# IEEE 802.21 (Media Independent Handover services) Overview

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*Abstract*— In recent years, multi-technology enabled terminals are becoming available. Such multi-mode terminals pose new challenges to mobility management. In order to address some of these challenges, the IEEE is currently working on a new specification on Media Independent Handover services (IEEE 802.21 MIH). The main aim of this specification is to improve user experience of mobile terminals by enabling handovers between heterogeneous technologies while optimizing session continuity. In this article, we provide an overview of the current status of the IEEE 802.21 specification.

#### I. INTRODUCTION

Several indicators point towards the coexistence of heterogeneous networks in the future. Some operators and manufacturers have already taken up the development and introduction of dual-mode and multi-mode handsets to permit connectivity across 3G and WLAN-based networks among other technologies. In such a scenario, future users will expect that their mobile terminal is capable of detecting the different wireless technologies available and selecting the most appropriate one based on the information that the terminal can gather about neighboring cells. In this context, the IEEE is currently working on the specification of a new standard called IEEE 802.21 MIH (Media Independent Handover Services). While the completion of the 802.21 standard is planned for the end of 2007, the main lines of the future standard have already been agreed upon. The rest of the article is based on the latest version of the IEEE 802.21 standard draft [1].

The main purpose of IEEE 802.21 is to enable handovers between heterogeneous technologies (including IEEE 802 and cellular technologies) without service interruption, hence improving user experience of mobile terminals. Many functionalities required to provide session continuity depend on complex interactions that are specific to each particular technology. 802.21 provides a framework that allows higher levels to interact with lower layers to provide session continuity without dealing with the specifics of each technology. That is, the upcoming protocol can be seen as the "glue" between the IP centric world developed in IETF and the reference scenarios for future mobile networks currently being designed in 3GPP and 3GPP2 or other technology specific solutions. Additionally, while IETF does not cover specific layer-2 technologies, 3GPP/3GPP2 only addresses cellular technologies and how to integrate in them upcoming technologies such as WLAN. IEEE 802.21 provides the missing, technology-independent, abstraction layer able to provide a common interface to upper layers, thus hiding technology specific primitives. This abstraction can be exploited by IP stack (or any other upper layer) to better interact with the underlaying technologies, ultimately leading to an improved handover performance.

Section II deepens on the aims and objectives of 802.21. To achieve these goals, IEEE 802.21 defines a media independent entity that provides a generic interface between the different link layer technologies and the upper layers. To handle the particularities of each technology, 802.21 maps this generic interface to a set of media dependent Service Access Points (SAPs) whose aim is to collect information and to control link behavior during handovers. In addition, a set of remote interfaces terminal-network and network-network are defined to convey the information stored at the operator's network to the appropriate locations, e.g. to assist the terminal in handover decisions. All of these aspects, are covered by the 802.21 reference model and architecture which are explained on section III. All the functionality of 802.21 is provided to the users by a set of services, namely Event, Command and Information services. These services are the core of the specification and define the semantic model of the communication with the lower layers and with the network. A detailed explanation of the services can be found on section IV. To conclude this work, section V presents a use case of inter-technology handover and section VI sketches some open topics currently under development.

# II. 802.21 OBJECTIVES

Following the lines presented in the introduction, the contribution of the 802.21 standard is centered around the following three main elements:

*i*. A framework that enables seamless handover between heterogeneous technologies. This framework is based on a protocol stack implemented in all the devices involved in the handover. The defined protocol stack aims at providing the necessary interactions among devices for optimizing handover decisions.

- *ii.* The definition of a new link layer SAP that offers a common interface for link layer functions which is independent of the technology specifics. For each of the technologies considered in 802.21, this SAP is mapped to the corresponding technology-specific primitives. The standard draft includes some of these mappings.
- *iii.* The definition of a set of handover enabling functions that provide the upper layers (like e.g. mobility management protocols such as Mobile IP[2]), with the required functionality for performing enhanced handovers. These functions trigger, via the 802.21 framework, the corresponding local or remote link layer primitives defined above.

