Survey of IEEE802.21 Media Independent Handover Services

Jared Stein stein.jared@gmail.com

Abstract

This survey reports on the IEEE 802.21 Draft Standard which provides services that assist in handover between two 802 networks or an 802 network and a non-802 network.

See also: Fast Mobile IP (FMIP), Hierarchical Mobile IP (HMIP), Detecting Network Attachments (DNA)

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1. Introduction

Computer networks have evolved over time from coaxial to Ethernet, from 802.11b to 802.11g, analog cellular to 1G to 2G to 2.5G to 3G, with many more improvements in store including 802.11n wireless, 802.16 metropolitan area network, and 4G cellular networks. The status quo has been to make improvements to the specific physical and MAC layers separate and apart from each other. IEEE802.21 Media Independent Handover is an evolution for all networks, providing capabilities to detect and initiate handover from one network to another. In the future, mobile devices will be able to seamlessly handover between any types of network. A cellular phone will be able to switch over to a less expensive Wi-Fi hotspot and back to the cellular network once the hotspot is no longer available. Laptops can be unplugged from an Ethernet jack and switch over to Wi-Fi with no loss of connection. This new standard will enhance how mobile devices are used.

The IEEE802.21 Draft Standard, hereafter referred to as the standard, provides methods and specifications for allowing Layer 2 handover. The standard assists in determining and initiating a handover, but leaves the specifics of how to handle the handover undefined. IEEE802.21 is considered a draft standard meaning two things: 1) it can change and 2) there is very little written concerning this topic anywhere else. The working group has just recently begun organizing their documents, but they are more like rough sketches compared to the draft. Furthermore, there is no specific research devoted to this topic. With that said the bulk of this survey is based on the IEEE802.21 Draft Standard.

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2. Architecture

The standard designed a new function to control access to the lower layers (Layers 1 and 2). This new function provides new service access points (SAPs) and allows for information to be queried by the upper layers (Layer 3 and higher). Both mobile devices and network hardware must implement the standard to work, but everything should remain backward compatible for non-MIH aware devices. Mobile handover and handover are equivalent, and will be used interchangeably, because if a device is being handed over that implies movement or mobility on the device's part from one Point of Access (PoA) to another. Handoff and handover are also essentially the same term; the latter is merely the British form [Handoff06].

2.1 Handover

In general, the standard will assist in handover between multiple physical layer network links. This concept is visualized in Figure 1 where a mobile device can connect to the Internet over any number of connections. In theory, the transition from one network type to another will be seamless and media independent, but in practice it will not be that easy. Quality of Service (QoS) and timing of the handover must be considered. If a person is on a Voice over IP call on 802.3 Ethernet and then switches to 802.11 Wireless this must be taken into account, with regards to user experience. Furthermore, a handover might result in a slight loss of data. Therefore, pauses in conversation or data transfer are the best time to handover.

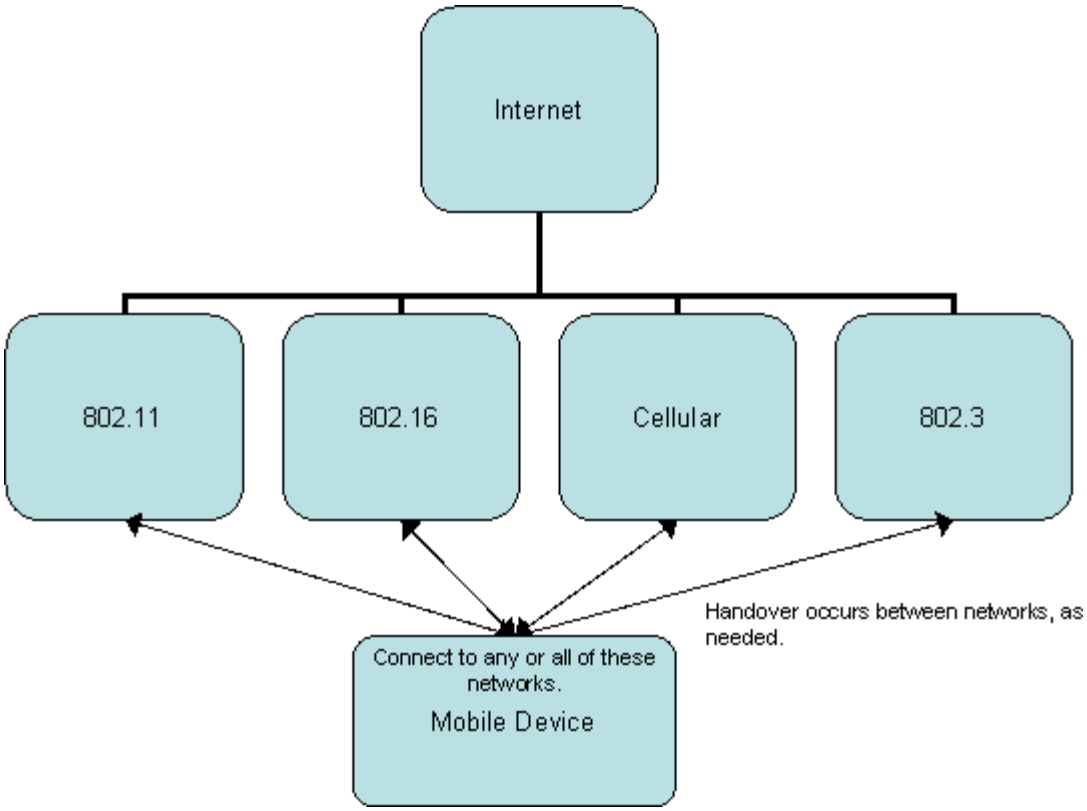

Figure 1 MIH Concept

The optimal handover is seamless and requires as few duplicated resources across the network as possible. There are several points concerning handover to point out.

