IEEE 802.21: Media independence beyond handover

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ABSTRACT

The IEEE 802.21 standard facilitates media independent handovers by providing higher layer mobility management functions with common service primitives for all technologies. Right after the base specification was published, several voices rose up in the working group advocating to broaden the scope of IEEE 802.21 beyond handovers. This paper aims at updating the reader with the main challenges and functionalities required to create a Media Independence Service Layer, through the analysis of scenarios which are being discussed within the working group: 1) Wireless Coexistence, and 2) Heterogeneous Wireless Multihop Backhaul Networks.

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1. Introduction and motivation

Recently the work performed within the Media Independent Handover Services group of the IEEE has been approved as the IEEE 802.21 [1,2] standard. The main purpose of IEEE 802.21 is to enable handovers between heterogeneous network access technologies (including IEEE 802 and cellular technologies) while maintaining service continuity, hence improving the user experience of mobile terminals. This standard opens a new set of possibilities in the field of mobility across heterogeneous networks.

The key novelty of the IEEE 802.21 specification is that, for achieving technology independent handovers control, it defines a technology-independent abstraction layer able to provide a common interface to upper layers, thus hiding technology specific primitives. Therefore, 802.21 provides new functionality for inter-technology handovers by defining an abstraction layer which is used by upper layers to interact with different link layer technologies in a uniform way. This layer belongs to the control plane, it allows to configure and control the data plane, but it does not interfere with the normal processing of data packets, i.e., it does not introduce overhead in the data plane.

Along the above lines, the strategic concept introduced by the IEEE 802.21 standard is the Media Independence paradigm. This concept is very attractive, as it allows hiding the complexity of each technology behind a set of standardized primitives thereby reducing the complexity of higher layers. This increases the number of lower-layer capabilities that are accessible without technology- or driver-specific adaptation, hence improving the reusability of code and reducing the necessary development and maintenance cost.

After the IEEE 802.21 working group (WG) published its main specification at the end of 2008, it has been discussing possible synergies with other standards and the possibility of defining a generic Media Independent Service Layer, extending the Media Independence paradigm to other scenarios beyond handovers. One possibility that is being discussed is the change of the name of the IEEE 802.21 WG to "Media Independent Services", with "Handover Services" being just one of the possible services under the umbrella of this WG. In order to do that, several new ideas are being discussed within the WG. These ideas usually do not only involve the IEEE 802.21 WG but also consider possible synergies with other WGs which are just beginning their work, and which could benefit from the functionality provided by an independent service layer. This is the case for one of the applications that has been considered, the Coexistence of Wireless technologies in shared spectrum, mainly focused on White Spaces [3,4]. The WG in charge of developing a standard for this scenario is IEEE 802.19.1. Several discussions and joint sessions between this WG and the IEEE 802.21 WG have already taken place, in order to understand how the functionality provided by an extended IEEE 802.21 abstract layer can be reused for this

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specification. The second scenario – already discussed by the IEEE 802.21 WG – considers Heterogeneous Wireless Mesh Networks [5]. A Study Group has been created within the IEEE 802.21 specifically to study the feasibility of the application of the media-independent service layer to this scenario.

This article focuses on the above two applications because their importance and the involvement of the authors in the related discussions within the IEEE 802.21 WG. We would like to emphasize that the ideas presented in this article are the personal instantiation of a set of discussions that are taking place within the IEEE 802.21. This article gives an overview of the discussions about the design of a generic media independent layer that is still a quite open topic within the IEEE. We believe that this abstract layer is an interesting approach due to the multi-heterogeneous technology environment in current networks. It can be a key component to enable the automation of operation and configuration activities, by making the control algorithms independent from the particularities of specific technologies. For these reasons, we expect it to get more attention within and outside the IEEE in the near future.

The remainder of the paper is structured as follows. Section 2 briefly presents an overview of the IEEE 802.21 standard, which is the underlying foundation of this work. Section 3 discusses the main challenges on extending IEEE 802.21 to form a generic Media Independent Service Layer (MISL). Section 4 presents two scenarios that would benefit from an extended scope of IEEE 802.21 to handle the heterogeneity of radio technologies, namely Wireless Coexistence (Section 4.1) and Wireless Heterogeneous Mesh Networks (Section 4.2). Based on the analysis of the requirements of these two scenarios, in Section 5 we present the most important functionality required by the MISL to enable future services, comparing it against current functionality provided by IEEE 802.21. Finally, Section 6 concludes this work.

2. IEEE 802.21 overview

The IEEE 802.21 [1,2] (or Media Independent Handover, MIH) technology is an enabler for the optimization of handovers between heterogeneous IEEE 802 systems as well as between 802 and cellular systems. The goal is to provide the means to facilitate and improve the intelligence behind handover procedures, allowing vendors and operators to develop their own strategy and handover policies. For this purpose, the IEEE 802.21 aims at optimizing the handover procedure between heterogeneous networks by adding a technology independent function (Media Independent Handover Function, MIHF) which improves the communication between different entities, either locally (mobile node) or remotely (network functions). Sharing information allows handover algorithms to guarantee seamlessness while moving across different points of attachment in the network and the use of common commands greatly simplifies the design of the algorithms.

