Context Awareness and Class of Service Satisfaction for Modeling Handover Decision-Making

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ABSTRACT
The next generation mobile system is expected to support the continuous increase of users requirements. Through the high flow rates of these networks, new applications constraints are more complex and may be change dynamically and rapidly for wireless systems. The service heterogeneity provided by these applications has a great influence on system performance in terms of ability, availability and the context aware provided to make handover decision. To facilitate the negotiation process between the user and the network, we define some class of service that guarantees QoS for interworking between 3GPP and non-3GPP networks and the critical context criteria which influence the handover decision. In this context, our proposed approach supports the interaction between context-aware and class of service considering the use of the particular features of each class of service to make handover decision and providing the application required QoS. In this paper we conceive a new approach, called Enhance Simple Additive Weighting, for network selection that reduces computational complexity, the handover latency and eliminates networks which do not satisfy a minimum requirement compared to other existing approaches based on AHP strategy.

General Terms
Heterogeneous access networks Performance; Analytic Hierarchy Process; Computer-Communication Networks.

Keywords
Context Awareness; Class of Service; VHO Decision Making; AHP; Multiple Attribute Decision Making; E-SAW

1. INTRODUCTION
In the future cellular network the problem of detection of optimal access networks will be more difficult, because the context-aware will be much more diversified. As well the reasons for triggering a handover process depend on different criterion as :

- Lack of coverage in a particular area;
- Degradation of the quality of communication;
- The load of a given radio cell;
- Services consolidation;
- Load balancing between networks;
- Etc.

The concept of quality of service represents a multidimensional one and it is considered to improve network performance based on various criteria that should be guaranteed. The QoS basic constraint is the classification mechanism of the traffic deriving from different class of service. Class of Service requirements vary for different application constraints: minimum required bandwidth, maximum loss rate, latency allowed, etc. Thus, some class of service metrics is critical for decision making. They can be dynamically and rapidly collected from the context provided to decide which the network can be used by the currently class of service.

To achieve this, the relevance of contextual information depends on the application and the situation to be achieved. Based on various contexts provided and the requirements of different class of services, the solution should be able to making decision in a dynamic situation to select the most appropriate target network. The main contribution of our approach is the use of the provided networks context aware service and the features of the class of service to make handover decision.

The remainder of this paper is organized as follows. Section 2 gives an overview of some related works. Section 3 defines the main candidate for 4G (LTE-Advanced and mobile WiMAX). Section 4 describes different class of service conceived for heterogeneous radio access networks. Section 5 details the context awareness and the relevancies of contextual information used in our work. Our proposed model for handover decision process, Class of service weight parameter and network selection process are depected in section 6. We develop a study case in section 7 with numerical analysis and evaluation of the described solution with other existing approaches. The last section will conclude our work with some observations and results.

2. RELATED WORK
In heterogeneous wireless networks many research activities were carried on to facilitate and ensure a seamless handover quality in order to maintain a continuous wireless connection. Many researchers have been proposed that implement novel architectures which modeled context information to make handover decision. An overview of some of these approaches is given in this section in order to situate our work and prove our contribution. In [8], authors propose a general framework for handover decision that can collect the context information from a given network access and the mobile user equipment. This framework can update the decision algorithm and the context data. This solution defines the context provided by networks and the user but not define how interpret the context to make the adequate decision. Authors in [14] define a novel architecture Hybrid Interworking Unit (HIU) of a serving node as a bridge between two different access networks to

enable integration of various heterogeneous networks. They consider the Signal to Interference Ratio (SIR), the mobile station velocity, the user preferences, the applications requirements and the terminal capabilities to make vertical handover decision and optimize the handover initiation time as well as the selection of the most optimal network. The proposed decision algorithm uses the Dwell Timer concept to minimize handover costs which analyzed in terms of unnecessary and unbeneficial handovers rate. Development middleware architecture designed to ease mobility-aware service that offers a set of facilities for context awareness and handover management is proposed by [20]. It defines a Received Signal Strength Indication-Grey Model (RSSI-GM) to estimate future RSSI values by using the GM prediction model. With this technique, the proposed architecture exploits a threshold-based technique to estimate both handover probability and latency. Moreover, middleware proxies to receive and store incoming flows during handover to avoid frame losses and re-transmissions after handover completion. Authors in [18] proposed a new handover algorithm based on the terminal speed and the sub-channel's channel state information (CSI). They make the handover decisions based on the service capability of candidate cells. This algorithm reduces the signaling overhead and improves the handover performance except for reduced mobility situation. The aim work in [5] is focused on novel architecture that supports seamless service continuity in heterogeneous systems. This architecture requires slight modifications by integrating the existing mechanisms and control protocols both in the core and the access networks and supports handover decision functionality that is based on the context information.

Other work, specifically related to handover scheme is addressed to the optimization of the context-aware by the use of different optimization policy. For example, the authors in [19] give an overview of the most interesting and recent algorithm to make vertical handover decision. They classify such algorithms in different categories to compare each algorithm to the others: Traditional "RSS-based" algorithm, Function-based algorithm, User-centric algorithm, Fuzzy Logic and Neural Networks algorithm, Context-aware strategies and Multiple Attribute Decision (For example: Simple Additive Weighting SAW, Technique for Order Preference by Similarity to Ideal Solution TOPSIS, Analytic Hierarchy Process AHP and Grey Relational Analysis GRA) algorithm. Each vertical handover decision taken by these categories is based on different context metrics. Authors in [11], propose a context-awareness handover based on a planning mechanism in heterogeneous wireless networks. They develop two integrated approaches for context awareness handover planning mechanisms: AHP for assigning the weight of each level and TOPSIS for making decision approach and Genetic Algorithm GA approach which guarantees QoS requirements. Also in [15] authors present an overview of vertical handover techniques during different phases: Handover information gathering, Handover decision and Handover execution. They proposed and classified the main vertical handover decision algorithm used in the literature (AHP, GRA, TOPSIS, SAW…) into different categories depending on diverse metrics and parameters to evaluate the best candidate networks in order to make handover decision. The goal of [17] is to design an efficient Radio Resource Management (RRM) mechanism for various radio access technologies solving availability problems. The Decision making represents the heart of RRM, in this way they present an overview of the recent vertical handover procedure and classify them in three approaches: Network centric approach for which decisions are made at the network operator, User-centric approach where the decision can be made at user terminals and Collaborative approach that combines the two previous ones. In [28], authors present a comprehensive survey of VHD algorithms designed to satisfy and to provide the required Quality of Service. They describe the algorithms based on the main handover decision criterion used and evaluate tradeoffs between their implementation complexity and efficiency. Authors of [21], consider a modified Weighted Product Method (WPM) for access network selection. Their approach uses a weight distribution method to assign the weight of each criterion and make decision based on WPM and TOPSIS method. The particularity of this method is the use of different profile for the selection of the best access networks. The authors of [16] compare SAW and WPM methods to select the best network. They gave an overview of reducing the processing delay in handover mechanism.

