

A modified-SAW for network selection in heterogeneous wireless networks

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ABSTRACT

In the context of heterogeneous networks, users with multi-mode terminals can connect to different radio access technologies such as IEEE802.11, 3G (HSPA and HSPA+) and Long-term Evolution (LTE) at the same time. The challenge is to achieve the Always Best Connected (ABC) concept; the main issue is the automatic choice of the suitable Radio Access Technology (RAT) from the list of the available RATs. This decision is called the network selection (NS).

In this paper, we propose a modified Simple Additive Weigh (modified-SAW) function to deal with the drawbacks of the existing solutions. Indeed, the existing Multiple Attribute Decision Making (MADM) methods suffer mainly from the famous problem of rank reversal once an alternative is added or removed, other problems occur in the legacy MADM such as the sensitiveness to the user preference in Technique for Order Preference by Similarity to Ideal Solution (TOPSIS); the penalization of the alternatives with poor attributes values in Weighted Product Model (WPM). Our simulations brought out the lakes of the traditional MADM approach in the context of network selection. We modify the SAW method intelligently and we use it to solve the NS problem. Finally, we compare the performance of our solution with the previous works in different scenarios; the simulations show that our proposal outperforms the other existing methods.

Keywords: Always Best Connected, Multiple Attribute Decision Making, Modified-SAW, Network selection, Radio Access Technologies.

1. INTRODUCTION

Up to the third generation network, the radio access network was mainly homogeneous and the user has to connect to only one RAT. After that, the development of the network technologies has led to an impressive growth of the internet applications and services, and an increasing in the mobile user's industry. People now are equipped with Smartphones try to achieve for the ABC concept. It is obvious that

no single network technology can sustain that, therefore, it was necessary to change the whole design, i.e. switching from the homogeneous systems to the heterogeneous systems. The aim of the fourth generation network is to achieve the ABC concept by offering the mobile users the ability to take advantage of networks having different architectures and performances.

Nowadays, we have a variety of RATs, the WLAN basically IEEE802.11, UMTS, HSPA and the LTE. This variety constitutes the elements of the heterogeneous environment [1]. The heterogeneous system allows mobile users to choose a RAT among a list of RATs based on several criteria, this choice is called network selection and this is the scope of this paper.

The network selection procedure consists of the dynamic and the automatic selecting the best available network among the available RATs. The best network may differ from one user to another due to the different criteria involved cost, Quality of service (QoS), energy consumed etc. In the classical cellular systems, the network selection is directed by the physical layer parameters, and the mobile terminal is often associated with the base station having the best received signal. Such a selection policy is obviously not suited for the heterogeneous wireless access technologies. For instance, a user may favour connecting to a less loaded RAT at a larger distance with a lesser Received Signal Strength (RSS), rather than a more loaded cell with a high RSS. The ultimate goal is to satisfy the users with the best QoS.

The network selection in a heterogeneous environment can be reported to the MADM problems since it involves a huge number of criteria. The MADM approach has been widely used to solve the NS problem [2], [3], [4]. Other methods like fuzzy logic and game theory [5], [6], [7] have also been used to solve the network selection. Many studies in the literature propose algorithms that select a network among a set of candidate networks. These algorithms try to find and connect to the best networks and this is not always good because, several users may choose the same network simultaneously, thus the network become loaded and it becomes quickly unreachable. So, it would be interesting to have the optimal rank of networks and then select the best network not loaded. This is the motivation of this work.

Our study seeks to find the best network, in addition, we give the users the other alternatives in the case when the best network is unreachable, i.e., we give the list of the ranked networks to select one

Manuscript received on May 31, 2017 ; revised on June 9, 2017.

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of them according to the network load. In this paper, we try to bring out our solution based on the modified-SAW and we make a comparison with the legacy MADM methods.

The rest of the paper is organised as follows Section 2 presents the problem formulation and the related works, in Section 3 we give the mathematical description of the proposed method, in Section 4, the simulations are presented and the performance analysis is provided, finally a conclusion and perspectives are given in section 5.

2. NETWORK SELECTION

In this section, we present the context of network selection; we discuss the involved criteria in the process and the steps of the NS procedure. After that, we give an overview of the existing works in the area of NS, a detailed description of the methods used in this paper can also be found in this section.

2.1 Problem context

In the Next Generation Network, the heterogeneous wireless access is a promising feature in which the users are sufficiently flexible to select the most appropriate network according to their needs. In these circumstances, the network selection has an important task for the smooth functioning of the whole communication system. Indeed, the NS process consists of switching between RATs to serve the user with the best network [6]. So, when a user with a multi-mode terminal discovers the existence of various RATs within the same area Fig.1 he should be able to select the best network to get the desired service.

