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DESIGN AND EVALUATION OF AN ANALYTICAL MODEL FOR CONVERGENCE OF WIRELESS NETWORKS UNDER THE 802.21 STANDARD USING VERTICAL HANDOVER

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ABSTRACT

Generate a convergence of wireless technologies with heterogeneous architectures is the purpose to which the current telecommunications are addressed to, because as it is evidenced in this article, you can move from an LTE network to a network such as WiMax or wireless, through the procedures of the Vertical handover, which are intended to provide users with continuous availability of connection, in space and time of the services provided by different operators. The IEEE has begun to frame such transfers under the 802.21 standard in which they disclosed several points about the connection between systems of different architectures; on this basis, we designed an algorithm that allows us to choose, in an efficient way, when and where to make the transfer of a call between heterogeneous systems. For this algorithm we used the fuzzy logic and the multicriteria decision (AHP) methods, that were simulated in R Studio, and with which it was possible to quantize the values of various criteria and define what the most appropriate network is. The fuzzy logic and the multiple criteria decision methods are applied in the area of Wireless due to, in order to make a coherent decision, we should take into account more evaluation criteria than those used in the horizontal handover; for this reason we decided to include these methods in our algorithm.

KEYWORDS: *Analytic Hierarchy Process (AHP); Algorithm; Vertical Handover (VHO); Media Independent Handover (MIH); fuzzy logic.*

1.INTRODUCTION

The method of transferring calls between cells called Handover, ensures continuity of the service of cellular mobile and has a variety of decision criteria to perform this action or decide not to and, with this, ensures the user of the network the usage of a channel and the channel having the best features in signal strength, in traffic, service and signal quality, among others.In the horizontal handover, the transfers between cells are carried out in homogeneous systems, which are similar to, for example, LTE, UMTS or GSM systems that use the architecture PLMN (Public Land Mobile Network), which belongs to each operator. This type of transfer can also be performed between heterogeneous networks, which is known as a Vertical Handover, and is applied to networks of different architectures and with different characteristics, which also provides different services such as a mobile telephone network and a WLAN network (Wireless Local Area Network). Since mobile phones currently possess a variety of antennas and also offer many services, you can consider switching between different types of networks and, in this way, ensure continuity of the service. For this reason, it is a reality that the direction in which the networks will be unified is through the Vertical Handover, this generates the convergence of the services provided by the operators in different platforms, which would be a great technological, economic and social advance. Due to the need to unify the services, the Vertical Handover has begun to be standardized. The IEEE 802.21 is developing standards that allow the transfer and interoperability between the different types of heterogeneous networks, including the networks that belong to the standard 802, and also those that do not make part of such a standard (Khattab & Alani, 2014b). The next step is to design algorithms that allow us to make the transfer decision. As you are dealing with heterogeneous networks, the process of selection and transfer is performed in a different way to that used in homogeneous systems, for this reason, in this article it is disclosed an algorithm for the handover in heterogeneous networks using the fuzzy logic and the multicriteria decision AHP (Analytic Hierarchy Process) method, developed in the R Studio software (Grossmiller, 2012).

2.PROCEDURE OF THE VHO

In order to perform the transfer of a call it is required that the network to which you are connecting has some appropriate features, and has availability to perform this operation, in the first instance we need a place from where to take the information, after that an algorithm to make the decision whether to perform the handover or not, and, finally, its proper execution.

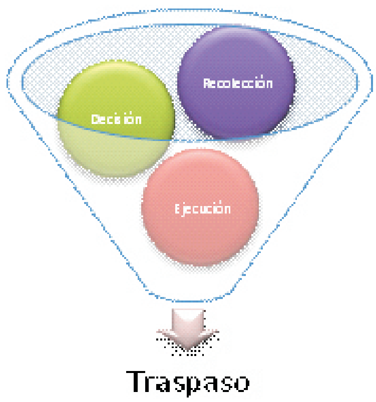


Figure1. Procedure of handover management

2.1 COLLECTION OF INFORMATION

In the phase of collection of the information it is collected not only the network information, but also information about the other components of the system, such as the properties of the network, devices, access points, and user preferences, for this reason this phase receives different names depending on the author(Boussen, Tabbane, Tabbane, & Krief, 2014)as: Handover initiation, Information Discovery, System information Discovery, among others. In this phase, the information is collected to be used and processed for making decisions in the next phase, called the DECISION PHASE; generally, the information collected refers to several parameters of the networks such as:

• Availability of the links of neighboring networks: Network performance, network cost, packet loss rate, transfer rate, received signal strength (RSS), signal-to-noise ratio (SNR), Speed of information (CIR), the ratio signal interference ratio rate (SIR), bit error rate (BER), distance, location and the quality of service parameters.

