A New Fuzzy-TOPSIS based Algorithm for Network Selection in Next-Generation Heterogeneous Networks

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Abstract — The overuse of next-generation wireless networks such as 4G and future generations has made the appearance of the vertical transfer to allow mobile users to move between different heterogeneous networks at any time and anywhere. This rapid evolution of wireless communication technologies imposes an improvement of the quality of service (QoS) in order to keep the user Always Best Connected (ABC).

The purpose of this paper is to discuss the trouble of network selection employing the multi-attribute decision-making (MADM) methods to improve decision making at the time of a vertical handover. We propose a network selection approach based on the enhancement of the Fuzzy technique for order preference by similarity to the ideal solution (FTOPSIS) algorithm, applied to classify the available networks. Afterwards Fuzzy analytic hierarchy process (FAHP) method used to obtain the weights of Criteria.

Implementation and simulation experiments are presented to evaluate our proposed approach. The factual results show that our FE-TOPSIS algorithm outperforms the classic FTOPSIS algorithms.

Index Terms—Vertical Handover, Network selection, MADM, Fuzzy TOPSIS, Fuzzy AHP.

I. Introduction

The increased evolution of wireless and mobile technology makes the subject of vertical handover more attractive. Especially with the development of many heterogeneous wireless communication technologies, the mobile user requires continuity and quality of service (QoS). Thus, the next generation of 5G networks offers the properties of always best connected (ABC) to give mobile users access to stay connected anywhere and anytime ubiquitously.

The gradual revolution of wireless technologies requires an uninterrupted handover it builds a crucial step in the process of vertical handover, it enables ubiquitous handover and achieves the best QoS in a heterogeneous environment. This step is based on the selection of the best destination network among the candidate networks.

The concept of vertical handover (VHO) presented by [1] refers to all operations implemented to enable a mobile terminal to move from one network to another without loss of connection. It can be divided into three steps: handover information gathering, handover decision, and handover execution. A decision VHO concerns several parameters of QoS dedicated to the network, as well as other criteria such as user profile and network status.

In this work, the focus is on the decision-making step (2nd step of VHO) that is articulated in the network selection process. This process can be manipulated by the mobile terminal manually. Nevertheless, with the progress of the new generation networks, the selection of the network can be started automatically. actually, mobile users have multiple interfaces such as LTE, 3G, WLAN. Thus, users would roam between available wireless networks avoiding the discontinuity of service. However, several algorithms were developed to optimize the network selection problem. They can be classified by the basic algorithms (based on the received signal strength (RSS), the bandwidth, etc.), The gaming theory, Genetic algorithms, Artificial intelligence, neural networks, Multi Attributes Decision-Making Methods (MADM).

Recent scientific research dealt that MADAM is one of the most promising methods that can be applied to the problem of network selection. Thereby, 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.

The goal of this contribution is to forward our network selection approach by using Fuzzy Enhanced-TOPSIS in order to choose the best access network. That can meet the user's preferences and maximize the performance measured by the FE-TOPSIS algorithm.

The rest of this paper is arranged as follows: Section 2 summarizes the related works of vertical handover decision (VHD), network selection strategies, and the algorithms of MADM method. In section 3 we detail the system model by implementing the proposed approach. The approach for network selection problem using Fuzzy-MADM described in section 4. in section 5, we briefly presented the proposed method with enhanced F-TOPSIS. In Section 5, we present numerical results and discussion. Finally, section 7 concludes the work and gives perspectives.

II. Related works

Mobility is an essential feature that is needed in an environment of heterogeneous networks. it focuses on roaming mobile devices throughout the network and

Manuscript received June 25, 2018; revised February 21, 2019.
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doi:10.12720/jcm.14.3.194-201

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being able to connect to different radio access technologies. Vertical transfer is a crucial step to allow ubiquitous transfer and obtain the best quality of service (QoS) in a heterogeneous environment, it requires a dynamic selection of the best network, this decision phase is the most important in this case. Nevertheless, it involves analyzing and gathering the states of the candidate networks and classify them to choose the one which suits the best of the mobile user's preferences.

