Optimized FMIPv6 Handover using IEEE802.21 MIH Services

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Abstract—The emerging IEEE802.21 standard defines Media Independent Handover Functions (MIHF) that assist mobile nodes to seamlessly roam across heterogeneous access networks. The aim of this paper is to present a mechanism which uses existing IEEE802.21 MIH services to optimize the Fast Handovers for Mobile IPv6 (FMIPv6) procedure. For this, we have exploited the 802.21 Information services in particular to tackle issues such as radio access discovery and candidate access router discovery which are critical to the handover performance of FMIPv6. We will show through analysis that, when our proposed mechanism is applied, it increases the probability of predictive mode of operation by reducing the anticipation time and thereby reduces the overall expected handover latency in FMIPv6.

I. INTRODUCTION

In the vision of 4G wireless communications, it is requisite to provide seamless mobility support across heterogeneous access networks. Such integrated disparate network access technologies are seemingly converging their core network infrastructure to the Internet Protocol Suite (IPv4/6) [1][2]. In order to enable mobile users to seamlessly roam across such heterogeneous network while enjoying the plethora of ‘all-IP-based’ services, there are many challenges arising from inter-technology ‘Vertical’ handovers. Among many proposed mobility management solutions, Mobile IPv6 (MIPv6) [3] has been widely accepted in the academic world and industry as the front runner for tackling these challenges.

Handover performance control is a vital part in the end-to-end delay and packet loss control for the QoS provisioning of real time services in heterogeneous networks. The period during which the MN looses connectivity with its current link till the time it receives the first packet after connecting to the new link is known as handover latency. The overall handover latency in MIPv6 is consist of Layer 2 (L2) handover latency and Layer 3 (L3) handover latency. The L2 handover latency is the period when the MN is disconnected from the air-link of the current Access Router (AR) till the time it connects to the air-link of the new AR [7]. During the L3 handover, there will be latencies incurred due to the processes of movement detection, Care-of-Address (CoA) configuration and Binding Updates (BU). Time stringent real-time applications, such as VoIP and streaming multimedia, have very high requirements for handover latencies.

There have been numerous proposals within the IETF (Internet Engineering Task Force) to reduce MIPv6 handover latency. As an extension to MIPv6, FMIPv6 [4] protocol is one of them. FMIPv6 focuses on eliminating the latencies involved in the movement detection, CoA configuration, CoA testing (i.e., Duplicate Address Detection) in the standard in MIPv6. This is done with the aid of anticipation based Layer 2 (L2) trigger information and by obtaining the subnet prefix information from the New Access Router (nAR) while it is still attached to it’s current/old Access Router (oAR). In order to form a new CoA, FMIPv6 relies on the oAR to resolve the network prefix of the nAR based on the L2 identifier reported from the MN.

However, FMIPv6 concentrates on the protocol operation and does not consider issues such as network radio access discovery and Candidate Access Router Discovery (i.e., how the that need to be addressed: AR could map the network prefix with the corresponding L2 identifier). Moreover, although the anticipation mechanism specified by FMIPv6 is useful, it also introduces additional problems

- The additional Anticipation time imposed by FMIPv6 causes the handover to start earlier than planned, hence reducing the certainty about the MN’s movement.

- Also, due to sudden degradation of the wireless link during the handover initiation phase, the MN may lose connectivity with the oAR. In this case, if the anticipation time is large, then the MN may not have sufficient time for new CoA (NCoA) configuration while being attached to the oAR’s link. As a result, there would be long handover latencies.

The IEEE802.21 - Media Independent Handover (MIH) Service Work Group [5], which was formed in 2003, is developing a draft standard to enable handover and interoperability between heterogeneous networks including both 802 and non 802 networks. In this paper, we propose a new mechanism through which the handover procedure of FMIPv6 is optimized by using the IEEE802.21 MIH services. Particularly, we exploit the IEEE802.21 Information Services to tackle the issues related to radio access discovery and candidate AR discovery in FMIPv6. We have defined an ‘Information Report’ consisting of L2 and L3 information of neighboring access networks for this purpose. Moreover, we propose to use a special cache which will be maintained by the MN to reduce the anticipation time in FMIPv6, thereby increasing the probability of the predictive mode of operation. We will analyze the signaling process to show that the overall expected handover (both L2 and L3) latency in FMIPv6 can be reduced in the proposed mechanism.
II. RELATED WORKS

