Heterogeneous Networks Handover Decision Triggering Algorithm Based on Measurements Messages Transfer using IP Option Header

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***Abstract*—The handover issue is one of the most important challenges in the next generation mobile networks. Traditional handover triggering conditions mainly based on signal strength, while the requirements for other triggering conditions such as user controlled handover or service based handover become an urgent need; especially when the handover is required among different networks. We propose a simple and easy mechanism for exchanging the handover metrics using proof of concept and logical visibility. This handover metrics represent the base in which the handover decision algorithms are constituted on. Metrics information can be transferred not only among different nodes that belong to the same radio access technology but also among different wireless access technologies as well. In this paper, we introduce new fields in the IP option header which are used for the handover metrics information exchange. We focus on some important metrics and how they can be read and written in the IP header. This allows any handover decision algorithm to openly use our scheme in a flexible way. The choice of the IP protocol comes from the trend of the next generation networks, which is based on IP networks.**

Keywords-handover; vertical; horizontal; mobility; IP header; wireless; ping pong effect

I. INTRODUCTION

Nowadays, the handover becomes a generic term because the Mobile Terminal (MT) not only needs to make the handover among different nodes inside the same wireless network, but also it needs to make the handover among different radio access networks; so it is called multi-interface or multi-mode mobile terminal [1]. If the MT requires the handover inside its current wireless access network it will be called Horizontal Handoff (HHO) or homogeneous handover, while it will be called Vertical Handoff (VHO) or heterogeneous handover if it requires making the handover among different technologies. Next generation wireless networks typically constitute different types of radio access technologies [2].

The handover terminology not only linked to the user mobility but also non-movable nodes can make the handover as well. For example, the user may request the handover from one wireless technology to another due to the cost factor; which is independent on the mobility.

The generic handover process requires three phases: network discovery and measurements phase, taking the handover decision based on specific decision criteria phase and handover execution phase [3].

Jawad et al. [4] focused on the network selection, and how to choose network from a number of available networks in a heterogeneous system based on the Quality of Service (QoS). They achieved their target by proposing an architecture that combines QoS-Broker and network selection. For any network with sufficient QoS parameters, that matches the user request, the connection to that network will be triggered. While their mechanism is successful for guaranteeing the required QoS, it lacks of other metrics consideration, such as the vehicular speed moreover, the QoS-Broker is not an easy solution to implement because it requires additional cost.

In [5], George et al. introduce in their paper a network-based approach for access and interface selection in the context of resource management in heterogeneous wireless environments Universal Mobile for Telecommunications Service (UMTS), Wireless Local Area Network (WLAN) and Digital Video Broadcasting-Terrestrial (DVB-T). They interested in designing decision criteria by trying to optimize predefined cost function; however, they didn't consider the metrics and parameters criteria in their study.

Adiline and Anandha [6] proposed a user centric approach for controlling the handover between heterogeneous networks. In their approach, the mobility management is fully controlled by the terminal, and network selection is user-centric, power-saving, cost-aware, and performance-aware. However, they didn't address how the proposed handover metrics is practically achieved; moreover, they based the handover execution phase only on the Mobile IPv6. As well as, they protocol is not open for any wireless network.

A vertical handover using Media Independent Handover (MIH) layer is another protocol; this protocol is proposed by IEEE 802.21 working group [7]. MIH has many protocols which are developed for the heterogeneous networks handover. However, MIH is still limited to the handover preparation phase, as well as it

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lacks of triggering and performance evaluation mechanisms. Dai et al. [8] address the triggering condition mechanisms but it is limited to only WLAN and Worldwide Interoperability for Microwave Access (WiMAX). Another work related to the vertical handover is presented in the literature [9]-[13]. Zhang et al. introduce an estimation of WLAN network conditions based on media access control network allocation vector occupancy [9], [10]. They used a Fast Fourier Transform (FFT) to detect the WLAN signal decay, but both of them didn't address how to estimate the WiMAX network conditions. In [11], Garg et al. introduce a handover criterion that combines the location using Global Positioning System (GPS) and IEEE 802.21 information elements; however, not all mobile terminals have GPS capabilities. Paper of [12] proposes handover rules based on a theoretically computed throughput, but without presenting any method to collect this information. In [13], Hassawa et al. proposed a generic vertical handover decision function, which provides handover decisions when roaming across heterogeneous wireless networks. However, it is very difficult to collect parameters such as cost, signal strength and vehicular speed then exchange them between MT and network nodes.