A brief literature review of papers [2,3] dealing with an overview of the vertical handover process, their types, protocols, algorithms, and architecture proposed. Furthermore, plenty of research efforts have been focused on vertical handover decision algorithm [4]. In [5], the author uses the RSSI as a main criterion for the vertical handover procedure, though this algorithm is not practical, may often cause a ping pong effect. Therefore, using a single parameter it is unable to meet the requirements of the user in a handover process. In this context, authors [6,7] offer several schemas dependent on several parameters such as battery power, bandwidth, delay, jitter, user preferences. A decision of the vertical handover depends on a variety of network QoS parameters as well as many other criteria. Due to a large number of these criteria, the multiple attribute decision-making method (MADM) has been proposed to reinforce this problem.

The goal in MADM methods is amply used for solving VHO decisions due to their implementation simplicity and decision precision. There are several authors [8,9] compare different types of MADM algorithms (SAW, TOPSIS, GRA, AHP, and MEW) for providing handover solution. MADM problems have various common features such as Alternatives, Multiple attributes, Decision matrix, Attribute weights and Normalization. The most known algorithms [10-12] to calculate the corresponding weighting of the criteria are analytic hierarchy process (AHP), fuzzy analytic hierarchy process (FAHP), analytic network process (ANP) and fuzzy analytic network process (FANP). whereas dedicated algorithms [13-17] for classifying candidate networks are the simple additive weighting (SAW), multiplicative exponential weighting (MEW), technique for order preference by similarity to the ideal solution (TOPSIS), Gray Relational Analysis (GRA) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR).

However, algorithms based on artificial intelligence are the most powerful for decision-making. it's build on techniques of intelligence implementation such as fuzzy logic [18] and neural networks [19]. In [20], Fuzzy Logic is used for VHO's decision in dealing with QoS parameters, and user preferences. In [21] presented a fuzzy TOPSIS method based on the fuzzy extension, which calculates the fuzzy relative closeness of each alternative by resolve the nonlinear programming models.

In this context, we explore the use of Fuzzy AHP to determine the relative weights of the evaluation criteria and Fuzzy TOPSIS to rank the alternatives using the modified TOPSIS method. The mathematical modeling of these methods is given in the next section. Thus, the purpose of this paper is to extend the Fuzzy TOPSIS method to decision-making problems with stochastic data.

III. SYSTEM MODEL

This work led us to study the weaknesses of the TOPSIS method used to classify access networks, one of the problems attributable to TOPSIS before and which still persists with Fuzzy TOPSIS is the reversal phenomenon. in this phenomenon the alternatives order of preference changes when an alternative have to be moved or added from the decision problem. In order to improve the limits of the TOPSIS method, some authors [22,23] pose the problem of rank reversal but they do not provide a solution to the problem.

Our contribution is to give an improvement to the Fuzzy TOPSIS algorithm based vertical handover decision, by assembling the Fuzzy-AHP method applied to obtain the weights of the criteria, and the proposed FE-TOPSIS method for classifying available networks. The decision makers must choose the best network among the available ones based on the QoS metrics.

As disclosed in Fig. 1, we begin by collecting information such as alternatives, evaluation criteria. Subsequently, we built the decision of the matrix using the different information collected in the first step. Afterward, the pairwise comparison process is launched according to each QoS class: Conversational, Streaming, Interactive, and Background. we used eventually to compute the weight vectors the Fuzzy-AHP method considering the throughput, data rate, jitter, latency, and battery of each participating access networks to make the handover decisions. Thereupon, our new proposed method FE-TOPSIS is applied to the Fuzzy weighted matrices to have the ranking of the available networks.

Finally, our new approach based on Fuzzy Enhanced-TOPSIS technique (FE-TOPSIS) to solve the problem of decision making in heterogeneous networks, expressed in the four following steps:

1- Construction of the decision matrix Q, where each line i corresponds to an available network $(A_1, A_2, A_3 \dots)$ and each column j corresponds to a different criterion $(C_1, C_2, C_3 \dots)$.
2- Assigned the weight conveniently to each criterion by used the FAHP method, taking into consideration each traffic classes.
3- Calculate the performance of each access network by using our new approach based on FE-TOPSIS.
4- Ranking the alternatives of our new method in descending order.

