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A Review of Vertical Handover Decision Making Algorithms

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Abstract: **The next generation wireless network (NWGN) is figured as the combination of different wireless access technologies. The main aim of such technology is to providing the user with the best anywhere any time connection and to provide the seamless continuous connection to access various wireless technologies. Each technology requires different Quality of Service so the network selection may vary accordingly. To achieve this goal & to select a best network for a mobile terminal when moving from one network to another it is necessary to have a better decision making algorithm, which decide the best network for a specific application that the user needs based on QoS parameter. This paper presents a review of handover types, handover procedure and classification of vertical handover decision parameters and Algorithms.**

Keywords: Handover, Horizontal and Vertical Handover, VHD algorithms, Quality of Service (QoS).

1. INTRODUCTION

In present scenario next generation wireless system offers many access networks to the user. Hence the mobile users have facility to access wide range of applications provided by multiple wireless networks. In this context when the mobile user moves from one place to another there is a need for communication channel to switch from one network to another which is Handover. This switching or handover have to consider the features and user requirements also. When handover is taking place between different networks then it called as Vertical Handover. This leads to the need of mechanism which will select the best network from different available networks, for this purpose Vertical Handover Decision Algorithms or strategies plays important role.

In this paper we are focusing as follows: next section is going to explain types of Handover, than handover procedure and classification of Vertical Handover parameters are described in rest sections. Finally the last one concludes the whole works about this paper.

2. HANDOVER TYPES & PROCEDURE

2.1 Types of Handover

Handover can be classified into two types: Horizontal Handover (HHO) and Vertical Handover (VHO) [1]. Horizontal Handover means the switching of a Mobile Node (MN) from one area to neighbor one within same wireless access network technology. Similarly, Vertical Handover means switching a mobile node within different or heterogeneous wireless access network technology. In both cases parameter of handovers are also varying.

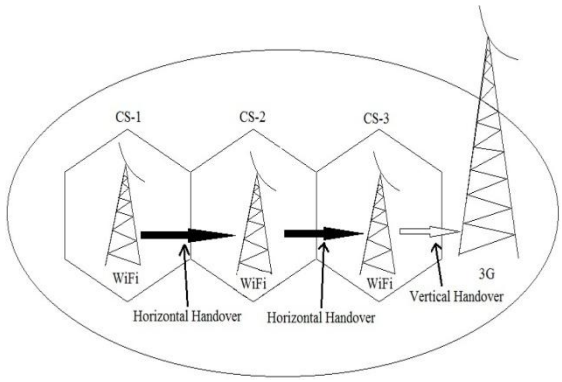

Figure 1: Types of Handover

Vertical Handover is an asymmetric process in which MN moves between different networks with different characteristics so it is necessary to select the best network which provide high performance and fulfill the user requirements. The Vertical Handover should provide a minimum overhead authentication of mobile user, provide seamless connection, minimize the packet loss & transfer delay.

TABLE 1: Parameter comparison between HHO & VHO

Parameters	Horizontal Handover	Vertical Handover
Access Technology	Not changed	Changed
QoS Parameter	Not changed	May be-changed
IP Address	Changed	Changed
Network Interface	Not changed	May be-changed
Network Connection	Single	More than one connection

2.2 VHO Procedure:

The vertical Handover process can be divided into three main steps [2], namely Handover initiation, Handover decision, and Handover execution [3].

i) **Handover Initiation Phase:** In order to trigger the Handover event, information to be collected about the network from different layers likes Link Layer, Transport Layer and Application Layer. These layers provide the information such as RSS, bandwidth, link speed, throughput, jitter, cost, power, user preferences and network subscription etc. Based on this information Handover will be initiated in an appropriate time.

ii) **Handover Decision Phase:** The mobile device decides whether the connection to be continued with current network or to be switched over to another one. The decision may depend on various parameters which have been collected during Handover initiation phase.

iii) **Handover Execution Phase:** Existing connections need to be re-routed to the new network in a seamless manner. This phase also includes the authentication and authorization, and the transfer of user's context information.

3. OVERVIEW & CLASSIFICATION OF VHO

As we described in last section handover is a process of maintaining user's active session when MN changes Point of Attachment (PoA) or we can say, changes its connection from one place to another or one wireless access technology to other. A vertical Handover occurs between points of attachment supporting different network technologies [4]. VHO can classify into four types:

i) **Upward and Downward Handover:**
In Vertical Handover, if the mobile switches from the network with a small coverage to a network of larger coverage, it is termed as upward Handover. On the other hand, a downward Handover occurs in the reverse direction, i.e. from a network of larger coverage to a network of smaller coverage.