There are many handover protocols designed for VHO, but most of them focused only on the handover execution phase. For example, the following literature didn't show how network discovery and measurements collection phase or handover decision are addressed. For the IP supporting networks, the Mobile Internet Protocol (MIP) [14] is a typical mobility enabling protocol. It can be used for MIP version 4 (MIPv4) [15] and version 6 (MIPv6) as well [16]–[18]. Hierarchical Mobile IPv6 (HMIPv6) [19] facilitates local mobility management. The work in [20] introduced a Fast handover for MIP protocol that was used to reduce interruption time during handover. In [21], IPv6 protocol is used to enable a mobile node to configure a new Care of Address (CoA), when it changes its subnet. It was demonstrated in [22] that, Cellular IP (CIP) protocol can offer local mobility and handover support for moving nodes. CIP can co-operate with MIP to provide wide-area mobility support. In [23], a domain based approach for mobility support is proposed, which is called Handover Aware Wireless Access Internet Infrastructure (HAWAII). The handover issues that include horizontal and vertical handover using Hierarchical MIPv6 were discussed by Lee [24]. Maltz et al. [25] proposed Transport Control Protocol (TCP) connection that can divide the end to end connection into two connections: end to proxy and proxy to end. In [26], Multimedia Sockets (MSOCKS) uses Maltz technique for connection migration that can support multiple IP addresses. Seamless IP diversity based Generalized Mobility Architecture (SIGMA) [27] and Mobile Stream Control Transmission Protocol (mSCTP) [28] support soft handoff using IP diversity. Another technique is used in [29] to freeze the current TCP connection, till making the handover by advertising a zero window size to the core network, then unfreezes the connection after finishing the handover. Nowadays, numerous studies are focused on the mobility supported Session Initiation Protocol (SIP) at the application layer level [30]. The details of how the SIP protocol can provide terminal and service mobility is discussed in [31].

Some of the above mentioned work only focused on the handover execution phase, while the rest concentrated on the triggering conditions of the handover decision phase. However, there is no specific study focused on how to exchange non-traditional triggering handover information such as user forced handover or speed based handover especially in VHO. The purpose of this paper is to introduce a new concept for exchanging the handover information using the IP option header.

In this paper, we consider the following hypothesis: any user terminal is equipped with more than one wireless interface. Moreover, we suppose that, more than one wireless access technology is always available for any user access. We will not expose to how the wireless network is discovered or how the handover protocol is executed.

The rest of the paper is organized as follows. Section II describes the reason for why we choose the IP protocol as a transport layer for handover information exchange. The details of events and measurements metrics; which can be transferred through the IP option header and used to take the handover decision, will be discussed in Section III. In Section IV, we will introduce a handover decision phase algorithm, which based on our proposed new handover metrics. The proposed algorithm is called as a ping pong and vehicular speed handover decision-based algorithm. Finally, Section V presents both paper conclusion and future work.

II. The Importance of Using the IP Protocol as a Base for our Scheme

The IP is a dominate protocol that is used for the Next Generation Wireless Network (NGWN). The term All IP Networks comes from converging all network services that are based on the IP protocol; irrespective of whether the access is wired or wireless. The NGWN is one network that transports all media sources by encapsulating them into packets, such as we have on the Internet.

All IP based network has most important advantages over its predecessors. First of all, the IP protocol not only becomes integrated in all networks but it is also independent of the used radio access technologies as well. This means that, a core IP network can support different wireless access technologies such as cellular, WiMAX and WLAN. Now the core IP network can be evolved independently from the access network; this is the key advantages of using all IP. Also implementation and investment of the IP network is very easy with low costs. Moreover, using the IP protocol gives any user the availability to have just one terminal that can support any type of service with low cost. All the above mentioned advantages of using the IP protocol emphasize the right choice of the IP protocol as a base for our scheme.

III. IP ADDED HANDOVER OPTION HEADER FIELDS

In this section, we introduce new added fields in the IP option header for handover purposes.

A. Normal IPv4 Packet Header Overview

The IPv4 header consists of 20 byte as a mandatory header and 40 byte as a variable option header [32]. The IP option header is not normally used; it may be used according to the need. For example, the security option header may be required in all IP packets. The IP option header has a variable length according to its type. There are two types of the IP option header. Type-1 consists of one option byte; and type-2 consists of type, length and value fields.

B. The Handover Fields

The option type '11111' is not assigned for any purpose, so that we select this option field to exchange the handover related information that is carried directly in the header of the IP packet. We can transfer the handover information whenever it is needed, without interrupting any user session. Moreover, this information can be inserted directly whenever it is required. This means that, a very low delay is taken for the handover information exchange from one point to another among different network nodes.