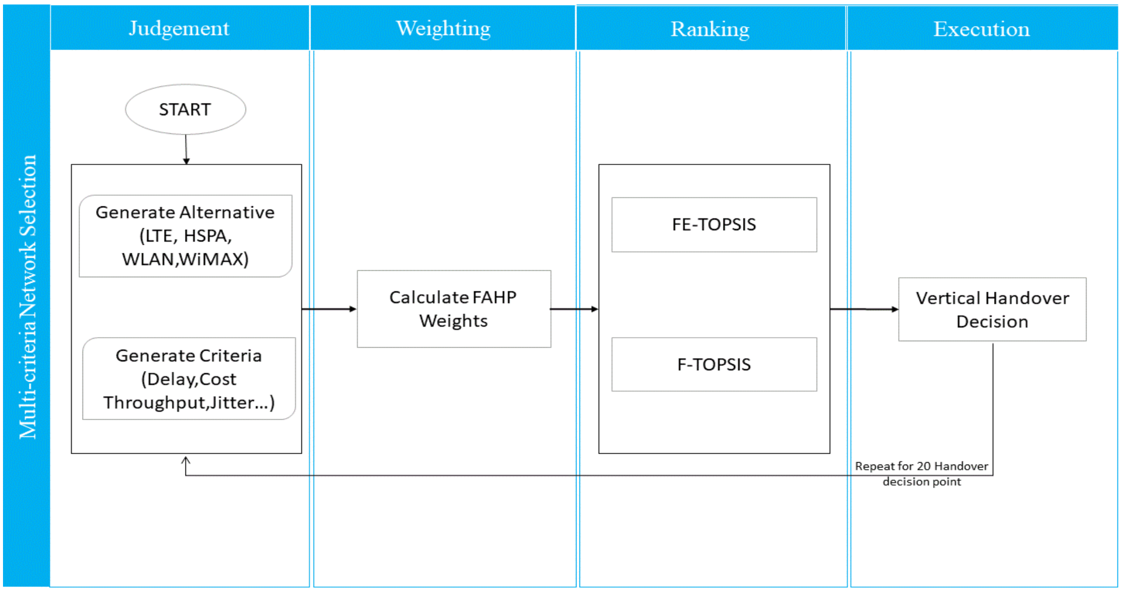

Fig. 1. Flowchart of the system model.

IV. FUZZY-MADM THEORY

A. Fuzzy set and linguistic variables

Facing to deal with vagueness of human thought, Zadeh [24] introduced the fuzzy set theory has been used as a modeling tool for complex systems that can be controlled by humans but hard to defined fairly. Its ability in representing vague data is considered as the major contribution of fuzzy set theory to science and technology. With fuzzy sets one element may partially belong to the set, that is most commonly specified with interval of real numbers between 0 and 1 using "Linguistic terms".

- **Triangular Fuzzy Numbers (TFNs):**

In the existing researches, the triangular and trapezoidal fuzzy numbers (TFN) are used to define the vagueness of parameters. In this analysis, we used trapezoidal fuzzy number [25,26] to perform the pairwise comparison that will be defined by four real numbers expressed by $\mu_{A(x)} = (a, b, c, d; w)$ [27], where a, b, c and d are real values and $0 < w \leq 1$ presented in Fig. 2. A TFN can be defined as:

$$\mu_{A(x)} = \begin{cases} w\frac{x-a}{b-a}, & a < x < b \\ w, & b < x < c \\ w\frac{d-x}{d-c}, & c < x < d \\ 0\ , & Otherwise \end{cases} \quad (1)$$

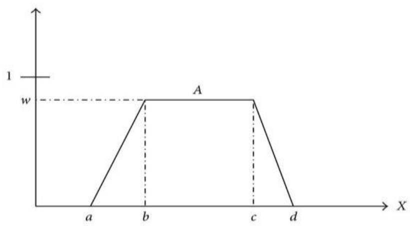

Fig. 2. Trapezoidal fuzzy number $\mu_{A(x)}$.

The choice of TFN is related to the number of classifications by using linguistic variables [28,29], as in Table I. to evaluate the importance of the criteria and the ratings of alternatives with respect to qualitative criteria.

TABLE I. MEMBERSHIP FUNCTION OF LINGUISTIC VARIABLES.

