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Research paper

A Fuzzy-AHP Based Approach for Enhancing Network Selection in Heterogeneous Networks Using Battery Energy Criterion

Imane Chattate[1]*, Mohamed El Khaili[2] And Jamila Bakkoury[2]

[1]*Laboratory of Signals, Intelligence Artificial and Systems Distributed (SSDIA), ENSET Mohammedia, Hassan II University, Casablanca, Morocco*
[2]*Department of Electrical Engineering, ENSET Mohammedia, Hassan II University, Casablanca, Morocco*
**Corresponding author E-mail: imane.chattate@gmail.com*

Abstract

Today, the rapid evolution of communication technologies requires a certain improvement of the quality of service (QoS) in order to meet the needs of the user. Vertical handover enables a mobile terminal to move from one network to another without loss of connection. Vertical handover management is one of major challenges to ensure seamless mobility in order to achieve efficient resource utilization while maintaining the quality of service (Qos). In this paper, we propose an approach for network selection based on the combination of AHP method with fuzzy logic including a new criterion which is the battery energy in order to reduce the number of executed handoffs, while extending the Mobile battery life. Performance results of the proposed system are also compared with those of the classical method, it is found that our proposed method outperforms the classical method with the highest relative standard deviation. Subsequently TOPSIS method is applied to rank the available networks.

Keywords: *Vertical Handover, Network selection, Fuzzy Analytic Hierarchy Process, Multi-Attribute Decision Making, TOPSIS.*

1. Introduction

Nowadays, the rapid evolution of wireless and mobile technology has imposed the development of new cellular access technologies (5G, LTE, 3G) and IEEE (WiMAX, WIFI). The heterogeneous nature of future generation wireless networks raises the issue of continuity and quality of service. The improved performance of these networks requires effective use of a vertical handover system.

In general, the handover process itself can be decomposed into three steps: data collection, transfer decision, and Execution of the transfer. In this work, the emphasis is on the decision-making step. A VHO decision depends on various network QoS parameters as well as many other criteria that can be related a user profile, network state or even to the capacity of the battery energy. In order to solve the problem of the increasing number of these criteria, multiple attribute decision making (MADM) has been proposed.

Moreover, MADM is one of the most promising methods that can be applied to network selection problem, it's simple to implement and do not require particular physical resources. The most known algorithms for MADM are analytic hierarchy process (AHP), analytic network process (ANP) used to calculate the criteria weight, or the algorithms TOPSIS, SAW, VIKOR used for alternatives ranking problem.

In order to solve and optimize the network selection problem in heterogeneous environment, while maintaining QoS for multimedia services. This paper focuses on the adoption of a fuzzy approach to enhance vertical handover decision, as well as to optimize decision delays, QoS criteria and to select the best network for mobile users, as it is shown in Fig. 1. It is noteworthy to choose the suitable network among heterogeneous networks and grant wireless access for all users.

The paper is organized as follows: Related works about Vertical handover decision (VHD) are summarized in section.2. In section 3 & 4, presents a system model and the approach for network selection problem using Fuzzy-MADM. Section.5 describes simulation parameters and results. Finally, section.6 concludes the work.

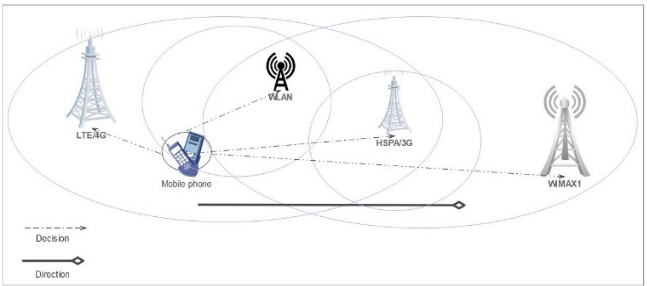

Fig.1: Vertical handover topology for network selection.

