# A Mechanism for Vertical Handover Based on SAW Using IEEE 802.21*

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**Abstract.** Nowadays, there is a lot of devices which are able to access wireless networks through a wide range of access technologies. For a device to move among these heterogeneous networks and stay always connected, mechanisms of vertical handover are needed. This paper proposes a handover decision mechanism using the Simple Additive Weighting (SAW) in a heterogeneous wireless network environment using the IEEE 802.21. The proposed mechanism considers user preferences like cost as parameters of the candidate network to choose the best available network. We present some experiments that use a developed simulator to validate our mechanism. The results of these experiments show that the proposed solution distributes better the mobile nodes among the networks.

**Keywords:** Wireless Networks, Next Generator Networks, Handover, IEEE 802.21.

## 1 Introduction

Nowadays, there is a lot of devices and wireless network technologies. Each technology has advantages and drawbacks depending on the scenario, for instance, the use of a Wi-Fi network is suitable for wireless LANs. The WiMAX (Worldwide Interoperability for Microware Access) is suitable for WANs. The cellular networks will be based on the IP protocol and these new networks are known as Next-Generation Wireless Systems (NGWS) [1].

Currently, one of the main research challenges for next generation of IP wireless networks is the development of intelligent techniques for mobility management that take advantages of IP based technology to reach global roaming among wireless technologies [1]. In an environment of multiple access technologies, the concept of being always connected becomes always best connected (ABC) [2]. Many issues about network integration (composition) are a challenge to the research community.

The IEEE 802.21 standard [3,4] defines a common Media Independent Handover Function (MIHF) between layers 2 and 3, which enables mobility across

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heterogeneous networks including both IEEE 802 and non-IEEE 802 networks. The main goal of this standard is to maintain connection during handover across different networks. Media Independent Handover Services define link-layer services to enable handovers among different radio air interfaces. Examples of 802.21 handovers are IEEE 802.11 networks to/from IEEE 802.16 networks, or IEEE 802 networks to/from cellular networks [5]. Despite offering mechanisms to the network, the 802.21 standard does not specify the handover decision algorithm.

In current wireless network technologies, such as IEEE 802.11 networks and cellular networks, handover decisions are usually based on the level of the received signal strength and IEEE 802.11 priority. The user's preferences are not taken into account and in the case of vertical handover, the signal can not be enough to decide the handover due to asymmetrical nature of radio technologies. In the next wireless network generation systems, the users can have a lot of networks alternatives and each one of them can have many features like cost, bandwidth, power consumption, etc, and the users must choose which is the best one to connect according to their needs.

In this paper we propose a mechanism for decision making of handovers that uses the SAW method. The proposed mechanism has three main parts: An algorithm for decision making handover, extensions of the IEEE 802.21 messages and the Information Server (IS) entity, proposed in this standard, and the creation of the SAW module inside the IS. These three main parts together are responsible for making the handover decision for the user.

The SAW (Simple Additive Weight) method is a type of Multiple Attribute Decision Making (MADM). The MADM refers to making decisions in the presence of multiple, usually conflicting criteria [6]. There are many methods to solve MADM problems, for instance, ELECTRE, TOPSIS, AHP (Analytic Hierarchy Process), etc. The SAW method has been chosen as a suitable option to solve this kind of problems, as discussed in [7]. The SAW method is used to rank the available networks to the mobile nodes. The users preferences like cost and bandwidth are used as handover parameters in order to make the decision. Besides these parameters, the network current load is considered to achieve load balancing, thus improving the network utilization. All computing processing for handover decisions is performed by a network entity, consequently, the mobile node (MN) minimizes the power consumption.

The rest of this paper is organized as follows. In Section 2, we briefly review related work. In Section 3 an overview about SAW method and the IEEE 802.21 standard is presented. We propose the IEEE 802.21 handover protocol extensions and the handover decision algorithm (HDA) in Section 4.2. The Section 5 shows simulation results, comparison, and analysis. Finally, we present conclusion in Section 6.

## 2 Related Work

In the future networks, there will be several alternatives of wireless access technologies, therefore IEEE 802.21 will be increasingly important to integrate these networks in a seamless way for the users. The handover decision mechanisms and algorithms are a key part in this process. There are several handover decision algorithms in the literature.

Tawill et all. [8] propose a handover decision algorithm using the SAW method in a distributed manner. They use, as evaluation metrics to making handover decision, bandwidth, dropping probability, and cost.

