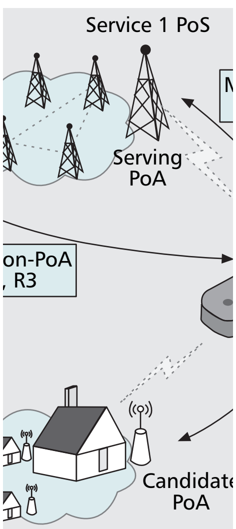
AN OVERVIEW OF IEEE 802.21: MEDIA-INDEPENDENT HANDOVER SERVICES

ANTONIO DE LA OLIVA, ALBERT BANCHS, IGNACIO SOTO, UNIVERSIDAD CARLOS III DE MADRID
TELEMACO MELIA, NEC NETWORK LABORATORIES
ALBERT VIDAL, I2CAT FOUNDATION



In recent years, multi-technology enabled terminals are becoming available. Such multi-mode terminals pose new challenges to mobility management. To address some of these challenges, the IEEE is working on a new specification on Media Independent Handover services.

ABSTRACT

In recent years multitechnology-enabled terminals have become available. Such multimode 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.

INTRODUCTION

Several indicators point toward the coexistence of heterogeneous networks in the future. Some operators and manufacturers have already taken up the development and introduction of dual-mode and multimode handsets to permit connectivity across third-generation (3G) and wireless LAN (WLAN)-based networks, among other technologies. In such a scenario future users will expect their mobile terminal to be capable of detecting the different wireless technologies available and selecting the most appropriate one based on the information 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, media-independent handover services (MIH). While completion of the 802.21 standard was planned for the end of 2007, the main lines of the future standard were already agreed on before that point. 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 the user experience of mobile terminals. Many functionalities required to provide session continuity depend on complex interactions that are specific to each particular technology. IEEE 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 the Internet Engineering Task Force (IETF), and the reference scenarios for future mobile networks currently being designed in the Third Generation Partnership Project (3GPP) and 3GPP2 or other technology specific solutions. While the IETF does not address specific layer 2 technologies, the interest of 3GPP/3GPP2 in noncellular layer 2 technologies, such as WLAN, is restricted to its integration into cellular environments. IEEE 802.21 provides the missing, technology- independent, abstraction layer able to offer a common interface to upper layers, thus hiding technology-specific primitives. This abstraction can be exploited by the IP stack (or any other upper layer) to better interact with the underlying technologies, ultimately leading to improved handover performance.

We deepen 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 service interface to a set of media-dependent service access points (SAPs) whose aim is to collect information and 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, explained later. All the functionality of 802.21 is provided to the users by a set of services: Event, Command, and Information. These services are the core of the specification, and define the semantic model of the communication with the lower layers and

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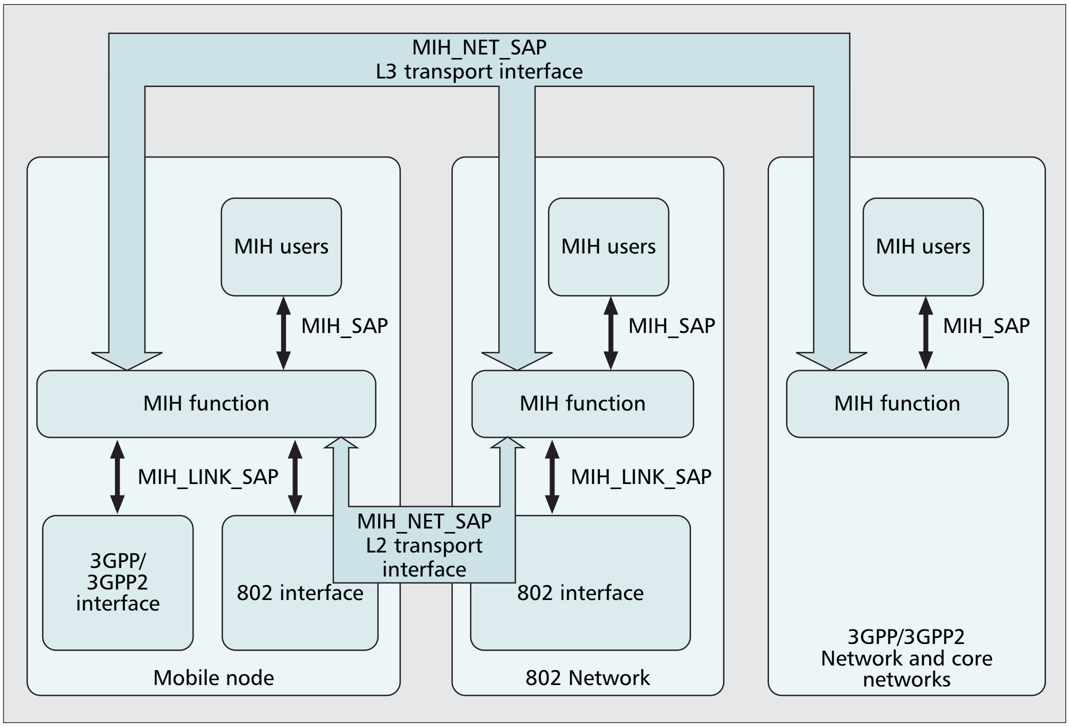


