

# Seamless Handover across Heterogeneous Networks – An IEEE 802.21 Centric Approach

Ashutosh Dutta, Subir Das, David Famolari, Telcordia Technologies, NJ  
Yoshihiro Ohba, Kenichi Taniuchi, Toshikazu Kodama, Toshiba America Research Inc., NJ  
Henning Schulzrinne, Computer Science Department, Columbia University, NY

## *Abstract:*

Supporting seamless handover across heterogeneous access networks requires several functionalities to be taken into account such as service continuity, application class, service quality, network discovery and selection, security and power management of the mobile. In this paper, we present seamless handover techniques based on the emerging IEEE 802.21 standards efforts. The IEEE 802.21 group is creating a framework that defines a Media Independent Handover Function that will help mobile devices to seamlessly roam across heterogeneous access networks. We describe the three primary components of this framework, including the event service, command service and information service and discuss how such services can optimize handover between heterogeneous access networks such as 802.11, 802.16, CDMA and GPRS while interfacing with policy and higher layer mobility protocols. Lastly, we present an experimental testbed implementation and performance results that show an 802.21-based approach to mobility can reduce disconnection times and packet losses during handover.

## 1 Introduction

Roaming across heterogeneous access technologies such as 802.11, WiMAX, and CDMA as well as wired access networks such as xDSL and cable will become a requirement of future networking devices rather than an additional feature. However, supporting seamless roaming between heterogeneous networks can be challenging since each access network may have different mobility, QoS and security requirements. Moreover, interactive applications such as VoIP and streaming media have stringent performance requirements on end-to-end delay and packet loss. The handover process stresses these performance bounds by introducing delays due to discovery, configuration and mobility binding updates. Performance can also be tied to the specific access networks and protocols encountered. For example, configuring a PPP interface takes more time than configuring an interface using DHCP in a LAN environment [14]. Network-specific authentication and authorization protocols may introduce additional delays. Thus, it is essential to reduce delays during each step of the handover process.

Handover decisions, particularly within heterogeneous networking environments, play an important role in

mobility management. Getting network information a-priori (via lower layer triggers or higher layer information elements) and applying intelligent policies in the handover process can minimize delays. In such cases however, it is essential to get cooperation from other network elements and services. The IEEE 802.21 standards effort is defining a framework to support information exchange that aids mobility decisions, as well as a set of functional components to execute those decisions.

The rest of the paper is organized as follows. Related work is described in Section 2. Section 3 describes the IEEE 802.21 framework and its core architecture. The main functional components of the 802.21 architecture and their benefits to the mobility process are elaborated in Section 4 and a specific mobility example is presented. Results of a testbed implementation are described in Section 5. Section 6 concludes the paper.

## 2 Related Work

References [1] through [8] describe mobility management techniques that support fast-handover by enhancing currently available mobility management protocols. References [9] and [10] devise mechanisms to reduce handover delay at layer 2 and layer 3 respectively. These solutions, however, do not discuss heterogeneous access scenarios. Currently, there are several initiatives to optimize mobility across heterogeneous networks. The MOBOPTS working group within the IRTF and the DNA working group within the IETF have been looking into devising ways to support optimized handover by using appropriate triggers and events from the lower layers. References [11] and [12] describe mobility management techniques that consider both security and heterogeneous mobility. Although many of these techniques use some sort of cross-layer mechanisms and “make-before-break” algorithm to provide fast-handover, it is desirable to have a standardized method to handle mobility across heterogeneous networks in an efficient manner. The IEEE 802.21 [13] standards group is currently discussing a variety of scenarios in detail and is in the process of ratifying a standard based around a Media Independent Handover framework. We describe this framework and

present results of mobility experiments conducted on a testbed implementing the 82.21 framework concepts.

### 3 802.21 Framework

The IEEE 802.21 framework [13] is intended to provide methods and procedures that facilitate handover between heterogeneous access networks. These handover procedures can make use of information gathered from both the mobile terminal and network infrastructure to satisfy user requirements. There are several factors that may determine the handover decision. Typically these include service continuity, application class, quality of service, network discovery and selection, security, power management and handover policy.

