IEEE 802.21: Media Independent Handover: Features, Applicability, and Realization

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ABSTRACT

Providing users of multi-interface devices the ability to roam between different access networks is becoming a key requirement for service providers. The availability of multiple mobile broadband access technologies, together with the increasing use of real-time multimedia applications, is creating strong demand for handover solutions that can seamlessly and securely transition user sessions across different access technologies. A key challenge to meeting this growing demand is to ensure handover performance, measured in terms of latency and loss. In addition, handover solutions must allow service providers, application providers, and other entities to implement handover policies based on a variety of operational and business requirements. Therefore, standards are required that can facilitate seamless handover between such heterogeneous access networks and that can work with multiple mobility management mechanisms. The IEEE 802.21 standard addresses this problem space by providing a media-independent framework and associated services to enable seamless handover between heterogeneous access technologies. In this article, we discuss how the IEEE 802.21 standard framework and services are addressing the challenges of seamless mobility for multi-interface devices. In addition, we describe and discuss design considerations for a proof-of-concept IEEE 802.21 implementation and share practical insights into how this standard can optimize handover performance.

INTRODUCTION

The evolution of data networks and wireless devices is making mobile Web browsing, banking, social networking, and multimedia entertainment a fact of life today. In addition to the proliferation of various Wi-Fi [1] access technologies in unlicensed bands, licensed cellular networks are planning evolutionary paths to support high-rate packet data services including WiMAX [2], ultra mobile broadband (UMB) [3], and long-term evolution (LTE) [4]. Although debate continues regarding the need for three very similar mobile broadband technologies; cost factors, backward-compatibility issues, and competing business interests make it unlikely that the industry will converge on a single standard. As a consequence, the wireless landscape will remain diverse for the foreseeable future, making heterogeneity an import factor for providers and device manufacturers to address.

Device manufacturers are integrating more network interfaces into their devices. Many cell phone models now support both Wi-Fi and third generation (3G) wireless. Notebook computers are available with built-in support for Wi-Fi, WiMAX, and 3G. As this trend in multi-interface devices continues, operators with multiple networks must facilitate easy access across their multiple technologies through a single device. Supporting seamless roaming and inter-technology handover is a key element to help operators manage and thrive from this heterogeneity. Operators who have the ability to switch a user's session from one access technology to another can better manage their networks and better accommodate the service requirements of their users. For example, when the quality of an application running on one network is poor, the application can be transferred to another network where there may be less congestion, fewer delays, and higher throughput. Operators also can leverage this ability to manage multiple interfaces to balance traffic loads more appropriately across available networks, improving system performance and capacity.

IEEE 802.21 defines [5] a media-independent handover (MIH) framework that can significantly improve handover between heterogeneous network technologies. The standard defines the tools required to exchange information, events, and commands to facilitate handover initiation and handover preparation. IEEE 802.21 does not attempt to standardize the actual handover execution mechanism. Therefore, the MIH framework is equally applicable to systems that employ mobile IP at the IP layer as to systems that employ Session Initiation Protocol (SIP) at the application layer.

The remainder of this article is organized as follows. The next section presents the benefits to standardizing MIH technology, and the section after that one provides an overview of the IEEE 802.21 MIH standard. We describe candidate deployment scenarios. Then, we discuss a proof-of-concept realization and laboratory testbed environment. The final section concludes the article by addressing the challenges and future roadmap for this standard.

BENEFITS TO STANDARDIZATION

One way to ensure handover interoperability across multiple access technologies is to create multiple, media-specific extensions. For example, access technology T1 could be extended to interoperate with access technology T2, whereas another extension would be required to ensure interoperability with T3. Similarly, access technologies T2 and T3 would require their own extensions. Continuing in this fashion requires $N \times (N - 1)$ media-specific extensions to ensure that N access technologies all interoperate with each other. The complexity of this type of approach grows on the order of N^2 and does not scale well as more access technologies are considered.

A media-independent framework is a more scalable and efficient method of addressing inter-technology handovers. With a common platform in place to address handovers, each access technology requires only a single extension to ensure interoperability with all other access technologies. The complexity of this approach grows on the order of N and scales more efficiently than a media-specific approach. This is the approach embraced by the IEEE 802.21 standard, which defines a common set of MIH services that interact with the higher layers of the protocol stack. Each access technology then requires only one media-specific extension to ensure interoperability with the common IEEE 802.21 framework.

IEEE 802.21 is unique within IEEE standards in that it provides interworking within IEEE 802 systems (e.g., IEEE 802.11 and IEEE 802.16e) and between IEEE 802 and non-IEEE 802 systems (e.g., cellular networks). The need for MIH services spanning multiple external networks led to the creation of the IEEE 802.21 WG with a project to create a standard that "defines extensible 802 media access independent mechanisms that enable the optimization of handover between heterogeneous 802 systems and may facilitate handover between 802 systems and cellular systems" [6].