Linguistic Variables	Scale of fuzzy number
Very Low (VL)	(0, 0, 0.1, 0.2)
Low (L)	(0.1, 0.2, 0.2, 0.3)
Medium Low (ML)	(0.2, 0.3, 0.4, 0.5)
Medium (M)	(0.4, 0.5, 0.5, 0.6)
Medium High (MH)	(0.5, 0.6, 0.7, 0.8)
High (H)	(0.7, 0.8, 0.8, 0.9)
Very High (VH)	(0.8, 0.9, 1.0, 1.0)

B. Fuzzy AHP

On the basis of the concept of fuzzy set theory, fuzzy AHP it is a robust technique of solving complex multiple-criteria decision-making problems, presented by [30,31]. Thus, the fuzzy AHP approach is proposed to improve the weaknesses of the classical AHP [32,33]. This method is applied to many decision problems, in our case is used to calculate the weight of alternatives for network selection. Using Trapezoidal fuzzy number (see Table I) and via pairwise comparison, the fuzzy evaluation matrix $Q = (q_{i,j})_{n*m}$ is constructed, as: $q_{i,j} = (a_{i,j}, b_{i,j}, c_{i,j}, d_{i,j})$ and $q_{i,j}^{-1} = \left(1/a_{i,j}, 1/b_{i,j}, 1/c_{i,j}, 1/d_{i,j}\right)$.

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:

$$A = \begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{bmatrix} \quad (2)$$

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

$$a_{ij}S_i = \sum_{j=1}^{m} q_{ij} \odot \left[\sum_{i=1}^{n}\sum_{j=1}^{m} q_{ij}\right]^{-1} \quad (3)$$

- As $S_1 = (a, b, c, d)$ and $S_2 = (e, f, g, h)$ are two Trapezoidal fuzzy numbers, the degree of possibility of $S_2 = (e, f, g, h) \geq S_1 = (a, b, c, d)$ is defined as:

$$V(S_2 \geq S_1) = \sup_{y \geq x}\{\min(S_1(x), S_2(y))\} \quad (4)$$

This can be equivalently expressed as follows:

$$V(S_2 \geq S_1) = f(x) = \begin{cases} 1, & f < b \\ 0, & b\text{-}g \geq h + a \\ \frac{g\text{-}b+h+a}{h+a}, & 0 < b\text{-}g < h + a \end{cases} \quad (5)$$

- 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 by:

$$V(S \geq S_1, .. S_k) = V\,[(S \geq S_1) \cap (S \geq S_2) \cap \ldots (S \geq S_k)] = min\big(V(S \geq S_i)\big), i = 1,2 \ldots, k \quad (6)$$

- Via normalization, the normalized weight vectors are:

$$W' = (w'_1, w'_2, \ldots, w'_m)^T \text{Where } A_i(i1,2, \ldots, m) \text{ are m attributes.} \quad (7)$$

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.

C. Fuzzy TOPSIS

The fuzzy technique for order performance by similarity to ideal solution (FTOPSIS) is a method to choose the best alternative closest to the ideal positive solution (FPIS) and distant from the ideal negative solution (FNIS), was first introduced by Hwang and Yoon [34]. The basic logic of the FTOPSIS method is to represent the alternatives as points in a n-dimensional Euclidean space with each dimension representing each criterion and their ranking is produced according to their proximity to the ideal and anti-ideal points. The method is used in order to evaluate the selection of the network using linguistic variables.

The steps to implement the FTOPSIS method is as follows:

Step 1: Construction of the fuzzy decision matrix for the ranking with *m* alternatives and *n* criteria.

$$A = \begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{bmatrix} \quad (8)$$

Where $\tilde{a}_{ij}$, $i = 1,2, \ldots, m$, $j = 1,2, \ldots, n$ are expressed as a linguistic variable or TFN.

Step 2: Construction of the weighted normalized fuzzy decision matrix, by using the equation (9).

$$\tilde{v}_{ij} = \widetilde{w}_j * \tilde{r}_{ij} \quad (9)$$

Where $\widetilde{w}_j$ represents the weight of the j^{th} criteria with appropriate linguistic variables $\widetilde{w}_j = (\widetilde{w}_{jl}, \widetilde{w}_{jm}, \widetilde{w}_{ju})$.