The 802.21 framework facilitates the network discovery and selection process by exchanging network information that helps mobile devices determine which networks are in their current neighborhoods. This network information could include information about the link type, the link identifier, link availability and link quality etc. of nearby network links. This process of network discovery and selection allows a mobile to connect to the most appropriate network based on certain mobile policies.

As the mobile moves between different network Points of Attachment (PoA), it is essential to maintain proper security associations between the communicating end-points. These security associations can be obtained both via lower layer and higher layer mechanisms.

#### 3.1 802.21 Core Architecture

The heart of the 802.21 framework is the Media Independent Handover Function (MIHF) which provides abstracted services to higher layers by means of a unified interface. This unified interface exposes service primitives that are independent of the access technology. This interface is called Service Access Point (SAP). A detailed description of the SAPs are defined in Section 4.4.

Figure 1 illustrates examples showing how the MIHF can communicate with access specific lower layer MAC and PHY components, including 802.16, 802.11 and cellular, using lower layer interfaces, as well as with upper layer entities.

MIHF defines three different services: namely, Media Independent Event Service (MIES), Media Independent Command Service (MICS) and Media Independent Information Service (MIIS). Media Independent Event Service provides triggered events corresponding to dynamic changes in the link characteristics and link status. Media Independent Command Service helps the MIH user to manage and control the link behavior relevant to handovers and mobility. MICS uses the information obtained from the event service as part of the subscription and notification process and acts upon it accordingly. MIIS provides an information model that passes on the information regarding

the neighboring networks and their capabilities. A detailed description of these services sets are described in Section 4.

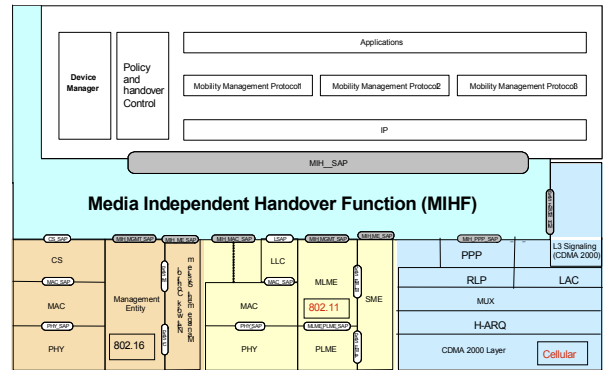


Figure 1 – Media Independent Framework

### 4 802.21 Functional components

In the following subsections, we describe in greater detail the three main functional components of the Media Independent Functions such as MIES, MICS and MIIS. Figure 2 shows the interaction of these services with upper layers and lower layers of the protocol stack.

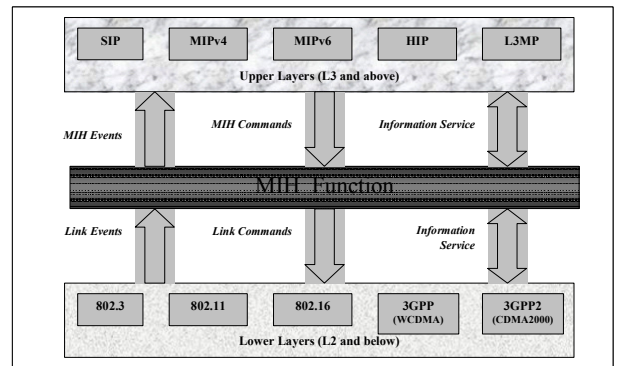


Figure 2 – Interaction between MIH components

#### 4.1 Media Independent Event Service

Media Independent Event Service (MIES) provides services to the upper layers by reporting both local and remote events. Local events take place within a client whereas remote events take place in the network elements. The event model works according to a subscription/notification procedure. An MIH user (typically upper layer protocols) registers to the lower layers for a certain set of events and gets notified as those events take place. In the case of local events, information propagates upward from the MAC layer to the MIH layer and then to the upper layers. In the case of remote events, information

may propagate from the MIH or Layer 3 Mobility Protocol (L3MP) in one stack to the MIH or L3MP in a remote stack. Some of the common events defined include “Link Up”, “Link Down”, “Link Parameters Change”, “Link Going Down”, “L2 Handover Imminent” etc. As the upper layer gets notified about certain events it makes use of the command service to control the links to switch over to a new point of attachment.

