A Survey on MIH vs. ANDSF: Who Will Lead the Seamless Vertical Handover through Heterogeneous Networks?

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Abstract

Ubiquitous networks allow the co-existence of different wireless technologies (3GPP and non-3GPP) such as GSM (Global System for Mobile Communication), Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX), Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE). One of the challenging issues in Next Generation Wireless Systems (NGWS) is seamless Vertical Handover (VHO) during Mobile User (MU) mobility between these technologies therefore, the telecommunication operators will be required to develop a strategy for interoperability of these different types of existing networks to get the best connection anywhere anytime. In this survey, we overview two mechanisms which were proposed independently by IEEE and 3GPP, namely; Media Independent Handover (MIH) and Access Network Discovery and Selection Function (ANDSF), respectively that enable seamless VHO between the different types of technologies (3GPP and non-3GPP). We survey the VHO approaches proposed in the literature and classify them into three main categories based on these mechanisms for which we present their objectives, issues and evaluate their complexity of implementation. Finally, a conclusion about who will lead RATs through VHO is given.

Keywords: *Vertical Handover (VHO), Media Independent Handover (MIH), Access Network Discovery and Selection Function (ANDSF), Heterogeneous Wireless Networks*

1. Introduction

With the advancement of wireless communication and computer technologies, mobile communication has been providing more versatile, portable and affordable networks services than ever. Therefore, the number of users of mobile communication networks has increased rapidly as an example; it has been reported that "today, there are billions of mobile phone subscribers, close to five billion people with access to television and tens of millions of new internet users every year" [1] and there is a growing demand for services over broadband wireless networks due to diversity of services which can't be provided with a single wireless network anywhere anytime [2-6]. This fact means that heterogeneous environment of wireless systems such as GSM (Global System for Mobile Communication), Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX), Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE) will coexist providing Mobile Users (MUs) with roaming capability across different networks. To fulfill these requirements of seamless Vertical Handover (VHO) two mechanisms were proposed independently by IEEE and 3GPP, namely; Media Independent Handover (MIH) and Access Network Discovery and Selection Function (ANDSF), respectively [7]. Each of them enables a seamless VHO between the different types of technologies (3GPP and non-3GPP) such as GSM, UMTS, Wi-Fi, WiMAX and LTE, this is shown in Figure 1.

In this survey, we classify the VHO approaches proposed in the literature into three main categories based on these mechanisms for which we present their objectives, issues and evaluate their complexity of implementation.

The rest of the survey is organized as follows: In Section 2, we review the VHO procedure. In Section 3, we present MIH and ANDSF mechanisms with their components and benefits. In Section 4, we classify the VHO approaches proposed in the literature based on the mechanisms in Section 3. In Section 5, a comparison of the approaches is presented. Finally, our conclusion is given in Section 6.