OVERVIEW OF IEEE 802.21

The purpose of IEEE 802.21 is to improve the user experience by providing an MIH functionality that facilitates both mobile-initiated and network-initiated handovers. The specification [5] consists of the following elements:
• MIH function (MIHF), which encompasses three types of services:
  –The media-independent event service (MIES) detects changes in link layer properties and reports appropriate events from both local and remote interfaces.
  –The media-independent command service (MICS) provides a set of commands for both local and remote MIH users to control link state.
  –The media-independent information service (MIIS) provides information about neighboring networks including their location, properties, and related services.
• Service access points (SAPs), which define both media-independent and media-specific interfaces. In particular, the SAPs include:
  –MIH_SAP, a media independent SAP that provides a uniform interface for higher layers to control and monitor different links regardless of access technology.
  –MIH_LINK_SAP, a media specific SAP that provides an interface for the MIHF to control and monitor media specific links. For the MIHF to provide MIES and MICS for a specific link layer, it must implement the MIH_LINK_SAP for that specific link layer.
  –MIH_NET_SAP, a media-dependent SAP that provides transport services over the data plane on the local node, supporting the exchange of MIH information and messages with the remote MIHF.
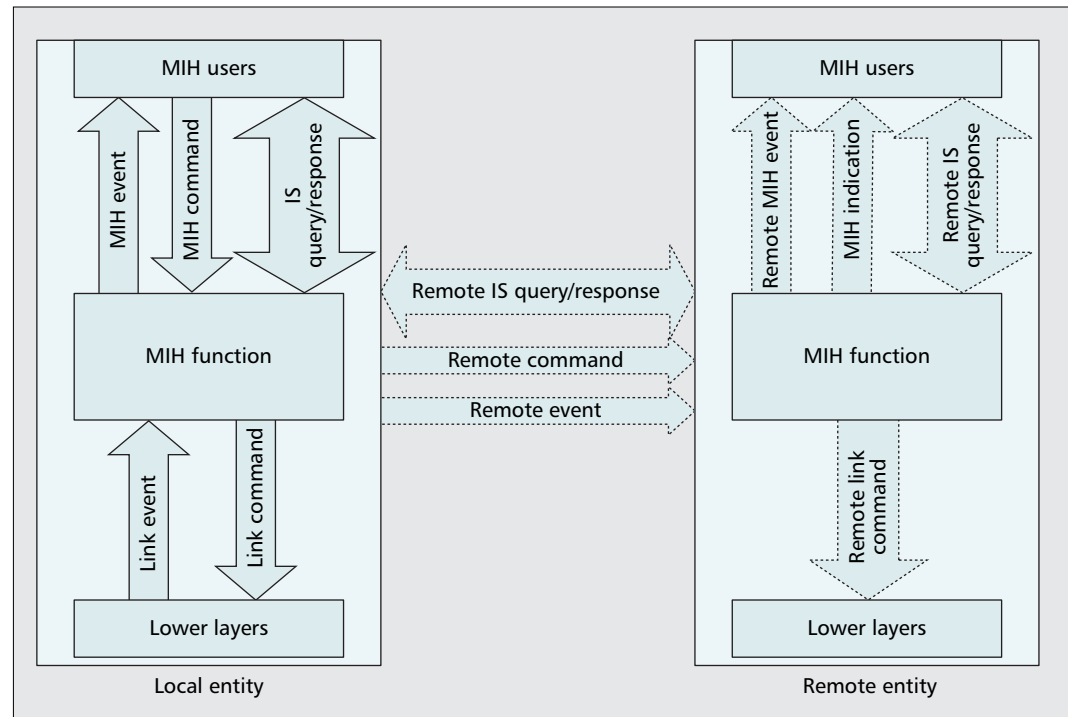• MIH users, which are the functional entities that employ MIH services.

The MIHF is a logical entity that provides abstract services to the higher layers through a media independent interface and obtains information from the lower layers through media specific interfaces. MIH services may be either local or remote, with local operation occurring within a protocol stack and remote operation occurring between two MIHF entities. For example, remote communication can occur between an MIHF entity in a mobile node (MN) and another MIHF entity located in the network.

The MIH SAPs are defined in terms of primitives in the IEEE 802.21 specification, which provides information about their functionality and parameters. The 802.21 specification does not mandate a specific programming language for representing the primitive and requires implementers of the MIHF to define specific application programming interfaces (APIs) in terms of their chosen programming language.

MIH users are abstractions of the functional entities that employ MIH services, that is, consumers of MIH services. A typical user of MIH services could be a mobility management application that would use these services to optimize handovers. For example, MIH users can subscribe with the MIES to be notified when specific events important to the handover decision and process occur.