2. Related Work

In a heterogeneous network, mobility feature is essential because mobile devices must be able to roam throughout the network and able to connect to various radio access technologies. Network selection is a critical step in accomplishing a smooth vertical transfer and achieving the best QoS in a heterogeneous environment. This requires dynamic selection of the best practical network, and the decision-making and selection process is the most

crucial in this case. It is a matter of assembling the performance of each candidate network and classifying them into the goal of selecting the best network.
[1,2] Presented an overview of vertical handover process, their types, protocols, algorithms, and architecture proposed in the literature. Therefore, many researchers have been done on vertical handover decision algorithm. Paper [3] is considering the RSSI as the only main criterion for the vertical handover procedure so this algorithm is not practical. In the same context of heterogeneous environment, authors [4,5] have compared different types of MADM methods (SAW, TOPSIS, GRA, AHP, and MEW) for providing handoff solution. MADM methods are widely used for solving VHO decisions because of their implementation simplicity and decision accuracy. The most efficient MADM methods used in VHO process are SAW, TOPSIS and VIKOR [6, 7]. Their principle is based on ranking candidate networks within their computed score. The authors of [8] proposed giving weights to know the relative importance of each metric or attribute in the considered QoS Class. [9,10] used AHP or M-ANP to calculate the vectors of weight and TOPSIS method is applied to determine the ranking of access network. Their results showed the importance of those weights in the decision.
However, Computational-intelligence based algorithms are the most performing. For the decision-making, these algorithms use techniques of intelligence implementation like fuzzy logic [11] and neural networks [12]. Fuzzy logic can be used for VHO decision by dealing with imprecise information related to radio, QoS parameters and user preferences [13]. Indeed [14,15,16] explored the use of Fuzzy AHP to determine the relative weights of the evaluation criteria and Fuzzy TOPSIS to classify the alternatives, in order to solve the MADM problem by seeking an improved solution to a related problem. These constraints led us to use the fuzzy logic in a model in order to ensure the selection of the network.

3. System Model

The objective of this study is to propose a multi-attribute-decision approach (MADM) to evaluate the alternatives, taking into account Battery Energy. Our contribution consists in handover decision phase. The decision makers must choose the best network from the available networks. Then, as we have proposed in Fig. 2., which describes the model of our system, we begin by identifying alternatives and evaluation criteria, subsequently we constructed a hierarchy of decisions.
Weight factors are assigned conveniently to each criterion to report its importance which is determined by fuzzy-AHP, we have reconfigured the weights done previously in the literature, considering Throughput, Data rate, Jitter, Latency and Battery Energy of the participating access networks to make the handover decisions. Subsequently, TOPSIS is applied to the weighted matrices to have the ranking of the available networks.
Finally, we compare our new approach based on a new Battery Energy attribute with the classical method to solve the problem of decision making in heterogeneous networks.

- F-TOPSIS: The fuzzy Analytic Hierarchy Process (FAHP) is applied to determine the relative weight of the evaluation criteria without considering the Battery Energy attribute, and TOPSIS method is applied to classify the available networks.
- F-TOSIS-BE: The fuzzy Analytic Hierarchy Process (FAHP) method is used to obtain a weight of the decision criteria with considering the Battery Energy attribute, and the TOPSIS method is applied to classify the available networks and to select the access network with the highest value.