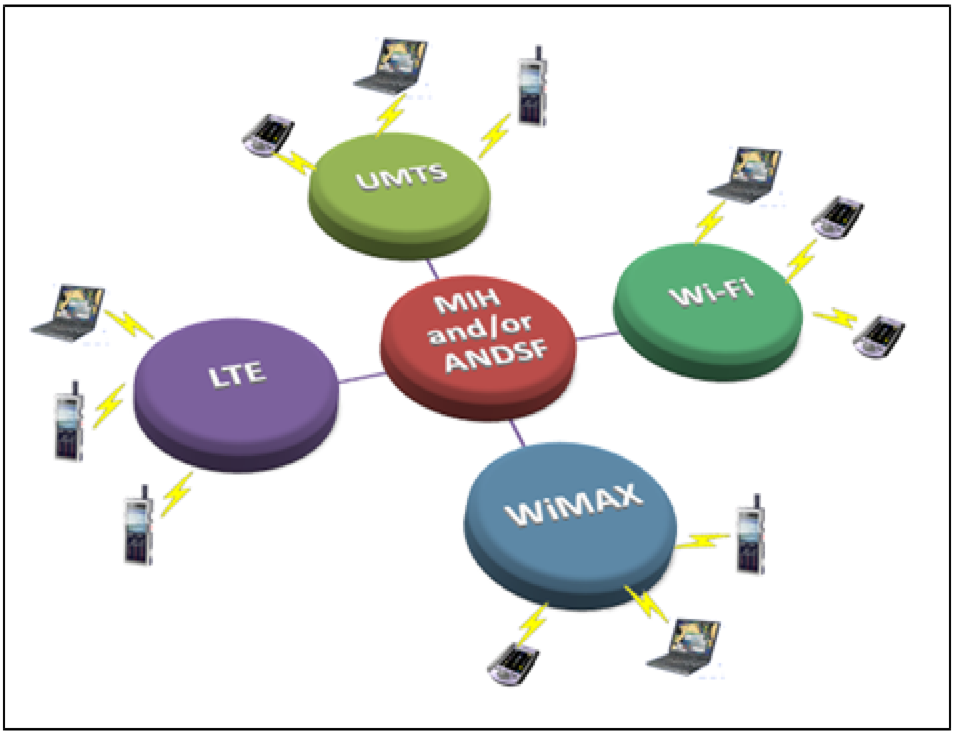

Figure 1. Various Radio Access Technologies (RATs) Integration Supported by MIH/ANDSF

2. Vertical Handover Procedure

The mechanism which allows MUs to continue their ongoing sessions when moving within the same Radio Access Technology (RAT) coverage areas or traversing different RATs is named Horizontal Handover (HHO) and VHO, respectively. In the literature, a VHO procedure has been divided into three phases: Collecting Information, Decision and Execution [8-15] as described below.

Handover Collecting Information

In this phase, all the required information for VHO decision is gathered some related to the user preferences (such as cost, security), network (such as latency, coverage) and terminal (such as battery, velocity).

Handover Decision

In this phase, select the best RAT based on aforementioned information and informs the handover execution about that.

Handover Execution

In this phase, the active session for MU will be maintained and continued on the new RAT, after that the resources of the old RAT is eventually released.

The key of VHO management procedure is the Access Network Selection (ANS) in the decision phase. There are many proposals introduced by researchers about ANS, *e.g.*, [8, 9]; however, the proposed ANS schemes lack unity while a number of issues still need to be resolved such as the goals discrepancy between user centric and network centric, where in user centric scheme the goal is how to get best connection anywhere anytime regardless of network operation complexities associated with this which matters from operator's perspective [16].

3. MIH & ANDSF Mechanisms

One challenge of wireless networks integration is the ubiquitous wireless access abilities which provide the seamless handover for any moving device in the heterogeneous networks. This challenge is important as MUs are becoming increasingly demanding for services regardless of the technological complexities associated with it. To fulfill these requirements of seamless VHO two mechanisms were proposed independently by IEEE and 3GPP, namely; MIH and ANDSF, respectively. In this section, we present these mechanisms which have the same goal of enabling a seamless VHO between the different types of technologies (3GPP and non-3GPP), Also we show their components and benefits.

3.1. Media Independent Handover (MIH)

The IEEE group proposed IEEE 802.21 standard Media Independent Handover (MIH) to provide a seamless VHO between different RATs [17-24]. IEEE 802.21 defines two entities: first; Point of Service (PoS) which is responsible to start communication between the network and the MU under MIH and the second; Point of Attachment (PoA) which is the RAT access point. Also MIH provides three main services: Media Independent Event Service (MIES), Media Independent Command Service (MICS) and Media Independent Information Service (MIIS) [25], such that MIH relies on the presence of mobility management protocols, *e.g.*, Mobile Internet Protocol (MIP) and Session Initiation Protocol (SIP), this is shown in Figure 2.

Media Independent Event Service (MIES)

It is responsible to report the events after detecting, *e.g.*, link up on the connection (established), link down (broken), link going down (breakdown imminent), *etc.*, [26].

Media Independent Information Service (MIIS)

It is responsible for collecting all information required to identify the need for handover and provide them to MUs, *e.g.*, available networks, capabilities, cost, *etc.*, [26], this is shown in Figure 3.

Media Independent Command Service (MICS)

It is responsible to issue the commands based on the information which is gathered by MIIS and MIES, *e.g.*, MIH handover initiate, MIH handover prepare, *etc.*, [26].

