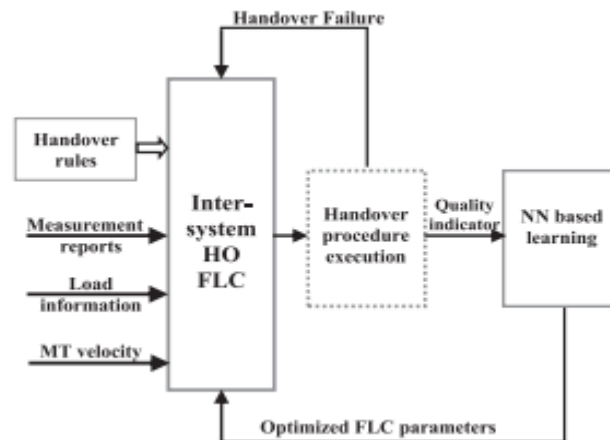


Fig. 1: Fuzzy-based AHP Vertical Handover Decision Scheme

The rest of the paper is as follows: Section 2 reviews all related works associated with the title. The proposed decision algorithm is discussed in section 3, while section 4 describes how the simulation was conducted with given parameters. Section 5 discusses the result while conclusion of the paper is found in section 6.

2.0 Related Work

It is one of the essential features of heterogeneous wireless network to consider mobility to enable roaming in order to connect to various radio access technologies. Network selection on another hand, is a critical way to accomplish seamless vertical handoff for best QoS in a heterogeneous environment. This, however, require robust selection of the preferred network. Therefore, it is the gathering of performances from different candidate network and rating them to enable selecting the best preferred network.

Many research works have been conducted in recent years on how to design algorithms for effective vertical handover decision. Among the scheme is in Gaur et al, (2020), where they proposed a light weight containerized solution for efficient vertical handover using multi-criteria vertical Handover Decision (MCVHD) to deal with imprecise data. The experiment result showed reduction in number of handover and handover failures but it does not take in to consideration the packet loss and jitter. In Kaur et al, (2020), an algorithm that can help overcome handoff related issues and improve efficiency of the system was proposed. However, it only considers traffic classes for the decision making phase.

Subramani et al, (2021) used a two stage fuzzy logic based vertical handover scheme. Fuzzy logic based handover requirement analysis is carried out in the first stage based on Received signal strength (RSS), data rate and latency. This stage minimizes the unnecessary handover. In the second stage, fuzzy analytic process (Fuzzy-AHP), fuzzy technique for order preference by similarity to ideal solution (fuzzy TOPSIS) are used in ranking and selecting the target network. The work did not consider testing with neuro fuzzy based algorithm.

The RSS-based vertical handover decision method proposed by Miyim et al, (2014) and Yen et al, (2013), where inclusion of parameters like hysteresis were 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.

Numerous fuzzy based solution for handover have been proposed. In the work of Obajuluwa et al, (2017), they proposed a mobility management in heterogeneous wireless network using Adaptive fuzzy logic. Some of the networks considered are WLAN, 3G, WiMAX and 4GLTE, using parameters which include RSS, Data rate, coverage area and mobile velocity. It shows better performance for the handover in terms of handover time and the



selection of network, however the proposed scheme did not consider the security of the candidate network during handover. In Thiago et al. (2019) proposes an architecture which provides an intelligent decision making support system based on fuzzy logic for saving energy of mobile devices within integrated LTE and Wi-Fi networks. The architecture can only provide energy by using Quality of Experience metrics and did not include inputs for the fuzzy system.