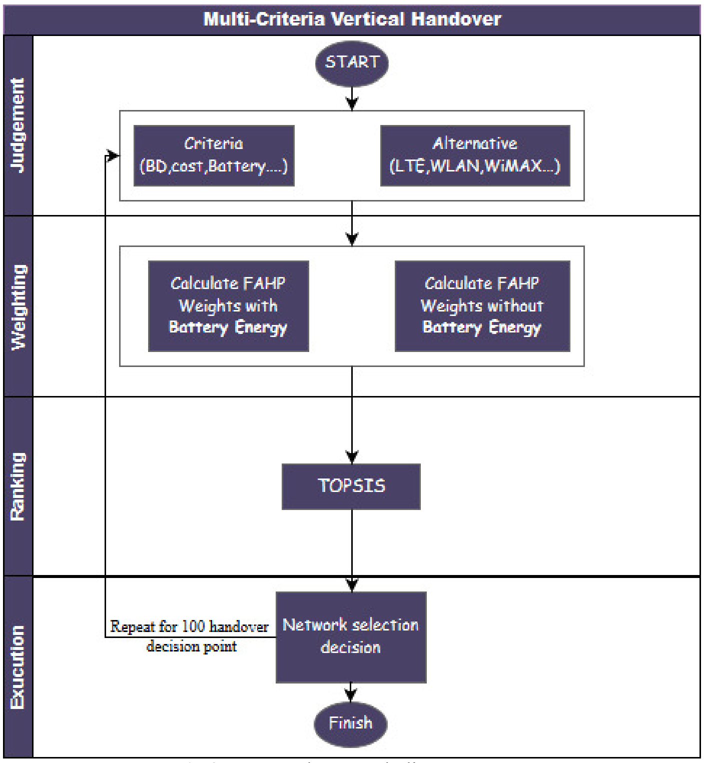

Fig.2: Proposed approach diagram.

4. Network Selection Based Fuzzy-MADM Theory

4.1. Fuzzy Set Theory

In order to deal with vagueness of human thought, Zadeh [17] introduced the fuzzy set theory oriented to the rationality of uncertainty due to imprecision or vagueness. Its ability in representing vague data is considered as the major contribution of fuzzy set theory to science and technology. A fuzzy set A in X is characterized by a membership function $f_A(x)$ which associates with each point in X a real number in the interval [0,1], with the values of $f_A(x)$ 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 [18]. The choice of TFN is related to the number of classifications or tunings (Low, Medium, and High in case of TFN) (see Table 1.).

$$\mu_{A(x)} = \begin{cases} \frac{x-l}{m-l}, & l < x < m \\ \frac{u-l}{u-m}, & m < x < u \\ 0 \;, & Otherwise \end{cases} \tag{1}$$

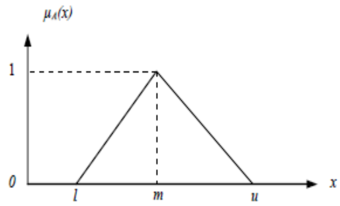

Fig.3: Triangular fuzzy number.

Table 1: Membership function of linguistic scale.

Fuzzy number	Linguistic scales	Scale of fuzzy number
$\tilde{1}$	Equally important (EQ)	(1,1,3)
$\tilde{3}$	Weakly important (WK)	(1,3,5)
$\tilde{5}$	Essentially important (Es)	(3,5,7)
$\tilde{7}$	Very strongly important(Vs)	(5,7,9)
$\tilde{9}$	Absolutely important (Ab)	(7,9,9)

4.2. Fuzzy Analytic Hierarchy Process: FAHP

The AHP is a technique for organizing and analyzing complex decisions. However, some researchers claim that there are some weaknesses in Saaty's AHP method, such as Yang and Chen [19,20]. FAHP is a problem-solving technique which is a combination of AHP process use of fuzzy logic and linguistic variables. The main step of fuzzy AHP is to generate the relative fuzzy importance of each pair of factors in the same hierarchy. Using TFN and via pairwise comparison, the fuzzy evaluation matrix $Q = (q_{i,j})_{n*m}$ is constructed, as: $q_{i,j} = (l_{i,j}, m_{i,j}, u_{i,j})$ and $q_{i,j}^{-1} = \left(1/u_{i,j}, 1/m_{i,j}, 1/l_{i,j}\right)$.

The process of weighting criteria with using Fuzzy AHP approach is as follows:

- Making hierarchy
- Construct of the pair-wise comparisons: to establish a decision, FAHP builds the pair-wise matrix comparison such as:

$$A = \begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{bmatrix} \quad (15)$$

- The fuzzy synthetic extent value Si with respect to the ith criterion is defined as Eq.

$$a_{ij} S_i = \sum_{j=1}^{m} q_{ij} \odot \left[\sum_{i=1}^{n}\sum_{j=1}^{m} q_{ij}\right]^{-1} \quad (16)$$

