ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 9(14), DOI: 10.17485/ijst/2016/v9i14/86601, April 2016* ISSN (Online) : 0974-5645

An Overview of Vertical Handover Process and Techniques

Loveneet Kaur Johal and Amandeep Singh Sandhu*

School of Electronics and Electrical Engineering, Lovely Professional University, Jalandhar -144001, Punjab, India; lovi.johal11@gmail.com, sandhu.aman17403@gmail.com

Abstract

Objectives: Advances in the communication system have led to increase in services provided by various Radio Access Technologies. In a heterogeneous environment in order to access these various services, improved handover process is required. In this paper we aim to design a VHO decision algorithm that ensures that a mobile user is transferred to the desired network at an appropriate time in order to maintain better quality of service. **Analysis\Methods:** Enhanced VHO algorithm can be designed by combining various network selection techniques so that it adapts according to the user and his requirements at that instant of time. This can be done by combining Fuzzy AHP with an optimization technique. **Findings:** To satisfy increasing user demands in Heterogeneous environment, there is need to design an VHO algorithm that is most effective and efficient with respect to evaluation matrices. **Improvement:** The network selection technique suggested in this paper proposed the best network selection algorithm along with network selection techniques that will enhance the performance of the network.

Keywords: Evaluation Matrices, Heterogeneous Network, Network Selection Algorithm, Network Selection Techniques, Vertical Handover

1. Introduction

Communication system found its origin from analog technology (1G), for transmission of data over a wide range of distance and has advanced towards digital network (2G, 3G, 4G) and has become an integral part of our daily life. Fourth generation wireless network consist of a heterogeneous network comprising of different Radio Access Technologies (RAT) like WiMAX, WiFi and LTE. Different RATs facilitate user with different services which has increased users' need to stay connected to best network anytime, anywhere depending on their demands and requirements. To achieve the best connectivity and QoS, handover process should execute seamlessly so that the ongoing sessions are sustained[1,2].

Handover is a process in which ongoing call or data session of the mobile user is transferred from current network to new available network. Handover process is categorized into Vertical handover and Horizontal Handover (HHO), as shown in Figure 1. When mobile user is switched between same RAT (for e.g. WiFi to WiFi), the process is called horizontal (or symmetric) handover; which is present in homogeneous network and when switched between different RATs (for e.g. WiMAX to LTE), it is known and vertical (or asymmetric) handover; which is present in heterogeneous network[3].

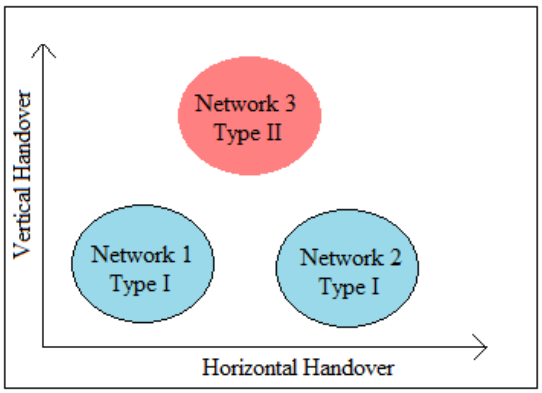

Figure 1. Vertical and Horizontal Handover.

* *Author for correspondence*

Some of the differences in VHO and HHO are:

- More than one type of network connection is present in VHO.
- RAT in VHO is changed.
- QoS and network interface may be changed in VHO.
- IP address is changed in both VHO and HHO.

1.1 Classification of VHO

As depicted in Figure 2, Vertical handover is classified into four categories, depending on its process, control, decision and direction[4,5].

1.1.1 Depending on Direction- Downward and Upward

When a mobile user switches to the network with larger coverage area from the network with the smaller coverage area, then the handover is known as upward handover, else known as downward VHO.