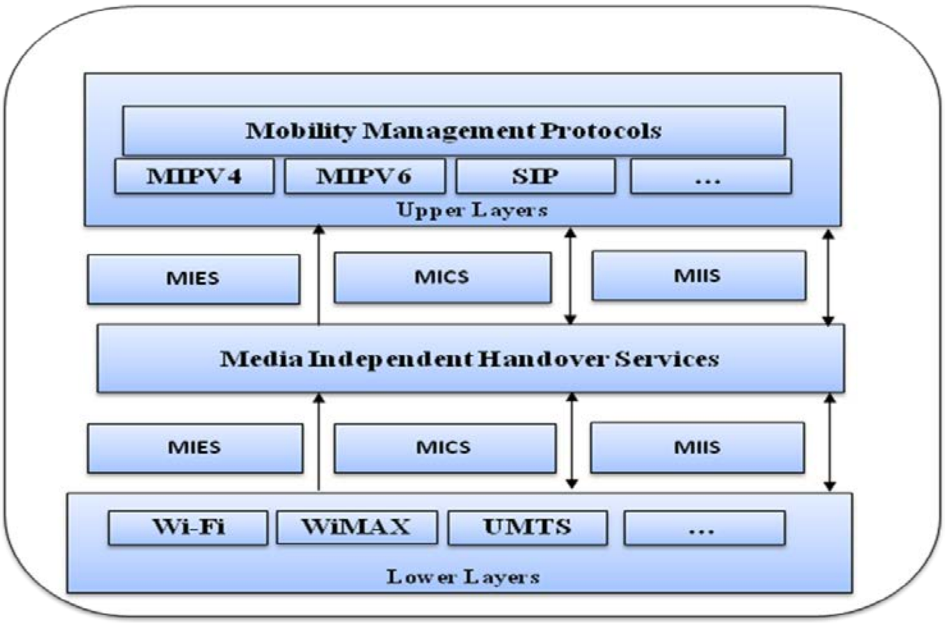

Figure 2. Media Independent Handover (MIH) [26]

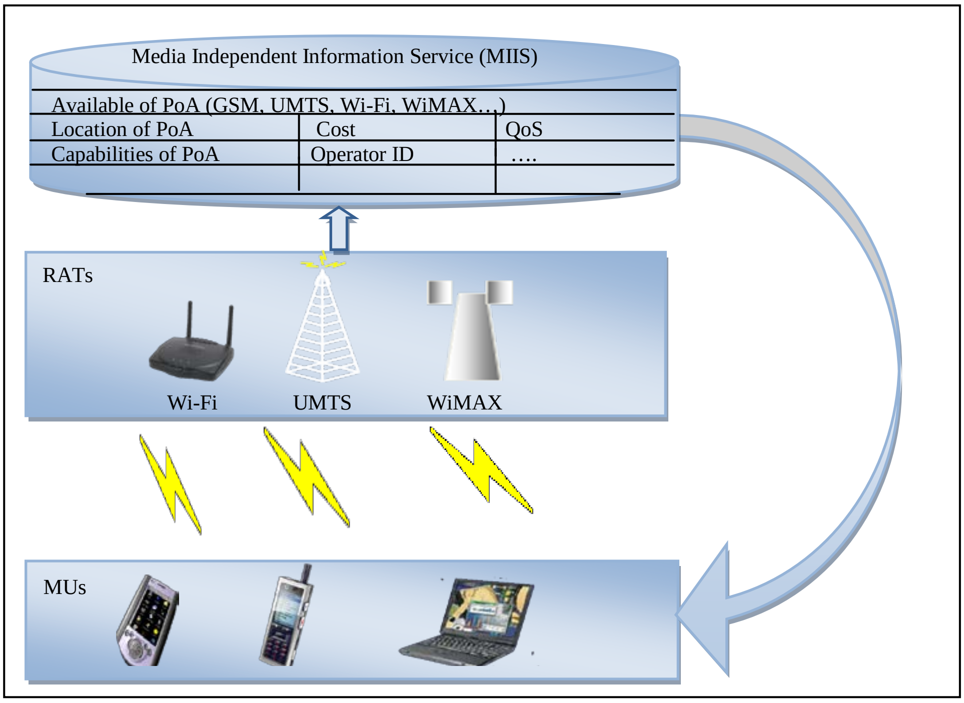

Figure 3. Media Independent Information Service (MIIS) Passing Information about Radio Access Technologies (RATs) to Mobile User (MUs)

