

Media Independent Handover in Heterogeneous Multi-hop Mobile Networks

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¹**Abstract**— In next generation wireless systems, achieving seamless service continuity when transitioning between heterogeneous networks is a challenging task. An approach to optimize these handover procedures through the introduction of a standardized framework is followed by the IEEE 802.21 working group. The Media Independent Handover (MIH) function of IEEE 802.21 is mainly designed for "client-network" scenarios and not applicable to multi-hop connectivity models. In this paper, we propose an extended MIH model for accommodating multi-hop mode of operation in heterogeneous mobile networks. Our objective is to effectively use the services and the messages associated to the framework, so as to enhance the scope of MIH functionality and contrastingly, enable multi-hop heterogeneous networking in personal ubiquitous environments [16].

I. INTRODUCTION

One of the foremost objectives towards next generation IP networks is to provide seamless network services with various wireless and wired terminals. With the proliferation of devices and access network technologies, the user is surrounded by heterogeneous elements (networks and devices) offering complementary services and resources. For optimized resource management, it is essential to regroup all these resources and utilize them efficiently. For instance, if we could switch among different user terminals and networks adaptively according to their availability, quality, cost or usability, the most appropriate resource (device/network) can always be used. Here, the main motivation is to create a Personal Ubiquitous Environment (PUE) [3][4][15] that allows users to access the network without being aware of the individual network and devices in their environment.

Traditionally, networks are accessed by devices in single hop, for instance, the UMTS terminal connected to a base-station. In heterogeneous environment, the network resources can be shared among interfaces of the same device. However, in order to regroup resources within the user's environment, a communication channel is required which facilitates interaction among the different devices. This interaction is tuned over high data-rate, low-range unlicensed spectrum technologies such as Bluetooth, WiFi, and UWB (Ultra Wide Band) etc. The inter-device communication enable any device to access any resource within its PUE. However, offering uninterrupted seamless communication during this multi-hop handover is an open issue and considerable research efforts are in progress.

The PUE concept allow users to move freely between different networks (through different devices) while maintaining application continuity. However, managing the device mobility in heterogeneous networks is a challenging problem and

frequent handovers yield noticeable delays and packet drops [16]. In our proposed mobility management architecture for PUE [4], a seamless handover framework is incorporated with the Media Independent Handover (MIH) function of IEEE 802.21 [17], designed to support fast handovers in heterogeneous access networks like Wi-Fi, WiMAX and UMTS. However, MIH function is mainly designed for "client-network" scenarios and not applicable to multi-hop connectivity models, as interpreted in personal environments. The heterogeneous multi-hop connectivity/handover towards the infrastructure network imposes serious concerns over application performance, as the latency and packet drop increases. To this end, seamless multi-hop handover mechanism is desired to be developed, which extends the single-hop intelligent handover procedures towards multi-hop in order to guarantee uninterrupted application behaviour during frequent handovers.

Integration of infrastructure and multi-hop networks has attained maturity in the research domain and various solutions related to mobility management and routing has been proposed [6]. An integrated protocol for IPv6-based hybrid wireless multi-hop networks based on Cellular IP and the AODV routing protocol [14] was proposed in [9]. The performance of Mobile IP integrated with AODV was studied in [10]. In [11], Hierarchical MIPv6 protocol is proposed, which piggybacked with AODV protocol offers mobility management in hybrid wireless networks. Moreover, in [12], the authors proposed the personal Access-Point (AP) concept, where the entire context of old connection is transferred from the old AP to the new AP.

The existing research towards the integration of multi-hop and infrastructure networks only aims at Interworking and connectivity without considering the seamless handover experience in these networks. Most of the solutions are based on layer-3 message exchanges, which results into high delay and packet loss in case of handover. Moreover, if in case layer-2 information is used as discussed in [11] [13], no standardized cross-layering mechanism is proposed, which may affect the design, compatibility and extendibility of the entire system. Efficient cross layering mechanisms are required to exchange updated information about the link level characteristics and also from the applications, so that the routing and mobility management protocols can tune their performance and take handover decisions according to the application and link layer characteristics. In [5][18], mobility management strategies based on cross layer designs utilizing IEEE 802.21 handover services are proposed which integrates SIP for session mobility and MIP for terminal mobility as coordinated approaches for network registration.