- As $S_1 = (l_1, m_1, u_1)$ and $S_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $S_2 = (l_2, m_2, u_2) \geq S_1 = (l_1, m_1, u_1)$ is defined as:

$$V(S_2 \geq S_1) = \sup_{y \geq x}\{\min(S_1(x), S_2(y))\} \quad (17)$$

Where x and y are the values on the axis of the membership function of each criterion as show in Fig. 4.
This expression can be written as:

$$V(S_2 \geq S_1) = f(x) = \begin{cases} 1, & m_2 < m_1 \\ 0, & l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2)(m_1 - l_1)}, & Otherwise \end{cases} \quad (18)$$

The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers S_i $(i = 1,2 \ldots \ldots k)$ defined in [21] by:

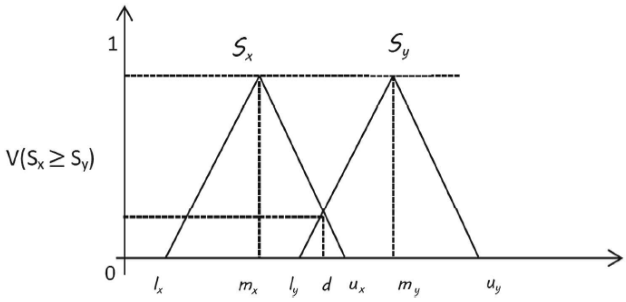

Fig.4: The intersection between S1 and S2.

$$V(S \geq S_1, S_2, ..S_k) = V\,[(S \geq S_1) \cap (S \geq S_2) \cap .. \cap (S \geq S_k)] = min(V(S \geq S_i)), i = 1,2 \ldots, k \quad (19)$$

- Via normalization, the normalized weight vectors are:

$W' = (w_1', w_2', \ldots, w_m')^T$ Where $A_i (i = 1,2, \ldots, m)$ are m attributes. (20)

Where W' is a non-fuzzy number.
Finally, the fuzzy AHP method is applied for the four classes of QoS and the weights are correspondingly generated.

4.3. Topsis

For the assessment of machine selection, one of the MADM methods named TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), has been developed in 1981 by Hwang and Yoon [22], is a simple ranking method in conception and application. TOPSIS attempts to indicate the best alternative that simultaneously has the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. The steps of TOPSIS are cited in [23]:

- Construct normalized decision matrix of beneficial and non-beneficial criteria.

$$a_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (7)$$

- Calculate the weighted normalized decision matrix as follows:

$$v_{ij} = W_i \,.\, n_{ij} \quad Where \sum_{j=1}^{n} W_i = 1 \quad (8)$$

- Determine the positive ideal and negative ideal solutions.

$$A^+ = \{v_1^+, v_2^+, \ldots\}, v_j^+ = \max_i(v_{ij}) \quad (9)$$

$$A^- = \{v_1^-, v_2^-, \ldots\}, v_j^- = \min_i(v_{ij}) \quad (10)$$

- Calculate the distances. The separation of each alternative A^i from the ideal solution A^+ and the separation of each alternative A^i from the ant-ideal solution A^- are calculated as:

$$d_i^+ = \sqrt{\sum_{j=1}^{M} |v_i^+ - v_{ij}|} \quad (11)$$

$$d_i^- = \sqrt{\sum_{j=1}^{M} |v_i^- - v_{ij}|} \quad (12)$$

- Calculate the relative proximity to the ideal solution. The relative proximity of A_i with regards to A^+ and A^- is given by R_i and can be expressed as:
-

$$R_i = \frac{d_i^+}{d_i^+ + d_i^-} \quad (13)$$

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

5. Results and Discussion

5.1. Simulations

In order to evaluate our proposed method based on Fuzzy MADM to improve the quality of service (QoS) compared to the classical MADM method, we realized simulation experiments for FAHP used in sec 4. B. taking into consideration a new important criterion Battery Energy attribute, the results obtained for a new approach are then compared to those of the classical method.
In the simulation scenarios, we considered five available networks (WLAN, HSPA(3G), LTE(4G), WIMAX1 and WIMAX2). On the user side, we consider four types of applications with different QoS requirements including (Conversational, Streaming, Interactive, and background). During the simulation, for each candidate networks, the measures of five attributes throughput (Mb/s), data rate (Mb/s), Jitter (Ms), Latency (Ms) and Battery Energy (%) are randomly varied according to the ranges shown in table 2. The Battery Energy (BE) value range is divided into 3 parts: (BE1: Low) = 1-15%, (BE2: Medium) = 15-50% and (BE3: high) = 50-100%. At each level interval, corresponds to a different weight vector. For each simulation, the five algorithms were run in 100 vertical handoff decision points by using MATLAB simulator.