- Horizontal handover- roaming within homogeneous technologies over the same access network (from one 802.11 access point to another).
- Vertical handover- roaming across heterogeneous technologies over different access networks (from 802.3 to 802.11).
- Hard handoff (Break-before-make)- break the original connection before setting up the new one.
- Soft handoff (Make-before-break)- make the new connection before breaking the old one.

2.2. Services

Handover will require complex algorithms and policy implemented by each specific vendor. These algorithms will need specific information from the lower layers which MIH will provide. The three services, event, command and information, are discussed in Section 3. Network discovery will allow mobile nodes (MNs) to accumulate all the networks it has access to that are nearby. Network selection used in conjunction with network discovery will provide neighboring network information from all the links and allow the MN to select a link. Security will be handled by the upper layers. Before security is established the communication is insecure, but the data is insensitive and the operation is fast. For battery powered MNs, there are mode messages (sleep or idle) to preserve battery life.

2.3. Communication Models

Performing and deciding on the handover is not part of the standard's scope. The standard merely assists

in providing information to determine when to handover and initiating the handover through several services.

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3. Media Independent Handover (MIH) Function

The biggest change the standard proposes is the MIH Function (MIHF). As you can see in Figure 2, it is between Layer 2 and Layer 3.

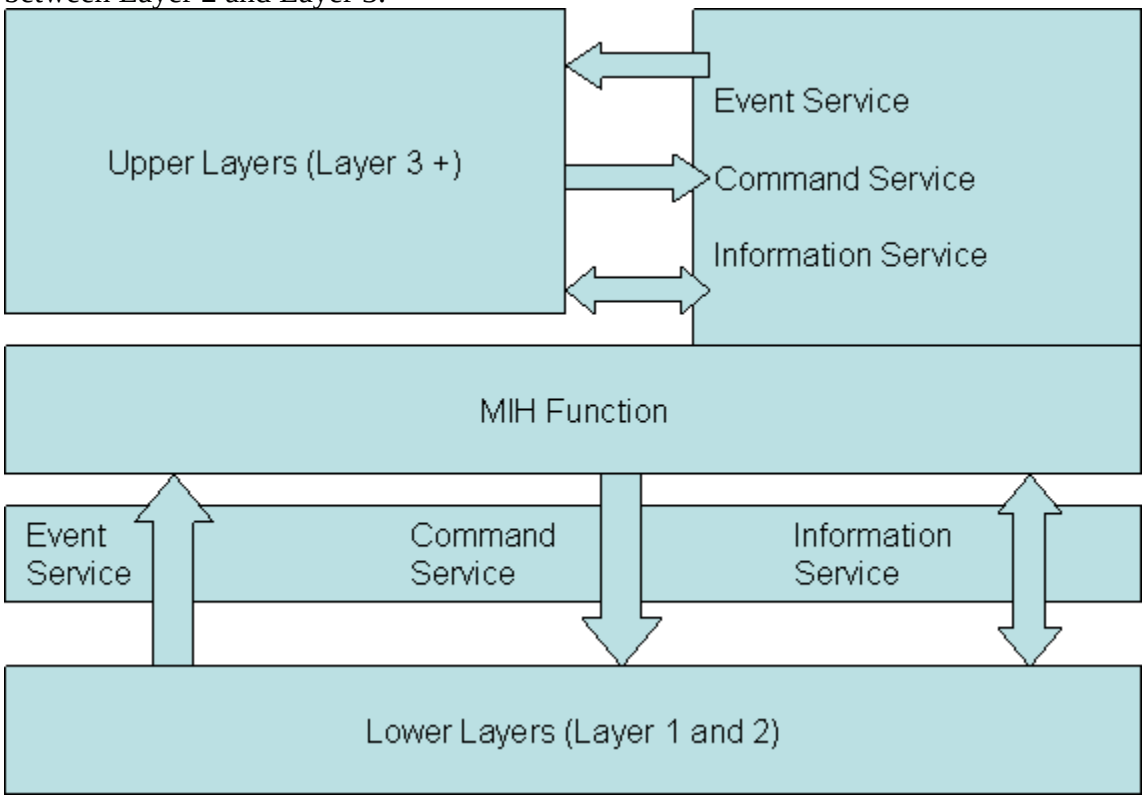

Figure 2 MIH Function

Along with the MIH Function are three services that allow for messages to be passed along the stack. Table 1, compiled from [IEEE802.21], outlines the basic functions of these services.

Table 1 Services Outline

MI Services	Origin	Destination	Flow	Use Cases
Event	MIHF or lower layers	MIHF or upper layer remote or local stack	(remote MIHF or lower layers)->local MIHF -> upper layers	link up/down/going down, transmission status
Command	MIHF or upper layers	MIHF or lower layer remote or local	(remote MIHF or upper layers)-> local MIHF ->	switch links, get status

		stack	lower layers	
Information	upper or lower layer secure or insecure port	upper or lower layer remote or local stack	Outside the scope of the standard.	information elements (IEs), neighbor reports

