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Wireless Broadband Access: Policy Implications of Heterogeneous Networks

Juan Rendon Schneir

WIK-Consult
Cost Modelling and Internet Economics Department
Rhoendorfer Str. 68, 53604 Bad Honnef, Germany
e-mail: jrendons@gmail.com

Abstract:
A wireless heterogeneous network can help increase the access transmission speed and contribute thereby to the broadband deployment policies of administrations and telecommunications operators. Given the technical particularities of wireless heterogeneous networks, the deployment of wireless heterogeneous networks raises a number of challenges that need to be addressed by policy and regulatory authorities. This article analyses the following policy implications: standardisation and technology neutrality, spectrum management, market analysis, open access and infrastructure sharing, interconnection pricing and charging, broadband deployment policies, and privacy and security issues.

Keywords: 4G, heterogeneous networks, cooperative networks, spectrum management, regulation, wireless networks

This article represents the opinion of the author and does not necessarily represent the opinion of WIK-Consult.

1.- Introduction

Broadband access provisioning is on top of the agenda of many administrations and telecommunications operators. Essentially, broadband access can be provided through fixed or wireless networks. Broadband fixed networks can be realised by deploying fixed Next Generation Networks (NGNs) based on fibre or cable infrastructure. 3.5G wireless systems, such as HSDPA, already provide users with broadband access, but due to the bandwidth-hungry demand of applications requested by users, new technologies with higher access speeds have been developed and will be deployed. In this regard, several mobile operators have announced that they will adopt the 4G wireless network Long Term Evolution (LTE) to provide broadband wireless access.

One alternative solution to 4G LTE is the complementary utilisation of overlay wireless technologies such as 3.5G, WiFi and mesh networks. This approach consists of using the most appropriate wireless technology for a particular location, i.e., the available network with the fastest access speed or the most reliable network. Such a network is called a wireless heterogeneous network, and researchers over the last few years have been proposing solutions to the many technical challenges that the interaction of different wireless access networks poses. Two examples of the possible use of this type of network are explained in the following: a) a mobile handset with simultaneous access to WiFi and 3.5G wireless networks that chooses the access network with the highest access speed; and b) a wireless operator that has deployed a 3.5G network in urban and suburban areas and WiMAX in some specific rural areas. These scenarios are possible due to the use of Dynamic Spectrum Access (DSA) techniques, which *inter alia* involve the use of Software Defined Radio (SDR), Cognitive Radio (CR) and intersystem control.

Given the technical particularities of wireless heterogeneous networks, the following questions arise: What are the policy and regulatory implications of this network? Does the Information and Communications Technology (ICT) and telecommunications regulatory framework enable it, or are there any significant obstacles that need to be removed first so that wireless heterogeneous networks can become a reality? The purpose of the article is to address these issues. The policy and regulatory implications that are described in the article are standardisation and technology neutrality, spectrum management, market analysis, open access and infrastructure sharing, interconnection pricing and charging, broadband deployment policies, and privacy and security issues.

A few studies have partly investigated a few of these topics. For example, Pujol (2007), describes how emerging radio technologies affect spectrum management. William H. Lehr and Chapin (2009, 2010) analyse the features of Hybrid Wireless Broadband Networks, which are heterogeneous networks, and the implications for regulatory policy. Other authors have addressed several issues that concern spectrum management for Cognitive Radio and Software Defined Radio (Anker, 2008, 2010; Veenstra & Leonhard, 2008).

The objective of the article is not to provide an in-depth description of wireless technologies, but rather to describe the possible policy implications of these technologies. The reader is referred to the specialised technical literature in order to obtain a profound knowledge of technical aspects of these networks (E3 Project, 2010; Fitzek & Katz, 2006).

The article is divided as follows. Section 2 describes technical aspects of wireless heterogeneous networks and elements that help construct a wireless heterogeneous network. Section 3 addresses the policy implications of the deployment of wireless heterogeneous networks. Finally, Section 4 contains the conclusions.

