IEEE 802.21 Information Service: Features and Implementation Issues

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***Abstract* - The next generation of wireless networks terminals is expected to support multiple wireless radio access networks as Bluetooth, Wi-Fi, Wi-Max and UMTS in which users can maintain the connection when they switch from one network to another, in seamlessly manner. Supporting this type of handover in heterogeneous networks requires several constraints to be considered such as radio signal strength, coverage, security, QoS, user policies, cost, etc. In order to store information from several networks and operators, the new IEEE 802.21 standard specifies a media independent information service that supports various information elements providing network information within a geographical area, focusing on optimization of the handover process. This article presents a general approach towards Information Service management infrastructure in a heterogeneous mobile environment addressing the main features, security and implementation issues.**

***Index Terms* — Mobility, IEEE 802.21, Heterogeneous Networks, Media Independent Handover, inter-domain, service discovery, security.**

I. Introduction

With the proliferation of Wi-Fi (802.11) hotspots, the advent of Wi-Max (802.16) networks and the global reach of 3G mobile wireless services, the possibility of ubiquitous mobility for data transport is both a reality and a challenge. To make use of the available networks the mobile node (MN) will need to be equipped with several radio interfaces enabling them to associate with different networks from distinct operators in the future mobile Internet.

In this heterogeneous wireless environment, seamless handover is very important in order to minimizing aspects as data lost, low control overhead and transfer delay duration. In the literature [1], seamless handover is a type of handover in which service continuity and disruption time must be minimal. The handover can occur either between access points that use the same wireless technology (horizontal handover) or among two different points of attachment (PoA) belonging of different link layers technology (vertical handover). In such cases, the most important requirement is to provide the MN with sufficient information about neighbor networks to make an accurate handover decision.

In traditional (horizontal) handover, such as between cellular networks, the handover decision is based mainly on relative signal strength (RSS) information in the border region of two cells, as an indicator for service availability from a PoA. However, traditional RSS comparisons are not sufficient to make a vertical handover decision, as they do not take into account the various attachment options for the MN. This is because in heterogeneous network environments more parameters and information will be needed to make an accurate vertical handover decision. Besides RSS handover decision criteria, several other parameters such as current network utilization, expected throughput, cost per use, QoS supported, PoA geographical position and security are important.

In this way, the network information discovery phase is highly critical. To accomplish it, MN must be able to discover what types of network connectivity are accessible to them. Essentially, there are three basic alternatives to obtain network information: (1) the MN is provided with manually static information about geographical networks by means of a configuration file; (2) the MN listens to network “service advertisements” (e.g., 802.11 beacon frames and DCD 802.16 frames) to learn the accessible offered network services and (3) the mobile node can consult a network information entity, which can store information from several networks and operators. In this work, we will demonstrate the main benefit of using such network information discovery technique.

To assist seamless handover between networks belonging to same or different technologies, a network information service (IS) may be used. The main goal of IS usage is to allow the MN to acquire a global view of all heterogeneous networks information in the area before connectivity loss is experienced, hence improving the handover decision and mobile user experience.

At the forefront of network IS specification, the IEEE 802.21 [2] standard group is currently working on the standardization of a media independent information service (MIIS) that provides capability for obtaining information about lower layers such as security, neighbor maps, QoS and cost, as well as information about available high layer services such IP configuration methods and Internet connectivity. Moreover, the MIIS offers a set of information elements (IEs) containing different groups of mobility services that could be retrieved from different link layers technologies. Usually, these IEs are intended to provide mostly static information such as channel information, geographic position and security. Dynamic information such as pricing, current available resource level and current network utilization should be obtained directly from the interaction with the access network.

The MIIS must allow the information to be accessed from any single network, related not only to the technology to which the MN is currently attached, but to the surrounding available technologies. By way of example, a MN using its Wi-Fi interface should be able to access information from all others IEEE 802 based networks as well as 3G cellular networks.

