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A Proactive VHD Algorithm in Heterogeneous Wireless Networks for Critical Services

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Abstract:
Progress in the telecommunications sector has opened new scenarios where users want to access any application or service from any device anywhere at any time, connected to any network. In this environment, the Heterogenerous Wireless Networks (HWN) is the main operating infrastructure, intended to support the technical and quality needs that these users and services demand, along with the versatility and availability that comes with being able to connect to any interface. One of the most important characteristics of HWN is the possibility to connect many kinds of Radio Access Networks (RAN) like WiFi, WiMAX,GSM, UMTS, HSPA, LTE, among others. This brings many challenges in HWN surroundings, one of the most important is ensuring that a user terminal can move from one access network to another without losing connectivity and, of course, the service.
The aim of this paper is to propose a Vertical Handover Decision Algorithm (VHO-DA) that enables a single user terminal to initiate a proactive decision based on user preferences and QoS parameters, while at the same time considering the networks conditions to avoid over burdening an interface. The development of our VHO-DA was addressed like a Multi Criteria Decision Making Problem (MCDM) in order to provide the best possible connection for critical services and maintaining load balancing in networks.
Keywords: Multi criteria decision making problem, Handover decision, Heterogeneous wireless networks, Vertical handover.

1 Introduction

Thanks to advances in the areas of electronics, computers and communications, the way we perceive and interact with the world has been transformed. Nowadays the majority of our daily activities are related in some way with the use of these technologies, from how to educate, to health care processes, and access to government services, to name a few. So it's clear to the academic community and the business world that Information Communications and Technologies (ICT) play an important role in their daily lives and in all business and market processes that surround them.

A study conducted by International Data Corporation (IDC) on the top 10 current trends in the ICT sector for Latin America, found that two of them are directly related to the topic of infrastructure for mobile communications. The first trend shows an environment where the impact of mobility is very high, as consumers of multiple services want to access their information anywhere at any time, while the second shows that the incursion of fourth generation networks will facilitate the first trend, causing an explosion of new services that need to be supported by this new infrastructure [1]. That is, we have a scenario where users (both personal and corporate) can access any application from any device, anywhere, anytime. This new scenario is an infrastructure that operates what is now known as the Heterogeneous Wireless Networks (HWN) or Next Generation Mobile Networks (NGMN) which are intended to support the growing needs, both technical and qualitative, that users demand from their current and new services.

Among the most important characteristics defined for HWN networks are: to support data transmission up to 100 Mbit/s in downlink and 50 Mbit/s in uplink in a channel with a bandwidth of 20 MHz and a low latency from one end to another in less than 30 ms. As a result of proposed developments within the new networks, HWN is looking to provide wireless competitive broadband services with high data rates and an excellent balance between cost and performance. Not only will it help to achieve better technical standards, but it's also expected to achieve great benefits for end users, significantly improving the user's experience with existing services and future data and multimedia services, which will make broadband Internet easily accessible with excellent mobile performance [2].

This new proposed ecosystem is expected to generate multiple challenges for telecommunication service operators, especially in the design and implementation of network infrastructure since it must allow the provision of various services independent of location, time, device or access network. One of the most challenging problems is maintaining service continuity across this ecosystem, the possibility that one user can change their access network without the loss of the service. This transfer between RANs of different technologies is called Vertical Handover and is usually driven by the requirements of the services, and also by the need to improve network performance [3], [4], [5], [6].

2 Related Works

Lots of articles mention the subject of the different phases in handover, in [7] the authors describe the decision, radio link transfer and channel assignment phases of the handoff. In [8] the authors establish the phases of network discovery, handoff decision and handoff execution. From these it's determined that there is a data acquisition phase where the information the algorithm uses is obtained and that afterwards the choice elected by it commences the handover execution without affecting any other part of the process. In other words, since it's isolated, it can't affect the rest of the process beyond its decision, and so the work can be specified to only the decision algorithm. It concentrates mainly on applying the decision function to the values given as input, which are obtained by the candidate interfaces and given to the mobile device. The way the operators give this information or how the handoff works after the decision is made is not considered.