2.- Wireless heterogeneous networks

This section describes the components of a wireless heterogeneous network. There can be different types of heterogeneous networks, and a few elements that can make a wireless heterogeneous network a reality are addressed: a network with different wireless access networks, wireless cooperative networks, Cognitive Radio, Software Defined Radio, ad-hoc networks, mesh-networks, and 4G LTE.

2.1 Description of wireless heterogeneous networks

A wireless heterogeneous network is a network that enables a mobile terminal to have a connection with different wireless access networks. Figure 1 shows an example of a heterogeneous network. In this case, the mobile has a simultaneous access to UMTS, HSPA, LTE and WiFi networks. Alternative wireless networks such as WiMAX can be considered in a wireless heterogeneous scenario. A key aspect of wireless heterogeneous networks is the network resource management, because it enables the interworking and management of resources between the different access networks.

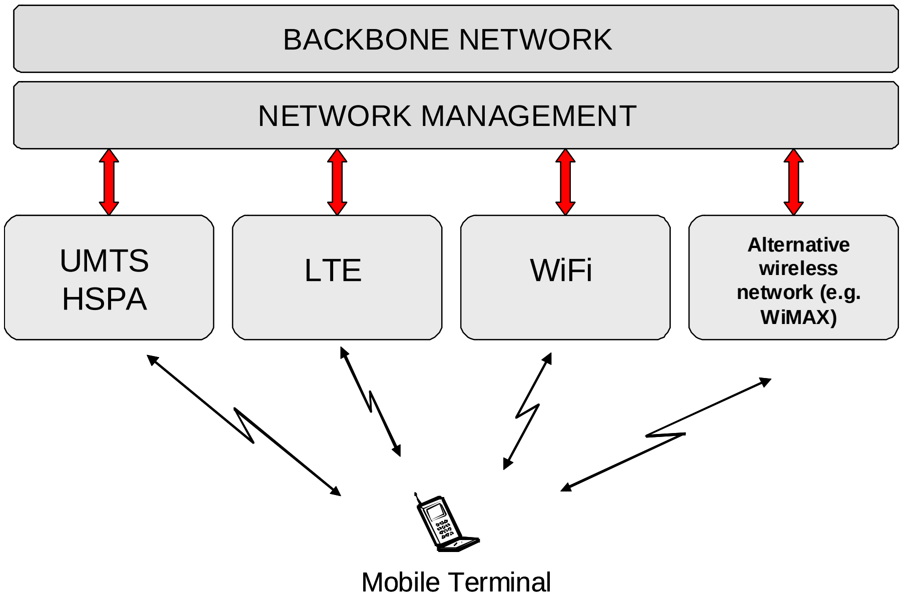

Figure 1: A wireless heterogeneous network, based on Demestichas and Koenig (2010)

2.2 Wireless cooperative networks

A wireless cooperative network is a type of heterogeneous network. The difference lies in the fact that in a cooperative network, a terminal can have simultaneous wireless connections with different nodes. Zhang, Fitzek, and Katz (2006) describe two types of cooperative network architectures: a) a macro cooperative network architecture, in which the mobile network gains access to one access point through different relay terminals; and b) a micro cooperative network where the terminal communicates with the base station and also with other terminals. Figure 2 shows both scenarios.

