Quality of Service aware Vertical Handoff Decision Algorithm between WiFi WiMax and LTE

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Abstract
One of the major design issues for providing seamless mobility is the support of vertical handoff. Vertical handoff occurs when a mobile terminal switches from one network to another. Different networks have different characteristics, which makes it very difficult to keep up Quality of Service (QoS). The number of mobile users and their bandwidth demands has experienced significant growth. This paper proposes a Vertical Handover Decision (VHD) algorithm using Fuzzy-Linear Programming (FLP) approach, in Heterogeneous Wireless Networks (HWN), to integrate WiFi (Wireless Fidelity), WiMax (Worldwide Interoperability for Microwave Access) and LTE (Long Term Evolution) for connecting to the optimal network. Initially the traffic classes are identified using heuristic decision and then the handoff decision will be carried out based on Fuzzy decision matrix which will lead to handover based on the objective function. The simulation results show that our proposed scheme performs better in many evaluating patterns and the delay gets minimized when compared to SAW (Simple Additive Weighting), MEW(Multiplicative Exponential Weighted) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution).

Keywords: Handoff, SAW, Vertical Handoff Decision, WiFi, WiMax.

1. INTRODUCTION
Next generation wireless network requires seamless mobility by maintaining the required Quality of Service (QoS) for different applications. Efficient vertical handoff management is essential for maintaining seamless connectivity. Vertical Handover is the act of moving a User Equipment (UE) from one type of network to another. Based on the developing trends of mobile communication, 4G (Fourth Generation) provides the users with variety of choices for selecting the suitable network. They can either choose Wireless Local Area (WLAN) for utilizing moderate access cost, worldwide interoperability for Microwave access (Wi-Max) to meet higher data rate and Long Term Evaluation (LTE) to achieve good Quality of Service (QoS) (Zekri et al., 2012). Every Vertical Handover (VHO) mechanism should do a decision-making process by evaluating the different QoS parameters for the available wireless access networks. During VHO, many network criteria such as cost of service, security, power consumption, network conditions and network performance are considered for deciding whether to perform handover or not (Sun et al., 2011). There are different strategies used to monitor these parameters for different network (Ickin, 2010; Seema et al., 2011). These different strategies are classified into categories namely function based (Wang et al., 1999), user centric (Calvagna et al., 2004), Multi Attribute Decision Making (MADM) based (Song et al., 2005), fuzzy logic and Neural Network based (Chan et al., 2001). MADM methods are widely used for solving multi-criteria decision problems including the network selection problem. The aim of (MADM)-based methods are to keep the mobile users connected with best of the available signals anytime and anywhere. Some of the popular MADM methods SAW (Simple Additive Weighting Method), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), MEW(Multiplicative Exponential Weighted), AHP(Analytic Hierarchy Process), ELECTRE (Elimination and Choice Expressing Reality) and GRA (Grey Relational Process).

A number of proposals have been found for MADM based vertical handoff decision algorithm in literature. Wang et al. apply SAW method in network choice strategy. Here a policy-enabled handover system is used for selecting the “best” wireless network at any moment (Wang et al., 1999). Mc Nair and Zhu introduce performance criteria’s such as congestion, battery power, latency, service type etc., for evaluating seamless vertical mobility (Nair et al., 2004). Tudzarov et al. use fuzzy logic controller and Genetic algorithm for optimization of multi-criteria input. Based on the past knowledge of the service performance of available wireless network, handover is performed...
on given time intervals (Tudzarov, 2011). Lu et al. develop a multi-objective optimization algorithm for Wireless Sensor Network (WSN) for improving the searching process aiming to optimize the unstable convergence problem. (Lu et al., 2016). Nguyen-Vuong et al. analyze the SAW algorithm and proposed the use of MEW method for decision-making mechanism. On the basis of numerical analysis Nguyen-Vuong et al. proves that the result of SAW is inaccurate and their work performs better (Nguyen-Vuong, 2008).

Niyato and Hossain use dynamic evolutionary game for solving VHO decision problem from the given limited amount of bandwidth, to share the available network from different groups of users in different areas (Niyoto, 2005). Calhan and Ceken propose a VHD algorithm for selecting network parameters such as data rate, monetary cost and RSS. One of the drawbacks of this method is that it needs more memory for achieving the required matrix (Calhan, 2012).