C. Vertical or Horizontal HandoverFlag

This is '1' bit flag that is used to determine whether the associated handover information, which is carried in the IP header belongs to HHO or VHO. A vertical handover scenario is required in case the value of this flag equals to one, otherwise a horizontal handover information exchange is required. Using this flag means that, our mechanism can be useful not only for HHO scenarios but also for VHO.

D. Handover Counter

This portion of IP option header consists of four bits, which are used for exchanging the number of handover counts among network elements. Four bits means we have maximum up to '16' horizontal or vertical handover attempts. This field together with vertical or horizontal handover flag can be used to decide either it is needed to make VHO or HHO. By this way, we are able to count the number of vertical or horizontal handover events for a specific MT. This information is one of the key factors that are used to take a handover decision, especially in the VHO.

E. Forced Handover Flag

The handover decision not only controlled by the network itself, but also it may be based on the user choice. This is considered as one of the most important requirements of the next generation mobile networks. In other words, we need to support user controlled handover as well as network controlled handover [33]. The purpose of this flag is to make it easy for the MT to request from the network or force it to trigger the handover process. In this case, the handover decision is taken by the user or MT and transferred to the network side in the IP header to proceed in handover execution. If the value of this flag equals zero, the user will leave the handover decision to the network hand.

F. Vehicular Speed Based Handover Flag

This flag is used to give a chance of triggering the handover decision based on the vehicular speed. Moreover, another field is required to show the vehicular speed level; so that the handover decision can be triggered vertically from one system to another accordingly. The levels of the vehicular speed can be handled by a speed based handover field, which will be discussed later in the next paragraph. The value of this flag controls the presence of optional speed based handover field. If we set this flag by one this means that, we have vehicular speed based handover field, otherwise there is no existence to this field at all.

G. Speed Based Handover Field

The length of speed based handover header consists of '3' bits that gives '8' permutations. According to the vehicular speed level, we can judge which appropriate target network suitable for the handover. Table I states the ranges of these '8' vehicular speed levels. We suppose that, three bits are enough to differentiate among '8' vehicular speed levels.

This field is optional; its presence depends on a vehicular speed based handover flag. If the value of this flag equals '1' it will report the presence of the vehicular speed based handover.

There are many systems that have different coverage cell size such as Public Land Mobile Network (PLMN), WiMAX, WLAN or Personal Area Network (PAN). So that more precise vehicular speed levels are required for accurate actions. This explains why we have many levels that represent these mobility classes.

We prefer transmitting the vehicular speed range indicator to exchange the absolute vehicular speed value. This is because it will save the header length as long as the range is enough to take accurate action. We need to confirm the difference between both vehicular speed-based handover and handover counter fields. The former not only depends on handover counter, but also it depends on other key factors. The handover decision can be taken not only based on the user mobility factor, but also it can be taken based on other factors such as the network cost, network load, user choice and many other metrics that can trigger the handover. Many of previous factors can trigger the handover while they are independent on the mobility. So that the handover counter can be used for other purposes rather than the mobility in the handover decision.

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TABLE I. MOBILITY CLASSES FIELD

Value	Description of mobility classes in Kilo meter per hour
000	Vehicular speed 0 km/h
001	Vehicular speed > 0 km/h to 1Km/h
010	Vehicular speed > 1 km/h to 5 km/h
011	Vehicular speed > 5 km/h to 10 km/h
100	Vehicular speed from 10 to 60 km/h
101	Vehicular speed from 60 to 120 km/h
110	Vehicular speed from 120 to 250 km/h
111	Vehicular speed from 250 to 350 km/h

H. Service Priority Levels

Priority level field consists of ‘4’ bits this means that, we have ‘16’ permutations of the service levels. The MT can carry service information based on the user setting at the terminal side. We can use service priority levels field to transfer this information. By this way, the handover decision can be taken based on the service type. We suppose that, there is a table that contains a mapping between the service and its corresponding suitable network. Moreover, we can transfer the service priority information which can trigger the change in the current serving network. This enhances the availability of taking the handover decision based on the service type. Table II shows all service priority levels. The term Not Applicable (N/A) means that, the corresponding network doesn’t support the service right now; however, it may be available in the future.

I. Green Field indicator

This field is used to book a room in the IP header, which is particularly dedicated for battery level indication. We assign two bits to represent four battery levels. Table III shows the proposed battery levels from the strongest to the weakest level.