In recent years, many VHO - DA have been proposed, these algorithms use different decision strategies to select the best connection. In [9] Kassar, Kervella, and Pujolle propose a classification of them into five categories: functions, user-centric, Fuzzy Logic and Neural Network-based, multi-criteria, and context-aware strategies; although these are not mutually exclusive.

Several decision algorithms developed use a multi criteria strategy, for example in [10] Zhang presents an algorithm that uses fuzzy logic combined with some classical Multi Attribute Decision Making (MADM) methods, Simple Additive Weighting (SAW) and Technique for ordering preferences by similarity to ideal solution (TOPSIS), for handover decision in order to combine and evaluate multiple criteria simultaneously. Song and Jamalipour in [11] explain an algorithm that combines the analytic hierarchy process (AHP) and the grey relational analysis (GRA) methods to decide the best network for mobile users through finding the tradeoff among service application, network condition, and user's preference.

In [12] by Yang and Wu, their proposal uses fuzzy logic and MADM; the proposed Algorithm is divided into four parts: traffic classification, resource estimation for reservation, admission control and RAT selection. One similar algorithm was presented by lsmail and Roh [13], their proposal was a user adaptive fuzzy MADM handover decision scheme. They applied different fuzzy MADM methods (TOPSIS, SAW, Maximin, ELECTRE and AHP) to find out best alternative for handover and to evaluate the performance of these methods. Lahby, Leghris, and Adib [14] focuses their work in a hybrid method based on multi attribute decision making methods AHP and TOPSIS to select the best network alternative.

The work presented in [15] by Tamea, Biagi, and Cusani, proposes and analyzed a modified version of TOPSIS to include risk information; this proposal allows the reduction of outage probability at the cost of parameters performance loss. Inside the work of Kim Et al. [16] , they design a vertical handover decision algorithm that is a combination of a policy and a multi-criteria decision making approaches; this algorithm intends to achieve an effective and seamless handover between heterogeneous radio access networks, especially between the LTE and the WLAN systems.

3 Problem Statement

As previously stated this work focuses on proposing a Vertical Handover Decision Algorithm (VHO-DA) that enables a single user terminal to propose a proactive decision based on user preferences and QoS parameters, while at the same time considering the networks conditions to avoid over burdening an interface. Since the proposed problem involves more than one decision parameter, we intend the use of a multi criteria decision making method with the aim to provide always the best possible interface connection available for critical services.

Some MADM Algorithms were addressed like TOPSIS, GRA and SAW. Each of them work in a different way, but they're all decision algorithms, which is to say that they compare many different options based on one or more attributes and choose the alternatives which satisfy the conditions the best. However, according to [17] the results of each are almost the same.

In addition a VHO-DA must consider the limitations associated with the computing power in a mobile user device; this is the reason why we need to select the algorithm with lowest algorithmic complexity in order to lessen the burden placed on the mobile device. Based in [18] we selected a Simple Additive Weighting (SAW) Method as it was the MADM Algorithm with the lowest computational complexity.

3.1 Simple Additive Weighting (SAW) Method

SAW Technique is one of the most used MADM techniques. It is simple and is the basis of most MADM techniques such as AHP and PROMETHEE that benefits from additive property for calculating final score of alternatives.

SAW for all the m alternatives determined a score (V_i) calculated by multiplying the weight assigned to each attribute (w_j) by a comparable rating scale of each attribute (r_{ij}) and then summing these products over all the n attributes.

$$V_i = \sum_{j=1}^{n} w_j \cdot r_{ij}, \forall i = 1, \ldots, m. \tag{1}$$

3.2 Mathematical Model

In order to take this decision, all factors available in a heterogeneous network must be evaluated. In this article, the factors chosen were QoS parameters and charging rates available on 3GPP/LTE, Wi-Fi and WiMAX. The QoS parameters are divided into two main groups: Ascending parameters, those who are deemed better the larger in value they are, and descending parameters, those who are deemed better the smaller in value they are.

