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An Overview of Decision Techniques for Vertical Handoff Across Wireless Heterogeneous Networks

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Authors' contributions

This work was carried out in collaboration between all authors. Author UCA carried out the study and review of relevant literature, organized the structure of the study and wrote the original manuscript. Authors AMA and ENO originated the idea of the study, guided the course of the study, proof read and ensured relevance of the article. Author AJO developed the final version of the manuscript, especially editorials, figure clarity and attendance to review. All authors read and approved the final manuscript.

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ABSTRACT

Future wireless communication networks popularly known as beyond third generation (B3G) or Fourth generation (4G) networks will likely consist of heterogeneous wireless networks which will be IP-Centric based. These networks will offer a wide range of high data multimedia services to mobile users. To achieve this, Vertical Handoff (VHO) is considered as the method of realization and it is defined as the process by which users will seamlessly roam amongst these heterogeneous networks while communicating. To realize VHO, effective and efficient algorithms for accurate VHO decision are of utmost importance and hence form an area of current research focus. In this regards, several efforts have been made and it is the specific objective of this paper to provide an overview of efforts made thus far while discussing related VHO concepts. Specifically, handoff types, handoff process and classification of vertical handoff, metrics required, and existing works are presented. We seek to provide a concise background for not just VHO decision algorithms but also for understanding the basic concept of VHO.

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1. INTRODUCTION

Currently, different wireless and mobile networks including wireless Local Area Network (WLAN), Third Generation (3G) mobile Communication such as Universal Mobile Telecommunication System (UMTS) have emerged and are continuously being developed to achieve high speed transmission. However, no single type of existing wireless and mobile network can provide all the desired types of services, for example, ubiquitous coverage, high bandwidth and low cost [1]. Therefore one challenge encountered in the realization of next generation wireless communication is the interaction of existing and future wireless technologies and the support of transparent and seamless Vertical Handoff (VHO) without degrading quality of service between heterogeneous networks [1-2].

VHO is the ability to transfer the data session of a mobile user that is currently on a particular access network, e.g. WLAN, to another target access network technology, e.g. CDMA, without losing connectivity while keeping the active session of the mobile user [3-4]. There are three distinct stages in the implementation of VHO; these are Network discovery, Decision and Execution phase. We focus our discussion on the decision phase of VHO as it determines the choice of a candidate network for handoff and consequently the Quality of Service (QoS) experienced by the user. Traditionally, handoff research has been based on evaluation of the Received signal strength (RSS) at the mobile node. However traditional received signal strength (RSS) comparisons are not sufficient to make a VHO decision as they do not take into account the various attachment options for the mobile user. It is therefore apparent that the decision should be based on various considerations such as available bandwidth, pricing, power consumption, user preference and security of each network. This multivariate concept for decision making has led to the development of several algorithms. However, little is available to clearly classify and provide a unified structure for discussing existing VHO decision algorithm. Consequently, we present in this paper an overview on handoff types, handoff process and classification of vertical handoff, metrics required, and existing works as a concise background for understanding the concept of VHO, with the aim of overviewing the basic understanding of VHO and related concepts in the decision stage.

2. GENERAL TYPES OF HANDOFF

Handoff can be classified into two components namely: Horizontal Handoff (symmetric), which means the handoff within the same cell of a homogenous wireless access network technology [5] and Vertical Handoff VHO (Asymmetric) which means handoff among heterogeneous wireless access network technology [1–8]. Fig. 1 shows a diagram of heterogeneous wireless networks while Fig. 2 shows horizontal and vertical handoff in a wireless overlay network. For instance, the two cells B and C situated at the centre of the diagram are using the same network technology while cell A is using a different network technology.

As an example, the handoff of a mobile terminal between two neighbouring IEEE 802.16e base station using Received Signal Strength (RSS) is termed Horizontal Handoff (HHO). On the other hand, handoff from a WLAN Access Point (AP) to an overlay UMTS network is considered a Vertical Handoff (VHO). Parameters which describe horizontal and vertical handovers as they vary in their individual attributes are provided in Table 1.