Step 3: Calculate the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS), respectively, are defined as:

$$\tilde{A}^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \tilde{v}_3^+, \ldots, \tilde{v}_n^+) \qquad \tilde{v}_j^+ = \max_i v_{ij} \quad (10)$$

$$\tilde{A}^- = (\tilde{v}_1^+, \tilde{v}_2^-, \tilde{v}_3^-, \ldots, \tilde{v}_n^-) \qquad \tilde{v}_j^- = \min_i v_{ij} \quad (11)$$

Where $\tilde{v}_j^+ = (1,1,1)$ and $\tilde{v}_j^- = (0,0,0)$, $j = 1,2, \ldots, n$

Step 4: Calculate the distance of each alternative from FPIS and FNIS by using the m-dimensional Euclidean distance as follows:

$$S_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+) \;\; i = 1,2, \ldots, m \quad (12)$$

$$S_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \;\; i = 1,2, \ldots, m \quad (13)$$

Step 5: Calculate the relative closeness to the ideal solution, is defined by:

$$C_i = \frac{S_i^-}{S_i^- + S_i^+} \;\; (i = 1,2, \ldots, n) \quad (14)$$

Step 6: The ranking of the alternative is performed by sorting the values of relative closeness Ci, in descending order.

V. THE PROPOSED FE-TOPSIS BASED METHOD

The FTOPSIS method ranks alternatives with respect to Euclidean distances from ideal positive solution (FPIS) and ideal negative solution (FNIS) in order to calculate the closeness C_i for each access network. The best alternative is the closest to the ideal positive solution and the farthest from the ideal negative solution. This can be credible if one sets equivalent values to the same distances regardless of the locations over the range of the best ideal positive solution and the worst ideal negative solution. By respecting FTOPSIS method, that means a distance closer to the S_i^+ (Eq. (12)) should be more weighted compared to the same distance closer to the S_i^-(Eq. (13)).

In this regard, we are working on the same process evoked by lahby [35], but we use the Fuzzy TOPSIS to select the best access network. The procedure of our method proposed named FE-TOPSIS starts from modifying the equation (Eq. (14)) of classical method FTOPSIS, to construction of two relative importance (μ_1, μ_2) respectively of the ideal and anti-ideal solution, to calculate the new value of relative closeness to the ideal solution, we use the new equation $C_i^{Proposed}$ as follow:

$$C_i^{Proposed} = 1 - \frac{\mu_1 * S_i^{+} + \mu_2 * S_i^{-}}{S_i^{+} + S_i^{-}} , i = 1, \dots, n \qquad (15)$$

However, the step described in the equation (Eq. (15)) in which the closeness is calculated is obtained by using AHP method to find the relative importance μ_1 and μ_2 for each traffic classes.

So basically, after finishing the ranking of the alternatives the closeness coefficients are ranked in descending order. the network with the highest value $C_i^{Proposed}$ is used to determine the rank.

VI. Numerical results and discussion

A. Simulations

To assess our presented algorithm, we foremost use a numerical example to compare Fuzzy TOPSIS and our proposed method using enhanced Fuzzy TOPSIS. Subsequently, we consider four available networks (LTE(4G), HSPA(3G), WLAN and WIMAX), and we perform the simulation for four QoS traffic classes namely (interactive, conversational, background, and streaming) to provide the average value of the number of handovers. Each traffic class is attached with six different QoS parameters: Available Bandwidth (AB), Security (S), Cost per Byte (CB), Packet Jitter (J), Packet Delay (D), and Packet Loss (L) shown in Table II. Although the simulation was run in 20 vertical handover decision points by using MATLAB simulator.

Thus, we establish fuzzy decision matrix by the evaluation of alternative networks by linguistic variables as Table I. Nonetheless, linguistic variable [36] shown in Table I. is used to create pairwise comparison matrix using Fuzzy-AHP method to generate the different weights shown in Table III. After weights was determined, we use AHP method to determine the relative importance μ_1 of the ideal solution and μ_2 of the anti-ideal solution shown in Table IV. For each QoS [37] traffic classes. Afterward, we use our FE-TOPSIS to calculate the new relative closeness to the ideal solution $C_i^{Proposed}$ (Eq. (15)). Finally, the ranking of each access network for the four traffic classes.