Under those circumstances, the IEs can be stored on a single centralized MIIS server [2] or distributed among several MIIS servers in a decentralized way [3]. In the interaction between an MIIS server and a MN, a series of steps are required before information is able to be delivered back to the MN. Initially, the MIIS server must be discovered by the MN, probably using layer 2 or layer 3 based mechanisms depending of its location in the network. Subsequently, a secure association may be established in order to ensure the validity of the data communication. Finally, the MN and the MIIS server can exchange information using a transport protocol which works whether MIIS server is on the same subnet or deep in the network.

The rest of this article is organized as follows. Initially, we briefly present the main network information discovery techniques by which the MN can discover a service or a network. After that, the main entities and services of the emerging IEEE 802.21 standard are showed focusing on the MIIS domain. Then we introduce a mobility information structure, including its elements and data representation mechanism. Subsequently, we discuss the MIIS server discovery procedures as issues associated with the transport and security of IEEE 802.21 messages through an operation signaling flow example. Next, we present the main security and implementation issues. As a final point, we conclude this work with some final considerations and open topics for future works.

II. Network Information Discovery

In order for a MN to obtain connection to a PoA such as Wi-Fi access point or Wi-Max and 3G base stations, it needs to first discover the services offered by the PoAs in the vicinity. Typically, the available information about candidate networks is rather minimal but sufficient for a MN to learn some parameters before choosing and joining the network. In this section, we describe the main network information discovery techniques.

A. Statically Preconfigured Information

The MN is provided with manually preconfigured static information about geographical networks by means of a configuration file. One advantage of using such a technique is that no messages are exchanged, therefore no traffic is generated to the network, and hence overhead is reduced. On the other hand the method clearly presents no benefits and is not scalable. By using such approach the MN risks not to have updated network information ever.

B. Network Service Advertisement

Some technologies such Wi-Fi and Wi-Max wireless networks already have an existing means of detecting a list of neighborhood networks within the vicinity. Typically, the MN turns on its wireless interface and can listen to network “service advertisements” messages (e.g., 802.11 beacon frames, IEEE 802.16 DCD) and attempt to connect to PoA. Usually, a service advertisement message contains just enough information which is necessary for a client station to learn about the parameters of the PoA before joining to the network.

The benefit of using this network discovery technique is that the network information comes within the periodic broadcast message saving the MN the task of consulting any entity of the network. Conversely, scanning multiple channels on different technologies is very expensive or consuming both in terms of time and battery-level. In addition, the MN must be a network in range to receive the advertisements messages and the operator must be willing to distribute network information.

C. Accessing a MIIS Server

In the last network information discovery technique, the mobile node can consult a MIIS server, which stores information from several access networks and operators. To access this information, the MN must perform some steps before obtaining the desired information. It may require link-layer supports, transport protocol capability and security considerations. The main advantage of using such a technique is that the MN may have a complete and consistent view of the whole network. In addition, this approach allows MN mobility over several networks and operators. In this work, we will use this approach to demonstrate the benefits of use MIIS server technique in a heterogeneous mobile network environment.

III. IEEE 802.21 Overview

The present section shows the general architecture of the new IEEE 802.21 standard [2]. The standard specifies a Media Independent Handover (MIH) framework that facilitates handover in heterogeneous access networks (which may be wireless or wired) by exchanging information and defining commands and event triggers to assist in the handover decision making process.

The 802.21 standard supports cooperative use of information available at the MN and within the network infrastructure. Both the MN and the network may make decisions about connectivity in that the MN is well-placed to detect available networks and the network is suitable to store overall network information, such as neighborhood cell lists, location of MNs and higher layers of service availability.

To allow those functionalities, both the MN and the network PoA such as base stations and access points may be multi-modal (i.e., capable of supporting multiple radio standards and simultaneously allow connections on more than one radio interface). Specifically the standard consists of the following elements:

- A framework that enables service continuity while a MN transitions between heterogeneous link-layer technologies.
- A set of handover-enabling functions within the protocol stacks of the network elements that provide the upper layers (e.g., mobility management protocols such as Mobile IP Mobile IPv6, Fast Mobile IP and SIP) with the required functionality to perform enhanced handovers. Usually, the upper layers protocols are referred as MIH users.
- A new logical entity created therein called the media independent handover function (MIHF). It is located in both local MN and the remote network node.
- A media independent handover service access point (named MIH_SAP) and associated primitives are defined to provide MIH users with access to the MIHF services.
- The definition of new link layer service access point and associated primitives for each link-layer technology. Moreover, IEEE 802.21 standard compatible equipment should be able to co-exist with legacy equipment.