3.2. Access Network Discovery & Selection Function (ANDSF)

The 3GPP group proposed ANDSF mechanism to provide seamless VHO between different RATs which belong to 3GPP and non-3GPP. In this mechanism, there is no need for the measurements reports between the different RATs and hence, no need to the modification on legacy radio systems. The ANDSF also works as a store of RATs information such as information about neighbor cells, operator’s policies and preferences, *etc.*, [27] that is queried by MU to make handover decision, this is shown in Figure 4.

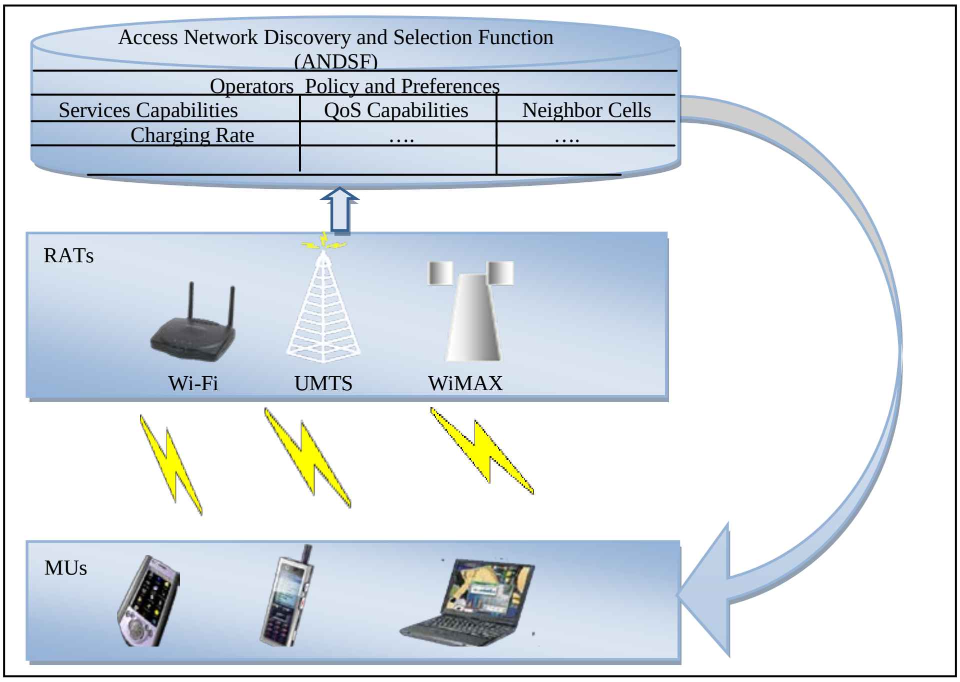

Figure 4. Access Network Discovery and Selection Function (ANDSF) Passing Information about Radio Access Technologies (RATs) to Mobile Users (MUs)

As shown in Figure 3 and Figure 4, each of MIH and ANDSF mechanisms are responsible for collecting all information required to identify if a handover is needed and perform it successfully. The benefits of these mechanisms include: a) sufficient information is provided to MU (*e.g.*, available networks, locations, capabilities, cost.etc) b) the MU would need a single receiver for the ongoing session while there is no need for a second receiver for searching the availability of networks which results in low battery consumption for MU c) no need to upgrade legacy cells (2G/3G) to broadcast information about 4G neighbors cells such as WiMAX and LTE which implies no additional cost.

4. VHO Approaches

In this section, we classify the VHO approaches proposed in the literature into three main categories based on MIH and ANDSF mechanisms in order to present their objectives, issues and evaluate their complexity of implementation. We identify the three main categories as: ANDSF based VHO approaches, MIH based VHO approaches and MIH and ANDSF combination based VHO approaches.