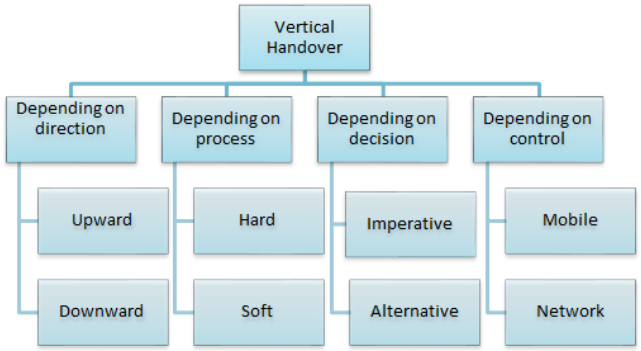

Figure 2. Vertical handover categorization.

1.1.2 Depending on Process- Hard and Soft Handover

When mobile user breaks the connections with current network before switching to target network then it is known as hard handover (or break before make) and if mobile network maintains connections with current network till it is fully associated with target network it is known as soft handover (or make before break).

1.1.3 Depending on Decision- Imperative and Alternative

In imperative handover, Received Signal Strength (RSS) is main handover criterion. When the value of RSS decreases the threshold value handover is initiated known as imperative handover. While in alternative handover several handover parameters such as bandwidth, monetary cost, are taken into consideration.

1.1.4 Depending on Control- Mobile Controlled and Network Controlled

In mobile controlled, handover is controlled by the mobile node. While in a network controlled, central management entity is responsible for controlling the handover process.

2. Vertical Handover Process

VHO process can be categorized into 4 stages, as shown in Figure 3: Initiation phase, system discovery phase, decision-making phase and handover execution phase[6-8].

2.1 Handover Initiation

The process is initiated by one or more network selection parameters such as RSS and bandwidth. For example in an RSS based VHO algorithm, handover is initiated when the value of RSS decreases below a certain threshold value. Avoiding unnecessary handovers is the task of initiation phase.

2.2 System Discovery

In this phase the mobile terminal collects all the necessary information about the available candidate networks and various services provided by them so as to select an

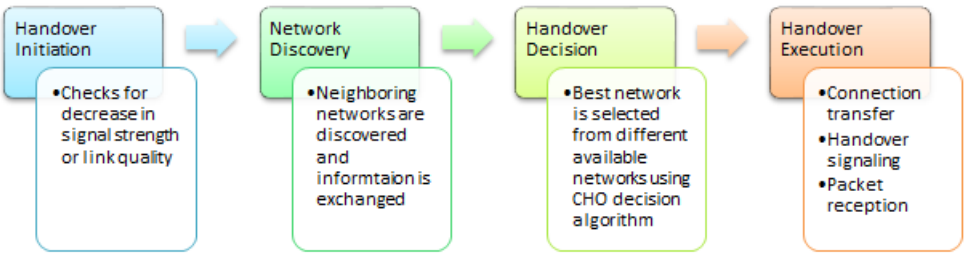

Figure 3. VHO process.

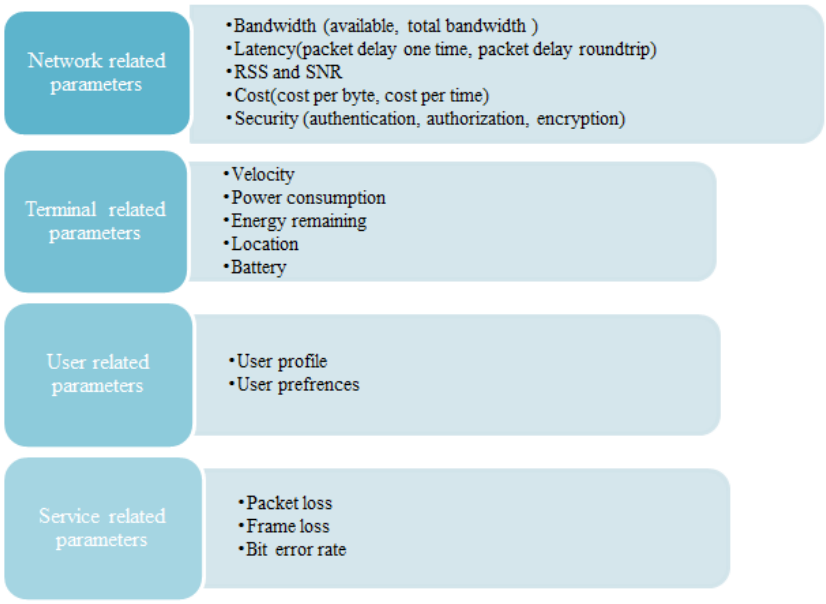

Figure 4. Vertical handover parameters.

optimum network for handover. This information can be exchanged between the networks and mobile terminals on QoS parameters.