3.1 Media Independent Event Services (MIES)

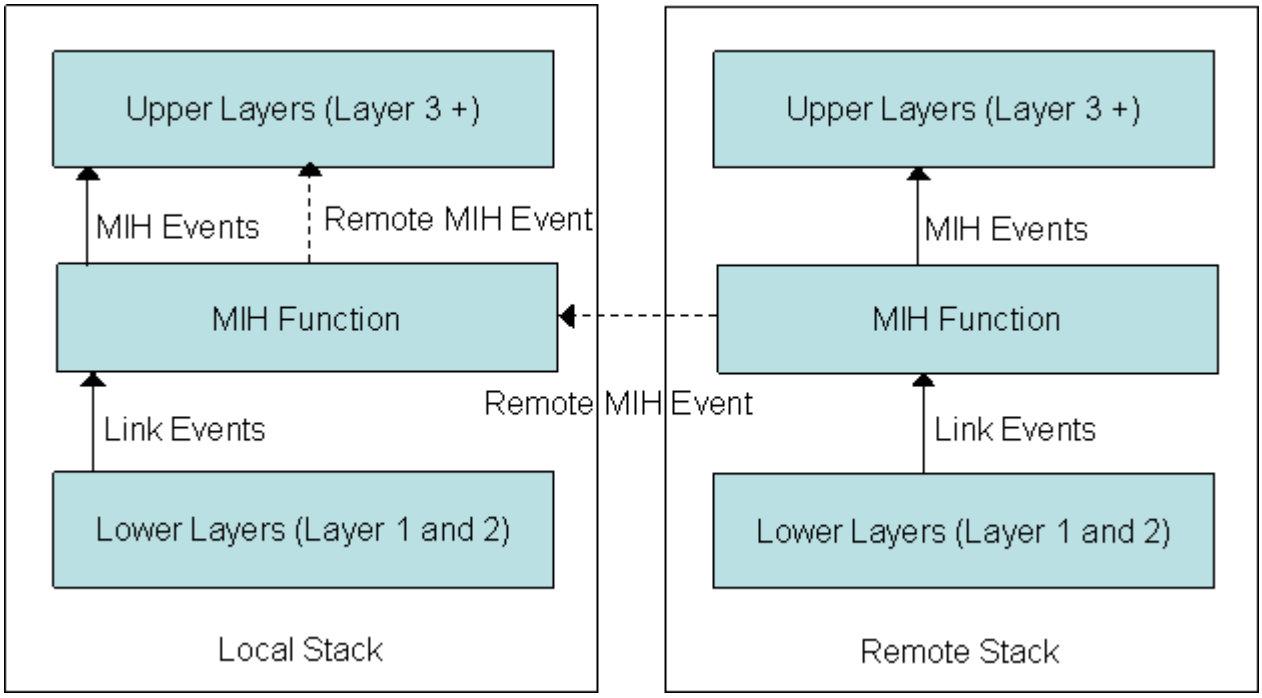

Figure 3 Remote and Local Events

The MIES provides event classification, event filtering and event reporting corresponding to dynamic changes in link characteristics, links status, and link quality [IEEE802.21]. Notice in Figure 3 the flow of events and the two corresponding terms which (Link Event and MIH Event) are divided by the MIH Function. The MIH Function registers Link Event notifications with the interfaces. Any upper layers entities in either a local or remote stack can register for an MIH Event notification, either in groups or with predetermined thresholds. The lower layers will generate a Link Event and send it to the MIH Function which will report to any entity that has registered either an MIH Event or a Remote MIH Event. The information reported is meant to merely notify of an event occurrence. The enumerated Link Events and MIH Events, from [IEEE802.21] are included in Table 2. These events, both link and MIH, fall into six categories: administrative, state change, link parameter, predictive, link synchronous, and link transmission.

Table 2 Link Events and MIH Events

No.	Event Type	Event Name	Description	(L)ocal (R) emote	Direction

Link Events					
1	State Change	Link Up	L2 connection is established and link is available for use	-	-
2	State Change	Link Down	L2 connection is broken and link is not available for use	-	-
3	Predictive	Link Going Down	Link conditions are degrading & connection loss is imminent	-	-
4	State Change	Link Detected	New link has been detected	-	-
5	Link Parameters	Link Parameters Change	Link parameters have crossed specified threshold	-	-
6	Administrative	Link Event Rollback	Previous link event needs to be rolled back	-	-
7	Link Transmission	Link SDU Transmit Status	Indicate transmission status of all PDU segments	-	-
8	Link Synchronous	Link Handover Imminent	L2 handover is imminent based on changes in link conditions	-	-
9	Link Synchronous	Link Handover Complete	L2 link handover to a new PoA has been completed	-	-
MIH Events					
1	State Change	MIH Link Up	L2 connection is established and link is available for use	L, R	Client -> Network Network -> Network
2	State Change	MIH Link Down	L2 connection is broken and link is not available for use	L, R	Client -> Network Network -> Network
3	Predictive	MIH Link Going Down	Link conditions are degrading & connection loss is imminent	L, R	Client -> Network Network -> Network Network -> Client
4	State Change	MIH Link Detected	New link has been detected	L, R	Client -> Network Network -> Network
5	Link Parameters	MIH Link Parameters Report	Link parameters have crossed specified threshold and need to be reported	L, R	Client -> Network Network -> Network Network -> Client
					Client -> Network

6	Administrative	MIH Link Event Rollback	Previous link event needs to be rolled back	L, R	Network ->Network Network -> Client
7	Link Transmission	MIH Link SDU Transmit Status	Indicate transmission status of all PDU segments	L	N/A
8	Link Synchronous	MIH Link Handover Imminent	L2 handover is imminent based on changes in link conditions	L, R	Client -> Network Network -> Network Network -> Client
9	Link Synchronous	MIH Link Handover Complete	L2 link handover to a new PoA has been completed	L, R	Client -> Network Network -> Network Network -> Client