#### 4.2 Media Independent Command Service

The higher layers use the Media Independent Command Service (MICS) primitives to control the functions of the lower layers. MICS commands are used to gather information about the status of connected links, as well as to execute higher layer mobility and connectivity decisions to the lower layers. MIH commands can be both local and remote. These include commands from the upper layers to the MIH and from the MIH to the lower layers. Some examples of MICS commands are MIH Poll, MIH Scan, MIH Configure, and MIH Switch. The commands instruct an MIH device to poll connected links to learn their most recent status, to scan for newly discovered links, to configure new links and to switch between available links.

#### 4.3 Media Independent Information Service

As a mobile is about to move out of the current network it needs to discover the available neighboring networks and communicate with the elements within these networks so as to optimize the handover. Media Independent Information Service (MIIS) provides a framework and corresponding mechanisms by which an MIHF entity can discover and obtain network information within a geographic area. MIIS primarily provides a set of information elements, the information structure and its representation and a query/response type mechanism. The information service provides access to both static information as well as dynamic information. Examples of static information may include the names and providers of the mobile terminal’s neighboring networks. Dynamic information may include parameters such as channel information, MAC addresses, security information, and other information about higher layer services that will help make effective handover decisions. This information can be made available via both lower layers and upper layers. In some cases certain layer 2 information may not be available or may not be sufficient to make intelligent handover decisions. In such cases, higher-layer services may be consulted to provide additional information to assist in the mobility decision making process. The MIIS specifies a common way of representing this information across different technologies by using a standardized format such as XML or ASN.1. Having a higher layer mechanism to obtain the information about the neighboring networks of different access technologies alleviates the need for a specific access-dependent discovery method. We have

implemented an application layer mechanism based on RDF/XML as part of our experimental testbed.

#### 4.4 Service Access Point (SAP)

Service Access Points (SAPs) are the APIs through which the MIHF can communicate with the upper layer and lower layer entities using 802.21 primitives. There are three types of SAPs; lower layer SAP, upper layer SAP and management plane SAP. Lower layer SAPs are network access specific and are defined by each MAC and PHY type. Each Radio Access Network (RAN) defines its own SAP to communicate with the MIHF. Upper layer SAPs define the interface between MIHF and upper layer mobility management protocols or policy engines that may be resident within a client or in the network. Lastly, the management SAPs define the interfaces between the MIHF and the management planes of various networks. The MIHF can also use the management SAPs to communicate with the MIES, MICS and MIIS.

#### 4.5 802.21 assisted mobility management

The service primitives defined in the 802.21 framework can work with any type of L3 mobility management protocol such as SIP, MIPv6 or MIP. A mobile can make use of the service primitives to communicate with policy managers, device drivers and other mobility management protocols during its movement.

Figure 4 shows an illustration of how a SIP-based mobility management mechanism can benefit from interaction with 802.21-based components. As shown, the mobile has two types of interfaces (Network X and Network Y). Initially, the mobile is using Network X as its primary interface to communicate a multimedia session with a correspondent host. Within the mobile’s neighborhood, there are many networks of type Y. The mobile queries an information server to learn the number of networks that are of type Y that are nearby. Once it receives the networks that are of type Y, it picks a specific network and gets more information about that network, such as address and type of security servers, DHCP server address, MAC address of the access point etc.