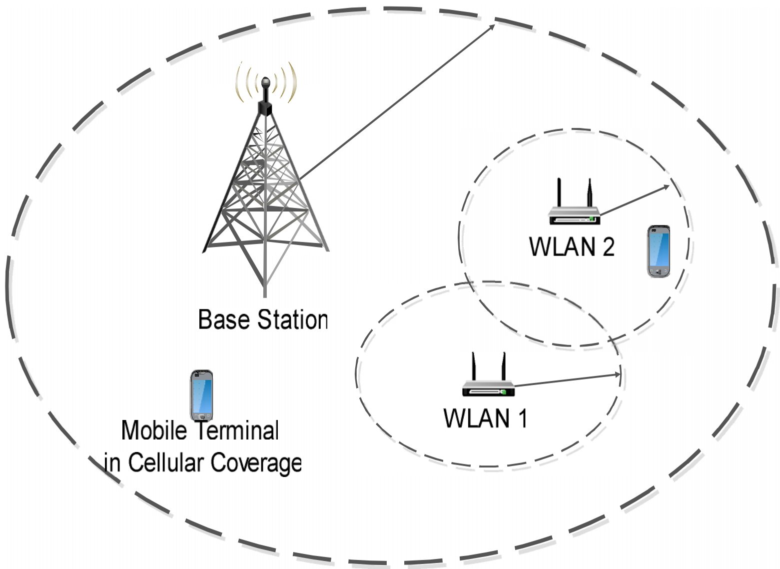

Fig. 1. Heterogeneous wireless networks

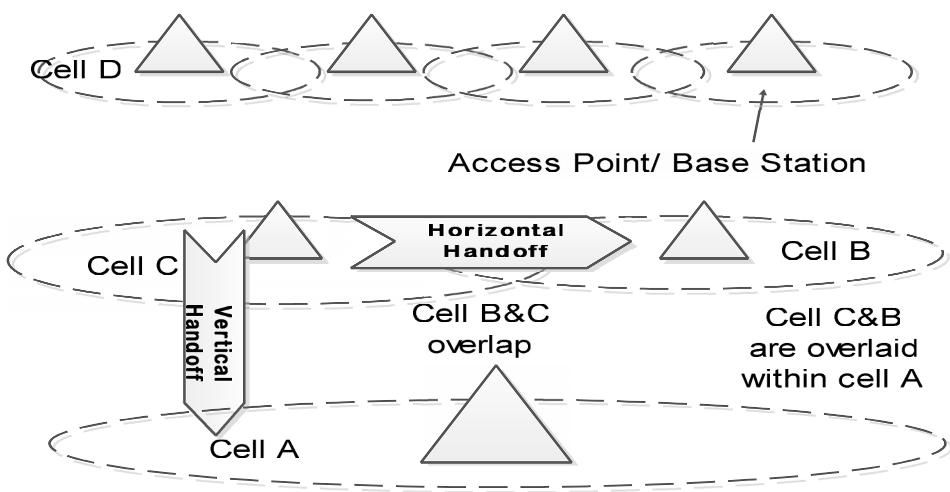

Fig. 2. Horizontal and vertical handoff in a wireless overlay network [4]

Table 1. Vertical and horizontal handoffs

Parameters	Horizontal Handoff	Vertical Handoff
Access technology	Does Not change	Changes
QoS parameter	Does Not change	May change
IP Address	Changes	Changes
Network interface	Does Not change	May change
Network connection	Single	More than one connection

There are some other concepts of handoff popularly discussed in the literature. One concept is that of upward and downward handoffs [9]. Upward handoff occurs if the mobile switches from the network with a small coverage area to a network with larger coverage. For example, a user travelling and consequently moves from a smaller coverage area (WLAN) to higher coverage area (UMTS). A downward handoff occurs in the reverse direction, i.e., from wider transition region network to a network of smaller transition region.