FMIPv6 was proposed to address the handover issues related to movement detection, CoA configuration and BU in MIPv6. FMIPv6 does this by exploiting various L2 triggers to prepare for a New CoA (NCoA) at the nAR in advance while being connected to oAR’s link. Upon receiving a L2 trigger, FMIPv6 starts to ‘anticipate’ or prepare for the forthcoming handover beforehand. During the anticipation, the oAR assists the NCoA formation by resolving subnet prefixes based on L2 identifier reported by the MN. This idea assumes that an AR is configured with a table containing its own and the neighbouring Point-Of-Attachment’s (PoA’s) MAC addresses and the corresponding AR subnet Prefix. There are three FMIPv6 signaling messages involved in the anticipation phase: Router Solicitation for Proxy Advertisement (RtSolPr), Proxy Router Advertisement (PrRtAdv) and Fast Binding Update (FBU). These messages are used for aiding movement detection and NCoA configuration.

When using the FMIPv6 based mobility management, there are a few aspects which can be improved for reducing the handover latency and handover packet loss:

- **Neighbouring access network discovery**: The FMIPv6 doesn’t address any radio access network discovery mechanism. Discovering the available PoAs by actively searching/scanning all the channels provided by the neighbouring networks takes a considerable amount of time, which has significant contribution to the overall handover latency. For example, in 802.11b, the L2 scan time takes about 400ms up to 800ms.

- **Information exchange with neighbour ARs**: The method of how ARs and their neighbouring ARs exchange the information that enables the construction of PrRtAdv messages is not specified in the original FMIPv6. The IETF SEAMOBY WG produced Candidate Access Router Discovery (CARD) protocol [6] to address this issue. The CARD protocol allows MNs to dynamically construct, populate to maintain their own CAR tables, which contain the mapping between the L2 PoA ID and corresponding IP addresses of the Candidate Access Routers. However, the use of CARD protocol so far is very limited for the reason that it will need additional support and upgrade to the IPv6 implementation in routers. Also, CARD enables a MN to gather attributes associated with target subnets so that a suitable AR could be selected for handover. It does not provide the MN with appropriate L2 information in order to tackle the issue of radio access discovery FMIPv6 faces.

- **The Cost of Anticipation**: In FMIPv6, the L2 handover is triggered by the degrading of link conditions. There is no guarantee that the MN will be connected to the oAR long enough to send and receive all FMIPv6 messages. When anticipation is used, the MN may not have sufficient time to update the oAR with the FBU. As a result, if the MN has already lost connection with oAR, then MN is forced to operate in the reactive mode and handover latency will increase consequently.

- **The Ping Pong Movement**: Time used by the signalling exchange of the three FMIPv6 messages (RtSolPr, PrRtAdv and FBU) is long enough to increase the uncertainty of a MN’s mobility. For example, the handover may take place earlier than originally anticipated by the Link layer. The border between overlapping cells may change dynamically due to objects (e.g., building, tree etc) blocking signal between the APs and MN. Due to the intrinsic dynamic nature of wireless channels, the MN may not move to the originally anticipated PoA. It may not move after all, or it may move somewhere else. That is to say that the MN would ping-pong between cells. Hence premature forwarding of data by the oAR (upon reception of an FBU) could be harmful because the MN may move to the anticipated PoA. As a result there will be packet losses and long handover latencies.

This issue alongside with the previous issue, handover triggers, are both related to the long anticipation in FMIPv6, which is addressed in [7] [8] respectively. However, these works fail to specify how the ARs would gather information of about the neighbouring network information. Moreover, AR would need additional support which would cause deployment obstacles.

There are several initiatives to optimize mobility across heterogeneous networks. The MIPSHOP Working Group within the IETF and the IEEE802.21 standard Working Group have been working to develop a framework in which the mobility management protocols would use the 802.21 to enhance the handover process. Reference [11] describes the transport and security requirements for the MIH signalling in order to aid IP handover mechanisms. References [10] outline few usage models of Event, Command and Information services. They also discuss security considerations for these services. In reference [9], 802.21 assisted SIP based mobility Test-bed across heterogeneous access network was implemented. The IEEE802.21 Working Group is addressing various scenarios in detail and is in the process of standardizing a Media Independent Handover Framework.

III. IEEE 802.21 MEDIA INDEPENDENT HANDOVER FUNCTION

In the mobility management protocol stack of both mobile node and network element, the Media Independent Handover Function (MIHF) is logically defined as a shim layer between the L2 datalink layer and L3 network layer [6]. The upper layers are provided services by the MIH function through a unified interface. The services exposed by the unified interface are independent of access technologies. This unified interface is known as Service Access Point (SAP). The lower layer protocols communicate with the MIHF via media dependent SAP.