There are other works summary to improve handover decision making in heterogeneous system [10, 22, 9, 30, 6, 29]. The proposed solutions for vertical handover decisions given in the previously indicated works, don't consider the interaction between a required context and a given class of service due to the dynamically change of application requirements in pervasive environment not forgotten the high level of complexity occupied by these proposed approaches. So in our work we develop a new context aware vertical handover based on the concept of multiple attribute decision making, taking into account QoS defined by different class of service criterion.

3. OVERVIEW OF THE 4G

Broadband wireless networks and communication diversity services offer currently an unlimited access to an important number of applications in order to provide ubiquitous broadband access. The next generation of mobile telecommunication technologies is expected to meet continuously the increase of such requirements such as depicted in figure 1.

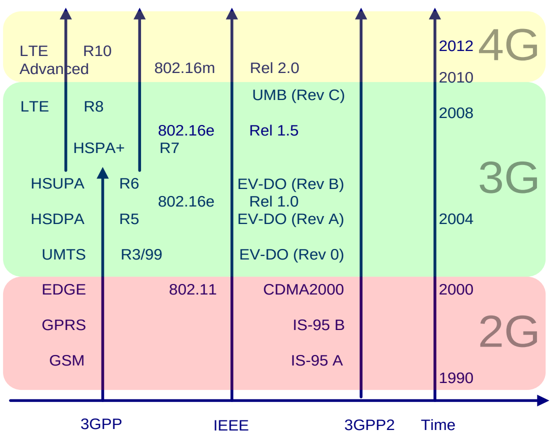

Fig 1: Mobile network generations growth.

The major high-level requirements must be achieved by the 4G:

- Seamless access;
- Services compatibility;
- Low blocking probability;

- High quality mobile services;
- High bandwidth utilization;
- Secured access;
- Reduced network cost (cost per bit);
- Providing better QoS;
- Interworking with other Radio Access Technologies.

Among the main candidates for 4G, we can consider LTE Advanced [1, 2, 3] and mobile WiMAX IEEE802.16m [12, 13]. They can provide services to high-speed users, low latency in mobile network and can increase the flexibilities of network deployments in the same geographical area. Table 1 summarizes the most important requirements for mobile WiMAX and LTE-Advanced.

Table 1. Access Parameter requirements for mobile WiMax (IEEE802.16m) and LTE-A

Parameter	mobile WiMAX	LTE advanced
Channel BW	From 5 to 40 MHz	Up to 20 - 100 MHz
Modulation	DL: OFDMA UL: OFDMA	DL: OFDMA UL: SC-FDMA
Duplex	FDD and TDD	FDD and TDD
Control plane latency	100 ms	Less than 50 ms
Throughput	DL: 1 Gbps UL: 500 Mbps	DL: 1 Gbps UL: 500 Mbps
Peak spectrum efficiency	DL: (4x4) 15.0 bps/Hz UL: (2x4) 6.75 bps/Hz	DL: (4x4) 30.0 bps/Hz UL: (2x4) 15.0 bps/Hz
Mobility	Up to 500 km/hr	Up to 350 until 500 km/hr
Antenna support	DL: (2x2) ,…, (8x8) MIMO UL: (1x2) ,…, (4x4) MIMO	DL: (2x2) ,…, (8x8) MIMO UL: (1x2) ,…, (4x4) MIMO

4. CLASS OF SERVICE (CoS)

Mobile networks from 3G to 4G must be designed to support a wide range of network traffic. Through the high flow rates of these networks, new communication services encompassing voice telephony and multimedia services can be provided. The mix of these services has a great influence on system performance in terms of ability and availability. Therefore, the QoS analysis is generally assimilated by the discrimination of services, in other words by the definition of different class of service. These classes are defined to facilitate the negotiation process between the mobile equipment and the network. As part of the work of 3GPP many service classes are defined [4]: Conversational, Streaming, Interactive and Background. The IEEE standard also provides four quality classes of service for transport applications, these four classes are: Unsolicited Grant Services, Real-time Polling Services, Non-Real-time Polling Services and Best Effort. The major difference between these classes is the sensitivity of each relative to transfer delay, delay variation and the packet loss ratio. The diverse classe of service in the two systems are very similar. Both systems have 4 different service classes. The Unsolicited Grant Service and Conversational Service are highly complementary and are considered as conversational services having an unsolicited profile. They include very sensitive delay applications. The Real Time Streaming class requires same attributes as the two previous classes, from the system. The difference with the two other classes is only the level of delay sensitivity, real time streaming services are more critical in delay sensitivity. Interactive, Non-Real Time, Background and Best Effort Service are also equivalent. These applications are less sensitive to delay but are much more sensitive to transfer errors. The conclusion is that the QoS classes of the two systems are practically identical. We can define a general classification with respect specification of each class as described below:

- Class 0

The applications of this class require a bidirectional service in real time with stringent QoS requirements such as voice over IP, video conferencing, interactive gaming. Services of this class require strict constraints on the transfer delay and delay variation, jitter, in the order to not degrade the human perception of the signal in other terms to guarantee the mobile user perceived quality of experience (QoE). Therefore this class demands less requirements on packet loss ratio and round trip delay.

- Class 1

This class is used for unidirectional flow applications like audio/video streaming. These are real-time applications and asymmetric where the data is transferred from the network to the mobile. The lacks interactivity between the two entities allows a sensitivity limit to delay less stringent than for Class 0 without affecting the QoS but they are more sensitive to the packet loss ratio. By cons, delay variation is an important parameter because this variation is perceptible by the user.

- Class 2

Interactive class is used for applications requiring interaction between the two extremities of the communication as web browsing, and generates a request and response by a remote server. This class does not have time constraints contrary to the two previous classes, real-time performance are not necessary, it is only waiting for a response with low round trip delay. However, this class must provide a packet loss rate low enough because the applications carried by this class are very sensitive to loss.