IEEE 802.21 MIH function [17] acts as a 2.5 layer between the network and link layers; where the main functionality is to mount the link and physical layer events towards applications and to execute commands initiated from the higher layers for the

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lower layers. In 802.21 draft standard, the MIH functionality supports 'client-network' connectivity thus shielding the PUE resources to be exchanged among all PUE member devices. Therefore, the handover procedures and thereby the resources are limited to the extent of the availability of the network entity. This is inconvenient to mobile nodes (MN) when there is no direct network connectivity, but the presence of other MN's with network access. This scenario can be averted by introducing a 'client-client' connectivity aspect to the MIH function and adapting the MIH services accordingly. In this multi-hop 802.21 scenario, the handover information can be useful for the routing and mobility management protocols to offer seamless experience to multi-hop handover. Apart from that, distributing the MIH function provide more flexibility to the heterogeneous personal environment, such as more choice of networks (exploiting the resources available at the neighbouring nodes) and selection of the best network (single/multi-hop) in terms of required-QoS levels.

In this work, we aim at extending the MIH function towards accommodating both the single-hop and multi-hop mode of operation in heterogeneous PUE networks. Our aim is not to enhance the IEEE 802.21 protocol itself, but to effectively use the specific services and the messages associated to these services, offered by the standard, so as to extend the scope of MIH functionality and contrastingly, enable multi-hop heterogeneous networking in PUE environments.

The paper is structured as follows. Section II describes the IEEE 802.21 Media Independent Handover (MIH) enhancement to enable heterogeneous seamless multi-hop handover. In section III, the performance evaluation and comparisons are outlined and discussed. Finally, conclusions and future works are presented in Section IV.

II. MIH SUPPORT FOR MULTI-HOP HETEROGENEOUS NETWORKING SCENARIOS

A. MIH MULTI-HOP COMMUNICATION MODEL AND ARCHITECTURE

The MIH (Media Independent Handover) function communicates between the MN and the heterogeneous access networks available to the MN's. Each access technology either advertises its MIH capability or responds to MIH specific queries. There are mainly 5 communication reference points defined for MIH function which are under the scope of IEEE 802.21, as illustrated in [17]. These reference points specify the essential communication between the MIH functions in the MN's, MIH PoS (Point of Service) and the network PoA (Point of Attachment). The three 802.21 MIH function services: the Event Service (ES), Command Service (CS) and the Information Service (IS) are defined in the 802.21 draft standard to facilitate handover across heterogeneous networks.

To introduce the multi-hop aspect and the 'client-client' connectivity into MIH, we define a new reference point, R6 which assign new roles to the MIH functions of MN's. This is shown in Figure 1. Reference Point R6 refers to MIH specific procedures between MN's. R6 encompass communication interfaces over both L3 and L2 and above, and content exchanged over R6 maybe related to the extended Information Service, Command Service or Event Service. The extended IS, CS and ES are defined for enabling client-client communication and directly depends on the MIH IS, MIH CS and MIH ES, as defined in the IEEE 802.21 standard.

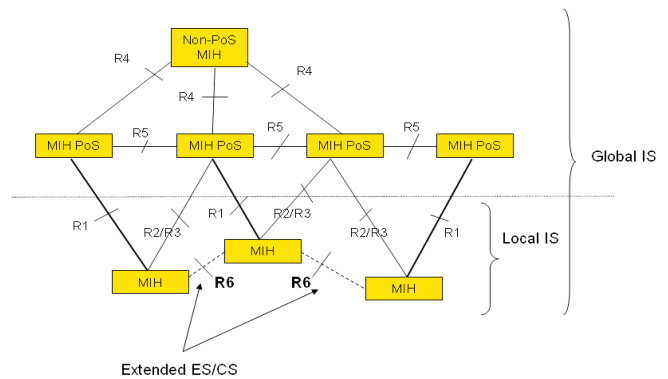


Figure 1: Extended 802.21 MIH Communication Model

For each of the functional services, different extensions introduced for extended MIH support are described below.