The ascending parameters (ap) are: Received Signal Strength Indicator(rss) and Availability(av). The rss determines how strong the interface's signal is. Availability is the rate of the interface's uptime over its uptime plus its downtime. While the descending parameters (dp) are: Packet Loss(pl), Jitter(j), Delay(d), Cost(c) and Load(l). Packet loss is the rate of how many packets were received over how many were sent. Delay is amount of time it takes for a packet to travel from one point of the network to another. Jitter is the variation of the delay of multiple packets over a network. Also it's important to establish that there is a set of n interfaces I which includes the one we are already connected to, and a set of n-1 interfaces to which we could connect named J.

For our case the alternatives are the RANs available at a given point in time. The decision maker assigns the weight of every attribute based on the needs of each service, so each operator can state which parameters are most important for it and find the most appropriate network.

Given the above statement the mathematical model proposed is a SAW equation, where all the parameters are accounted for and evaluated. Attributes are normalized and if it's a parameter where less is better, it is inverted or subtracted from a total percent.

$$V_i = W_d \cdot \frac{1}{(\frac{d}{d_m})} + W_j \cdot \frac{1}{(\frac{j}{j_m})} + W_{pl} \cdot \frac{1}{(\frac{pl}{pl_m})} + W_{av} \cdot (\frac{av}{av_n}) + W_{rss} \cdot (\frac{rss}{rss_n}) + W_c \cdot (1 - \frac{c}{c_n}) + W_l \cdot (1 - \frac{l}{l_n}) \quad (2)$$

Where the n_{th} value of a parameter is the highest of the available interfaces and the mth value of a parameter is the lowest of the available interfaces.

Some Specific Parameter Functions

Cost. Cost must also be determined. In this paper, the charging models evaluated are: Free, Monthly fee, Bits consumed rates and Time consumed rates. Free are interfaces where the user would not incur in any financial cost if he were to connect to them. Monthly fee are interfaces which use fixed rate charging so no matter how much is consumed, they charge the same. For the purposes of this paper, Monthly fee and Free are essentially the same, as the user doesn't incur in any additional cost by connecting to that interface. Bits consumed rate are interfaces which charge by how many bits are used in the connection. Time consumed rate are interfaces that have a flat-rate charging model that bills according to how much time the user is connected to the Interface. In order to compare the two, time consumed rate interfaces are converted into Bits consumed rate using the following formula:

$$Bit\ consumed\ rate = \frac{\frac{T.\ consumed\ rate(in\ minutes)}{60}}{Throughput} \quad (3)$$

Load. Load is the representation of the load balancing factor into the equation; it's the theoretical capacity of the network according to its technology, which the mobile device already has, minus the current throughput of the interface, given to the mobile device by the network; all of this over the theoretical capacity.

$$Load_i = \frac{Theoretical\ Capacity_i - Throughput_i}{Theoretical\ Capacity_i} \quad (4)$$

It should be noted that this configuration of load is done in order to maintain the idea that lower the Load of a network, the less it is being used and the more available the resources are.

All of these parameters, excluding Load, are either percent's or values given by the interfaces, so no calculation must be done with them. Except in the case that it's a Time consumed rate and must be converted to Bit consumed rate.

3.3 Heuristic Implementation

We chose to solve this problem through a heuristic method do to it being the fastest and most precise way that the answer could be found with the information available and the restrictions placed by the infrastructure.

The chosen VHO-DA is a straightforward process that runs continuously in the background. First, it searches for all the available networks it detects. Then it gathers all the information of those interfaces, including QoS parameters and its condition, in addition to the preferences of the active services (Critical Services). Then it compares the information of each interface in order to determine the highest and lowest values, and then proceeds to normalize all of them and obtain it's SAW weighted value. The first interface that scores the highest value is the chosen interface to switch to; that is, if it is different from the current interface. Figure 1 present the flow diagram of the heuristic described.

For our case the alternatives are the RANs available at a given point in time. The attributes chosen to take part in the decision are: Delay (d), Jitter (j), Packet Loss (pl), Availability (av), Cost (c), Received Signal Strength (rss), and Load (l). The decision maker assigns the weight of every attribute based on the needs of each service, so each operator can state which parameters are most important for it and find the most appropriate network.