4.1. ANDSF Category

The ANDSF based VHO approaches includes new additional entities proposed in [28, 29] in order to provide seamless VHO integrated with ANDSF mechanism taking into account WiMAX and 3GPP scenario.

In [28], new logical element proposed named Forward Authentication Function (FAF) which was collocated with the ANDSF and located in the target network. The FAF plays the role of target RAT to perform its functionalities, *e.g.*, if the MU moves toward 3GPP E-UTRAN, the FAF emulates Node-B while if the MU moves toward WiMAX, the FAF emulates WiMAX Base Station (BS). The FAF has two main goals: first; to enable the transmission from WiMAX to 3GPP (Authentication). The second is to avoid direct link between 3GPP and WiMAX, *i.e.*, “avoid the WiMAX access scheduling measurement opportunities to the MU in order to measure neighbor 3GPP sites" [28]. Nevertheless, the authors in [28] failed to tackle two vital aspects in the VHO procedure: first; the source network was not informed by the MU about its movement to the target network which resulted in packet losses. Second; it lacked releasing procedure for the resources of the network; however, no performance evaluation or validation provided about their work. In [29], the Data Forwarding Function (DFF) logical entity located in source network was presented to solve the problems that were raised in [28] such that simulation experiment considering video streams showed improvements in packet loss compared to the proposed [28].

4.2. MIH Category

This category is primarily based on MIH mechanism to provide seamless VHO between different types of RATs scenarios [2, 3, 17, 18, 25, 30 -36].

In [2], the authors proposed an approach called tunneling mechanism to guarantee the continuity of service during a communication session in heterogeneous wireless technologies between Wi-Fi, WiMAX and 3G scenarios. The Radio Signal Strength (RSS), link layer throughput, link quality and contention rate parameters were considered to make VHO decision. Empirical work real environment considering streaming traffic was used to evaluate their work. In [3], new approach was proposed that was based on user profile, the network information services and scoring mechanism to select the best RAT between Wi-Fi and UMTS scenario. The RSS parameter was considered to make VHO decision while Constant Bit Rate (CBR) traffic was used to evaluate their work. The results showed an improved QoS. In [17], the authors presented the integration process of MIH between Wi-Fi, WiMAX and UMTS scenarios in order to provide seamless VHO with low latency and zero packet loss. The RSS parameter was considered to make VHO decision before source PoA link was disconnected due to fading RSS. Latency was divided into two phases: Handover Preparation Latency (HPL) and Handover Execution Latency (HEL). The HPL was the time interval in which the MU queried the MIIS about available RATs for handover, the HEL was the time since the MU sent/received authentication messages to it's the target network (new PoA) until the reception of the first packet on the target network. Simulation experiment considering two types of traffic IPTV and VoIP was used to evaluate their work. In [18], five principles were proposed to support seamless VHO mobility to satisfy requirements of applications between WiMAX and GPRS scenario. The RSS parameter was considered to make the VHO decision. However, no performance evaluation or validation provided about their work. In [25], the authors presented evaluations for VHO process between Wi-Fi, WiMAX and UMTS scenarios. The RSS and network capacity parameters were considered to make VHO decision. The CBR traffic was used in order to evaluate VHO latency, throughput and packet loss by simulation experiment. In [30], middleware architecture was proposed in order to continue ongoing multimedia sessions that could be transferred seamlessly and securely between Wi-Fi to UMTS and UMTS to Wi-Fi scenarios. The Signal-to-Noise Ratio (SNR) parameter was considered to make VHO decision. The handover latency represented the time elapsed between when a decision to handover was executed until the traffic was redirected to the new target network. Video traffic was used in order to evaluate the VHO latency, throughput and perceived video quality by simulation experiment. The results showed that when a VHO was based on the proposed MIH, the handover latency was reduced while the perceived video quality was improved compared to a non-MIH. In [31], new approach was proposed to select the best RAT with QoS between Wi-Fi and WiMAX scenario. The RSS parameter was considered to make VHO decision. Simulation experiments considering CBR traffic showed good results on handover performance. In [32], the authors presented fast handover approach for heterogeneous networks that utilized MIH in Proxy Mobile IPv6 (PMIPv6) to support heterogeneous networks performance between Wi-Fi and WiMAX scenario taking into account RSS to make VHO decision. The analytical modeling results showed that the proposed approach reduced latency time by 26% and packet losses by 90% compared to the original PMIPv6 handover. In [33], new approach was proposed to support seamless mobility while reducing handover latency and call dropping probability between Wi-Fi and WiMAX scenario. The RSS, MU's velocity, neighbor discovery unit and handover signaling latency were parameters considered to make VHO decision; however, no performance evaluation or validation provided about the work. In [34], the authors presented MIH vertical handover approach in order to provide seamless VHO with low latency between Wi-Fi and WiMAX scenario, also presented MIH Layer 2 (MIH L2) trigger handover decision algorithm based on RSS. Analytical modeling and simulation experiment considering FTP traffic showed that latency was considerably reduced compared with MIPv4 through the pre-registration process using the L2 trigger. In [35], a new approach that enabled seamless VHO handover in wireless heterogeneous environments was presented. The proposed approach combined the MIPv6 mobility management protocol, the MIH, and a mobility control entity to perform VHO with minimal packet loss and latency between Wi-Fi and 3G scenario taking into account RSS parameter to make VHO decision. The authors divided latency into two periods: Handover Latency (HL) and Handover Execution Latency (HEL). The HL was the time interval in which the MU did not receive any packets as a result of handover until the first packet received by target network; the HEL was the time since the MU sent a Binding Update (BU) to its Home Agent (HA) until the reception of the first packet on the new target network. Testbed experiment considering two types of traffic video and VoIP showed significant improvement on handover performance. In [36], the authors presented analytical modeling of the VHO latencies of PMIPv6, Proxy-Fast MIPv6 (PFMIPv6), and IEEE 802.21-enabled PMIPv6 between Wi-Fi and WiMAX scenario [37], [38] taking into account RSS to make VHO decision. The results showed that the handover latency of PMIPv6 could be reduced with the IEEE 802.21.