Although the main purpose of IEEE 802.21 is to enable the handover between heterogeneous technologies, a set of secondary goals have also been defined. These secondary goals are:

- Service Continuity, defined as the continuation of the service during and after the handover procedure. One of the main goals of 802.21 is to avoid the need for restarting a session after a handover.
- Handover aware applications. The 802.21 framework provides applications with functions for participating in handover decisions. For instance, a voice application may decide to execute a handover during a silence period in order to minimize service disruption.
- QoS (Quality of Service) aware handovers. The 802.21 framework provides the necessary functions in order to take handover decisions based on QoS criteria. For instance, we may decide to handover to a new network that guarantees the desired QoS.
- Network discovery. This is an 802.21 feature that allows to provide users with information on the candidate neighbors for a handover.
- Network selection assistance. Network selection is the process of taking a handover decision based on several factors (such as QoS, throughput, policies or billing). In line with the above, the 802.21 framework only provides the necessary functions to assist network selection, but does not take handover decisions which are left to the higher layers.
- Power Management can also benefit from the information provided by 802.21. For instance, power consumption can be minimized if the user is informed of network coverage maps, optimal link parameters or 'sleep' or 'idle' modes.

# III. IEEE 802.21 ARCHITECTURE

In this section we present the general architecture of IEEE 802.21. We describe the different layers in the 802.21 protocol stack and their interaction, both at the node and network level. Figure 1 shows the logical diagram of the general architecture of the different nodes in an 802.21 network. It shows a Mobile Node with an 802 interface and a 3GPP one, and that is currently connected to the network via the 802 interface. The figure shows the internal architecture of the Mobile Node, the 802 network, the 3GPP network and the Core Network.



Fig. 1. 802.21 General Architecture.

As it can be observed from the figure, all 802.21 compliant nodes have a common structure surrounding a central entity called MIHF (the Media Independent Handover Function). The MIHF acts as intermediate layer between the upper and lower layers whose main function is to coordinate the exchange of information and commands between the different devices involved in taking handover decisions and executing the handovers. From the MIHF perspective, each node has a set of MIHF users, which will typically be mobility management protocols, that use the MIHF functionality to control and gain handover related information. The communications between the MIHF and the other functional entities such as the MIHF users and the lower layers are based on a number of defined service primitives that are grouped in Service Access Points (SAPs). Currently, the following SAPs are included in the 802.21 standard draft (see Figure 1):

- MIH\_SAP: This interface allows communication between the MIHF layer and the higher layer MIHF users.
- MIH\_LINK\_SAP: This is the interface between the MIHF layer and the lower layers of the protocol stack.
- MIH\_NET\_SAP: This interface supports the exchange of information between remote MIHF entities.

It is worth to notice that all communications between the MIHF and lower layers are done through the MIHLLINK\_SAP. This SAP has been defined as a media independent interface common to all technologies, so that the MIHF layer can be designed independently of the technology specifics. However, these primitives are then mapped to technology specific primitives offered by the various technologies considered in 802.21. A table with the mapping of the primitives of several technologies is included in the 802.21 draft. Figure 2 presents the 802.21 reference model, which includes the following network entities:

• MIH Point of Service (MIH PoS): This is a network entity that exchanges MIH messages with the Mobile Node. Note that a Mobile Node may have different PoS as it may



Fig. 2. Reference Model.

exchange messages with more than one network entity. This is the case, for instance, in the example of Figure 2.

- MIH non-PoS: This is a network entity that does not exchange MIH messages with the Mobile Node. Note that a given network node may be a PoS for a Mobile Node with which it exchanges MIH messages and a non-PoS for a network node for which it does not.
- MIH Point of Attachment (PoA): This is the endpoint of a L2 link that includes the Mobile Node as the other endpoint.