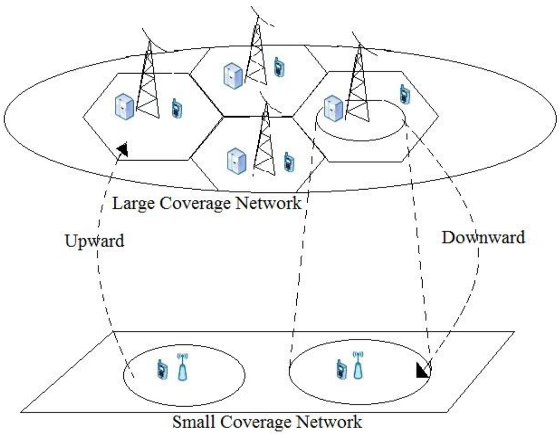

Figure 2: Upward and Downward Handover

ii) **Hard and Soft Handover:**
When the mobile node switches to the target network only after the disconnection from current network is called as hard Handover or break before make. On the other hand, in soft handover a mobile node maintains the connection with the previous base station till its

association with the new base station is completed. This process is also termed as make before break.

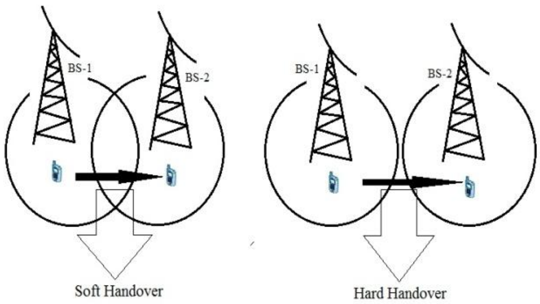

Figure 3: Hard and Soft Handover

iii) Imperative and Alternative handover:
When there is loss of signal strength an imperative Handover occurs. For imperative Handover the RSS is sufficient to be considered. On the other hand, an alternative vertical Handover is initiated to provide the user with better performance. For alternative Handovers several other network parameters such as available bandwidth, supported velocity and cost of the network are to be considered in addition to the device parameters such as quality of service demanded by the application and user preference.

iv) Mobile controlled and Network Controlled Handover:
Vertical Handovers can further be classified based on who controls the Handover decision. If mobile node controls the Handover decision, it is termed as Mobile controlled Handover (MCHO). In Network controlled Handover (NCHO) networks control the Handover decision. The Handover decision control is shared between the network and mobile in case of Mobile controlled Network Assisted (MCNA) and Network Controlled Mobile Assisted Handovers (NCMA). MCNA Handovers are more suitable because only mobile nodes have the knowledge about the network interfaces they are equipped with and user preferences can be taken into consideration.

4. PARAMETERS FOR VHO DECISION MAKING

In heterogeneous wireless network to initiate the process of VHO we need to apply Vertical Handover Decision Algorithms. A decision algorithm gives a better performance when we consider several parameters to help in making decision about handover [5], [6]. VHO decision making parameters are:

1. *Received Signal Strength (RSS):* RSS is the one of the mail criteria for VHD. The RSS is easy to measure and it is directly related to the quality of service. A signal must be strong enough between base station and mobile unit to maintain signal quality at receiver. The RSS should not be below a certain threshold in a network during Handover. Traditional Handover initiation is concerned with measurement of RSS [7].
2. *Network Cost:* A multi criteria algorithm for Handover should also consider the network cost factor. Different charging policies are followed for different type of traffic. So that in some situation cost should also be consider as a factor for decision making.
3. *Network load & Security:* Network load is to be considered during effective Handover. It is important to balance the network load to avoid deterioration in quality of services. In a wireless environment, the security features provided in some wireless products may be weaker; to attain the highest levels of integrity, authentication, and confidentiality, network security features should be embedded in the Handover policies.
4. *Power Consumption:* During Handover, frequent interface activation can cause considerable battery drainage. It is also important to incorporate power consumption factor during Handover decision.