MIHF defines three main services that facilitate handovers between heterogeneous networks: Media Independent Event Service (MIES), Media Independent
Command Service (MICS) and Media Independent Information Service (MIIS). Detailed discussions of each of the services are given below.

A. Media Independent Event Service

Media Independent Event Services (MIES) provide event reporting, event filtering and event classification corresponding to the dynamic changes in link characteristics, link quality and link status. The MIES report both local and remote events to the upper layers. The upper layers perform registration to receive events from the MIHF using a request/response primitive. Some of the events that have been specified by IEEE 802.21 are “Link Up”, “Link Down”, “Link Detect”, “Link Parameter Reports” and “Link Going Down”.

B. Media Independent Command Service

Media Independent Command Services (MICS) use the MIHF primitives to send commands from higher layers (e.g. Policy Engines to Mobility protocol) to lower layers. The MICS commands are utilized to determine the status of the connected links and also to execute mobile and connectivity operations in predictive mode. By reducing anticipation time, the probability of reducing the number of signalling messages during the anticipation phase and thereby reducing the overall configuration procedure time can be decreased and thereby tackling the candidate AR discovery issue in FMIPv6. For the MN, this knowledge would eliminate the need to scan and search for available radio access networks, and helps to resolve the radio access discovery issue FMIPv6 suffers from and reduce L2 handover latency.

With the L3 information of corresponding PoAs, the MN will learn of subnet prefixes of the nAR and form the NCoA prior to handover. This also reduces the router discovery time and the L3 handover latency in FMIPv6. Note that the HNI Report maintained by an IS will be similar to the mapping table maintained by the ARs for resolving L2 Identifiers of corresponding subnet prefixes. This could eliminate the need for ARs to exchange neighbouring information mapping table and thereby tackling the candidate AR discovery issue in FMIPv6.

Furthermore, in order to reduce the adverse impacts of the long anticipation time in FMIPv6, we propose to create a Neighbouring Network Report (NNR) Cache in the MN for storing and maintaining the HNI report. This would help to reduce the number of signalling messages during the anticipation phase and thereby reducing the overall anticipation time. The HNI report will be delivered to the MN through the ‘MIH_Get_Information’ request/reply service primitives. By reducing anticipation time, the probability of operations in predictive mode is increased. Also the CoA configuration procedure time can be decreased and thereby the L3 handover latency is reduced.

### IV. PROPOSED MECHANISM

A. Overview

In this section, we propose to use IEEE802.21 MIH services to assist FMIPv6 to enhance the overall handover performance by addressing the issues discussed in Section 2. The crux of this proposal lies in exploiting the existing IEEE802.21 Information Services (MIIS). In the current 802.21 MIIS specification, a MN gets the heterogeneous neighbourhood information by requesting Information Elements (IEs) from the IS. It also allows the neighbourhood information to be delivered to the MN by using pre-defined Information Reports. In IEEE 802.21 draft, the defined IEs provide mostly static L2 information.

In this context, we propose to include the provisioning of L3 information of neighbouring access networks in the MIIS service. We define a new IE known as ‘Subnet Prefix’ (see figure 3) to provide subnet prefixes of neighbouring ARs. Alongside with the L2 information, they form a pre-defined Heterogeneous Network Information (HNI) report.

Only the L2 information that is related to available neighbouring PoAs, such as channel range, MAC address, data rates etc (see figure 3), will be included in the HNI report. For the MN, this knowledge would eliminate the need to scan and search for available radio access networks, and helps to resolve the radio access discovery issue FMIPv6 suffers from and reduce L2 handover latency.

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particular, security association establishment in these ARs to adapt MIIS capabilities which may be unrealistic. In this way, the server can serve many access subnets simultaneously which can reduce administrative overheads. Figure 5 shows a topological view of how the IS will be deployed. It will be seen that neighboring access networks are divided into domains. Each domain is served by an IS. Replicate servers could also be deployed to prevent single point of failure case. A L2 or L3 based mechanism is required to identify or discover a valid IS. Such a mechanism will be discussed in detail in the next section.

V. DETAILED HANDOVER PROCESS OF THE PROPOSED 802.21 ASSISTED FMIPv6

In this section, we will describe the detailed procedure of the 802.21 assisted FMIPv6 handover as we proposed in Section (IV). We illustrate the procedure in Figure 6.

A. Events Registration

At the very beginning, when a MN is switched on (refer to figure 6), the FMIPv6 protocol in the MN will register for Media Independent Event Service (MIES) notifications (i.e. L2 triggers) within its local stack. This will be done via MIH Event Registration service primitives which work in a request/response mode [5]. The events services that will be registered by the FMIPv6 protocol are shown in Table 1.