Figure 1. *802.21 general architecture.*

Power Management can 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.

the network. A detailed explanation of the services can be found later. To conclude this work, we present a use case of intertechnology handover and sketch some open topics currently under development.

802.21 Objectives

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

- 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 to provide the necessary interactions among devices for optimizing handover decisions.
- The definition of a new link layer SAP that offers a common interface for link layer functions and 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.
- The definition of a set of handover enabling functions that provide the upper layers (e.g., mobility management protocols such as Mobile IP [2]), with the required functionality to perform 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 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 to restart 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.
- Quality of service (QoS)-aware handovers. The 802.21 framework provides the necessary functions in order to make handover decisions based on QoS criteria. For instance, we may decide to hand over to a new network that guarantees the desired QoS.
- Network discovery. This is an 802.21 feature that allows users to be provided with information on candidate neighbors for a handover.
- Network selection assistance. Network selection is the process of making a handover decision based on several factors (e.g., QoS, throughput, policies, and billing). In line with the above, the 802.21 framework only provides the necessary functions to assist network selection, but does not make 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.

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 at both the node and network levels.

It is worth noticing that communications between the MIHF and lower layers are done through the MIH LINK 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.

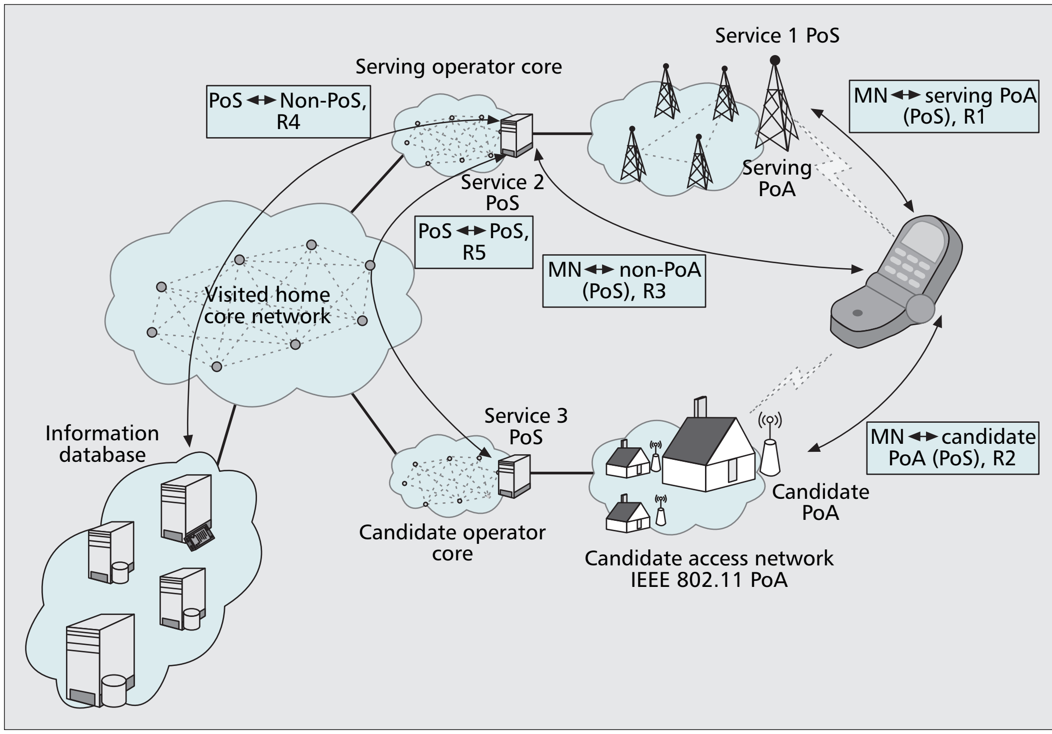


Figure 2. *Reference model.*

Figure 1 shows a 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, 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. As can be observed from the figure, all 802.21-compliant nodes have a common structure surrounding a central entity called the media-independent handover function (MIHF). The MIHF acts as an 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 making handover decisions and executing handovers. From the MIHF perspective, each node has a set of MIHF users, typically mobility management protocols, that use the MIHF functionality to control and gain handover-related information. The communications between the MIHF and other functional entities such as the MIHF users and lower layers are based on a number of defined service primitives that are grouped in SAPs. Currently, the following SAPs are included in the 802.21 standard draft (Fig. 1):