5. *Available Bandwidth:* Bandwidth is a measure of the width of a range of frequencies. Higher the bandwidth, lower the call dropping and call blocking probability.
6. *User Preference:* Based on the application requirements like (real time, non-real time), service types (Voice, data, video), Quality of service etc. the user may prefer different network according to the network performance which is the important benefit of heterogeneous networks.
7. *Handover Latency:* The time elapses between the last packet received via the old access router and the arrival of the first packet along the new access router after a Handover. This is known as Handover latency. Handover Latency affects the QoS and it is essential to consider Handover latency while designing any Handover technique.
8. *Network Throughput:* Network throughput refers to the average data rate of successful data or message delivery over a specific communications link. Handover to the network which has higher throughput is desirable.
9. *Velocity:* Velocity of the host should also be considered during Handover decision. Because of the overlaid architecture of heterogeneous networks, handing to the small cell area, travelling at high speeds is discouraged since a Handover back to the original network would occur very shortly afterwards.

5. VERTICAL HANDOVER DECISION ALGORITHMS

In this section, we introduce a group of the most well designed vertical handover decision strategies proposed in the literature.

5.1 Received Signal Strength (RSS) Based Algorithm

In RSS based algorithms Received Signal Strength is the main criteria. These types of VHD algorithms compare the RSS of the current point of attachment against the others to make handover decisions.

The algorithm is proposed [8] for handover between 3G networks and WLANs by combining the RSS measurements either with an estimated lifetime metric or the available bandwidth of the WLAN candidate. We can describe the method using following two scenarios.

In the first scenario, when the mobile terminal moves from the coverage area of a WLAN into a 3G, a handover to the 3G network is initiated. When RSS average of the WLAN connection falls below a predefined threshold, and the estimated lifetime is less than or equal to the handover delay, the handover is triggered. In the second scenario when the mobile terminal moves towards a WLAN cell, the handover to the WLAN is triggered if the average RSS measurements of the WLAN signal are larger than a threshold and the available bandwidth of the WLAN meets the bandwidth requirements of the application.

An algorithm is proposed [9], between WLAN and 3G which is based on comparison of the current RSS and a dynamic RSS threshold when a mobile terminal is connected to a WLAN access point. The dynamic RSS threshold is useful in the way that it reduces the incidences of false handover initiation and keep the handover failures below a limit.

To eliminate the unnecessary handovers which is introduced in the above method, a travelling distance prediction based algorithm [10, 11, and 12] is developed. The algorithm considers the time the mobile terminal is expected to spend within the cell. The method relies on the estimation of WLAN traveling time (i.e. time that the mobile terminal is expected to spend within the WLAN cell) and the calculation of a time threshold. A handover to a WLAN is triggered if the WLAN coverage is available and the estimated traveling time inside the WLAN cell is larger than the time threshold.

The main advantage of this method is that it minimizes handover failures, unnecessary handovers and connection breakdowns however increased handover delay is introduced.

5.2 Multiple Attributes Decision Making (MADM) Based Algorithm

Multiple attribute decision making (MADM) is the handover decision problem deals with making selection among limited number of candidate networks from various service providers and technologies with respect to different criteria. Term such as multiple objectives, multiple attribute and multiple criteria are often used interchangeably in the study of decision making. Distinctions can be made between the different concepts. Multiple Criteria Decision Making (MCDM) is sometimes applied to decisions involving multiple objectives or multiple attributes. But, generally when they both apply. Multiple Objective Decision Making (MODM) consists of a set of conflicting goals that cannot be achieved simultaneously. MADM deals with the problem of choosing an alternative from a set of alternatives which are characterized in terms of their attributes. The most popular classical MADM models are –

• Simple Additive Weighting (SAW): the overall score of a candidate network is determined by the weighted sum of all the attribute values.

• Technique for Order Preference by Similarity to Ideal Solution (TOPSIS): the chosen candidate network is the one which is the closest to ideal solution and the farthest from the worst case solution.

• Analytic Hierarchy Process (AHP): decompose the network selection problems into several sub— problems and assign a weight value for each sub problem.

• Gray Relational Analysis (GRA): is then used to rank the candidate networks and selects the one with the highest ranking.

A comparison along with three of these models was established with attributes like Bandwidth, delay, jitter & BER. SAW and TOPSIS provide similar performance to the traffic classes used. GRA provides a slightly higher bandwidth and lower delay for interactive and background traffic classes. AHP is used to determine the weights of the three models requiring information about the relative importance of each attribute.