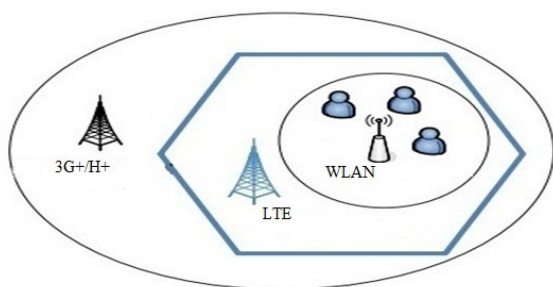


Fig.1: *Heterogeneous wireless environment [6].*

The different RATs provide different characteristics in terms of delay, jitter, throughput and packet loss rate. For this reason, in the context of heterogeneous systems, selecting the best RAT is a hard task. Many parameters influence the decision process of the best RAT [8], the battery level status level, the energy required for the requested services, the Signal to Interference plus Noise ratio received (SINR), the cost to pay, the bandwidth required, the user preferences, QoS etc The NS procedure is the decisive part of

the vertical handover process (VHO), it can be either centralised (network-centric) or decentralised (user-centric).

For the centralised approach, the operator controls the whole process and makes the decisions, the users obey these decisions and execute them, and this can be a good strategy to avoid problems like the selfish behaviour of users who always try to get the best RAT resulting in a congestion situation. On the other hand, this approach assumes a situation of a single operator with multiple networks RATs; this strategy cannot be used in the case of multiple operators.

For the user-centric approach, users make decisions by themselves; this approach is decentralised and can easily generate a congestion situation because of the selfish nature of users. Nowadays, almost all operators offer 3G and 4G radio access and even the Wi-Fi connections, so, the centralised approach is suitable to use. The network selection procedure consists of the following parts:

Monitoring step: the objective of this step is to discover the available RAT, collect the network radio conditions, and the other characteristics of the RATs. In this stage, some of the parameters are estimated and others are calculated.

Decision step: the network selection decision is started. The choice of the best network is based on the monitoring process and other parameters provided by the mobile device, the network and the user preferences. At this stage, a decision algorithm is used to rank the different RATs.

Execution step: consists on connecting to the target RAT.

2.2 Related work

Several works in the literature treat the NS problem, these works focus on the optimisation of the network selection decision for the users in order to support many services with the best QoS in a smooth manner. In the following, we present an overview of the related works in the field of network selection.

In [9] the authors have used the Simple Additive Method SAW to get a ranked list of networks, while in [10] the authors make a mix between game theory and SAW method. The main benefits of SAW are the simplicity and the low complexity, it has two major drawbacks, first: a parameter can be outweighed by another one, second: the rank reversal phenomenon that represents a problem of the entire MADM approach.

A comparison study is performed in [9], indeed, the authors compare the performance of the vertical handover VHO using SAW and TOPSIS. The authors conclude that the TOPSIS method outperforms the SAW method. In general, we can say that the compensatory methods such as TOPSIS avoid the problem where a parameter can be outperformed by another one; this is allowed using some trade-

off between the criteria. This means that a poor value in one criterion is neglected by a good value in the other criteria, this concept provides more credibility for whole NS process comparing to the non-compensatory methods, which use the thresholds and do not allow any kind of trade-off between criteria.

In [11] the authors have proposed an algorithm based on TOPSIS and the weight vector is calculated using the Entropy formula. They claim that the obtained numerical results demonstrated that the proposed algorithm can select the best available network in heterogeneous environments based on user preferences and/or service requirements.

A comparative study between SAW and WPM in the context of vertical handover is done [12]. The authors use the relative standard deviation as a metric of comparison and they obtain a conclusion that WPM is better than SAW. In [13], the authors use the M-ANP method in the context of heterogeneous systems, their conclusion is that the combination of M-ANP with TOPSIS is a more robust approach for dynamic decision making to avoid penalising the attributes with poor quality to a greater extent.

The AHP method is used in [14] to rank the importance of various criteria used and to compare the desirability of different Internet advertising networks; the proposed model provides an objective and effective decision model for advertisers to be used in selecting an Internet advertising network. Authors in [15] have compared the original AHP with a modified version called the Fuzzy AHP, the important criterion used is the Quality of Experience QoE; indeed, the authors used the fuzzy complementary matrix and the fuzzy consistent matrix to relax the consistency requirement in the conventional AHP. The Numerical results show that the proposed scheme Fuzzy AHP outperforms the conventional AHP scheme.