Lee et all. [9] propose a vertical handover decision algorithm based on a utility function to satisfy the QoS requirements. This utility function considers signal to interference plus noise ratio (SINR), bandwidth, traffic load and user's mobility, its goal is to maximize the network throughput.

Kim and Jang [10] propose a vertical handover decision algorithm using IEEE 802.21. The mobile node periodically measures the Receive Signal Strength (RSS). The mobile node computes an RSS's mean to figure out which is the best time to execute the handover. The solution is based on same idea of the traditional handover that makes the decision based on the signal power.

The work closer to the proposed solution is presented by Tawill et all.[8]. Despite the authors use the SAW method to ranking the networks and computing the network score in a distributed way, the solution does not take into account the networks' current traffic load (bandwidth) at the time of decision. Using just SAW method to decide which is the better network, a network that fits the user's needs could remain more loaded than others, reducing their quality of service. Futhermore, the solution does not use the IEEE 802.21 services to obtain the networks' information, thus it is more complicated than the proposed solution. In the works developed by Yang et all. [11] and Lee et all. [9], the whole decision calculation is performed by the MN, decreasing their battery level quickly.

## 3 Background

This section presents some basic concepts about IEEE 802.21 standard and SAW method.

### 3.1 IEEE 802.21

Due to the heterogeneity of protocols and technologies involved, vertical handover is much more difficult to implement than horizontal handover. The IEEE 802.21 standard comes up to facilitate the vertical handover. This proposal provides a framework that enables the optimization of handover among heterogeneous networks. The purpose is to improve the user experience of an MN by faciliting handover among networks including both 802 and non 802 networks, and wired and wireless networks [3]. As show in Fig. 1. the IEEE 802.21 defines a service layer between the network and link networks. This layer is called Media Independent Handover Function (MIHF) and provides three types of services: the media-independent event service (MIES), the media-independent command service (MICS) and the media-independent information service (MIIS).

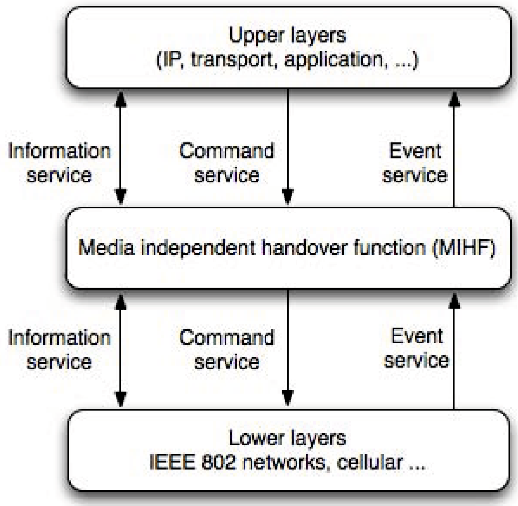


**Fig. 1.** MIH services

The main role of MIES is to detect events that occur in local or remote interfaces and report them to upper layers. Examples of events that may be reported to upper layers are degradation of the signal power, unavailability of link, among others.

The MICS is responsible for making available commands to uppers layers. These commands are responsible for controlling the lower layers, more specifically to control the handover procedures.

The service information (MIIS) provides information about network's service and available networks. This information is used by the MN to decide which network is a good choice to connect to. This information may include, for instance, GPS coordination, channels information, etc.

The standard proposes an information server (IS) to cope with all related network information. This information supports MN choosing the best available network, therefore facilitating network handovers. IEEE does not define where the IS is located. For instance, it can be located within the MN domain. Similarly, the database structure is not defined. The IS has a key role in the development of our proposed solution. The proposed algorithm uses information provided by the IS.

### 3.2 SAW - Simple Additive Weight

Decision makers often deal with problems that involve multiple, usually, conflicting criteria. In our problem, the user has several options to join a network and needs to decide what is the best alternative based on its preferences.

The SAW method, also called weighted sum method, is the simplest and still the widest used MADM method. In order to produce a value, a decision

**Table 1.** Decision Table

| Network | Bandwidth (Mbps) | Weight | Cost | Weight |
|---|---|---|---|---|
| Wi-Fi | 54 | 0.5 | $0.70 | 0.5 |
| WiMAX | 70 | 0.4 | $1.00 | 0.6 |
| Cellular | 42 | 0.1 | $5.00 | 0.9 |

table must be mounted based on each alternative and criterion available. Each alternative is a line and each criterion is a column. First, all elements of the decision table need to be normalized, then, the SAW method can be used for any type and any number of criteria. The Table 1 shows an example decision table. In this table each alternative is a network with its respective criteria and weights.