B. IS Discovery and Usage

The system would need to provide discovery mechanisms, security association (SA) bootstrap, and transport of information services over IP. Then, a valid information server will need to be identified or discovered through either layer 2 or layer 3 mechanisms. At the time of writing, DHCP (Dynamic Host Control Protocol) was selected as a candidate solution for discovering the IS in IEEE802.21 MIIS specification. Figure 4 shows the three phases related to our MIIS usage scenario: Discovery, SA bootstrap, request/response. The MIIS will be used by the MME, an upper layer entity which implements network selection handover algorithms. The MME in our scenario initially uses DHCP [8] to acquire the location of IS. Specifically, the IS server’s IP address, the IS server’s FDQN (Fully Qualified Domain Name) and URI (Uniform Resource Identifier).

C. SA Bootstrap

Before the MME can exchange any messages with the IS server, a set of Security Associations (SA) have to be established. Authentication and encryption must be provided by each SA for keeping the mobile device anonymity so as to prevent eavesdroppers. The SA negotiation mechanism depends on the used transport layer and required security

Additionally, the FMIPv6 can use the 802.21 MIES to get the L2 trigger, and therefore quickly detect any L3 movement and perform handover initiation for NCoA configuration before a L2 handover. Also, the upper layer including the Mobility Management Entity (MME) that implements network selection and handover decision algorithms and utilizes mobility signalling protocols at MN or network side could use the MICS to control the behavior of the underlying Link Layer.

B. Existing IEEE802.21 MIH Services to be used

We propose to utilize a subset of existing IEEE802.21 MIH services to enhance the handover process in FMIPv6. Table 1 lists the chosen MIH services, their corresponding primitives and parameters.

<table>
<thead>
<tr>
<th>Primitives</th>
<th>Service</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIH_Link_Going_Down</td>
<td>MIES</td>
<td>MN MAC Addr, MAC Addr of Current PoA</td>
</tr>
<tr>
<td>MIH_Link_Up</td>
<td>MIES</td>
<td>MN MAC Addr, MAC addr of new PoA, Link ID</td>
</tr>
<tr>
<td>MIH_Link_Down</td>
<td>MIES</td>
<td>MN MAC Addr, MAC addr of new PoA, Reason Code</td>
</tr>
<tr>
<td>MIH_Link_Switch</td>
<td>MICS</td>
<td>Handover Mode, Old Link ID</td>
</tr>
</tbody>
</table>

C. The Structure of HNI Report

The MIIS ‘HNI’ report will be delivered through a request/response type mechanism and will be represented in a standard format such as XML, ASN.1 or TLV. Figure 2 illustrates in HNI request message in TLV format by which the MN can obtain HNI_report by specifying the Link Type and Operator Identifiers. Figure 3 shows the HNI response message in which our defined IE containing the L3 information is the ‘PoA Subnet Prefix’ IE.

The HNI report containing the IEs will be produced and stored in an IS. Amongst the MIH services, the MIIS is deployed over IP [10]. The IS could be co-located in the AR, and the AR has access to the information to assist the handovers [11]. Such a scenario is partly addressed by experimental information services in CARD and FMIPv6. However, this brings us back to the issue of upgrading the ARs to adapt MIIS capabilities which may be unrealistic. In particular, security association establishment in these environments is warranted [4] [6].

D. IS Deployment

In our proposed mechanism, the IS is deployed outside the MN’s subnet. This has the advantage of not requiring explicit
Figure 4: Information Server Discovery & Message Exchange

For Instance, TLS will be advised to use if upper layer protocols use TCP, whilst ESP using IPSec/ IKE will work in most situations without need to worry about the upper layer protocol, as long as the IS protocol identifiers are handled by IKE [11].

D. Retrieval of Neighbouring Network Information (HNI Report) from the IS

After the IS discovery and SA association phase in figure 4, MME uses the ‘MIH_Get_Information’ service primitive to retrieve the HNI report from the IS. The ‘MIH_Get_Information’ primitive works in a request-reply mode. The ‘MIH_Get_Information’ Request primitive will contain the encoded HNI request in TLV format as shown in Figure 2. The MIHF in the IS will respond with a MIH_Get_Information primitive and encodes the HNI Response in TLV format, as shown Figure 3, as its parameter.