In Bin et al. (2015) proposed a fuzzy multi-parameter based Vertical Handover decision algorithm. The study considers five parameters of network and the user applies a multi-mode smart terminal based speed adaptive Vertical Handover policy to improve the network and update speed and lower blocking probability. Also Divya et al, (2015) proposed fuzzy based handover decision algorithms. Parameters used include RSS, Data rate, and interference rate. The result show the proposed scheme performs better in terms of execution time and power consumption than existing scheme. However, Ashima et al, (2014) worked on fuzzy rule vertical handoff decision strategies for heterogeneous wireless network, an intelligent wireless selection model was designed using fuzzy logic. Network include UMTS, WiMAX, and WLAN. The model used TOPSIS algorithm technique for ranking wireless network and analytic hierarchy process to assign weight to each criteria. Parameters used include jitter, bit error rate, end to end delay and bandwidth. From their result, the proposed scheme showed better performance in terms of minimized handovers.

In Miyim et al, (2017), a multilevel vertical handover decision was proposed. It employs multi-attribute decision making in selecting the best network to optimize the vertical handover. Parameters used include RSS, Cost and bandwidth. The result of the simulation show how vertical handover optimization could be realized by selecting the right target network. However, the work did not consider the ping-pong effect of the networks. Benatou et al, (2017) proposed two algorithms in vertical handover decision on heterogeneous wireless network. The first of them based on Received signal strength and the second is based on fuzzy logic system that uses RSS, bandwidth, Battery power and power loss as input parameter. The result shows that the algorithm based on fuzzy logic leads to a reduction of the number of handovers and minimization of power consumption as compared to the first algorithm used here. However, the work did not assess the energy cost of different handover schemes in heterogeneous wireless network environment.

Malathy et al, (2015) worked on vertical handover in heterogeneous wireless network using knapsack TOPSIS technique. In their work, they proposed a network controlled handoff model, two wireless network Wi-Fi and WiMAX are considered. Some of the networks include RSS, traffic in the candidate networks. The result showed a reduction in unnecessary handover by 24%. However, the work did not consider security support during handovers through authentication schemes. In the work of Jain and Tokekar (2015), they proposed a vertical handoff decision technique that depends on the coverage area of the network and the velocity of the mobile user. The results show reduction in the number of unnecessary handoff and improves quality of service. They only Consider UMTS and WLAN network.

In the same context of heterogeneous environment, Lahby et al (2015) and Bikmukhamedov et al (2016) did compare different methods of MADM (SAW, TOPSIS, GRA, AHP, and MEW) in providing handoff solution. Due to its simplicity and decision accuracy, MADM methods stand out to be acceptable for solving VHO decisions. The most efficient MADM methods used in VHO process are SAW, TOPSIS and VIKOR (Xu, 2015) and Narayanan et al (2014). They based their work on ranking candidate networks from computed scores. In the work of Stevens-Navarro et al (2006), weights were given in determining the relative importance of each attribute for considering QoS. Lahby et al (2017) and Savitha & Chandrasekar (2011) used AHP or M-ANP to compute weight vectors. Furthermore, in trying to determine the preferred access network, TOPSIS method was applied in ranking. The idea of intelligence using Fuzzy logic techniques was adopted in the work of Kunarak and Sulesathira (2017) when implementing the decision-making algorithms. Khan et al (2017) found Fuzzy logic technique which deals with imprecise information useful for VHO decision in determining QoS parameters and user preferences. Indeed, Torfi et al (2010), Kaleemy et al (2012) and Sasirekha & Ilanzkumaran (2013) explored the use of Fuzzy AHP to determine the relative weights of the evaluation criteria and Fuzzy TOPSIS in classifying the alternatives, in order to solve the MADM problem. These constraints led to using the fuzzy-based AHP model in order to ensure the selection of the network.

It is for this backdrop therefore, that lifespan of the battery energy and mobility was considered for the handover decision algorithm in heterogeneous wireless networks that can handover resources from one location to another without losing quality of service (QoS) and enhancement (QoE).

3.0 Proposed Algorithm

The objective of this study is to propose a Multi-Attribute-Decision Approach (MADM) in evaluating alternatives, taking into account the metrics for handoff. The proposal finds relevance in multi-criteria decision making algorithm in choosing preferred network from many available networks and is shown in Fig. 2. The figure describes the system model by evaluating the criteria and identifying alternatives, through a hierarchy of decisions. Weight factors were later assigned to each criterion to determine its importance by the Fuzzy-AHP. The metrics considered in this are throughput, data rate, jitter, latency and power (Energy) level of the participating access networks for the handover decisions. Consequently, TOPSIS was applied to the weighted metrics for ranking of the existing networks. At the end, the proposed system was compared based on Energy consumption of UE with the other methods to Solve the problem of decision making in heterogeneous networks.