> *MIH users are abstractions of the functional entities that employ MIH services, that is, consumers of MIH services. A typical user of MIH services could be a mobility management application that would use these services to optimize handovers.*

■ **Figure 1.** *Communication between local and remote MIHF entities.*

MEDIA INDEPENDENT HANDOVER SERVICES

IEEE 802.21 defines three main services that facilitate handovers across heterogeneous networks: MIES, MICS, and MIIS. These three primary services are managed and configured by a fourth service called the management service. The management service consists of MIH capability discovery, MIH registration, and MIH event subscription. Through the service management primitives, MIHF is capable of discovering other MIHF entities. Registration also can be performed to obtain proper service from a remote entity.

By providing a standard SAP and service primitives to the higher layers, the MIHF enables applications to have a common view across different media-specific layers. Media specific SAPs (LINK_SAPs) and their extensions enable the MIHF to obtain media-specific information that can be propagated to the MIH users using a single media independent interface (MIH_SAP).

Media Independent Event Services — The MIES defines events that represent changes in dynamic link characteristics such as link status and link quality. Events may indicate changes in the state and transmission behavior of the physical, data link, and logical link layers or predict state changes of these layers (e.g., Link_Up, Link_Down). There are two main categories of events: link events that originate from the lower layers and propagate upward and MIH events that originate from the MIHF. MIH users subscribe to receive notifications when events occur. Events also can be classified further as either local or remote. Local events are subscribed to by the local MIHF and are contained within a single node. Remote events are subscribed to by a remote node and are delivered over a network

by MIH protocol messages. Event notifications can be sent to the MIHF or any upper-layer entity that can be located within a local or a remote node. For example, a Link_Up event generated from the link layer of a node is forwarded to the MIH user of the same node if it is a local event. If a remote MIH user subscribed to this event, the local Link_Up event is delivered over the network to this remote MIH user as depicted in Fig. 1.

Media Independent Command Service — The MICS provides commands to control the link state. Commands can be invoked either locally or remotely by MIH users or by the MIHF itself. For example, an MIH user can control the reconfiguration or selection of an appropriate link (e.g., Link_Get_parameters, Link_Actions). The recipient of a command can be located within the protocol stack that originated the command or within a remote entity. Local commands propagate from the MIH users to the MIHF and then from the MIHF to the lower layers. Remote commands are carried by MIH protocol messages and may propagate from the MIHF in the local protocol stack to the MIHF in a peer protocol stack. Also, remote commands can travel down to lower layers as link commands or go up to MIH users as MIH indications. For example, a Link_Actions command generated from an MIH user propagates from the MIHF to the link layer of the same node when it is a local command and propagates from the local node MIHF to the link layer of the remote node through peer MIHF when it is a remote command (Fig. 1).

Media Independent Information Service — The MIIS defines a set of information elements (IEs), their information structure and represen-

tation, and a query-response-based mechanism for information transfer. The MIIS provides a framework for MIH entities to discover information useful for making handover decisions. For example, the MIIS can be used to discover specific information about networks within a specific geographical area to enable more effective handover decision making and execution.

The MIIS uses both resource description framework (RDF) [5] and type-length-value (TLV) format to specify a media-independent way of representing information across different technologies. Using the RDF framework, information provided by the MIIS conforms to a specified structure and semantics defined by the RDF schema [7]. Because RDF is an extendible framework, the MIIS easily can support the creation of new information elements. Vendor-specific extensions are possible through the extended-schema namespace defined within the IEEE 802.21 specification. Furthermore, RDF provides support for efficiently responding to complex queries. For example, using the RDF schema, the MIIS can be used to identify nearby networks that meet a complex set of specified criteria quickly and efficiently. Relying on TLV exchanges for the same queries may result in a greater number of message exchanges that require more bandwidth and introduce greater handover latency.

In cases where the information required for handover decisions is not available locally, the MIH protocol can be used to access remote information sources. Network and other information can be stored in a network element referred to as an information server.

MEDIA-INDEPENDENT SERVICES FRAMEWORK

Figure 1 depicts the MIH services framework and the communication between a local and a remote MIHF entity. In this figure, we assume that the events, commands, and information service queries are initiated by the local entity only and are propagated as remote events, commands, and information service query-responses to the remote entity. Dotted lines are used to represent the remote events, commands, and information service query and response.

The MIH protocol facilitates communication between peer MIHF entities through the delivery of MIH protocol messages. The MIH protocol defines message formats, including a message header and message parameters appended in TLV format. These messages correlate with the MIH primitives that trigger remote communication.