Stevens et al. propose a Markov Decision Process (MDP) model by considering the bandwidth and delay of candidate network and address an issue about user monetary budgets for their connection (Stevens, 2008). Khan and Han propose a vertical handover management scheme that performs handover triggering using SAW on the data rate of AP and here the network selection is based on TOPSIS by considering different parameters such as delay, jitter, bit error rate, packet loss ratio, communication cost, response time and network load and it has been tested in different mobility scenario (Khan, 2015). Sun et al. propose an A-star algorithm to improve the efficiency and accuracy of optimal path selection by weighting process and heuristic function (Sun, 2016). Vidal et al. propose an algorithm, using buffers in parent peers at the UE (Vidal, 2010). Amali et al. propose an Enhanced MIH (Media Independent Handover) to guarantee better QoS and minimal handover rate by considering packet loss, handover latency and average throughput (Amali et al., 2014).

Bari and Leung propose a modified version of ELECTRE algorithm for network selection problem by computing a concordance set (CSet) which has a list of parameters that shows the comparisons of current network with other candidate networks (Bari, 2007). Hassawa et al. introduces a cost function based VHD algorithm between heterogeneous networks using the method of QoS normalization and weight distribution. Here the authors did not concentrate on the network parameters such as security and interference level (Hasswa, 2007). Tawil et al. proposed a cost function based VHD algorithm by introducing a weight function and handover calculation based on network instead of UE. This method requires extra co-operation between UE and network, by which it adds extra latency and excessive load (Tawil, 2008).

Even though different handoff decision algorithms are proposed in the literature, most of the algorithms makes the handoff decision based on current RSS and current UEs condition, but not on the basis of user preferences and budgetary cost. But, the proposed work considers the state of the network (bandwidth, delay and cost), state of the user and UE (velocity and location), and user preferences and users monetary budget. By considering these aspects, a new method using Fuzzy- Linear Programming (FLP) approach is proposed for reducing the delay by improving the QoS and for keeping up the monetary budget of each call based on user preferences.

when compared to them the contribution of this work can be summarized as follows:

- A heuristic decision based algorithm is used for classification of type of service such as Interactive or conversational or multimedia services with three different wireless technologies i.e.; WiFi, WiMax and LTE
- Fuzzy linear programming approach is designed for vertical handoff decision and the best Access Point (AP) or Base Station (BS) will be selected based on the objective function.
- Performance of the proposed algorithm is compared with that of others found in the literature, i.e.; SAW, MEW and TOPSIS
- Developed vertical handoff decision algorithm is modeled using MATLAB software. During the simulation, all networks work concurrently for more realistic estimation.

2. HEURISTIC BASED HANDOFF DECISION

During each mobile connection lifetime, a number of vertical handoffs occurs. The heterogeneous wireless environment consists of WiFi, WiMax and LTE and it is called as collocated network. Periodically, the mobile terminal receive information from the collocated networks within its receiving range. Each network advertises the available bandwidth and the average delay of the particular network continuously. Based on the advertisement, the UE decide whether to stay in the same network or be re-routed to another network, which can give better performance (e.g., lower cost, higher throughput). Because of this re-routing process, the complexity of the processing and signaling load of the network increases. Thus, there is an important tradeoff between the QoS of the mobile connection, and the processing and signaling load incurred on the network. To maintain a Vertical Handover
Decision (VHD), an algorithm is proposed using Fuzzy-Linear Programming (FLP) approach in Heterogeneous Wireless Networks (HWN) by considering an integration of Wi-Fi, WiMax and LTE for connecting to the optimal network. The proposed block diagram of the Heuristic handoff trigger based Fuzzy-Linear Programming (FLP) approach is shown in Figure 1.

**Figure 1 Proposed Architecture**

The heuristic decision block initiates handoff process based on the system discovery information such as RSS, velocity, cost, bandwidth and user preferences. The output of the heuristic decision block gives the information about the nature of traffic classes. Based on the nature of traffic classes the handover decision is made using fuzzy linear programming approach and finally, the best network will be selected based on the multi-criteria based objective function.

### 2.1 Heuristic Handoff Trigger and Service Selection

The heuristics followed for initiating handoff trigger is, the RSS and bandwidth of the UE is compared with the threshold. The RSS of the present UE is compared with the threshold RSS (RSS$_{TH}$) (Mohanty, 2006) obtained using Equation (1)

$$RSS_{TH} = RSS_{min} + 10 \beta \log\left(\frac{d}{d - L_{BA}}\right) + \epsilon$$  \hspace{1cm} (1)

where $L_{BA} = d \sqrt{\tau^2 V^2 + d^2 (P_f - 2 + 2 \sqrt{1 - P_f})}$

$RSS_{min}$ (dB) is the minimum level of RSS needed for UE to communicate with an access point, $\beta$ is the path loss coefficient, $d$ is the side length of the cell (in meters for both WLAN and WMAN), $L_{BA}$ is the shortest distance between the point at which handover is initiated and WLAN boundary and it depends on the desired handover failure probability ($P_f$), the velocity of the mobile terminal (v), the handover delay between WLAN and WMAN ($\tau$) and $\epsilon$ (in dB) is a zero-mean Gaussian random variable.