B. Discussion of Results

With the enhancement approved by the proposed FE-TOPSIS method to ensure a better network selection decision that enables a ubiquitous vertical handover. FE-TOPSIS supply a ranking that allows a speedy and intelligent vertical transfer.

The results of the comparison accomplish in this paper show that the proposed Fuzzy approach FE-TOPSIS is performant for the selection of the network compared to the classical method. In the first simulation, we provided

TABLE II: THE QOS CRITERIA.

Technology	Throughput (Mb/s)	Data Rate (Mb/s)	Jitter (ms)	Delay (ms)	Packet loss (%)	Cost (price)
LTE (4G)	G (0.7,0.8,0.8,0.9)	G (0.7,0.8,0.8,0.9)	G (0.7,0.8,0.8,0.9)	F (0.4,0.5,0.5,0.6)	MG (0.5,0.6,0.7,0.8)	G (0.7,0.8,0.8,0.9)
HSPA (3G)	MG (0.5,0.6,0.7,0.8)	G (0.7,0.8,0.8,0.9)	MG (0.5,0.6,0.7,0.8)	G (0.7,0.8,0.8,0.9)	MG (0.5,0.6,0.7,0.8)	G (0.7,0.8,0.8,0.9)
WLAN	F (0.4,0.5,0.5,0.6)	F (0.4,0.5,0.5,0.6)	G (0.7,0.8,0.8,0.9)	VG (0.8,0.9,1.0, 1.0)	MG (0.5,0.6,0.7,0.8)	G (0.7,0.8,0.8,0.9)
WiMAX	F (0.4,0.5,0.5,0.6)	P (0.1,0.2,0.2,0.3)	G (0.7,0.8,0.8,0.9)	G (0.7,0.8,0.8,0.9)	MG (0.5,0.6,0.7,0.8)	G (0.7,0.8,0.8,0.9)

TABLE III: WEIGHTS

Traffic Class	Throughput (Mb/s)	Data Rate (Mb/s)	Jitter (ms)	Delay (ms)	Packet loss (%)	Cost (price)
Conversational	(0.1,0.2,0.2,0.3)	(0.2,0.3,0.4,0.5)	(0.1,0.2,0.2,0.3)	(0.1,0.2,0.2,0.3)	(0.2,0.3,0.4,0.5)	(0.2,0.3,0.4,0.5)
Streaming	(0.1,0.2,0.2,0.3)	(0.1,0.2,0.2,0.3)	(0.4,0.5,0.5,0.6)	(0.5,0.6,0.7,0.8)	(0.1,0.2,0.2,0.3)	(0.1,0.2,0.2,0.3)
Interactive	(0.1,0.2,0.2,0.3)	(0.1,0.2,0.2,0.3)	(0.1,0.2,0.2,0.3)	(0.5,0.6,0.7,0.8)	(0.1,0.2,0.2,0.3)	(0.1,0.2,0.2,0.3)
Background	(0.2,0.3,0.4,0.5)	(0.1,0.2,0.2,0.3)	(0.2,0.3,0.4,0.5)	(0.5,0.6,0.7,0.8)	(0.2,0.3,0.4,0.5)	(0.1,0.2,0.2,0.3)

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TABLE IV. THE RELATIVE IMPORTANCE μ_1 AND μ_2 FOR EACH TRAFFIC CLASSES.

Traffic class	μ_1	μ_2
Conversational	0.900	0.100
Streaming	0.750	0.250
Interactive	0.833	0.166
Background	0.875	0.125

a numerical example to clarify the comparison between the proposed approach and the classical method. In the second simulation, we provide the average of the number of handovers.

Fig. 3. show that the FE-TOPSIS algorithm reduces the number of handovers for the four applications (Background, Interactive, Streaming, Conversational) better than the FTOPSIS algorithm. This improvement makes it possible to hide the weaknesses of the FTOPSIS algorithm in the decision-making phase.

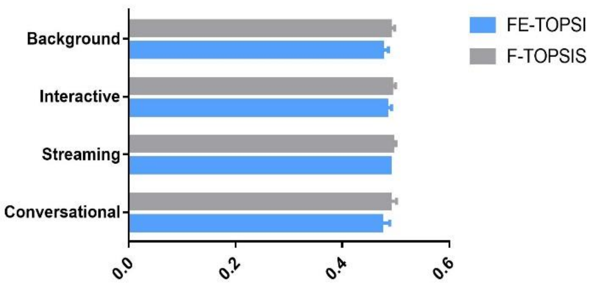

Fig. 3. The results obtained from the comparison of FE-TOPSOS with F-TOPSIS for each class of traffic.