Another classification is Hard and soft handoffs [9-10]: Handoff is said to be hard when the mobile user switches to the target radio network only after a disconnection from current network i.e. Break before make. Soft handoff implies that a mobile terminal keeps its active connection with the old base station till its association with the new base station is completed i.e. make before break. For example user equipment (UE) with more than one network interfaces card (NIC) can simultaneously switch to multiple available access networks during soft handoff.

Also, Imperative and Alternative handoffs are also popularly encountered [5]. When there is a loss of signal strength, an imperative handoff occurs. For imperative handoff, the received signal strength (RSS) is sufficient to be considered for handoff. On the other hand, an alternative handoff is initiated to provide better performance for the mobile user. For alternative handoff, several other network parameters such as available bandwidth, supported velocity and cost of the network are to be considered in addition to the device parameter such as quality of service demanded by the application and user preference.

3. HANDOFF DECISION MECHANISM

In terms of decision-making, handoff can be classified based on who controls the handoff decision. Handoff decision mechanism can be located in the Mobile Terminal (MT) itself i.e. the Mobile Node (MN) controls the handoff decision and this is called Mobile Controlled Handoff (MCHO) or by a network entity e.g Base Station (BS) and this is called Network Controlled Handoff (NCHO).

In NCHO [9], BS controls the handoff decision by considering the received signal strength measurements of user equipment from a number of serving BS. The RSS information for all users is made available at a single point in the network which facilitates appropriate resource distribution. A disadvantage of the NCHO is that the radio network does not incorporate multiple metrics for handoff decision such as operator policies and user preference. Alternatively, MCHO is defined as the process by which the end user is completely in control of the handoff procedure. The user equipment (UE) initially discovers the entire available reachable network by comparing the received signal strength (RSS) and the Co-channel interference of the various BS within its neighbourhood and makes final evaluation for handoff decision. Initiation of handoff can also be made whenever the serving BS signal strength deteriorates in comparison to another BS by a certain threshold.

Another approach is the Network-assisted handoff (NAHO) [9] and here, the responsibility of who controls the handoff is shared between the network and the mobile. A network basically offers assistance to the MT in making decision by collecting and analysing the data. The location and some of the other information of the MT is provided to the network for the analysis. However, the MT executes the final decision. The handoff decision control is shared between the network and mobile in case of mobile Controlled Network Assisted (MCNA) and Network Controlled Mobile Assisted Handoffs (NCMA) MCNA handoffs are more suitable since the mobile terminal is aware of its NIC and user Preference can be taken into consideration [3].

4. REALIZING VERTICAL HANDOFF

The process of realizing VHO can be classified into three phases namely: network discovery phase, handoff decision phase and handoff execution phase [2].

4.1 Network Discovery Phase

In the Network discovery phase, the user equipment (UE) which has more than one network interface card (NICs) is responsible for determining the access networks and reachable available services. This phase requires that information is collected about the network from different layers such as, application layer, data-link and transport layer. These layers provide information such as RSS, bandwidth, link speed, throughput, jitter cost, power, user preferences and network. This information is processed and used for making decisions to the handoff. When networks are discovered, the best amongst the available is chosen using a suitable algorithm. For example a MT having multiple NIC and currently on a UMTS network may start experiencing deterioration in signal strength and then it needs to discover another available access network such as WIMAX and possibly handoff to it.

4.2 Handoff Decision Phase

Handoff decision is the mechanism which decides if the mobile device continues with the current radio access network or switches over to another network. The decision to handoff depends on different metrics which have been collected during handoff discovery phase. Handoff can be made based on the transmission signal from a target neighbouring BS which exceeds the RSS from the current serving BS by a predetermined threshold value. In [2,6], several numerous types of metric were identified which include:

4.2.1 Quality of service

To achieve maximum quality of service, it most desirable to handoff to a network having best network conditions such as high available bandwidth, low network latency and a higher performance such as received signal strength, signal to noise ratio (SNR) , Bit Error Rate (BER) in order to guarantee a higher quality of service.