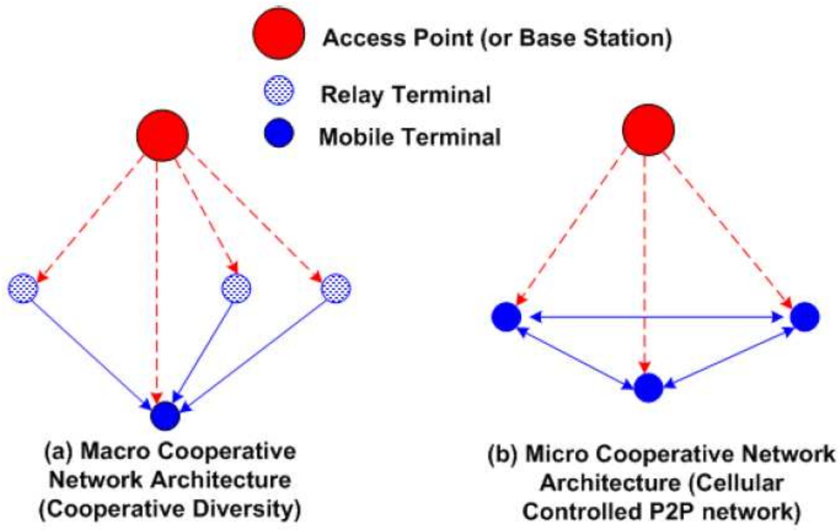

Figure 2: Two cooperative networking architectures, taken from Zhang et al. (2006)

2.3 Technologies and networks that facilitate the deployment of wireless heterogeneous networks.

In recent years, researchers have been proposing and defining techniques and networks that can be employed in order to configure a wireless heterogeneous network. A few of these techniques and networks are Cognitive Radio systems, Software Defined Radio, ad-hoc networks, and mesh-networks. 4G LTE networks incorporate some functions that can be employed to design a wireless heterogeneous network.

2.3.1 Cognitive Radio systems

A Cognitive Radio system is used to increase the efficiency of the spectrum by identifying and employing available spectrum resources. A Cognitive Radio system identifies the existence of white spots, which are frequencies not used by primary users in a particular time and specific geographic location, and allocates them to secondary users (Anker, 2008; Haykin, 2005).

The definition of the ITU-R of a Cognitive Radio is as follows: “A radio system employing technology that allows the system: to obtain knowledge of its operational and geographical environment, establish policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained” (ITU-R, 2009).

One of the main concerns about the implementation of Cognitive Radio systems is the possibility that the terminals that follow an opportunistic behaviour can cause interference in the spectrum that is already being used. In this sense, a Dynamic Spectrum Access system can lead to the hidden node problem, which is generated when a secondary user is not able to detect the primary use of a frequency channel. Three types of solutions exist to address this problem: a) a cooperative or collaborative detection, where terminals share information about the use of frequency bands in one area; b) the use of a database with information about the local use of a frequency band; and c) the use of a beacon with information about the use of a frequency band in an area. A Cognitive Pilot Channel (CPC) can be employed to help implement these solutions (Anker, 2008).

2.3.2 Software Defined Radio

Software Defined Radio can be employed by wireless terminals to change their parameters by downloading and installing new software (Veenstra & Leonhard, 2008). The ITU-R defines Software Defined Radio as “a radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard” (ITU-R, 2009).

Cognitive Radios can be considered a subset of SDRs (Akalu, 2008). With SDR it is possible to change essential radio operating parameters, whereas with Cognitive Radio the terminals have to choose the right radio channel for the communication (Veenstra & Leonhard, 2008).

2.3.3 Mesh and ad-hoc networks

Mesh networks and ad-hoc networks are networks where the individual nodes in the networks can also act as independent routers. This way a packet can be transmitted from terminal to terminal until the destination is reached. Unlike the nodes in mesh networks, where the nodes tend to have fixed positions, the nodes or terminals in ad-hoc networks are fairly mobile. In this sense, mesh networks are a specific case of an ad-hoc network. Another feature of ad-hoc networks is that these are peer-to-peer (P2P) self-organizing networks of mobile terminals. Mesh and ad-hoc networks can help to implement a cooperative network due to the possibility of having a direct wireless connection between mobile terminals.

2.3.4 4G LTE networks

Long Term Evolution is a 4G standard developed by the 3GPP. Several operators have adopted LTE as the 4G wireless standard, and in a few countries the deployment of LTE has already started. LTE is a promising technology because it can offer over 100 Mbps and 50 Mbps in downlink and uplink transmissions, respectively.

