A VERTICAL HANDOVER DECISION APPROACHES IN NEXT GENERATION WIRELESS NETWORKS: A SURVEY

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ABSTRACT

In next generation wireless network the most desirable feature is its ability to move seamlessly over various access network regardless of the network infrastructure is used. The handover between these dissimilar networks can be explored by using vertical handover algorithms. This paper focuses on the vertical handover decision methods and algorithms effectiveness. Most of the algorithms which are based on RSS values provide vertical handover with small delay at a lower rate of throughput. There are such algorithms which provide significant improvements in throughput but at a cost of higher delays. As per the need for the real time applications in next generation wireless networks there is a requirement of developing new optimized algorithms that are able to produce high throughput and minimizing signalling cost and delay.

KEYWORDS

Vertical handover, QoS, mobile networks, next generation wireless networks.

1. INTRODUCTION

Mobile wireless technology has gained tremendous popularity due to its ability to provide ubiquitous information access to users on the move. However, presently, there is no single wireless network technology that is capable of simultaneously providing a low latency, high bandwidth, and wide area data service to a large number of mobile users. In new generation wireless network, mobile users are connected to the best available networks that suit their service requirements and switch between different networks based on their service needs. Efficient mobility management protocols are required to support mobility across heterogeneous access networks [5]. This next-generation of wireless systems represents a heterogeneous environment with different access networks technologies that differ in bandwidth, latency or cost. In this kind of environment, mobility management is the essential issue that supports the roaming of users from one system to another. Handover management, one of the mobility management components, controls the change of the MT's point of attachment during active communication [2]. Mobility management[4,42,43,44] contains two components: location management and handover management. Location management enables the system to track the locations of mobile users between consecutive communications. On the other hand, handover management is the process by which users keep their connections active when they move from one base station (BS) to another. Handover in wireless networks result in performance degradation to applications of these handover protocols. Handover management issues include mobility scenarios, metrics,

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decision algorithms and procedures. Mobility scenarios can be classified into horizontal (between different cells of the same network) and vertical (between different types of networks). In homogeneous networks, horizontal handover are typically required when the serving access router becomes unavailable due to MT's movement. In heterogeneous networks, the need for vertical handover can be initiated for convenience rather than connectivity reasons (e.g., according to user choice for a particular service).

Two of the major challenges in vertical handover management are seamlessness and automation aspects in network switching. These particular requirements can refer to the Always Best Connected concept, of being connected in the best possible way in an environment of multiple access technologies, according to policies (expressed by rules based on parameters such as network conditions or user preferences) [3]. For that, a handover management technique must choose the appropriate time to initiate the handover and the most suitable access network.

In the context of future wireless networks, many analysis, studies and tutorials were proposed in the literature: mobility management solutions [4,42,43,44], vertical handover design in 4G context [1], handover in hybrid mobile data networks [2], etc. No one was proposed including the different existing strategies in the vertical handover decision problem. So, our paper analyzes the most interesting and recent ones in the literature. It shows how advanced tools as well as proven concepts can be used to solve such a problem and thus answering ABC requirement. It classifies the strategies into five main categories: function based, user-centric, multiple attribute decision, Fuzzy Logic and Neural Networks based, and Context-aware strategies. The paper is organized as follows. Section 2 presents the vertical handover decision process criteria in a heterogeneous environment and the vertical handover decision and its characteristics taken into account in the study. Section 3 analyzes the different existing strategies and compares each one with the others. Finally, Section 4 concludes the work and gives some perspectives.

2. VERTICAL HANDOVER DECISIONS

Unlike homogeneous networks, heterogeneous networks provide tremendous challenges since the environment in which the MH resides may have different characteristics. These different characteristics should be considered carefully so that the most optimal decision for selecting the right time of the instance for the handover may be achieved when a mobile roams between dissimilar networks.

In this paper, methods for vertical handover decisions are divided into five distinct categories based on the decision criteria and the approach used.

2.1. Network Conditions

Handover decision criteria help us to determine which access network should be chosen and the handover decision policy represents the influence of the network on when and where the handover occurs. Handover decision criteria can be static or dynamic. Following are the key points to consider viz. network coverage, bandwidth, latency; link quality i.e. received signal strength (RSS), SIR, BER, monetary cost and security levels etc. The traditional handover decision policy is based only on RSS which is the dynamic criteria for handover. 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, not surprisingly, a large number of studies have been conducted in this area [36, 27, 34, 29, 38, and 7].

- if *RSSnew* > *RSSold* then choose the new BS

- if *RSSnew* > *RSSold and RSSold* < *T* then choose the new BS which has the RSS with threshold T, RSS with a certain threshold is typically used to avoid the problem of handing over to an access point too quickly to a neighboring base station.
- if *RSSnew* > *RSSold* + *H* then choose the new BS which has RSS with hysteresis H
- if *RSSnew* > *RSSold* + *H and RSSold* < *T* then choose the new BS which has RSS, hysteresis and threshold. RSS coupled with hysteresis avoids the problem of the 'ping pong' effect at cell borders. In such cases, a handover is initiated to a neighboring cell only when the RSS is equal or above a certain threshold value.