• The status of the mobile device: by collecting information about the battery status, the resources, the speed and the class of service.
• User preferences: such as the budget and the necessary services (Barja & To, 2012; Khattab & Alani, 2014a; Stract & Ords, 2008)

According to the regulation of the IEEE 802.21 the information about the networks is collected in a subsystem called the Media Independent Information Service (MIIS). It is responsible for collecting the information required to identify whether the handover is necessary or not, and provides the mobile units such information. Such as, available networks, capabilities, costs, among others (Barja & To, 2012).

2.2. DECISION PHASE

The decision phase is one of the most critical during the transfer, this phase is also known as System Selection, Network Selection or Handover preparation, based on the information collected in the previous phase, this phase is devoted to deciding when and where to perform the transfer, the decision of the when refers to the precise moment of time at which it is optimal to perform the handover, while the where refers to which network the transfer should be made in order to meet the requirements of the transfer.

In the case of the homogeneous networks, the decision depends on the values of RSS and, the when and where, it is not an issue while we use the same network technology, this is what we call Horizontal Handover. For the heterogeneous networks, the decision is much more complex, in order to make the best decision, the information gathered must have many criteria taken from the mobile unit, the network and the user preferences (Boussen et al., 2014; Liang, Tian, Fan, & Bai, 2015).

2.2.1 Vertical Handover Decision Algorithms (VHDAs), these algorithms are used to give a weight or value, and evaluate each parameter involved in the decision. In this stage, techniques such as fuzzy logic, neural networks, pattern recognition, among many others(Boussen et al., 2014)are used;in our case we will use the fuzzy logic and a technique of multicriteria decision called AHP (Analytic Hierarchy Process), this is the stage in which we emphasize the most to the development of our algorithm, since it is the strongest of the techniques for the transfer, a good development at this stage ensures a good performance of the method created (Stract & Ords, 2008).

2.2.2 WHEN AND WHERE

2.2.2.1 WHEN refers to the exact moment at which you decide to do the transfer for which you will have two triggers defined below:

Manual this is due to the fact that the user wants to change network by his own will and with his own rules, so that he is the one who sets a few parameters so the transfer is of his liking, in this way the user preferences are the most important and the transfer will be made counting at all times with the settings set by the user. The configurations set by the user limit the operation of the algorithm to his tastes and preferences and if these are not fulfilled the transfer will not be executed.

Automatic when the user selects this mode, the configurations are taken automatically always thinking about improving the use of the resources of the user, so that, when the mobile unit detects any variation of the networks, which can benefit the user, it will execute it. For example, if when moving from one place to another the value of RSS goes down and also the use of the channel is restricted for any reason, the algorithm will look for its own account a network with better features to perform the handover to that network, in case of not finding it will not execute the transfer and will continue looking for a network to ensure the user the use of a channel.

2.2.2.2 WHERE this refers to which network the transfer should be made in order to accomplish with the requirements of the same, depending on which mode was chosen in the WHEN according to the user's preferences, here is where we use the multiple criteria analysis method AHP (Analytic Hierarchy Process) to determine which is the network that must be connected to the mobile device, with this method, what we do, is to give a value or weight to each variable to be considered in the network and after performing its respective analysis and quantize these values to a unique value that each network represents, it generates a priority list that indicates which network is the best to perform the transfer.

2.3. EXECUTION PHASE

In this phase the handover itself is performed. Besides performing the handover, it should also ensure a process of smooth transition. This phase is generally referred to as execution of the transfer and it takes into account the features and functions of the networks. The information of the collection phase should take into account the dynamism of the information available on the devices and the network. Making decisions based on highly dynamic information with a certain degree of mobility of the device requires a fast and reliable decision algorithm. Therefore, the execution of the VHO must be carefully controlled to achieve precision, taking into account the geographical location, the selected network and time (Boussen et al., 2014).

2.4 IEEE 802.21 STANDARD

The standard IEEE 802.21 frames the transfer of calls and data between systems of different platforms, this defines mechanisms independent of the method or mode of access to the medium which enables the optimization of the handover between networks of the same type, different networks 802, or between mobile networks. The standard provides information to allow the transfer of service between networks from one base station to another, where they can include cells of different sizes of the different network types, such as 802.3, 802.11, 802.15, 802.16, 3GPP and 3GPP2 through different mechanisms and with overlapping coverage (Johann, Telekom, Carlos, & Interdigital, 2012).