Fig. 4. emphasizes the performance of FE-TOPSIS overlook to the average number of handovers for each class of traffic. Although, all the values provided by our method are higher than the other values of the classical method. We notice that the FE-TOPSIS algorithm reduces the number of handover with a value of 43%, 44% and 46% for background, conversational, and (interactive, streaming).

TABLE V. IMPROVEMENT OF FE-TOPSIS FOR ALL TRAFFICS.

Traffic class	FE-TOPSIS
Conversational	3% ↓
Streaming	3% ↓
Interactive	1% ↓
Background	1% ↓

Table V. below represents the improvement achieved by the FE-TOPSIS algorithm for the four types of traffic. The proposed FE-TOPSIS approach has succeeded to reducing the number of handovers, for conversational and streaming traffic since dropped by up to 3% compared to the F-TOPSIS algorithm. Nonetheless, interactive and background traffic decreased by up to 1% compared to the classic F-TOPSIS algorithm. For this if the FE-TOPSIS accuracy is high it makes it easy to identify the ranking order and simply select the best network. This means that our proposed approach has better solved the problem of handover in a heterogeneous environment.

VII. CONCLUSIONS

In order to avoid service discontinuity in heterogeneous networks, a new mechanism for network selection based on the enhancement of the Fuzzy TOPSIS algorithm is implemented for an omnipresent network. Our mechanism uses the Fuzzy AHP method for the weighting of the evaluation criteria, combined with the ranking method enhanced Fuzzy TOPSIS. To evaluate the effectiveness of our proposed FE-TOPSIS method based on the concept of multi-criteria, we had to compare it with the classical method F-TOPSIS.

The simulation experiments prove that our proposed method achieves a significant QoS improvement over the classical method. The proposed vertical handover decision algorithm is able to determine the best candidate access network in lower delay with less complexity.

In future work, we intend to compare the FE-TOPSIS method with other MADM methods, in order to certify its effectiveness. In addition, we intend to simulate our

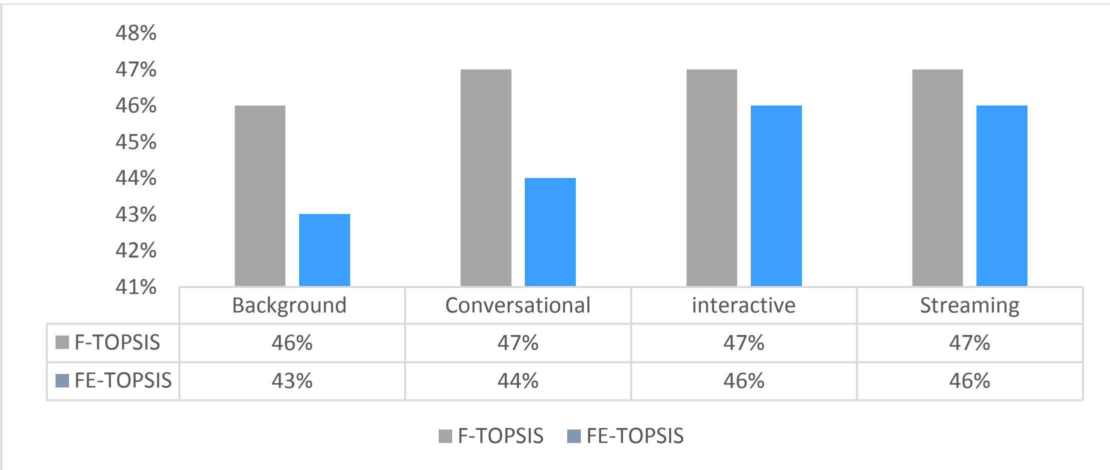

Fig. 4. Average of the number of handover for all traffic.

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proposal on other simulators in order to compare performance using real-time data.

ACKNOWLEDGMENT

This work is supported by the grant of National Center for Scientific and Technical Research (CNRST -Morocco) (No.16UH22016).

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