Hierarchical Neighbor Discovery Scheme for Handover Optimization

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Abstract—In the future mobile Internet, one of the most challenging aspects is to discover the available neighbor access networks and its characteristics as the user moves. Using the IEEE 802.21 Media Independent Handover (MIH) standard, this letter proposes a new neighbor network discovery mechanism, considering a hierarchical view of the network information. Through a NS-2 based simulation, it is shown that the proposed model can significantly improve the mobility user experience.

Index Terms—Heterogeneous networks, IEEE 802.21, media independent handover, mobility.

I. INTRODUCTION

THE integration of different wireless technologies (UMTS, IEEE 802.11 Wi-Fi and IEEE 802.16 Wi-Max) allows mobile users to choose an optimum network interface in accordance with the desired requirements in terms of quality of service (QoS), price, transmission rate, security and other characteristics. The IEEE 802.21 standard [1] aims to facilitate handover procedures in heterogeneous access networks by providing information, events and commands to the entities that assist in the handover decision. In this heterogeneity of technologies, discovering the available access networks is one of the main challenges.

The standard [1] specifies a Media Independent Information Service (MIIS) server supporting various information elements that provide network information within a geographical area. Based on information from several access networks and operators, a Mobile Node (MN) can take an optimized handover decision. The information available via the MIIS can be categorized as:

- General Information and Access Network Specific Information: presents a general overview about the networks covering a specific area such as network type, operator identifier, QoS, security, cost and roaming partners.
- Link connection point information: provides information about Points of Attachment (PoA) for each available access network and categorizes aspects such as geographical location, data rate, channel configuration, and so on.

There are many shortcomings related to the specification of a single MIIS server: 1) too much information to store when hundreds of access networks and dozens of operators exist; 2) can represent a single point of failure and 3) high discovery delay if the MIIS server is located many hops away from the MN. It’s clear that the usage of a single MIIS server for a large city or a whole country with several operators is not desirable. Moreover, this centralized architecture is not scalable when information queries from the MN are highly frequent. Finally, inaccurate or unrelated network information results in sub-optimal handovers. Therefore, in this letter, we propose a hierarchical neighbor discovery scheme which enhances the performance of the MN in terms of experienced throughput and discovery response time.

II. HIERARCHICAL NEIGHBOR DISCOVERY SCHEME

This section describes our proposed scheme and how it supports an optimized MN mobility performance. We argue that a solution considering multiple networks and operators has to contemplate a hierarchical splitting of the existing information. This is due to the fact that the amount and detail of information pertaining to specific PoAs of a single access network, and the combination of all these details for a number of access networks and different operators, may be very large.

The IEEE 802.21 allows the MN to restrict the response message size by optionally setting the MaxResponseSize parameter in the query message. When the response message exceeds the maximum size, some information must be removed from the MIIS response. Clearly, this is not suitable for the user. Removing important information may cause a sub-optimal handover decision. Considering this, and in order to improve the MIIS response in quality, we propose a hierarchical neighbor discovery scheme in which the network coverage area is divided into mobility zones, managed by different MIIS servers as illustrated in Fig. 1.

From bottom to up, the first level of the hierarchy is composed by mobility zones defined by the amount of existing networks, users, while even considering areas where networks are overlapped. In the second level, there are Zone MIIS servers (ZMIIS) which are in charge of supplying...
highly detailed information about specific PoAs in a particular mobility region. The third level refers to the Local MIIS servers (LMIIS) managing information of different mobility zones, which belong to the same operator. Finally, a Global MIIS server (GMIIS) is specified to be used in multi-operator environments. Fig. 2 shows how the hierarchical neighbor discovery scheme operates.

Whenever a MN wishes to obtain information regarding the surrounding networks, it sends a MIH Get Information request message to its ZMIIS server. The MN is able to send this message when it detects a new network or when the signal level has crossed pre-defined thresholds. In this work we have opted for the first method of triggering the MIIS query message. The MN sends a request message to the ZMIIS server through the current PoA link. If the query is related to an entity outside that zone, it is forwarded to the LMIIS server which is able to contact the target zone’s ZMIIS and obtain the required information. In the case that the request zone belongs to another operator, the LMIIS server forwards the message to the GMIIS server, acting as an interface pointer between relevant mobility regions of different operators. In this way, it knows which ZMIIS server holds the desired information, to which it replies using the MIH Get Information response message. In case none of the MIIS servers store information about the detected PoA, the GMIIS server replies with a null MIH Get Information response message.