TABLE II. SERVICE PRIORITY LEVELS

Priority ID	Priority level
0	N/A (Not Applicable)
1	Level1 (Higher priority)
2	Level2
3	Level3
4	Level4
5	Level5
6	Level6
7	Level7
8	Level8
9	Level9
10	Level10
11	Level11
12	Level12
13	Level13
14	Level14
15	Level15 (Lower priority)

TABLE III. GREEN FIELD BATTERY INDICATOR

Value	Battery level
00	Strong bateery level
01	Level 2
10	Level 3
11	Ver low battery level

J. Uplink /Downlink Flag

This field is ‘1’ bit flag which is used to check the direction of exchanged information. From one side, the MT can exchange the handover information to the network; however, the network from the other side can transfer the handover information to the MT. We can use this information together with the source and destination IP addresses to check the exact path of handover information transfer.

This information is useful for different scenarios. For example, specific information can be transferred from one network node to another different network node. This can give the MT information about the availability of its surrounding wireless networks. This helps the MT during its handover discovery phase. Normally, the network discovery phase is done by the MT itself not by the network, however; we can seek the help of this network information in the discovery phase by using this proposed flag. Of course, this saves the mobile station battery life and guides the MT to make the smooth handover. The study of how the network discovery phase is done by the network side is out of this research scope.

IV. PING PONG AND VEHICULAR SPEED HANDOVER DESCISON-BASED ALGORITHM

This algorithm is mainly based on both the vertical or horizontal flag and the handover counter field. We introduce this algorithm to avoid the ping pong phenomena; by frequently transferring from serving wireless network node to another. In other words, we can transfer from vertical to horizontal handover to avoid vertical ping pong effect; or transfer from horizontal to vertical handover to avoid horizontal ping pong phenomena. In this paper, we will focus in avoiding the horizontal ping pong effect. This algorithm uses the handover counter to count the handover attempts in a specific time. We will refer to this time by timer ‘T’; the handover decision may be triggered, when the wireless access node detects the value of handover counter exceeds certain threshold within the time ‘T’. The handover type can be detected by checking the vertical or horizontal handover flag. Fig. 1 depicts the signaling flow diagram according to the proposed handover decision algorithm.

We assume the threshold value of horizontal handover counter equals ‘10’. If the handover attempts reach this threshold within a certain time ‘T’, the vertical handover decision will be triggered. Fig. 2 shows the flowchart of the proposed algorithm.

The ping pong effect may be caused by the serving wireless technology coverage instability. In this case, it is recommended to search for another available wireless network to serve this user. Moreover, the proposed algorithm is also feasible in case we think about certain user with multi-interface terminal navigate with WLAN, while its vehicular speed increasing rapidly see Fig. 3. If available, our algorithm recommends the bigger coverage

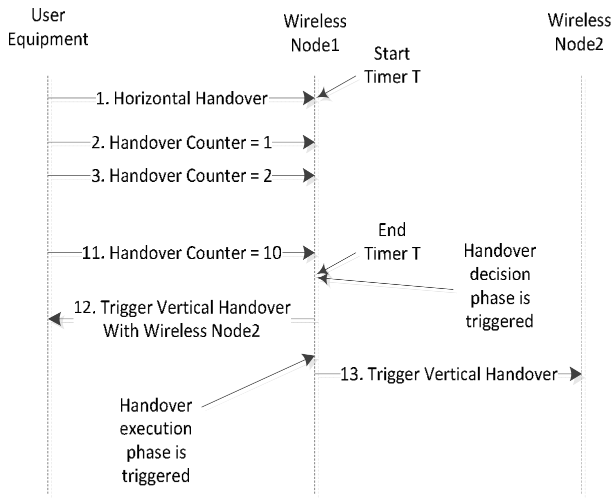

Figure 1. Signaling flow of horizontal ping pong and vehicular speed handover descision-based algorithm.