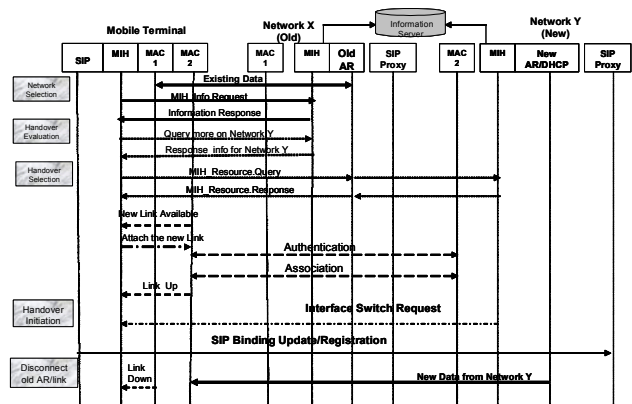


Figure 4 – 802.21 assisted SIP-based mobility management

In the very beginning the mobile's MIHF subscribes to an event so that it gets notified when the new link becomes available. In order to make sure that there is enough bandwidth and resources available in the new network, so that it can maintain the multi-media communication when the new link is available, the mobile makes an MIH query to find out about the available bandwidth and resources. Since the mobile has already subscribed to an event for the availability of the new link, it obtains the information about the availability of the new link through MIES. Once the link is up the mobile performs a series of authentication/association requests. At this time MICS helps switch the interface to the active interface (i.e. interface for network Y). This switch command generated from MICS can originate either from the local client or from a remote network element. After the mobile has decided the new interface to be its primary interface, it goes ahead with other configuration process such as obtaining the IP address from the new network. During this time the mobile is still communicating through the primary interface connected to network X. Since it takes time to configure an interface with IP address and other parameters, interface configuration in the new network takes place in the background. The mobile sends a binding update to the correspondent host after the new interface is configured with the new IP address. At this time traffic to the mobile flows through the new interface and the handover is complete.

## 5 Test-bed Implementation and Results

This section describes a specific implementation centered on the 802.21 mobility approach. It also provides evaluation results and compares them with non-802.21 based handover. Figure 5 shows a specific scenario and associated network elements in the experimental testbed. There are four networks defined in the implementation environment.

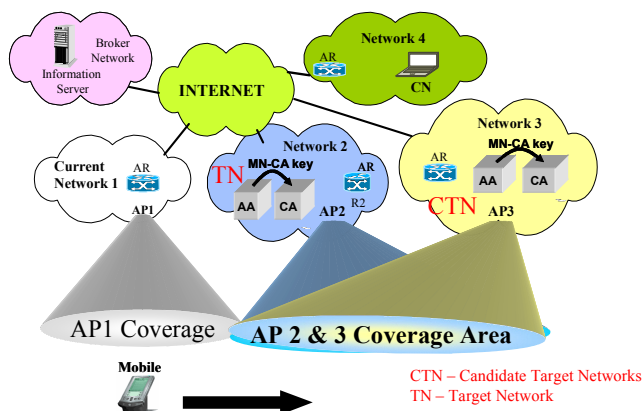


Figure 5: Specific scenario for 802.21 framework

Network 1 is the current point of attachment (cPoA), Networks 2 and 3 are possible new points of attachment (nPoA), and network 4 is where the correspondent node (CN) resides. The mobile is initially in Network 1 and starts communicating with the correspondent node. Network 1, network 2, and network 3 do not need to be adjacent. The Mobility Management Protocol (MMP) is SIP Mobility (SIP-M), the configuration protocol is DHCP, the authentication agent (AA) is a PANA Server, the configuration agent (CA) is a DHCP Relay Agent and the Access Router (AR) is R2, which can provide IP-in-IP tunneling functions. The MN's SIP user agent communicates with CN's SIP user agent. After a successful connection setup, voice traffic flows between the MN and the CN. This voice traffic is carried over RTP/UDP. We have used RAT (Robust Audio Tool) as the media agent and the streaming traffic is generated using a CODEC with a spacing of 20 ms between packets.

