A Study on Handover in Heterogeneous Networks

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***Abstract*— Next generation wireless networks integrate different wireless technologies. Vertical handover decision (VHD) algorithms are essential components in heterogeneous scenario. These algorithms are designed in a manner to provide required Quality of Service (QoS) and allowing seamless mobility among various access network technologies. In this paper a comprehensive study of VHD algorithms is presented.**

***Index Terms*— Vertical handover, Next-generation wireless system, QoS, RSS.**

I. INTRODUCTION

Increasing user demand for access to communication technologies anywhere at any time is speeding up the integration of various wireless access technologies. Consequently, network selection techniques play a vital role in ensuring quality of services in heterogeneous networks. This points to provide the user the best available QoS at any time.

Handover is the process of maintaining a user's active sessions when a mobile terminal changes its connection point to the access network (called "point of attachment"), for example, a base station or an access point [1]. Depending on the access network that each point of attachment belongs to, the handover can be either horizontal or vertical. A horizontal handover takes place between points of attachment supporting the same network technology, for example, between two neighbouring base stations of a cellular network. On the other hand, a vertical handover occurs between points of attachment supporting different network technologies, for example, between an IEEE 802.11 access point and a cellular network base station.

A handover process can be split into three stages: handover decision, radio link transfer and channel assignment [1]. Handover decision involves the selection of the target point of attachment and the time of the handover. Radio link transfer is the task of forming links to the new point of attachment, and channel assignment deals with the allocation of channel resources.

VHD algorithms assist mobile terminals to choose the best network to connect to among all the available candidates. Here, the focus is on the research efforts and recent development on improving the efficiency of VHD process. Horizontal decision algorithms mainly used to consider RSS as the only decision criteria. In the case of VHD algorithms, criteria such as cost, power consumption and velocity of the mobile terminal are required to be taken into account, to maximize user satisfaction.

J. McNair and F. Zhu in Vertical handoffs in fourth generation multinetwork environment [2] states that driving force for 4G is to move for a universal wireless access and ubiquitous computing through seamless mobility. The major challenge for seamless mobility is the development of vertical handover protocol for the users that traverse between different types of networks.

II. PERFORMANCE EVALUATION FOR VHD ALGORITHMS

The performance of VHD algorithms can be evaluated in different scenarios by calculating and analysing the handover delays, the recurrent nature of handovers, failure of handovers and the overall throughput of a session. These metrics are further explained below:

A. Handover delay

It refers to the period between the initiation and completion of the handover process. Handover delay is significantly related to the complexity of the VHD process. For voice and multimedia sessions which are delay sensitive, reduction of handover delay is necessary.

B. Number of handovers

Limiting the number of handovers is typically favoured as repeated handovers would cause wastage of network resources. A handover back to the previous point of attachment within a short period of time is considered to be superfluous. For better performance such ping-pong handovers should be minimized.

C. Handover failure probability

A handover failure happens when the handover is initiated but the intended network does not have adequate resources to execute it, or when the mobile terminal moves out of the coverage of the target network before the process get completed. In the earlier scenario, the handover failure probability is related to the channel availability of the target network, while in the latter scenario it is related to the mobility of the user.

D. Throughput

The throughput refers to the data rate delivered to the mobile terminals on the network. Typically handover to a network candidate with higher throughput is preferred.

III. VERTICAL HANDOVER DECISION ALGORITHMS

To provide further insight into the VHD algorithms, these algorithms are classified into four categories. Some algorithms may consider more than one VHD criteria, and in such cases, the main criterion used for classification are considered.

A. RSS based VHD algorithms

In RSS based VHD algorithms, handover decisions are made by comparing RSS of the current point of attachment to other networks. It is a simple method considering the hardware requirements for the measurement of RSS. Hence a large number studies have been conducted in this area.

RSS threshold based dynamic method

P Mohanty and Akyildiz [3] proposed a WLAN to 3G handover decision method based on comparison of the current RSS and a dynamic RSS threshold (Sdth) when a mobile terminal is connected to a WLAN access point. Sdth (in dBm) is calculated as

$$S_{dth} = RSS_{min} + 10\beta \log 10\,(\frac{d}{d - L_{BA}}) + \epsilon$$

where RSS_{min} (in dBm) is the minimum level of the RSS required for the mobile terminal to communicate with an access point, β is the path loss coefficient, d is the side length of the WLAN cell (in meters, a WLAN cell is assumed to have a hexagonal shape in this study), L_{BA} is the shortest distance between the point at which handover is initiated and WLAN boundary, and ϵ (in dB) is a zero-mean Gaussian random variable with a standard deviation that represents the statistical variation in RSS caused by shadowing. The distance LBA depends on the desired handover failure probability P_f , the velocity of the mobile terminal v, the WLAN to 3G handover delay τ, and is calculated as,

$$L_{BA} = [\,\tau^2 v^2 + d^2(P_f - 2 + 2\sqrt{1 - P_f})]^{\frac{1}{2}}$$

Dynamic RSS threshold aids in decreasing the false handover initiation and keeps the handover failure below a limit. But, in this algorithm, the 3G network coverage is assumed to be available all the time so the handover failure probability from 3G network to a WLAN cell is assumed to be zero, and hence according to the mechanism, a handover to a WLAN is always preferred whenever the mobile terminal steps into the WLAN coverage. Also if handover occurs when the mobile terminal's traversal time inside a WLAN cell is less than the handover delay, it will cause wastage of network resources and reduces the efficiency.

