Potential of IEEE 802.21 as Backbone Standard in Heterogeneous Environment

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Abstract: - The availability of multiple wireless access technologies, together with the increasing use of real-time multimedia applications, are creating strong demand for handover performance, measured in terms of latency and losses. 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. The main purpose of IEEE 802.21 standard is to enable handovers between heterogeneous technologies, without service interruption, hence improving the user experience of mobile terminals. In this paper objectives and benefits of IEEE 802.21 standard implementation are described and emphasized.

Key-Words: Heterogeneous wireless networks, seamless handover, QoS.

1 Introduction
The aim of technological progress in the field of wireless communications is constituted by the provision of ubiquitous connectivity between individuals and a multiplicity of existing and future pervasive devices which permeate our environment [1]. The currently dominant cellular (a combination of metropolitan, local and personal area networks) as well as the emerging mobile ad hoc network (MANET) architectures constitute the major contenders for the role which would facilitate the realization of wireless networking [2], [3]. The heterogeneous networks inherits the vital complementary characteristics of both classical and ad hoc network topologies. Thus, it has the potential of attaining the levels of performance and efficiency required by the future wireless communications. Wireless ad hoc networks rely on peer-to-peer cooperation, where the mobile terminals utilize peer terminals as relays in order to gain access to the network’s infrastructure. The necessarily of peer-to-peer cooperation suggests a suitable open access approach to spectrum management, where a substantial portion of the frequency spectrum is made available to the network’s and users, as opposed to the network operators in the case of commercial cellular networks [4].

The availability of multiple wireless broadband access technologies, together with the increasing use of real-time multimedia applications, is creating strong demand for 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.

The main purpose of IEEE 802.21 standard 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.

Seamless mobility can be achieved by enabling mobile terminals to conduct seamless hangovers across diverse access networks. A seamless handover is characterized by the two following metrics:

1. the handover latency should be no more than a few hundred milliseconds and
2. the QoS provided by the source and target system should be nearly identical.

Supporting seamless roaming and inter-technology, handover is a key element to help operators manage and thrive form the 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 can manage multiple interfaces to balance traffic loads more appropriately across available networks, improving system performance and capacity.

IEEE 802.21 standard defines a Media Independent Handover (MIH) framework that can significantly improve handover between heterogeneous network technologies [5]. This standard defines the tools required to exchange information, events and commands to facilitate handover initiation and handover preparation. IEEE 802.21 standard 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 network layer as to systems that employ Session Initiation Protocol (SIP) at the application layer.

2 Objectives
The main purpose of IEEE 802.21 standard is to enable handover between heterogeneous technologies. The contribution is centered around:

(a) framework that enables seamless handover between heterogeneous technologies,
(b) the definition of a new link layer service access points (SAPs), and
(c) the definition of a set of handover enabling functions that provide the upper layers with the required functionality to perform enhanced handovers.

The framework that enables seamless handover between heterogeneous technologies is based on 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.

SAPs define both media – independent and media – specific interfaces. SAP offers a common interface for link layer functions and is independent of the technology specific. For each of the technologies in 802.21, SAP is mapped to the corresponding technology – specific. Some of these mappings are included in the standard draft. Functions concerning the definition of a set of handover provide the upper layers, e.g., mobility management protocols such as Mobile IP, with the functionality to perform enhanced handovers [6].

The secondary goals are service continuity, handover-aware applications, Quality of Service (QoS) – aware handovers, network discovery, network selection assistance and power management [7].

The 802.21 standard presents a framework that supports a complex exchange of information aiming to enable seamless handover between heterogeneous technologies. Service continuity is defined as the coming continuation of the service during and after the handover procedure. It is very important to avoid the need to restart a session after handover.

From the point of view of handover-aware applications, it is important to take into account that 802.21 framework provides applications with functions for participating in handover decisions. For example, a voice application may decide to execute a handover during a silence period in order to minimize service disruption.

The services defined by the 802.21 standard provide information on networks that are potential handover targets, report events and deliver commands related to handover. These services speed up handovers while helping to retain end-to-end connectivity. Also, the 802.21 framework provides the necessary functions in order to make handover decision based on QoS criteria. For example, we may decide to handover to a new network that guarantees the desired QoS.

Network discovery is an 802.21 feature that allows users to be provided with information on candidate neighbors for a handover.

Network selection assistance is the process of making a handover decision based on several factors like QoS, throughput, policies, billing, and etc [8]. 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.

Finally, power management can also benefit from the information provided by this standard. For example, power consumption can be minimized if the user informed of network converge maps, optimal link parameters, or idle modes.