CANDIDATE DEPLOYMENT SCENARIOS

The IEEE 802.21 specification describes high-level MIHF reference models for IEEE 802 and the 3G family of networks and shows how existing primitives or protocols can be mapped to the media-specific link SAPs. We present two example deployment scenarios where IEEE 802.21 can improve the user experience by facilitating seamless handover across heterogeneous access technologies.
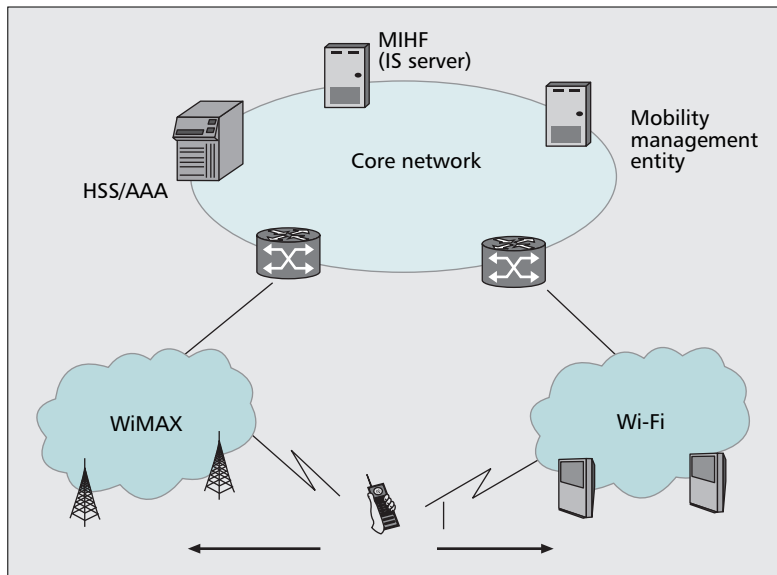

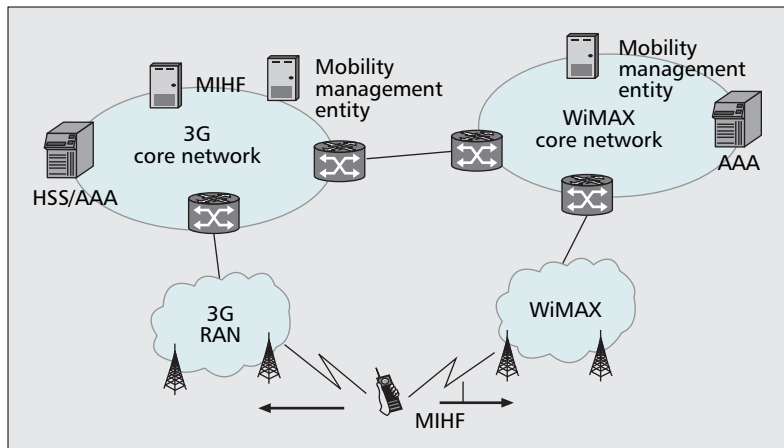■ **Figure 2.** *Handover scenario between WiMAX and WLAN networks.*

EXAMPLE 1: HANDOVER BETWEEN WIMAX AND WI-FI NETWORKS

Figure 2 represents a handover scenario between WiMAX and Wi-Fi access networks administered and managed by the same operator. Although the IEEE 802.11 and IEEE 802.16 working groups have defined standards to support seamless mobility within their own networks, neither group addresses handover across these two technologies. The IEEE 802.21 working group is filling this gap by providing a media-independent framework to support handover preparation and initiation.

MIH services can be integrated in the common core network elements and mobile devices to facilitate such handovers. Dual-mode mobile devices can access the IEEE 802.21 services through either access technology. For example, while a mobile node is within the WiMAX network, it can query the information server to obtain available Wi-Fi network information without activating and directly scanning through the Wi-Fi interface. This can conserve the battery power of the mobile device significantly. Using the information provided by the information server, the mobile node can activate its Wi-Fi interface, confident that an appropriate Wi-Fi network is available. Then, the MN can associate and authenticate with the Wi-Fi network while the session is active through the WiMAX interface. The MIES allows new links to be discovered and qualified prior to handover, while MIH commands can be used to begin the handover process. Use of the MIH services allows much of the time-consuming work associated with handover initiation and preparation to be completed before the handover takes place, thus significantly reducing handover latencies and losses.

Both the IEEE 802.11 and IEEE 802.16 working groups are creating media-specific extensions to their respective task groups to enable interaction with the IEEE 802.21 framework. After these extensions are completed, the

■ **Figure 3.** *Handover scenario between 3G and WiMAX networks.*

MIH framework can enable seamless roaming scenarios similar to the one described previously.

EXAMPLE 2: HANDOVER BETWEEN 3G AND WiMAX NETWORKS

Figure 3 represents a handover scenario between 3G and WiMAX networks where the WiMAX operator has a roaming relationship with the 3G operator. Again, placement of IEEE 802.21 entities can occur in either or both of the provider core networks; however, in this scenario, we assume that MIH functionality resides within the 3G core network.

As in the first example (Fig. 2), MIH services can play an important role in improving handover decision making, prolonging battery life, and reducing handover latencies. The MIIS can be used to discover the presence and characteristics of available WiMAX networks, while the MICS can instruct the mobile device to activate its WiMAX interfaces only when WiMAX coverage is available. Carrying this information over the 3G radio access network (RAN) allows the mobile device to discover and assess available WiMAX networks without activating its WiMAX radio, eliminating the need to actively scan, and thus, preserving battery life. Efforts are required in 3G standards and WiMAX forums to incorporate such MIH services to support this type of interworking.

