Vertical Handover in Wireless Heterogeneous Networks

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***Abstract*—Handover is one of the enhancement mechanisms that plays a central role in heterogeneous wireless networks. Designing a handover algorithm for heterogeneous networks becomes an essential issue since it is responsible for providing better Quality of Service (QoS) and higher level of Quality of Experience (QoE) to users. Similarly, the proposed algorithms must fulfill the user's QoS requirements and must also provide seamless roaming across different networks. This paper presents an overview of some key issues pertaining to the design of Vertical Handover (VH) in 4G and 5G wireless networks. The VH measurements and decision mechanisms are studied in relation to network types and frequency used mechanisms. Moreover, the advantages and drawbacks of the existing works are investigated in detail and the challenging issues of the next generation of wireless networks are presented as well.**

***Index Terms*— Handover; Vertical Handover; 4G; 5G.**

I. Introduction

The recent global explosion in the number of internet users has expedited the development of different fixed and mobile broadband technologies to provide adequate support for ubiquitous coverage, high speed data streaming of multimedia contents, and personalized services with unhampered QoS. Though the existing Wireless Local Area Network (WLAN) and the third generation (3G) technologies had successfully provided broadband access over the last couple of years, they have their specific weaknesses that inhibited their full potentials. For instance, WLANs suffered from short radio coverage range and restricted capacity. On the other hand, the 3G systems was constrained by low bandwidth and cost of infrastructural procurement. The culmination of the recent IEEE 802.16-based WiMAX family of 802.16a, 16d and 16e standards for Wireless Metropolitan Area Networks has filled the gap between the LAN and WAN technologies. The WiMAX technology offers true broadband access solution which include high bandwidth, low cost internet services and extended coverage areas. This has resulted in its rapidly adoption as the leading broadband access technology and of course as a formidable candidate in 4G networks. While the IEEE 802.16d based on OFDM [1] technology (commonly termed Mobile WiMAX) provides fixed broadband access within a metropolitan area, the new mobile air interface specified in the IEEE 802.16e, which is referred to as the mobile WiMAX, has successfully addressed the issues of higher data rates and spectral efficiency for full fledged mobile broadband access. WiMAX Base Station (BS) can support both fixed and mobile broadband wireless access.

This paper focuses mainly on Vertical Handover (VH) which is one of the most important aspect of handover mechanisms in heterogeneous wireless networks. This study offers a variety of choices when roaming across different networks showing the cost, user preferences and all QoS provided by each mechanism. This can be achieved by evaluating and comparing the performances of the available networks in terms of network type and frequency used.

The rest of this paper is organized as follows. The motivation of this study is explained in section 2. The type of network in section 3 and frequency used mechanisms in section4. Section 5 presents the conclusion and draws the challenging issues of the future wireless networks.

Over the past decade, the mobile wireless traffic has experienced an unprecedented upsurge as a result of vast applications of mobile devices coupled with the recent application of social networks, e-commerce, traditional real-time voice communication and entertainment, resulting in exponentially growing in the number of electronic devices and data traffic. However, it is generally believed that the 4G mobile networks will not be able to meet the requirements of the trending scenario that will shape the mobile networks by 2020. Since the existing wireless networks are approaching the critical limits, the capacity of wireless communication systems can be further improved through innovation and by optimizing the network schemes and infrastructures to accommodate the next generation multimedia wireless traffic requirements. Seamless communication can be achieved by integrating short rang wireless networks (i.e. WLAN) and wide rang wireless networks (i.e. LTE, LTE-A, WiMAX). The seamless and systematic handover from one type of access technology to another, known as vertical handoff, is required, though this remains a challenging problem.