2.4.1 Media IndependentHandover (MIH)

The IEEE 802.21 standardizes the handover in Independent Media (MIH), in order to provide transparency in the VHO between wireless heterogeneous networks that include both the 3GPP and non-3GPP, and media wiring. IEEE 802.21 defines two entities: in first place, point-of-service (POS), which is responsible for establishing the communication between the network and the MU (mobile unit), under the MIH, and in second place, point of attachment (PoA), which is the point of union of Radio Access Technologies (RAT) that represents the end point of the network connected to the mobile unit (MU). Also MIH provides three main services: Media Independent Events (MIES), and Media Independent Command Services (MICS) and the Media Independent Information Service (MIIS) (Johann et al., 2012; Stract & Ords, 2008).

Media Independent Event service (MIES)

It is responsible for reporting the events after detecting, e.g. link up on the connection (established), link down (broken), link deterioration (imminent breakdown), among others (Johann et al., 2012; Stract & Ords, 2008).

Media Independent Information Service (MIIS)

It is responsible for collecting all the information necessary to identify whether there is a transfer or not, and provide this information to the UM, for example, available networks, locations, capabilities, costs, etc(Johann et al., 2012).

Media Independent Command service (MICS)

It is responsible for issuing the orders on the basis of the information that is gathered by MIIS and MIES, e.g. MIH handover initiate, MIH prepare handover, MIH handover, MIH full delivery (Johann et al., 2012; Stract & Ords, 2008).

However, any transfer decision is made within MIH "the algorithms to be implemented are left to the designers", and the implementation of the decision algorithm is out of the scope of MIH (Johann et al., 2012).

3. RELATED RESEARCH

Currently, researchers have proposed a variety of algorithms to improve the performance of Vertical Handover (Xiaona & Qing, 2014)as shown in the articles analyzed. In(Boussen et al., 2014)the authors focus on the transfer decision problem and propose a solution that aims to meet user preferences and to take into account the applications requirements and network capabilities. In(Khattab & Alani, 2014a)] the authors present an algorithm for VHO using two major frames networking that were proposed by the IEEE and 3GPP based on MIH and IMS and the use of the fuzzy logic to provide the connection with a low probability of loss of calls in the heterogeneous wireless networks environment, in addition of low-cost and low signaling for the improvement of the networks. Also in(Stract & Ords, 2008)the authors discussed an algorithm related to Quality of Experience (QoE) based on MIH which aims to maintain the multimedia service with an acceptable quality of experience and to avoid the unnecessary transfer in the heterogeneous network. In(Ranjan et al., 2015)the authors perform algorithms to facilitate the transfer of calls and to improve the characteristics of the transfer, taking into account parameters such as SNR, RSS, QoS, among others. In other documents the algorithms that use fuzzy Logic and the multi-criteria method AHP are related by the authors in (Chinnappan & Balasubramanian, 2016; Guo, 2015; Khattab & Alani, 2014a, 2014b; Xiaona & Qing, 2014; Zineb, Mohanmed, & Tabbane, n.d.). In(Barja & To, 2012)it is proposed a list of algorithms for the VHO to 4G networks where the mobile unit is capable of selecting between an Access Point of networks 2G, 3G and 4G to make the transfer. The algorithms analyzed in this document use methods of fuzzy logic, neural networks, multicriteria, among others. Theresults are analyzed. In addition, in(Bagdure & Ambudkar, 2015)the algorithm uses delay as the central axis to select the network in the VHO using the MDP method (Markov Decision Process). Guiding us in the research of the authors in (Rajule & Ambudkar, 2015)that proposes an optimized algorithm in order to have a continuous communication using VHO, where this proposed method uses the fuzzy logic to select the network while maintaining the QoS between LTE and WiMax. Likewise, through the simulation performed by the authors in (Guo, 2015), they make comparisons between the algorithm proposed and the previous algorithm by using another adaptive method.

4. ALGORITHM

The algorithm proposed in this article has as reference some of the criteria set in the IEEE 802.21 as MIIS, PoA, PoS, among others, so that, the subject matter of the collection of the information is taken as performed, in this case, the mobile unit performs the search and collection of new networks based on the information submitted by the MIIS, in other words, it is a dynamic database that has the data of the networks and some criteria of the user. From here the algorithm has two parts, the first is the shot of the selection of networks, which is generated by applying fuzzy logic to the data collected by the mobile unit, in this process the algorithm fuzzifies the values collected, and with an inference machine processes the data so that the result falls between the ranges specified for the output, that output is defuzzified finding its centroid to obtain a fixed value, this value indicates if among the different networks found there is any that can mean an improvement for the user in the quality of the service, after this process, the second part of the algorithm is responsible for completely processing the data of the networks to which the mobile unit can access and make the decision of which of the networks should be connected, all of this taking into account the preferences established by the user. Algorithms that use this type of data treatment are found in(Grossmiller, 2012; Khattab & Alani, 2014a).