In order to make the communication between these network entities possible, the reference model specifies several communication reference points:

- Communication Reference Point R1 ("MN↔Serving PoA (PoS)"): This communication reference point is used by the Mobile Node to communicate with its PoA. Among other purposes, it may be used by the Mobile Node to gather information about the current status of its connection.
- Communication Reference Point R2 ("MN↔Candidate PoA (PoS)"): This communication reference point is used by the Mobile Node to communicate with a candidate PoA. It may be used to gather information about candidate PoAs before taking a handover decision.
- Communication Reference Point R3 ("MN↔non-PoA (PoS)"): This communication reference point is used by the Mobile Node to communicate with a MIH PoS

located on a non-PoA Network Entity. It may be used by a network node to inform the Mobile Node about the different IP configuration methods in the network.

- Communication Reference Point R4 ("PoS↔non-PoS"): This communication reference point is used for communications between a MIH PoS and a MIH non-PoS. This reference point is typically used when a MIH server that is serving a Mobile Node (the PoS) needs to ask for information to another MIH server (the non-PoS).
- Communication Reference Point R5 ("PoS↔PoS"): This communication reference point is used between two different MIH PoS located at different network entities.

#### **IV. MIH SERVICES**

The 802.21 architecture and reference model explained on section III, present a framework which support a complex exchange of information aiming at enabling seamless handover between heterogeneous technologies. 802.21 defines three different types of communications with different associated semantics, the so called MIH services. The three services are, i)Event services (ES), ii) Command Services (CS) and iii) Information Services (IS). These services allow the MIHF users to access handover related information as well to deliver commands to the link layers or to the network. The MIH services can be delivered in an asynchronous or synchronous way. Events generated in link layers and transmitted to the MIHF or MIHF users are delivered by an asynchronous method, while commands and information, generated by a



Fig. 3. Event, command and information services flow mode.

query/response mechanism are delivered in a synchronous way.

#### A. Media Independent Event Service

The IEEE 802.21 supports handover initiated by the network or the mobile terminals, hence, events related with handovers can be originated at the MAC layer or MIHF layer located in the node or at the point of attachment to the network. As several entities could be interested in the generated events, the standard specifies a subscription delivery mechanism. All entities interested in a event type should register to it, when the event is generated it will be delivered to the subscription list. MIH remote events may be delivered using the R1 ("MN $\leftrightarrow$ Serving PoA (PoS)"), R2 ("MN $\leftrightarrow$ Candidate PoA (PoS)") and R3 ("MN $\leftrightarrow$ non-PoA (PoS)") reference points of the model explained in section III.

It is important to notice that an entity is not forced to react on the reception of an event, being event's nature advisory.

Events can be divided in two categories, Link Events and MIH Events. Link Events are generated within the link layer and received by the MIHF. Events that are propagated by the MIHF to the MIHF users are called MIH Events. Note that Link Events propagated to upper layers become MIH Events. Entities being able to generate and propagate Link Events are the defined IEEE 802.x, 3GPP and 3GPP2 MIH\_LINK\_SAP interfaces.

The Media Independent Event Service can support several event types:

- MAC and PHY State Change events: These events inform about a definite change in the MAC or PHY state. An example of this type of events are the Link Up or Link Down events.
- Link Parameters events: These events are generated due to a change in the link layer parameters. They can be generated in a synchronous way (a parameters report on a regular basis) or by an asynchronous method like reporting when a specific parameter reaches a threshold.

- Link Synchronous events: These events report deterministic information about link layer activities that are relevant to higher layers. The information delivered does not need to be a change in the link parameters, it can be indications about link layer activities such as the native link layer handover methods which are performed autonomously by the link layer, independently from the global mobility protocol.
- Link Transmission events: These events inform of the transmission status of higher layers PDUs by the link layer. By these events, the link layer may inform the higher layer of the losses in the ongoing handover. This information can be used to dimension the buffers needed for seamless handover or to adopt different retransmission policies at higher layers.