- Class 3

The applications carried by this class are applications which the user does not expect a response within any special requirement on delay such as E-mails, SMS, download of databases. In absence of interaction, therefore they are applications that do not require real-time constraint and less sensitive to delay, but are very sensitive to errors in transferring information.

5. CONTEXT AWARENESS

The context-awareness is all type of information presents in the environment which describes the situation of the user required service and the network in terms of location, time, user activity and network provider [23, 25]. It can be got back from a big variety of sources and may be formed by various metrics such as network availability, network capability, bandwidth, signal strength, user preference, access cost, quality of service, security, mobility location, user activity, etc. The context metrics are subdivided under two categories:

- Context Dynamic: The parameters can be distributed between various elements and they have a dynamic aspect which allows them to evolve constantly during time: network load, transmission bandwidth, traffic intensity, variety of services, RSSI, delay…
- Context Static: The parameters are easily accessible to a single entity of network and which are pre-determined: network capability, access point bandwidth, communication cost, security, battery consumption…

One of the first researchers [7] who generalized the notion of context, they specified three necessary stages for the context awareness: capture the context, interpretation of the context and supply the interpreted information to make it usable by a higher level. The growing presence of heterogeneous wireless networks has an impact in the diversification of the context metrics. It is very difficult to develop a handover algorithm based in all this metrics. We can regroup the context criteria by considering the particular characteristics of each class of service:

- Received signal strength (RSS): power of the received signal is the most widely used criterion in handover mechanisms and it differs from a network to another;
- Bandwidth: better performance when higher bandwidth is available;
- Data Rate: the maximum transfer rate that can be maintained between two endpoints;
- Round Trip Time: it refers to the duration of round trip time between mobile terminal and a considered point of attachment;
- Latency: low latency required for real time application;
- Jitter: defined as the variation of the end-to-end transit delays;
- Reliability: ensure a good quality of the link such as packet loss is classified as independent factor that ensures quality of service;
- Cost: mobile user should choose the low provided cost for a required service connection;
- Security: The user maintains a network with higher security level during the roaming through various network accesses and may choose the one that will provides best level of data security.

6. HANDOVER DECISION PROCESS

A service class is a combination of specific limits values of QoS parameters defined as quality of service objectives for the type of carried application. These classes are defined to facilitate the negotiation process between the user and the network. When establishing connection, the user communicates to the network the desired service class and the values of QoS parameters requested to transport the data. All these parameters form the required context by the user. During the process of gathering information, several networks are established one after the other to form a set of candidate point of attachment. According to each access network, are the context parameters which can be estimated to be transported and consequently forming the context provider. However, we define parameters of the context that we consider essential to characterize the behavior of each class. Based on these measured values, the network can guarantee the quality of service requested by the user or it sends to user explicitly limit values that can guarantee. The user can then accept or reject according to these values and its QoS requirements.

In figure 2, we define a general model for handover decision, it consider the granularity level of the class of service in the classification of traffic to satisfy the context-aware required by the user. Every application running on the MS has its own QoS requirements that can influence the handover decision regardless of network status. By allowing the user to choose a preferred network, the system is able to take into account the specific requirements of each class of service. The demand for context-awareness in heterogeneous wireless networks is related to the QoS classes.

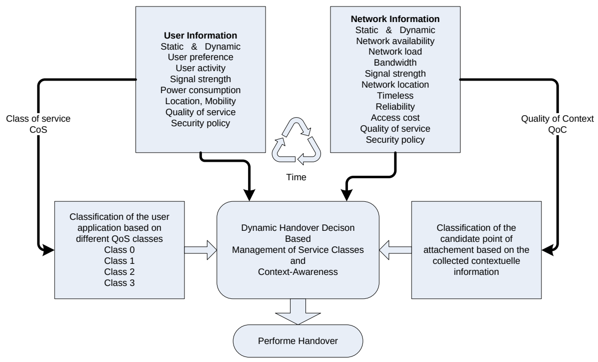

Fig 2: Handover decision based CoS and QoC

6.1 Definition of the Class of Service Weight Parameter

The Analytic Hierarchy Process (AHP) is developed by Thomas L. Saaty [26, 27]. It is popular and widely used, especially to resolve decision situation problem when multi criteria are involved such as: choice, ranking, prioritization, resource allocation, quality management… The goal might be to establish a consistent way through pair-wise comparison to allow users to judge the relative weight of different class of service based on various context criteria. The procedure for using the AHP consists of the following steps:

Step 1: Structuring the decision problem into hierarchy model

This step consists of building hierarchy model based on the context criteria. On the top level containing the decision goal and in intermediate level the context criteria (sub-criteria) according to their common characteristics. Figure 3 gives an overview of this model for radio access network selection.

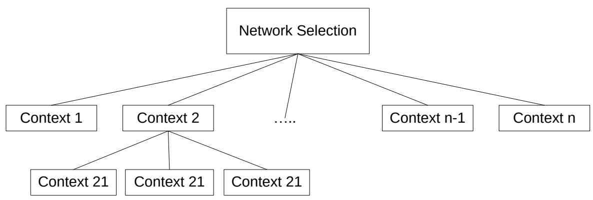

Fig 3: AHP hierarchy model for network selection

Step 2: Establish local priorities of each criterion by making pair-wise comparison matrix.

To make pair-wise comparison we need to judge the context criteria two by two and indicate how many times a criterion is more important than the other one. Each of these judgments is assigned a scale number as shown in Table 2. The intensity of importance use 9 point scale to convert these judgments to numerical priorities for every context criteria. For example if context A is strongly important than context B and we assign it the scale 7, then context B must be less important than context A and we assign it 1/7. The matrix is inversed with respect to the main diagonal that is equal to 1 because the diagonal represent the same context criteria compared with it.

Table 2 The Fundamental pair-wise comparison scale for AHP [24].

Intensity of importance	Definition	Description
1	Equal importance	Element A_i and A_j are equally important
3	Weak importance of A_i over A_j	Experience and Judgments slightly favour A_i over A_j
5	Essential or strong importance	Experience and Judgments strongly favour A_i over A_j
7	Demonstrated importance	A_i is very strongly favoured over A_j
9	Absolute importance	The evidence favouring A_i over A_j is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate	When compromise is needed, values between two adjacent judgments are used

The local priorities are established by calculating the principal eigenvector of the pair-wise comparison matrix as given by equation 1:

$$AW = \lambda_{max} W \tag{1}$$

with A is comparison matrix, λ_{max} is the largest eigenvalue of A and W is the corresponding eigenvector. The eigenvector are then normalized to become the priorities vector.