4.2.2 Cost of service

This is a major key factor to be considered during handoff decision. It is a network-operator factor that employs different types of billing plan either for voice or data service for consequently handoff decision.

4.2.3 Battery power consumption

The power consumption of a mobile terminal is a significant criterion for handoff. For example, when the battery power drops to a level based on frequent interface activation, then it becomes economical to handoff to a network with a lower power demand.

4.2.4 Security

Security is another significant criterion for mobile users who seek to handoff. Network operator needs to secure and guarantee the integrity of their customer's data, Confidentiality and prevent attacks from intruders, software virus and hackers. Hence, network having a high level of encryption is preferable when handoff content information exchanged is most confidential.

4.2.5 User preferences

This consists of the user's choice of network operator, network technology type, security, reliability and billing plan which can be used to cater for special requests before handoff is made.

4.2.6 Mobile terminal conditions

This includes processing power, available bandwidth demand, velocity of mobile, networks supported, location information moving pattern and storage space which are considered as some of the criterion for seamless handoff. For example the speed of the mobile has a denser attribute on vertical handoff than in horizontal handoff. Handoffs to a larger coverage network are preferred to handoff to a smaller coverage area especially for vehicular movement of MT.

4.2.7 Application types

The applications types and services include multi-media applications, voice and data that needs different rate of data, network latency, security and reliability to process information. For data intensive application, it is encouraged that higher bandwidth is available in order to achieve better performance. On the other hand, real-time applications provide low network delay whereas non-real-time applications remain insensitive to network latency.

4.2.8 Network load balancing

Adequate network load balancing is to be considered during seamless handoff. It is important to balance the network load in order to avoid deterioration in providing quality of service.

4.3 Vertical Handoff Execution

This is the final phase in the handoff process. Its main function is to execute the procedure for VHO by associating the mobile terminal with the target access radio. This phase ensures that the existing connections of the MT are re-routed to the new target network. This handoff stage also incorporates authorization and the transfer of on-going user's active session information. Protocols such as mobile IP and stream control transmission protocol can be implemented.

5. VERTICAL HANDOFF DECISION ALGORITHMS

As an important step towards actualizing the goal of enabling seamless vertical handoff, the IEEE 802.21 or Media Independent Handover (MIH) standard has been proposed as a framework that will provide interoperability, generic link layer intelligence and to enable efficient handoff management between heterogeneous access networks. This section provides a review of relevant vertical handoff related proposals and algorithms aimed at providing seamless vertical handoffs [3,5].

5.1 Received Signal Strength (RSS) Based VHDAs

The Received signal strength (RSS) is evaluated as the main metric along with other decision metrics. This forms the first class of Vertical Handoff Decision Algorithms (VHDAs). This approach considers the RSS of an initialized network with the RSS of the available target network. In [7] an optimization scheme for performing handover using user dwell time to achieve mean throughput was presented. The method presented used the dwell timer of the mobile to optimize handoff decision for the target access network. In [8] an algorithm for handoff between 3G radio and WLANS access network was presented. The proposed scheme combined the Received signal strength measurement either with bandwidth or dwell timer. The proposed algorithm provides maximum throughput of the mobile user.

5.2 Cost Function-Based VHDAs

The use of Cost functions forms the second class of VHDAs. This method employs the evaluation of the user choice and networks measurement as criteria for handoff. Authors in [9] presented a policy which enabled VHO across heterogeneous networks based on different parameters such as power consumption, available bandwidth and service cost. An evaluation of VHD using adaptive cost function was presented while vertical handoff decision algorithm for heterogeneous network was evaluated using Markov decision process [10]. The use of cost function based VHDA is typically known to be efficient, flexible and has a low implementation complexity.