The MADM methods are widely used to solve the network selection problem, this is due to the multiple criteria nature of this problem; in addition, these methods are easy to use and understand, these methods have also a low computational complexity. The drawbacks of these methods are summarised in the following:

- The MADM methods don't have the same performance toward the different services (VoIP, Video Calls, web browsing), indeed, these methods have a good performance for the VoIP service and a bad performance for the best effort services. This instability involves great problems because users use different services.

- MADM methods suffer from the problem of ranking abnormality, i.e. it is a phenomenon that occurs in the MDAM methods when an exact replica or a copy of an alternative was introduced or eliminated, authors in [16] has shown that the rank reversal problem occurs in most of the well-known MADM methods, this problem has been addressed in other works

[17], [18] by modifying methods, but the original versions of MADM methods suffer from the rank reversal phenomenon. Another remark to add is that some methods like AHP are very complicated and has a high complexity computation. For all these reasons, we can say that MADMs are a good and acceptable solution for the NS problem, but the lack of a general method that serves all kinds of services and the rank reversal phenomenon is a big problem.

2.3 MADM methods: Mathematical description

In this section, we describe the well-known methods used to solve the network selection. In particular, MADM methods, these methods are used in section 4 to make the comparison with our proposal.

The MADM approach is a famous mathematical approach in the context of preferential decisions; it treats problems involving many decision criteria and many alternatives. This branch of decision making is widely used in various fields such as the economy sector [19], [11], [9]. Indeed, ordinary people in the daily life use this approach, for example, to buy a car or a house having different characteristics "etc.

This approach MADM is very adapted to the network selection problem because of the multi-criteria nature of the NS problem [20]. In [21] the authors present the basics of this approach: Alternatives: represent the different choices of actions available to the decision maker. The set of alternatives is assumed to be finite. In the NS scenario, the alternatives are the different RATs. Set of criteria: called also goals, it represents the attributes used in the decision-making process. The attributes may conflict with each other because they represent the different dimensions from which the alternatives can be viewed; for instance, the cost may conflict with profit, etc. Here, an important aspect must be clarified, the MADM are very hard to solve because of the possible different units of the attributes. So, the attributes are heterogeneous and haven't the same unit, the solution is the use of the normalisation methods to unify the unit. For our NS scenario, criteria are throughput, jitter, delay, cost ...etc Weights: it means the importance of the criterion in the decision process, the sum of the weight is equal to one. Different methods are used to determine the weight values.

Finally, we get a decision matrix representing the system, where the columns are the criteria and the lines are the alternatives. Several methods use the MADM approach philosophy have been proposed in this context, such as Simple Additive Weighted SAW, Technique for Order Preference by Similarity to Ideal Solution TOPSIS, Weighted Product Model WPM, Analytic Hierarchy Process AHP, Grey relational analysis GRA "etc [11]. In the following, we give a general description of these algorithms.

- Simple Additive Weight SAW:

SAW is a well-known method for the case of multiple criteria systems, it assumes that data treated have the same unit, so to get a comparable scale among parameters, it is mandatory to normalise the data for each parameter [11], [9], [22]. Finally, the alternative with the highest value is selected. The mathematical formulation of SAW is:

$$R_{\text{saw}} = \sum_{i=0}^N (W_j * r_{ij}) \quad (1)$$

R_{saw} : is the value of each alternative.

w_j is the weight value of the criterion j .

N is the number of the decision criteria.

$r_{ij} = \frac{m_{ij}}{\max(m_{ij})}$ is the normalised value of the criterion j and the alternative i . Then, the chosen alternative is the one with the maximum value.

- Technique for Order Preference by Similarity to Ideal solution TOPSIS:

TOPSIS is an aggregating compensatory method based on the concept that the chosen solution should have the shortest geometric distance from the positive ideal solution [19], [23] and the longest geometric distance from the negative ideal solution. The TOPSIS method consists mainly of these actions: normalising the data, after that, compute the geometric distance between each alternative and the ideal alternative. The TOPSIS process is as follows:

$$P_{\text{TOPSIS}} = \frac{D_P}{D_P + D_N} \quad (2)$$

Where

$$D_P = \sqrt{\sum_{i=0}^N (w_j^2 * (r_{ij} - b_j^P)^2)}$$

$$D_N = \sqrt{\sum_{i=0}^N (w_j^2 * (r_{ij} - b_j^N)^2)}$$

The w_j represents the weight value, r_{ij} is the normalised value of the parameter j and the network i . b_j^P represents the best alternative, a^N is the worst alternative and N is the number of the decision criteria.