Figure 3 shows the main components of the LTE network architecture. Two of the main elements of the LTE network are the Evolved Packet Core (EPC) and the Radio Access Network (RAN). The IP Multimedia Subsystem (IMS) helps to control the network and arranges for the control of the call signalling with Public Switched Telephony Networks (PSTNs) and with Packet Data Networks (PDNs). The components of SAE are the Mobility Management Entity (MME), the Serving Gateway (S-GW) and the Packet Data Network Gateway (PDN-GW). MME is used for the signalling, whereas S-GW and PDN-GW are employed for the transport of user data. In the RAN, Evolved-UMTS Terrestrial Radio Access Network (e-UTRAN) is the radio interface. In comparison with the UTRAN of UMTS, which has two nodes, Node B and Radio Network Controller (RNC), e-UTRAN has only the eNode B.

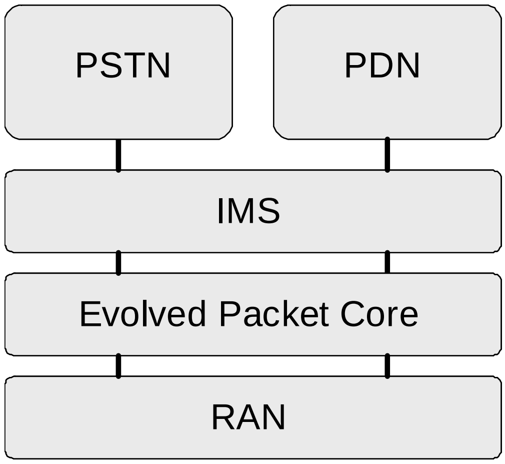

Figure 3: System Architecture Evolution (SAE), taken from Schwaiger (2009).

One important function of the LTE is that the EPC is a multi-access core network based on the Internet Protocol (IP) and it supports different access technologies. It also can be employed for wireless technologies such as LTE, UMTS, GPRS, GSM, WiMAX, WLAN and for different fixed network architectures (Ethernet, DSL, cable, and fiber). This means that the LTE core network supports a wireless heterogeneous scenario. The EPC follows the paradigms of mobility, policy management, and security (Bogineni et al., 2009).

LTE radio access is based on Orthogonal Frequency-Division Multiplexing (OFDM) and supports different carrier frequency bandwidths (1.4-20 MHz) in Time-Division Duplex (TDD) and Frequency-Division Duplex (FDD) modes (Bogineni et al., 2009). Multiple-Input Multiple-Output (MIMO) techniques are also employed in LTE. Several functionalities of the wireless heterogeneous networks are implemented in the LTE standard. A few of these functionalities are Dynamic Spectrum Management (DSM), Joint Radio Resource Management (JRRM), and Self-Organizing Networks (SONs), which are self-x (self-configuration or self-optimisation) (Demestichas & Koenig, 2010).

A femtocell already works in 3G networks and will be used in 4G LTE wireless networks. A femtocell has the function of a home router and it is employed to provide coverage indoors. It connects with the terminal through the same wireless cellular interface and with the wireless core network through a broadband access line (xDSL, fibre, or cable).

3.- Policy implications of the introduction of wireless heterogeneous networks

The deployment of a new telecommunications network or technology raises a number of issues on the regulatory field because it can have an impact on the market structure of a telecom service and it can also generate new legal and policy challenges. This section addresses the possible regulatory implications of the deployment of wireless heterogeneous networks.

The points that will be addressed in this section are standardisation and technology neutrality, spectrum management, open access and infrastructure sharing, interconnection charging and pricing, broadband deployment policies, and privacy and security issues. The two scenarios that are considered in the analysis are wireless heterogeneous networks, which can be present in a scenario nowadays and over the next few years, and wireless heterogeneous cooperative networks, which are more related to a futuristic scenario, because they involve the use of mobile peer-to-peer terminals that can exchange information between themselves. The aspects described in this section are not particular to any jurisdiction.