5.3 Multiple Criteria VHDAs

The third class of VHDAs employs some multiple criteria for handoff decision execution. The multiple criteria VHDAs combine the cost function based algorithm and the computational intelligence based algorithm for selecting a suitable target network among heterogeneous network. This approach can be divided into multiple attribute decision making (MADM) and the multiple objective decision making (MODM) Handoff decision in an access networks can be evaluated using (MADM) algorithm such as weighted sum model (WSM) or Multiplicative Exponent weighting (MEW), Technique for order preference by similarity to ideal solution (TOPSIS), Analytic hierarchy process (AHP) and Grey Relational Analysis (GRA). In [11], authors proposed two mathematical combinations of AHP and GRA techniques in an algorithm for selecting networks between WLAN and UMTS. The AHP was employed to achieve weighting of QoS parameter based on service application and user performances whereas the GRA was used to rank the network alternatives with faster and simpler implementation than AHP. In [12], an improvement on the technique in [11] was proposed using QoS parameters in packet switched networks while evaluating using real measurements. The proposed algorithm depends on the quality of service requirements of the service requested by the user equipment. Multiple criteria VHD algorithms are efficient, flexible and have a medium-level implementation complexity.

5.4 Computational Intelligence VHDAs

The fourth class of VHDAs relies on computational intelligence. This approach makes VHD by applying any computational intelligence technique such as Fuzzy Logic (FL), Fuzzy Multiple Attribute Decision Making (FMADM), Artificial Neural Networks (ANN), Simulating Annealing (SA) or Genetic Algorithm (GA). Authors in [13] proposed a speed adaptive policy enabled VHDA based on type-2 Fuzzy logic to discover and select best handoff candidate network with maximum throughput for vehicular heterogeneous network. In [14], user preference along with ANN was used to execute handoff for the best offered service among different reachable networks. Generally, Computational intelligence based handoff decision algorithms have high implementation complexity; however, they improve user's satisfaction during roaming and have high efficiency.

5.5 Contexts-Aware Approaches

The fifth category of VHDAs employs the knowledge of the context-aware of information relating to the MT and the network. This approach considers user information, network and device to guarantee high quality of service and to maintain connectivity for high level user's satisfaction. Authors in [15] proposed context aware VHDA that calculates the boundary area using mobile terminal speed and cell size of the WLAN. Handoff is triggered from WLAN to 3G whenever the mobile terminal enters the boundary area of the WLAN. Authors in [16] proposed congestion – aware proactive vertical handoff scheme that uses coalition game. This scheme was shown to manage congestion better than the traditional congestion control algorithm.

6. SOME OPEN RESEARCH ISSUES

With several efforts invested in proposing new efficient VHDAs, some challenges still exist towards realizing a functional VHO based system. In this regards, we present some unresolved contemporary VHO issues to be addressed as follows:

1. Maintaining connectivity for user on the go to avoid experiencing uninterrupted service continuity at anywhere and anytime
2. Guaranteeing quality of service with newer data-intensive multimedia applications including best effort and real time traffic, throughput, bandwidth timeliness, reliability, perceived quality, and cost.
3. Dynamic use of licensed and unlicensed spectrum through Cognitive Radio based VHO technology.
4. Configurable power-efficient multimode mobile devices that can accommodate new wireless access technologies in a variety of frequency bands.
5. Choosing among different access network type based on network characteristics, service offered need and user preferences.
6. Preserving key centric capabilities across boundaries networks, devices and services to improve security in VHO based systems.

7. CONCLUSION

In this paper, we have presented a basic introduction to the concept of Vertical Handoff with the aim of reviewing some basic concepts. Different concepts of VHO existing in the literature were presented to provide new and interested researchers with the necessary background for understanding the VHO concept. Issues were discussed as simplified as possible with a comprehensive survey of vertical handover decision schemes in heterogeneous wireless network also presented. These techniques were classified and particular methods in each category were highlighted. Furthermore, basic and contemporary existing research challenges were also highlighted for future considerations towards realizing a fully functional VHO system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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