PROOF-OF-CONCEPT REALIZATION

In this section, we describe our implementation of MIH services. First, we present the MIHF implementation along with local command and event services and then, discuss information server (IS) implementation.

MIHF IMPLEMENTATION

Figure 4 depicts the software components for the MIHF prototype. The MIHF provides an interface to the MIH users through a software interface that embodies the MIH_SAP as defined in the IEEE 802.21 specification. MIH users can execute commands or receive event notifications through this interface. Likewise, a software interface called the link provider embodies the MIH_LINK_SAP, providing a

common interface to a variety of link types. Because there are no device drivers supporting the IEEE 802.21 standards yet, we wrap media-specific link implementations for a variety of experimental link providers.

The MIHF is implemented in Java 1.5, which facilitates operating system portability. Our experimental link providers currently support local command and event services for IEEE 802.11 and code division multiple access evolution-data optimized (CDMA EV-DO) interfaces in the Linux environment.

The MIHF includes the following logical components:
• The **MIH user manager** manages the MIH users served by the MIHF, including privileges to change the state of a local link and requests to process specific commands received in MIH messages. When an MIH message is received, the MIH user manager notifies the corresponding registered MIH user to process a request message or to receive a response/indication message.
• The **event subscription registrar** maintains event subscriptions of local users to local and remote events and remote user subscriptions to local events. It also triggers notification (Indication) to the subscribers when the subscribed event occurs.
• The **MIH protocol** provides methods to compose and send MIH messages to remote MIHF entities, such as in the case of a local MIH user interacting with a non-local link. User Datagram Protocol (UDP) is used for message transport between MIHF entities. The MIH protocol also receives and parses MIH messages sent to the local MIHF entity and invokes the appropriate message processing within MIHF.
• The **Link Manager** is responsible for managing local links through commands and events. It controls the local link state by responding to invoked MIH commands. It also monitors the local link state by receiving notifications from the lower layers related to link event subscriptions.

These logical components interact with each other to provide the MICS and MIES for the MIH users.

MIH INFORMATION SERVER IMPLEMENTATION
An IEEE 802.21 IS was implemented as an MIH user. The IS supports RDF query language (SPARQL) query for RDF-based information elements. It has a local database that contains network information essential for handover decisions and executions. The IS registers to the MIHF to receive MIH Get Information request messages, which are part of the MIH information service. When the IS receives this message, it queries its database and generates a RDF response that is sent by the MIHF to the originator of the request.

TESTBED INTEGRATION
We choose to demonstrate MIH services with the media-independent pre-authentication (MPA) client acting as the mobility management entity. MPA [8] is a mobility management technique that facilitates handover by establishing

higher layer-security associations and configurations with a target network before a link-layer handover is made. By performing many of the handover steps prior to making a layer-2 switch, MPA in combination with MIH can significantly reduce handover latencies and packet losses. Whereas the MPA client is responsible for executing the inter-technology handover, the MIH services can be used to provide valuable information to assist in handover preparation and initiation.

Figure 5 depicts the integrated testbed set up and includes the following components:
• A multi-interface MN equipped with Wi-Fi and EV-DO interfaces. The MN runs an MPA client.
• An MPA server equipped with several modules including an authentication agent (AA), tunneling module, configuration agent (CA), and buffering module. Ideally, the MPA server should reside in the cellular provider's network if it is a cellular provider's control handover but in this case, it resides in our enterprise network because there is no access to the EV-DO network.
• An MIH IS, which contains information about the EV-DO network and its coverage. Similar to an MPA server, the IS also resides in our enterprise network.

In the demonstration scenario, the MN communicates through a voice over IP (VoIP) application (Skype) to a corresponding node (CN) over a Wi-Fi network. While still connected to the Wi-Fi network, the MPA client utilizes the MIH services to determine when to trigger an authentication and configuration process with the EV-DO network in anticipation of the pending move of the MN. The choice of target network is determined by the MPA client through a
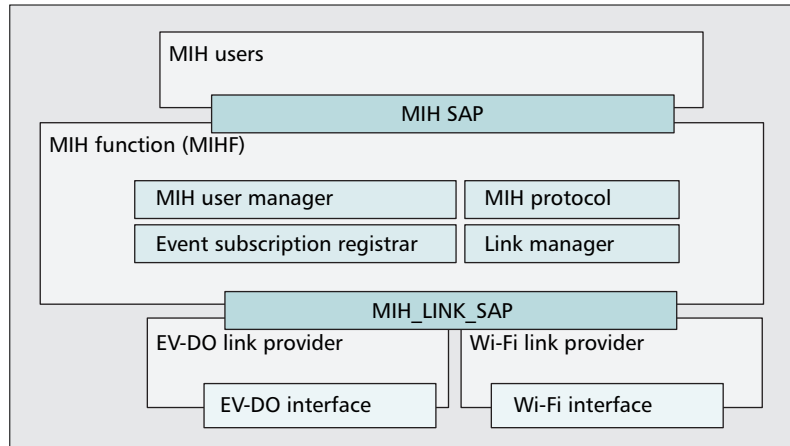

■ **Figure 4.** *MIHF software components.*

query to the MIH IS when the Wi-Fi signal strength indicates that the MN may be moving out of range. Our demonstration uses signal strength to trigger the IS query, but many other metrics can be used to trigger the IS query.