A weight is given for each criterion and the sum of all weights must be 1 [6]. The importance of each criterion is determined by a weight. This combination of criterion plus weight composes the score. The score of the SAW method is given by:

$$Score_i = \sum_{j=1}^{M} W_j(m_{ij})normal \tag{1}$$

where $Score_i$ is the score of the alternative $i$; $W_j$ is the weight of criterion $j$; $M$ is the number of available criteria; $m_{ij}$ is the criterion value of the alternative $i$ for the criterion $j$; *normal* are the values normalized.

## 4 Handover Protocol and Proposed Decision Algorithm

Some extensions were made in the messages of IEEE 802.21 handover protocol in order to include metrics used by the proposed algorithm. In the next subsections the messages extensions of the IEEE 802.21 handover protocol are present as well as the proposed handover decision algorithm.

### 4.1 IEEE 802.21 Handover Protocol

The Fig. 2. presents the steps that the MN takes according to IEEE 802.21 to choose the best network to connect to. Proposed extensions in the standard are commented below.

First, the MN sends a message to the IS to figure out which networks are available in its coverage area (1). We have extended this original message including a handover field, thus the MN may send into the handover field "fromHandoff" or "newCon" string. If the MN is trying a handover, it includes the "fromHandoff" string into the field, otherwise, "newCon" string is included meaning that the MN wants to perform a new connection.

Second, the IS verifies which networks are available to the MN and sends a message to all of them (2). We've added an information in this step, the IS

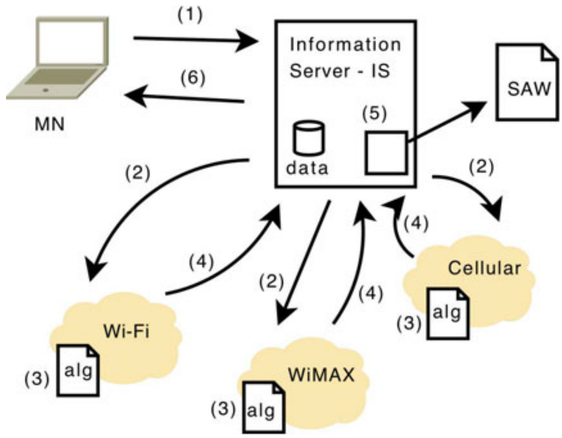


**Fig. 2.** Operation of the solution

informs to the networks if the MN has one network option in its coverage area through the boolean field isUnique. If there is just one option, the isUnique field is true.

Then, each network runs the Algorithm I (3) (see next section), and verifies if it can accept the MN or not. The answer message is sent to the IS (4). We have extended this message adding the actual_load_bw field, thus each network sends to IS its current traffic load inside the answer message.

Next, the IS mounts a decision table, as shown in Table 1 with all network's answers and sends this table to the SAW module (5). We added the SAW module in the IS to calculate the SAW score. The SAW module computes the final score of all networks. Each network score is divided by its current traffic load. After that, the SAW module sends the scores to the IS. Then, the IS sends a message to the MN (6) with all available networks with their respective scores. Finally, the MN chooses the network with the higher score to connect to.

The Fig. 3. shows a use case diagram of the IEEE 802.21 protocol with proposed extensions. All messages that are exchanged between the MN and the IS are showed. First, the user sets its preferences (bandwidth and cost) with its respective weights (1). Then, the application (UP layers) sends an MIH_Get_Information_request message to the MIH User (2). In this message the fields bw, weightB, cost, weightC were added to inform to the IS the bandwidth (bw), bandwidth's weight (weightB), cost (cost) and cost's weight (weightC). These fields represent the user's requirements or user's criteria used by the IS to choose the best network. In this message the handover field is filled out as explained before. After that, the MIH User uses the MIHF to send a message to IS (3). Then, the IS executes the procedures showed before (Fig. 2.) and sends an MIH_N2N_HO_Query_Resources_request message to all candidate networks (4). In this message we add the field isUnique. Through this field, the IS informs if the MN has one or more available network(s) to connect to. Then, an