3.2 Media Independent Command Services (MICS)

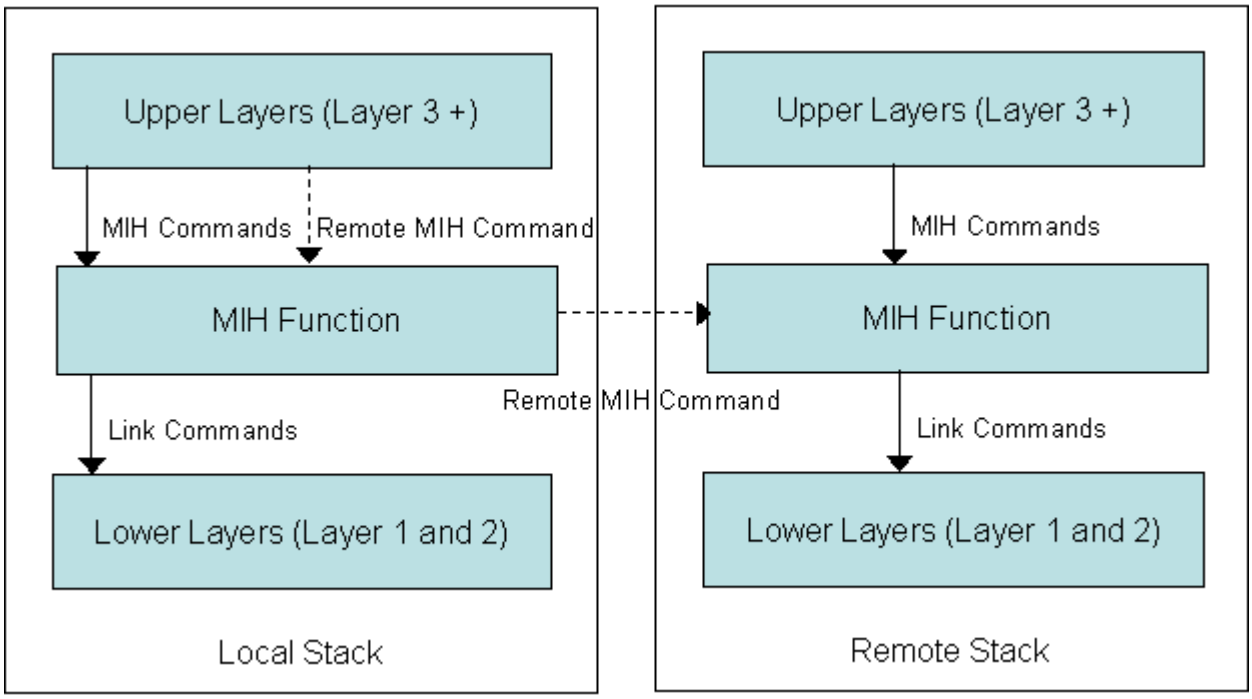

Figure 4 Remote and Local Commands

The MICS enables MIH users to manage and control link behavior relevant to handovers and mobility [IEEE802.21]. Figure 4 shows that MIH Commands originate from the upper layers down to the MIH Function. From there it either becomes a Remote MIH Command to a remote stack or and otherwise it continues down to the lower layers as a Link Command from the MIH Function. Link Commands are specific to the access network being used, see Section 4, and *are local only* [IEEE802.11]. Table 3 taken from [IEEE802.21] lists the MIH and Link Commands.

Table 3 MIH and Link Commands

No	Command	(L) ocal (R) emote	Direction	Comments
MIH Commands				
1	MIH Get Status	L, R	Network -> Client	Get the status of links
2	MIH Switch	L, R	Network -> Client	Switch the links as specified
3	MIH Configure	L, R	Network -> Client	Configure a link
4	MIH Configure Thresholds	L,R	Network-> Client	Configures thresholds for link events
5	MIH Scan	L, R	Network -> Client	Scan a link
6	MIH Handover Initiate	L, R	Client -> Network Network -> Client	Network or client may initiate handover and send a list of suggested networks and associated Points of Attachment
7	MIH Handover Prepare	L, R	Network->Network	This command is sent by current MIHF entity to target MIHF entity to allow for resource query and handover preparation
8	MIH Handover Commit	L, R	Client -> Network Network -> Client	In this case the client or network commits to do the handover and sends the choice of selected network and associated PoA
9	MIH Handover Complete	L, R	Client -> Network Network->Network	Notification from new serving MIHF to previous serving MIHF indicating handover completion, and any pending packets may now be forwarded to the new MIHF
10	MIH Network Address Information	L, R	Network->Network	Sent from current serving MIHF entity to target MIHF entity to obtain reconfigured network address on target network for the client
Link Commands				
1	Link Configure Thresholds	-	-	Configure the thresholds for various link layer events such as Link Going Down
-	-	-	-	-

3.3 Media Independent Information Services (MIIS)

MIIS provides the capability for obtaining the necessary information for handovers [IEEE802.21] including neighbor maps, link layer information, and availability of services. Essentially, this service

provides a two way street for all the layers to share information elements (IEs) to be used to make handover decisions. Four main concerns should be noted regarding the information:

1. Access neighbor maps for networks in a geographic area from any network entity. Wi-Fi hotspot knows about cellular towers and vice versa.
2. Static link layer informational parameters. QoS support and restricted networks.
3. Use reports to allow efficiency. Channel range prevents the need for scanning.
4. Vendor specific features. Prioritize networks, network labels.