2.3 Handover Decision Phase

In this phase one of the VHO decision algorithms is used to decide whether to continue with the currently connected network or to switch to a candidate network. This selection depends on a number of parameters including the type of service, access cost, available bandwidth, and users' preferences. Handover decision phase involves selection of target network and channel assignment, which involves allocation of channel resources.

2.4 Handover Execution Phase

This is the final stage in VHO process. Once the decision is made, connections are re-routed from the current network to target network seamlessly. This phase involves radio link transfer along with authorization and authentication.

3. VHO Parameters

In VHO process, the mobile terminal decides whether to continue with the current network or to switch to the new network. This decision depends on a number of parameters known as network selection parameters[9,10], which are categorized into 4 categories [4] as shown in Figure 4.

3.1 Received Signal Strength (RSS)

Most HHO algorithms use RSS as the main network selection parameter. It is one of the most widely used handover criteria for horizontal handover since it is easy to measure and has a direct relation with quality of service[5]. RSS is considered as a good indicator of network signal strength and link quality[6]. But RSS based handover is not a good solution for seamless handover since in heterogeneous environment, different networks have different values of channel coding, noise and power, which makes RSS incomparable for different RATs.

3.2 Network Connection Time

It is the time span for which user terminal remains connected to a particular network. It is necessary to calculate this connection time in order to choose the perfect moment for triggering the handover, so as to maintain QoS and to decrease the number of handover failures since handover done too early can result in resource wastage and done too late can cause handover failure.

3.3 Handover Latency

It is time duration between last packets received from the old network and arrival of the first packet from target network. It affects the quality of service.

3.4 Available Bandwidth

Bandwidth refers to the speed of bit transmission in the channel in bits/sec, so available bandwidth is a good indicator of traffic state and conditions in target network and become an essential factor in applications which are delay sensitive. Generally network with higher bandwidth is preferred for handover since call dropping and call blocking probability decreases with increase in bandwidth[4,5,7].

3.5 Power Consumption

Power becomes critical if the mobile terminal battery is low. In such cases, the network which may extend battery life is preferable for handover.

3.6 Monetary Cost

It defines charging policy of a network. Different networks have different charging policies so sometimes it is necessary to consider the cost of a network service to make the handover decision.

3.7 Security

For the applications demanding high confidentiality and integrity of transmitted data, the network providing a high level of security is chosen for handover.

3.8 User Preferences

Users' personal preferences based on application requirements like service type- data, video, voice and quality of service, may be taken into consideration while the selection of target network among the available networks.

4. VHO Decision Algorithm

A VHO algorithm helps the mobile terminal to select the best network to handover to, among the candidate network. There are various ways to differentiate the VHO decision algorithm.

4.1 RSS based Algorithm

In RSS based algorithm, RSS is main handover parameter, where RSS of the current network is compared with RSS of candidate network to make the handover decision. Since RSS is easy to measure many handover decision algorithms have been designed taking RSS as main handover criterion. Zahran et al.[8] proposed RSS based VHO algorithm for 3G cellular networks and WLANs.

In RSS based VHO algorithm new network selection decision is based on RSS only[11]. Handover process is initiated if any of these conditions (taken into consideration by designer) are satisfied:

- *RSS*: $RSS_{old}<RSS_{new}$.
- *RSS with threshold T*: $RSS_{old}<T$ and $RSS_{old}<RSS_{new.}$
- *RSS with hysteresis H:* $RSS_{old}+H<RSS_{new.}$
- *RSS with threshold T and hysteresis H:* $RSS_{old}<T$ and $RSS_{old}+H<RSS_{new}$

4.2 Bandwidth based Algorithm

In these algorithms available bandwidth is a major criterion for handover decision. In some algorithm, both RSS and bandwidth are taken into consideration for designing VHO algorithm. Lee et al.[12] proposed QoS-based VHO algorithm in which they considered residual bandwidth and user requirements for the network comprising of WLAN and WWAN.