The communication flow followed by events is shown in figure 3. As an example of use, event services are helpful to detect when a handover is possible. There are several events such as Link Up, Link Down or Link Parameters Change that could be used to detect when a link has become available or when the radio conditions of this link are appropriate to perform a handover to this new link. Examples of event services used to detect new links and their parameters can be found in [3], [4] and [5].

## B. Media Independent Command Service

The Media Independent Command Service (MICS) refers to the commands sent from the higher layers to the lower layers in order to determine the status of links or control and configure the terminal to gain optimal performance or facilitate optimal handover policies. The mobility management protocols should combine dynamical information regarding link status and parameters, provided by the MICS with static information regarding network status, network operators or higher layer service information provided by the Media Independent Information Service, to help in the decision making. The receipt of a certain command request may cause event generation, and in this way the consequences of a command could be followed by the network and related entities. Commands can be delivered locally or remotely. Through remote commands the network may force a terminal to handover, allowing the use of Network Initiated Handovers and Network Assisted Handovers. A set of commands are defined in the specification to allow the user to control lower layers configuration and behavior, and to this end some PHY layer commands have being specified too. The communication flow mechanism is shown in figure 3. MIH remote commands may be delivered by the R1 ("MN↔Serving PoA (PoS)"), R2 ("MN⇔Candidate PoA (PoS)"), R3 ("MN⇔non-PoA (PoS)") and R5 ("PoS↔PoS") reference points.

Commands are classified into two main categories:

• MIH Commands: These commands are sent by the higher layers to the MIHF, in the case the command is addressed to a remote MIHF, it will be sent to the local MIHF which will deliver the command to the appropriate destination through the MIHF transport protocol. To enable network initiated handovers as well as mobile initiated handovers, the command service provides a set of commands to help with network selection. Examples of such commands are MIH Handover Initiated or MIH Handover Prepare. It is worth to notice that all these commands do not affect the routing of user packets. All commands are designed to help in the handover procedure but the routing of the user packets is left to the mobility management protocols located at higher layers, like Mobile IP or SIP [6].

• Link Commands: These commands are originated in the MIHF, on behalf of the MIH user, in order to configure and control the lower layers. Link commands are local only and should be implemented by technology dependant link primitives to interact with the specific access technology. New link commands shall be defined as amendments to the current technology standard.

#### C. Media Independent Information Service

Media Independent Information Service (MIIS) provides a framework through which an MIHF located in a user terminal or in the network is able to acquire network information within a geographical area to facilitate handovers. The objective is to gain knowledge about all heterogeneous networks in the area of interest of the terminal to facilitate handovers when roaming across these networks.

MIIS is based in Information Elements (IEs) and these elements provide information essential to the network selection algorithm to make a successful handover across heterogeneous networks and technologies. The information provided by the IEs can be related to lower layers such as neighbor maps. coverage zones and other link parameters. Information related with higher layer services such as lack of internet connectivity in certain zones or availability of certain services may also be provided. MIIS is designed to provide information mainly about 802, 3GPP and 3GPP2 networks, although this list may be extended in the future. All the information related not only to the technology the mobile node is currently attached to, but the surrounding available technologies can be accessed from any single technology. As an example, a MN connected to a 802 network such as WiFi, will be able to gather information about the 3G cellular network within its geographical area, without the need to power up its 3G interface to obtain this information. This characteristic allows an optimal power utilization.

The main goal of MIIs is to provide the MN with essential information that may affect the selection of the appropriate networks during a handover. The information provided by this service is intended to be mainly static, primary being used by policy engines which do not require dynamic and updated information, although network changes may be accounted for. The dynamic information about the active networks should be obtained by the use of the MIH Event and Command services explained in sections IV-A and IV-B.