Step 3: Measurement of consistency of the comparisons and the overall priorities.

The Consistency Ratio (CR) is calculated to validate the pair wise comparison matrix and to ensure reliability in determining the priorities of a set of context criteria. It is calculated by:

$$CR = \frac{CI}{RI} \tag{2}$$

$$CI = (\lambda_{max} - n)/(n-1) \tag{3}$$

where CI is the Consistency Index, λ_{max} is the largest eigenvalue of A, n is the matrix size and RI Random Consistency Index. Saaty [24] has provided average consistencies (RI values) of randomly generated matrices for a simple size of 500. The RI values for different matrix sizes are presented in table 3. The value of Consistency Ratio is acceptable if it's equal or less than 0.10 for n≥5.

Table 3. The Random Index RI value

Matrix Size	1	2	3	4	5	6	7	8
RI Index	0.0	0.0	0.52	0.89	1.11	1.25	1.35	1.40

Use the local priorities obtained from the comparisons matrix to obtain global priorities through multiplying the local priorities of the sub-criteria by their parent's criteria and local priorities become global priorities if they do not have a sub-criterion.

Step 4: Weighting class of service

After assignment of the priorities for a set of context criteria involved to decision making, AHP uses relative model to weighting class of service. This model is more accurate in the comparison between the different class, where class of service are compared with each other using pair-wise comparison matrix as to which one is more important with respect diver context criteria. The definitions of the context criteria follow the hierarchy of the figure 3. Once the judgments are given with respect to each context criteria, we multiply the vector of priorities for the different class by the priority of the corresponding criterion. The idealized weight for each class of service is obtained by dividing priorities values by their sum for every criterion to define $Weight_{class}$ vector. A brief description of this model is shown in figure 4.

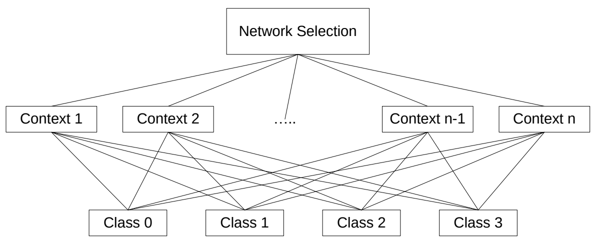

Fig 4: Relative model for weighting class of service

6.2 Classification Process and Network Access Selection

In heterogeneous environment the selection of suitable target network is the major problem when taking multi-context criteria. The MADM is the best known method to resolve this problem. It evaluates detected network in terms of multi criteria. However, a variety of model is proposed in the literature to assure successfully use of different context-aware in making decision.

6.2.1 Simple Additive Weighting (SAW) decision model

SAW [16] is the simplest MADM method for ranking all networks detected. To make a decision, we need to follow the following steps:

Construct the context matrix CM_{PoAi} of networks for all context criteria. When m is the number of networks, n is the number of context criteria and a_{ij} denotes context criteria j of candidate network i.

$$CM_{PoAi} = \begin{bmatrix} a_{11} & \cdots & a_{1j} & a_{1n} \\ \vdots & \ddots & \vdots & \vdots \\ a_{i1} & \dots & a_{ij} & a_{in} \\ a_{m1} & \dots & a_{mj} & a_{mn} \end{bmatrix} \tag{4}$$

We have two types of context criteria, benefit and cost criteria. For the benefit criterion, the best value is the largest value, it have the highest acceptable value such as: RSS and bandwidth. For the cost criterion, the best value is the lowest value, it have the lowest acceptable value such as: delay and reliability. Thus, the context matrix CM_{PoAi} is normalized using these equations:

$$â_{ij} = \frac{a_{ij}}{\overline{a_j}} \tag{5}$$

for the benefit criteria and

$$â_{ij} = \frac{\underline{a_j}}{a_{ij}} \tag{6}$$

for the cost criteria, where $\overline{a_j}$ and $\underline{a_j}$ are the highest and lowest possible value for the jth criteria for all networks. The CMN_{PoAi} matrix is given after normalization.

$$CMN_{PoAi} = \begin{bmatrix} â_{11} & \cdots & â_{1j} & â_{1n} \\ \vdots & \ddots & \vdots & \vdots \\ â_{i1} & \ldots & â_{ij} & â_{in} \\ â_{m1} & \ldots & â_{mj} & â_{mn} \end{bmatrix} \tag{7}$$

The weights vector for every class of service is given by $Weight_{class}$. Where W_j denotes the weight of criteria j, and their sum is equal to 1.

$$Weight_{class} = [w_1 \quad \ldots \quad w_j \quad \cdots \quad w_n] \tag{8}$$

The next step is to construct CM_{SAWi} matrix by multiplying each context criteria by their weight.

$$CM_{SAWi} = \begin{bmatrix} â_{11}w_1 & \cdots & â_{1j}w_j & â_{1n}w_n \\ \vdots & \ddots & \vdots & \vdots \\ â_{i1}w_1 & \ldots & â_{ij}w_j & â_{in}w_n \\ â_{m1}w_1 & \ldots & â_{mj}w_j & â_{mn}w_n \end{bmatrix} \tag{9}$$

The SAW model evaluate all networks and make decision by the use of equation below to ranking all candidates networks. The performed PoA with highest value of C_{SAWi} is selected.

$$C_{SAWi} = \sum_{j=1}^{n} â_{ij} W_j \tag{10}$$

6.2.2 Weight Product Method (WPM) decision model

The WPM [16] it's another method to make decision where several criteria is involved. It's similar to SAW model. The main difference is in the treatment of the benefit and cost criteria and instead of additive operator when ranking the networks there is multiplicative.