Fuzzy-TOPSIS: The application of Fuzzy-based Analytic Hierarchy Process (F-AHP) set up to determine the relative weights of the evaluation criteria while considering the power level attribute.

F-TOPSIS-P: The fuzzy Analytic Hierarchy Process (F-AHP) method is used to obtain a weight of the decision criteria with consideration of the energy consumption as attribute. It also applied for classifying the available networks for network selection of access network with the highest value.

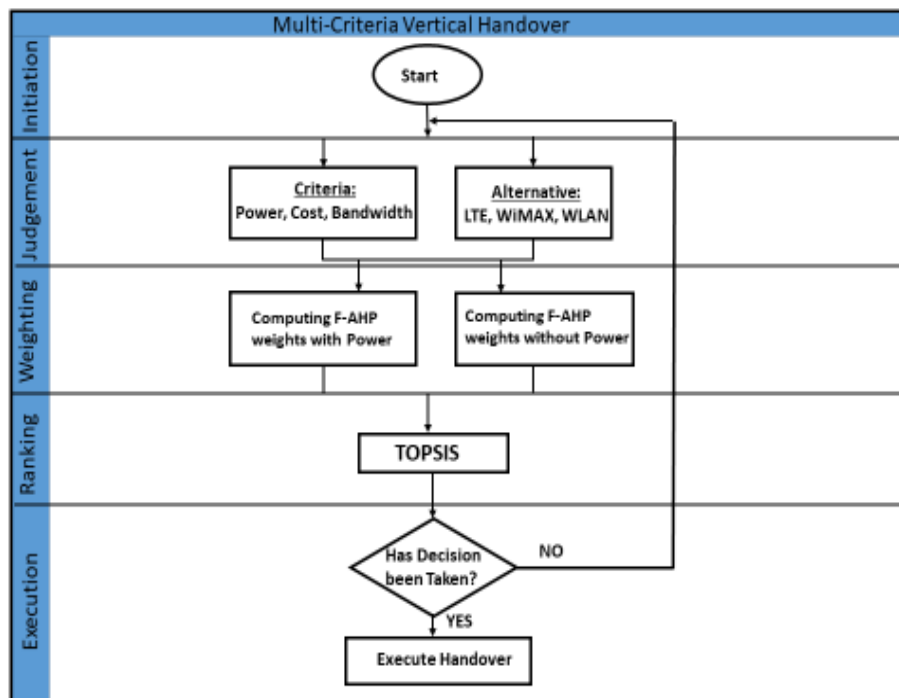


Fig. 2: Proposed Multi-Criteria Handover Decision

Fuzzy-based MADM Theory

The fuzzy set theory introduced by Wichapa and Khokhajaikiat (2017) is based on the rationale of uncertainty caused by the non-precision of the network. This phenomenon of wrong data representation constitutes the main contribution of fuzzy set theory to science and technology. A fuzzy set A in X is characterized by a membership

function $fA(x)$ which associates with each point in X , a real number in the interval $[0,1]$, with the values of $fA(x)$ at x representing the "grade of membership" of x in A .

- Triangular Fuzzy Numbers (TFNs): In this study, the triangular fuzzy numbers (TFN) are used to present the fuzzy relative importance. The TFNs used in the pair-wise comparison are defined by three real numbers expressed as a triple (l, m, u) where $l \leq m \leq u$ for describing a fuzzy event shown in Fig. 3.



Fig.3: Triangular Fuzzy Number (Miyim et al, 2017).