- Weighted Product Model WPM:
WPM called also Multiplicative Exponential Weighting MEW is similar to SAW method, [19], [23]. The difference is the replacement of the addition operation in SAW with the multiplication operation in WPM; each decision alternative is compared with the others ones by making a number of multiplication of ratios, one for each decision criterion. Each ratio is raised to the power equivalent to the relative weight of the corresponding criterion. The mathematical description is as follows:

$$R_{\text{WPM}} = \prod_{i=1}^N (w_j * r_{ij}) \quad (3)$$

- Analytic Hierarchy Process AHP:
AHP considers decomposition of a complicated problem into multiple hierarchical simple sub-problems [19]. The AHP steps are as follows:

- First, decompose the problem into a set of hierarchical sub-problems, where the top node is the final goal and in the lower nodes that are the alternative solutions of the problem.
- Second, Determination of the relative importance of the criteria with respect to the objective. In each level, the decision factors are compared pair-wise according to their levels of influence with respect to the scale shown in Table1.
- Third, calculate the weights in all the hierarchy levels.
- Fourth, in general, AHP method is coupled with Grey Relational Analysis GRA method, the AHP for weighting and the GRA used to rank alternatives.

Table 1: AHP scale of importance [19]

Definition	Importance
Equal importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9
Intermediate importance	2,4,6,8

In this sub-section, we presented the famous methods of the MADM approach. These methods are widespread to solve the network selection problem; however, these methods present certain shortcomings.

In the next section, we proposed a solution for network selection; this solution solves the shortcomings of the legacy MADM methods.

3. THE MODIFIED-SAW ALGORITHM

The purpose of the proposed network selection procedure named modified-SAW is to ensure that the user gets a good quality of service during the call session and to guarantee the correct distribution of the users on each network. The proposed solution assigns the user to the best network from the available networks at the present instant while the selected network reachable i.e., not loaded. This process is repeated at several instances until the user's call session is ended. In the following, we will compare the performance of our solution with the existed MADM solutions.

So, when a user claims for a particular service, it sends a request to the operator, the request contains some information like the service required and the battery level. The other parameters needed for the network selection procedure are gathered by the operator. Then, the operator triggers the process of ranking the available networks. The results will be forwarded to the user who selects the best available network. The forwarded result contains the list of the networks ranked from the best network to the worst one. Obviously, the user will choose the network having the best rank while the network is not loaded. A loaded network normally cannot gets the best rank,

simply because a loaded network has a higher delay and lesser throughput, thus, it just has a bad QoS performance, so it is quite unlikely to get the best-ranked network a loaded network, see Fig2.

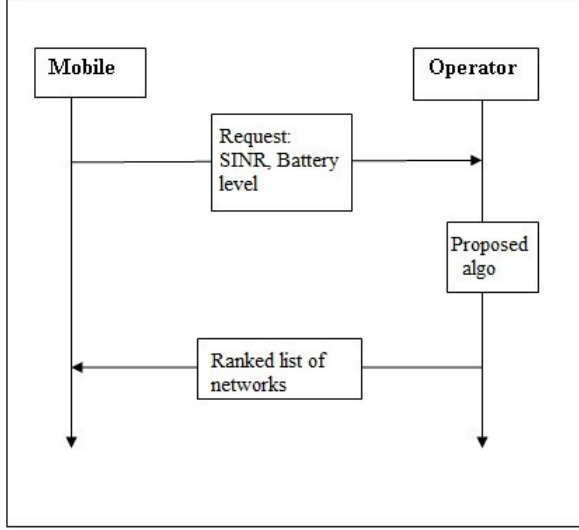


Fig. 2: The NS process.

In our description based on Fig 2, we have two sides: the mobile user that seeks for the best RATs and the operator side that triggers the ranking process of the available networks. The idea behind the objective function is simple.