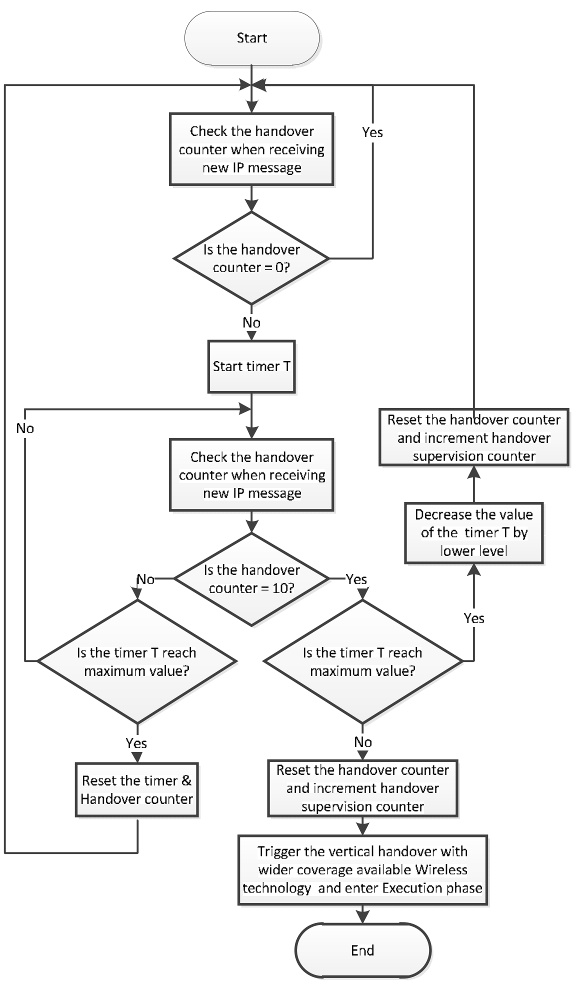

Figure 2. Flowchart of the horizontal ping pong and vehicular speed handover decision-based algorithm.

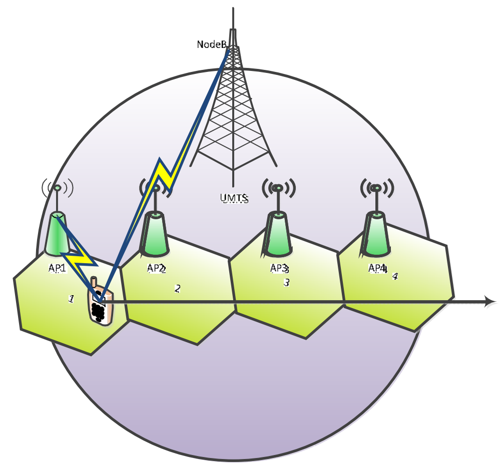

Figure 3. Triggering vertical handover condition based on horizontal ping pong and vehicular speed handover decision-based algorithm betwwen WLAN and UMTS networks.

area supporting technology to deal with either high vehicular speed or ping pong handover scenarios.

If the handover counter value is less than or equals to ‘10’, another counter called supervising counter will be incremented; while resetting the value of both handover counter and timer ‘T’ by zero. Note that, the supervising counter is a software module counter, and it doesn’t exchange in the IP option header. Assume that, after checking the handover counter we found its value equals ‘10’ in the same time, the vertical or horizontal handover flag equals ‘0’. This means that, ten horizontal handover attempts are performed.

Now, the network node can take a decision of a vertical handover. By the same way, the horizontal handover decision is taken in case there are a lot of vertical handover attempts are detected. By adding this field, the handover performance will be improved very much, and it will be easy to have an optimum handover decision.

We have many handover scenarios may be happened. Different handover software modules may use these metrics, which are introduced in our proposed fields; from different perspective. This guarantees the flexibility of using our scheme.

V. CONCLUSION

To sum up, we introduce in this paper a mechanism that let us use the IP option header for handover information exchange. We introduce new IP option header fields, which are dedicated for handover metric information exchange.

We put extra ‘25’ bit in the IP header, which is normally has at least ‘160’ bit. These extra bits are used to introduce new eight handover metrics. Our scheme increases the IP signaling overhead by 13.51%; however, it gives more varieties for the handover decision algorithms to use our proposed metrics.

We also introduce handover decision algorithm that is based on our new metrics for both vertical or horizontal

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flag and handover counter as well. This handover decision algorithm gives the flexibility to change the handover from horizontal to vertical and vice versa; to avoid the ping pong effect and address vehicular speed-based handover.

The choice of IP protocol for handover information transfer complies with the trend of the next generation wireless network, which is based on IP protocol. Our scheme gives the availability to take the handover decision not only based on traditional handover measurements such as signal strength but also based on new metrics. We introduce new added handover information such as vertical or horizontal handover flag, forced handover flag ;which is based on the user desire, handover counter, vehicular speed based handover flag, speed based handover field, service priority levels, green field that indicates to the user equipment battery level and finally the uplink /downlink flag. The use of forced handover flag guarantees the availability of using both network controlled and user controlled handover. This is smoothly done by easy and simple notification way.

Our proposed mechanism flexibly works for both horizontal and vertical handover. Any horizontal or vertical handover protocol can use our proposed methodology to enhance its performance. Different decision algorithms can also use our scheme to enhance the handover performance. Moreover, the implementation of our proof of concept scheme will be left as a future work; in which we can move from conceptual to realistic level.

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