There are many algorithms which are based on RSS for vertical handover decisions. Zahran et.al. [5] proposed an algorithm for 3G and WLAN networks, which is based on RSS in combination with an estimated lifetime of the available bandwidth to decide the handover time. Advantage of this algorithm is that it provides the adaptation to application requirements and user mobility. It also provides the improvement on the available bandwidth. However the drawbacks include packet delay that increases with the lifetime of the connectivity due to the deterioration of the channel condition as the mobile host approaches the edge of the WLAN cell and extra lookup table. Mohanty and Akyiliz's[29] calculated a dynamic RSS threshold and then it is compared with the current RSS to determine the handover time from WLAN to 3G. This proposed algorithm provides the reduction of the false handover initiation and handover failure probabilities. However this scheme have increase of handover failure probability from 3G to WLAN and also there are wastage of network resources. Yan et. al. [48] proposed an algorithm for cellular networks and WLAN in which a dynamic threshold is calculated and compared with the predicted travelling time inside the WLAN to help with handover decisions. It provides the minimization of handover failure, unnecessary handover and connection breakdown probabilities with increase in handover delay. A bandwidth-based vertical handover decision algorithm between WLAN and wideband CDMA (code division multiple access) networks have been proposed in [6, 7, 8] that uses the signal to interference and noise ratio (SINR) as its main criterion. This algorithm provides users with a higher overall throughput as well as a balanced load between the WLAN and the WCDMA network. However, this approach might introduce excessive handover given the dynamic variations of the SINR and may result in a 'ping pong' effect between access points.

2.2. Cost Function

The basic idea of a cost function based vertical handover decision algorithm is to choose a combination decision making parameters of network such as RSS, network covering area, available bandwidth, service cost, reliability, security, battery power etc. and define a cost function based on these factors to evaluate the performance of target networks. The handover decision can then be made accordingly. Zhu et.al proposed a cost function based vertical handover algorithm between any two heterogeneous wireless networks. A multiservice based algorithm [18,19] relies on a cost function which is used to calculate the cost of all possible target networks in the proximity. In which all the active applications are assigned a priority and cost of each possible target network for the service with highest priority is computed. This method is characterized by the use of cost function, user satisfaction and reduced handover blocking probability.

Hassawa et.al proposed a cost function algorithm between any two heterogeneous wireless networks. In which they had provided the methods for QoS normalization and weight distribution. Also proposed a handover necessity estimator to avoid unnecessary handover. A network quality factor is used to evaluate the performance of a handover target candidate. With the help of this method high system throughput and user's satisfaction is achieved. However there is a difficulty in estimating the parameters such as security and interference level.

According to H.Wang et. al. [9], a cost function is obtained by the sum of weighted function of certain parameters such as dynamic network condition, user defined policies and stability period. It is calculated for each available access network and network with highest utility is chosen. The author had chosen Mobile IP with added enhancements for load balancing and for seamless and stable handover [9]. The major advantage of this approach is the increased user satisfied request and the reduction in blocking probability. There is no significant directions are given on the way in which QoS parameter is normalized or how the weights were assigned. The main feature of their algorithm is that they have introduced a cost function and users' active applications are individually handed over to target networks with the minimum cost. It has increased user satisfaction and low blocking probability. However there is no significant description about QoS normalization and how the weights are assigned to make the algorithm realistic.

Tawil et.al proposed a similar algorithm between any two heterogeneous networks. The main feature of this algorithm is that it introduced a weight function and the handover calculation is delegated to the visited network instead of MT. By assigning the calculation to the visited network, the resource of the mobile terminal can be saved so that the system is able to achieve short handover decision delay, low handover blocking rate and high throughput. However, the method requires extra cooperation between the mobile terminal and the point of attachment of the visited network, which may cause additional latency and excessive load to the network when there are a large number of mobile terminals.