The Information Elements (IE) provided by the MIIS can be divided in the following groups:

- General Information: These IEs give a general overview about the networks covering an specific area such as network type, operator identifier or service provider identifier.
- Access Network Specific Information: These IEs provide specific information for each technology and operator. The information is related to security characteristics, QoS information, revisions of the current technology standard in use, cost, roaming partners etc..
- Point of Attachment (PoS) Specific Information: These IEs provide information for each PoA (for each technology and operator). The information comprises aspects like MAC address of the PoA, geographical location, data rate, channel range etc..
- Higher Layers services/information per PoA: The information provided is related with the available services on this PoA and network. The information provided may be the number of subnets this PoS support, the IP configuration methods available, or even a list of all supported services of the PoA.
- Other Information can be added, like vendor specific information or services.

It is important to note that the MN should be able to discover whether the network supports IEEE 802.21 by the use of a discovery mechanism or information obtained by MIIS through another interface. It is also important that the MN is able to obtain MIIS information even before the authentication in the PoA is performed in order to be able to check the security protocols, support of QoS, or other parameters before performing a handover. The communication between the different entities of the IEEE 802.21 network in order to gather information related to the MIIS may be performed through all the communication reference points defined in section III.

# V. USE CASE: INTER-TECHNOLOGY HANDOVER PROCEDURE

Figure 4 shows the message exchange involved in a mobile initiated handover from 3G to WLAN. In the following a detailed explanation of the messages and procedures is presented:

- The handover procedure starts by the MIH User of the MN querying the MIHF located on the MN itself about the surrounding networks (message 1). This query is forwarded by the MIF to the information server located in the operator network (or a third party network). The query is started by message 1 and answered by message 4. Through these four messages the MN gets the required information in order to gain an understanding of the networks to which perform a handover while roaming through this specific geographical area. As the answer contains information regarding a possible WLAN network, the MN switches on its WLAN interface and starts listening for beacons.
- Once a beacon is received, the IEEE 802.11 link layer will generate a Link\_Detected.indication event (message 5). The link layer, through an IEEE 802.11 defined primitive, indicates the detection of a new link. This



Fig. 4. Inter-technology Handover Example.

primitive is mapped into the event through the use of the MIH\_LINK\_SAP. This indication is forwarded by the MIHF to the MIH User on message 6.

 When the MIH User receives the MIH\_Link\_detected.indication, it triggers the mobileinitiated handover by sending to its PoS (located on the 3G network) the information regarding potential candidate networks discovered up to the moment. This information is sent on message 7 to the MIHF which forwards this query to the serving PoS (message 8).

• After receiving message 8, the serving PoS starts querying the available candidate networks (taking into account the information provided by the MN) asking for the list of resources available and including the QoS requirements of the user (exchange 9). This is performed by a successive exchange of Query\_Resources messages with one or several candidate PoSs. The result of the queries is sent to the MN through message 10 and 11. At this point, the MN have enough information about the surrounding networks to take a decision on the network to which hand over.

- Once the MIH User has decided the target network to hand over, it delivers a Switch command to the MIHF (message 12) which will trigger a WLAN L2 connection. After issuing the commands to start the WLAN connection establishment, the MIHF sends an event to the MIH User indicating the start of the connection (message 13). Once the connection is established, the WLAN MAC layer issues an event reporting the end of the L2 handover to the MIHF (message 14) which will be forwarded to the MIH User (message 15).
- Once message 15 is received a higher layer handover procedure can start. In this case Mobile IP has been selected, although any other mobility management protocol would be equally suited.
- When the handover is completed at the higher layers, the MIH User sends a MIH\_HO\_Complete message to the MIHF which will inform the target PoS (messages 16 and 17) which becomes the new serving PoS. At this point the target PoS informs all the implied network entities of the handover finalization (exchange 18). Specifically, the Target PoS has to inform the serving PoS of the handover completion so it can release any resources.
- Finally message 19 close the handover procedure, indicating to the MN that the procedure has finished, and message 20 informs the MIH User.