4.3 Cost Function based Algorithm

In these algorithms power consumption, security, monetary cost and bandwidth are taken into consideration for designing of VHO decision algorithm. The selection of new network is done by computing and comparing values of these parameters for the available networks[7]. Patel et al.[13] proposed VHO decision method by combining cost factor and weight distribution calculations, taking RSS, monetory cost, user preferences and security as selection parameters. Weights of various network parameters are generated and cost of candidate network is calculated using cost function. The candidate network with least cost is then chosen for handover process. Chandralekha et al.[14] proposed VHO algorithm taking power consumption and throughput as handover matrices which reduced the number of handover and latency.

4.4 Combination Algorithm

These VHO algorithms use a complex set of inputs to make the handover decision. When we use a large number of parameters, VHO algorithm becomes complex, then machine learning processes are applied to model the process[7]. Khera et al.[15] proposed QoS-based VHO algorithm for heterogeneous environment taking into consideration network bandwidth, RSS, threshold bandwidth, power dissipation, power consumption, network conditions as VHO decision parameters. The algorithm improved decision-making efficiency and minimized power drain, making handover faster by reducing handover latency helping to maintain signal quality.

5. Performance Evaluation Matrices for VHO Algorithm

VHO algorithms are compared using various scenarios. These are number of handovers, probability of handover failure, throughput and latency[7].

- *Handover delay:* It is time duration between initiation and execution of VHO process. It becomes critical in delay sensitive applications.
- *Number of handovers:* There is need of VHO algorithm which results in less number of handovers as frequent handovers may result in wastage of resource and more power consumption.
- *Probability of handover failure:* When VHO process is initiated but either the mobile user moves out of the coverage area of the selected network or the selected network does not have sufficient amount of resources to execute the handover process, then handover failure occurs. An algorithm should minimize this failure probability.
- *Throughput:* It is the data rate that is delivered to a mobile user by the mobile terminal on the network. Generally network with higher throughput is preferred for handover.

6. Techniques used for Network Selection

Three issues that dominate network selection are[8]

- Selection of most appropriate handover parameters.
- Identification of algorithm that fully exploit these parameters.
- Identification of weighting technique that weights each criterion.

There are four main network selection techniques used in the heterogeneous network. These are Multiple Attribute Decision Making (MADM), Fuzzy Logic and neural network, Game Theory and Utility Theory.

6.1 Multiple Attribute Decision Making (MADM)

Based To deal with vertical handover problem, decision algorithm based on multiple attribute decision making have been introduced. MADM includes many methods such as Analytic Hierarchy Process (AHP), Simple Additive Weighting (SAW), Multiple Exponential Weighting (MEW), Gray Relational Analysis (GRA), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Distance to Ideal Alternative (DIA).

- TOPSIS is applied to determine the ranking of access networks. The network selected has ranking closest to the ideal solution and is obtained by considering the best value for each VHO parameter[16]. Compared to other techniques TOPSIS requires only one subjective input (weight-age) to make final handover decision and provide higher throughput and lower packet loss[4].
- AHP method is used to determine the weight of each criterion by dividing network selection problem and assigning weights to each sub-problem.
- GRA is used to rank the candidate network and select the network with the highest ranking.
- SAW method is used calculate the overall score of candidate network by addition weighted sum of all the selection parameters.

Pahal et al.[17] proposed Cross-layer based VHO decision algorithm using TOPSIS for network selection. Verma et al.[18] proposed network selection algorithm using GRA technique for heterogeneous environment. Jamalipour et al.[19] proposed network selection mechanism for next generation networks using AHP and GRA technique.

The problem with MADM techniques is that there is a ranking of a finite number of alternatives with multiple attributes while the network chosen by MADM technique is cheapest[20].