Data: The matrix $mat [m][n]$ and the weighting vector $w[], \alpha = m$

Result: Income vector for each network

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for ( $j = 0; j < m; j ++$ ) do
  for ( $i = 0; i < n; i ++$ ) do
     $tab[i] = mat[i][j];$ 
  end
   $tabind = Sort(tab);$ 
  for ( $k = 0; k < Tabind.length; k ++$ ) do
     $income[tabind[k]] =$ 
     $income[tabind[k]] + (\alpha - k) \times w[k]$ 
  end
   $return income[];$ 
end
  
```

Algorithm 1: Modified-SAW function

We formulate the system as a minimising function in which the lowest value for each criterion gives the best-ranking order for the networks. Consequently, it gives it the highest local gain. This process is repeated until all the criteria will be evaluated. Its representation is as follows: for each network ‘i’, we do:

$$R_i = \sum_{j=1}^m income_{ij} \quad (4)$$

$$income_{ij} = (\alpha - k_{ij}) * w[j] \quad (5)$$

$$k_{ij} = \min(Vect_{ij}) \quad (6)$$

Where:

α : is a fixed integer number equal to the number of alternatives.

k_{ij} : it represents the rank order of the network i for the criterion j .

$Vect_{ij}$: is the column vector from the matrix mat where j is fixed.

$w[j]$: is the weight associated with the criterion ‘j’ for the alternative ‘i’.

i : is the alternative and j is the criteria.

$mat[n][m]$: is the input matrix, it is represented by Table2.

We start by dividing the input matrix to a set of column vectors to get a group of vectors equal to the number of criteria.

For each vector, the networks are ranked according to their data values. Then, each network receives a local income equal to the mathematical multiplication between ‘ α ’ minus the rank value for this network and the weight value of the criterion. ‘ α ’ is a fixed value equal to the number of criteria. This process is repeated for the other criteria using equation (5).

The total income value is equal to the sum of all the local incomes for each network, see equation (4). We use the weight value of each criterion to differentiate between the criteria as all the MADM methods do. It is well known that the delay and the Packet loss Ratio (PLR) criteria are the most important comparing to the other criteria. They represent the QoS parameters.

The relative revenue based on network rank for each criterion system allows us to control the revenue of each alternative according to its rank for all criteria. For example, a network proposing a delay value of 30 ms and another proposing a delay of 100 ms don’t have the same local income, here in this example having a small value of delay is good and offers a higher gain to the network. In the other hand, having a higher bandwidth will be translated in higher local incomes. The process of evaluating the criteria is repeated until exhaustion of the criteria.

For each network ‘i’, the best case is having a minimal value for the criterion ‘j’ this means the highest local ranking, thus $k_{ij} = 0$ and the revenue is $R_{ij} = \alpha * w[j]$ in this study $\alpha = 5$ (the number of criteria).

The worst case is when the network has the maximum value for the criterion ‘j’, i.e., $k_{ij} = \alpha - 1$, i.e., the revenue is $R_{ij} = w[j]$

The use of the weight concept is to allow us to give more sense to our objective function which ranks the networks based their values for each criterion. The weight vector allows us to distinguish the significant criteria from the other less important criteria depending on the application requirements and therefore assigns higher incomes to the networks with highest values for the important criteria.

In this study, we modify the use of this concept

weight vector by associating this concept with the ‘ α' ’ value. This modification has mainly two advantages:

- Avoid the situation in which a network that has a good value for a non-important criterion will have the same revenue as another network with a good value for an important criterion. This situation exists in the SAW method for example due to the use of the ordinary weight vector (without the modification proposed in this work).
- The weight concept is the representation of application requirements in the system and that’s how we distinguish between applications because each one has specific requirements. VoIP requires a minimum time delay and PLR for the video application, in addition to the requirements of VoIP service, it demands also a good throughput, for the best-effort applications, they accept the existing conditions, but the cost criterion is so important. This information is transformed into digital values with the eigenvector method.