5.ANALYTICAL MODEL

5.1 Handoverinitiation

In the first instance we decided to take a reference value that serves us as a trigger to know if it is good to perform a handover to another network that has a different architecture, a different one to which we are connected, to do this we took the values of multiple nearby networks, which are perceived by the mobile unit, of which we chose three parameters RSS (Ratio Strength Signal), DATA RATE (data transfer) and LATENCY (latency), these data that are characteristic of each network and regardless of their architecture are present, were chosen so in the moment of doing a processing by fuzzy logic (Boussen et al., 2014; Khattab & Alani, 2014a)we can get a uniquevaluewhichwecalltheHANDOVER FACTOR (HF), afterthisprocesswewillhave a fixed numbe rthat qualifiesifitwould be goodtoperform a handoverornot, in our case the transfer istriggeredif HF > 0.55

As a first step, for the implementation of the fuzzy logic, we assign to the variables some ranges of work to have as a reference, these values are fuzzified, after that, they undergo a treatment by an inference machine with some rules that are set beforehand, finally a defuzzification is done to these values, in order to obtain a single numeric value assigned to a variable, which in our case is called Handover Factor (HF).

For the simulation of the fuzzy logic we used the software R Studio, and a library of fuzzy logic called SETS, as we take THREE parameters to process, we give it some ranges and work the membership functions of each criterion and to each variable must be assigned a universe of discourse, for example, to the RSS we assign three values, which we call low, normal and high, and a working range between (-80 dbm and -40 dbm) and similarly for the other two parameters DATA RATE between (0 Mbps and 100 Mbps) and LATENCY between (0 ms and 200 ms), it should be noted that the latency has an inverse relationship with the allocation of the ranges, since a latency of a very large value means a low range and a lower latency means a high range, since we have 3 fuzzy variables and 3 fuzzy sets for each variable, we have a variety of rules and the maximum possible value of rules is : 3^3=27 , this value of twenty-seven rules, will determine the output ranges, the output is defined as a diffuse variable with 5 fuzzy sets called LOWER, LOW, MEDIUM, HIGH, HIGHER this diffuse output is called Handover Factor (HF).

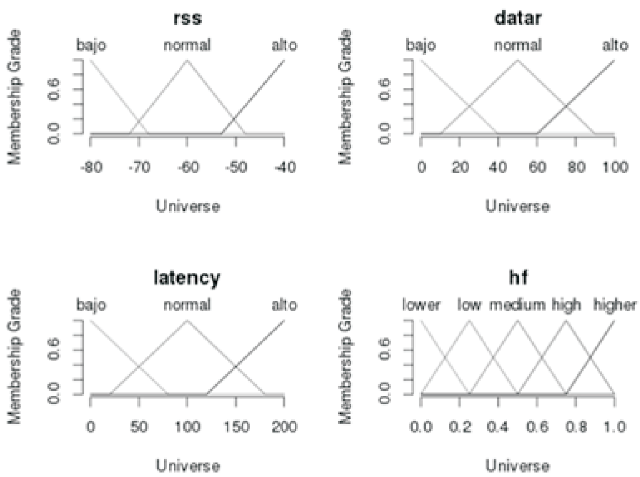


Figure 2.Defined variables in fuzzy logic in R Studio.