The choice of TFN is related to the number of classifications (Low, Medium and High as presented in Table 1 (Membership function of linguistic scale). Fuzzy number Linguistic Scales from $\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$ and represented as Equally important (EQ) Weakly important (WK) Essentially important (Es) Very strongly important (Vs) Absolutely important (Ab).

Table 1. Membership Function of Linguistic Scale.

Fuzzy Number	Linguistic Scale	Scale of Fuzzy Number
1	Equally Important (EQ)	(1,1,3)
3	Weakly Important (WK)	(1,3,5)
5	Essentially Important (Es)	(3,5,7)
7	Very Strongly Important (Vs)	(5,7,9)
9	Absolutely Important (Ab)	(7,9,9)

Fuzzy Analytic Hierarchy Process (F-AHP):

The AHP is a technique that organizes and analyse complex decisions. F-AHP is a problem-solving technique which combines use of fuzzy-AHP and linguistic variables. The main step of fuzzy AHP is to generate the relative importance of each pair of fuzzy factors in the same The Fuzzy-AHP method is after all, applied to the four classes of QoS and the weights generated in sequence.

TOPSIS

As one of the network selection methods, MADM use Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) as a simple ranking method in conception and application. TOPSIS attempts to rank the best alternative with the closest ideal solution and distant from the negative ideal solution. Thus are the steps of TOPSIS:

- The expression in Eq. 1 below is for the construction of normalized decision matrix for both beneficial and non-beneficial criteria.

$$a_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} \tag{1}$$

- To compute the weighted normalized decision matrix, the given expression in Eq. 2 is used:

$$v_{ij} = W_i \cdot n_{ij} \text{ where } \sum_{j=1}^n W_i = 1 \tag{2}$$

- However, determining the positive ideal and negative ideal solutions Eq. 3 is adopted.

$$\begin{aligned}
 A^+ &= \{v_1^+, v_2^+, \dots\}, v_j^+ = m_i ax(v_{ij}) \\
 A^- &= \{v_1^-, v_2^-, \dots\}, v_j^- = m_i in(v_{ij})
 \end{aligned}
 \tag{3}$$

• Therefore, the separation of each alternative A_i from the ideal solution A^+ and that of not-ideal solution A^- are calculated as given in Eq. 4, thus:

$$\begin{aligned}
 d_i^+ &= \sqrt{\sum_{j=1}^M |v_i^+ - v_{ij}|} \\
 d_i^- &= \sqrt{\sum_{j=1}^M |v_i^- - v_{ij}|}
 \end{aligned}
 \tag{4}$$

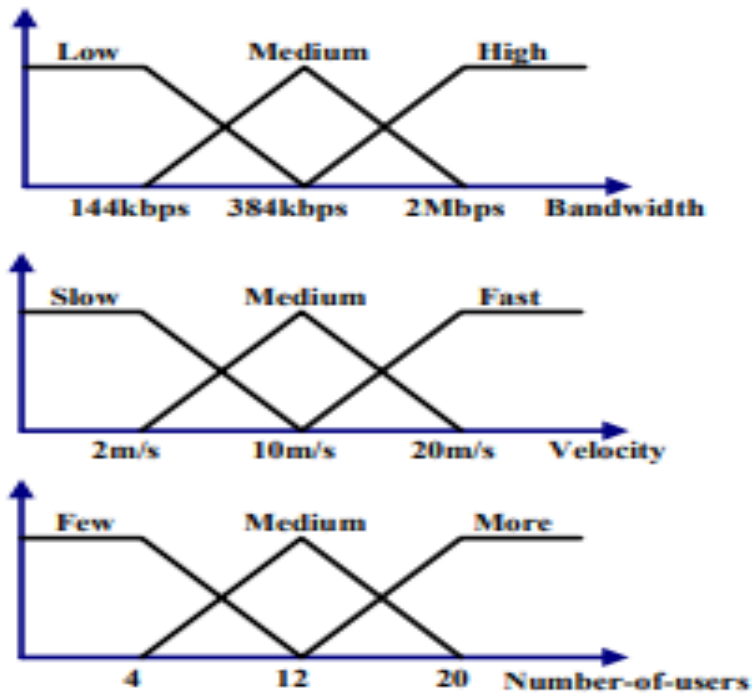


Fig.4. the Membership Functions of Input Variables

• Calculation of relative proximity to the ideal solution. (i.e. relative proximity of A_i with regards to A^+ and A^-) is given by R_i as expressed in Eq. 5