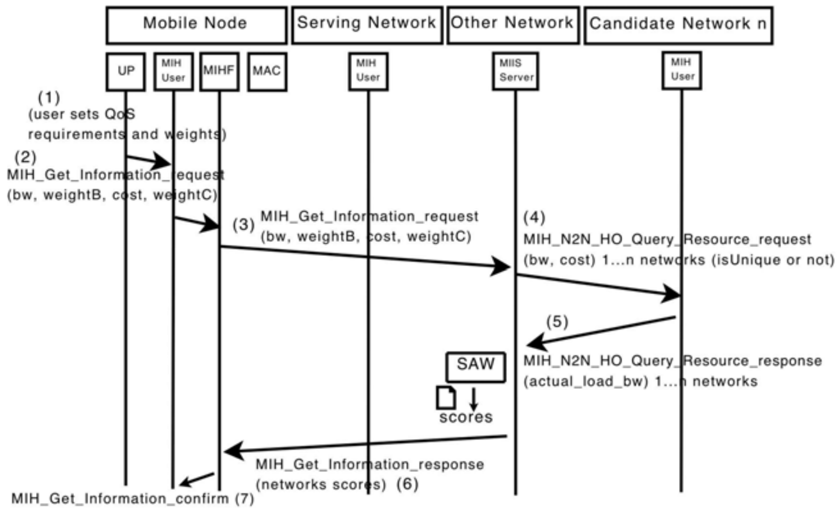


**Fig. 3.** Use case diagram of the IEEE 802.21 with proposed extensions

MIH_N2N_HO_Query_Resources_response message comes into the IS (5). As we explain before, we added the actual_load_bw field that informs the current load of each network. Now the IS executes the showed procedures (Fig 2. (5)). Finally the IS sends an MIH_Get_Information_response (6) to the MN.

## 4.2 Handover Decision Algorithm (HDA)

Algorithm I shows the proposed algorithm. This algorithm uses information provided by the IS and the MN to decide if the network may accept the MN or not. This algorithm is performed in each network as shown in Figure 2, step (3).

Initially, the algorithm verifies if the network can accept the MN by testing the user's criteria (bandwidth and cost) (line 1). This test compares the user's requirement with the network's resource, in other words, if the network may offer a bandwidth greater or equal than the user's request bandwidth and if the network's cost is lower or equal than the user's request cost. Next, the algorithm performs three tests (lines 2, 9 and 16) in order to distinguish the kind of connection of the MN, and then verifies two thresholds that will admit or deny the MN's connection. We defined two thresholds. The threshold1 (thr1) is used when the MN requests a new connection and there are more than one available network to connect to. The threshold2 (thr2) is used when the MN requests a new connection and there is just one available network to connect to as well as if the MN is coming from another network (handover=fromHandoff) and there are more than one available network to connect to. The use of two thresholds in the Algorithm I allows a carrier to assign priority to MNs. The algorithm can differentiate if the MN is trying to perform a handover (handover=fromHandoff) or is starting a new connection (handover = newCon). These thresholds are useful to maintain the MN's connection in the case where the MN is already connected and it performs a handover.

*Algorithm I - Handover Decision Algorithm*

```
 1. if( (cost >= networkCost) or (bw <= networkBw) ) {
 2.     if (handover=newCon) and (not isUnique) {
 3.         if (((actual_load_bw + bw) <= thr1) and
 4.             ((actual_load_bw + bw) <=
                   max_load_bandwidth) ) {
 5.                 actual_load_bw = actual_load_bw +
                         bandwidth;
 6.                         connection accepted; }
 7.          }else
 8.              connection refused; }
 9.     else if((handover=newCon)and(isUnique)) or
            ((handover=fromHandoff)and(not isUnique)){
10.             if (((actual_load_bw + bandwidth) <= thr2) and
11.                ((actual_load_bw + bandwidth) <=
                                max_load_bandwidth) ) {
12.                   actual_load_bw = actual_load_bw +
                            bandwidth;
13.                            connection accepted;
14.             }else
15.                   connection refused; }
16.     else if (handover=fromHandoff) and (isUnique) {
17.          if (((actual_load_bw + bandwidth) <=
                              max_load_bandwidth) {
18.              actual_load_bw = actual_load_bw +
                      bandwidth;
19.                      connection accepted; }
10.          else
21.              connection refused; }
22.     else
23.         connection refused;
24. } else
25.     connection refused;
```