3.1 Standardisation and technology neutrality.

As is mentioned in EC-RSPG (2010), "standardisation is bridging the gap between the research and the commercial implementation phase". The definition of a standard enables the manufacturers to produce equipment that can interwork. As one of the key features of IMT-2000 is the possibility of having word-wide roaming, it is helpful to have mobile terminals that can support multiple standards (ITU-R, 2007). Moreover, the certification of a mobile terminal that incorporates specific standards helps avoid the interference problem, which is detrimental to good communication.

If the technical constraints at the technological level are removed, then there could be competition between different technologies in the same frequency bands (SPORTVIEWS, 2007). A technology neutrality approach can help guarantee technology competition.[1] One possibility for public authorities to promote the introduction of disruptive technologies is the continuous incorporation of emerging standards (Bohlin, Burgelman, & Rodriguez Casal, 2007). It is also important to keep in mind that if the regulatory barriers are removed, then the technical constraints will have to be increased in order to avoid interferences (SPORTVIEWS, 2007). The harmonisation of standards will also be useful for the global circulation of terminals.

Veenstra and Leonhard (2008) have described the problematic situation that might arise with the certification of the mobile terminal. A mobile terminal can only be put into service in Europe if it complies with the Radio and Telecommunications Terminal Directive, and member states must ensure that the terminal complies with the essential requirements defined in the directive. The use of Software Defined Radio can have a few implications. A terminal needs a "declaration of conformity" before it can be placed on the market. However, "once the apparatus is on the market and is in use the end user is responsible for the apparatus. Changing essential equipment parameters has, or can have, an unpredictable influence on the validity of the declaration of the conformity" (Veenstra & Leonhard, 2008).

For the use of wireless heterogeneous networks, it is necessary that manufacturers produce multi-mode terminals that contain several standards accepted by local authorities. The certification of reconfigurable mobile terminals is a basic requisite that should be met, and the free circulation of terminals with CR and SDR capabilities between different jurisdictions will help to establish connections through wireless heterogeneous networks.

3.2 Spectrum management

Probably one of the main concerns for a wireless operator is the spectrum it can obtain to provide a specific group of services (voice, data and video). The distribution of the digital dividend can seriously affect the business model of the operators that try to provide wireless broadband access services. A discussion about the optimal frequencies for 4G wireless networks can be found in NGMN Alliance (2007). If cooperative networks with mesh or ad-hoc networks are employed, then it is necessary to study whether the spectrum used by these networks is license-free or not (Pujol, 2007).

Moreover, Spectrum Management Authorities (SMA) face a few challenges with the scenarios that emerge with Cognitive Radio and Software Defined Radio. As is described by

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[1] In the European Union, technology neutrality has been a guiding element in the regulation of telecommunications services. However, for the provisioning of a few services, the corresponding regulation has been technology-oriented.

Anker (2008), international treaties do not forbid the use of Dynamic Spectrum Access in general or of Cognitive Radio specifically. Nevertheless, some barriers restrict the use of a dynamic form of spectrum access. In many countries, the spectrum management follows a static approach and the frequency bands can only be employed by licensees to provide a specific set of services. For the realisation of wireless heterogeneous technologies, it will be necessary that the bands can be used for other technologies and services. Therefore, the international and national regulatory framework should be adapted to adopt a new approach of spectrum management.