$$R_i = \frac{d_i^+}{d_i^+ + d_i^-}
 \tag{5}$$

Where $0 \leq R_i \leq 1, i = 1, 2, \dots, m.$

4.0 Simulation Scenario

In evaluating the proposed method for improving the quality of service (QoS), the Fuzzy-based MADM (F-AHP) was compared with other MADM methods while taking into account criterion of received signal strength (PL), cost (C) and bandwidth (BW) metrics. In the simulated scenario considered, three different networks (WLAN, LTE (4G), WiMAX) as demonstrated in Fig. 5. Considering the mobile user, four different applications with different QoS requirements were used. Attributes like throughput (Mb/s), data rate (Mb/s), Jitter (ms), Latency (ms) and

power (Battery) of the mobile equipment in % were randomly varied in the simulation. Each of the parameters were subjected to a number of iterations using MATLAB simulator. The table, below shows the parameters used for the simulation.

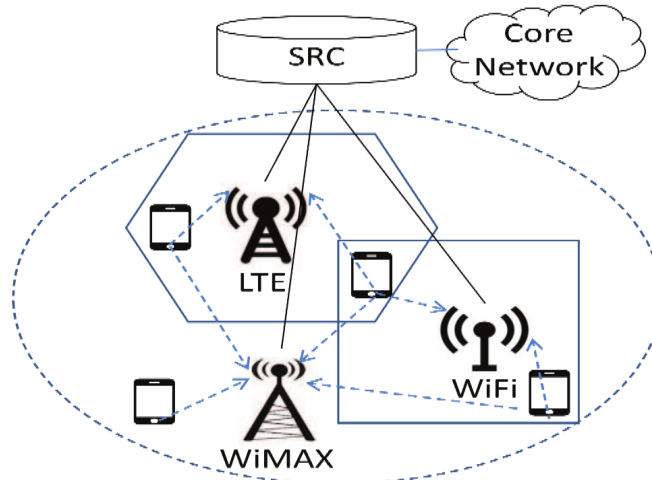


Fig. 5: Simulation Scenario (Source: Xiaohong et al, 2018)

Evaluations

The effectiveness of the method proposed was evaluated in which the performance of the F-AHP algorithm was compared with other methods to confirm the strength the proposed method has over the rest. Therefore, the analysis of the results tried to bring out the best performances in terms of reduced number of handoffs. The traffic analysis of the proposal compares the performance of F-TOPSIS-BE and F-TOPSIS and is presented in Fig. 6. The figure presents the weights generated using both FTOPSIS-E, VIKOR, F-TOPSIS and VIKOR methods. It indicates that bigger weight values were assigned high throughput by the new F-AHP-P technique that make it a better preferred network of choice. On the other hand, the proposal was found to have fair weight for jitter resulting in reduced ping pong effect, though VIKOR technique stand to have better ping pong effect.