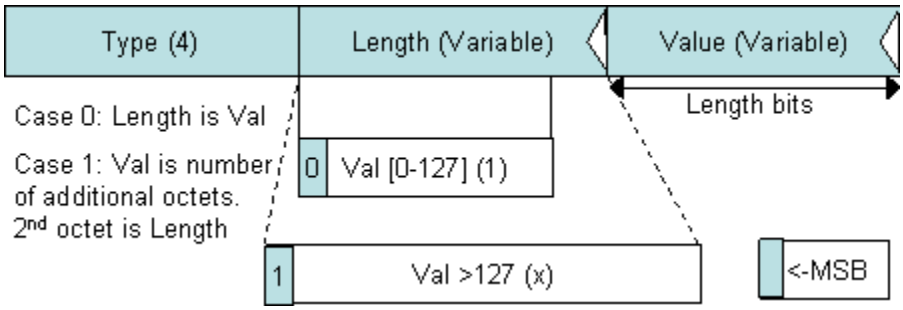

Figure 5 TLV message (octets)

Table 4 Information Element Type

Range	Description	Comments
0x00000000	Reserved	-
0x00000001 - 0x000000FF	Reserved for 802.21	Core 802.21 Header specific IEs
0x00000100 - 0x1FFFFFFF	Reserved for 802.21	Core 802.21 specific IEs
0x2 || (16 bit OUI) || (14 bit)	Vendor specific IE	IEs defined on a per vendor basis. 16 bit OUI: Vendor Id 14 bit ID:
0x30 || (8 bit Working Group identifier) || (16 bit WG specific ID of IEs)	Reserved for different Working Groups.	May be reserved for other different SDOs and 802 WGs such as 802.11, 802.16 etc., if they want to define anything specific for heterogeneous handovers.
0x31 || (24 bit ID)	Reserved for IETF.	May be reserved for IETF protocols and other higher layer IEs.
0x32 || (24 bits)	Reserved for playpen area.	May be used in development and testing. Should not be used in released products. Avoids collision during development.
0x33000000 - 0xFFFFFFFF	Reserved	For future use.

The IEs are delivered as a Type-Length-Value messages (TLV), refer to Figure 5, and are categorized into five groups: General Information (operators), Access Network(roaming, cost, security, QoS), Information about PoA (location, data rate, channel range), Higher Layer, Other Information (vendor specified). Enumerated in Table 4 are the Types for the TLV [IEEE802.21].

The defined IEs include (the full list is available in the standard):

- General Information Elements

TYPE_IE_LIST_OF_NETWORKS, TYPE_IE_NUMBER_OF_OPERATORS, TYPE_IF_LIST_OF_OPERATORS

- Access Network

TYPE_IE_NUMBER_POA, TYPE_IE_OPERATOR_IDENTIFIER, TYPE_IE_ROAMING_PARTNERS, TYPE_IE_COST, TYPE_IE_NETWORK_SECURITY, TYPE_IE_QOS

- PoA

TYPE_IE_POA_ADDRESS, TYPE_IE_POA_LOCATION, TYPE_IE_POA_DATA_RATE, TYPE_IE_POA_PHY_TYPE, TYPE_IE_POA_MAC_TYPE, TYPE_IE_POA_CHANNEL_RANGE

- Higher layer services

TYPE_IE_POA_SUBNET_INFORMATION, TYPE_IE_POA_CAPABILITIES

- Other

Vendor specific

This service is used to merely quickly transfer data with very little decoding complexity. Two formats for transferring the reports can be used. By default the TLV is used, but a schema called Resource Description Framework (RDF) which is represented in Extensible Markup Language (XML) can also be used.

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4. Reference Models

As depicted in Figure 6, The MIHF provides convergence of link-layer state information from multiple heterogeneous access technologies into a unified presentation to the upper layers of the mobility management protocol stack [IEEE802.21]. The MIH_SAP allows access from the upper layers. MIH_NMS_SAP allows for management. MIH_LINK_SAP is a generalization, each access network has preexisting SAPs for such access.