The first test (line 2) verifies if the MN's connection is not unique (not isUnique) and also if the connection is new (handover=newCon), in this case, it verifies (lines 3 and 4) if the network's current traffic load (actual_load_bw) plus the requested bandwidth (bw) is less than the thr1 and less than the max bandwidth supported by the network (max_load_bw). If these conditions are satisfied, the network admits the MN (line 6), otherwise the MN is refused by the network (line 8). The second test occurs when the MN is starting a new connection (handover=newCon) and this connection is the only one available (isUnique), or the MN is trying to perform a handover (handover=fromHandoff) and has more than one available connection (line 9). In this case, the thr2 is the limit to admit (line 13) or deny (line 15) the MNs. In the third and last test, the algorithm tests if the MN is trying to perform a handover (handover=fromHandoff) and if the connection is the only available (isUnique) (line 16). The algorithm verifies if the bandwidth requested plus the current traffic load (actual_load_bw) is less than the max bandwidth supported by the network (max_load_bw).

In the cases where the network accepts the MN's request from the IS, the bandwidth is reserved (lines 5, 12 and 18) and the request is stored with a unique id, and a timeout is started. In the case the MN does not perform a request to connect to the network later, the reserved resource is released when the timeout expires. The steps after the handover decision are out of the scope of this paper.

## 5 Performance Evaluation

The purpose of this study was to compare how the proposed solution distributes mobile nodes through available networks. The resource utilization of networks was measured as well as the blocked ratio. The proposed solution was compared with an ordinary solution, where MNs choose the network, based on the network priority [12]. The MN first tries to connect to the Wi-Fi network. If it can not connect, it tries a WiMAX network and finally it tries the cellular network. In the next sections we call the ordinary decision, Wi-Fi algorithm, and our entire proposed mechanism, HDA. We show that our mechanism improves average network utilization. In the next paragraph, we describe our simulator as well as the developed experiments.

### 5.1 Simulator Implementation

A discrete event simulator was developed in Java. First of all, a traffic generator creates an event list sorted by time. Each event has a corresponding Mobile Node. This MN has an id, user's preferences (bandwidth, cost), MN's coordinates, and the kind of the MN's connection (fromhandoff or newCon). The id is a sequencial number, the other informations are generated using a uniform distribution up to a limit value. To each event created by the traffic generator, a departure event is created to define the time that the mobile node will leave the system. This time is generated using an exponential distribution using the MEANDEPARTURETIME variable as mean.

A control plane is a module responsible to control all functionalities of the simulator. There are three main modules: the stat, the network and the decision module. The stat module defines all statistics of the simulator, and it is customizable, in other words, it is able to be changed in order to be suitable to different situations. The network module deals with the information about the networks stored in the system. This module stores all information about the networks, for instance, the kind of network (e.g Wi-Fi, WiMAX), max supported bandwidth, the propagation model, the transmit power, the thresholds and the access point/base station (AP/BS) coordinates. The communication radius in MNs is calculated by the network module using a combination of information such transmit power and depends on the propagation model defined in the simulator's configuration. The Tworayground propagation model was implemented in this simulator. This model is the same used by ns simulator [13]. The decision module is responsible to run the decision algorithm, and emulates messages produced by the IS.

### 5.2 Simulation Results

The topology of the simulated scenario consists of three networks. A Wi-Fi, a WiMAX and a Cellular network. In the Wi-Fi network, the transmission power of the AP is 0.281838db. The max supported bandwidth is 25.6 Mbps. In the WiMAX network, the transmission power of the BS is 0.481838db. The max supported bandwidth is 65 Mbps. In the Cellular network, the transmission power of the BS is 4.982838db. The max supported bandwidth is 41 Mbps. The AP/BS location is in the same place and the MNs are uniformly distributed around it, as shown in Fig. 4. We assumed no interference between the MNs and the AP/BS. For this scenario, it is assumed the presence of an admission control mechanism, so that the MN just receives the requested bandwidth. We ran each experiment 14 times, and we calculated a 95 percent of confidence interval.

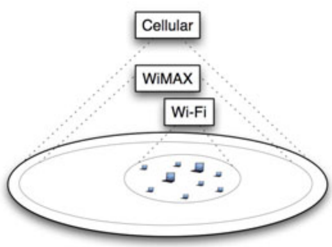


**Fig. 4.** Distribution of mobile nodes across the coverage area of the networks

The simulation results of the utilization ratio of resources are shown in Figs. 5-8. We can learn that the MNs were well distributed among the available networks by the HDA.