Figure 6 is an example of utilizing an MIH framework for pre-authentication from a Wi-Fi to EV-DO network. In this example, the MN is initially connected to the Internet through Wi-Fi and then moves out of range of the hotspot. The MPA client uses two thresholds for triggering its behaviors. The first threshold is set for triggering a query for candidate networks. The second threshold indicates that the signal is weak, and a candidate network may be able to provide a better network experience for the user and hence, triggers the pre-authentication process.

Using the MIH management service, the MPA client first subscribes to two MIH events
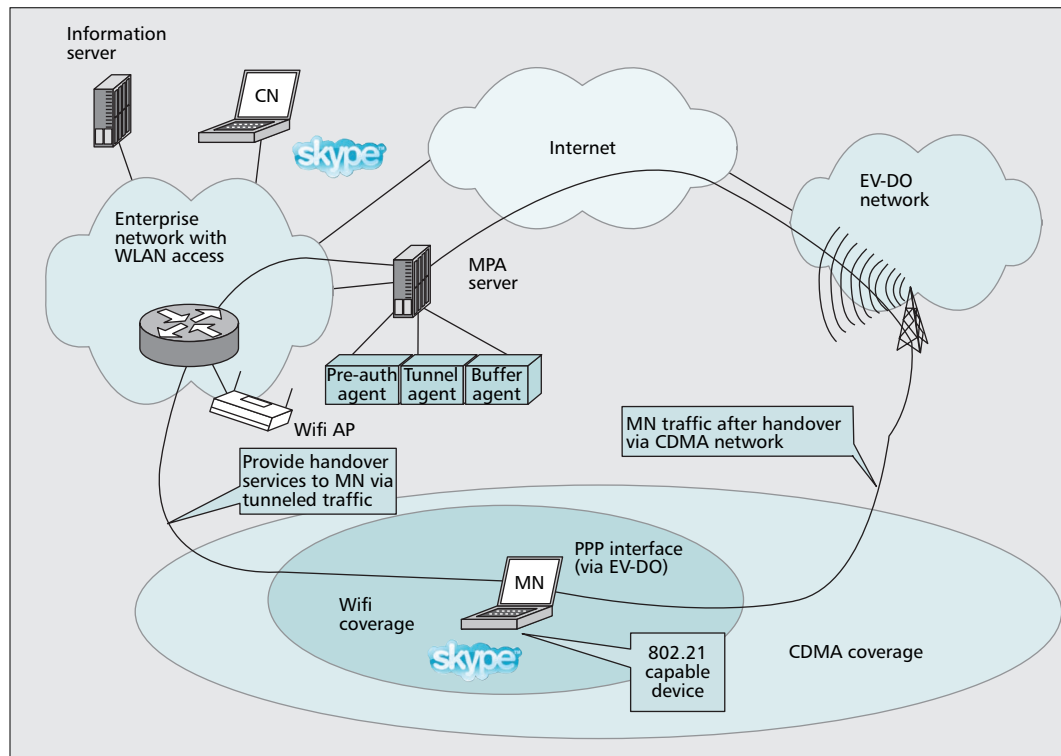
■ **Figure 5.** *Test-bed integration setup.*