The context matrix CM_{WPMi} is given with raise the power of each criterion by the vector weight of the currently class of service as follows:

$$CM_{WPMi} = \begin{bmatrix} a_{11}{}^{w_1} & \cdots & a_{1j}{}^{w_j} & a_{1n}{}^{w_n} \\ \vdots & \ddots & \vdots & \vdots \\ a_{i1}{}^{w_1} & \ldots & a_{ij}{}^{w_j} & a_{in}{}^{w_n} \\ a_{m1}{}^{w_1} & \ldots & a_{mj}{}^{w_j} & a_{mn}{}^{w_n} \end{bmatrix} \tag{11}$$

with positive power for benefit criterion and negative power for cost criterion. Instead of addition WPM use multiplication to assign C_{WPMi} for each network such as:

$$C_{WPMi} = \prod_{j=1}^{n} a_{ij}{}^{Wj} \tag{12}$$

The ranking of all candidates network is given by the ratios with the ideal PoA as explained by equation (13).

$$R_i = \frac{C_{WPMi}}{C_{WPM*}} = \frac{\prod_{j=1}^{n} a_{ij}{}^{Wj}}{\prod_{j=1}^{n} (a^*{}_j)^{Wj}} \tag{13}$$

where a^*_j is the best solution of the j[th] criterion: the highest value for benefit criteria and lowest value for cost criteria.

6.2.3 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) decision model

The TOPSIS [11] model is another method to ranking the network. It defines an index that compares the separation of each network to the best and worst network that provide respectively ideal and bad solution. Construct the normalized context matrix $CMN_{TOPSISi}$ of networks for all context criteria.

$$CMN_{TOPSISi} = \begin{bmatrix} â_{11} & \cdots & â_{1j} & â_{1n} \\ \vdots & \ddots & \vdots & \vdots \\ â_{i1} & \ldots & â_{ij} & â_{in} \\ â_{m1} & \ldots & â_{mj} & â_{mn} \end{bmatrix} \tag{14}$$

with $â_{ij}$ is obtained by

$$â_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}} \tag{15}$$

Calculate the weight normalized matrix $CM_{TOPSISi}$ by multiplying each context criteria by their weight class.

$$CM_{TOPSISi} = \begin{bmatrix} â_{11}w_1 & \cdots & â_{1j}w_j & â_{1n}w_n \\ \vdots & \ddots & \vdots & \vdots \\ â_{i1}w_1 & \ldots & â_{ij}w_j & â_{in}w_n \\ â_{m1}w_1 & \ldots & â_{mj}w_j & â_{mn}w_n \end{bmatrix} \tag{16}$$

Identify the positive and negative ideal solution. For the positive ideal solution, we determine the highest value for benefit criteria and lowest value for the cost criteria and the inverse for negative ideal solution. Equations (17) and (18) show respectively the best and worst solution for every context criteria.

$$a_j{}^{best} = \left(\begin{pmatrix} Max(a_{ij}) \\ if\ j \in benifit\ criteria \end{pmatrix} and \begin{pmatrix} Min(a_{ij}) \\ if\ j \in cost\ criteria \end{pmatrix} \right) \tag{17}$$

$$a_j{}^{worst} = \left(\begin{pmatrix} Min(a_{ij}) \\ if\ j \in benifit\ criteria \end{pmatrix} and \begin{pmatrix} Max(a_{ij}) \\ if\ j \in cost\ criteria \end{pmatrix} \right) \tag{18}$$

The separation measurements of each network for the positive and negative ideal solution are given by these equations.

$$d_i{}^+ = \sqrt{\sum_{j=1}^{n} \left(a_{ij} - a_j{}^{best}\right)^2} \tag{19}$$

$$d_i{}^- = \sqrt{\sum_{j=1}^{n} \left(a_{ij} - a_j{}^{worst}\right)^2} \tag{20}$$

The final step is selecting the highest value of $C_{TOPSISi}$ after their ranking by calculating the relation of each network to the best and worst solution.

$$C_{TOPSISi} = \frac{d_i{}^-}{d_i{}^+ + d_i{}^-} \tag{21}$$

6.2.4 The proposed method of network selection E-SAW

The ranking model in the related methods is computationally expensive especially in add or remove of networks. In our developed solution we propose enhanced-SAW model and use it for decision making. The E-SAW model based on the simplest processing of SAW and eliminates computational cheaper caused by other method. The fundamental goal of our solution is to reduce the handover latency by introducing a threshold value of the required context in the ranking of networks. This threshold eliminates candidate networks with low requirements in order to satisfy the user quality of experience QoE. The steps for using E-SAW are described as follows:

After construction of the context matrix CM_{PoAi} of networks with all context criteria, it will be normalized where its coefficient are defined by equation (12).

$$\hat{a}_{ij} = \frac{a_{ij} - a_j{}^{th}}{\overline{a_j} - a_j{}^{th}} \tag{22}$$

where $a_j{}^{th}$ is threshold or acceptable value for the j[th] criteria for all networks and $\overline{a_j}$ is the highest value for benefit criteria and the lowest value for the cost criteria. The CMN_{PoAi} matrix is given after normalization as in (23).

$$CMN_{PoAi} = \begin{bmatrix} \hat{a}_{11} & \cdots & \hat{a}_{1j} & \hat{a}_{1n} \\ \vdots & \ddots & \vdots & \vdots \\ \hat{a}_{i1} & \ldots & \hat{a}_{ij} & \hat{a}_{in} \\ \hat{a}_{m1} & \ldots & \hat{a}_{mj} & \hat{a}_{mn} \end{bmatrix} \tag{23}$$

At this stage, our matrix normalized CMN_{PoAi} can differentiate three types of numerical value for context criteria:

- **Positive** value: where context criteria are widely satisfied ($a_{ij} > a_j{}^{th}$).
- **Zero**: where context criteria are just satisfied ($a_{ij} = a_j{}^{th}$).
- **Negative** value: where context criteria are unsatisfied ($a_{ij} < a_j{}^{th}$)

The goal of this step is to ignore only the network that not satisfies some context criteria of mobile user. These criteria are chosen based on services classes requirements actually actived. For example connection is required if the RSSI and bandwidth are higher than the threshold. Then, removal of networks which not meet these contextual criteria. After filtering context matrix CMN_{PoAi}, we shall have an optimal satisfied solution but our objective is to choose the best solution. Thus it's time to introduce the weight class to select the highest Networks as illustrated by (24).

$$CM_{E-SAWi} = \begin{bmatrix} \hat{a}_{11}w_1 & \cdots & \hat{a}_{1j}w_j & \hat{a}_{1n}w_n \\ \vdots & \ddots & \vdots & \vdots \\ \hat{a}_{i1}w_1 & \ldots & \hat{a}_{ij}w_j & \hat{a}_{in}w_n \\ \hat{a}_{m1}w_1 & \ldots & \hat{a}_{mj}w_j & \hat{a}_{mn}w_n \end{bmatrix} \tag{24}$$

To choose the better networks, we suppose that the obtained rate for the remainder networks as described below:

$$C_{E-SAWi} = \sum_{j=1}^{n} \hat{a}_{ij} W_j \tag{25}$$

6.3 Relative Standard Deviation (RSD)

To make good decision, several statistic methods are used for ranking networks based on various context criterions. It is possible that these methods do not give the same ranking when the networks requirements are similar. For this reason, the relative standard deviation is defined to make decision in this case. The RSD is calculated as following :

$$RSD = \frac{STDEV(C_{xxi})}{Avg(C_{xxi})} * 100 \tag{26}$$

where (C_{xxi}) is the method involved in RSD, STDEV is the standard deviation of the ranking values and Avg their average value.