Changing policies of spectrum management can take several years because the legislation has to be changed at the international and national levels. In the international arena, the ITU has already initiated activities related to the incorporation of Cognitive Radio and Software Defined Radio (Anker, 2008). Before the World Radiocommunications Conference of 2007 (WRC-07), the ITU-R submitted the question 241-1/5 *cognitive radio systems in the mobile service*. The ITU-R also addressed the issue of software defined radio in ITU-R (2007). Moreover, at the WRC-07, the following two aspects were put on the agenda of the next World Radiocommunications Conference to be held in 2012 (WRC-12): a) issues that enable more flexibility in the use of spectrum; and b) “to consider regulatory measures and their relevance, in order to enable the introduction of software-defined radio and cognitive radio systems, based on the results of ITU-R studies” (ITU-R: The World Radiocommunication Conference, 2007). Study Group 1 of Spectrum Management of the ITU-R is in charge of the studies that will be used for the WRC-12 Conference. An overview of the contribution of different bodies (CEPT, ITU-R, RSPG, GSMA, and ETSI) to the debate about the definition of Software Defined Radio can be found in Tardy and Grøndalen (2010).

With the use of wireless heterogeneous networks, it probably would be necessary to deploy additional functionalities that prevent the interferences. For example, one solution to the hidden node problem is the use of a database with information about the current use of frequency bands.

A wireless heterogeneous network requires that every network has an available spectrum. Moreover, the terminals should be able to gain access to the frequency bands and/or to communicate between themselves (in a wireless cooperative network) without causing interferences. Regulatory authorities could promote the implementation of tools that alleviate and avoid the hidden node problem.

3.3 Market analysis

A wireless heterogeneous network could contribute to the provisioning of a high-speed wireless broadband access service. It remains to be seen whether wireless heterogeneous networks enable the provisioning of a new service or not. If the new products are not substitutable for today’s services, then probably a new market should be defined. It should be analysed whether the level of competition between different telecom providers can change or not. It is relevant to understand how the markets for voice, data, SMS and video in terms of supply-side and demand-side issues at both the wholesale and retail levels could be affected by the deployment of wireless heterogeneous networks. Regarding the fixed-mobile substitution, it should be addressed whether the wireless broadband access services substitute or complement fixed broadband access services. If it is found that an operator has Significant Market Power (SMP), what are the regulatory options that should be employed? And which specific remedies should be applied?

For the case of wireless heterogeneous networks, a market analysis will help determine if the network operator is providing a different service or not. The deployment of a heterogeneous network could help increase the market share of an operator. A wireless heterogeneous network could contribute to eliminate more of the differences between fixed and mobile wireless broadband access markets.

3.4 Open access and infrastructure sharing

One of the remedies that can be imposed on operators with Significant Market Power is a mandatory infrastructure sharing. On the other hand, a wireless operator might be willing to voluntarily promote an open access scheme in order to share costs with other operators and thereby reduce investment risk.

A wireless operator can share the radio spectrum and the network infrastructure. The questions that should be addressed are: What are the main regulatory barriers for a network operator to share part of (or all) its network?; which sharing category should be employed? (SAPHYRE, 2010); and which price should be defined for the network infrastructure sharing?

The design of a wireless heterogeneous network could be different from the design of a wireless network with only one radio interface for the access. Therefore, a heterogeneous wireless access network could pose more technical challenges in addition to the challenges that are faced when defining an infrastructure sharing scheme for a wireless network. The corresponding access pricing should also be defined.

3.5 Interconnection charging and pricing

For the interconnection between network operators, current interconnection charging principles, which are mostly based on a cost analysis, or Bill and Keep, can be employed. If a cost model is employed for the calculation of the price of a wholesale service in a wireless heterogeneous networks, then the cost model will take into account the network elements present in the network architecture. It should be determined whether a wireless heterogeneous network needs additional network elements to those that are already in place in a wireless network infrastructure. For the realisation of a wireless heterogeneous network, new functionalities would probably be needed. Some of these functionalities could be deployed in current nodes or probably new nodes could be necessary.

One issue that should be studied in more detail occurs when two wireless access networks are employed by one mobile terminal for one communication. For example, if there is a handover between two access networks that belong to the same operator during one session, how should the pricing mechanism be defined for the use of both networks?

