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Vertical Handover Decision (VHD) algorithms in Fourth Generation Heterogeneous Wireless Networks

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ABSTRACT
One of major objectives of the fourth generation wireless network architecture is to facilitate seamless mobility of users between heterogeneous networks while satisfying QoS requirements. Vertical handover decision (VHD) algorithms are essential components of the architecture of the Fourth Generation (4G) heterogeneous wireless networks. These algorithms need to be designed to provide the required Quality of Service (QoS) to a wide range of applications while allowing seamless roaming among a large number of access network technologies. In this paper, we present a comprehensive study of the VHD algorithms designed to satisfy these requirements.

Keywords
Handover, Vertical handover, VHD algorithms, QoS.

1. INTRODUCTION
Fourth Generation Wireless Network consists of heterogeneous network managed by different operators like WiMax,WiFi etc. 4G wireless systems will provide significantly higher data rates, offer a variety of services and applications previously not possible due to speed limitations, and allow global roaming among a diverse range of mobile access networks [1]. Mobility is one important issue in 4G Wireless Networks , when a mobile user is switch from one network to another network or base station to BS there a mechanism is used "Handover". Handover is used to redirect the mobile user service from current network to a new one. Handover, there are two types one Horizontal handoff (HHO) and another Vertical handoff (VHO). When the mobile users switching between the networks with the same technology this process called HHO. In VHO the mobile users switching in different networks which have different technology. So in heterogeneous network vertical handoff decision (VHD) is mainly used for continuous service.

Rest of this paper is organized as follow. Section II gives an introduction of vertical handover. VHD criteria and performance evaluation metrics are discussed in section III and IV. Vertical Handover Decision (VHD) algorithms are discussed in section V. Finally, concluding remarks are presented.

2. VERTICAL HANDOVER
Vertical handover is happened when a mobile node moves across heterogeneous access networks. Differently from horizontal handover, the used access technology is also changed as well as IP address, because the mobile nodes moves different access network which uses different access technology. In this case, the main concern of vertical handover is to maintain on-going service although not only the change of IP addresses but also the change of network interfaces, QoS characteristics, and etc. In horizontal handover, which occur between similar networks, the handover decision is mainly based on received signal strength (RSS) in the border region of two cells. However, in vertical handover, the situation is more complex, compared to the horizontal handover, the signal strength is sometime not sufficient to trigger the vertical handover because of heterogeneous networks have different system characteristics and their performance cannot be simply compared using the signal strength of two cells. Other new metrics such has service type, system performance, network conditions, and mobile node network. Therefore, the user can choose the best access point with maximum bandwidth for connecting to the internet.

A handover process can be split into three stages: handover information gathering, handover decision and handover execution [2].

Handover Information Gathering: used to collect all the information required to identify the need for handover and can subsequently initiate it. It can be called also handover initiation phase or system discovery.

Handover Decision: used to determine whether and how to perform the handover by selecting the most suitable access network (taking into account some criteria such as user preferences) and by giving instructions to the execution phase. It is also called network or system selection.

Handover Execution: used to change channels conforming to the details resolved during the decision phase.

3. VHD CRITERIA
Handover criteria are the qualities that are measured to give an indication of whether or not a handover is needed. We can regroup different criteria as follows:

- Received signal strength (RSS) is the most widely used criterion because it is easy to measure and is directly related to the service quality. There is a close relationship between the RSS readings and the distance from the mobile terminal to its point of attachment. Majority of existing horizontal handover algorithms use RSS as the main decision criterion, and RSS is an important criterion for VHD algorithms as well.
- Available bandwidth is a measure of available data communication resources expressed in bit/s. It is a good indicator of traffic conditions in the access network and is especially important for delay-sensitive applications.

- Network connection time refers to the duration that a mobile terminal remains connected to a point of attachment determining the network connection time is very important for choosing the right moment to trigger a handover so that the service quality could be maintained at a satisfactory level. For example, a handover done too early from a WLAN to a cellular network would waste network resources while being too late would result in a handover failure.
- Cost: For different networks, there would be different charging policies, therefore, in some situations the cost of a network service should be taken into consideration in making handover decisions.