In order to achieve a total network convergence, the next generation all-IP networks must be designed to enable all the component parts to function separately and independent of any particular access network technology. This will help the service providers to deliver timely and value-added network services to their customers without worrying about the type of networks or the terminal capabilities. Continuity of service in heterogeneous networks is driven by all-IP based applications that requires increase bandwidth and throughput, and reduced packet loss. Mobility management with Quality of Service (QoS) support is a critical issue in Next Generation Networks (NGNs) as it enables users to move between wireless data and cellular networks of different underlying technologies without encountering service disruptions. This process is generally known as a handover. The handover, which occurs between two networks using the same technology, is called horizontal handover, for instant, WiMAX-to-WiMAX, LTE-to-LTE handovers, etc. [2]. Whereas, a handover that occurs between two networks of different technologies is called vertical handover, for instant, from LTE to WiMAX or vice versa [3]. The research community has generally categorized these process as horizontal, vertical and diagonal handovers. Usually, each type of network can be recognized by the type of architecture or technology they use as expressed in Fig. 1. We will discuss the main technical aspects and the core handover decision metrics normally used by both horizontal and vertical handovers in their handover decision making.

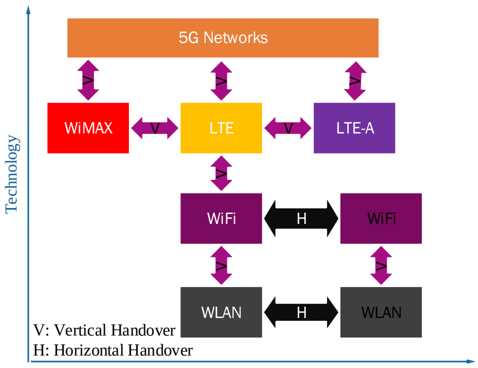

Figure 1: The handover types over heterogeneous networks.

II. MOTIVATION

In principle, every active mobile station in an open wireless environment is linked with at least one network access point, also known as a base station. The area serviced by each base station is referred to as a cell. The capacity, profile and type of every cell depend on the base station's capability such as the transmission and receiving power. Usually, cells of the same network type overlap with each other in a way that any mobile device is constantly within the coverage area of multiple base stations. On the other hand, the heterogeneous network's slots are overlaid within each other. Hence, the main focus of every mobile host is to make a periodic decision to determine which base station of which network will reliably perform the signal transmissions and the handoff to and from a particular host. We classify handoffs based on several factor. In this paper, their terms handoff and handover are used interchangeably, we have classified the handover approaches into two main types as follows:

i. Based on the network types, i.e., it could be Horizontal handover (HHO) or Vertical handover (VHO).
ii. Based on the frequencies engaged, i.e., it could be intra-frequency handover and inter-frequency handover.

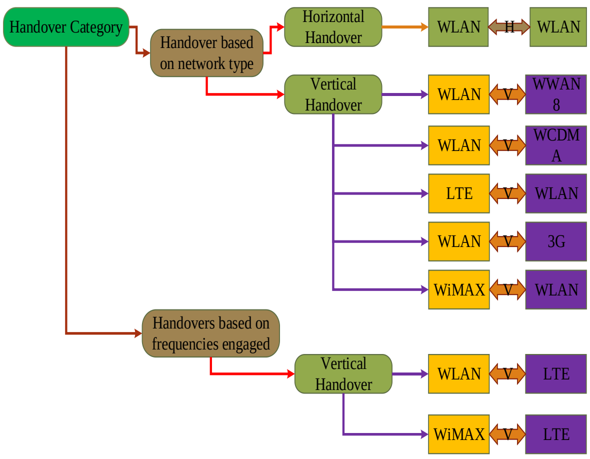

Figure 2: Main Handover Types from Related Issues

The enrichment and broadness of this concept complicates the discussion on general aspects of this topic. This is the reason we have summarized this wide range of topics in Fig. 2, for simplicity and without loss of generality.