3 Benefits and Challenges
A media independent framework is a more scalable and efficient method of addressing inter-technology handovers. To address handovers, each access technology requires only a simple extension to ensure interoperability with all other access technologies. The complexity of this approach grows on the order of $N$ access technologies and scales more efficiently than a media-specific approach. This is the approach adopted by the IEEE 802.21 standard which defines a common set of Media Independent Handover (MIH) services that interact with the higher layers of the protocol stack. Then, each access technology then requires only one
media-specific extension to ensure interoperability with the common IEEE 802.21 framework. IEEE 802.21 provides internetworking with IEEE 802 systems and between IEEE 802 and non-IEEE 802 systems (i.e. 3GPP systems). In fact, the need for MIH services, spanning multiple external networks led to the creation of the IEEE 802.21 Working Group with a project to create a standard that will define 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 [9].

IEEE 802.21 facilitates, speeds and thus increases the success rate of intertechnology handover decision making and other pre-execution processes. These processes include intertechnology candidate network discovery, target network selection, target network preparation, and handover execution timing and initiation.

There are special challenges in inter-radio access technology (RAT) handovers as compared to intra RAT. Addressing these special challenges, IEEE 802.21 adds unique value in the inter-RAT case [10]. In intertechnology handovers the decision/pre-execution phase has greater significance than in intra-technology handovers, for example within code-division multiple access (CDMA) or Global System for Mobile (GSM) communications. Inter RAT handover decision making has a greater impact on both system performance and user experience. This is because intertechnology handover is likely to involve higher signaling complexity, more radio resources allocation difficulty, and higher system management complexity on both source and target networks. Some of the challenges in intertechnology handovers together with the corresponding description and 802.21-based solutions are as follows:

a) Network discovery and selection. Handover decision making entity must continuously evaluate available access networks in a power efficient manner. IEEE 802.21 enables inter-RAT network advertisement and provides a mechanism to query candidate target networks and their properties based on user equipment.

b) IP session continuity. Minimizing user disruption during handover requires session continuity when transitioning across radio technologies. An IEEE 802.21-based solution requires mobility signaling and provides link layer triggers that can optimize the performance of the mobility management protocols.

c) Low latency and single radio transmission handovers. It is necessary to minimize handover latency to support real-time multimedia applications. Coexistence and interference issues may mandate that only one radio in dual-radio user equipment can transmit at a given time during handovers. Both issues require target network preparation, while still connected to the source network. IEEE 802.21 standard provides signaling for the resource query and resource reservation on target network. This also requires inter-RAT interface between access gateways.

d) Operator control in target network selection. Operators may want to control which target network the user selects. Thus, there is a need to support network-initiated handovers. This also requires reporting radio measurements (e.g., link signal strength) across different radio access networks. IEEE 802.21 enables operators to enforce handover policies and decisions. Also, inter-RAT measurement reporting is enabled.

It can be concluded that functions in IEEE 802.21 standard provide handover intelligence in order to help address these challenges. As for the major challenges, an important fact is facing IEEE 802.21 as the unification of all the media specific technologies under one abstract interface. This goal is preferable to media-specific approach in terms of scalability and complexity [11]. 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. However, some technologies may require extensions to media-specific primitives. Such work requires cross-organization standardization activities. 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) to incorporate MIH services to support handovers between worldwide interoperability for microwave access (WiMAX) and 3GPP system architecture evolution/long-term evolution (LTE) networks [12]. Another challenge to widespread adoption of IEEE 802.21 is the lack of a conformance statement detailing mandatory set of primitives required to realize a particular use case. In that way, 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.

Important features to the deployment of MIH services, such as Media Independent Information Service (MIIS) provisioning, MIH security and
multi-radio power management are not fully addressed in the specification. 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. Operating multiple radios can be a significant drain on the battery of a device. Thus, mechanisms must be in place to facilitate better power management for multi-radio devices.

4 Scope of the IEEE 802.21 Standard in Handover

IEEE 802.21 offers the mechanisms for triggering a handover as well as preparing the handover to a new link. IEEE 802.21-based handover consists of three major blocks: initiation, preparation and execution [13].

In the first step handover initiation involves the procedures of old link configuration, radio measurement reports, as well as new link discovery. This means that old devices should be configured to report measurements when specific thresholds are crossed. The type of this measurement report may indicate an urgent handover request or just a periodic informational message. Moreover, new link discovery may be realized with specific triggers from the available link layer.