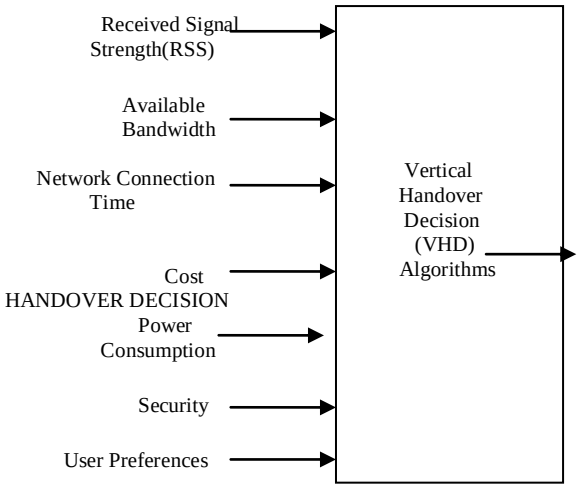

Fig. 1: Parameters used for making VHD decisions

- Power consumption becomes a critical issue especially if a mobile terminal's battery is low. In such situations, it would be preferable to handover to a point of attachment which would help extending valuable battery life.
- Security: For some applications, confidentiality or integrity of the transmitted data can be critical. For this reason, a network with higher security level may be chosen over another one which would provide lower level of data security.
- User preferences: A user's personal preference towards an access network could lead to the selection of one type of network over the other candidates.

4. PERFORMANCE EVALUATION METRICS

- Performance evaluation metrics for VHD algorithms are given as
- Handover delay: It refers to the duration between the initiation and completion of the handover process. Handover delay is related to the complexity of the VHD process, and reduction of the handover delay is especially important for delay-sensitive voice or multimedia sessions.
- Number of handovers: Reducing the number of handovers is usually preferred as frequent handovers would cause wastage of network resources.
- Handover failure probability: A handover failure occurs when the handover is initiated but the target network does not have sufficient resources to complete it, or when the mobile terminal moves out of the coverage of the target network before the process is finalized. In the former case, the handover failure probability is related to the channel availability of the target network, while in the latter case it is related to the mobility of the user [3].
- Throughput: The throughput refers to the data rate delivered to the mobile terminals on the network. Handover to a network candidate with higher throughput is usually desirable.

5. VHD ALGORITHMS

In this section, we discuss a representative set of VHD algorithms. Their operational fundamentals are summarized along with their comparative advantages and disadvantages. These algorithms are divided into one of the four categories

RSS based VHD algorithms

RSS is used as the main handover decision criterion in this group. RSS based VHD algorithms compare the RSS of the current point of attachment against the others to make handover decisions. Because of the simplicity of the hardware required for RSS measurements, a large number of studies have been conducted in this area. We describe three RSS based VHD algorithms.

An adaptive lifetime based handover heuristic : Zahran and Liang [4] proposed an algorithm for handovers between 3G networks and WLANs by combining the RSS measurements either with an estimated lifetime metric (expected duration after which the mobile terminal will not be able to maintain its connection with the WLAN) or the available bandwidth of the WLAN candidate. Advantage of this algorithm is that it provides improvement on the available bandwidth. Its disadvantage is long packet delay and extra lookup table.

An RSS threshold based dynamic heuristic: Mohanty and Akyildiz [5] proposed a WLAN to 3G handover decision method based on comparison of the current RSS and a dynamic RSS threshold when a mobile terminal is connected to a WLAN access point. The use of a dynamic RSS threshold helps reducing the incidences of false handover initiation and keeping the handover failures below a limit. However it may result in wastage of network resources.

A traveling distance prediction based heuristic: To eliminate unnecessary handovers in the method presented in last Section, Yan et al. [6] developed a VHD algorithm that takes into consideration the time the mobile terminal is expected to spend within a WLAN 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 heuristic is that it minimizes handover failures, unnecessary handovers and connection breakdowns. But the method relies on sampling

and averaging RSS points, which introduces increased handover delay.

Bandwidth based VHD Algorithms

Bandwidth based VHD algorithms consider available bandwidth for a mobile terminal or traffic demand as the main criterion [7]. In this section, two typical bandwidth based VHD algorithms are discussed in detail.

A QoS based heuristic : Lee et al.[8] devised a QoS based VHD algorithm which takes residual bandwidth and user service requirements into account in deciding whether to handover from a WLAN to Wireless Wide Area Network (WWAN) and vice versa. When the mobile terminal is connected to a WLAN, the handover algorithm is initiated if the measured RSS is consistently below a threshold (RSST1). Approximate value of the residual bandwidth of the WLAN is evaluated by the following formula:

Residual bandwidth = throughput *(1 -a*channel utilization)*

(1 – Packet loss rate);

where throughput is the throughput that can be shared among mobile terminals in the WLAN, channel utilization is the percentage of time the access point senses the medium is busy using the carrier sense mechanism, a is a factor that reflects IEEE 802.11 MAC overhead and packet_loss_rate is the portion of transmitted medium access control (MAC) protocol data units (MPDUs) that require retransmission, or are discarded as undeliverable. The values of channel utilization and packet_loss_rate are obtained from the information in the beacon frame carrying the QoS basic service set (QBSS) load sent by an access point, as defined in IEEE 802.11e.