6.2 Fuzzy Logic based Network Selection Solution

In this network selection technique, physical measurements are converted into fuzzy logics. This technique is applied to design a computerized method which would rely on human intelligence for network selection because knowledge based system has the ability to simplify the decision process. In this technique user

Table 1. Comparison between different network selection techniques

Technique	Selection time	Operation Simplicity	Precision	Efficiency	User-centric
MADM	Less	Less complex	High	High	Yes
Game Theory	Moderate	Highly complex	High	Moderate	No
Utility Theory	Less	Less complex	Moderate	Moderate	Yes
Fuzzy logic	Less	Less complex	Moderate	High	Yes

and network side attributes are placed in the fuzzy logic controller to carry out final decision process, yielding the result called fitness ranking[20]. The network with highest fitness rank is selected for handover. Since the rules for network selection have to be manually configured by the user, the scalability of this technique is extremely low. Fuzzy Logic deals with imprecise data and multiple inputs for VHO decision which increases the efficiency of handover and reduces unnecessary handover. Shorey et al.[20] and Kaleem et al.[21] proposed VHO algorithm for network selection based on fuzzy logic, to improve the robustness of the algorithm.

6.3 Game Theory based Network Selection

Game theory is set of mathematical models designed to examine the decision process, estimate the outcome and select favorable approach. Game theory is classified into non-cooperative and cooperative game theory. Cooperative game theory studies the behavior of collaboratively working rational players while non-cooperative game theory studies the interaction results of competing players where players independently choose their strategy to maintain their service and minimize cost. The players in game theory are user and the network. Radhika et al.[22] presented VHO algorithm based on game theory network selection solution, taking QoS requirements and velocity of the mobile user along with available bandwidth and cost per bit as network selection parameters. The algorithm thus designed is able to reduce the handoff delay.

6.4 Utility Theory based Network Selection

Utility is the measure of user satisfaction. In a heterogeneous network, every candidate network available for handover has a utility function. The network providing greatest utility value is chosen for handover, which is obtained from the weighted sum of selection parameters. The network which provides maximum value and satisfies user demand is best for handover. Selection of utility function is challenging since the function is related to user preferences or user priorities for low cost, improved QoS and increased bandwidth. Chamodrakas et al.[23] proposed utility based network selection technique using Fuzzy TOPSIS for heterogeneous environment.

6.5 Combining Multiple Methods for Network Selection

Different network selection techniques can be combined to form new network selection method to get better performance. Silah et. al.[6] combined MADAM with Game Theory to develop new network selection method to avoid unnecessary handover. Table 1[6,9], provides a comparison of network selection techniques depending on the various criterion. The table depicts that every network selection technique has some advantages over other selection technique. So in order to overcome the limitations of one network selection technique, two or more techniques are combined to form a hybrid, so as to enhance the performance of the process.

7. Conclusion

This paper provides a brief review of various network selection parameters for handover in the heterogeneous environment along with various network selection algorithms. We have also discussed various network selection techniques and compared these network selection techniques on the various criterion. These network selection techniques are chosen depending on the designers requirements. These network selection techniques can be integrated in order to further improve the performance of the handover decision algorithm. We can design a VHO decision algorithm by integrating various network selection techniques for example game theory can be integrated with TOPSIS or Fuzzy integrated with TOPSIS and AHP or any game theory and neural networks for various networks like WiMAX, LTE, UMTS, CDMA etc. Vertical handover algorithm can also be designed by taking into consideration the user, for instance, an algorithm designed for a student may consider cost parameter as the main factor whereas an algorithm designed for an official or a businessman may consider higher throughput along with QoS. An adaptive algorithm can also be designed which can take users desired parameters for making the handover decision.

8 . References

1. Shidrokh G, Wan Haslina H, Mohammad HA, Ahmad S. A comparative review of vertical handover decision-making mechanisms in heterogeneous wireless networks. Indian Journal of Science and Technology. 2015 Sep; 8(23):1–20.
2. William JS, Jong-Moon C, Daeyoung L, Chaegwon L, Sungho C, Taesun Y. Improvements to Seamless Vertical Handover between Mobile WiMAX and 3GPP UTRAN through the Evolved Packet Core. IEEE Comm Magazines. 2009 Apr; 47(4):66–73.
3. Savitha K, Chandrasekar C. Comparision of Vertical Hand-