MIH Event Service (ES): refers to the events sent from lower layers to the layers in the MIH reference model. The distributed handovers can be initiated by the MN in case of absence of access network or perhaps in the event of specific QoS policies. The Extended ES are used to initiate and help optimize this distributed handover process. The remote MIH events initiated at the user node, which does not have direct connectivity with the network, are relayed by an intermediate user node towards the network. Similarly, the remote events produced at the network are relayed towards the user node (not having one-hop connectivity) in a multi-hop fashion. The local events are largely unaffected by this extension as they stay within the node (or network) itself. The events can also be reported between the nodes (i.e. user node can send the information about certain threshold reached (event) to the neighbouring node(s)).

MIH Command Service (CS): refers to the commands sent from higher layers to the lower layers in the MIH reference model. In case of client-client communication, the extended CS maybe used by the upper layers and other MIH users to determine the status of links, control handover, and control the multi-mode device for optimal performance.

In case of local commands, there is no change since the message exchange stays within the node (or network) itself. Whereas, the remote commands can be send hop-by-hop from the network to the user and vice versa. The multi-hop operation extension not only permits the communication between user and network but also between different users. As in Figure 4, the user node can also send commands to the neighbouring nodes in order to execute certain optimization functions.

MIH Information Service (IS): The Media Independent Global IS is used by a mobile node or a network entity to discover and obtain homogeneous or heterogeneous networks to facilitate seamless handovers across the networks. The purpose of information service is to acquire a global view of the heterogeneous networks to facilitate seamless handovers across those networks. We classify the existing IS element in MIH as the Global Information Service (*Global IS*). The extended MIH IS is termed as the *Local IS*, and has the purpose of acquiring and exchanging local information of the MN's. The local IS messages are exchanged between MN's by virtue of the *HELLO* messages defined at L3, L2 beacons or using wireless ad-hoc routing protocols. The Local IS request messages are also defined similar to MIH Global IS: the MIH Local Information Request and MIH Local Information Response. The local IS related information is stored at the user nodes and shared with

other nodes (when requested). The local IS information includes: available networks, neighbouring nodes topology (network graph), available QoS at each of networks etc. The local IS information is analogous to multi-hop routing protocol information stored at the node, extended with further useful information about the available networks (such as security, QoS and so on). This information is very useful for the nodes that only have multi-hop connectivity with the access network. In such case, the node queries neighbouring nodes to reach the network. The neighbouring node replies after consulting its local information service and provides the list of networks available to it.

Mobile Node Architecture: In order to ensure multi-hop exchange of MIH messages among mobile nodes, a certain set of interfaces between different mobile node components are required. *Local Information Service (IS)* is a new entity which is proposed as a multi-hop enabler of MIH messages. Ad-hoc routing protocol and gateway discovery modules are required to discover routes towards other mobile nodes and infrastructure components respectively. When a mobile node looks for a resource, which is not in its one-hop reach, it consults its Local IS in order to scan the multi-hop environment. The Local-IS having its interfaces with Ad-hoc routing and gateway discovery protocols discover the neighbouring resources. Moreover, the detailed information about available network entities (in single/multi-hop) such as type of AP, its data rate, load, range and address and other information such as Cell-ID (for GSM), SSID (for IEEE 802.11), and BSID (for IEEE 802.16) is stored at Local IS and acquired from the Global IS (running at network entities). The ad-hoc routing protocol coupled with gateway discovery make the mobile node to connect to different network entities in multi-hop manner in order to maintain the interface between Global and Local IS.

B. MIH MULTI-HOP USAGE SCENARIOS

In this section, we present the multi-hop usage scenarios of MIH, where the MIH information is exploited in multi-hop manner for seamless handover and QoS-triggered handover, respectively.

Seamless Multi-hop Handover: As shown in the scenario in Figure 2a, User node A is connected to the Network N and data flow is established. Further, due to the mobility of node A, it moves out of the range of network N and it finds no one-hop connectivity to the network nodes. It soon discovers a link (Personal Network) with a neighbouring node B which has connectivity with network M. Now, the node A connects to the network M in multi-hop manner. The extension of MIH permits this seamless multi-hop handover.