In Figure 2 we can observe the graphs generated in the software environment R for each variable with their respective ranges and the degree of membership for each variable; the inputs are the rss variables which refer to the Ratio of Strength Signal, datar that refers to the Data Rate or the data transfer, and latency that refers to the latency, the output is defined as HF and refers to the Handover Factor which is a defuzzified value with which it defined whether to make the transfer or not.

```
>
> ## do inference
>
>
> inferenci1 <- fuzzy_inference(system, list(latency=200,rss=-60, datar=10))
> inferenci2 <- fuzzy_inference(system, list(latency=100,rss=-55, datar=70))
> inferenci3 <- fuzzy_inference(system, list(latency=30,rss=-50, datar=93))
>
> ## plot resulting fuzzy
>
> plot(inferenci1,main=' Handover Factor LTE ' ,col ='red')
> plot(inferenci2, main='Handover Factor WiFi', col ='green' )
> plot(inferenci3, main='Handover Factor WiMax', col= 'blue')
>

>
> ## defuzzify
> gset_defuzzify(inferenci1, "centroid")
[1] 0.25
> gset_defuzzify(inferenci2, "centroid")
[1] 0.5859344
> gset_defuzzify(inferenci3, "centroid")
[1] 0.7824078
>
>
> hf_red1<- gset_defuzzify(inferenci1, "centroid")
> hf_red2<- gset_defuzzify(inferenci2, "centroid")
> hf_red3<- gset_defuzzify(inferenci3, "centroid")
> ### vertical handover
>
> ##PRIMER PARTE: logica diffuza
```

Figure3.Inferenceforvalues of three different networks and their respective defuzzified outputs R software.

In the previous Figure, we can see how in the environment of the R software we carry out the necessary inferences to process the input data and as they are defuzzified we have unique values that give us a representation of all the data taken from a network. The defuszzified outputs for a some fixed values of three networks that are a LTE network, a WiFi network and a WiMax network, for each of the input parameters in this case HF = 0.25 for the network 1 which belongs to an LTE network , the HF = 0.5859344 for the network 2 that belongs to a WiFi network and HF = 0.7824078 that belongs to a WiMax network, as we can see in figure 3, the defuzzification is processed by finding its centroid, according to these values in two of the analyzed cases a change of network should be done, since they have good characteristics and according to the chosen criteria this transfer would be convenient, to find these defuzzified values 27 rules were set up, in addition to the variables, , which in the environment of the R software were defined using logical operators AND assigning ranges to each of the entered values and when processing, by an inference machine, such data with the established rules, one can obtain some values that, at last, defuzzify to obtain a single value that represents the ranges of the entered variables, and if these exceed the value of 0.55, you must shoot the transfer of the call to the next step which is the selection of the network(Grossmiller, 2012).

5.2 Priority List

After this, we must create a priority list and for this purpose we use the AHP method, it is a multicriteria decision method very currently used, which gives a more concrete and accurate approach of which is the network that meets the criteria to perform a handover successfully and efficiently. For the AHP method we must take each of the criteria that we will denote with the letter C and a number, for example (C1, C2,...) and assign a weight according to the scale of Saaty, as we can see in table 1, to each criterion an importance value was assigned in comparison to all the others; that value is reflected in a weight. For our algorithm we take into account 9 criteria of the networks that the mobile unit recognizes, with these weights already assigned we generate a comparison matrix, as in table 2, with which the treatment for the multicriteria decision will be made.

Table 1 Criteria and scales.

Criteria	Verbscale	Numberscale	Name
Data rate	Extreme importance	9	C2
Security	VeryVeryStrong	8	C6
Reliability	Verystrong	7	C5
Latency	Strong plus	6	C4
Servicecost	Strong	5	C9
RSS	Prefer	4	C7
CoverageArea	Equalimportance	1	C1
Mobile velocity	Equalimportance	1	C3
Batterypower	Equalimportance	1	C8

Table 2.Criteria matrix

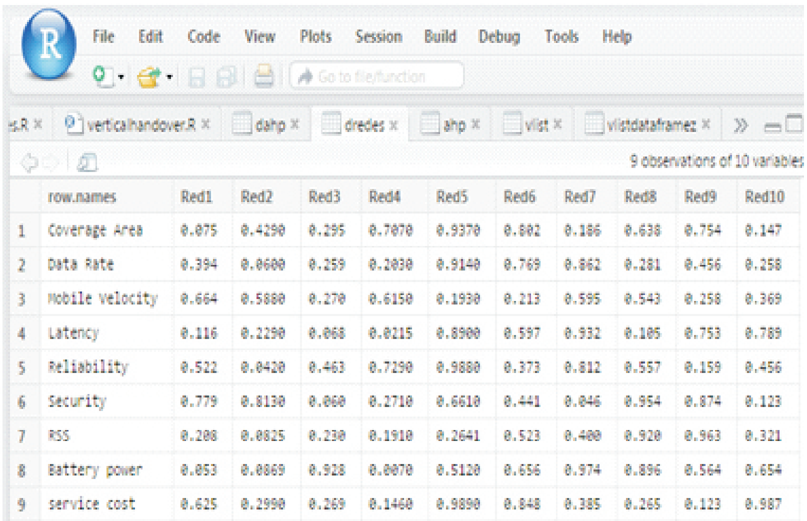
Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	1/9	1	1/6	1/7	1/8	1	1/4	1/5
C2	9	1	9	9	9	9	9	9	9
C3	1	1/9	1	1/6	1/7	1/8	1	1/4	1/5
C4	6	1/9	6	1	1/7	1/8	6	6	6
C5	7	1/9	7	7	1	1/8	7	7	7
C6	8	1/9	8	8	8	1	8	8	8
C7	1	1/9	1	1/6	1/7	1/8	1	1/4	1/5
C8	4	1/9	4	1/6	1/7	1/8	4	1	1/5
C9	5	1/9	5	1/6	1/7	1/8	5	5	1