off Decision Scheme in Heterogeneous Wireless Network. ICCIC, IEEE International Conference. Coimbatore. 2010 Dec. p. 1–5.
4. Bhuvaneswari A, Dharma Prakash Raj EG. An overview of vertical handoff decision making algorithms. I. J. Computer Network and Information Security. 2012 Aug; 4(9):55–62.
5. Mahmood A, Hushairi Z, Al-Khalid O. Vertical Handover Decision Processes for Fourth Generation Heterogeneous Wireless Networks. Asian Journal of Applied Sciences. 2013 Dec; 1(5):229–35.
6. Yass KS, Ong HS, Rabha WI, Salman Y, Azlan I. An overview of intelligent selection and prediction method in heterogeneous wireless networks. J Cent South Univ. 2014 Aug 8; 21(8):3138–54.
7. Xiaohuan Y, Ahmet S, Sathya N. A survey of vertical handover decision algorithms in Fourth Generation heterogeneous wireless networks. Elsevier. 2010 Feb 10; 54:1848–63.
8. Zahran AH, Liang B, Saleh A. Signal threshold adaptation for vertical handoff in heterogeneous wireless networks. Mobile Network and Applications. 2006 Aug; 11(4):625–40.
9. Hoshang K, Avinash A. Review on Vertical Handover Techniques among Heterogeneous Network. Int J Advanced Networking and Applications. 2014; 5(5):2066–69.
10. Atiq A, Leila MB, Dominique G. Enabling Vertical Handover Decisions in Heterogeneous Wireless Networks. IEEE Communication. 2014; 16(2):776–811.
11. Meriem K, Brigitte K, Guy P. An overview of vertical handover decision strategies in heterogeneous wireless networks. Elsevier. 2008 Jun 25; 31(10):2607–20.
12. Cheng WL, Li Ming C, Meng CC, Yeali SS. A framework of handoffs in wireless overlay networks based on mobile IPv6. IEEE Journal on Selected Areas in Communications. 2005 Nov; 23(11):2118–28.
13. Nikhil P, Kiran P. Quality Dependent Vertical Handover Decision Algorithm for Fourth Generation (4G) Heterogeneous Wireless Networks. IJCEM. 2012 Mar; 15(2):33–6.
14. Chandralekha, Praffula KB. Optimization of Vertical Handover Performance parameters in Heterogeneous Wireless Networks. IJMER. 2011; 1(2):597–601.
15. Shelej RK. QOS Parameters based Vertical handoff Decision in Heterogeneous Network. IJARCCE. 2014 Jul; 3(7):7359–62.
16. Miyim AM, Mahamod I, Rosdiadee N. Vertical Handover Solutions Over LTE-Advanced Wireless Networks. WPC. 2014 Aug; 77(4):3051–79.
17. Sudesh P, Brahmjit S, Ashok A. Cross Layer Based Dynamic Handover Decision in Heterogeneous Wireless Networks. WPC. 2015 Jan 15; 82(3):1665–84.
18. Rajiv V, Niraj PS. GRA Based Network Selection in Heterogeneous Wireless Networks. WPC. 2013 Sep; 72(2):1437–52.
19. Gita M, Mahamod I, Rosdiadee N. Vertical Handover Decision Algorithm Using Multicriteria Metrics in Heterogeneous Wireless Network. Journal of Computer Networks and Communications. 2015; 2:1–8.
20. Manpreet SD, Amol P, Dinesh KA, Manika K, Rajeev S. Fuzzy Logic Based Handoff In Wireless Networks. Vehicular Technology Conference Proceedings, IEEE 51st. Tokyo, 2000; 3:2375–79.
21. Kaleem F, Mehbodniya A, Islam A, Yen KK, Adachi F. Dynamic Target Wireless Network Selection Technique Using Fuzzy Linguistic Variables. China communications. 2013 Jan; 10(1):1–16.
22. Radhika K, Venugopal R. Vertical handoff decision using game theory approach for multi-mode mobile terminals in next generation wireless networks. International Journal of Computer Applications. 2011 Dec; 36(11):31–7.
23. Ioannis C, Drakoulis M. A utility-based fuzzy TOPSIS method for energy efficient network selection in heterogeneous wireless networks. Elsevier. 2011 Jun; 11(4):3734–43.