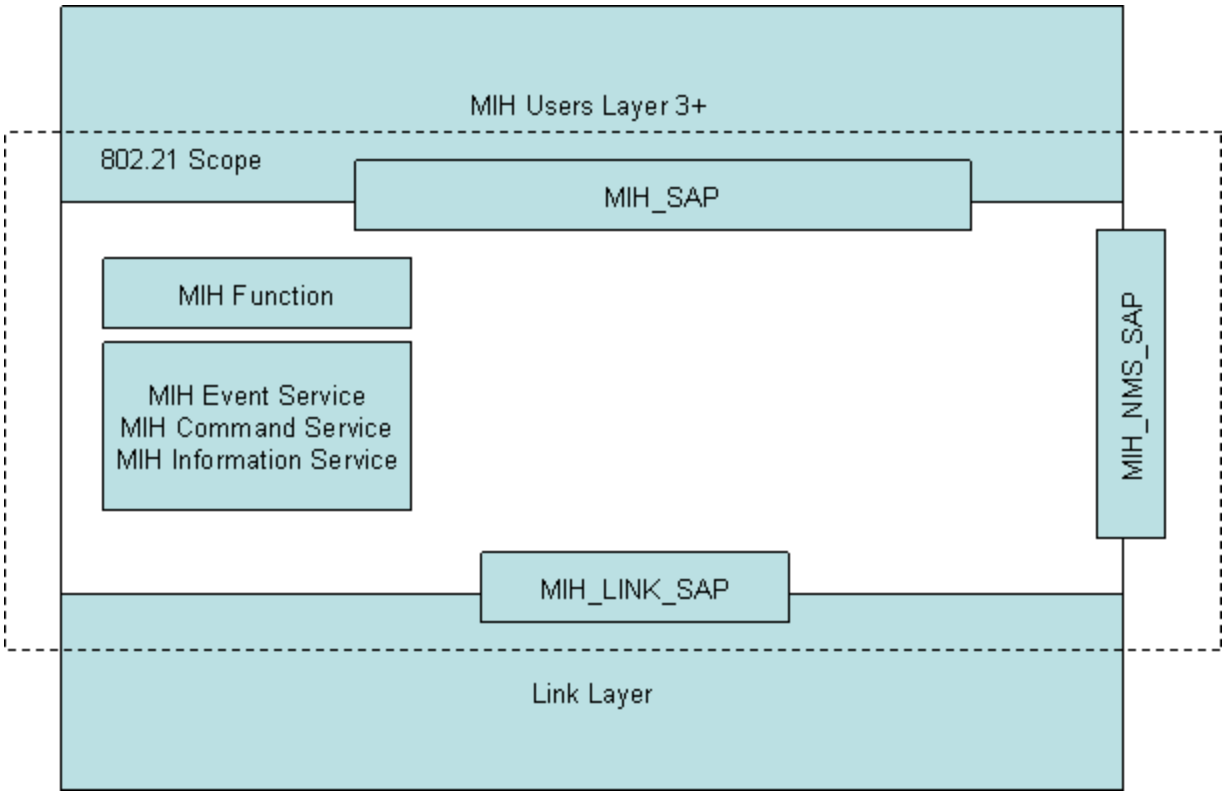

Figure 6 General Reference Model

Each or any number of the access networks will interface directly with the MIH Function using their own SAPs. Four access network reference models are provided as examples. They are based on the information provided in the standard which are based on the standards themselves. Amendments and advice need to be fluid between all the standards for handover to be effectively and easily implemented. Further, these interfaces in essence can support MIH, but they require corresponding changes with regards to SAPs. The amendments will be required for everything to connect. Any changes in those standards at a later date could have an adverse affect on this standard.

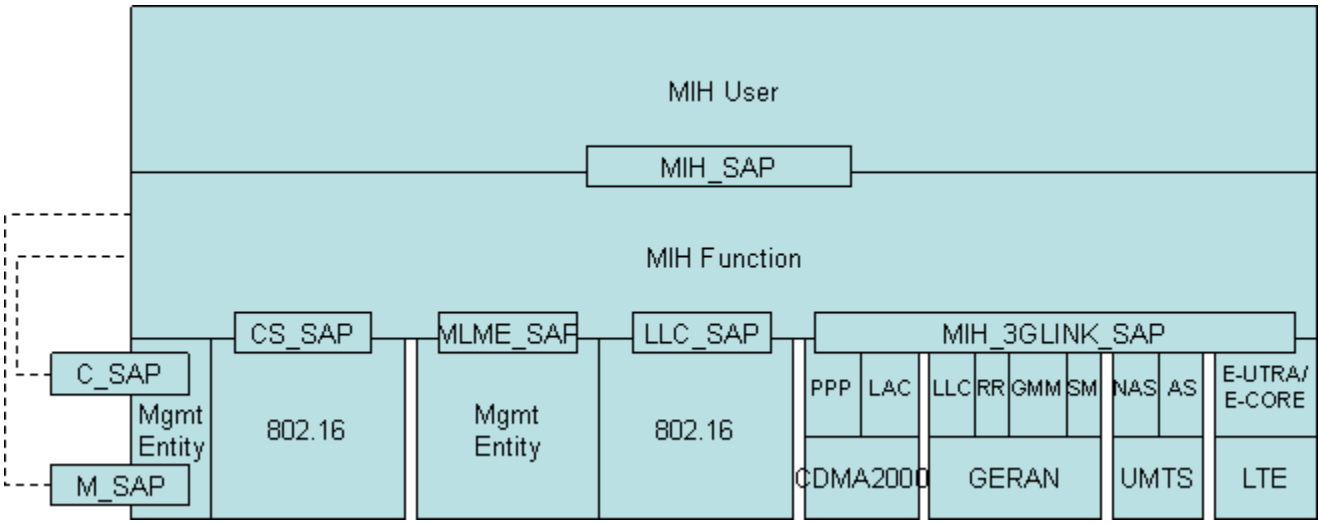

Figure 7 Multiple Access Network Reference Model

4.1 IEEE 802.3

MIH is supported on 802.3 over the existing LSAP for data, as depicted in Figure 7. To support the MIH Frame over the LSAP, a new ethertype Type will need to be added to the standard.

4.2 IEEE 802.11

Notice in Figure 7, MIH is supported on 802.11 over LLC_SAP for data and MLME_SAP for management. Some primitives used will be system configuration and link state change triggers. The 802.11 link layer should be enhanced with the standard's SAPs.

4.3 IEEE 802.16

Figure 7 displays the MIH support through CS_SAP for data, C_SAP and M_SAP both for management. Some primitives used will be handovers, idle mode mobility management, subscriber and session management, radio resource management, AAA server signaling, and media independent function services.