2.3. Multiple-Attribute

Multiple-attribute Vertical handover decision is nothing but a mathematical optimization problem that deals with the problem of choosing the best alternative from a set of alternatives based on their attributes i.e. a MADM (multiple attribute decision making) problem [10, 11]. The most popular classical MADM methods are:

(1) SAW (Simple Additive Weighting): the overall score of a candidate network is determined by the weighted sum of all the attribute values.
(2) TOPSIS (Technique for Order Preference by Similarity to Ideal Solution): the chosen candidate network is the one which is the closest to ideal solution and the farthest from the worst case solution.
(3) AHP (Analytic Hierarchy Process): decomposes the network selection problem into several sub-problems and assigns a weight value for each sub-problem.
(4) GRA (Grey Relational Analysis) is then used to rank the candidate networks and selects the one with the highest ranking.
The vertical handover decision with multiple attribute is a complex problem; AHP is the most popular method to decompose it into a hierarchy of simpler and more manageable sub problems [18]. These sub problems can be decision factors or weights according to their relative dominances to the problem. Decision factors can be solution alternatives and AHP selects the solution alternative with the largest synthesized weight. Briefly, AHP method is a three step process [19]:

(1) Decomposes the decision problem into different levels of the hierarchy (identification of the decision criteria).
(2) Compares each factor to all the other factors within the same level through pair wise comparison matrix (such as comparing objectives at the first level and networks with the respect of each objective at the second level).
(3) Calculates the sum of products of weights obtained from the different levels, and selecting the solution with the highest sum.

This method is considered as a well-known and proven mathematical process. Otherwise, such a classical method remains insufficient to handle a decision problem with imprecision in decision criteria. More advanced methods are needed or combined with classical ones to get more efficient decision strategies. It is the scope of the following sections.

In this approach, the network decision process is formulated as a problem of MADM and does the evaluation of access networks based on a 'multiple attribute wireless network selection function' i.e. WNSF. It is an objective function which measures the efficiency of using radio resources as well as the weighted gains in QoS from handing off to a particular network. The network having the highest WNSF value is selected as the best network to handover from the current access network. The parameters considered include host attributes, network conditions, service and application requirements, cost of service, and user preferences. The network selection algorithm requires the input data from both the user and the system The objective function for a network should achieve fair signal strength, good network coverage, optimum data rate, low service cost, high reliability, strong security, good mobile velocity, low battery power requirements, and low network latency. However, this approach is not optimized to handle problems with uncertain conditions [12].

2.4. AI Approaches

Fuzzy logic and neural networks are two artificial intelligence (AI) approaches that may be used in conjunction with other methods to handle uncertainty as well as improve performance for vertical handover. Neural network based vertical handover architecture was designed to address user bandwidth requirements [13]. Many combination algorithms have been proposed [6, 17, 19, 25,31,35,37, and 38]. Nasser et al. developed a VHD algorithm based on artificial neural networks [31]. According to Nasser et. al. usually the mobile device collects all the necessary features of available wireless networks and sends them to a middleware generally known as vertical handover manager through the existing links. These network features are used for helping handover decisions and also include the parameters such as network usage cost, security, transmission range and capacity. The vertical handover manager consists of three major components viz. network handling manager, network feature collector and artificial neural network training /selector. A multilayer feed forward artificial neural network based on user preferences is used to determine the best handover target wireless network available to mobile device. The topology which is used for artificial neural network. It consists of an input layer, a hidden layer and an output layer. The author has used the cost function as in [18], and for artificial neural network training they have generated a series of user preference sets with random weights. Later the system has been trained to select the best network among all the available candidates. According to the author it is observed that the best available network was successfully found out by properly selecting the learning rate and acceptable error value. However due to training process the algorithm suffers from long delay. According to Pahlavan et.al.[13], they have applied their algorithm on WLANs and GPRS in which the different RSS samples are collected as the inputs of the neural network and the system is trained before being used in handover decision. Such a system has reduced number of handover and there is an elimination of ping pong effect. However algorithm has certain disadvantages such as there is insufficient details on training process and parameter selection. Also the algorithm suffers from traing delay and system complexity is increased. A fuzzy logic heuristic proposed by Xia et.al.[38] is used to handle handover between WLANs and cellular networks in [14].

In this approach, a fuzzy logic based normalized quantitative decision (FNQD) is applied. The FNQD has three procedures: 'fuzzification', normalization and quantitative decision. The three inputs – current RSS, predicted RSS and bandwidth – are 'fuzzified' and normalized to generate performance evaluation values. A handover from the WLAN to the cellular network is initiated when the velocity of the mobile host is higher than a certain velocity threshold so as to ensure service continuity. However, this is subject to the following condition - if either the predicted RSS from the WLAN is larger than its threshold, or the predicted RSS from the cellular network is smaller than its threshold, then handover is not initiated. The approach used is able to achieve improved performance by lowering the number of unnecessary handover, thereby reducing the 'ping pong' effect.