In our study, we use many parameters such as cost, energy consumption, average throughput achieved, average delay, average PLR and network load. An example of our matrix is presented below; the values are given from simulations. These parameters present here in our matrix are the margin values that the simulations bring to us.

The modified-SAW function consists on the decomposition of the input matrix in column vectors, after that, it uses the Sort function to rank the networks of these vectors and return their indices ranked from the best network to the worst; the ranked indices are stocked in the “Tabind” vector. After that, we calculate the local income for each network using the equation (5). The process is repeated for all the vectors with by making the mathematical sum of all the local incomes and like this, the local incomes become total incomes when we treat all the criteria.

In this work, we use two examples of each type of network to bring out the rank reversal problem and solve it with the proposed method. The values of the matrix used in the processing are generated randomly based on Table 1. The matrix used in the processing is represented in Table 2.

Table 2: *The matrix model*

	Bwidth	Delay(ms)	PLR (%)	Energy	Cost
Wi-Fi	1-11	100-150	0.2-3	-	1
3G	1-14	25-50	0.2-3	-	5
LTE	1-100	60-100	0.2-3	-	2

The energy consumption parameter is related to the level of the battery of the mobile device as well as the duration of the call session, i.e. with a high-level of the battery, the power consumption will not be as important in the system because the mobile equipment can ensure that the session will not be interrupted. In the opposite case, if the battery level

is low and the duration of the session is long, this means we may witness a breaking in the session due to battery drain. So in the situation that the battery is low, the energy parameter becomes very important and will have a higher weight in the system to avoid depletion of the battery and therefore a break in the session.

Based on [25] the energy required to execute the user’s request will be calculated for each RAT. The energy consumption parameter is set using equation (7):

$$P[mJ/s] = \alpha_u * th_u + \alpha_a * th_a + \beta \quad (7)$$

α_u , α_d and β are parameters, their values are different from one RAT to another [25], th_u and th_d are uplink and downlink throughput. The power in mJ/s means that the energy depends on the session duration time.

4. PERFORMANCE EVALUATION

In this section, we evaluate the performance of the proposed algorithm and we compare it with the MADM methods described in section II based on the input data from Table 3. In this study, we consider three types of services, VoIP, video service and the best effort service.

The study is composed of two parts:

- In the first part, we compare our proposal with the legacy MADM methods in the normal case where no RATs disappear in the middle of the selection process.
- The second part is the case when one network disappears from the list of the available networks, this case allows us to prove that MADM methods suffer from the rank reversal phenomenon (this is a well-known situation), and we will see if this problem occur or not in our proposal.

The following matrix represented by Table 3 represents the data input matrix where the values are randomly generated from Table 2; this matrix is used in our tests.

Table 3: *The input matrix*

	Bandwidth	Delay	PLR	Energy	Cost
N (0)	1.730	105.85	7.94	1.00	0.2
N (1)	5.076	134.88	6.70	2.6	0.2
N (2)	6.849	43.98	2.84	6.26	1
N (3)	6.329	32.15	3.05	5.86	1
N (4)	66.66	95.15	6.32	12.78	0.4
N (5)	62.5	99.73	5.80	10.28	0.4

The weight values of each type of application VoIP, video services and the best effort applications are generated using the Eigenvector method using equation (8). We decided to use the Eigenvector method because it is already used in the AHP process. So, to

be fair, we have decided to use the same method to get the weight vectors for all of the methods.

$$(mat - \gamma) * w = 0 \quad (8)$$

Where mat is the input matrix, γ is the Eigen-value, I is the identity matrix and w is the associated eigenvector containing the weights values.

Table 4 contains the weights vector generated for each type of application.

We start with the first part of this study, the ordinary case, i.e. having all networks available.

Table 4: The weight vectors

	Bandwidth	Delay	PLR	Energy	Cost
Wi-Fi	0.047	0.486	0.371	0.047	0.047
3G	0.458	0.101	0.302	0.074	0.063
LTE	0.299	0.146	0.146	0.108	0.299

In this study we are interested in the total ranking order of the networks and not only the network with the best rank because the best network is most likely becomes loaded quickly after a given time due to the connect request and then it will be unavailable, i.e. overloaded, so, it is necessary to get an optimal total ranking of all networks.