5.2. Evaluations

To evaluate the effectiveness of our proposed method with the classical MADM method, a simulation set is processed with the MATLAB simulator to compare the performances of our proposed algorithm, and to prove the importance of the Battery Energy attribute. For every QoS class, we will compare decisions of the 2 approaches and see if our approach gives same roaming decisions results as classical approach. Therefore, we analyze the results of the method that provides the best performances in order to reduce the number of handoffs, afterwards we will compare the proposed methods using the relative standard deviation (RSD).
The relative standard deviation is often times more convenient. It is expressed in percent and is obtained by multiplying the standard deviation S by 100 and Divide this product by the average $\bar{x}$.

$$RSD = \frac{S}{\bar{x}} * 100 \quad (15)$$

- **Simulation for background traffic:**

The traffic analyzed in this simulation is background, we compare the performance of F-TOPSIS-BE and F-TOPSIS.
Fig. 5. presents a comparison of the weights generated by the F-TOPSIS-BE and F-TOPSIS methods. For the background class, battery energy was assigned high weight value by our FAHP-BE technique, as shown in Fig. 5., and this is expected to give better selection of the desired network.

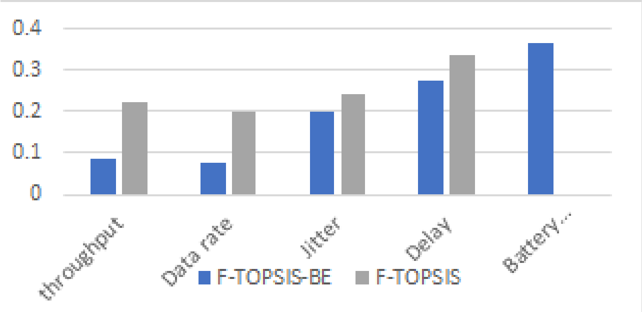

Fig.5: Associated weights for background traffic.

Through simulation in Fig. 6., we notice that F-TOPSIS-BE method can reduce the number of handovers to 38%, while classical F-TOPSIS method can only it to 45%.

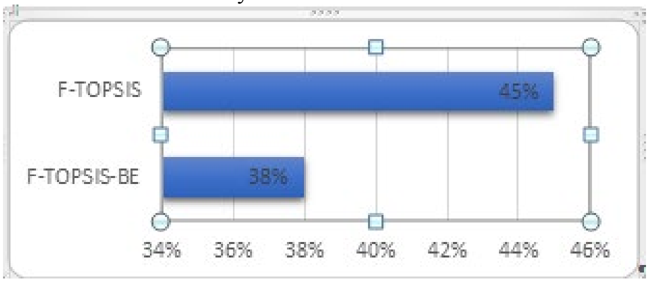

Fig.6: Average of the number of handover for background.

- **Simulation for interactive traffic:**

The traffic analyzed in this simulation is interactive, we compare the performance of F-TOPSIS-BE and F-TOPSIS.

Fig. 7. presents a comparison of the weights generated by the F-TOPSIS-BE and F-TOPSIS methods.

Table 2: The QoS criteria.