Multiple attribute is a difficult problem during vertical handover decision. AHP seems to be the most popular method to decompose it into a hierarchy of simple and more manageable sub-problems. These sub problems can be decision factors or weights according to their relative dominances. AHP model has a three step process-

1) Decomposes the decision problem into different levels of the hierarchy.
2) Compare each factor to all the other factors within the same level through pair wise comparison matrix.
3) Calculates the sum of products of weights obtained from the different levels, and selecting the solution with the highest sum.

5.3 Decision of Cost Function (CF) Based Algorithm

Vertical handover decision cost function is a measurement of the benefit obtained by handing over to a particular network. It is evaluated for each network n that covers the service area of a user. It is sum of weighted functions of specific parameters. The general form of the cost function fn of wireless network n is:

$$f_n = \sum_{s}\sum_{i} W_{s,i} \, . \, P_{s,i}^{n}$$

$P_{s,i}^{n}$ is the cost in the ith parameter to carry out services s on network n, $W_{s,i}$ the weight assigned to using the ith parameter to perform services.

The first policy-enabled handover strategy was proposed in 1999, which introduced the cost function to select the best available network in the decision making. The parameters used are bandwidth B_n that network n can offer, power consumption P_n of using the network device for n and cost C_n of n. The cost of using a network n at a certain time, with N(i) as the normalization function of parameter i is defined as: $f_n = w_b . N(1/B_n) + w_p .N(P_n) + w_c .N(C_n)$

$$f = w_b . N\left({}^{1}/_{B_n}\right) + w_p . N(P_n) + w_c . N(C_n)$$

The network that is consistently calculated to have the lowest cost is selected as the target network. Therefore, this cost function based policy model estimates dynamic network conditions and includes a stability period to ensure that a handover is valuable for each mobile.

The proposed policy-enabled handover system allows users to express policies on what is the best network and when to handover. The system operating environment is a Mobile IP infrastructure in which all the handover decisions and operations are done at the MT. In handover operation, the packets sent by CN to the MN go through it's HA. The HA routes the packets either to the multicast CoA of the MN. When MN is in WLANs, a reverse tunneling is used where packets are routed to the HA first then to the CN. To achieve flexibility, the system separates the decision making scheme from the handover mechanism. To achieve seamlessness, the system considers user involvement with minimal user interaction.

5.4 Authentication Based Algorithm

In NGN, security is considered as one of the most challenging problems introduced by mobile networking. User mobility increases the risk of illegal users masquerading as legal users. So there is a need that the handover process should provide security as well as authentication scheme. Also it should be able to reduce the authentication delay during the handover process.

An authentication scheme for fast handover between WI-Fi access points is proposed [13], in which the author has used the EAP-SIM (Extensible Authentication Protocol). The scheme uses the pre-authorization and it eliminates the need for communication with the remote server when the handover actually takes place. This scheme is capable of reducing the authentication delay and the linear dependency on the RTT (round trip delay) between the AP and the authentication server is also broken.

In [14], the author has proposed a holistic approach that eliminates the repeated steps of authentication without affecting the security level, to optimize QoS parameters during handover. In this method a valid certificate is issued at the time of registration of MN with AAA server. This valid certificate is in consensus with all the service providers which will be unique and valid for each network. This method reduces the number of repetitions which will save the bandwidth, time and cost. Reduction is handover latency, packet loss and cost is obtained.

5.5 Context Aware (CA) Based Algorithm

This handover concept is based on the knowledge of the context information of the mobile terminal and the network in order to take intelligent and better decisions. As a result, a context aware decision strategy manages this information and evaluates context changes to get decision on whether the handover is necessary and on the best target access network.

Context aware handover decision algorithm consists of two main components:

1. *The context repository*- which gathers, manages, and evaluates context information from different parts of *the network.*
2. *The adaptability manager*- it decides about adaptation to context changes and handover execution.

The context aware decision algorithm is processed for each service type currently running on the device. Primary objectives were defined in terms in terms of lowest cost, preferred interface, and best quality (i.e. maximizing throughput, minimizing delay, jitter and BER) this intelligent handover decision algorithm is based on the AHP including the session transfer (application management) which is considered as mobile initiated and controlled solution. This algorithm has five stages in which first two are pre-configuration stages, this stages as follows:

1. *Taking user inputs:* defining the relative priorities among the primary objectives, the available interfaces and three types of services (which are defined as real time, interactive and streaming) with fixing priority scores between 1 (for most preferred one) and 9 (for least preferred one).
2. *Mapping limit values from discrete preferences:* expressing user QoS preferences as limits in order to provide better flexibility while comparing them with network QoS parameters. These limit values, which are related directly to the priority given to the objectives of Best Quality (i.e. BER, delay, jitter, and throughput), are mapped for each of the three services types. It is based on QoS

requirements of specific service type and device capabilities.