- MIH_SAP: This interface allows communication between the MIHF layer and 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 noticing that all communications between the MIHF and lower layers are done through the MIH LINK SAP. This SAP has been defined as a media-independent interface common to all technologies, so the MIHF layer can be designed independent 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 the MIH LINK SAP interface to the link 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 PoSs as it may exchange messages with more than one network entity. This is the case, for instance, in the example of Fig. 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 layer 2 link that includes the mobile node as the other endpoint.

In order to make 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 making a handover decision.
- Communication reference point R3 (MN↔non-PoA (PoS)): This communication reference point is used by the mobile node to communicate with an 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 an MIH PoS and an MIH non-PoS. This reference point is typically used when an MIH server that is serving a mobile node (the PoS) needs to ask for information from another MIH server (the non-PoS).
- Communication reference point R5 (PoS↔PoS): This communication reference point is used between two different MIH PoSs located at different network entities.

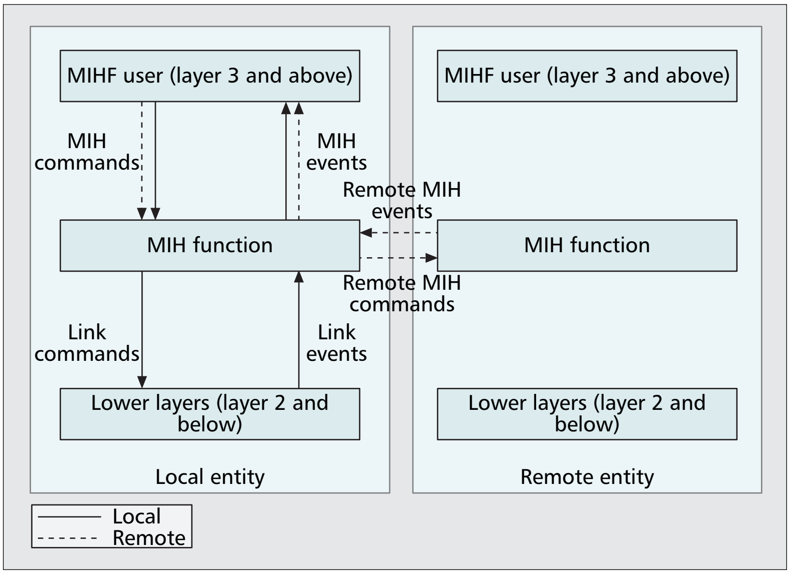


Figure 3. *Event, command and information services flow mode.*

MIH Services

The 802.21 architecture and reference model explained earlier present a framework that supports a complex exchange of information aiming to enable seamless handover between heterogeneous technologies. IEEE 802.21 defines three different types of communications with different associated semantics, the so-called MIH services:
- Event services (ES)
- Command services (CS)
- Information services (IS)

These services allow MIHF users to access handover-related information as well as deliver commands to the link layers or network. MIH services can be delivered asynchronously or synchronously. Events generated in link layers and transmitted to the MIHF or MIHF users are delivered asynchronously, while commands and information generated by a query/response mechanism are delivered synchronously.