In the case of our baseline scenario without 802.21 concepts, the handover delay and attributed packet loss take place during the mobile's movement, IP address assignment, post-authentication, and mobility binding update. The DHCP procedure takes a long time to complete the detection of duplicate IP addresses in the network and binding updates can take a long time if the correspondent node is too far from the mobile node. The non-802.21-based handover took up to 4 seconds delay due to all the above factors. We observed approximately 200 packets were lost during the handover. It may take up to 15 seconds if the neighboring network is of the type CDMA or GPRS due to lengthy authentication and connection establishment procedures in those networks.

In the case of the 802.21 based handover, we took advantage of the network discovery mechanisms of the 802.21 framework that provide details of the access points in the neighboring networks, including channel numbers and Ethernet addresses and subsequently other parameters such as DHCP server, PANA server etc. We have used an RDF/XML-based query response mechanism to obtain the required information from the information server. Information obtained regarding the neighboring networking elements helps the mobile to communicate with them ahead of time and perform a more proactive handover. The MN communicates with the DHCP Proxy to obtain an IP address from the target network which is relayed back to the mobile. After the MN gets the new IP address (nCoA), an IP-in-IP tunnel is created between Router 2 and the mobile. An example of the RDF-based query and responses is shown in Table 1. Responses of both the initial query and subsequent query are illustrated. Timing associated with the first query-response seems to be more than the second query-response. We also observed that processing time takes the bulk of the total time. This query time plays an important role in deciding when to start the pre-authentication process.

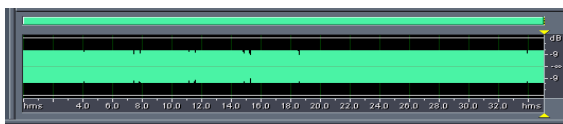
Figure 6 shows the audio output from both non-802.21-based and 802.21 assisted handoff. As observed in the figure, the total handover delay is limited to 14 ms and is largely bounded by layer 2 delay. Since the spacing between the audio packets is about 20 ms, only 1 packet was lost. Buffering mechanisms at the access router can actually reduce packet losses even further at the expense of some added delay.

Table 1: Example of RDF-based Query/Response

MIIS Query 1	Response 1	MIIS Query 2	Response 2
Current PoA: AP1 Query list of 802.11 type neighboring networks	Neighbor 0 : PoA ID:00:20:A6:53:B2:5E Tariff: 20  Neighbor 1: PoA ID:01:23:45:67:89:AB Tariff:50	Neighbor 0 selected, Query a list of network elements for Neighbor 0	Target Network Channel: 10 SSID: ITSUMO newpoal Router address: 10.10.10.52 Router MACID: 00:00:39:e6:8b:ee Subnet: 255.255.255.0 DHCP Server address: 10.10.10.51 PAA address: 10.10.10.52



Non-802.21 assisted SIP-based mobility



802.21 assisted SIP-based mobility – Optimized handoff

Figure 6: Audio output at the mobile (Non 802.21/802.21)

In this example network, candidate protocols can always be replaced by other protocols; for example, the mobility management protocol can be replaced by Mobile IPv6. Similarly, the tunnel management protocol can always be replaced by IKEv2 and IPSec. It is normal to assume the performance values will be different based on the type of candidate protocols used. We also found that L2 delay while switching the access points can vary based on the drivers and operating system used.

## 6 Conclusions

In this paper we have presented 802.21-based framework that helps provide secured handover between

heterogeneous access networks. We have discussed several functional components of the framework and their respective roles in providing the optimization. We explain a laboratory experimental setup where we have implemented some parts of 802.21 framework that include network discovery, network selection, pre-configuration, pre-authentication, and proactive handover using certain parts MIES, MICS and MIIS. Results obtained from the experiment prove the effectiveness of 802.21 framework. Thus an 802.21-assisted handover helps perform the secured proactive handover by reducing the delay and packet loss during the handover to a level that is acceptable for interactive VoIP and streaming traffic.

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