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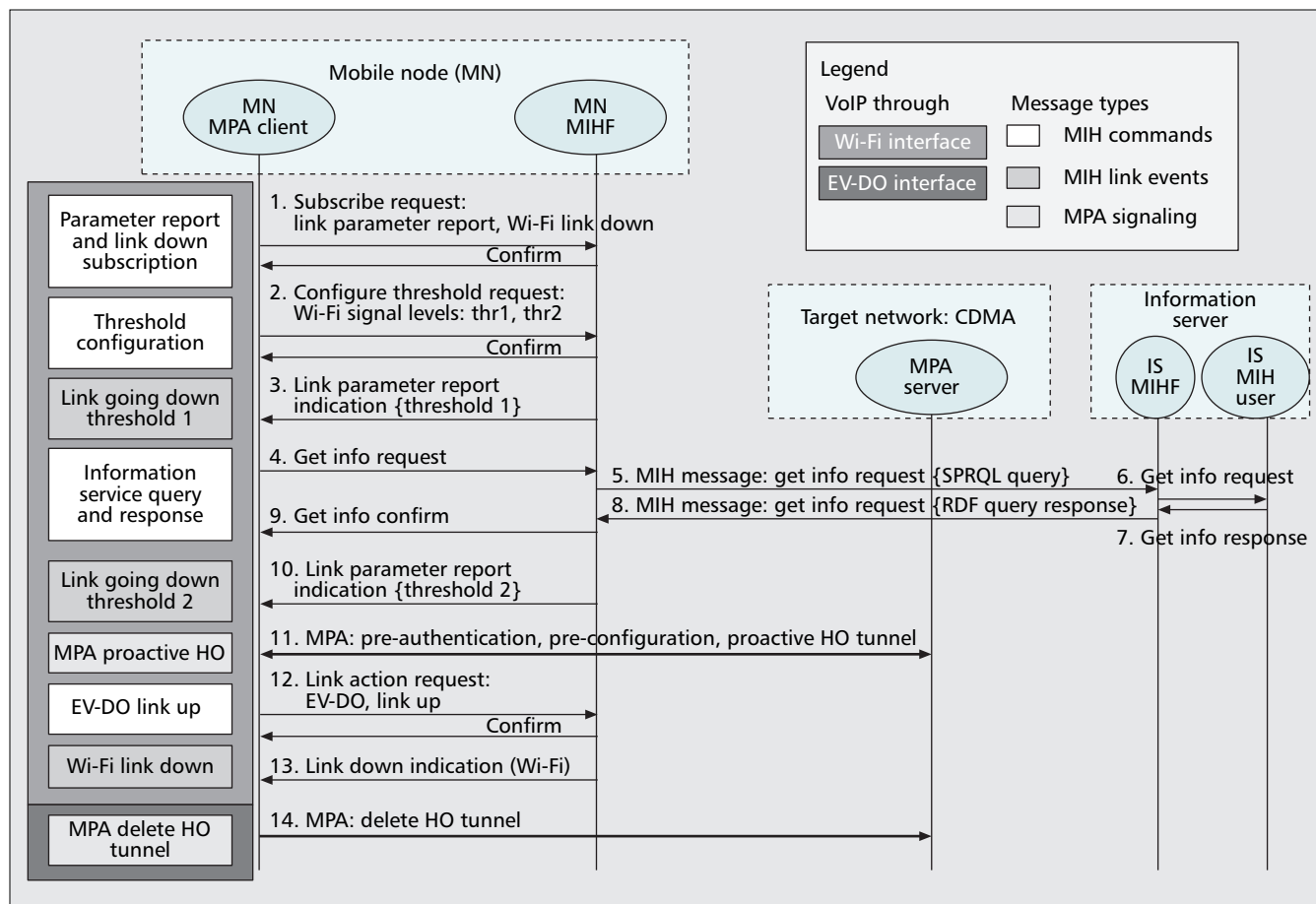
■ **Figure 6.** *MPA client using MIH services: Wi-Fi to EV-DO handover scenario.*

on the Wi-Fi interface (1). One event is the MIH_Link_Param_Report event, which provides link parameter reports. The other is the MIH_Link_Down event, which triggers the handover. The MPA client then uses the MIH_Link_Configure_Threshold command to establish a set of Wi-Fi signal strength levels that trigger notifications (2).

When the MPA client receives the first link indication (3) reporting that the Wi-Fi signal strength has weakened, the MPA client queries the MIH IS (4–6) for available neighboring networks using the current location of the MN. The IS then reports that the cellular network is available (7–9). This enables the MPA client to be aware of the cellular network coverage without turning on the EV-DO interface.

When the signal strength weakens further and the second threshold is crossed (10), the MPA client starts setting up the cellular connection (pre-authentication, pre-configuration, and start proactive handover (HO) tunnel procedures as described in [8]) through the serving Wi-Fi interface (11). Then, the MPA client brings the EV-DO interface up using the Link_Up MIH command (12).

When the mobile leaves the Wi-Fi coverage area, the Wi-Fi interface goes down, the MPA client receives a Link Down indication (13), and the handover operation is completed. The MPA client then uses the MICS to deactivate the Wi-Fi interface and deletes the MPA HO tunnel (14).

The IEEE 802.21 services supply the MPA client with knowledge of available networks, allowing the device to avoid active scanning and to power off interfaces when no appropriate networks are available. Furthermore, the IEEE 802.21 framework provides an extensible way for the MPA client to create flexible handover policies based on the link state. Through the MIES, the MPA client can be notified instantly of important changes in the state of the lower layers and then can use the MICS to issue handover initiation and preparation commands.

Alternatively, MIH services can be integrated with a SIP client for obtaining interface-changed information when running on a multi-interface device. MIH can provide notifications of events and trigger the SIP client to issue re-INVITE messages to preserve session continuity during mobility. The SIP client registers to all interfaces for MIH link-up and MIH link-down events. After a notification is received and a SIP session exists, the SIP client can utilize the re-INVITE message to ensure continuity. To further improve handover performance, the SIP client also can use additional link state information provided by the MIH_Link_Param_Report event.