#### VI. CONCLUSION AND OPEN ISSUES

On this work, we provided an overview of the current status of the upcoming IEEE 802.21 specification. The IEEE 802.21 aim is to enable inter-technology handovers maximizing session continuity as a way of improving users' satisfaction while using mobile terminals. Mobile terminals are used worldwide nowadays, and even more, terminals with several interfaces and access technologies are starting to be introduced in the market. Envisioning such scenario, the IEEE 802.21 specification will play an important role on near future communications, providing technological solutions for layer 2 inter-technology handovers and interfaces with layer 3 mobility solutions.

Open issues include the integration of 802.21 with the IP transport layer for layer three transport. In the IETF MIPSHOP WG efforts are currently undergoing to specify a protocol for mobility services transport. Document [7] gives general statements on what issues the solution space document should address. Another open issue not addressed in 802.21 is the use of different transport technologies to carry 802.21 transactions. A typical scenario could include a layer two transport (802

networks) on the wireless link up to the PoA, and a layer three transport between the PoA and the PoS. Such scenario is referred in the draft as proxy scenario. Initially proposed for information services only, in [8] the authors propose to use the same mechanisms as well for event and command services. Utilizing such an approach brings a certain number of advantages. Since the proxy method allows two MIH peers to complete a handshake while one of the peers contacts a third MIH peer to make information available at the requesting peer, the mobile node implementing the MIHF does not need to discover a specific IS/ES/CS server when it contacts its default up-link MIH peers (discovered via 802.21 specific mechanisms). An alternative application of the proxy scenario is the centralized approach for network initiated handovers discussed in [9]. In fact, while the current draft does not prevent the execution of NIHO, a more optimized approach could be possible with slight modifications to the current specifications. Thus, the document [9] presents the necessary modifications, namely better network to network message exchange, enabling a centralized mechanism for network controlled and initiated handovers.

#### REFERENCES

- "Draft IEEE Standard for Local and Metropolitan Area Networks: Media Independent Handover Services (Draft 05)." IEEE May 2007.
- [2] D. Johnson, C. Perkins, and J. Arkko, "Mobility Support in IPv6," in *RFC 3775.* IETF, 2004.
- [3] T. Melia, A. de la Oliva, I. Soto, C. J. Bernardos, and A. Vidal, "Analysis of the effect of mobile terminal speed on WLAN/3G vertical handovers." IEEE Global Telecommunications Conference (GLOBECOM), San Francisco, California, USA, 27 November - 1 December 2006.
- [4] A. de la Oliva, T. Melia, A. Vidal, C. J. Bernardos, I. Soto, and A. Banchs, "A case study: IEEE 802.21 enabled mobile terminals for optimised WLAN/3G handovers." accepted to appear in Mobile Computing and Communications Review (M2CR).
- [5] T.Melia, D.Corujo, A. de la Oliva, A. Vidal, R. Aguiar, and I.Soto, "Impact of heterogeneous network controlled handovers on multi-mode mobile device design." Presented at IEEE Wireless Communications and Networking Conference 2007 - Networking.
- [6] J. Rosenberg, H. Schulzrinne, G. Camarillo, A. Johnston, J. Peterson, R. Sparks, M. Handley, and E. Schooler, "SIP: Session Initiation Protocol," in *RFC 3261*. IETF, June 2002.
- [7] T. Melia, E. Hepworth, S. Sreemanthula, Y. Ohba, G. Vivek, J. Korhonen, R. Aguiar, and S. Xia, "Mobility Independent Services: Problem Statement," in *draft-ietf-mipshop-mis-ps-00*. IETF, January 7, 2007.
- [8] A. Vidal, T. Melia, and A. Banchs, "Proxy functionality for Event Service and Command Service," November 2006. [Online]. Available: http://www.ieee802.org/21/doctree/2006-11\_meeting\_docs/21-06-0795-00-0000-ES\_CS\_Proxy.doc
- [9] A. Vidal and T. Melia and A. Banchs, "Support for Centrally Coordinated Network Initiated Handovers," November 2006. [Online]. Available: http://www.ieee802.org/21/doctree/2006-11\_meeting\_docs/21-06-0783-00-0000-centralized\_NIHO.doc