Upon receiving the MIH_Get_Informantion response, the MN will process the received HNI report and store its contents will be stored as a list in the NNR cache. A time stamp for periodical access to the IS. This would help the MN renew its contents and also check whether it is in same or different IS domain. It must be noted here that the communications between the MN and the IS will be handled by the MIH protocol defined by the IEEE802.21 draft. The MIH protocol defines frame structure for exchanging messages between MIH function entities. The payload of the MIH message contains service specific TLVs. In our case, the MIH message will carry the MIH_Get_Information request/response TLV as the payload. Further details on the MIH protocol message structure is provided in [5].

The MIH message in our proposal is carried over IP based transport protocol. However such a transport protocol should be generic (i.e. not specific to any link type) in nature and considers both security and signaling requirements. Requirement for such MIH transport design and security requirements are discussed in [5].

E. Handover Operations - Network Selection

Our proposed mechanism can be applicable to both the MIPv6 and FMIPv6 handover procedures. But in this paper we only consider FMIPv6. In our proposed 802.21 assisted FMIPv6, we replace the RtSolPr/PrRtAdv messages with MIH_Get_Information request/reply messages. Also, the MIH_Get_Information request/reply is done much before the L2 trigger (i.e. MIH_Link_Going_Down), unlike the original FMIPv6 in which the RtSolPr/PrRtAdv only occurs after L2 triggers (when the MN senses the signal strength of existing link is becoming too weak). Later, when the signal strength of the PoA that the MN is connected with becomes weak, the MIH Event service will be informed by the MAC layer of the MN. The MIHF (Event Service) will scope and filter this link layer information against the rules set by the MIH user (FMIPv6 in this case), and then produce a ‘MIH_Link_Goin_Down’ event indication message, and sends it to network layer where FMIPv6 protocol resides.

Upon receiving this event notification, the MN checks its NNR Cache and selects an appropriate PoA to handover to. Since the MN knows the radio link information(i.e. MAC address and channel range of PoAs etc) of the neighbour network, the time to discover them is eliminated. In IEEE802.11 networks, for example, there will be no need to use the ‘scanning’ mechanism to find the neighbour APs. The criteria for selecting the appropriate PoA can be very flexible. For instance if the data rate is an important facet to the ongoing applications (e.g. video streaming), the bandwidth supported by the PoA will have higher priority than the channel parameters. Full discussion of such selection criteria is out of scope of this paper.

F. Handover Operations – Switching Link

After selecting an appropriate radio access network, the MME in the MN utilizes MIHF MICS, and generates a link switch command using ‘MIH_Link_switch’ primitive. As it can be seen from Table 1, the parameters, such as the handover mode, may be used to perform a ‘make-before-make’ mechanism along with the target link
Following the link switch command, the MN use the L3 information, the PoA Subet Prefix, to form a NCoA, and sends a FBU to its default AR (oAR). There is no longer any need to send the RtSolPr/PrRtAdv messages for router discovery as the candidate AR information (i.e. ‘Subnet Prefix’ IE) is already in the NNR Cache. The CoA address configuration procedure that relating to the candidate AR discovery or RtSolPr/PrRtAdv is greatly decreased. During the anticipation phase, only the FBU message will be sent to the oAR. As oppose to the original FMIPv6 operation, in our proposed mechanism only a single signalling overhead will be incurred during the anticipation phase. Apparently, the probability of a Predictive Mode of operation in FMIPv6 will be increased, and the L3 handover latency in FMIPv6 will be reduced. After the receiving the FBack message on the oAR’s link and necessary L2 authentication and association procedure, a MIH_Link_Up event notification will be sent to inform the FMIPv6 that the L2 connection with the target PoA is established. After the MIH_Link_Up notification, the FNA message is immediate sent. Once the traffic starts to flow from the new link, the MIHF in the MN sends a MIH_Link_switch response.

VI. Conclusion

In this paper, we have proposed a mechanism which optimizes the original FMIPv6 handover procedure with the assistance of IEEE802.21 MIH services. To do so, we have exploited the existing the MIH services. Most notably, we have utilized the 802.21 MIIS and proposed to include the provisioning of L3 information of neighbouring access networks in the MIIS service. We defined a new Information Report, the ‘HNI Report’ which contains L2 and L3 information of neighbouring access networks. Such information will be help the FMIPv6 protocol tackles issues such as radio access discovery and candidate AR discover. Moreover, contents of the HNI report would be stored a newly defined NNR cache which will be maintained in the volatile memory of the MN. This eliminates the need for RtSolPr/PrRtAdv messages which in turn reduces the long anticipation time imposed by FMIPv6 by reducing signalling overheads. Therefore, when our proposed mechanism is applied to FMIPv6, it can increase the probability predictive mode of operation and also reduces overall (both L2 and L3) handover latency.

References