A. Simulation 1: All RATs available

In this case, the networks in the covered area of the user do not disappear and remain available during the whole process.

- VOIP scenario:

The results in Table 5 concern the first case VoIP.

Table 5: The weight vectors

Method	Rank					
TOPSIS	N (3)	N (2)	N (0)	N (1)	N (5)	N (4)
AHP	N (3)	N (2)	N (0)	N (4)	N (1)	N (5)
WPM	N (3)	N (2)	N (0)	N (1)	N (5)	N (4)
SAW	N (3)	N (2)	N (0)	N (1)	N (5)	N (4)
M-SAW	N (3)	N (2)	N (4)	N (5)	N (0)	N (1)

Based on results in Table 5, the methods TOPSIS, WPM and M-SAW give the same order for the first two networks. For the third position, our method M-SAW chooses the N (4) but TOPSIS, WPM and AHP choose N (0). So, we must compare the performance of N (4) and N (0) to see which method bring the right rank.

Fig.3 shows that N (0) propose a delay of 105,85 and a PLR of 7,94. The N(4) has a delay of 95,15 and a PLR of 6,32. So, N (4) is better than N (0) and this means that our method brings the right rank order and it outperforms the TOPSIS, WPM, and AHP.

In the case VoIP, we showed that the proposed method M-SAW gives the best ranking order compared to the MADM methods, Table5 and Fig.3.

- Video scenario

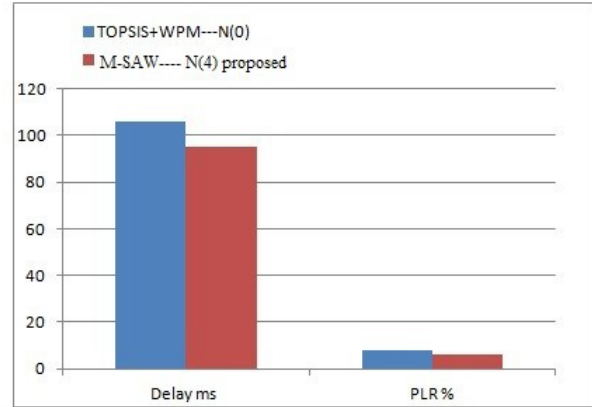


Fig.3: delay and PLR comparison between N (0) and N (4).

The results in Table 6 concern the second case video service, using the matrix in Table 3. From Table 6, the SAW method has always a wrong ranking order. For the other methods, TOPSIS chooses N (5) while WPM and M-SAW choose N (4).

Table 6: Ranking results for Video service

Method	Rank					
TOPSIS	N (5)	N (4)	N (2)	N (3)	N (1)	N (0)
AHP	N (2)	N (3)	N (5)	N (4)	N (1)	N (0)
WPM	N (4)	N (5)	N (3)	N (2)	N (1)	N (0)
SAW	N (4)	N (2)	N (0)	N (3)	N (5)	N (1)
M-SAW	N (4)	N (2)	N (3)	N (5)	N (1)	N (0)

From the Table 6, M-SAW and WPM select the N (4) and TOPSIS chooses N (5) as the best network.

In Fig.4, N (4) has higher bandwidth and lower delay. The N (5) has a better PLR, but in this case interactive scenario, the importance is given to the bandwidth and delay, so the best choice is the N (4).

Now, for the second place, WPM selects the N (5) and M-SAW select N (2). N (5) has a bandwidth of 62.5 and delay of 99,73 and a PLR of 5,80. N (2) has a bandwidth of 6,85 and delay time of 43,98 and a PLR of 2,84.

Considering these values, we see that the N (5) has a larger bandwidth, but the bandwidth of N (2) is also good and can ensure the video service. In this case, we use the property of giving the user the minimum value of bandwidth that satisfies the application's requirement, this means that the application has some requirements, these requirements must be satisfied. Once the network satisfies these requirements it is considered as acceptable and the user can choose it.

For the other parameters (delay and PLR), N (2) is very good compared to N (5), see Fig.5.

Here we can see that the bandwidth parameter monopolise the ranking decision in TOPSIS, having the best bandwidth enforce the algorithm to neglect the

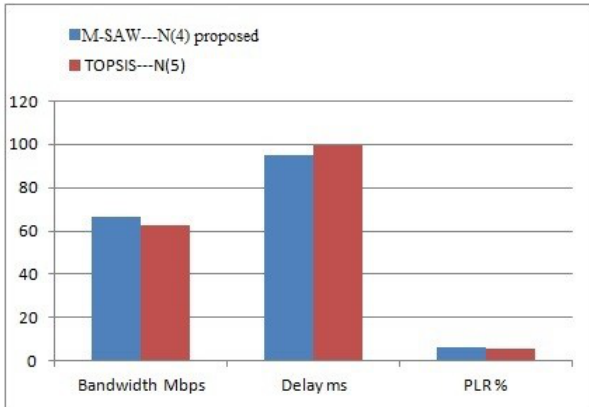


Fig.4: Comparison between N (5) and N (4).

huge delay and PLR. So, based on Fig.5, our method M-SAW brings the best choices with this service type.

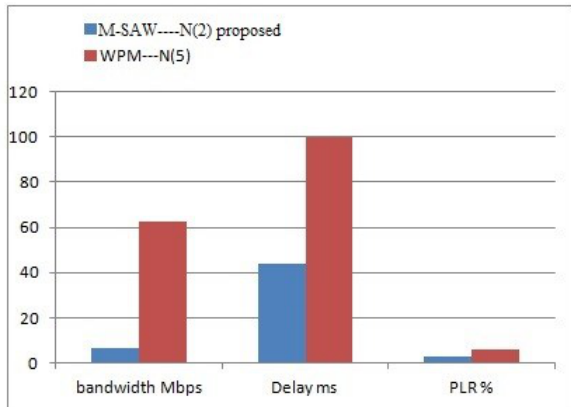


Fig.5: Comparison between N(2) and N(5).

- Best effort scenario

Table 7 represents the results for the third case (data connections).

Table 7: Ranking results for best effort service

Method	Rank					
TOPSIS	N (5)	N (4)	N (2)	N (3)	N (1)	N (0)
AHP	N (5)	N (1)	N (4)	N (2)	N (3)	N (0)
WPM	N (4)	N (5)	N (1)	N (2)	N (3)	N (0)
SAW	N (4)	N (5)	N (2)	N (3)	N (0)	N (1)
M-SAW	N (4)	N (5)	N (2)	N (3)	N (1)	N (0)

WPM and M-SAW have the same first and second ranking order, the third one WPM chooses N(1) and M-SAW chooses the N(2). Form Fig.6, we see clearly that N(2) is better than N(1).

From all these cases we conclude that our proposed method M-SAW algorithm gives the best performances compared to the other methods, our method choose the best alternative at each stage of the pro-

cess and gives at the end of the process the best choices

In this subsection, we made a comparative study between our algorithm M-SAW and the MADM algorithms, our proposed algorithm gives the correct order of networks compared to the others algorithms in every case. This comparison showed us too that the TOPSIS methods had the most suitable ranking order among the legacy MADM algorithms.