Figure. 5 shows the distribution of 26 MNs among the networks. Comparison between the HDA and Wi-Fi algorithm shows that our proposed mechanism distributes better the MNs among the networks. The network load of 26 MNs is low, smaller than the total capacity of the three networks. Note that almost all MNs connect in the Wi-Fi network using the Wi-Fi algorithm, meanwhile the other networks are empty. This occurs because Wi-Fi algorithm selects the Wi-Fi network first to connect to. The requested bandwidth of almost all MNs fits to Wi-Fi network capacity, leaving other networks empty.

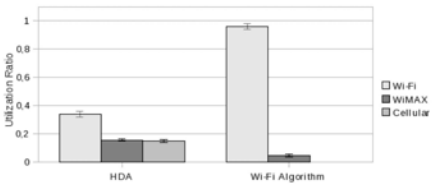


**Fig. 5.** Utilization Ratio of resources with 26 MNs

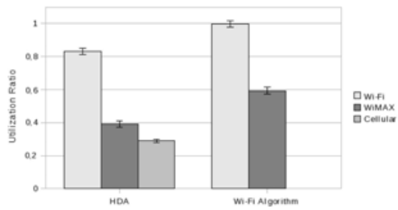


**Fig. 6.** Utilization Ratio of resources with 50 MNs

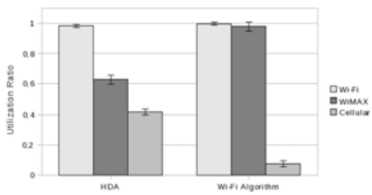


**Fig. 7.** Utilization Ratio of resources with 70 MNs

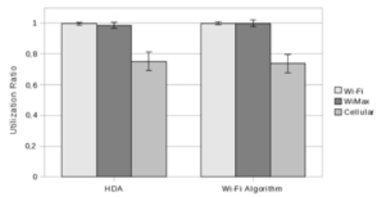


**Fig. 8.** Utilization Ratio of resources with 100 MNs

In Figures 6, 7, 8, the number of MN's request was increased to 50, 70 and 100, consequently, the network load was increased.

Up to 70 MNs, the HDA distributes the MNs among the networks better than the Wi-Fi algorithm, causing a load balancing among the networks. In the case where the number of MN is 100, both approaches distribute in the same way as shown in Fig. 8, but the blocked ratio of Wi-Fi algorithm is higher than HDA as shown in Table. 5, which causes a delay in the handover procedure.

The simulation results of the blocked ratio can be seen in Tables. 2-5. When the network load is low, the blocked ratio is low in both approaches. As the network load increases, the Wi-Fi algorithm blocks more MNs than the HDA, initially to enter into the Wi-Fi network, and after to enter into WiMAX and Cellular networks. When the MN's request is 100, the Wi-Fi algorithm blocks twice MNs than HDA for the Wi-Fi network, almost 40 percent more than HDA for the WiMAX network. There are no blocks in both approaches for the Cellular network.

**Table 2.** 26 MNs - Blocked Ratio

| | Wi-Fi | WiMAX | Cellular |
|---|---|---|---|
| HDA | 0 | 0 | 0 |
| Wi-Fi | 0.05 | 0 | 0 |

**Table 3.** 50 MNs - Blocked Ratio

| | Wi-Fi | WiMAX | Cellular |
|---|---|---|---|
| HDA | 0 | 0 | 0 |
| Wi-Fi | 0.43 | 0 | 0 |

**Table 4.** 70 MNs - Blocked Ratio

| | Wi-Fi | WiMAX | Cellular |
|---|---|---|---|
| HDA | 0.1 | 0 | 0 |
| Wi-Fi | 0.59 | 0.07 | 0 |

**Table 5.** 100 MNs - Blocked Ratio

| | Wi-Fi | WiMAX | Cellular |
|---|---|---|---|
| HDA | 0.36 | 0.06 | 0 |
| Wi-Fi | 0.71 | 0.43 | 0 |

## 6 Conclusion

This paper presents a handover decision mechanism using the IEEE 802.21 standard and the SAW method. The proposed mechanism leverages a load balancing among heterogeneous networks. Moreover, it considers the user's preferences as well as the traffic load of the networks, thus, the users can choose the networks according to their needs and the carriers have the benefit of a better resource utilization, supporting more users. For future work, we would extend our simulator to take into account moviment patterns of the mobile nodes.

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