Fig. 1 depicts the 802.21 reference model with functional entities and associated interfaces, where the MIH technology is implemented in the mobile nodes and network side components, both being MIH-enabled. MIH defines three main mobility services:

- The Media Independent Event Service (MIES) provides event classification, event filtering and event reporting, corresponding to dynamic changes in link characteristics, link status and link quality.
- The Media Independent Command Service (MICS) enables MIH clients to manage and control the link behavior related to handovers and mobility. It also provides the means to mandate actions to lower layers, in a local or in a remote protocol stack.
- The Media Independent Information Service (MIIS) provides details on the characteristics and services provided by the serving and surrounding networks. The information enables effective system access and effective handover decisions.

The information exchange occurs between lower layers and higher layers, taking always the MIH Function as reference. Furthermore, information can be shared locally, within the same protocol stack, or remotely, between different network entities. Fig. 1 also presents the three more important Service Access Points (SAP) specified in IEEE 802.21:

- MIH_SAP: Media independent interface of MIHF with the higher layers or MIH users.
- MIH_LINK_SAP: Abstract media dependent interface of MIHF with the lower layers (the different technologies).
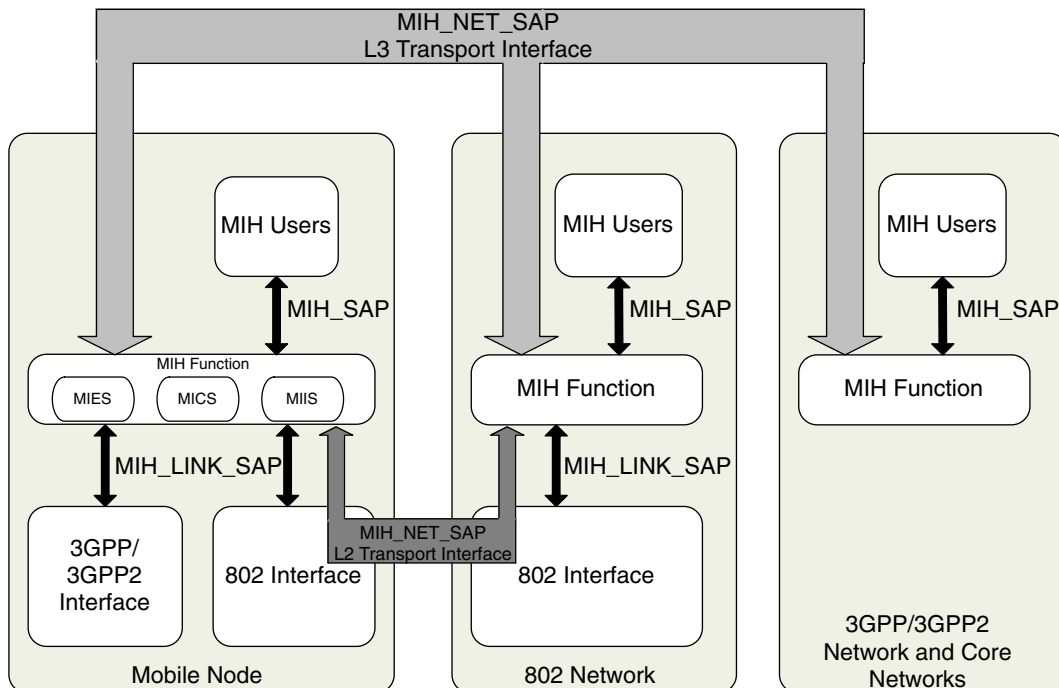

Fig. 1. IEEE 802.21 communication model.

• MIH_NET_SAP: Abstract media dependent interface of MIHF providing transport services over L2 and L3 over the data plane. This SAP supports the exchange of MIH information and messages with a remote MIHF or a Media Independent Information server.

The most important concept in IEEE 802.21, the Media Independence, is achieved by permitting the MIH Users to work on a mix of underlying technologies in a media independent way. These media independent mechanisms are enabled by the MIH_SAP, which provides a set of abstract primitives and concepts. Under this paradigm, the MIHF works as a translator which is able to convert the different abstract primitives into technology specific primitives, providing a mapping between the MIH_SAP and the MIH_LINK_SAP, which takes the form of technology dependent primitives.

In order to clarify this concept, Fig. 2 presents an example of the mapping between the MIH_SAP and MIH_LINK_SAP for two different technologies, IEEE 802.11 and IEEE 802.16. The figure shows how a media independent primitive (MIH_Link_Actions) can be used to power up two interfaces of different technologies. The MIH User issues the MIH_Link_Actions primitive containing a Link_Power_Up command to the two interfaces of the terminal. The MIHF translates this command to a technology specific primitive for each interface. In the case of IEEE 802.11, the command is translated to a primitive of the MSGCF_SAP (MAC state generic convergence SAP) as defined in IEEE 802.11u [3]. In the case of IEEE 802.16, the command is translated to a primitive of the M_SAP (Management SAP) as specified in IEEE 802.16g [4].

Taking the 802.21 architecture as described in this section as a starting point in the rest of this paper we describe the challenges of extending it to support other applications besides handover.

3. Extending IEEE 802.21 for media independent services

The aim of this paper is to present the concept of a Media Independent Service Layer (MISL) which extends the media independence ideas defined by IEEE 802.21, to a generic management layer which can be used by any control algorithm in the case of scenarios with multiple technologies. Although the starting point of these ideas is IEEE 802.21, this specification requires several extensions to become a foundation point of the envisioned MISL. This section is devoted to point out the key challenges on extending IEEE 802.21 that need to be addressed for the realization of the MISL.