Media-Independent Event Service

The IEEE 802.21 supports handover initiated by the network or mobile terminals; hence, events related to handovers can be originated at the medium access control (MAC) 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 an 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↔Serving PoA (PoS)), R2 (MN↔Candidate PoA (PoS)), and R3 (MN↔non-PoA (PoS)) reference points of the model explained above. It is important to note that an entity is not forced to react to the reception of an event, being event-nature-advised. Events can be divided in two categories, link and MIH. Link events are generated within the link layer and received by the MIHF. Events that are propagated by the MIHF to MIHF users are called MIH events. Note that link events propagated to upper layers become MIH events. Entities 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 MAC or PHY state. Examples of this type of events are link up and link down events.
- Link parameters events: These events are generated by a change in the link layer parameters. They can be generated in a synchronous way (a parameters report on a regular basis) or asynchronously such as by 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 of link layer activities such as the native link layer handover methods that are performed autonomously by the link layer, independent of the global mobility protocol.
- Link transmission events: These events inform of the transmission status of higher-layer protocol data units (PDUs) by the link layer. By these events, the link layer may inform the higher layer of losses in an 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 Fig. 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 the radio conditions of this link are

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.

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 [3–5].

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 dynamic 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 hand over, 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 Fig. 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; if 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 noting that none of these commands affect the routing of user packets. All commands are designed to help in the handover procedure, but the routing of 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.

Media Independent Information Service

Media-independent information service (MIIS) provides a framework through which an MIHF located in a user terminal or 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.

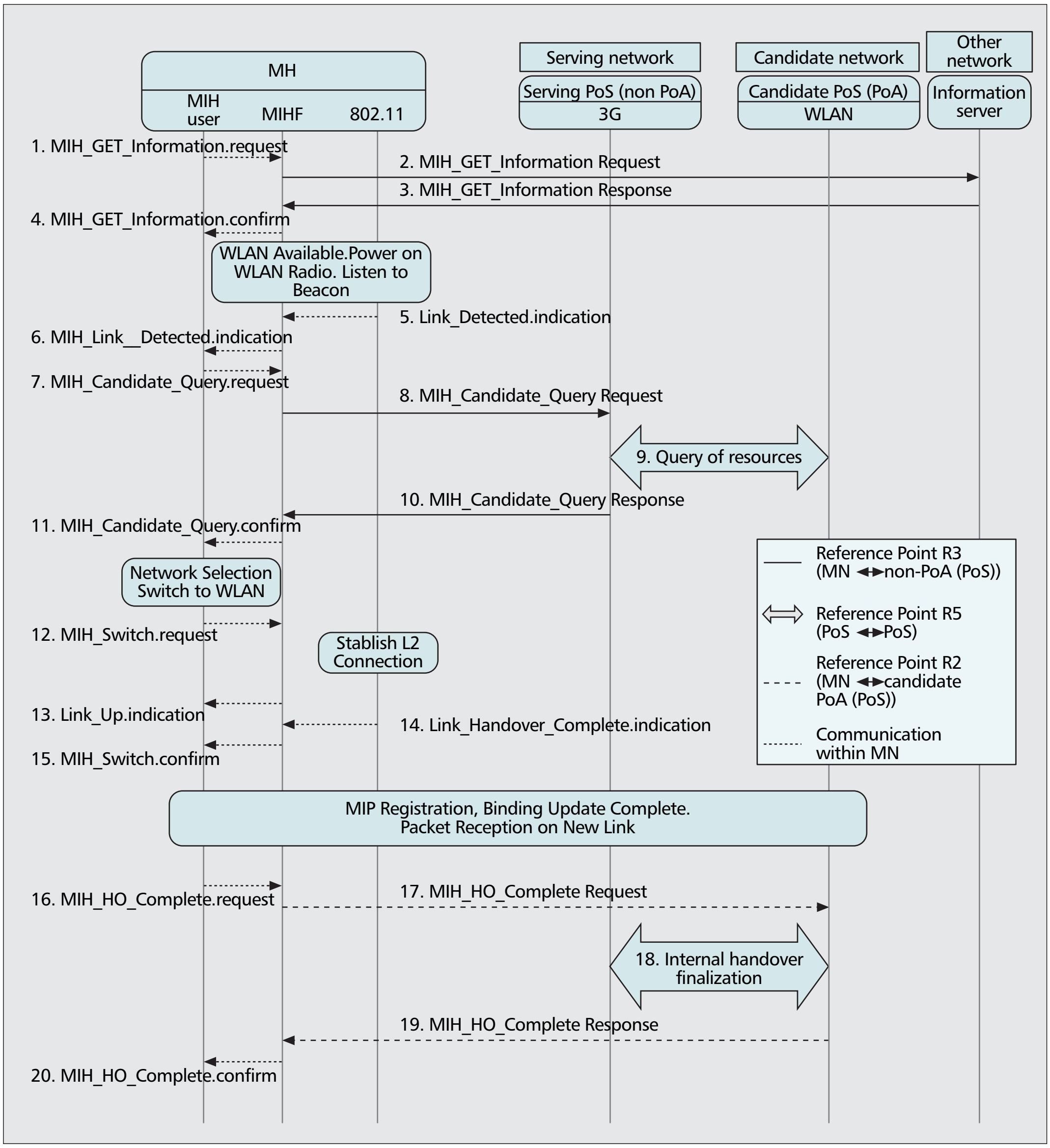
MIIS is based on information elements (IEs), and these elements provide information essential to the network selection algorithm to make a successful handover across heterogeneous networks and technologies. The information provided by the IEs can be related to lower layers such as neighbor maps, coverage zones, and other link parameters. Information related to 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 to which the mobile node is currently attached, but the surrounding available technologies can be accessed from any single technology. As an example, a mobile node connected to an 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 optimal power utilization.