After a treatment of this matrix we obtain an eigenvector of it, and we call this vector criteria weight vector and the scoring of these criteria gives us 1.

$$\begin{pmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \\ W_6 \\ W_7 \\ W_8 \\ W_9 \end{pmatrix} = W_M \;, \begin{pmatrix} 0.01425 \\ 0.45500 \\ 0.01425 \\ 0.07146 \\ 0.12659 \\ 0.23485 \\ 0.01425 \\ 0.02684 \\ 0.04247 \end{pmatrix} = Eigenvector. \qquad (1)$$

$$W_T = W_1 + W_2 + W_3 + W_4 + W_5 + W_6 + W_7 + W_8 + W_8 + W_9 = 1 \qquad (2)$$

These weights give importance to each criterion, which allow us to quantize the data using a pre-assessment of the criteria, according to themselves. The input data of the networks must be pre-treated so that the decision consistent, so that each criterion according to the range established by the same, a straight line function is assigned, so that every numerical amount of the mentioned criterion belongs to a value between 0 and 1 as in figure 4.



	row.names	Red1	Red2	Red3	Red4	Red5	Red6	Red7	Red8	Red9	Red10
1	Coverage Area	0.075	0.4290	0.295	0.7070	0.9370	0.802	0.186	0.638	0.754	0.147
2	Data Rate	0.394	0.0600	0.259	0.2030	0.9140	0.769	0.862	0.281	0.456	0.258
3	Mobile Velocity	0.664	0.5880	0.270	0.6150	0.1930	0.213	0.595	0.543	0.258	0.369
4	Latency	0.116	0.2290	0.068	0.0215	0.8900	0.597	0.932	0.105	0.753	0.789
5	Reliability	0.522	0.0420	0.463	0.7290	0.9880	0.373	0.812	0.557	0.159	0.456
6	Security	0.779	0.8130	0.060	0.2710	0.6610	0.441	0.046	0.954	0.874	0.123
7	RSS	0.208	0.0825	0.230	0.1910	0.2641	0.523	0.400	0.920	0.963	0.321
8	Battery power	0.053	0.0869	0.928	0.0070	0.5120	0.656	0.974	0.896	0.564	0.654
9	service cost	0.625	0.2990	0.269	0.1460	0.9890	0.848	0.385	0.265	0.123	0.987

Figure 4. Standardized networks values generated by R software.

.

The value of the criteria already standardized is operated by the set functions for each one, defining a function of standardized criteria, called F(*x*)

$$F(x)_i = (x)_1 + (x)_2 + (x)_3 + (x)_4 + (x)_5 + (x)_6 + (x)_7 + (x)_8 + (x)_9 \qquad (3)$$

Then we define a variable called AHP FACTOR, to obtain the value of the AHP FACTOR, we perform the summation of the multiplication of each value of $(x)_i$ for each weight W_j

$$AHPF = \sum W * (x)_i = w_1(x)_1 + w_2(x)_2 + w_3(x)_3 + w_4(x)_4 + w_5(x)_5 + w_6(x)_6 + w_7(x)_7 + w_8(x)_8 + w_9(x)_9 \qquad (4)$$

According to the values taken by each criterion for that network, the value AHPF gives us between 0 and 1. After this process we have values AHPF of the different networks, in our algorithm, the values that come out of these criteria fill up a priority list depending on how much both meet their own criterion, being 1 an ideal network, the closest AHPF to this value will correspond to the first position in the list and then the second best that approaches the ideal, and so on. With these data we possess a criterion value to evaluate each network, which helps us to choose which is the most suitable and to which network the transfer must performed. Then we have to take into account the preferences of the user, as in the search and auto or manual connection.