The Bandwidth of the present UE is also compared with the threshold bandwidth (BW$_{TH}$) (Lee, 2006) using Equation (2).

$$BW_{TH} = tp \times (1 - \alpha \times c.u) \times (1 - PLR)$$  \hspace{1cm} (2)

Where $tp$ is the throughput, $\alpha$ is a factor that reflects IEEE 802.11 MAC overhead (set to 1.25) (Lee, 2005), $c.u$ is the channel utilization, that is, the percentage of time the access point senses the medium is busy using the carrier sense mechanism and PLR is packet loss ratio represents the part of transmitted medium access control (MAC) protocol data units (MPDUs) that require retransmission, or are discarded as undeliverable. Finally, the velocity of the UE will be calculated and based on this the decision will be taken place that is which network to move.

### 2.2 Multi-criteria decision based Fuzzy Linear Programming approach

Handoff decision is an important step in handoff mechanism. After getting the handoff trigger signal for a UE, the real need of handoff is strengthening by defining multi-criteria based objective function using fuzzy linear programming approach. The multi-criteria considered for choice of best network by maximizing RSS and bandwidth and minimizing budgetary cost. For making handover decision, the fuzzy linear programming approach is used. If
the UE moves slowly from one network to another, handoff decision making will be taken place using fuzzy linear programming approach and last the best network will be selected based on the objective function and the handover will be taking place. The various steps involved in HTBFLP based approach is as follows:

**Step 1:** Assume that the coverage area have ‘n’ Base stations ($BS_1, BS_2, ..., BS_n$) ‘m’ decision criteria ($DC_1, DC_2, ..., DC_m$), with a decision maker for a mobile node.

**Step 2:** Identify the proper linguistic variables and the right positive trapezoidal fuzzy number. The mobile node use the linguistic variables VL (Very Low) to VH (Very High) to assess the importance weight of the each decision criteria for improving the performance by reducing delay and maintaining the monetary cost and also the linguistic variables VP (Very Poor) to VG (Very Good) to assess the ratings of choosing Base Stations with respect to each decision criteria.

**Step 3:** Construct a fuzzy decision matrix to get the fuzzy weight of each criteria and the fuzzy rating is expressed in Equation (3)

$$R_k = (a_k, b_k, c_k, d_k) \ k = 1,2,..,n \ (3)$$

where $a = \min_k a_k , \ b = \frac{1}{k} \sum_{k=1}^{n} b_k, \ c = \frac{1}{k} \sum_{k=1}^{n} c_k$ and $d = \max_k d_k$

The value of the fuzzy weights ($\mathbf{\omega}$) of each criteria ($DC_1, DC_2, ..., DC_m$) and the fuzzy rating($\mathbf{X_{ij}}$) of ‘n’ Base stations ($BS_1, BS_2, ..., BS_n$) with respect to each criteria can be calculated and is expressed in matrix form as shown in Equation (4)

$$P = \begin{bmatrix}
    BS_1^T & BS_2^T & ... & BS_n^T \\
    \hat{p}_{11}^T & \hat{p}_{12}^T & ... & \hat{p}_{1m}^T \\
    \vdots & \vdots & \ddots & \vdots \\
    \hat{p}_{n1}^T & \hat{p}_{n2}^T & ... & \hat{p}_{nm}^T
\end{bmatrix} \ (4)$$

where $P_{ij}, \ i = 1,..,m$ and $j= 1,...,n$ are the fuzzy grades characterized by the membership function. The membership characteristics are made based on the preferences of the user criteria.

**Step 4:** Normalize the fuzzy decision matrix based on benefit criteria such as user preferences, bandwidth and RSS and cost criteria such as cost.