Figure 3 presents the MIH messages exchanged among user nodes and network elements. Once the node A detects a link with node B, it sends a query to node B in order to know which resources are available at B. After consulting its local IS node B replies to A's query, telling that it has connectivity with network M. Node A further acquires information about network M from the connected network. Node A also learns that the link to network N is going down. After consulting (reserving) the resources available at the network M, node A performs authentication and association procedures with network M, whereas node B helps in relaying the MIH messages generated at node A towards the network M. Once the link with network M is established, the handover takes place and node A starts sending data to network M in multi-hop fashion, passing through node B.

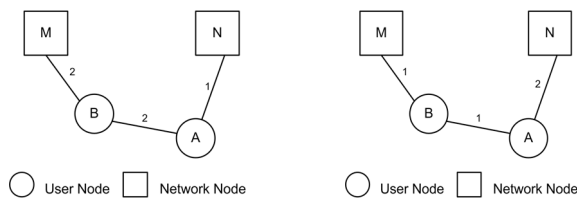


Figure 2: (a) User A moves out of coverage and performs multi-hop handover (b) User A handovers to Network N for QoS needs

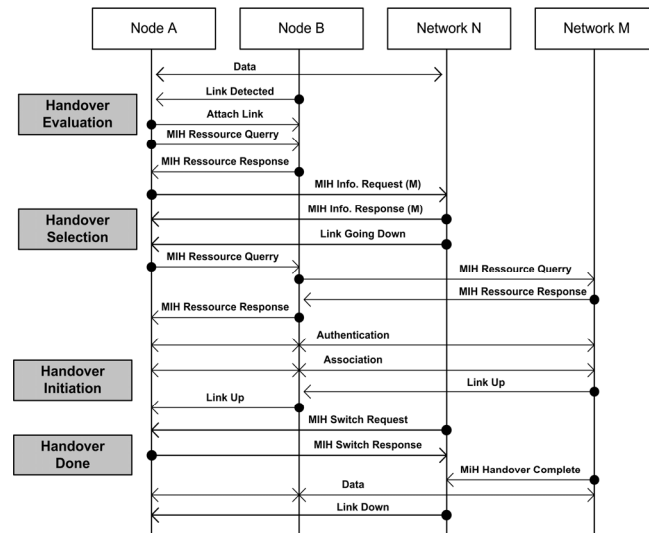


Figure 3: MIH Messages Exchange for Seamless Multi-hop Handover

QoS-triggered Multi-hop handover: As shown in the scenario in Figure 2b, node A is connected to the Network M in a multi-hop fashion and data flow is established. At the same time, node A notifies its QoS requirements to the network. When node A reports to the network that its QoS demands are not met, the network instructs node A to perform handover and connects to the network which is most suitable in terms of QoS. The multi-hop MIH permits this QoS-triggered multi-hop handover.

Figure 4 presents the MIH messages (event, command and information) exchanged among user nodes and network elements. While communicating with network M in multi-hop manner (passing through B), node A communicates its QoS requirements to the connected network M. Based on the QoS requirements, the network M configures node A's threshold for different QoS parameters. Meanwhile, the direct link is detected between node A and network N. As the threshold (set by network M) is crossed for a particular QoS parameter, the link parameter indication report is sent to network M. On this event information, network M instructs the node A to perform the handover and connect to the most suitable network, which meets the QoS demands. After reserving the resources at network N, authentication and association is performed and QoS-triggered handover is executed. Upon success, the old network (i.e. network M) is notified by the current network (i.e. network N). The application running at node A keeps on operating at an optimal QoS level (and is not interrupted with this handover).