Accessing critical information from other operators through non-secure links and 3rd party servers raises important security issues. Other than service agreements, the LMIIS servers must be able to access Authentication, Authorization and Accounting (AAA) frameworks where users can be authenticated prior to do the query. One solution in secure interdomain handover is presented in [2]. The authors propose a Media Independent Pre-Authentication (MPA) framework that enhances the inter-domain and inter-technology handover. The MPA specifies that a MN can establish a security association with the candidate network before it attaches to it and, subsequently, undergo a secure communication. Using this method, two or more different MIIS can establish a secure communication and interchange information. We also consider that a node can obtain direct network information without authentication, but in that case the information the MN receives is minimal.

### III. Performance Evaluation

To evaluate our hierarchical MIIS system performance we have implemented the MIIS functionality by enhancing the existing MIH implementation software package NS-2 [6]. The scenario (Fig. 3) features two operators.

The first one holds one UMTS network, two Wi-Fi PoAs and two Wi-Max PoAs. The second operator consists of one Wi-Max PoA. For each single operator the ZMIIS is installed on the Access Router (AR) of an access network and the LMIIS server is installed on the core network side. The GMIIS is a server located in the Internet or some common operator’s backbone. Finally, a multi-modal MIH-capable node

![Fig. 1. Hierarchical neighbor information scheme.](image1)

![Fig. 2. Hierarchical neighbor discovery algorithm.](image2)

![Fig. 3. Simulated heterogeneous scenario.](image3)
is moving through the scenario performing several handovers. The network parameters for the simulation are described in Table I.

Two performance metrics are evaluated (representing the average of fifteen independent runs): the average throughput and the neighbor discovery time.

A. Throughput

We first measure the average throughput experienced by the MN when moving through the scenario illustrated in Fig. 3.

Without using the MIIS functionality, the MN performs handovers to non-optimal PoAs due to the fact that it has no information about their status, as illustrated in the Fig. 4. Using the Standard MIIS, the MN performs optimized handovers, connecting to PoAs with low load values and obtaining a good throughput. However, the standard MIIS does not perform handovers between different operators, and thus does not take advantage of the Wi-Max network from Operator 2, after the 100s mark in the figure. Finally, using the hierarchical MIIS deployment, the MN has knowledge of which networks are good handover candidates. Through the GMIIS, the MN performs an inter-operator handover in the 100s mark, achieving much better throughput with the new link.

B. Neighbor Discovery Time

We also evaluated the neighbor discovery time, which is the total time from the instant the MN requests information up to the time when the MN receives a response from any MIIS server. The time mainly depends on two variables: the wired link delay and the hop count between the MN and the MIIS server. For this scenario, the one-way wired delay is set to 5ms and the hop count is summarized in Table II, close to the values used in [4].

Considering these times, the ZMIIS has a very fast response time, allowing the MN to make optimized handover decisions. The Standard MIIS and the LMIIS provide similar discovery times since they have the same physical location inside the network. However, the LMIIS presents two main benefits: 1) a high-level control about the information by knowing to which ZMIIS to redirect the requests; 2) a greater degree of options for MN handover is possible by filtering and pushing information between zones. The GMIIS presents a clear tradeoff between response time and handover quality, allowing inter-operator handovers. As values for comparison with other schemes: [5] presents a query delay of 2.2s for a MIIS centralized implementation and [3]-[4] show that the MN may experience discovery delays ranging from 80ms to 5.8s, depending on the technology and the scanning method.

IV. CONCLUSION

This letter presented a framework for storing network information in a hierarchical way while enabling multiple-operator scenarios. This information provides mobile terminals with a complete and consistent view of surrounding handover possibilities. The framework was compared with schemes featuring no MIIS server or with the standard centralized MIIS server, showing that our hierarchical solution is able to provide the terminal with optimized handover choices.

REFERENCES