The main goal of MIIs is to provide the mobile node 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, primarily used by policy engines that do not require dynamic and updated information, although network changes may be accounted for. Dynamic information about active networks should be obtained by use of the MIH event and command services explained earlier.

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 a 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, and so on.
- Point of attachment (PoA)-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, and so on.
- Higher-layer services/information per PoA: The information provided is related to 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, such as vendor-specific information or services.

It is important to note that the mobile node should be able to discover whether the network supports IEEE 802.21 by use of a discovery



■ **Figure 4.** *Intertechnology handover example.*

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.

mechanism or information obtained by MIIS through another interface. It is also important that the mobile 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 earlier.

Use Case: Intertechnology 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 mobile node (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 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 in message 6.

• When the MIH user receives the MIH_Link_detected.indication, it triggers the mobile-

The IEEE 802.21 specification will play an important role in near future communications, providing technological solutions for layer2 inter-technology handovers and interfaces with layer 3 mobility solutions.

initiated 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 in 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 layer 2 (L2) connection. After issuing the commands to start 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 an 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 NEs 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 closes the handover procedure, indicating to the MN that the procedure has finished, and message 20 informs the MIH user.

Conclusion and Open Issues

In this work we provide an overview of the current status of the upcoming IEEE 802.21 specification. IEEE 802.21's aim is to enable intertechnology handovers maximizing session continuity as a way of improving users' satisfaction while using mobile terminals. Mobile terminals are used worldwide nowadays; even more important, 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 in near future communications, providing technological solutions for layer 2 intertechnology handovers and interfaces with layer 3 mobility solutions.

Open issues include the integration of 802.21 with the IP transport layer for layer 3 transport. In the IETF MIPSHOP WG efforts are currently underway to specify a protocol for mobility services transport. Reference [7] gives general statements on the 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 2 transport (802 networks) on the wireless link up to the PoA, and a layer 3 transport between the PoA and the PoS. Such a scenario is referred to in the draft as a 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 uplink 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, [9] presents the necessary modifications — better network-to-network message exchange — enabling a centralized mechanism for network controlled and initiated handovers.

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Biographies

Antonio de la Oliva (aoliva@it.uc3m.es) received a telecommunication engineering degree from the Universidad Carlos III de Madrid, Spain, in 2004. He is currently working toward a Ph.D. degree in the Telematics Department, Universidad Carlos III de Madrid, where he has been working as a research and teaching assistant of telematic engineering since 2004. He is currently involved in several European projects such as EU IST Daidalos and EU IST OneLab.