In all studies above where MIH has been implemented "no handover decision is made within IEEE 802.21" [7], as "implementation of the decision algorithm is out of the scope of IEEE 802.21" [18], and "the actual algorithms to be implemented are left to the designers" [39], besides, there is inconsistency in IEEE 802.21operation; hence, it needs some improvements [2].

4.3. MIH and ANDSF Combination Category

This category includes combination of MIH and ANDSF mechanisms in order to improve VHO process taking into account WIMAX and LTE scenario.

In [7], combination between MIH and ANDSF was proposed; hence, there was no need for FAF and DFF to be exist as in [29], beside, the MU obtained operator's policies from ANDSF which has the role of selecting the target network. However, in [7] no evaluations or validations have been provided for the non exhaustive work which was complex as a result of combining between the two mechanisms.

5. Comparison of the Approaches

In section 4, we have discussed fifteen recent VHO studies found in the literature [2, 3, 7, 17, 18, 25, 28-36] and classified them into three main categories based on their implementation of MIH and ANDSF mechanisms. In order to provide comparison of the three main categories, we summarize their features on seven aspects: Main objective, input parameters for VHO decision, additional entity, complexity, traffic, evaluation method and applicable area, as shown in Table 1.

For the "Main Objective" criteria, the MIH category's performance considers many vital parameters to provide seamless VHO, *e.g.*, packet loss, latency, call dropping, *etc.*, while the (MIH and ANDSF combination category) and (ANDSF category) are content with packet loss and best RAT.

In terms of "Input Parameters" for VHO decision, the MIH category presents approaches makes VHO decision based on various parameters such as RSS, link layer throughput, link quality, *etc.*, while the other categories do not mention the input parameters for VHO decision.

For “Complexity“ and “Additional Entity”, the MIH and ANDSF combination category scores high due to the combination of MIH and ANDSF mechanisms. This followed by the ANDSF category with medium complexity as new logical entities are required (FAF and/or DFF), while MIH category has low complexity as it does not require additional requirements.