The main difference between IEEE 802.21 and the MISL is their focus; while MISL addresses generic media independent services, IEEE 802.21 focuses only on handovers between heterogeneous technologies. Due to this fact, the 802.21 architecture, and the abstraction concepts and services defined are related to mobility, leaving undefined any service which is not directly related to mobility. Hence, there are a number of challenges in 802.21 to extend the Media Independent Handover Services functionality defined by 802.21 to create a general MISL. Some of these challenges are discussed in the following:

• Mobile Node centric architecture: Current IEEE 802.21 architecture focuses on the Mobile Node (MN), and the rest of the Media Independent Handover (MIH) network entities are defined based on their relation to the MN. In this architecture, only a subset of the nodes in the network is IEEE 802.21 capable, since the functionality required in the network to facilitate handovers is limited. Even more, the communication reference model of 802.21 situates the MN as the central point of the communication, which can only talk with certain nodes located in the network, but never with other MNs. In the case of a generic MISL, it is probable that the nodes in the network have a peer relationship, being equal, hence the MISL must allow communication between peer entities, and also between nodes and management entities in the network.

• Definition of abstractions: The MN centric 802.21 standard defines a set of abstract concepts which must be revisited if they want to be applied to a broader scope. One example of these abstract concepts is the link definition. The current IEEE 802.21 defines a link as "A communication channel through which nodes communicate for the exchange of L2 protocol data units. Each link is associated with two endpoints and has a unique identifier". This definition is not general enough. On the one hand, it fails to model point to multipoint links, since no relation between links can be defined. This constraint is important when dealing with, for example, an IEEE 802.11 mesh link, where a node uses the same interface to connect to different terminals. Also the 802.21 definition of link does not cover broadcast and unidirectional technologies such as DVB (Digital Video Broadcasting). On the other hand, as the IEEE 802.21 scope is limited to links, it does not define any identifier for radio interfaces, hence it is not possible currently to apply a command to all links in an interface.

• Definition of new MIH SAP primitives: As explained in Section 2, the IEEE 802.21 defines the MIH_SAP which corresponds to the media
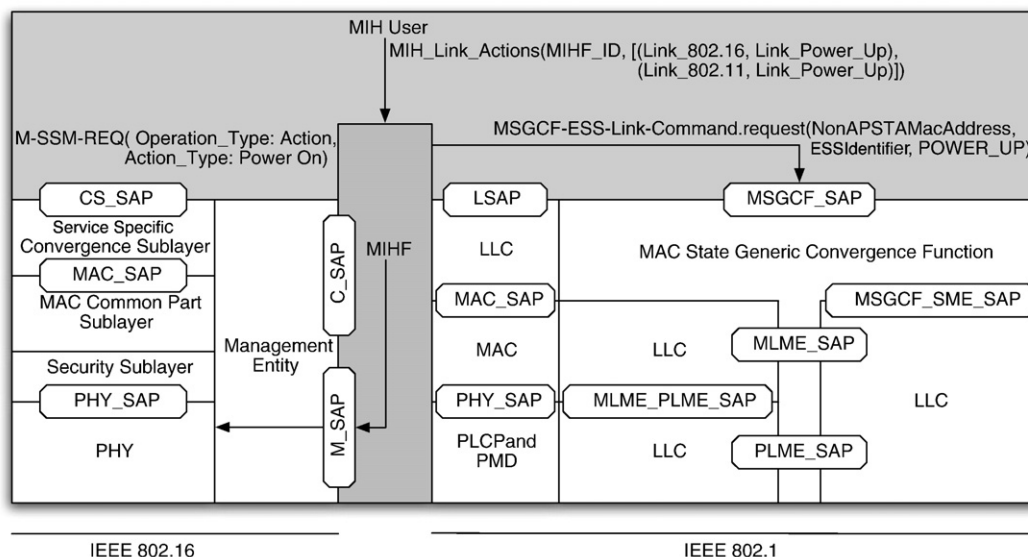

Fig. 2. IEEE 802.21 media independence example.

independent interface. This interface has been defined considering only mobility related services, hence much of the required functionality for a generic management layer is missing from it. As an example, we can consider current primitives defined for link control, the MIH_Link_Actions primitive of the MIH_SAP. This primitive enables the higher layer to perform a reduced set of operations in the interface, such as power up/down, scan or disconnect. In a generic case, the MISL must provide a more complete set of primitives, allowing the change of operating frequency and power, modulation, transmission schemas, etc., in order to provide a comprehensive interface for the management of the different devices.

- Extension of mapping to technologies: For this new media independent interface to work properly it is also required to define the mapping of the abstract primitives to each specific technology, hence extending the SAPs defined by each technology. As an example consider IEEE 802.11, the SAP defined for interaction with external networks is the MSGCF_SAP. This SAP must be extended with the appropriate primitives so the different parameters of the interface, such as transmission power or channel used can be modified by the MISL.

Having identified the main challenges, in the following we address them paying special attention to the two application scenarios, Wireless Coexistence and Heterogeneous Wireless Mesh Networks.

4. Application scenarios

Previous sections have presented the main ideas behind the concept of a Media Independent Service Layer, which allow the creation of smart higher layer users or algorithms which are able to handle different technologies in a media independent way, hence not knowing the actual specificities of each technology. In this section we present actual scenarios in which a generic MISL is required to manage the heterogeneity. Based on these scenarios, a set of desired functionalities is presented in Section 5.