Technology	Throughput (Mb/s)	Data Rate (Mb/s)	Jitter (ms)	Delay (ms)	Battery Energy (%)
HSPA (3G)	0,1 – 15	0,2- 6	5 - 20	25 -50	BE1
LTE(4G)	1 – 80	29 - 80	2 - 10	20 -80	BE3
WLAN	0,5 - 11	0,5 - 12,5	10 - 25	90 -150	BE2
WiMAX1	1 – 60	3 - 40	3 - 10	50 -120	BE1
WiMAX2	1 – 50	2 - 50	5 - 10	60 -100	BE3

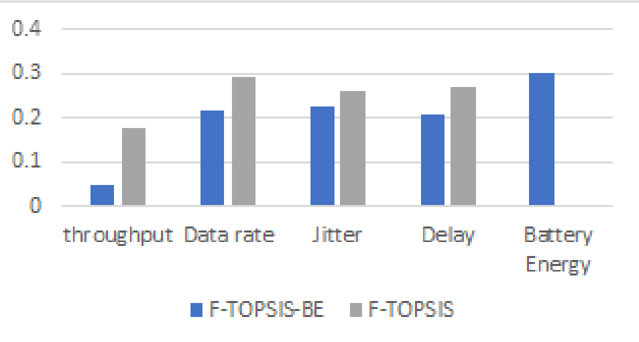

Fig.7: Associated weights for interactive traffic.

Based on the simulation showing in the Fig. 8., is shown that F-TOPSIS- reduce the number of handoff with value 29%, unlike the classic method which reduces it with the value of 34% for interactive traffic.

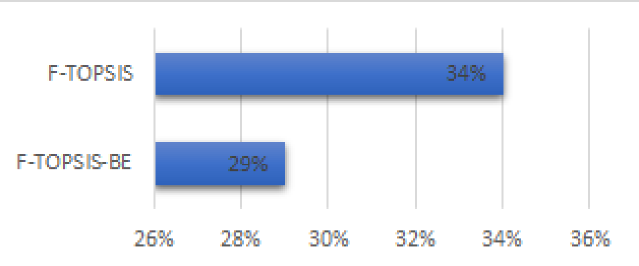

Fig.8: Average of the number of handover for interactive.

- **Simulation for conversational traffic:**

The traffic analyzed in this simulation is conversational, we compare the performance of F-TOPSIS-BE and F-TOPSIS.
Fig. 9. presents a comparison of the weights generated by the F-TOPSIS-BE and F-TOPSIS methods.

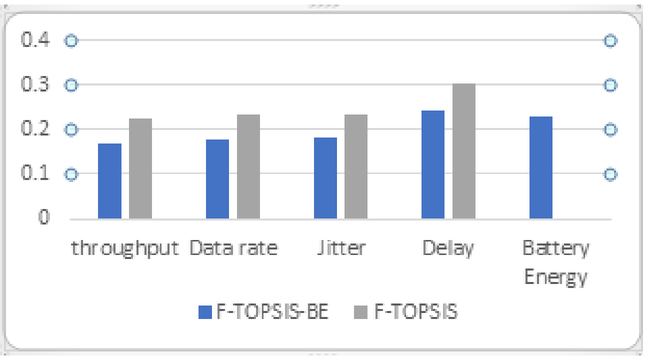

Fig.9: Associated weights for conversational traffic

After the comparison shown in the Fig. 10., we can illustrate that the F-TOPSIS-BE reduce the number of handoff with the value 38%, which shows that our proposed method always has better results.

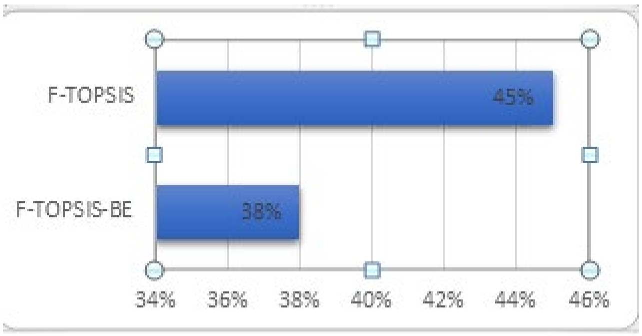

Fig.10: Average of the number of handover for conversational.

- **Simulation for streaming traffic:**

The traffic analyzed in this simulation is streaming, we compare the performance of F-TOPSIS-BE and F-TOPSIS.
Fig. 11. presents a comparison of the weights generated by the F-TOPSIS-BE and F-TOPSIS methods.