7. STUDY CASE : NUMERICAL EXAMPLES AND EVALUATION

The demand to perform handover in heterogeneous wireless networks is related to the context-aware provided by the network detected and the class of service executed in this time. In this case, we consider a scenario of mobility given by figure 5, composed by seven Point of Attachment uniformly distributed on a highway. We will assume at the beginning that the MN is in position A is connected and served by PoA_0. The idea of this purpose is to evaluate our handover performance in a scenario where the required context metrics vary according to different class of service.

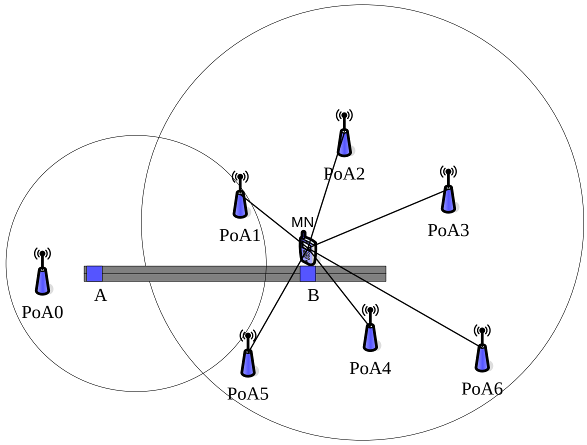

Fig 5: Topology studied

Every running application on the MN has its own QoS requirements that can impact the handover decision regardless the network status. MN will thus pursue its connection with PoA0, at the same time it examines the network by paging new signals. Then, close to the point B, the MN detects the presence of PoA_1, PoA_2, PoA_3, PoA_4, PoA_5 and PoA_6. The handover is initiated by notifying the currently PoA_0. This last one contacts the target PoAs, informs them about the request of the MN and start exchanging messages. Based on the context metrics required by the application and the provided context by the target PoAs as shown in table 4, we can use the weight for every class of service such as shown in table 5 to classifies these networks and make decision.

Table 4. Several PoAs provided context

Criteria	PoA1	PoA2	PoA3	PoA4	PoA5	PoA6
RSS	1	0.6281	0.4126	0.1298	1	0.6281
Bandwidth	0.4054	0.4054	0.1643	0.1643	1	0.4054
Data Rate	0.1193	0.2991	0.2991	1	0.2991	0.1193
RTT	0.13	1	0.2779	0.2779	0.2779	0.452
Latency	0.6272	0.6272	0.1476	0.382	1	1
Jitter	0.4054	0.1643	0.4054	0.4054	0.4054	1
Reliability	1	0.418	1	1	0.125	0.125
Cost	1	0.3816	0.1455	0.3816	0.3816	0.1455
Security	1	0.3543	1	0.1881	0.1881	0.3543

Table 5. Defined Weight of each Class of Service

Criteria	Class0	Class 1	Class 2	Class 3
RSS	0.151862	0.127608	0.142533	0.205429
Bandwidth	0.067487	0.226836	0.126684	0.182585
Data Rate	0.050133	0.137801	0.060779	0.088204
RTT	0.098899	0.046472	0.294026	0.074812
Latency	0.244269	0.121757	0.078547	0.067458
Jitter	0.21463	0.144203	0.080412	0.068731
Reliability	0.026276	0.02208	0.073986	0.106634
Cost	0.123764	0.154187	0.121746	0.175469
Security	0.022679	0.019057	0.021286	0.030679

Various methods are used to make decision for the target networks. We can see in the normalized matrix given below (cf. table 6) by E-SAW method that PoA number 3 and 4 has negatives values for the main criteria: coverage and availability. Thus, it is below the threshold values and don't satisfy the context needed to established the requested connection. Therefore, we remove this networks which not meet these contextual criteria and reduce unnecessary computation stages (cf figures 6-9).

Table 6. Normalized Matrix $CMN_{E\text{-}SAWi}$

$CMN_{E\text{-}SAWi}$=

RSS	Bandwidth	D-Rate	RTT	Latency	Jitter	Reliability	Cost	Security
1	0	-0.25653	-0.20482	0	0	1	1	0
0.366871	0	0	1	0	-0.40548	0	0	0
0	-0.40548	0	0	-1.28648	0	1	-0.38179	1
-0.48144	-0.40555	1	0	-0.65773	0	1	0	-0.2574
1	1	0	0	1	0	-0.50344	0	-0.2574
0.366871	0	-0.25653	0.241102	1	1	-0.50344	-0.38179	0