Two scenarios have been identified with clear requirements in terms of media independence. The first one corresponds to the upcoming standard on Wireless Coexistence in the TV band (IEEE 802.19.1), while the second one corresponds to the Heterogeneous Wireless Mesh Networks use case.

Regarding the first scenario, the ideas presented in the following section were discussed in a joint session between the IEEE 802.21 and IEEE 802.19.1 and were received positively [5], although the IEEE 802.19.1 is just beginning its work and its main architecture is not decided at present. Regarding the Heterogeneous Wireless Mesh Networks case, a Study Group (SG) within the IEEE 802.21 WG was recently created with the aim of analyzing the requirements imposed by this scenario.

As explained in the Introduction and motivation, each of the scenarios presented has been discussed within the IEEE 802.21 WG although the actual mapping to the IEEE 802.21 technology is a specific instantiation of the proposed ideas as understood by the authors of this article. In both scenarios, we envision the MISL as a central point in the architecture, extending the media independence capabilities of IEEE 802.21 and its communication mechanisms.

4.1. Wireless Coexistence

Nowadays, due to the proliferation of communication services in our society and its growth in demand from the common public, there has been a massive adoption of the wireless technologies as an easy way of connecting to the Internet. This trend is expected to continue as more and more services are moved to the Internet. Wireless networks use a scarce resource to operate, the electromagnetic spectrum, which now already starts to become too overloaded to handle all the business expectations on this kind of network.

In order to solve the above there are two possible solutions, improve the spectrum usage by developing more complex and optimized technologies or find some more spectrum to use. The first approach is being followed by all technologies, by defining new specifications which use higher modulation schemes, multi-antenna setups, etc. The second approach is also gaining momentum lately, with several initiatives defining technologies which use very high frequencies or already used spectrum areas.

Regarding the reuse of the spectrum, there are several initiatives defining technologies able to operate in the TV bands in an unlicensed basis, providing coexistence with the licensed users. Example of these technologies is the IEEE 802.11 which is studying how to operate in what is called the TV White Space (empty frequency bands between TV channels) or IEEE 802.22 [6] which expects to define a technology able to provide data access to rural areas by taking advantage of the TV spectrum. Each of these two technologies implements its own mechanism to detect other unlicensed users of the same technology or licensed devices in the used band but they do not implement a way of detecting users of a different unlicensed technology.

Due to the amount of different technologies willing to use this new spectrum band, it is required to define a new standard able to coordinate the operation of the multiple technologies so the interference between them and with licensed users is minimized. This role has been assumed by the IEEE 802.19 (Wireless Coexistence) and IEEE 802.19.1 (Wireless Coexistence in the TV White Space) for the TV band. Fig. 3 presents the reference model of this standard as defined in the IEEE 802.19.1 System Design Document [7]. The IEEE 802.19.1 scope encompasses the following entities:

- Coexistence Manager (CM): This entity is the brain of the system, its main functionality corresponds to the coexistence decision making. Once the corresponding coexistence configuration is decided, the CM issues the appropriate commands through the Coexistence Enabler (CE) to the TVBDs (TV Band Devices) which will be reconfigured accordingly. The CM uses three interfaces to communicate with the rest of 802.19.1 entities. Interface B1 connects to the CE while interface B3 connects to other CMs. Interface B2 enables the communication with the Coexistence Discovery and Information Server (CDIS) entity. The CM also connects to two external entities, the TVWS database, which stores the information regarding free channels in the specific geographical area and the Operator Management Entity, which allows the operator to influence the decisions taken by the CM.
- Coexistence Enabler (CE): The main task of this entity is to translate reconfiguration requests/command and control information issued by the CM to technology dependent primitives which are then sent to the specific TVBD. It is also in charge of requesting and obtaining information pertinent to coexistence from the TVBD. The CE communicates through two interfaces: Interface A is the interface connecting to specific TVBDs while the Interface B1 is defined for communication with the CM.
- Coexistence Discovery and Information Server (CDIS): This entity collects and aggregates information regarding coexistence, it also serves as a support point for the discovery of CMs.

Considering that IEEE 802.19.1 works on top of heterogeneous technologies (e.g. IEEE 802.22 and IEEE 802.11af), we argue that the CE shown in Fig. 3 plays a similar role to the Media Independent Service Layer envisioned by the IEEE 802.21 WG, providing a media independent interface to the CM, while providing translation of the primitives to TVBD technology dependent primitives.