A signal to interference and noise ratio (SINR) based heuristic: Yang et al. [9] presented a bandwidth based VHD method between WLANs and a Wideband Code Division Multiple Access (WCDMA) network using Signal to Interference and Noise Ratio (SINR). SINR based handovers can provide users higher overall throughput than RSS based handovers since the available throughput is directly dependent on the SINR, and this algorithm results in a balanced load between the WLAN and the WCDMA networks. But such an algorithm may also introduce excessive handovers with the variation of the SINR causing the node to hand over back and forth between two networks, commonly referred to as ping-pong effect.

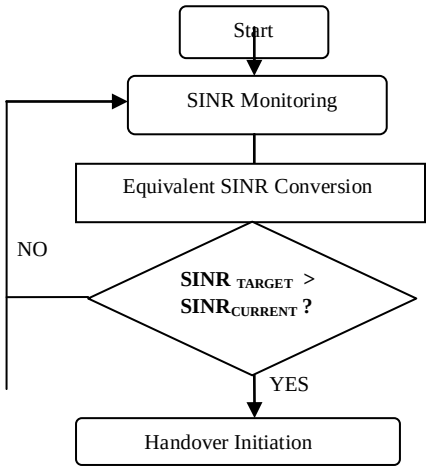

Fig. 2: Yang et al.'s VHD heuristic [10]

Cost function based VHD algorithms

This class of algorithms combines metrics such as monetary cost, security, bandwidth and power consumption in a cost function and the handover decision is made by comparing the result of this function for the candidate networks [11]. Different weights are assigned to different input metrics depending on the network conditions and user preferences. In this section, we analyse two cost function based VHD algorithms.

A multiservice based heuristic: A cost function is introduced in Zhu and McNair's [12] VHD algorithm and users' active applications are individually handed over to target networks with the minimum costs. The primary benefits brought by the use of cost function and by independently initiating handovers for different applications are the increased percentage of user satisfied requests and reduced blocking probability. However, the authors did not discuss how the QoS factors are normalized or how the weights for the QoS factors are assigned.

A cost function based heuristic with normalization and weights distribution: Similar to Zhu and McNair's method, Hasswa et al. [13] also proposed a cost function based handover decision algorithm in which the normalization and weights distribution methods are provided. A network quality factor is used to evaluate the performance of a handover. A handover necessity estimator is also introduced to avoid unnecessary handovers.

Combinational algorithms

Combination algorithms are based on artificial neural networks or fuzzy logic, and combine various parameters in the handover decision such as the ones used in the cost function algorithms. Many combination algorithms have been proposed. In this section we analyze one combinational algorithm.

A multilayer feed forward artificial neural network based heuristic : Nasser et al.[14] developed a VHD algorithm based on artificial neural networks (ANNs). As shown in Fig. 12, the mobile device collects features of available wireless networks and sends them to a middleware called vertical handover manager through the existing links. These network features are used to help with handover decisions and include network usage cost, security, transmission range and capacity. The vertical handover manager consists of three main components: network handling manager, feature collector and ANN training/selector. A multilayer feed forward ANN is used to determine the best handover target wireless network available to the mobile device, based on the user's preferences.

6. CONCLUSIONS

Vertical handover decision (VHD) algorithms are essential components of the architecture of the Fourth Generation (4G) heterogeneous wireless networks. From above discussion it is concluded that each type of VHD algorithm has its advantage and disadvantages. RSS based VHD algorithms are usually between macro cellular and microcellular networks, e.g. 3G and WLANs. In terms of complexity, RSS based algorithms are usually the simplest. Reliability of RSS based VHD algorithms are decreased due to the fluctuations of RSS. Bandwidth based VHD Algorithms are between any two heterogeneous networks. These are also simple to implement like RSS based VHD algorithm. They have reduced reliability because of the changing available bandwidth. Cost function based VHD Algorithms are between any two heterogeneous networks. These VHD algorithms tend to be more complex as

they need to collect and normalize various network parameters. In cost function based algorithms, some parameters such as security level are hard to measure, and they degrade their reliability. Combinational VHD Algorithms are also between any two heterogeneous networks. These algorithms are very complex to implement because of their pre-training requirements. They can be considered as the most reliable among the four groups.

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