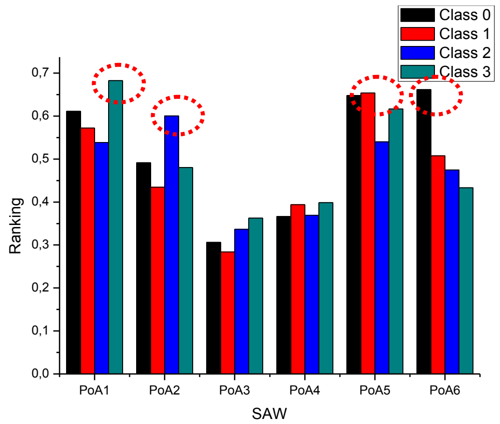

Fig 6: Result with SAW model

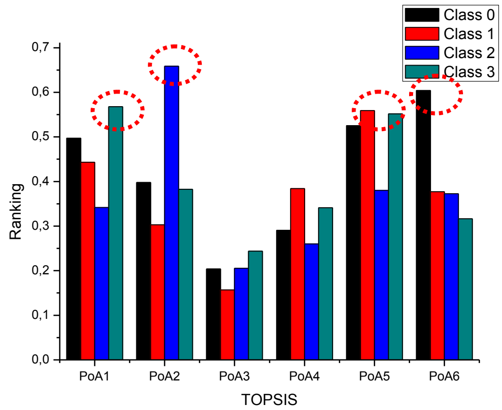

Fig 8: Result with TOPSIS model

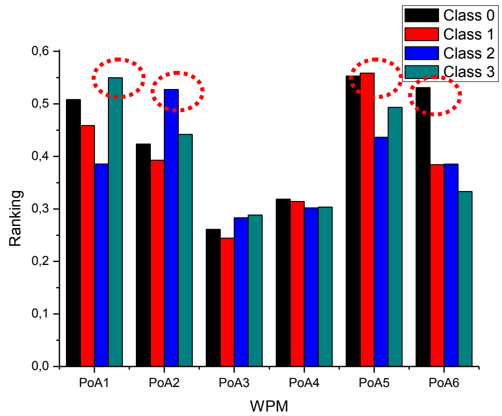

Fig 7: Result with WPM model

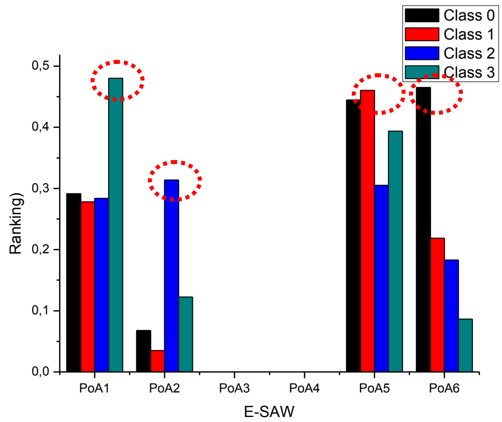

Fig 9: Result with E-SAW model

The mobile user required context can be varied form a given class of service to another. Figure 10 to 13 gives an overview of the behavior of all methods for each class of service. We can see that every class of service can be served by different PoAs and our method E-SAW provides results similar to the other methods much used in several research woks, but with low computation cost.

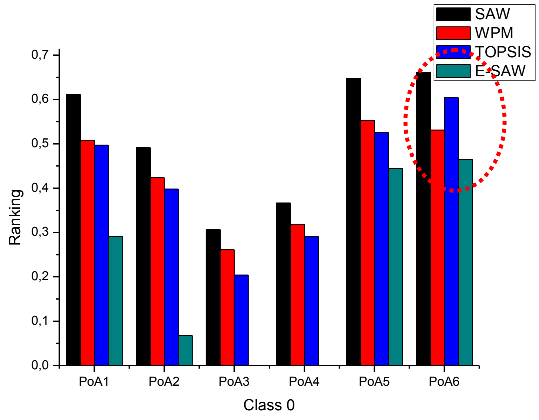

Fig 10: Result for class 0

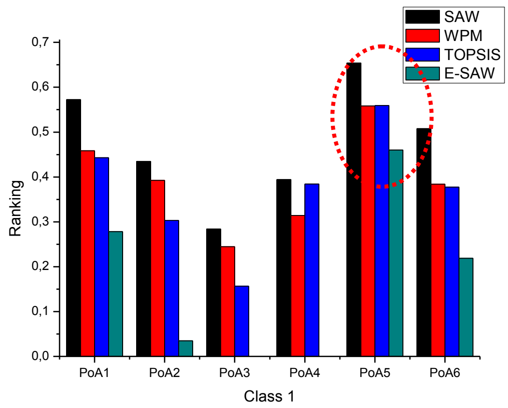

Fig 11: Result for class 1

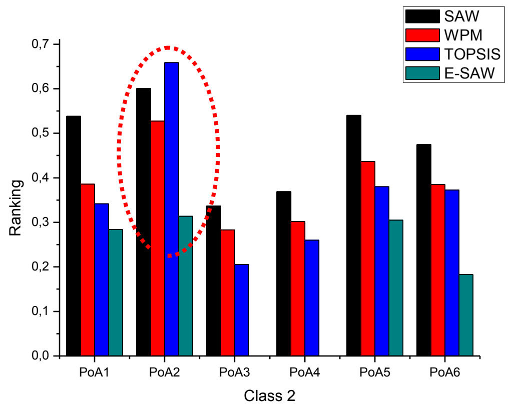

Fig 12: Result for class 2

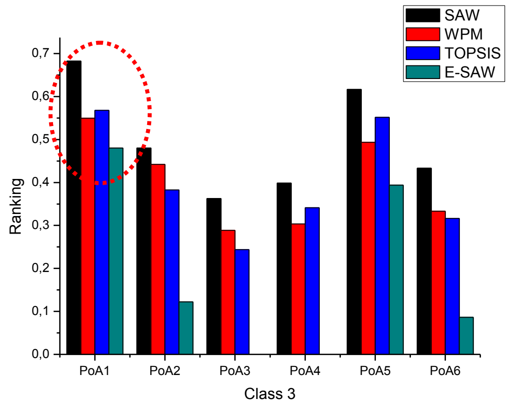

Fig 13: Result for class 3

In such a case the number of detected networks can increase continuously, therefore users will have to suffer from the increase of handover latency caused by the high level of computing complexity. The obtained results show that even with simple mechanism, we can see performance improvement. E-SAW can keep the same performance as the other algorithms by reducing the processing complexity and so the handover latency by minimizing the number of target PoAs.

8. CONCLUSION

In this paper, we presented an overview of class of service mechanisms to evaluate their influence on the required context and the point of attachment selection. We have seen that time constraints are strict for different class of service. Therefore, the performance study of our model can provide a different network selection based on the context criteria used by each class of service. Various methods are applied and compared with our proposal for ranking candidate networks giving a very close results. Our solution can help in performance improvement and in the selection of the best target network but don't guarantee that the context-aware will not change after making decision. This is due to the variation of the ubiquitous environment. With the present work we have conceived a new context-aware vertical handover decision process based on E-SAW. Our contribution reduces the decision delay by reducing the number of the target PoAs for different class of service features. The results have proven that E-SAW provides the same results as existing methods with a reduced complexity cost and reduced handover latency. In future work we intend to implement our proposal meaning a network simulator in order to validate concretely our analytical results.

9. REFERENCES

[1] 3GPP TR 36.913, Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) (LTE-Advanced), Release 10, 2011-04.

[2] 3GPP TS 36.101, Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception, Release 10, 2011-11.

[3] 3GPP TS 36.104, Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception, Release 10, 2011-11.