We think that this technology would greatly benefit from implementing a MISL, since providing this layer will allow control applications such as the CM to address the coexistence problem in an abstract way, hence decoupling it from the underlying technologies.
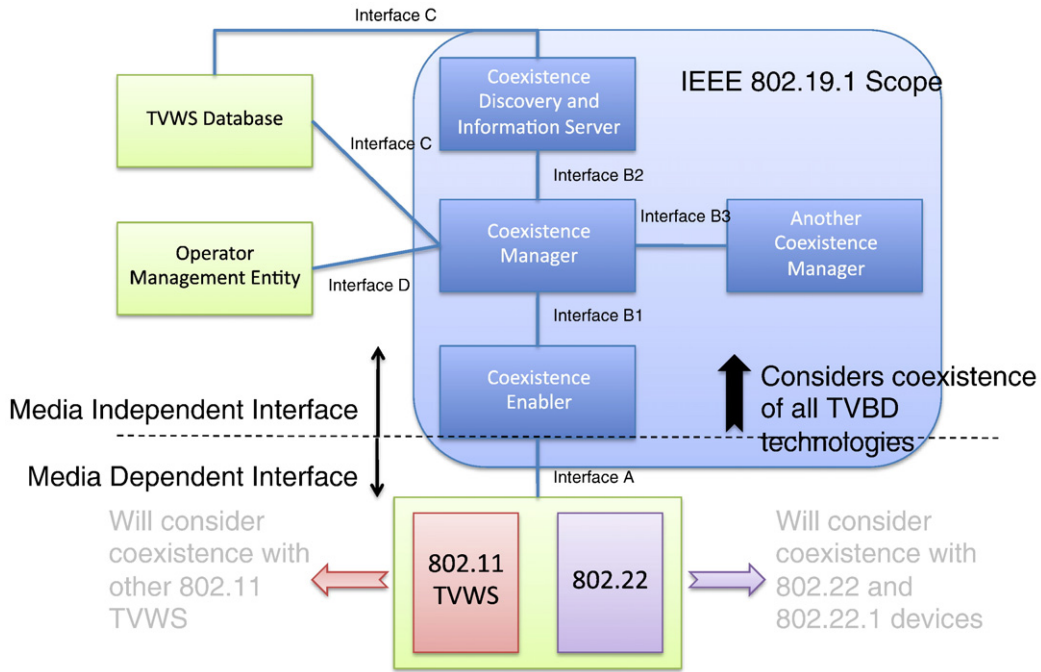
Fig. 3. IEEE 802.19.1 reference model and MISL relation.

Even more, in this case, an approach following the IEEE 802.21 model fits perfectly in the required functionality, as can be seen in Fig. 4.

In Fig. 4, we propose an implementation of IEEE 802.19.1 system design using the model of IEEE 802.21. The CE functionality is implemented within the MISL, extending the MIHF to cope with coexistence related primitives and information. The three media independent (Events, Command and Information) services are also used in this approach. The MIES is used to convey information from the TVBD to the CM through the CE. The MICS is used to reconfigure/manage the TVBD interface, while an extended version of the MIIS provides CDIS services.

All interfaces controlled by IEEE 802.19.1 (Interfaces A, B1, B2, and B3) can be implemented by extending current 802.21 SAPs, as shown in Fig. 4. Interface C and D, correspond to communication between the TVWS database or operator entities, hence they will probably be implemented through private interfaces, although extensions to the MIH_NET_SAP can be used. It is worth to notice, how the actual implementation of the IEEE 802.19.1 following the IEEE 802.21 model and reusing as much as possible from the interfaces will benefit from the already defined MIH protocols [8] in the IETF and from the already defined SAPs with the different IEEE 802 technologies.

We conclude that, with our proposal to incorporate the MISL concept into its architecture, the Wireless Coexistence application could be implemented to handle heterogeneity without adding significant complexity by means of reusing the generic MISL layer
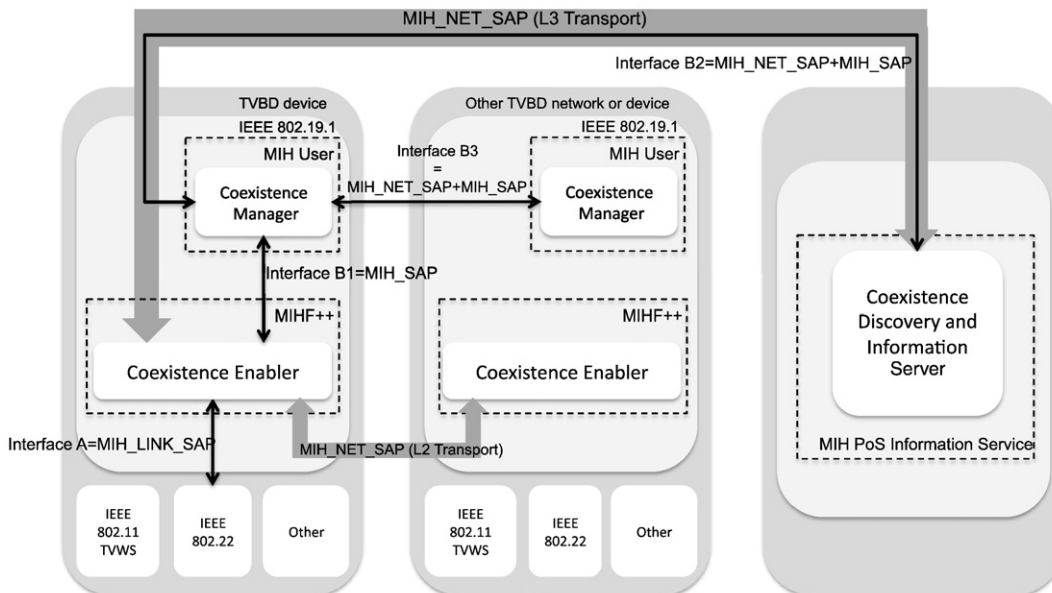

Fig. 4. IEEE 802.19.1 reference model and its implementation through an IEEE 802.21 model.

proposed here instead of using a specific layer for this application only.