2.5. Context-Aware

Context-aware handover are based on the information related to the mobile host, network and other contextual parameters for intelligent decision making. This information may include capacity, location, user preferences, network QoS, coverage, QoS requirements, and service type e.g. real-time, interactive or streaming traffic. In [15], an algorithm has been developed to facilitate vertical handover based on context changes. In their work, two entities are proposed i.e. a context repository that manages and evaluates context information, and an adaptability manager that manages context changes for handover execution. The selection is based on optimizing QoS requirements and entails satisfying multiple objectives such as user preference, maximizing throughput, and minimizing jitter, delay, packet loss, bit error rate (BER), and bandwidth fluctuations. These objectives were defined as 'lowest cost', 'preferred interface', and 'best quality'. The proposed framework is a mobile assisted solution where measurements are gathered from the host as well as the systems' environment. S. Balasubramaniam et. al. [17] proposed a hierarchical architecture based on active nodes, which maximizes the computational capabilities of various nodes within the pervasive computing environment, while efficiently gathering and evaluating context information from the user's working environment Hong et al. [42] propose a vertical handover scheme for ubiquitous environments, where handovers to suitable wireless access networks are performed based on combined QoS requirements of all the applications running on the mobile device. The use of a dwelling timer for avoiding ping-pong effect is also considered in their work. A context aware computing based vertical handover mechanism which matches QoS requirements of multimedia applications onto the QoS provided by the wireless networks. In their work they first determine the need for the handover and if so, it evaluates the available networks will provide the desired QoS. It explores a comprehensive context model for information about handover[8]. *Ahmed et. al.* [27] also proposes a context-aware vertical handover decision algorithm for the multi-homed devices. The work reported in [27]. It assumes that the information about the offered QoS will be published by the corresponding wireless network. The use of AHP method for the optimization is motivated by the use of AHP in [8] and [41]. The selection of AHP over other decision algorithm is its ability to vary the objective weights very useful for dealing with events considered by the context. Moreover, AHP involves simple mathematical computations, which do not result in much processing overhead on the mobile device.

3. Analysis of VHD Algorithms

Table 1 presents the five methods that have been summarized for comparison based on throughput and handover delay as their performance metrics. In general, all approaches are able to perform vertical handover between different systems. Traditional approaches such as those using RSS, SNR and/or BER are simpler implementations that have low handover delays but with low to medium throughput. Generally, VHDs that are based on cost function do not seem to yield higher throughput than simpler approaches. This is probably due to the greater emphasis on reducing the number of calls or connections being rejected during handover especially when networks are congested (call blocking probability). Furthermore, the handover delays in cost function based VHDs tend to be in the higher range most probably due to the increased in complexity when gathering information and calculating the cost function itself.

As the decision for handover is evaluated using multiple attributes, there is a general improvement in throughput. A more informed decision-making can be made which yields higher packet delivery. Unfortunately, the complexity in evaluating the different attributes increases the time for the handover delays. This is also true for more complex approaches such as those using AI and context-aware VHD methods. As such, an ideal approach that would facilitate seamless vertical handover should be found with the following characteristics:

1. It should be able to consider user, application, device and environmental (network) factors in formulating the VHD function.

2. Decision-making algorithm should not be overly complex i.e. computationally reasonable for handover delays to remain low;

3. It should be able to consider multiple attributes dynamically;

4. It should be able to perform some form of adaptive behavior;

5. It should be capable to handle uncertainty especially in dealing with user and application requirements.

Table 1. Analysis of VHD algorithms

Method	Criteria	Throughput	Delay	Remarks
Network	RSS SINR	Min - 0.6 Max - 2.4	Min- 2.5 Max- 9.0	Simple Low to Medium Throughput Low Delay
	RSS SINR	Min -0.5 Max - 5.5	Min- 5.0 Max- 6.0	
	RSS BER SINR	-	Min- 3.0 Max- 8.5	
Cost Function	Service Cost Security Power	Min - 0.4 Max- 1.0	Min - 2.5 Max- 9.0	Low Blocking probability Low throughput High Signaling traffic
	QoS Coverage Data rates	Min - .003 Max- 0.035	-	
	Cost User preference Network conditions	Min -0.030 Max- 0.095	-	
Multiple attribute	Bandwidth Call drop probability Cost	Min - 2.8 Max - 3.5	Min-0.4 Max-0.7	-
	Coverage QoS	Min - 2.8 Max- 3.6	Min-0.4 Max-0.8	High delays
AI	Cost of service	Min - 7.2 Max - 15	-	High throughput
	QoS Bandwidth	-	Min-20 Max-240	High Handover Delay
Context Aware	Bandwidth Dropping probability Cost	Min -2.0 Max- 6.5	-	Medium Throughput High Handover delay
	Cost Total & available bandwidth	-	Min -5.0 Max -6.5	

4. CONCLUSIONS

In this paper, a review of recent approaches to vertical handover decision methods was presented. This review suggests that improvements in performance may be achieved when multiple criteria are used for handover decisions. As the evaluation function for handover decisions become more complex, delays increases significantly. For real-time applications, this may not be feasible or appropriate. As such, there is need for ongoing work to develop hybrid methods that can yield optimal results without being overly complex with some form of adaptive or intelligent behaviour to handle uncertainty and address the dynamic nature of mobile environments

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