The MIHF is the central entity of the emerging IEEE 802.21 standard (Fig.1). Its primary roles are to facilitate handovers and provide intelligence to the network selector entity. The MIHF also provides three primary services: event services, command services and information services. These services help the MIH users maintaining service continuity, quality of service monitoring, battery life conservation, network discovery and link selection. In the IEEE 802.21 terminology, these three services are generally referred to as mobility services (MoS). A detailed explanation of each mobility service follows.

A. Media Independent Event Service

The media independent event service (MIES) is responsible for detecting events at lower layers and reporting them from both local and remote interfaces to the upper layers (the MIH users). A transport protocol is needed for supporting remote events. These events may indicate changes in state and transmission behavior of the physical, data link and logical link layers, or predict state changes of these layers.

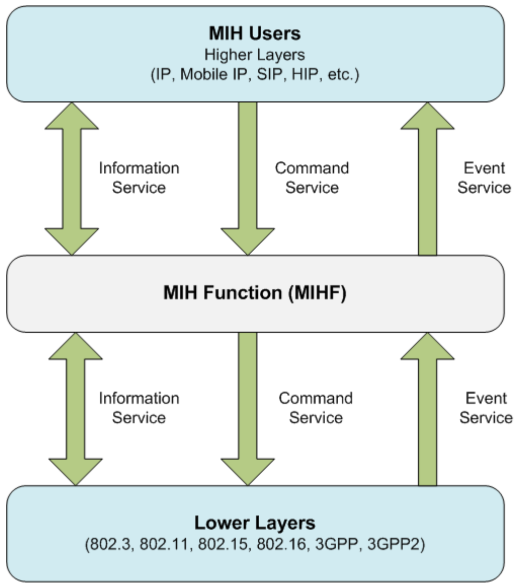

Fig 1. IEEE 802.21 Architecture

B. Media Independent Command Service

The media independent command service (MICS) refers to the commands sent from MIH users to the lower (physical, data link, and logical link) layers in order to control it. The commands generally carry the upper layer decisions to the lower layers on the local device entity or at the remote entity. These commands are mandatory in nature and the recipient of a command is always expected to execute it.

MIH users may utilize command services to determine the status of links and/or control the multi-mode device for optimal performance. The MICS provides dynamic information such as signal strength and link speed, varying with time and MN mobility. The standard defines a number of commands to allow the MIH users to configure, control and retrieve information from the lower layers including MAC, radio resource management and physical layer.

C. Media Independent Information Service

The media independent information Service (MIIS) provides a framework and corresponding mechanisms by means of which a MIHF entity may discover and obtain network information existing within a geographical area to facilitate the handovers. MIIS includes support for various information elements which provide information that is essential for a network selector to make intelligent handover decisions. The information may be present in some MIIS server where the MIHF in the MN may access it.

Moreover, the MIIS provides capability for obtaining information about lower layers such as neighbor maps and other link layer parameters, as well as information about available higher layer services such as internet connectivity. For instance knowledge of whether security, supported channels, cost per use, networks categories (such as public, enterprise, home) and QoS supported may influence the decision to select such an access network during handover process. The MIIS also allows this collective information to be accessed from any single network. Information about a nearby Wi-Fi hotspot could be obtained using a Wi-Max interface or any cellular network, whether by means of request/response signaling without the need to power up the Wi-Fi interface. This capability allows the MN to use its currently active access network and inquire about other available access networks in a geographical region.

IV. MOBILITY INFORMATION STRUCTURE

The following section aims at describing the mobility information structure that can be used in heterogeneous wireless networks environment. At first, the IEEE 802.21 information elements and its categories are presented. Finally, we furnish a representative mobility information structure example describing its common data representation.