4.2. Heterogeneous Wireless Mesh Networks

Wireless Mesh Networks (WMNs) are currently a hot research topic as a cost effective solution to extend operators' networks. The multi-hop nature of these networks enables them to efficiently cover large areas without requiring many interconnections to the wired network. This advantage is particularly crucial in rural areas or emergency situations, where wired networks are either not available or unusable. Properties of WMNs such as self-organization and self-healing, which are being currently researched, allow the reduction of operation and deployment costs [9].

Most existing WMN solutions are designed for a single, specific radio technology. However, combining different radio technologies to realize Heterogeneous Wireless Mesh Networks (HWMNs) allows for more flexible designs that benefit from the complementary characteristics of the different technologies. For example, meshed point-to-point microwave links are particularly suitable for long-range, line-of-sight connectivity between mobile base stations deployed on the roof-tops of high buildings. To extend the wireless mesh backhaul connectivity to pico-cellular base stations or WLAN access points deployed at street-level, a point-to-multipoint, non-line-of-sight technology like WiMAX [10] or WLAN [11] may be more appropriate.

Generally, the industry has recognized the usefulness of heterogeneous mesh technologies for a number of use cases [12,13]. Fig. 5 presents three application scenarios where HWMNs may be used.

The first one corresponds to backhauling small cells, like pico or outdoor femto cells. Such small cells are used as an underlay to the macro cell network for providing higher bandwidth in small and saturated "demand hotspots", like shopping malls or locations with a high saturation of users such as stadiums. In this scenario, where complex point-to-point microwave antennas cannot be assumed to be integrated with the pico cell hardware, low-cost non-line-of-sight point-to-multipoint wireless backhaul such as IEEE 802.11 can be a more reasonable solution.

The second scenario corresponds to the provisioning of backhaul connectivity to DSL routers. In rural areas, a possible solution to providing the last mile connection to the user's DSL home gateways is to – instead of copper or fiber lines – deploy HWMNs, which use long range technologies such as WiMAX or microwave together with short range high bandwidth IEEE 802.11 base stations to cover the rural location. Actually, the latter can simply be connected to and reuse an existing macro site backhaul.

Finally a hot topic which is currently being researched and standardized corresponds to the Smart Grid domain. In this scenario, electrical appliances and smart plugs are connected to the network providing information such as the price and status of the electrical grid. A vast amount of devices must be connected to the network, hence a major deployment of network attachment points, wireless or wired, is required to handle the amount of potential devices. Depending on the vicinity and capacity requirements of the devices, different technologies are used to connect them, such as Zigbee, WiFi or even proprietary technologies. With a HWMN the operator is able to join together the benefits of each technology hence improving its flexibility.

In order to provide the required functionality for the deployment of wireless backhauls based on HWMNs, two main functional blocks have been identified: i) heterogeneous link layer management, and ii) self-description and neighbor discovery. Each of these building blocks needs to handle different wireless technologies with specific characteristics and behavior. This suggests the need for a Media Independent Services Layer able to provide the required primitives used by each building block in an abstract way.

In our vision, the Media Independent Services Layer plays a key role in the architecture of HWMNs. It provides an abstraction layer enabling higher layers to interact with link layers in a uniform way.
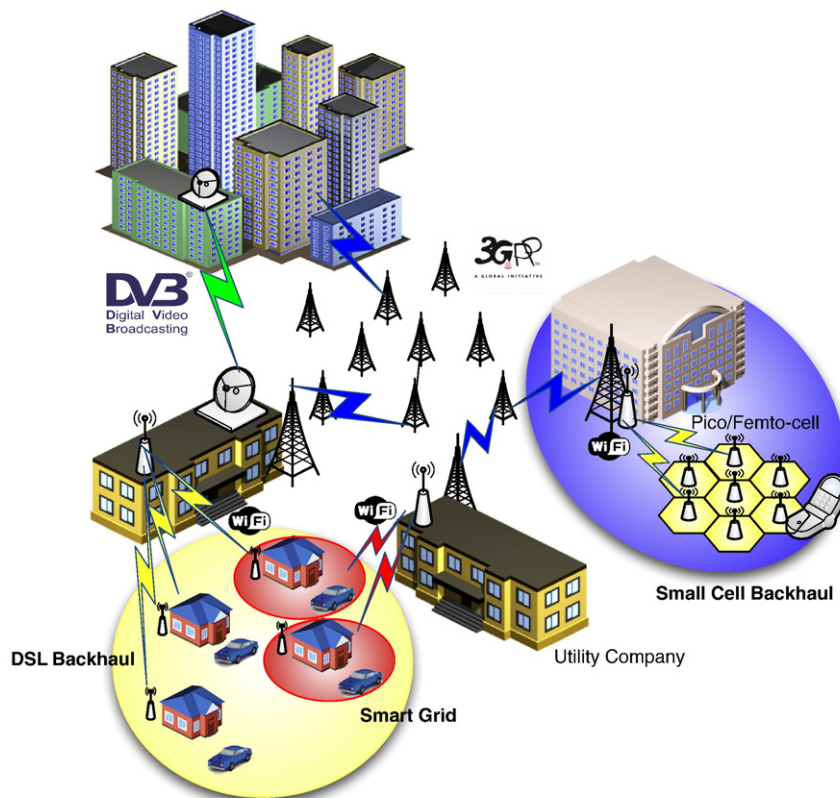

Fig. 5. Heterogeneous Wireless Mesh Network applications.