III. HANDOVERS BASED ON NETWORK TYPE

Many algorithms have been proposed for vertical handover mechanism based on a number of criteria, namely, the Received Signal Strength (RSS), available bandwidth, connection cost, Signal to Interference Noise Ratio (SINR), mobile station's velocity, handover delay, battery consumption and Quality of Service (QoS) guarantee. For instance, the mobile device checks the surrounding area and then handoff to the network which can guarantees the highest bandwidth and the lowest delay [4]. Based on this approach, evaluating two criteria (delay, bandwidth) will not be enough and will increase the false handover prediction ratio. Whereas [5] offers a handover technique with less complex algorithm while maintaining a decision robustness for vertical handover in heterogeneous networks. In addition, this approach relied on an assessment of the criteria of the multi attribute retrieved from the neighboring base stations to determine the potential target base station based on the received signal strength, available bandwidth, cost of the service, energy/power consumption and expected time of staying in practical network. To reduce the number of unnecessary handovers decision parameters described by the authors in [6], a handover decision scheme that impends the amount of time spent by a mobile node in a WLAN was proposed. This mechanism is largely dependent on the assessment and calculation of the threshold of the traveling time of users within a WLAN. This scheme handover to a WLAN only if the user's estimated travel time in that specific network is greater than the predefined threshold time. If a handover to a cellular network is desirable, two conditions must be satisfied, (i) RSS of the WLAN is constantly unacceptable and (ii) mobile station has reached the cell edge due to its high speed and a handover should be started. This organization reduces redundancy and the ratio of handover failures. However, arrangement increases the handover delays as the authors use sampling on average of RSS that is a time-consuming process. In [7], Cheng et al. proposed a QoS based vertical handover and user decision scheme based on available bandwidth to determine the handover direction from a WLAN to WWAN [8] and inverse. In a WLAN network, the proposed scheme enables the base station to initiate a handover process by comparing the RSS-level of the mobile node with the predefined thresholds. If the mobile node is found in the idle position, then the base station will handover the mobile to the desired and targeted access network else an offer of other user's preferences such as application type is considered for the handover. For delay-sensitive applications, handover process is initiated only if the current serving network is not suitable in terms of QoS to support the applications. In the same way as WWAN offers higher bandwidth than WLAN so handover is performed for delay-tolerant applications. The proposed scheme offers higher throughput and lower latency handover as a result of using the available bandwidth and application type as main handover criteria.

Authors in [5] observe that measuring the bandwidth in cellular networks is a complex task often resulting in high blocking rate for upcoming handover applications due to sin idle state. Bazzi [8] proposes a new scheme named as the softer vertical handover algorithm for heterogeneous wireless systems to support the discussion. This strategy takes into consideration the available bandwidth, network conditions of user mobility, and application type. The proposed definition focused mainly on the best effort service into the UMTS networks using different mobility scenarios. An analytical model also proposes a scheme for multi-mode terminals and mobility lists that measure the handover of the connected terminals for the best network selection. The proposed algorithm improves the overall system throughput of the so called softer handover, with little attention to other aspects of the QoS such as packet loss, handover delay, etc. Using a very similar technique, the authors in [9] present a bandwidth based handover decision scheme between WLAN and WCDMA. In this scenario when a handover is triggered, the network that shows larger SINR values is selected; Usually, SINR oriented handovers provide users with higher overall throughput than the ones base on RSS because the SINR is directly dependent on throughput. This is the reason that the proposed schemed can perform the task of load balancing in between two different networks in a heterogeneous network. However, the issue of excessive handovers may arise as a result of the variation in the SINR can lead to a ping-pong effect. Authors in [10] also presents a SINR-based approach using the back haul bandwidth and available data rate as the main handover decision metrics and for resource allocation optimization in the observed network. However, them propose scheme was vulnerable to latency induction due to improper network selection. Both [11] and [12] present the state of the LTE-WLAN “interworking” technologies and gave an overview of the network architecture. The author in [9], outlined some of the “interworking” architecture issues around the network discovery and selection, safety and mobility and gave some recommendations. However, there is no realistic solution for any of these issues.

In [13] the authors propose a novel handover technique for reduction of handover failure probability and the elimination of redundancy in handover process. This has resulted in the amalgamation of three different techniques: (1) signal trend detection; it indicates the need for upward or downward vertical handovers. For example, when a mobile station enters into a new WLAN network and the RSS is increasing with the new network than with the current network then the handover process will be initiated to the nearest access point in the new WLAN network. (2) Adaptive threshold setting; it is used as a trigger by the mobile station to detect variations in the signal strength and adjusts speed and channel parameters as well as to estimates the possible handover delay. (3) A Dwell Timer for fast moving terminals; it is beneficial at high speeds in a mobile station case as it helps the mobile station to clearly determine the appropriate time to handover or stay connecting to the current base station based. This timer enhances the handover duration and reduces the waiting time. This scheme has resulted in a significant handover failure reduction and elimination of ping-pong effect but some excess amount of signaling is observed which is the issue of packet loss.