IEEE 802.21 is not yet supported directly by device drivers. Although it is possible to implement some of the required MIH features by directly accessing the device driver API, in some instances it is not possible to obtain the required features directly through the device driver. In

particular, we choose to implement a wrapper (i.e., link provider) to support a unified MIH_LINK_SAP for each interface. Performance is affected by the efficiency of the wrapper implementation, and we expect this problem to abate as the IEEE 802.21 standard becomes de facto for all IEEE 802 devices.

In our testbed environment, we manually populate the MIH IS and apply basic queries to support the demo scenario. In practice, with the support of SPARQL and RDF, mobility management applications can utilize more flexible and complex queries to obtain valuable neighboring network information from the IS more quickly and efficiently.

CHALLENGES AND ROADMAP

This section describes some critical issues and major challenges in the current IEEE 802.21 specification, as well as a vision for its future success. These issues reflect the authors' personal understanding and the knowledge gathered by participating in the IEEE 802.21 WG, other standards meetings, and related work.

An important challenge facing IEEE 802.21 is the unification of all the media-specific technologies under one abstract interface (i.e., MIH_LINK_SAP). This is a noble goal, and as discussed earlier, preferable to a media-specific approach in terms of scalability and complexity. However, this approach may be difficult to realize in practice within a short period of time due to the large number of technology-specific standards within and outside the IEEE 802 systems that must be extended to conform to the MIH_LINK_SAP. In certain technologies, media-specific primitives already may be available, and all that is required is to correctly map them to the MIH_LINK_SAP primitives. Other technologies, however, may require extensions to media-specific primitives. We believe that such work requires cross-organization standardization activities.

Although ensuring interoperability among all access technologies is challenging, we are encouraged by the many liaison-based activities within the standards bodies. IEEE 802.21 established liaisons with IEEE 802.11 task group "u" and had liaisons with IEEE 802.16 task group "g." To support MIH services, appropriate primitives are added in IEEE 802.11 and IEEE 802.16. Proposals have been made to the Third Generation Partnership Project Standards Association (3GPP SA2) [9] to incorporate MIH services to support handovers between WiMAX and 3GPP system architecture evolution/long-term evolution (SAE/LTE) networks. Although the inclusion of these proposals into the Release-8 specification for the 3GPP was not accepted, MIH remains an attractive technology for enhancing IP mobility across heterogeneous accesses for future 3G releases. Also, the Internet Engineering Task Force Mobility for IP Performance, Signaling, and Handoff Optimization Working Group (IETF MIPSHOP WG) [10] is specifying the higher layer transport for the MIH protocol and mechanisms to discover MIHF peers.

Another challenge to widespread adoption of IEEE 802.21 is the lack of a conformance statement detailing the mandatory set of primitives and primitive sequences required to realize a particular use case. Such a statement would provide a method to verify that IEEE 802.21-based equipment conforms to the standard and would provide assurances to the community that equipment from different vendors will interoperate. Similar mechanisms have been successful in the Wi-Fi community to accelerate the adoption.

The IEEE 802.21 standard also must address a number of additional features to ensure acceptance. Standards must walk a thin line between encouraging innovation and ensuring interoperability. Some features are better left to individual companies to address, giving them an opportunity to distinguish themselves in the marketplace. However, if a required set of common hooks and interfaces is not in place and ensuring interoperability, industry adoption will be difficult. Important features to the deployment of MIH services, such as MIIS provisioning, MIH security, and multi-radio power management are not fully addressed in the specification yet. MIIS provisioning deals with issues concerning how information is populated to and stored in the information server. MIH security includes mechanisms to protect MIH protocol messages based on mutually authenticating MIH entities. Because operating multiple radios can be a significant drain on the battery of a device, mechanisms must be in place to facilitate better power management for multi-radio devices.

The IEEE 802.21 WG addressed some of the above challenges by creating new study groups (SGs). The Security SG has submitted a project on security optimizations and mechanisms to protect MIH protocol messages, which is under consideration by the IEEE New Standards Committee (NESCOM). The IEEE 802.21 Multi-Radio Power Management (MRPM) SG is devoted to addressing how MIH services can facilitate more efficient use of energy resources by multi-radio devices.

In summary, the success of this standard depends not only upon the activities within the IEEE 802.21 WG, but also upon the acceptance of this technology by other standards and industry forums. To achieve acceptance and wide deployment in the future, additional specifications describing use-case scenarios with requirements, features, and required extensions to media-specific technologies are required. This means continued effort on the part of the IEEE 802.21 WG, as well as close collaboration and liaison with other standards organizations. The ongoing efforts of the IEEE 802.21 WG, including the creation of new SGs, continued strong ties with the IEEE 802.11 and IEEE 802.16 groups, as well as a strengthening liaison with the IETF, 3GPP, and international mobile telephony (IMT)-advanced communities are hopeful signs pointing to the future success of the IEEE 802.21 MIH standard.

In summary, the success of this standard depends not only upon the activities within the IEEE 802.21 WG, but also upon the acceptance of this technology by other standards and industry forums.

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