**Step 5:** Construct weighted normalized fuzzy decision matrix based on normalized fuzzy decision matrix using Equation (5)

$$\mathbf{\bar{P}} = [\mathbf{\tilde{p}_{ij}}]_{m \times n} , i = 1,2,..,m , j = 1,2,..,n \ (5)$$

where $\mathbf{\tilde{p}_{ij}} = \text{normalized matrix ( ) weight}$

**Step 6:** Calculate the fuzzy positive ideal solution (I⁺) and fuzzy negative ideal solution (I⁻) in Equation (6) and Equation (7)

$$I^+ = (\tilde{v}_{1}^+, \tilde{v}_{2}^+, ..., \tilde{v}_{n}^+) \ (6)$$

$$I^- = (\tilde{v}_{1}^-, \tilde{v}_{2}^-, ..., \tilde{v}_{n}^-) \ (7)$$

where the positive ideal solution (I⁺) such as benefit criteria should be maximized and negative ideal solution(I⁻) such as cost criteria should be minimized.

**Step 7:** Calculate the closeness coefficients of each Base Stations according to the distances to fuzzy positive and negative ideal solutions using Equation (8).

$$CC_i = \frac{d^{-}_i}{d^+_i} , i = 1,2,..,m \ (8)$$

where $d^+_i$ the distance between each base station and fuzzy positive ideal solution $d^-_i$ the distance between each base station and fuzzy positive ideal solution.

**Step 8:** Build the linear programming model from the closeness coefficients to find the best BS/AP, the quality of service such as bandwidth, RSS should be high and cost should be low. Hence the final integrated linear programming objective function can be expressed in Equation (9).
\[ M(C, X_1, X_2, X_3) = X_1 \sum_{u_1} B_i(X) + X_2 \sum_{1 \leq i \leq n} R_i(X) - X_3(C_T) \]  

where \( X_1, X_2, X_3 \) are the coefficients of the respective function., the multi objective optimization statement of the high bandwidth, good RSS and low monetary cost are as shown in Equation (10)

\[ M - OPT = \text{Max} \ M(C, X_1, X_2, X_3) \]

3. RESULTS AND DISCUSSION

To verify the efficiency of the proposed approach, a heterogeneous simulation platform is set up using MATLAB. The network considered for simulation is WiFi, WiMax and LTE.

3.1 Analysis of Call dropping probability

Figure 2 shows the analysis of call dropping probability of the SAW, MEW, TOPSIS and Proposed algorithm approach with respect to simulation time. Using Poisson mass probability function (Boggia, 2007) the call dropping probability is calculated. The call dropping probability of the proposed approach decreases when compared to SAW, MEW and TOPSIS with respect to number of nodes due to distribution of load equally in all the networks.

![Figure 2 Call dropping probability](image)

3.2 Analysis of Bit Error Rate (BER)

The analysis of BER is compared with SAW, MEW and HTBFLP approach. The proposed approach calculates the BER using the method used by the author in (Hong, 1986) and also it shows that the performance of the proposed approach is better than SAW, MEW and TOPSIS which increase the signal power and decreases the noise power with respect to the average connection life time and is shown in Figure 3.
3.3 Analysis of End-to-end Delay

Figure 4 shows the end-to-end delay of the proposed approach with SAW, MEW and TOPSIS. For maintaining good Quality of Service in all types of services the delay should be low. The simulation results clearly show that the delay of the proposed approach gets reduced due to selection of traffic classes initially.

3.4 Analysis of Number of Handoff

Figure 5 shows the analysis of number of handoff with respect to speed of UE for SAW, MEW, TOPSIS and the proposed approach. The number of handoff occurs when the UE moves with the velocity of 10 Kmph is larger compared to the UE moving with a velocity of 30 Kmph, 50 Kmph, 70 Kmph and 90 Kmph. The optimization function for performing handoff is minimized. Further, unnecessary handoff can be limited and the system performance get improved.
3.5 Analysis of Bandwidth

Figure 6 shows the analysis of bandwidth available for the proposed approach during the connection life time with various algorithms such as SAW, MEW and TOPSIS. The proposed approach achieves good bandwidth with respect to time and hence the bandwidth hungry application such as multimedia streaming can be taken place without any delay.

4. CONCLUSIONS

A novel Vertical Handover Decision (VHD) algorithm using Fuzzy Linear Programming (FLP) approach is proposed. The algorithm is simulated between WiFi, WiMax and LTE networks. Initially, based on heuristic rules, the handoff triggering is performed and the traffic classes are identified. The analysis shows that the proposed method chooses the best network by considering multiple criteria. The result of the proposed approach is compared with SAW and MEW and TOPSIS. The result shows that it reduces the delay by improving the QoS and maintaining the monetary budget of each call based on user preferences.

REFERENCES

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