As for the handover preparation, additional scanning of RATs in the vicinity of the mobile node (MN) can be performed with the help of different IEEE 802.21 services. Discovering a new link may involve a query to a remote MIIS server that retains information about available networks in the area of a specific MN, or a network command to the MN to start scanning. In case of access to new network resources, the MN must authenticate itself to the network before proceeding. If the MN is authenticated at the new network, QoS context is transferred for checking resource availability. The result of radio resource availability check and other information from the network (for example pricing policies) represent the input to the handover decision algorithm. Radio resources must be reserved over the selected RAT.

The handover execution is out of the scope of the IEEE 802.21 standard as L2 signaling is treated by network specific procedures, and re-routing of IP traffic is usually performed with other protocols, such as mobile IPv6. On the other side, IEEE 802.21 may trigger the activation and deactivation of links in a way that may preserve resources over the old link for less handover interruption.

5 Media Independent Handover Services

In IEEE 802.21 standard, media refers to method/mode of accessing a communication system (cable, radio, satellite). Media Independent Handover Services standard provides link layer intelligence and other related network information to upper layer to optimize vertical handovers. This includes media types specified by 3GPP, 3GPP2 and both wired and wireless media in the IEEE 802 family of standards [14].

IEEE 802.21 defines three different types of MIH services in order to facilitate inter-technology handovers:

- Media Independent Information Services (MIIS),
- Media Independent Command Services (MICS), and
- Media Independent Event Service (MIES).

These services allow Media Independent Handover Function (MIHF) users to access handover-related information as well as deliver commands to the link layers or network. As for MIH services, they 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.

These primary services are managed and configured by a fourth service called the management service. This 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 can be performed to obtain proper service from a remote entity, too. 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 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. As an example, communication between local and remote MIHF entities is shown in Fig. 1. Also, this figure depicts the MIH service framework. It is assumed 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 – response to the remote entity. Dotted lines represent the remote events, commands and information service query and response. The MIHF 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. These messages correlate with the MIH primitives that trigger remote communication.

Fig. 1. Media Independent Handover Services framework and communication between local and remote entities.

5.1 Media Independent Information Service

The IEEE 802.21 standard defines Media Independent Information Service (MIIS) to provide information about heterogeneous neighboring networks, network topology, properties and available services. In other words, the MIIS defines a set of information elements, their information structure and representation as well as a query-response-based mechanism for information transfer. The MIIS provides a framework to discover information useful for making handover decisions. As an example, the MIIS can be used to discover specific information about networks within a specific geographic area to enable more effective handover decision making and execution. As another example a MN 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. Thus, optimal power utilization is allowed.

The main goal of MIIS is to provide the MN with essential information that may affect the selection of the appropriate networks during a handover. The information provided by the MIIS can be divided in the following groups:

- General information,
- Access network specific information,
- Point of attachment (PoA),
- Higher-layer services.

General information gives a general overview about the networks covering a specific area such as network type, operator identifier, or service provider identifier.

Access network specific information provides specific information for each technology and operator. The information is related to security characteristics, QoS information, revisions of the current technology standard in use, cost, roaming partners, etc. PoA related information comprises aspects like medium access control (MAC), address of the PoA, geographical location, data rate, channel range, etc.

The information provided in higher layer services/information per PoA is related to the available services on this PoA and network. For example, the information provided may be the number of subnets this point of service support, the IP configuration methods available, or even a list of all supported services of the PoA.

Other information such as vendor – specific information or service can be added. It is important to note that the MN should be able to discover whether the network supports IEEE 802.21 by use of a discovery mechanism or information obtained by MIIS through another interface. The MN is able to obtain MIIS information even before the authentication in the PoA is performed in order to be able to check the security protocols support of QoS, or some other parameters before performing a handover.

5.2 Media Independent Command Service

Media Independent Command Service (MICS) has to allow effective management and control of different link interfaces on a multimodal device and to enable both mobile and network initiated handovers. They support querying target networks about the status of quick – changing resources. Some MICS messages are part of the signaling between inter-RAT gateways.

Commands can be delivered either locally or remotely by MIH users or by the MIHF itself. In fact 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 combine dynamic
information regarding link status and parameters, provided by the MICS with static information regarding network states, network operators, or higher layer service information provided by the media independent information service, to help in the decision making. Through remote commands the network may force a terminal to handover, allowing the use of network initiated handovers and network assisted handovers. A set of commands are defined in the specification to allow the user to control lower layers configuration and behavior. There are two main categories of commands: MIH commands and Link commands.