Remaining three is known as real-time calculations, which performed for a particular type of running application as follows-

1. *Assigning scores to available networks:* comparing the capabilities of the reachable networks (i.e. interface, cost, and QoS) with the preconfigured user preferences (scores and limits based on primary objectives).
2. *Calculating network ranking:* based on AHP method through an objective pair wise comparison matrix at first level and network pair wise comparison matrix at the second level.
3. *Employing a session transfer scheduling algorithm managing the session:* in order to switch applications to the selected network.

6. PROPOSED ALGORITHM

Contextual information can be used as multiple criteria useful enough to avoid wrong handover decisions. Therefore we consider context aware vertical handover decision. Contextual information should know the MN movements and it should take into account QoS requirements for the demanding service. The VHO process consist first phase in order to gather information, notify events and execute commands. For the decision phase, we have used a VHA that considers the availability and the bandwidth offered for the decision making. Figure 4 shows the flow diagram of the VHDA when selecting a candidate network to switch to.

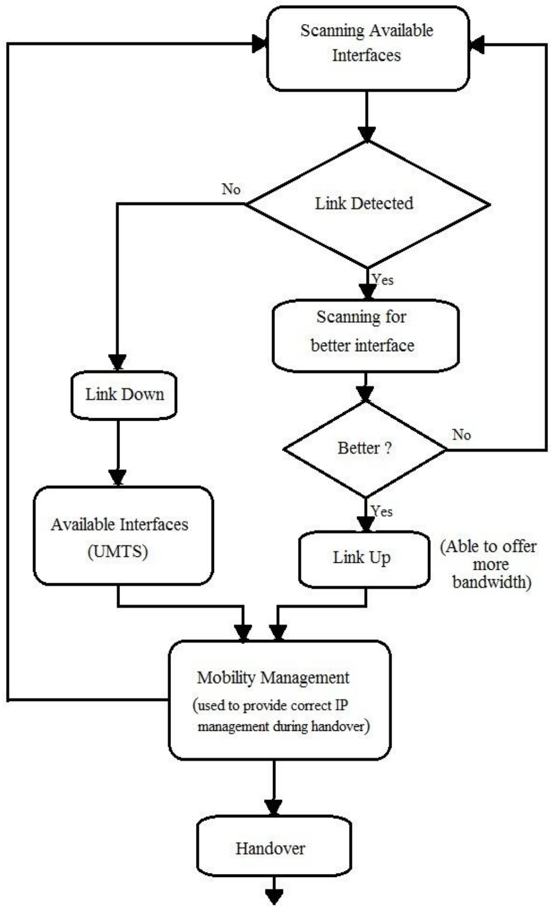

Figure 4: The proposed vertical handover decision algorithm

As observed, the User Equipment (UE) is continuously sensing the interfaces. When an event is triggered, and depending on the type of event, the VHDA performs different routines and subroutines in order to select the best candidate network, or simply chooses the UMTS network by default, due to the full UMTS coverage. Finally, considering the execution phase of the VHO process, we use Mobility support for Internet Protocol v.6 (MIPv6) to manage the mobility issues. It is important to emphasize that the events: Link Up and Link Down, determine the behavior of the VHDA. When a Link Detected event occurs, the user equipment will trigger other events such as Link Up if the technology detected is able to offer more bandwidth, negotiating with the new base station for the IP address; MIPv6 is in charge of this negotiation and notification to different components of the system. All these processes require complex actions which implies latency. On the other hand, when a Link Down event is detected, only a notification is performed by the MIPv6 agent, since the interface was already configured in a previous Link Up.

7. CONCLUSION

In order to offer continuous communications to mobile users, Vertical Handover (VHO) techniques should be considered. In This paper we present a complete review about Vertical Handover and at last a algorithm which is usually the underlay network that can provide better service at lower cost to the user as well as improve the overall system resource utilization. However, achieving both goals requires a well designed handover algorithms that can compromise the exchange between efficient resource utilization and user perceived QoS.

We conclude that different improvements can be suggested to outperform the current evaluated Vertical Handover Algorithms whenever the conditions differ from those considered in this paper. In particular, high degrees of congestion, as well as other parameters (user preferences, mobile capabilities, etc.), will require a more sophisticated decision algorithm.

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