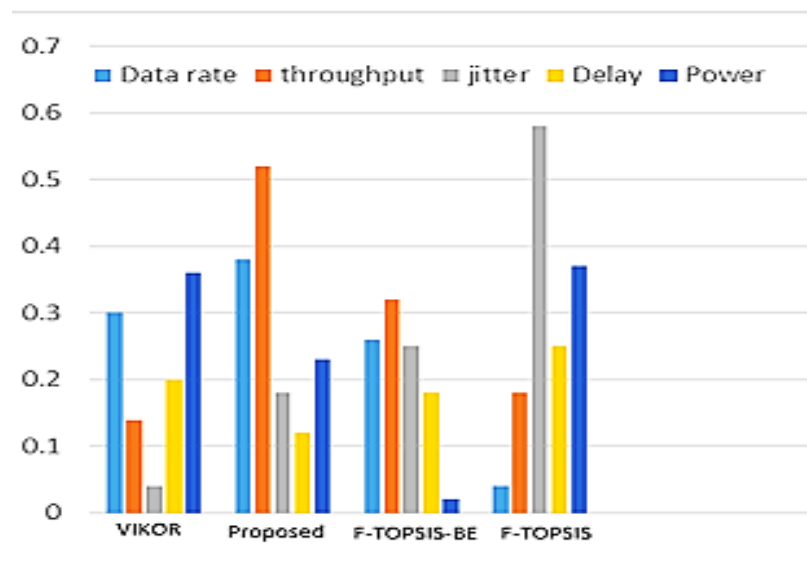


Fig. 6: Associated Weights Values for Traffic.

The result indicates that F-TOPSIS-P (proposed) method was able to reduce the UE battery power consumption during the handover processes by 48%. However, other methods could only achieve less as shown in Fig. 7

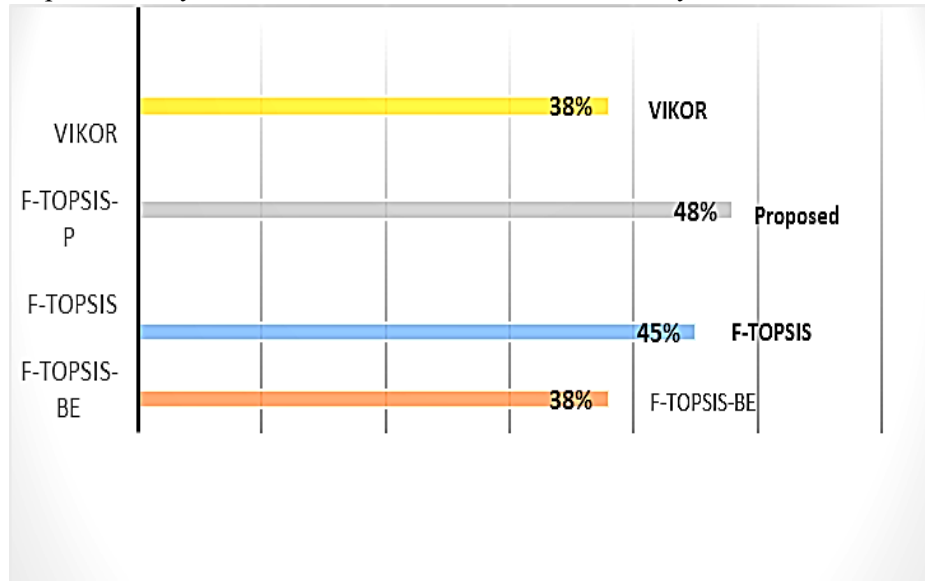


Fig.7: Average % of Battery Power Saved.

Table 2: The QoS Criteria.

Technology	Throughput (Mb/s)	Data Rate (Mb/s)	Jitter (ms)	Delay (ms)	Power (%)
LTE(4G)	1-80	29-80	2-10	20-80	46
WLAN	0.5-11	0.5-12.5	10-25	90-150	38
WiMAX	1-60	3-40	3-10	50-120	32

5.0 Result Discussion

The performance of the proposed algorithm is evaluated by simulation using MATLAB as shown in figure 7. The picture illustrates a handover trigger occurring between two different wireless networks: The LTE (which covers most simulation area) and WiMAX (partly overlaid at the end of LTE). The figure depicts the movement of mobile user terminal (MUE) as an overlaid network of LTE and WIMAX, where the curves RSS from base station and that of the access point (AP) whereas with the MT. It could be seen that the position of the access point is somewhere in the middle of the simulation time, but that does not mean is at the meeting point of the distance between the RSS and access point, rather the MT could be nearer the base station than the access point. The RSS model of LTE is given as following:

$$RSS(d) = P_t - PL(d) \quad (6)$$

Where P_t is the transmit power, and $PL(d)$ is the path loss at distance d (meters) between mobile user and base station. The path loss is however, defined as:

$$PL(d)_{dB} = S + 10n \log(d) + \chi_\sigma \quad (7)$$

Where S denotes the path loss constant, n denotes the path loss exponent and χ_σ represents the shadow effects which

is a zero-mean Gaussian distributed random variable with standard deviation σ (dB). In WiMAX, the path loss at distance d is formulated as:

$$PL(d)_{dB} = 20 \log\left(\frac{4\pi d_0}{\lambda}\right) + 10n \log\left(\frac{d}{d_0}\right) + \chi_\sigma \quad (8)$$

With the first term representing free space path loss at the reference distance d_0 , λ is the wavelength. The PL exponent

n was given a value of 4 and a carrier frequency set to 3.5 GHz.

In WLAN, the received RSS by mobile user is computed based on the propagation model as:

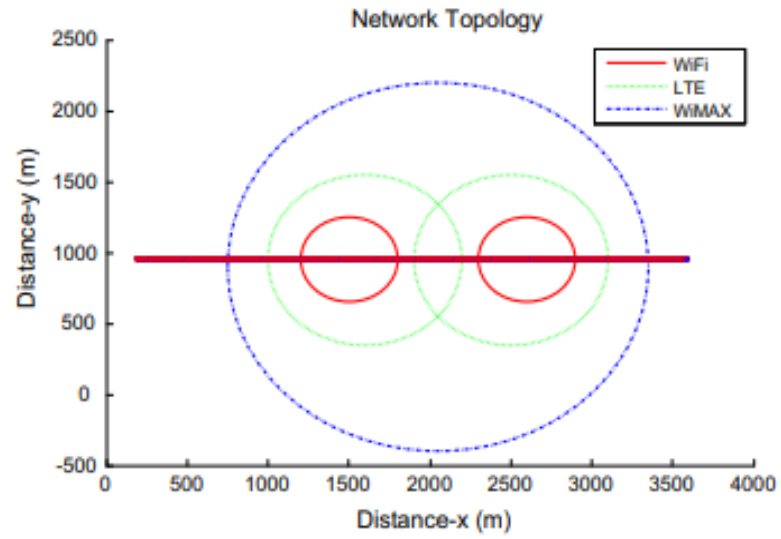
$$RSS(d)_{dBm} = 10 \log\left(\frac{100}{(39.37d)^\gamma}\right) \quad (9)$$

Where γ denotes the environmental factors of transmissions which is set to 2.8.

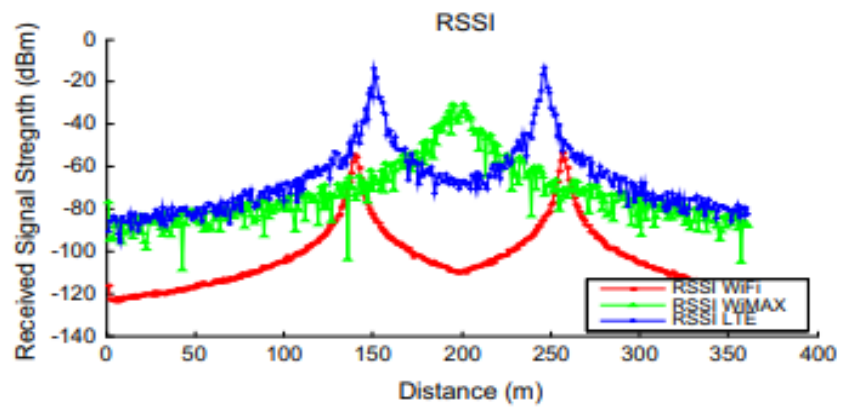
Therefore, the condition of the network for the MT in the handover procedure shows a little bit strength over the second handover, this means that the performance evaluation of the network in the previous handover is more than that of the second handover. This illustrates the advantage of the proposed algorithm in executing accurate handovers. The simulated topology is a route assumed to be a straight line movement that cut across the coverage areas of these networks, as illustrated in Fig. 8(a).