4.4 3GPP/3GPP2

As of yet there is no SAP link to 3GPP or 3GPP2, the standard will need to be amended to support MIH. Once they do they will link through MIH_3GLINK_SAP. The way this will be accomplished will be by using *service primitive for GSM, UMTS, LAC, PPP, LTE/SAE [all cellular technology acronyms].... [and] establishing a relationship between the 3GPP/3GPP2 primitives and IEEE 802.21 primitives at both the link layer and at the MIH level....Include 802.xx Radio Access Technology [(RAT)] within the Inter-RAT cell info list information element broadcast by 3GPP systems. Extend existing primitives to reflect awareness of 802.xx RATs.* [IEEE802.21].

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5. Service Access Points (SAPs)

The MIH Function has several defined SAPs for access to the handover features and the interfaces, which the MIH Function actually passes off to the Lower Layers acting as a man-in-the-middle. There are three SAPs defined for MIH they are MIH_SAP for the Upper Layer access to the Lower Layers and the MIH , MIH_LINK_SAP to connect the MIH Function and the Lower Layers, and MIH_NMS_SAP for management functions. Below are the primitives for each of the SAPs directly from the standard [IEEE802.21].

Table 5.1 MIH_SAP

No.	Primitives	Service Category	Description
1	MIH Capability Discover	System Management	Discover list of Events and Commands supported by MIH Function.
2	MIH Event Register	Event	Register for MIH event notifications
3	MIH Event DeRegister	Event	Deregister for MIH event notifications

4	MIH Link Up	Event	L2 connection has been established
5	MIH Link Down	Event	L2 connectivity is lost
6	MIH Link Going Down	Event	L2 connectivity is predicted to go down
7	MIH Link Event Rollback	Event	Predicted event has not occurred and hence event indication must be rolled back
8	MIH Link Parameters Report	Event	Link parameters have crossed specified threshold
9	MIH Link SDU Transmit Status	Event	Indicate transmission status of all PDU segments
10	MIH Link Handover Imminent	Event	L2 handover is imminent
11	MIH Link Handover Complete	Event	L2 handover has been completed
12	MIH Get Status	Command	Get the status of link
13	MIH Switch	Command	Switch session between specified links
14	MIH Configure	Command	Configure link parameters and parameter thresholds
15	MIH Configure Thresholds	Command	Configure thresholds for Link events
16	MIH Scan	Command	Scan the network
17	MIH Handover Initiate	Command	Initiate handover
18	MIH Handover Prepare	Command	Prepare for handover and query available resources
19	MIH Handover Commit	Command	Mobile node has committed to handover
20	MIH Handover Complete	Command	Handover has been completed
21	MIH Network Address Information	Command	Obtain network address on new link
22	MIH Get Information	Information	Request to get information from repository

Table 5.2 MIH_LINK_SAP

No.	Primitives	Service Category	Description
1	Link Event Discover	System Management	Discover link capabilities
2	Link Event Register	Event	Register for event notifications
3	Link Event Deregister	Event	Deregister for event notifications
4	Link Configure Thresholds	Command	Configure link thresholds for Link events
5	Link Up	Event	L2 connectivity is established
6	Link Down	Event	L2 connectivity is lost
7	Link Going Down	Event	L2 connectivity loss is imminent

8	Link Event Rollback	Event	Predicted event has not occurred and hence event indication must be rolled back.
9	Link Parameters Change	Event	Link parameters have crossed specified thresholds
10	Link SDU Transmit Status	Event	Indicate transmission status of all PDU segments
11	Link Handover Imminent	Event	L2 handover is imminent
12	Link Handover Complete	Event	L2 handover has been completed
13	Link Get Information	Information	Request for IEs

Table 5.3 MIH_NMS_SAP

No.	Primitives	Service Category	Description
1	Initialize	System Mgmt	Initializes the MIH Function
2	Reset	System Mgmt	Resets the MIH Function
3	Install link	System Mgmt	Informs the MIH Function of a new link that has been added to the mobile node or the network. The interface to new link may have been hot plugged or powered on.
4	Remove link	System Mgmt	Informs the MIH Function of an existing link interface that has been removed. The interface to new link may have been removed dynamically of shut down.

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6. MIH Protocol

The communication between layers occurs through the well-defined SAPs, covered in the previous section. But as was pointed out when discussing the MIHF. Remote MIHF can send each other reports and other information. The only problem is they have to send the data over some physical link, therefore the MIH Protocol takes care of encapsulating in MIH Frames and sending over the physical link. Each of the different physical links might require a slightly different method, but that is taken care of by the Reference Models.
The MIHF Protocol allows peer MIHF entities to interact with each other.... The nature of MIH communication may imply use of unacknowledged connection-less transport services to reduce transport overhead and ensure efficiency and reduced latency in the delivery of MIH messages [IEEE802.21].

6.1 Frame Format

The frame, pictured in Figure 8, is made up of two parts: the Fixed Header and the Variable Load for whatever data is being sent. The organization of the frame is still in flux, the standard actually has two different structures listed. In this one the OpCode has 2 and the Action ID has 10, but in another version on the same page the OpCode has 3 and the AID has 9. This is the general look of the frame though, with eventual modifications.