MIH commands are sent by the higher layers to the MIHF. If the command is addressed to 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 MN initiated handovers, the command service provides a set of commands to help network selection. All MIH commands are designed to help in the handover procedure. The routing of user packets is left to the mobility management protocols located at higher layers [15].

Link 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.

5.3 Media Independent Event Service

Media Independent Event Service (MIES) provides link layer triggers, measurements reports and timely indications of changes in link conditions. Generally speaking, 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 and logical link layers or predict state changes of these layers. There are two main categories of events: link events that originate from 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 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 notification can be sent to the MIHF or any upper-layer entity that can be located within a local or a remote node.

The IEEE 802.21 supports handover initiated by the network or mobile terminals. Hence, events related to handovers can be originated at the MAC or MIHF layer located in the MN or PoA to the network. The standard IEEE 802.21 specifies a subscription delivery mechanism as several entities could be interested in the generated events. All entities interested in an event type should register to it. When the event is generated, it will be delivered to the subscription list. An entity is not forced to react to the subscription list, being event nature advised. The MIH event service can support several event types like: MAC and PHY state change events, Link parameters events, Link synchronizations events and Link transmission events. MAC and PHY state information about a definite change in MAC or PHY state. Examples for this type of events are link up and link down events.

Link parameters events are generated by a change in the link layer parameters. They can be generated in a synchronous way or asynchronously such as by reporting when a specific parameter reaches a threshold. Link synchronous 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.

Link transmission events inform of the transmission status of higher layer protocol data units 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 transmission policies at higher layers.

Event services are used to detect when a handover is possible [16]. Several events like 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 appropriate to perform a handover to this new link.

6 Scenarios for MIH Services Implementation

As stated before, the MIES is provided from lower layers to upper layers. Commands follow a top-down direction as opposed to events. Typical commands are the configuration of network devices and the scanning of available networks. The service types also include MIIS which provides the mechanism for retrieving information and assisting handover decision. Such information can be static link layer parameters, link channel information, or
MAC address of the PoA. This is the basic scenario for MIH services.

A handover scenario between Wireless Metropolitan Area Network (WMAN) and Wireless Local Area Network (WLAN) managed by the same operator is shown in Fig. 2. The IEEE 802.21 provides a media independent framework to support handover preparation and initiation. MIH services are 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 MN is within WMAN, it can query the information server to obtain available WLAN information withoutactivating and directly scanning through the IEEE 802.11 interface. This can conserve the battery power of the mobile device. Using the information provided by the information server, the MN activates its WiFi interface, confident that an appropriate WLAN. Then, the MN can associate and authenticate with the WLAN while the session is active through the IEEE 802.16 interface. The MIES allows new link to be discovered and qualified prior to handover, while MIH commands can be used to begin handover process. Use of the MIH service allows much of the time-consuming work associated with handover initiation and preparation to be completed before the handover takes place. This significantly reduces handover latency and losses.

A handover scenario between WMAN and Wireless Wide Area Network (WWAN) is represented in Fig. 3. WMAN operator has a roaming relationship with the WWAN operator. Placement of IEEE 802.21 entities can occur in either or both of provider core networks. In this scenario it is assumed that MIH functionality resides within the WWAN core network. The MIH can be used to discover the presence and characteristics of available WMANs, while the MICS can instruct the mobile device to activate its IEEE 802.16 interfaces only when WMAN coverage is available. Carrying this information over the 3G radio access network allows the mobile device to discover and access available WMAN without activating its IEEE 802.16 interface, eliminating the need to actively scan, and preserving battery life.

7 Concluding Remarks
The success of the IEEE 802.21 standard depends upon the acceptance of this technology by other standards and industry forums, as well as upon the activities within the IEEE 802.21 Working Group. IEEE 802.21 covers many seamless mobility principles and therefore seamless mobility is supported. Seamless mobility is a critical factor if service requirements are to be supported efficiently in next-generation heterogeneous access networks.

IEEE 802.21 adds unique value by supporting the challenge decision and pre-execution phases of intertechnology handovers. This standard provides mechanisms to prepare the target network before handover execution occurs, reducing latency. Real-world use cases for such handovers, include responding to applications, operators, or users asking for higher data rates, lower costs, higher QoS, or improved traffic management, as well as to changes in mobility status or coverage. Mobile terminals with several interfaces are started to be introduced in the market. With such scenario the IEEE 802.21 specification provides 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 as well as specifying a protocol for mobility services transport. To achieve acceptance and wide deployment in the future, additional specifications describe use-case, scenarios with requirements, features and extensions to media specific technologies are required.

References:
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