A. Information Elements (IEs)

As already mentioned, the MIIS provides a set of IEs (Fig.2) which offer link layer information parameters assisting the network selection algorithm to make intelligent handover decisions. Typically, the information supplied by these elements is intended to be static such as channel information, geographic position and security, although dynamic information must also be accounted for [4].

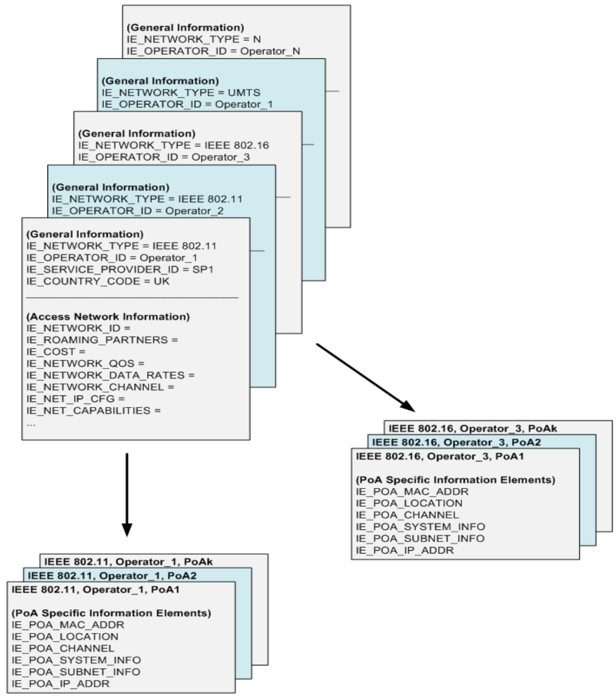

Fig 2. Mobility Information Structure

According with the IEEE 802.21 MIIS specification, the IEs can be divided in the following groups:

- General and access network information: give a general overview of the different available networks. These IEs are related to network type, operator, roaming agreements, cost per use or per traffic, security characteristics, QoS, data rate and type of mobility management protocol supported.
- Point of attachment (PoA) specific information: provides information about different PoAs for each available technology and operator. It covers information as MAC address of the PoA, IP configuration methods, channel range and geographical location.
- Vendor/network information: the standard can support other information such as access network specific, vendor/network proprietary services, etc.

The specification of IEs may involve both business and technical considerations. With regards to the business considerations, the main focus is on the Service Level Agreements (SLA) and possible charging rates that can or will be used in addition to the determination of specifically what IEs will be available. As an example, we may introduce the following use case: a MN detects two available wireless networks belonging to different operators. An operator may not want to disclose competitor´s information because this may lead MN moving out to the competition. In the case where one operator only reveals its own network information, a big problem arises as this could cause MN to not receive complete network´s information which could lead into a wrong handover decision. Referring to the technical issues, the IEs specification involves design, provisioning, discovery mechanisms, content delivery, transport-layer issues and security aspects.

Fig. 2 shows a mobility information structure as specified in the IEEE 802.21 standard. It shows the IEs layout of different networks in a geographical area stored on a MIIS server. All the network information may be either centrally stored on a MIIS server or distributed in each of the individual access networks. A detailed explanation of MIIS server location as well as technical discussion can be found later.

In this example, the mobility information structure is composed by one MIIS server that stores information from three different operators named Operator_1, Operator_ 2 and Operator_3. According to the IEEE 802.21 MIIS specification, each information element is of IE_XXX form, where IE denotes information element and XXX denotes its description (i.e. IE_COST indicates the cost for service or network usage, IE_QOS indicates the QoS characteristics of the link layer, IE_POA_LOCATION indicates the geographical location of PoA and so on). The IEs are defined in a tree hierarchy representation in according with the three groups specified above.

As it can be seen in Fig.2, an operator can provide support for multiple access networks technologies. The first set of IEs is well-known as “General information” which gives a general overview of the different available networks. In this example, the Operator_1 supports both Wi-Fi and UMTS wireless networks. In addition, the Operator_2 holds up Wi-Fi and Wi-Max access networks. Finally, in the Operator_3 we can find out information from Wi-Max and UMTS networks. Under those circumstances, multiple operators can provide support for a particular network and a single network may support various access networks.