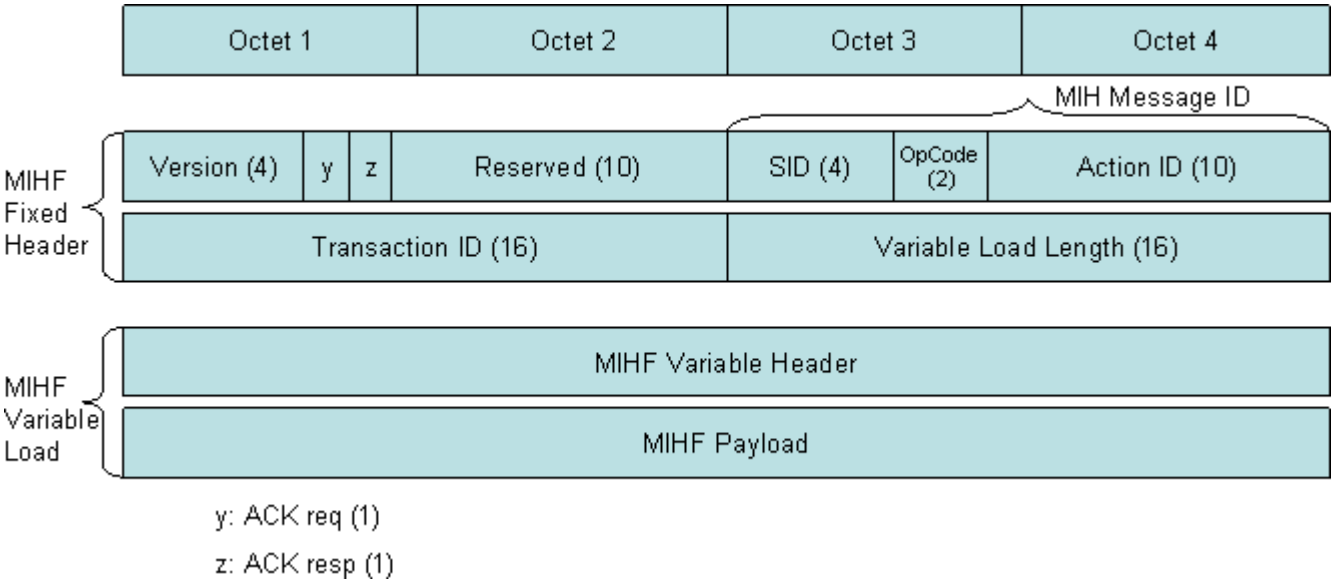

Figure 8 MIH Frame (bits)

6.2 Messages

Messages are sent with TLV, as well. The standard defines some Type value encodings for the TLV including: IP Renewal Flag, Link Down Reason Code, Confidence Level, Handover Mode, and Link Action. These messages and primitives allow for a standard communication arrangement.

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7. Industry

This is both a blessing and a curse for companies in the telecommunications industry. Cellular telephone companies who once had a solid grasp on mobile roaming will eventually give way to mixed mode IP/cellular phones that seamlessly switch back and forth. This use of the Internet will not only bring savings to the consumer, but to the companies that implement this technology.

7.1 Implementations

Today there are already implementations of handover in existence. Cellular phone companies use handover as part of their business model. With widespread tower coverage and roaming partners, your phone will automatically switch from tower to tower as you move farther from one and closer to another. Wireless Networking standards 802.16 already include a form of handoff, but it occurs at Layer 3 and as a result requires that you start a new connection, furthermore this handover is not among all access networks on 802.16. Some implementations for handover have been created for 802.11, but these

suffer from the same limitations. The new MIHS will not invalidate these efforts. It will complement them and provide them with more tools to get the handover done quicker, more efficiently and with better information. There is a commercial implementation similar to 802.21 called Generic Access Network (GAN) which allows seamless roaming between LANs and WANs and was adopted by 3GPP. It uses a server based system and always sends the data to the servers which distributes it.

7.2 Companies

Motorola was working on 802.21 compatible headsets. After they spun off Freescale Semiconductors, they continue to cooperate in the development. Until there is something closer to a standard the pre-Standard products can't be developed effectively. http://www.motorola.com and http://www.freescale.com/
GAN's website is accessible via http://www.umatechnology.org/overview/

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8. Conclusions

Products that support this standard will be a long time coming. First the standard will need to become a standard and then it will need to be tested. After implementation will take a long time. Then after that support will trickle in. There will be a strong need to manage the QoS issues that handover will bring up. The idea is wondrous, but it's a pipe dream. We envision this seamless handover that enables us to do more for "free", meanwhile no right-minded business would work hard if there was not some extreme benefit to them. Either they will create a new revenue stream or the quality of service will go down the tubes. Though all this remains to be seen. First, they need to fully define the standard.

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Summary

Media Independent Handover Services offers promise for the Next Generation of Internet connected devices and protocols. The services provided will allow mobile devices a seamless, standardized approach to enabled handover. This is not meant to replace the old SAPs or eliminate proprietary methods for handover. It is merely another tool that can be used for completing a handover. The standard has a long way to go before being ready for production, but so do the protocols it will depend on. Eventually, this standard will allow for seamless handover across multiple, diverse networks yielding a large savings in cost and enhancing user experience.

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General overview of Handoff.

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General overview of 802.21.

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List of Acronyms

3G	Third Generation
3GPP	3G Partnership Project
3GPP2	3GPP 2
FMIP	Fast Handover Mobile IP
HMIP	Hierarchical Mobile IP
IE	Information Element
MICS	Media Independent Command Services
MIES	Media Independent Event Services
MII	Media Independent Interface
MIH	Media Independent Handover
MIHF	Media Independent Handover Function
MIHS	Media Independent Handover Services
MIIS	Media Independent Information Services
MIP	Mobile IP
MLME	MAC Layer Management Entity
MN	Mobile Node
PoA	Point of Access
PLME	Physical Layer Management Entity
QoS	Quality of Service
SAP	Service Access Point
TLV	Type-Length-Value message
XML	Extensible Mark-up Language

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This paper is available online at http://userfs.cec.wustl.edu/~jws2/mihs/index.html