Higher layer modules comprise the Self-Configuration, the Routing, Mobility and Capacity Handling modules (Fig. 6). Every node in the mesh network has these modules, which interact with those in different mesh nodes and the respective modules in the core network. Information regarding lower layers is extremely useful for all higher layer modules.

The Self-Configuration module uses the functionality offered by the Media Independent Services Layer to gather information about neighboring nodes. The Routing module gathers information regarding neighbor nodes and the status of its interfaces, so it can quickly react upon e.g. failures of a link and start using backup routes. The Mobility management module is able to get information regarding the attachment of new clients through the use of link events, and finally the Capacity Handling module is able to get a global vision of the capacity status of the network by polling the resources of lower links through an abstract interface.

We conclude that, by incorporating MISL architecture into mesh, we can operate mesh networks based on heterogeneous technologies and hence benefit for greater flexibility and performance, at a similar cost of operating homogeneous mesh networks.

5. Media independent services functionality

The previous sections presented the description of the two scenarios where we have identified the need for a Media Independent Services Layer. These two scenarios have many synergies as both of them require some kind of abstraction layer to be able to cope with the heterogeneity of the radio access network. Based on the properties of each scenario, we extract a set of functional requirements. From this, we obtain the following list of desirable functionalities that the Media Independent Services Layer could implement:

- Self description of interface properties: Primitives allowing the self discovery of capabilities.
- Neighbor Discovery: Primitives allowing the discovery of neighbors via active or passive techniques.
- Configuration of radio interfaces: Primitives that allow nodes or other network entities to control channels, transmission characteristics, etc.

- Resource Management: Primitives allowing the management of the available resources of the network such as available bandwidth, delay, etc.

Some of the proposed functionality, specifically primitives regarding radio configuration, has already been proposed to the IEEE 802.21b Task Group. The contribution was accepted and can be found in the second version of the IEEE 802.21 draft that is still open to modifications.

5.1. Self description of interface properties

Any algorithm built on top of the MISL will require to be able to obtain an abstract description of the main characteristics supported by the different interfaces belonging to the node. These characteristics encompass information regarding the actual physical features of the interface, such as frequency bands in which it is able to operate, transmission power ranges, modulation schemes, etc. and also a description of the MISL supporting mechanisms of the interface, such as the support of events or commands or the support of different information schemas (e.g. if the MIIS stores coexistence information) in the MIIS serving the node.

Some of this functionality is already present in IEEE 802.21, which provides a complete set of primitives allowing accurate self description of the different MIHF mechanisms supported by the low layers. It also provides mechanisms to gather some of the information required by higher layers, although this information is constrained to mobility related information. Apart from the local resources that the MIHF enables, we must also consider the remote information services provided by the Media Independent Information Services (MIIS). This service can also be extended to store some information regarding specific information of some technology.

An example of an IEEE 802.21 primitive that can be used to obtain some of the required parameters for self description of interface properties we consider the Link_Capability_Discover primitive. This primitive allows the MIHF to retrieve information of the link layer events or commands supported by the lower layers. We argue that an extended version of this primitive, which considers also the query per physical interface may be used to provide the self description functionality.
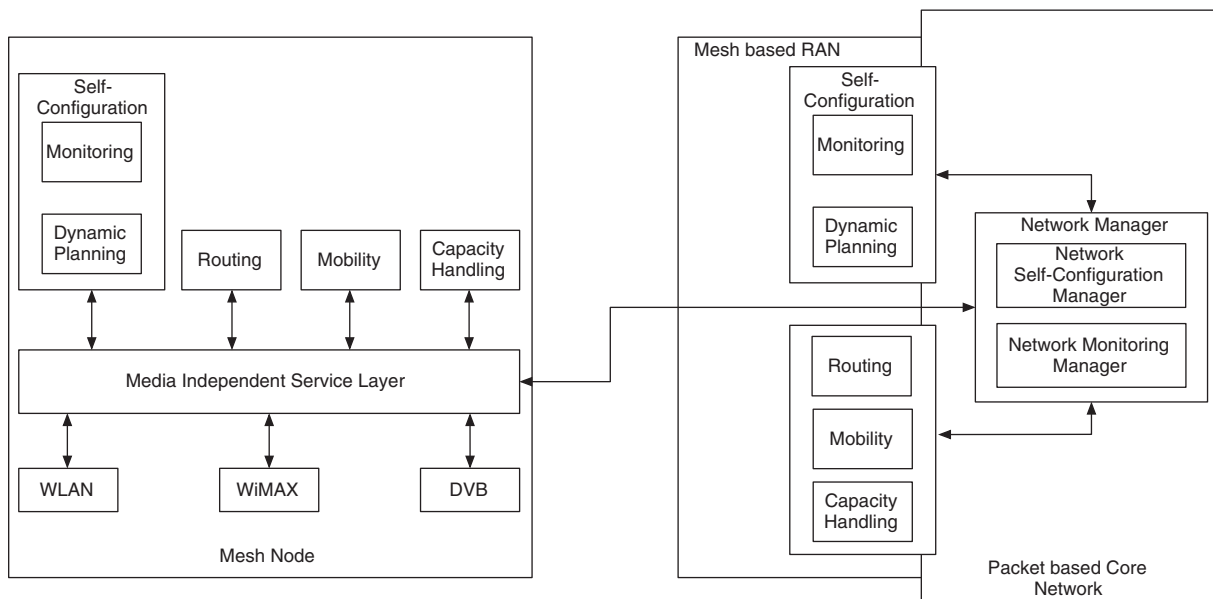

Fig. 6. Heterogeneous Wireless Mesh Network architecture.