Figure 8(b) indicates the locations where vertical handover decisions occurred. The figure describes the vertical handover decision with regard to the location x . It is shown that the F-AHP values of the candidate network serves as a reflection of the integrated evaluation of PL, C and BW in which the vertical handover decision is based on. The trajectory of the UE in the heterogeneous wireless network shows the changing curves of the RSSI from the candidate networks along the chosen path, which are varying with the changing of UE location as could be seen in Fig. 8a. At about 90 s of the UE movement, the RSS of the preferred network reaches its peak and slowly decreases and handed over to the WiMAX network having strong RSS enough to provide the required resources to the UE at 100 sec. The dramatic decrease in bandwidth occurred at a period 225 sec when the LTEA network once again takes over. The decrease consequently reduces the access point candidacy value of the WiMAX. The two (LTE-A and WiMAX) networks provides appropriate bandwidth for the services rendered. However, the candidacy of Wi-Fi (WLAN) remains unnoticed as a result of weak RSS and possible bandwidth cost. For every simulation time point of attachment (PoA) is calculated, as the mobile UE has access to all the three networks at any point in time. The PoA are determined by choosing the highest value of the RSS and the target network at every handover location is seen to happen at different time as shown in Fig. 8b.

The result associated with the simulation of the fuzzy-based vertical handover decision algorithm is shown in Figure 9. It describes the Normalization of power (PL), Cost (C) and bandwidth (BW) of the 2 model base stations (BSs), respectively. The values of these 3 metrics varies in accordance with the location of movement of mobile users along x -axis. The Figure describes the F-AHP values of the 2 BSs that determines the decision of vertical handover. The vertical handover decision density with regard to the location x and depicted in figure 9 describes how the Fuzzy-based VHD values of the candidate BSs serve as a reflection of the integrated evaluation of PL, C and BW.



(a)



(b)

Figure.8: Simulation of Handover Scenario for three Networks

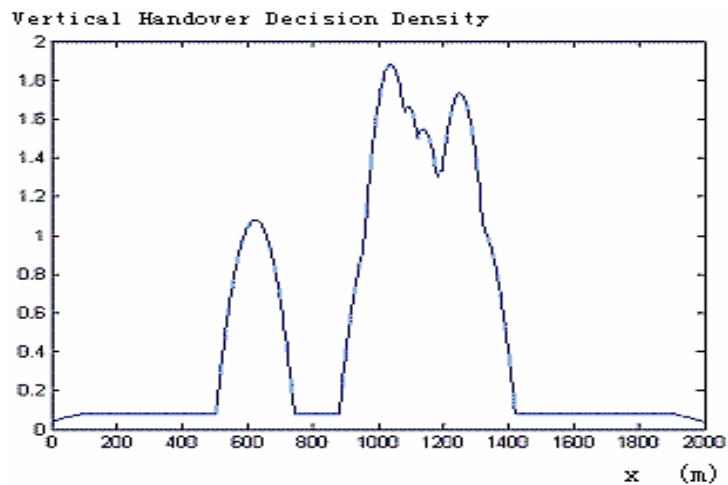


Figure 9. Vertical Handover Decision Density (VHDD)

VI. CONCLUSIONS

Though so many decision algorithms have been discussed for vertical handover, most of them, however, did not pay attention to the impact of handover failure in mobility management during the vertical handover process using fuzzy logic. A handover decision algorithm for mobility management in heterogeneous wireless network has been presented. The result show how the proposed F-AHP-P handover decision algorithm performs better in terms of handover priority and probability of minimizing handover failure, improved throughput and reduced power consumption of the UE. Equally, the decision density of the network selection was presented where the proposed method rates the candidate BSs as a reflection of the integrated evaluation of criterion. For better improved quality of enhancement (QoE), context-aware handover decision will be considered in the future research.

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