In terms of “Evaluation Methods” and “Traffic”, in this survey, there are various evaluation methods: Empirical work real environment, testbed, simulation experiment and analytical modeling. We notice that the MIH category evaluation method is mostly practical, it includes one empirical work and it considers various types of traffic (IPTV, VoIP, CBR, *etc*.,). The ANDSF category is content with one work provides simulation using video traffic, while the MIH and ANDSF combination category have not considered these criteria on their work.

Finally, the “Application Area” for ANDSF category and the MIH and ANDSF combination category is between WiMAX-3GPP and WiMAX-LTE scenarios, respectively, while the MIH category is applied to a variety of RATs combinations.

From the above discussion we conclude that any VHO procedure within MIH and/or ANDSF should take one of the following forms:

VHO Procedure1; includes ANDSF, FAF and a VHO algorithm.

VHO Procedure2; includes ANDSF, FAF, DFF and a VHO algorithm.

VHO Procedure3; includes ANDSF, MIH and a VHO algorithm.

VHO Procedure4; includes MIH and VHO algorithm.

Procedure 1 requires FAF as one additional entity for two reasons: first; to enable the transition from WiMAX to 3GPP (Authentication) and second; to avoid direct link between 3GPP and WiMAX, i.e. avoid the WiMAX access scheduling measurement opportunities to the MU in order to measure neighbor 3GPP sites between 3GPP and WiMAX. **Procedure 2** requires two additional entities (FAF and DFF) in order to provide seamless VHO integrated with ANDSF. **Procedure 3** includes the combination between two mechanisms, MIH and ANDSF, in order to provide seamless VHO without the additional entities (FAF and DFF); however, the combination results in high complexity. In **Procedure 4**, the MIH does not require additional entities to provide seamless VHO mobility; hence, the majority of VHO approaches in the literature [2, 3, 17, 18, 25, 30-36] were based on MIH mechanism. Although handover seamlessness generally means lower packet loss, minimal handover latency, lower signaling overheads and limited handover failures [40], the VHO approaches in the literature concentrate primarily on packet loss and latency whereas signaling cost and connection failure have not been considered thoroughly. Therefore, concentrating on **Procedure4** in order to produce a smart VHO algorithm taking into account signaling cost and connection failure factors will guarantee providing a seamless VHO under MIH mechanism.

6. Conclusion

In this survey we have overviewed MIH and ANDSF mechanisms for enabling a seamless VHO between the different types of technologies (3GPP and non-3GPP) such as UMTS, Wi-Fi, WiMAX and LTE. We have given an overview of their components and benefits. Also we have surveyed the VHO approaches proposed in the literature and classified them into three main categories based on these mechanisms for which we have presented their objectives, issues and evaluated their complexity of implementation. The MIH mechanism does not require additional entities to provide seamless VHO mobility; hence, the majority of VHO approaches in the literature are based on this mechanism. Although handover seamlessness generally means lower packet loss, minimal handover latencies, lower signaling overheads and limited handover failures, the VHO approaches in literature concentrate primarily on the packet loss and latency whereas signaling cost and connection failure have not been considered thoroughly. Therefore, it would be logical to concentrate on Procedure4 which is a combined MIH and VHO algorithm in order to produce a smart VHO algorithm taking into account signaling cost and connection failure factors to guarantee providing a seamless VHO under MIH mechanism in heterogeneous networks.

Table 1. Comparative Summary of the Three Categories

Category	Main Objective	Input Parameters for VHO Decision	Additional Entity	Complexity	Traffic	Evaluation Method	Applicable Area
ANDSF.	Minimal packet loss.	Not mentioned.	FAFand/or DFF.	Medium.	Video.	Simulation.	WiMAX-3GPP.
MIH.	Minimal packet loss. Minimal latency. Minimal call dropping. Ongoing session. Best RAT.	Multiple parameters.	No need.	Low.	IPTV, VoIP CBR, FTP, Video.	Empirical. Testbed. Simulation. Analytical.	WiMAX-GPRS. Wi-Fi-UMTS. Wi-Fi-WiMAX. Wi-Fi, WiMAX and 3G. Wi-Fi, WiMAX and UMTS.
MIH&ANDSF.	Minimal packet loss. Best RAT.	Not mentioned.	Combination (MIH/ANDSF).	High.	Not mentioned.	Not mentioned.	WiMAX-LTE.

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