Likewise, for each network supported by an operator there is a set of IEs identified as “Access network information”. In this group of IEs, we can distinguish information such as cost per use, type of mobility management protocol supported, QoS characteristics, roaming partners, supported data rates, IP configuration methods among others.

Following the MIIS structure illustrated in Fig.2, the last set of IEs is defined as “PoA information” wherein each access network supply a list of supported PoAs. Thereby, the access network UMTS belonging to Operator_1 supports several PoAs and the Wi-Max network from Operator_2 provides access to several PoAs as well. Here, we highlight important information such as the geographical location of PoA, its link layer and IP address, channel parameters and subnets supported. In summary, the MIIS structure offers mobility information that helps the MN to make an accurate handover decision across heterogeneous networks.

V. MIIS SIGNALING FLOW

In a heterogeneous wireless environment composed of several access networks, operators and MIIS servers, a series of steps are required before information is ready to be delivered back to MN when it is communicating with an MIIS server. In order to allow a MN to obtain network information, the deployment of an MIIS infrastructure would need to provide MIIS server discovery, integration of 802.21 networks with the IP transport layer and security association service in a variety of scenarios. The IETF MIPSHOP WG specified a general mobility framework design [5] for the IEEE 802.21 MIH protocol that addresses issues associated with the transport of MIH messages, services discovery mechanisms and security issues.

Fig.3 illustrates how a MN can obtain information from a MIIS server. The operation signaling flow between a MN and an MIIS server could be divided into the three following phases: discovery, security and transport.

The initial requirement is to provide the MN with a service discovery mechanism. In this way, the MN may use DHCP and DNS protocols for peer discovery which can operate over more than one network-layer hop. On the subject of the second requirement, a common security association method should be implemented between MN and MIIS server. Speaking about transport issues, the MN may use services provided by TCP and UDP for transporting 802.21 MIH messages which is not bound by any specific link layer technology. In this way, Fig.3 shows a MN requesting network information from a MIIS server. In this example, we use DHCP for MIIS server discovery and TCP for transport of MIH information. Following a detailed explanation of these three phases and interchanged messages is presented.

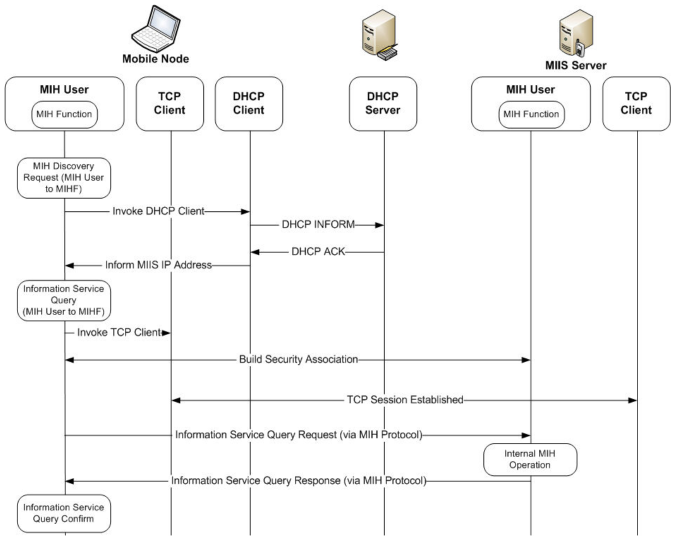

Fig 3. MN – MIIS Server Signaling Flow

A. MIIS Server Discovery

The MIIS server discovery mainly depends on the MIIS server position in the network which may be one of the three scenarios described in [3]. The main objective of this first phase is to provide the MN with the IP address of the MIIS server. Efforts are currently underway to specify two discovery techniques: DNS and DHCP mechanisms. For a detailed operation of these service discovery mechanisms, see [6] and [7] respectively.