5.2. Neighbor discovery: media independent scanning/sensing

Another important desired functionality in the MISL is to enable a media independent neighbor discovery. Currently, there is a trend in new technologies that is the use of some kind of scanning or sensing mechanism to detect neighbors or other devices using the same spectrum. This is the case of technologies designed to work in licensed spectrums as opportunistic users, such as the TV White Space version of IEEE 802.11 or IEEE 802.22. We think that this functionality should be also incorporated into the MISL, allowing the use by the higher layers of a unified scanning/sensing mechanism, which takes advantage of the newly defined sensing mechanisms of such technologies. This functionality is also important for HWMNs since the use of unlicensed spectrum represents a big opportunity for HWMNs, which can be deployed using this spectrum.

Both scenarios, Wireless Coexistence and HWMNs require of neighbor discovery functionality. The Wireless Coexistence scenario requires the detection of neighbors to be able to configure the nodes appropriately while the HWMNs scenario requires neighbor discovery in order to create the initial topology. Both scenarios will highly benefit from the existence of an abstract layer to detect neighbors for heterogeneous technologies, since the alternative that is dealing with specific technologies individually is fairly complex.

5.3. Configuration of radio interfaces

One of the most important functionalities that we envision for the MISL is providing mechanisms to perform media independent link control. Currently, all technologies which are working on issues related to heterogeneous technologies (such as the scenarios presented in Section 4) require the control of the different characteristics of the interfaces. In the case of IEEE 802.19.1, they require the CE to configure the operating frequency, transmission power or modulation rate, among others, in order to guarantee the coexistence of several technologies in the same spectrum band. In the case of a HWMN, this functionality is required by the self-configuration module, which needs to configure the interface of the nodes following a certain algorithm.

We argue that the different technologies which require to handle the configuration of heterogeneous technologies will benefit from a common media independent interface for configuration. If this approach is not followed, in the future we will find different interfaces for link control in different standards, hence having the same functionality implemented in a different way by parallel standards.

Currently IEEE 802.21 allows higher layers to perform a very rudimentary control of the interfaces. Specifically, it allows the user to turn on/off, go to sleep and scan for neighbors. A way of improving this functionality is extending the LINK_ACTION primitive of IEEE 802.21 by providing mechanisms to configure radio properties, although this extension will also require to open or modify the already existing SAPs with the lower layers.

Another issue involved in the configuration of the radio interfaces is the creation of links with peers. A generic link control mechanisms should allow the higher layers to decide the connection mode used for the links. IEEE 802.21 provides the functionality required for turning on an interface but it does not provide the primitives required to set up a connection with a neighbor in an explicit way. IEEE 802.21 indicates the creation of a new link by using the LINK_ACTION primitive; this primitive does not include any mechanism to explicitly define the type of link to create (e.g. ad hoc, WDS or infrastructure).

5.4. Resource management

A critical issue in heterogeneous networks is the management of the available resources in the network. Currently each technology has different mechanisms for QoS monitoring and resource management, which are not compatible between them. If we want to deploy an abstract layer for heterogeneous networks, we need to define a capacity concept which can be used by multiple technologies in an abstract way, so the operator is able to control the status of the network in a common way and algorithms which work on top of different technologies (such as routing) are able to have a complete vision of the available capacity of the network.

We advocate for the definition of a common capacity notion for all technologies which enables the use of standard traffic engineering techniques in heterogeneous networks. This task is far from trivial since the concept of capacity for a technology such as IEEE 802.11 where the resources are shared between all stations accessing the medium in a contention base is completely different from technologies based on centralized coordinated medium access such as IEEE 802.16. With this concept, an input to abstract parameters representing the capacity will be translated by the MISL to specific operations in the corresponding technology. A first step towards this idea was presented to the IEEE 802.21 WG in [14].

6. Conclusions

Currently operators are diversifying their offer in terms of available radio technologies for the Radio Access Network. This imposes a high complexity in the nodes of the network as they need to handle a variety of technologies.

Under this scope, the key contributions of this paper are: i) In line with current discussions within the IEEE 802.21 WG we have advocated for a new paradigm, a generic Media Independent Service Layer which extends current IEEE 802.21 standard to a broader set of services, providing a generic abstract layer decoupling higher layers from the specifics of the underlying technologies. ii) We have identified the key requirements for the MISL, analyzing the required extensions to IEEE 802.21 in order to form the basis of the MISL. iii) We have presented two applications that show the benefits of using the MISL, namely the upcoming standard on Wireless Coexistence (IEEE 802.19.1) and the Heterogeneous Wireless Mesh Networks scenario, showing also our personal view on how the MISL can play a crucial role on each of them. iv) Finally, we have outlined the main functionality to implement in the MISL to cope with these two scenarios and future applications.

The MISL belongs to the control plane and facilitates the automation of operation and configuration functions, by making the algorithms that control those functions independent from the particularities of specific technologies. The MISL does not introduce any overhead in the processing of data packets.

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