Telemaco Melia (melia@netlab.nec.de) received his informatics engineering degree in 2002 from the Polytechnic of Turin, Italy, and his Ph.D. in mobile communications from the University of Goettingen in April 2007. Since June 2002 he has been employed by NEC Europe Ltd., Heidelberg, Germany, in the Mobile Internet Group. He worked on IPv6-based mobile communication within the EU IST Moby Dick Project. He is currently working on mobility architecture issues in the EU IST Daidalos project. His main research areas are IP mobility support across heterogeneous networks and resource optimization control, closely following standardization bodies such as IEEE and IETF where he actively contributes. He is the author of several publications in international conferences and is currently employed as a senior research staff member.

ALBERT BANCHS (banchs@it.uc3m.es) received his telecommunications engineering degree from the Universitat Politècnica de Catalunya (UPC), Spain, in 1997, and a Ph.D. degree from the same university in 2002. He was a visiting researcher at ICSI, Berkeley, California, in 1997, and worked for Telefonica I+D, Spain, in 1998, and for the Network Laboratories of NEC Europe Ltd., Germany, from 1998 to 2003. Since 2003 he has beeen with the Department of Telematics of the Universidad Carlos III de Madrid, where is working in the field of QoS for wireless networks. His research interests include QoS, resource allocation, and performance evaluation of broadband and wireless networks.

IGNACIO SOTO (isoto@it.uc3m.es) received a telecommunication engineering degree in 1993, and a Ph.D. in telecommunications in 2000, both from the University of Vigo, Spain. He was a research and teaching assistant in telematics engineering at the University of Valladolid from 1993 to 1999. In 1999 he joined Universidad Carlos III de Madrid, where he has been an associate professor since 2001. His research activities focus on mobility support in packet networks and heterogeneous wireless access networks. He has been involved in international and national research projects related with these topics, including the EU IST Moby Dick and Daidalos projects. He has published several papers in technical books, magazines, and conferences, lately in the areas of efficient handover support in IP networks with wireless access, network mobility support, and security in mobility solutions.

ALBERT VIDAL (albert.vidal@i2cat.net) has been a researcher at the i2CAT Foundation, Barcelona, Spain, since May 2007. After receiving his telecommunications engineering degree from UPC in 2005, he worked as a researcher at NEC Network Laboratories, Heidelberg, on several projects in mobility between heterogeneous wireless access networks and quality of service combined with power saving mechanisms for 3G/WLAN dual mode terminals. He is the author of several technical papers and patent applications in these fields. From the standardization point of view, he currently participates in the IEEE standardization effort as a voting member and contributor to the 802.21 Working Group (Media Independent Handover), and previously he also participated in the elaboration of certification programs at the Wi-Fi Alliance.

MESSAGE FROM THE EDITOR-IN-CHIEF/*from page 3*

improve user experience of mobile terminals by enabling handovers between heterogeneous technologies while optimizing session continuity. The review process of this article was handled by Technical Editor Theodore Zahariadis.

I hope that the collection of articles published in this issue of *IEEE Wireless Communications* provides you with a good collection of research work on the topics of security and ad hoc networking among others. I am very keen to receive your feedback on any aspect of *IEEE Wireless Communications* to make it even better in future. Please send your comments directly to me at a.jamalipour@ieee.org.

BIOGRAPHY

ABBAS JAMALIPOUR [F] (a.jamalipour@ieee.org) holds a Ph.D. from Nagoya University, Japan. He is the author of the first book on wireless IP and three other books, has co-authored nine books and over 190 journal and conference papers, and holds two patents, all in the field of mobile networks. He is an IEEE Distinguished Lecturer and a Fellow of Engineers Australia. He was Chair of the Satellite and Space Communications TC (2004-2006), and is currently Vice Chair of the Communications Switching and Routing TC and Chair of the Asia-Pacific Board, Chapters Coordinating Committee. He is a Technical Editor of *IEEE Communications Magazine*, Wiley's *International Journal of Communication Systems*, and several other journals. He is a voting member of the IEEE GITC and has been a Vice Chair of IEEE WCNC '03-'06, Chair of IEEE GLOBECOM '05 (Wireless Communications), a symposium Co-Chair of IEEE ICC '05–'08 and IEEE GLOBECOM '06–'07, and General Co-Chair IEEE RWS '09. He is the recipient of several international awards including the Best Tutorial Paper Award and Distinguished Contribution to Satellite Communications Award, both from the IEEE Communications Society in 2006.