FLOW DIAGRAM OF THE SYSTEM

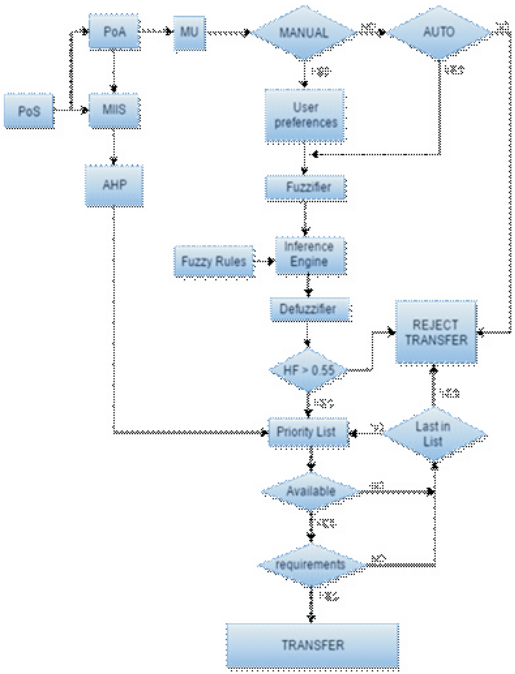


Figure 5. Handover decision algorithm

6.SIMULATION SCENARIOS AND RESULTS.

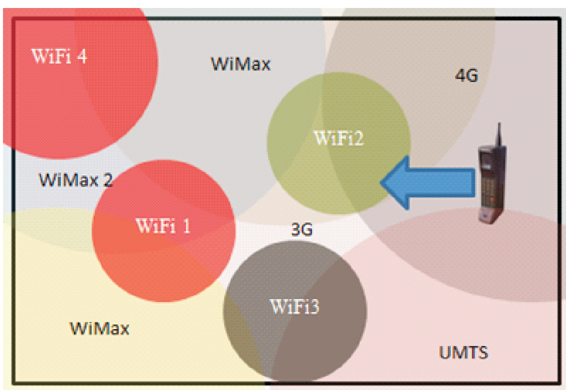


Figure 6. Simulationscenario.

6.1 Simulationscenario

The algorithm proposed in this article efficiently chooses the networks to which it will connect or will make the transfer. As scenario of simulation, we have a mobile unit that is connected to a 4G LTE network, and this unit is directed in the direction of where other networks of different architectures are found and the features of the 4G LTE network are deteriorated, so it is necessary a transfer as it is shown in figure 6, the algorithm, in first place, takes three criteria of the networks, and through fuzzy logic processes makes a categorization of such networks at a fixed value called the Handover Factor if this value is greater than 0.55 the algorithm is directed to the priority list and chooses which network is optimal to carry out the transfer. Values from 10 different networks were taken and it was made a categorization of them choosing which the best is through a value called the factor of priority, as seen in figure 7, and the order of these factors in the priority list in figure 8.

	row.names	Factordeprioridad
1	Red1	0.4780624
2	Red2	0.2706203
3	Red3	0.2430815
4	Red4	0.2777878
5	Red5	0.8354209
6	Red6	0.6189065
7	Red7	0.6317577
8	Red8	0.4951756
9	Red9	0.5351997
10	Red10	0.3318066

Figure 7. Priority factors generated by the algorithm implemented in R software.

	row.names	Lista de prioridad
1	Red5	0.8354209
2	Red7	0.6317577
3	Red6	0.6189065
4	Red9	0.5351997
5	Red8	0.4951756
6	Red1	0.4780624
7	Red10	0.3318066
8	Red4	0.2777878
9	Red2	0.2706203
10	Red3	0.2430815

Figure 8. Priority List generated by the algorithm implemented in R software

As a first result we have that to each network was calculated the Factor of priority, which categorizes them and gives them importance from the side of the user. In figure 8 it can be seen the priority list that indicates us, in a more accurate way, a ranking of which networks are more suitable to do the transfer; as we evaluate nine criteria, the network 5 is the most appropriate to perform the transfer followed by the network 7, if network 5 is chosen and the such network does not comply with the requirements set by the user the algorithm will take the following until the end of the priority list.