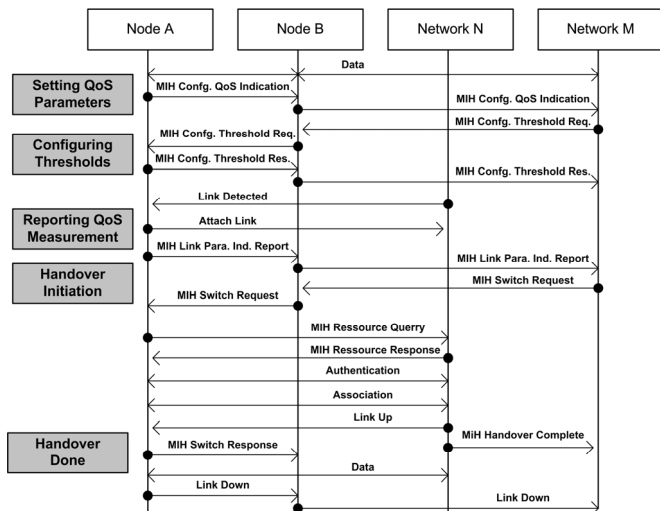


Figure 4: MIH Messages Exchange for QoS-triggered multi-hop handover

III. SIMULATION ANALYSIS

In this section, we evaluate the performance of the media independent seamless multi-hop handover mechanism. We evaluate and analyze the performance of multi-hop MIH in an IEEE 802.11-based hybrid network, using the NS-2 simulator version ns-2.29. We use the 802.21 simulation model contributed by NIST [8], as a part of its integrated simulation platform for NS-2. The 802.21 model is extended with multi-hop operation for event and command services. Furthermore, for multi-hop gateway discovery, we use locally modified and extended version of ad-hoc routing protocol AODV called AODV+ from Hamidian et al. [7], which implements the interconnection between multi-hop network and the Internet. MIPv6 is used for IP connection management. MIPv6 uses the services provided by 802.21 to manage, determine and control the state of the difference interfaces in the multi-hop scenario. The radio channel capacity for each mobile node is 2 Mbps, using the 802.11b DCF MAC layer and a communication range of 250 m. In addition, there are two interconnected gateways (Wi-Fi APs). A fixed node, which is the eventual destination node in the simulation scenarios, is connected directly to one of the gateways. All the fixed links have a bandwidth of 10Mbps. All mobile nodes and APs are 802.21, MIPv6 and AODV+ enabled.

Table 1: Simulation Model Parameters for Multi-hop 802.21

SIMULATION / SCENARIO		MAC / ROUTING	
Simulation Time	200 s	MAC protocol	802.11 DCF
Simulation Area	600 x 600 m ²	Gross Data Rate	11 Mbps
Traffic Type	CBR	Trans. Range	250 m
Data-rate	64 Kbps	Node Speed	1-5 m/s
Packet-size	160 bytes	Mobility Model	Random Way

A. SIMULATION SCENARIOS AND METHODOLOGY

As shown in Figure 5, the simulation scenario consists of a mobile node N1 which is connected to a Wi-Fi AP1 in infrastructure-mode, and sending data to a CN. Then, this node moves away from its AP1 and connects to another AP2 in multi-hop manner. Different simulations are considered varying the number of hops connectivity, when mobile node connects with new AP i.e. AP2. Total of 5 simulation scenarios are

investigated with number of hops constantly increased from 2 to 5. The simulation model parameters are presented in Table 1.

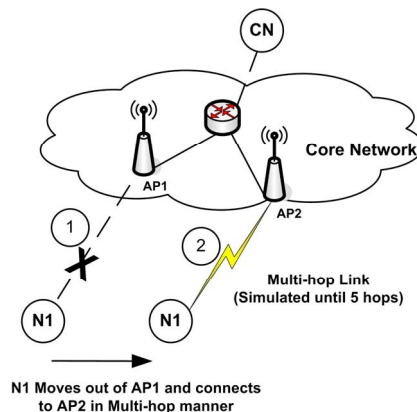


Figure 5: Simulation Scenario - Multi-hop Handover

B. SIMULATION RESULTS AND ANALYSIS

We investigated the performance of extended 802.21 and compared it with classical reactive and proactive gateway discovery protocols. Simulations were carried out with the variable number of hops (varied from 2 to 5). From Figure 6, we clearly see that MIH outperforms proactive and reactive discovery protocols in terms of switching delay. MIH experiences the switching delay of 60ms at 2-hops scenarios and it goes until 100ms for 5-hops scenarios. As expected, reactive discovery experiences more switching delay than proactive mechanism. This performance gain of proactive mechanism is attributed to its control overhead, by periodic gateway advertisements. The packet drops evaluation during the handovers is reported in Figure 7. Reactive discovery experiences the highest number of packet drops. Whereas, proactive and MIH mechanisms exhibit almost similar behaviour with until 3 hops, which further increases at 5 hops.