Emmelmenn et al. [14] proposes a design of a seamless handover technique for high mobility mobile stations using dynamic dwell timer. This mechanism focuses on the IEEE 802.11 networks and aims to delay the handover for the transfer of data by telemetry services. Two proposed cellular coverage areas, namely, micro and macro cellular constitutes the fundamental proposed model, operating on the same frequency. The authors report shows that their proposed method reduces the handover latency since the conventional handover phases were avoided, rather the proposed scheme uses a centralized Radio Control Unit (RCU) that adjusts the dwell timer according to the coverage area to speed up the process, giving that RCU already is in possession of all the handover related information. It is noteworthy that RCU has all the handover related information. As a mobile user enters into a macro cell the RCU immediately estimates its handover and transmits it to potentially targeted neighboring RCUs to which the mobile station is likely to handover. This reduces handover delay because of early binding and packet loss due to advance packet buffering.

According to the foregoing method, Chang et al. [15], [16] considered a cross layer approach based on regression polynomial predictive models RSS scheme with the Markov Decision-making Process (MDP) based network selection. The proposed scheme consists of two phases, namely, the decision phase, in which the measure predictive models of RSS with a value of hysteresis is carried out, and the network selection phase, in which the optimal goal is to determine the intended network to which to handover. A step backwards polynomial based methodology will be used in the first phase to approximate the movement of a mobile station within the wireless network. The second phase determines the possible candidates network with the lowest access cost and relies on the help of MDP for an optimum network selection for handover. The proposed scheme achieves load balancing and eliminates unnecessary handover procedures in the targeted networks while making use of the higher link and occupying it for longer time to reduce redundant protocols during the busy period of the wireless routes. Alternative solution in [17] is based on RSS which deals with the adaptation of QoS parameters according to the network traffic conditions in a given heterogeneous networks.

For a reliable mobility and end-to-end packet guarantees in heterogeneous environment, Kim et al. [18] proposed a handoveral decision scheme base on mesh Network. They have the user movement in mind, RSS and user preferences as core mobility decision parameters. The authors have considered two scenarios for the possible implementation between WLAN and WiMAX Networks i.e., moving into and out of the mesh overlay area. Each mesh router has two domains, one for WLAN and the other for WiMAX, When the mobile station roams out of the overlay area, the RSS from the access point is used as the main metric in the mobile node to initiate a vertical handover process. Similarly, when the mobile station roams into the WLAN network, the mobile station may decide whether to maintain connection with the WiMAX network or to initiate a handover to WLAN based on the WLAN network condition, the user preference and the current traffic of the target network. This scheme reduces the packet delivery delay and handover delay but network resource intensive as users switch between the two domains every now and then in ping-pong fashion.

Since the future wireless network promises to address the explosive growing demand of bandwidth hungry media-rich applications such as voice, video services as well as access to unpresented Machine Type