6.2 Cosistency in the weights of criteria in AHP

To know if in a multicriteria decision matrix there is consistency in the weights assigned to each one of them, you should do a treatment of the matrix in order to obtain a value called the basis of consistency, this number is due to that the weights are well balanced in the matrix and that no criterion has an excessive

weight,(Moreno Jiménez, 2002)have established the thresholds, depending on the order of the matrix, which allows an interpretation of the analogous inconsistency to the 10% for the Consistency Reason of Saaty. These values are 0.31 for n = 3; 0.35 for n = 4 and 0.37 for n > 4, our matrix is of order 9 so ot must have a consistency index < 0.37. The reason of consistency of the reciprocal matrix is defined in the following way and we calculate the reason of consistency with RC as the ratio between the consistency index and random consistency index
Consistency index is defined as:

$$IC = (\frac{nmax - n}{n - 1}) \qquad (5)$$

Random consistency index is defined as:

$$IA = (\frac{1{,}98 * (n - 2)}{n}) \qquad (6)$$

Finally, the consitency index is:

$$RC = (\frac{IC}{IA}) \qquad (7)$$

In our matrix RC is equal to 0.2256 < 0.37 which means that the matrix is consistent.

6.3 Comparison of decision criteria and system improvements

The proposed algorithm improves the processing time for triggers compared with the algorithm in(Khattab & Alani, 2014a)since the number of rules of inference is lower, the time it takes doing the inferences is also lower, in these algorithms it is a preliminary aspect so it is adecuate for it not to have so many inference rules and thus improves the processing speed, since this generates additional costs of data processing, and delays making the decision, comparing this process we can see in figure 9 the difference of the speed of data processing, it is evident that there is a reduction of one-third of the processing that must be performed and this increases the speed three times, and as the number of networks increases, this value becomes very significant.

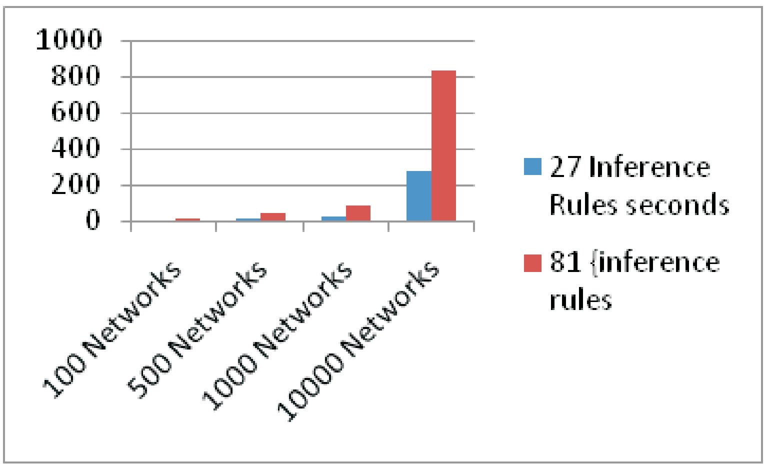


Figure 9. Comparison of processing times between 27 and 81 inference rules.

It should be noted that the variation in the aspects of selccion and comparison between the two options does not have a large variation in relation to the speed that is obtained by setting fewer rules of inference. On the other hand, in our algorithm is also created a priority list generated by the multicriteria decision AHP, in this part of our algorithm we ensure that the decision is consistent with respect to the values and criteria that are analyzed and processed to obtain the priority list, the method of the decision has 9 criteria previously listed, these criteria were evaluated and adjusted so they do not generate a overweight at the time of making the decision, the weights chosen for the criteria generate a quite consistent decision matrix which assures us that the decision taken by the method of selection is not biased, and that represents what is best for the user.

7. CONCLUSIONS

Our algorithm presents a solution to reduce the unnecessary transfers taking into account the preferences of the user and the optimization of networks, the fuzzy logic in union with the AHP makes a robust algorithm that optimizes the opportunities of generating a handover in an efficient manner.

This document proposes an algorithm that can achieve a scalable solution for heterogeneous networks and can be easily expanded to cope with the increase in the number of transfers and the criteria used.

The algorithm proposed can generate benefits both to the operator and to the quality of service provided to the user, because when multicriteria decision is performed taking into account the present networks and conducting an analysis of these networks the best network can be chosen with respect to the criteria of transfer and take good use of the available channels to the user, because when it is in places where it is possible to get more speed through the user's fixed operator it will stop being connected to the network of his mobile service provider.

In the multicriteria decision hierarchical method (AHP) is found the appropriate value for the weights of the criteria by ensuring that the decision is not biased but that is due to a consistent decision.

The algorithm is framed in the IEEE 802.21, so a wide-ranging work in the development of techniques for the transfer has begun using as reference the criteria that have been implemented in this standard.

In this article, we have studied several factors to improve the Vertical Handover Decision Algorithm (VHDA), as we found that it is possible to improve the speed of the triggers using a smaller number of inference rules and guarantee a consistent decision ensuring a correct value in the weights of the selected criteria.

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