[4] 3GPP TS 22.105, 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects Service aspects; Services and service capabilities, Release 9, 2010-09.

[5] Alexandros Kaloxylos, George Lampropoulos, Nikos Passas and Lazaros Merakos, A flexible handover mechanism for seamless service continuity in heterogeneous environments, Journal Computer Communications, Volume 29 Issue 6 pp. 717–729, March, 2006.

[6] Allan Borges Pontes, Diego dos Passos Silva, José Jailton, Otavio Rodrigues And Kelvin Lopes Dias, Handover Management in Integrated WLAN and Mobile WiMAX Networks, IEEE Wireless Communications, pp. 86-95, October 2008.

[7] Anind K. Dey and Gregory D. Abowd, Towards a Better Understanding of Context and Context-Awareness, HUC '99 Proceedings of the 1st international symposium on Handheld and Ubiquitous Computing, 1999.

[8] Christian Prehofer, Nima Nafisi and Qing Wei, A Framework for Context-aware Handover Decisions, 14th IEEE Proceedings on Personal, Indoor and Mobile Radio Communications (PIMRC 2003), pp. 2794-2798 vol.3, January 2004.

[9] David J Wright, Maintaining QoS During Handover Among Multiple Wireless Access Technologies, Sixth International Conference on the Management of Mobile Business (ICMB 2007), Juliet 2007.

[10] Hongwei Liao, Ling Tie and Zhao Du, A Vertical Handover Decision Algorithm Based on Fuzzy Control Theory, Proceedings of the First International Multi-Symposiums on Computer and Computational Sciences (IMSCCS'06) pp. 309-313, June 2006.

[11] Hsiao-Yun Huang, Chiung-Ying Wang, and Ren-Hung Hwang, Context-Awareness Handoff Planning in Heterogeneous Wireless Networks, Lecture Notes in Computer Science, Volume 6406 pp. 430-444, Springer-Verlag Berlin Heidelberg 2010.

[12] IEEE Std 802.16m-2011, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Broadband Wireless Access Systems, Amendment 3: Advanced Air Interface, May 2011.

[13] IEEE 802.16m-07/002r10, Project IEEE 802.16 Broadband Wireless Access Working Group, IEEE 802.16m System Requirements, January 2010.

[14] Ikram Smaoui, Faouzi Zarai, Mohammad M.Banat and Lotfi Kamoun, Heterogeneous Wireless Networks: Configuration and Vertical Handoff Management, Wireless Personal Communications: An International Journal, Volume 54 Issue 3 pp. 417-445, August 2010.

[15] Johann Márquez-Barja, Carlos T.Calafate, Juan-Carlos Cano and Pietro Manzoni, An overview of vertical handover techniques: Algorithms, protocols and tools, Computer Communications, Volume 34, No. 8 pp. 985-997, June 2011.

[16] K. Savitha and Dr. C. Chandrasekar, "Vertical Handover decision schemes using SAW and WPM for Network selection in Heterogeneous Wireless Networks", Global Journal of Computer Science and Technology Volume 11 Issue 9 Version 1.0 pp. 19-24, May 2011.

[17] Kandaraj Piamrat, Adlen Ksentini, Jean-Marie Bonnin and César Viho, Radio resource management in emerging heterogeneous wireless networks, Computer Communications, February 2010.

[18] LI Ming-ju, XU Ning, WANG Ying and ZHANG Ping, Handover with resource pre-allocation in the OFDMA systems, The Journal of China Universities of Posts and Telecommunications, Volume 14, Issue 4 pp. 27-31, December 2007.

[19] Meriem Kassar, Brigitte Kervella and Guy Pujolle, An overview of vertical handover decision strategies in heterogeneous wireless networks, Journal Computer Communications Volume 31 Issue 10 pp. 2607-2620, June 2008.

[20] Paolo Bellavista, Marcello Cinque, Domenico Cotroneo and Luca Foschini, Integrated support for handoff management and context awareness in heterogeneous wireless networks, MPAC '05 Proceedings of the 3rd international workshop on Middleware for pervasive and ad-hoc computing, 2005.

[21] Peyman TalebiFard and Victor C.M Leung, A Dynamic Context-Aware Access Network Selection for Handover in Heterogeneous Network Environments, IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS) pp. 385-390, June 2011.

[22] Rashid A. Saeed, Hafizal Mohamad, Borhanuddin Mohd. Ali and Mazlan Abbas, WiFi/WiMAX Heterogeneous Seamless Handover, Third International Conference on Broadband Communications, Information Technology & Biomedical Applications, pp. 169-174, December 2008.

[23] Ricardo Matos and Susana Sargento, Context-Aware Connectivity and Mobility in Wireless Mesh Networks, Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, Volume 32 Part 2 pp- 49-56, 2010.

[24] R.Ramanathan, A note on the use of the analytic hierarchy process for environmental impact, Journal of Environmental Management 63, pp. 27-35, 2001.

[25] Thomas Hofer, Wieland Schwinger, Mario Pichler, Gerhard Leonhartsberger, Josef Altmann and Werner Retschitzegger, Context-Awareness on Mobile Devices - the Hydrogen Approach, Proceedings of the 36th Annual Hawaii International Conference on System Sciences (HICSS'03), Track 9 Volume 9, 2003.

[26] Thomas L. Saaty, Decision making with the analytic hierarchy process, International Journal of Services Sciences (IJSSCI), Vol. 1, No. 1, pp. 88-98, 2008.

[27] Thomas L. Saaty, How to make a decision: The Analytic Hierarchy Process, European Journal of Operational Research 48, pp. 9-26, North-Holland 1990.

[28] Xiaohuan Yan, Y.Ahmet Sekercioglu and Sathya Narayanan, A survey of vertical handover decision algorithms in Fourth Generation heterogeneous wireless networks, Journal Computer Networks: The International Journal of Computer and Telecommunications Networking Volume 54 Issue 11 pp. 1848-1863, August 2010.

[29] Xu Haibo, Tian Hui and Zhang Ping, A novel terminal-controlled handover scheme in heterogeneous wireless networks, Journal Computers and Electrical Engineering, Volume 36 Issue 2 pp. 269–279, March 2010.

[30] Z. Dai, R. Fracchia, J. Gosteau, P. Pellati and G. Vivier, Vertical handover criteria and algorithm in IEEE 802.11 and 802.16 hybrid networks, IEEE International Conference on Communications 2008 (ICC '08), pp. 2480–2484, Mai 2008.