Finally, the receiver experienced delay is studied in Figure 8. The reported results are quite similar to the switching delay case. MIH outperforms both reactive and proactive discovery approaches and varies between 80 ms to 460 ms, for 2-hop to 5-hop scenarios, respectively. The end-to-end delay can be analysed by comparing switching delay and receiver experienced delay in Figure 7 and Figure 8, respectively. The receiver experienced delay is much higher than the switching delay, for instance, in case of MIH for 5 hops the receiver experienced delay is 460 ms, whereas the switching delay is only 100 ms. These results are quite understandable, as a certain delay is associated with every single hop added in the end-to-end route between the AP and the mobile node. This per hop delay increases the end-to-end delay experienced by each packet, while traversing from the mobile host to the Corresponding Node (CN). Moreover, the time to re-establish the end-to-end route, after handover takes place, also contributes in the increase of receiver experienced delay.

IV. CONCLUSIONS

In this paper, we discussed techniques deemed to be vital in realizing multi-hop seamless handover in the personal environments. The extended model for IEEE 802.21 MIH presented and evaluated in this paper elaborates message exchanges to enhance the functionality of event, command and information service of MIH. This extension to MIH results in offering seamless experience to heterogeneous handover in both single and multi-hop networking scenarios. We analyzed the

problem of handover in multi-hop networks and motivations behind seamless multi-hop handover in personal environments were highlighted.

Numerous problems and open issues remain in the field of seamless multi-hop handover and we are currently addressing most of these challenges. The personal environment is composed of heterogeneous resources and it is desirable to analyze the exchange of event and command service messages between the nodes which are connected to the network on multi-hop heterogeneous interfaces. This requires understanding about how one access network interprets the event/command generated by the other access network. In this paper, we simulated only Wi-Fi network (both infrastructure and ad-hoc mode) for multi-hop handover. We are extending the simulation studies over multi-hop heterogeneous networks.

Moreover, as the multi-hop seamless handover model is composed of routing/gateway discovery module, IP connection management scheme and fast handover component; the Interworking of these components should be analyzed, so that one component does not affect the performance of the other or the entire model. Similarly, these components of multi-hop seamless handover model should be coupled tightly, aimed at reducing the redundancy and duplicate exchange of similar information among nodes/network. Finally, Local Information Service (IS) is stored at each node which constitutes the information about routes to its neighbouring nodes and their available networks. This Local IS shares many similarities with the routing tables of ad-hoc routing protocols. Therefore, it is important to analyze how the routing protocol can be coupled to form this location information base at each node.

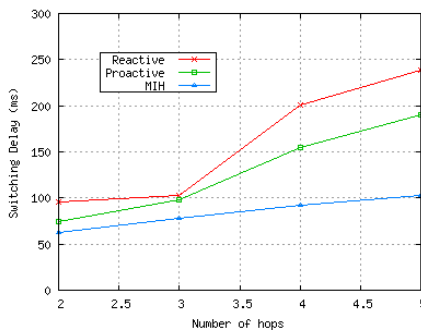


Figure 6: Switching Delay versus Number of hops

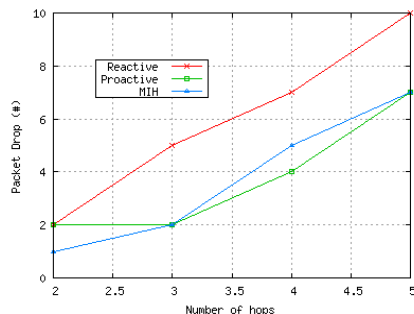


Figure 7: Packet Drops versus Number of hops

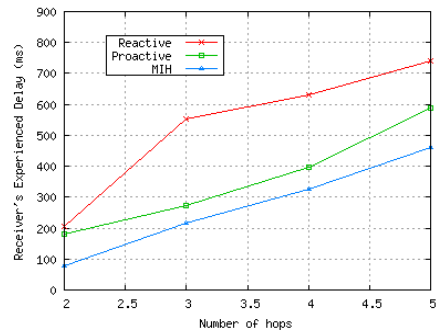


Figure 8: Receiver's Experienced Delay versus Number of hops

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