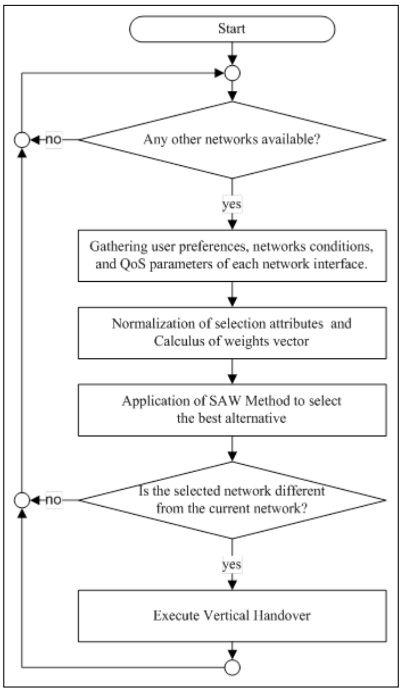

Figure 1: Proposed Heuristic Algorithm

3.4 Experimental Results

In order to verify the correct function of the proposed heuristic, we uses a case study scenario extracted from [19] in which multiple interfaces (UMTS, WiFi, WiMAX, GSM, HSPA+, EDGE, LTE) are given QoS attributes to be compared. The case is modified, to give it RSS values and the theoretical capacity of each interface. This scenario is just an example and is not meant to be a definitive sample of any of these interfaces.

We execute the VHO-DA on the scenario to evaluate its effectiveness using a demonstrative set of weights in which Load was given special consideration. The test results showed a satisfactory

Interface	Delay	Jitter	Packet Loss	Cost	RSS	Throughput	Availability	Th. Capacity	Load	Ranking
UMTS	45	1	0,0001	0	0,4398	384	0,99999	2400	0,984	0,6545
WiFi 1	180	11	0,4	4,35E-8	0,9473	23000	0,999999	54000	0,57407	0,5115
WiMax	70	9	0,0001	0,0001	0,4120	4000	0,99999	100000	0,96	0,47
EDGE 1	150	10	0,01	0,003	0,5904	178	0,9999	384	0,5375	0,4685
HSPA	**55**	**2**	**0,0001**	**0**	**0,8528**	**2000**	**0,999**	**7200**	**0,722**	**0,6767**
WiFi 2	110	9	0,0001	0,006	0,5204	4500	0,99999	65000	0,981	0,4421
GPRS 1	90	9	0,001	0,008	0,9851	80	0,9999999	114	0,298	0,6279
GPRS 2	135	9	0,005	0,003	0,6550	60	0,9999999	114	0,47368	0,5055
EDGE 2	100	7	0,0001	0,0016	0,4379	237	0,9999	384	0,383	0,5787

Table 1: Parameters values in the study case

result and prove that the algorithm first and foremost considers the burden on a channel before selecting it, while at the same time considering QoS values. Considering that this study case is specifically intended for critical services, we distributed the weights of the parameters as follows: Delay (0,15), Jitter(0,1),Packet Loss(0,1), Cost(0,05), Availability(0,15), RSS(0,15) and Load(0,3). It's important to know that result of the SAW vector V_i is represented by the value "Ranking", since we compare the result and from the highest we extract which interface should we connect to.

The VHO-DA was executed with the parameters values that you can see in Table 1. The highlighted interface, HSPA, is the chosen interface to connect to due to its results, being the interface with the highest Ranking. This is partly due to it having the second lowest delay, jitter, and shares the lowest cost and packet loss with a few other interfaces. And what's also noticeable is that the options is very well rounded, as it's only the best in two parameters that aren't the heaviest (Packet Loss and Cost). It definitely considered what we needed for the critical service.

4 Conclusions

The work concludes in three points. The first is that this VHO-DA proves to have a holistic consideration of the values, and forms a multicriterial decision that guarantees the best connection possible to the critical service. The second is that since it's also modifiable (to consider the necessities of the service in question), it's highly flexible and can be applied to any critical service and any network. Finally, the third point is that this VHO-DA considers special limitation for mobile devices and networks, implementing load balancing to assure the most advantageous use of the HWN infrastructure. Considering these three points make this algorithm an improvement in the VHO-DA field.

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