The next step now consists of testing our function in the case when one RAT is added or removed, this case present what we call the ranking abnormality when using the legacy MADM. The following simulation will show us, whether our approach avoids this problem or it falls in it too.

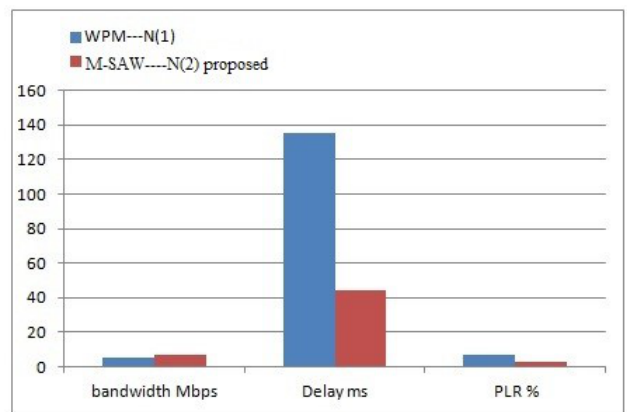


Fig.6: Comparison between N (2) and N (1).

B. Simulation 2: The rank reversal case

Now, we investigate the case that one network disappears in the middle of the ranking process, this case allows us to study the rank reversal phenomenon. So, we decided to eliminate one network, for example, the network N (4) from the Table 3, and we repeat the simulation by ranking the remaining networks in the case of VoIP service, the results are shown in Table 8.

Table 8: Ranking results for best effort service

Method	Rank				
TOPSIS	N (5)	N (3)	N (2)	N (0)	N (1)
AHP	N (0)	N (1)	N (5)	N (3)	N (2)
WPM	N (5)	N (3)	N (2)	N (0)	N (1)
SAW	N (1)	N (3)	N (2)	N (0)	N (5)
M-SAW	N (3)	N (2)	N (5)	N (0)	N (1)

Results in Table 8 show two information:

First, all the MADM (TOPSIS, SAW, WPM and AHP) methods suffer from the rank reversal phenomenon because the ranking results presented in Table 8 are different compared to those shown in Table 5, this result confirms the affirmation of the authors in [16] that all MADM methods suffer from the rank reversal phenomenon.

The second information is that our method M-SAW does not present the phenomenon of reversal's ranking when a network disappears; indeed, our proposed method just remove the disappeared alternative while keeping the other alternative's rank unchanged. This is a good result of our approach. These enhancement provided by M-SAW are due to the use of the modified formula of the weight. Indeed, each network receives a local income equal to the mathematical multiplication between ' α ' minus the rank value for this network and the weight value of the criterion. This new formulation of the weight allows us to control the income of each alternative according to its rank for the whole criteria.

To summarise, MADM methods give a ranking order that this is not always the optimal one; it is possible that one of these methods gives us the best-ranked network, so the user connects to this network. But, it is not always possible to connect to the best network given the number of users that select this best network, because, it will be easily loaded and then unreachable. To solve this problem we propose our algorithm that is a modified version of the SAW method. This process is done on the operator side to benefit from the operator's processing capacity and the permanent source of power which gives us efficiency and speed at the same time, in addition to this, the operator has all the information concerning networks and users permanently. The goal of the algorithm is to find the most optimal total rank of all the available networks and not only the best network from a list of networks. Having the right order total network allows us to be certain that at each instant, the user connects to the best available network among existing networks.

The second advantage of this algorithm is that it behaves well in the normal case when all the network remain available and in the case when one network disappears, in this case, the MADM methods present the problem of rank reversal.

5. CONCLUSION

In the aim to find the best network at each instant, the idea was to rank the existing networks to get the total optimal ranking order; in this case, the operator switches the users with the best network available in the ranked list of networks. In this paper, we present our approach named modified-SAW, the objective function is based on the relative ranking order of each alternative for each criterion at each round of the process, and this basic idea allows us to get a greedy algorithm that gives good results. Results show that our proposed approach outperforms the existing used methods in the normal case, i.e. when all networks are available. Another test is done where one of the networks disappears, the simulation shows that all the MADM methods present the rank reversal phenomenon, our proposed algorithm overcomes

this phenomenon and stays coherent and brings the same ranking order with eliminating the disappeared network.

As a future work, we aim to implement this selection algorithm in a real world case when the users are in permanent mobility. We aim also to implement this solution to map from simulation to realisation. Another thing to do is to insert this part of network selection in the global handover vertical process and the consideration of the mobility case.

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