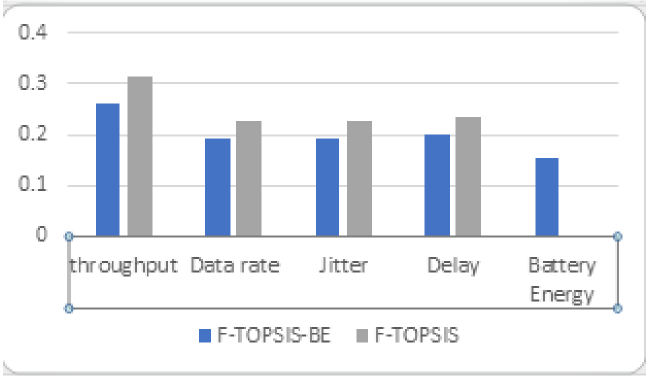

Fig.11: Associated weights for streaming traffic**.**

In the Fig. 12. showing the best results to reduce the number of handoffs it's with F-TOPSIS-BE. from there, we can conclude that in all the traffic used our proposed method can reduce the number of transfer better than the usual method.

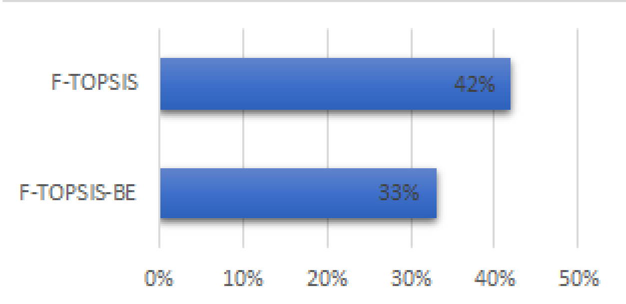

Fig.12: Average of the number of handover for streaming.

Fig. 13. illustrates the value of RSD obtained.it shows that our proposed method F-TOPSIS-BE has better RSD value compared to F-TOPSIS in all types of traffic. It is the best method for optimal network selection at the time of handoff because the best network is the closest to positive ideal solution but furthest from the negative ideal solution.

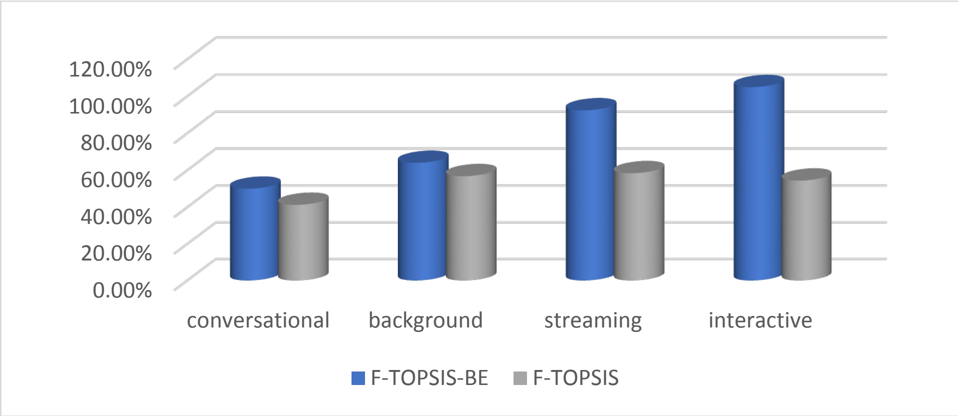

Fig.13: Relative standard deviation(RSD) of the MADM methods used for the network selection ranking.

6. Conclusion

In this paper, we propose an approach for network selection based on Fuzzy MADM using a new criterion which is the battery energy compared with the classical MADM method. we use FAHP to generate the weights of the evaluation criteria. Subsequently TOPSIS method is applied to rank the available networks. The proposed vertical handoff decision algorithm is able to determine the best candidate access network in lower delay with less complexity. The decisions are analyzed by the relative standard deviation and the best one is our proposed method.

In the future work, we intend to combine FAHP with other methods as VIKOR, SAW or MULTIMOORA in order to select the best access network. In addition, we intend to simulate our proposal on other simulators in order to compare performance using real-time data.

Acknowledgement

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