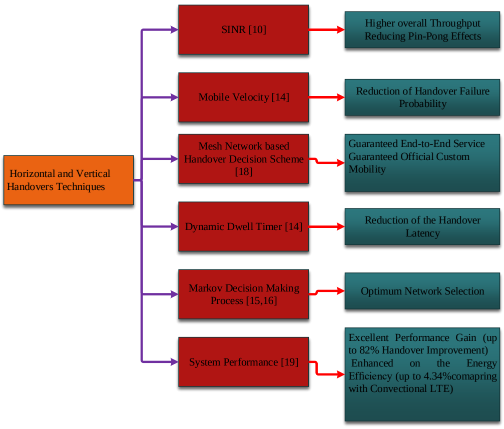

Figure 3: Horizontal and Vertical Handovers Techniques

Communication (MTC), the increasing number of small cells will be densely deployed in hot spots, which will result in Ultra-Dense Networks (UDN). As a main solution to future network issues, UDN is a step further towards a self-configuring, self-optimizing and low-cost network with the ability of high-frequent measurement, intolerable handover failure, and huge power consumption in both the terminal and access network. Thus, the mobility issue in ultra-dense scenario is such a critical problem in the next generation wireless systems such as the 5G networks. To manage this problem, the User plane has to be separated from Control plane as to infuse more flexibility and better service control mechanism. This has led the authors in [19] to focus on the redesign of the 5G network towards a macro-assisted data-only carrier system, with the intention to resolving the issues of massive access requirements, high probability of handover failure, low probability of small cell sleeping and huge-interference; where the key parameters in handover triggering are evaluated and analyzed in greater detail and the relationship between system performance and Ultra-Dense Network is derived. In addition, due to performance variation between the macro-macro handover and macro-small cell handover, a mobility management scheme is proposed to further enhance the mobility performance by optimizing the system parameters. The simulation results show that the gain of the system's handover failure improved by 53.6% by reconfiguring and optimizing the handover parameters in data carrier network. Moreover, the data carrier network has an excellent performance in Ultra-Dense Network with 82% handover improvement and 4.34% energy efficiency gain compared with the current LTE network, which may not be a suitable mobility strategy for future 5G networks. The drawback of this study is that the authors did not consider the mobility issue which could have address several key challenges that have to do with QoE for end users in 5G networks.

In [20], the authors propose an efficient selection algorithm for radio access technology that effectively manages the radio access technology handover process based on most suitable network that offers better system performance. The proposed scheme reduces the ping-pong effects and uses of a new system parameter named Reference Base Station Efficiency (RBSE) as the decision metric to trigger a handover process, which takes into consideration metrics related to both the user and the system such as the users' spectral efficiency, the base station traffic load and the BS transmit power. Simulation results indicate that the proposed selection mechanism considerably reduces the handover delay and the chances of handover failure as well as improves the overall system performance such as throughput and spectral efficiency. However, this study has a number of issues, firstly, the less management of the radio spectrum is obvious, secondly, the study needs to extend to cover not only the long shadowing (long shadowing is 8 dB). As shown below, selected handover techniques are summarized in Fig.3.

IV. HANDOVERS BASED ON FREQUENCIES

In [21], [22], the proposed approaches for WLAN-LTE interworking architecture is support interoperability in 4G networks. A hybrid router designed a with dual radio that can provide seamless handover between LTE and WLAN. The advantages of this architecture include simplicity as the need for modifying the existing WLAN functions was completely eliminated in this architecture. The simulation results offer the platform to verify the router architecture by making a performance comparison between the heterogeneous network (the cell containing the hybrid router and WLAN device) and the pure LTE (eNodeB and LTE user equipment). Services can be badly degrading when the network load is increased beyond the capacity of the network. Most real-time applications including multimedia traffic cannot cope with network degradation.

A new combination of handover approach was proposed based on the prediction of the base station and technology selection approach along with FRR3 technique [23], [24]. A dual thresholds modified multi criteria algorithm that permit the user to select the target technology (WiMAX, LTE) based on its preferences, such as the available bandwidth, received signal strength, connection cost and delay. The simulation results show an increases in efficiency of target network selection and a decrease in handover delay by approximately 15%. The authors suggested the inclusion of a general and extensible Media Access Control Layer (MAC) for the networks to increase the smooth transmission and allows the mobile station to receive data among different BSs of different network types. This system is expected to have less delay, low cost and better performance since no extra equipment is required for the mobile station to smoothly connect with different base stations and technologies.

In [25], the authors discussed implementation issues related to different network functions and outlined a number of tradeoffs v between the proposed architecture and the conventional cellular networks. Architectural ossification is a limiting performance obstacle for cellular networks. The architecture ossification syndrome can be overcome by cognitive and flexible network operation by decoupling data/control plane and CRAN. In this case, the cellular networks can be transform from a deterministic infrastructure into a flexible, cognitive, and context aware architecture. Such an innovation promises to improve network performance of the envisioned 5G network.

Finally, the unique handover approaches have been illustrated in terms of advantages and dis-advantages for each one, so the researchers can treat this table as reference point for the most appropriate approach for their handover demands.

V. CONCLUSION

This paper presents a thorough investigation on the existing Vertical Handover (VH) algorithms. VH in heterogeneous wireless networks provides users with seamless roaming among networks choosing the appropriate network which satisfies their QoS requirements. The investigation is based on the network type and frequency used mechanisms, which are considered as crucially important parameters in VH handover process. Moreover, the advantages and drawbacks of the recent works have been discussed. Also, some key handover challenges and design issues for the next generation of wireless networks have been studied.

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