In the considered flow in Fig.3, we are using DHCP for MIIS server discovery. In order to obtain an IP address from the MIIS server, the MN´s DHCP client sends a DHCP Inform message according to standard DHCP but with a new DHCPv4 option called MoS options which allows the MN to locate a MIIS server which hosts the mobility services (MIES, MICS and MIIS). The document [7] also defines DHCPv6 options for mobility services discovery. Following the signaling flow, the DHCP server of MN´s network sends to the MN a DHCP Ack message containing the IP address of the MIIS server.

B. Security Aspects

The main objective of the MN using the MIIS information is to make an accurate handover decision. Thus, it is essential that the information comes from a reliable source. This requirement is even more imperative when handovers are done across IP subnets or administrative domains. In this sense, before exchanging information with a MIIS server, it may require a security association of the MN to provide access to certain information.

To ensure the validity of data communication between a MN and MIIS server, the IETF MOBOPTS WG is specifying a new secure handover optimization mechanism named media-independent pre-authentication (MPA) framework [11] that works over any link-layer and with any mobility management protocol including Mobile IPv4, Mobile IPv6, MOBIKE, HIP and SIP mobility. In summary, MPA works assuming a MN which has connectivity to the current network but is not yet attached to any candidate network (CN). It´s functionality can be divided in four phases: (1) MN establishes a security association with the CN; (2) MN executes a configuration protocol to obtain an IP address as well as tunnel management protocol to establish a secure handover tunnel with the corresponding CN; (3) MN must send and receive packets over this secure handover tunnel; (4) the handover tunnel must be disabled immediately after the MN has attached to the CN.

C. Transport Considerations

Once the IP address of the desired MIIS server has been discovered and a security association and connection is established, the MN and the IS server may exchange information over any supported transport protocol. The reference [9] is the main contribution to transport 802.21 MIH messages. It provides a container capability to mobility support services, as well as any required transport operation required to provide communication. Also, it discusses some particular mobility services characteristics as network loss, congestion conditions, message rate and retransmission parameters. As was previously stated, the MIIS framework provides the ability to access information about all networks in a geographical area from any single L2 or L3 networks depending on how the IS server is implemented.

Following the signaling flow in Fig.3, MN uses TCP protocol to establish a transport connection with the corresponding MIIS server. After established such connection, the MN may obtain network information sending a MIH_Get_Information message to the MIIS server. Once the MIIS server receives the MN´s query, it generates an appropriate response frame containing the necessary information to the MN.

After making the discovery procedure, a security association and the connection establishment, the MN has/receives all neighbor networks information and now it can take the handover decision. Detailed signaling flow inter-domain handover examples could be founded in [10] and [11].

VI. IMPLEMENTATION ISSUES

Several IEEE 802.21 simulations and implementations models were appeared in the last years, but it will consider the most important here. The first "implementation" was provided by NIST [12]. They developed NS-2 models of IEEE 802.21 MIH architecture components such as the Event, Command, and

Information Services, and transport of Layer 2 trigger information to higher layers. They also produced a set of NS-2 models of MAC-layers such as IEEE 802.16 and IEEE 802.11 that are used with the MIH functions to model vertical, i.e. heterogeneous, handovers that are assisted by cross-layer information passage.

ODTONE [13] stands for Open Dot Twenty ONE and is an Open Source implementation of the Media Independent Handover standard using C++ APIs. ODTONE supplies the implementation of a MIHF, supporting its inherent MIES, MICS and MIIS, as well as supporting mechanisms (Capability Discovery, MIHF Registration, Event Registration, etc.). ODTONE aims to implement a MIHF that is capable of being deployed in multiple operating systems. It supports GNU/Linux and Microsoft NT-based operating systems and others. This means this implementation will be decoupled of highly dependent operating system mechanisms.

VII. Conclusion

In this article we have discussed the main characteristics and features for the design of an information server infrastructure in heterogeneous wireless networks. The main benefit of using a MIIS framework is to enable the MN to gain an overview of their environment enabling it to make an accurate handover decision. However, there are still some open issues that should be studied in future researches. Open investigation topics include new security mechanisms as new deployment real implementations modules.

Acknowledgments

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