B. Bandwidth based VHD Algorithms

The main criterion for bandwidth based VHD algorithms are available bandwidth for a mobile terminal or traffic demand.

A signal to interference and noise ratio (SINR) based Method

Yang et al. [4] presented a bandwidth based VHD method between WLANs and a Wideband Code Division Multiple Access (WCDMA) network. The performance is analysed using Signal to Interference and Noise Ratio (SINR) and it can be determined with the help of Shannon capacity formula. The receiving SINR from WCDMA is converted to an equivalent SINR and compared with the actual SINR from WLAN.

$$\gamma_{AP} = \Gamma_{AP}[\,(1 + \frac{\gamma_{BS}}{\gamma_{BAP}})^{\frac{w_{BS}}{w_{AP}}} - 1]$$

Where $\gamma_{AP}$and γ_{BS} are the SINR at the mobile terminal when associated with WLAN and WCDMA, respectively. Γ is the dB gap between the uncoded Quadrature Amplitude Modulation (QAM) and channel capacity, minus the coding gain, and Γ_{AP} equals to 3dB for WLAN and Γ_{BS} equals to 3dB for WLAN. w_{AP} And w_{BS} are the carrier bandwidths of WLAN and WCDMA links.

The available throughput is directly dependent on the SINR. Therefore SINR based handovers provide higher overall throughput compared to RSS based handovers. Also this algorithm results in a balanced load between the WLAN and the WCDMA networks. But one drawback of this kind of algorithm is, it may cause a node to handover back and forth between two networks, referred as ping-pong effect, due to the variations in the SINR.

C. Cost function based VHD algorithms

The cost function based algorithms consolidate metrics in a cost function. The network candidate that provides the lowest calculated value of the cost function in the network will provide the most benefit.

A multiservice based method

Zhu and McNair's [5] VHD algorithm depends on a cost function which calculates the "cost" of possible target networks. The algorithm prioritizes the applications, and then the cost of possible target networks with the highest priority are calculated as,

$$C_s^n = \sum W_{sj}^n Q_{sj}^n \quad , \qquad E_{sj}^n \neq 0\,,$$

Where C_s^n is the per-service cost for network Q_{sj}^n is the normalized QoS provided by network n for parameter j and service W_{sj}^n is the weight which indicates the impact of the QoS parameter on the user or the network, and E_{sj}^n is the network elimination factor, indicating whether the minimum requirement of parameter j for service s can be met by network n [5].

The total cost is the sum of the cost of each QoS metric like the bandwidth, delay and battery power. The candidate with minimum cost is chosen as the best network and the service is handed over to this network. The main advantages by the use of cost function are increase in user satisfaction and decrease in blocking probability. But this method has not discussed about how the normalization of QoS factors are done or how the weights for QoS factors are assigned.

D. Combination algorithms

Combination algorithms combine a number of metrics in the handover decision such as the coast functions. They are employed by artificial neural network or fuzzy logic.

A multilayer feed forward artificial neural network based method

Nasser et al. developed a VHD algorithm based on artificial neural networks (ANNs) [6]. In which, the mobile device gathers features of accessible wireless networks and sends them to a middleware called vertical handover manager through the current connections. These network features helps with handover choices and incorporate usage cost, security, transmission range and capacity. The vertical handover manager comprises of three primary segments: network handling manager, feature collector and ANN training/selector. A multilayer feed forward ANN is used to determine the best handover target wireless network accessible to the mobile device, in light of the user's preferences.

The topology of the ANN comprises of an input layer, a hidden layer and an output layer. The input layer comprises of five nodes representing various parameters of the handover target candidate networks. The hidden layer comprises of different number of nodes which are activation functions. The output layer has one node which produces the network ID of the handover target. For ANN training a series of user preference sets are generated with random weights. At that point the framework has been prepared to choose the best system among all the candidates. The best available network can be chosen successfully by providing proper learning rate and acceptable error value. However, the drawback of the algorithm is that the training process causes a long delay.

IV. CONCLUSION

VHD algorithms should be devised in such a manner to improve the overall performance of a mobile terminal managing efficiently the quality of services resources of the discovered wireless networks. But usually VH decision algorithms do not handle many QoS parameters and might be suitable only for particular instances. The main challenge is constructing an algorithm which takes into account the wide range conditions and user preferences. One possible solution would be to implement various VHD algorithms in a system and adopt the best algorithm intelligently according to the scenario.

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