3.6 Broadband deployment policies

It is expected that the use of wireless heterogeneous networks increases the data transmission speed. Therefore, they could be incorporated to meet the targets of high-speed broadband access that have been defined in some national broadband plans. Also, some municipalities might find these types of networks useful in order to provide citizens with high-speed broadband access. Aspects that are related to a broadband deployment policy are network financing and broadband universal service policies.

3.7 Privacy and security issues

In a wireless cooperative scenario, the peer wireless terminals will also receive packets that can be forwarded to the end-user. Privacy and security issues in wireless heterogeneous networks are a subject that needs to be addressed carefully because the vulnerability is higher due to the transmission through a wireless interface. Wireless cooperative networks could be exposed to more risk due to the presence of peer mobile terminals.

3.8 Summary of policy implications

Table 1 summarises the policy implications that have been described in this section.

Regulatory issues	Regulatory implications of the deployment of wireless heterogeneous networks
1. Standardisation and technology neutrality	Manufacturers could produce multi-mode terminals that contain several standards; the certification of reconfigurable mobile terminals is necessary; and the free circulation of terminals with CR and SDR capabilities between different jurisdictions needs to be resolved.
2.- Spectrum management	The assignment of spectrum to wireless operators and the definition of policies for medium access control that will avoid interferences should be defined.
3.- Market analysis	A market analysis will help determine if the network operator is providing a different service or not. The deployment of a heterogeneous network could increase the market share of an operator. A wireless heterogeneous network could help eliminate more of the differences between fixed and mobile wireless broadband access markets.
4.- Open access and infrastructure sharing	A heterogeneous wireless access network could pose more technical challenges in addition to the challenges that are faced when defining an infrastructure-sharing scheme of a wireless network. The corresponding access pricing should also be defined.
5.- Interconnection charging and pricing	If a cost model is employed for the definition of access pricing in wireless heterogeneous networks, then the network elements that permit the realisation of the network should be considered. One issue that should be studied in more detail is the pricing mechanism that should be employed when two wireless access networks that belong to the same operator are used by one mobile terminal for one communication.
6.- Broadband deployment policies	The deployment of a heterogeneous wireless access network could increase the access transmission speed. Therefore, a heterogeneous access network could be helpful to reach broadband access targets.
7.- Privacy and security issues	Privacy and security issues in wireless heterogeneous networks need to be addressed carefully because the vulnerability is higher due to the transmission through a wireless interface. Wireless cooperative networks could be exposed to more risk due to the presence of peer mobile terminals.

Table 1: Summary of policy implications of the deployment of wireless heterogeneous networks.

4. - Conclusions

The deployment of wireless heterogeneous networks raises a number of challenges that need to be addressed by policy and regulatory bodies. The technical features of wireless heterogeneous networks and the policy implications for regulators have been described in the article. A wireless heterogeneous network can have different access networks and it might need the use of Cognitive Radio and Software Defined Radio technologies. In a wireless cooperative network the nodes or terminals are employed as peer terminals and are used to forward packets to other mobile terminals.

Regarding standardisation, reconfigurable mobile terminals with Software Defined Radio and Cognitive Radio should be certified and the free circulation of terminals between different regions should be enabled. With regards to spectrum management, operators need a spectrum for the provisioning of different services, and policies for medium access control should be defined. A market analysis will determine if the wireless heterogeneous operator is providing a new service or not, the level of competition in a specific market and the possible regulatory remedies that could be applied. For infrastructure sharing, which parts of the network can be shared should be studied, as well as which pricing mechanism should be adopted. With respect to the interconnection pricing, the network elements that permit the realisation of the network should be considered. One issue that should be studied in more detail is the pricing mechanism that should be employed when two wireless access networks that belong to the same operator are employed by one mobile terminal for one communication. The deployment of wireless heterogeneous networks could also be beneficial for accomplishing the targets of broadband national plans. Finally, privacy and security issues need to be addressed carefully due to the vulnerability existing in wireless networks. Wireless cooperative networks could be exposed to more risk due to the presence of peer mobile terminals.

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