Efficient sharing of TV White Spaces utilizing mobile TV networks with a cognitive radio approach

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Abstract

The transition from analogue to digital terrestrial television (i.e. Digital Switchover - DSO) releases a significant amount of valuable spectrum in UHF band (i.e. Digital Dividend), that could be utilized in the future for the provision of multiple networking services, by innovative systems and sophisticated technologies. The spectrum resulting after DSO will be available in the form of a “cleared spectrum” of contiguous channels, as well as in the form of “interleaved spectrum”, namely TV White Spaces (i.e. TVWS), unused within given geographical locations so as to avoid causing interference to co-channel or adjacent channel DVB-T transmitters. The “cleared spectrum” and TVWS provide an opportunity to deploy Cognitive Radio (CR) networks, operating in UHF band, able to deliver multiple multimedia and networking services by sharing the available spectrum with other licensed systems in the same frequency band. In this context, this paper elaborates on the efficient sharing of TVWS by utilizing a mobile TV network with a CR approach. The mobile TV network is based on DVB-H standard and operates as an unlicensed secondary system, accessing TVWS channels via a spectrum broker in order to avoid causing interference to other licensed primary systems (i.e. DVB-T systems).

Keywords

Digital Switchover, Digital Dividend, TV White Spaces, Cognitive Radio, spectrum trading, spectrum sharing, spectrum commons, secondary spectrum market, DVB-H, mobile TV.

1. Introduction

The transition from analogue to digital terrestrial television (i.e. Digital Switchover - DSO) is planned to be completed in EU countries up to 2012 (DigiTAG, 2009), by adopting DVB-T standard (ETSI EN 300 744, 2004). Taking into account the spectrum efficiency of DVB-T in comparison with analogue television, a part of the UHF spectrum will be totally cleared for usage by future telecommunication systems, able to provide multimedia and networking services. On the other hand, frequency allocation planning of digital terrestrial television networks, results that a number of UHF channels are left unused within a given geographical location so as to avoid

causing interference to co-channel or adjacent channel DVB-T transmitters (Analysys Mason, 2009). These geographically interleaved channels (i.e. TV White Spaces - TVWS) are additionally considered as a valuable spectrum for usage by secondary unlicensed systems (Stirling, 2010). In this context, DSO releases a significant amount of valuable spectrum (i.e. cleared spectrum and TVWS), providing a "once in a lifetime" opportunity for the introduction of innovative systems and sophisticated new technologies, able to operate in UHF frequency band together with DVB-T systems. The total released spectrum (i.e. cleared spectrum and TVWS), namely "Digital Dividend" has a great potential for the provision of a wide range of services, as the radio signals in this range travel far and equipment can be easily used indoors. It represents a unique opportunity for Europe to meet the growing demand for radio spectrum, particularly providing wireless broadband to rural areas, thereby bridging the digital divide, and stimulating the take-up of new wireless services such as the next generation of mobile broadband, as well as supporting the development of digital terrestrial television. It can therefore contribute significantly to the Lisbon Agenda (CEPT Report 24, 2008) goals of competitiveness and economic growth and satisfy some of the important social, cultural and economic needs of European citizens.

"Digital Dividend" will become available throughout Europe within a relatively short space of time, as all Member States should complete the switch-off of analogue television by 2012. It is essential that this window of opportunity is used to ensure an appropriate level of coordination in the European Union to reap the full social and economic benefits possible from access to this spectrum, and provide a clear EU roadmap for Member States moving ahead at different speeds as a result of differing national circumstances. The opening of "Digital Dividend" spectrum for different services creates an opportunity particularly for wireless broadband network operators to gain valuable radio spectrum. This would allow for more effective competition in the provision of broadband services (CEPT Report 24, 2008).

The UK regulator, Ofcom, has led Europe in defining the spectrum referred as "Digital Dividend" (Ofcom, 2008). The UK's "Digital Dividend" comprises of (Figure 1):

- Cleared spectrum – 128 MHz that will become available for new uses primarily as a result of DSO.
- Geographical interleaved spectrum (or TV White Spaces - TVWS) – the capacity available within the spectrum that will be retained for digital terrestrial television after DSO. This is known as interleaved spectrum because not all this spectrum in any particular location will be used for the provision of DVB-T services and so is available for other services on a shared (or interleaved) basis.

Figure 1 -Spectrum allocation after Digital Switchover in UK

For the European Commission, "Digital Dividend" constitutes a great opportunity to realize significant elements of the EU Lisbon strategy (e.g. providing significant improvements in mobile broadband, multimedia and Internet access). "Digital Dividend" could be also valuably exploited by Cognitive Radio (CR) networks (RSPG Sectretariat, 2009), that enable for spectrum sharing between licensed (primary) and unlicensed (secondary) systems. CR networks are able to perform spectrum acquisition, either through trading in cleared spectrum or sensing in vacant channels (e.g. geographic interleaved spectrum), over a range of frequencies in UHF band, dynamically acquiring unused spectrum and operating at locations under a non-interfering basis while achieving service's QoS.

In this context, this paper proposes the efficient exploitation of the geographical interleaved spectrum (i.e. TVWS) by a mobile TV network, able to operate as a secondary system according to DVB-H standard (ETSI EN 302 304, 2004) with cognitive radio features. The proposed CR network utilizes two spectrum allocation models (i.e. spectrum commons and secondary spectrum market), (ACMA, 2007) for the efficient sharing of TVWS channels in UHF band. Spectrum trading of TVWS channels is achieved via a spectrum broker and a geolocation spectrum database.

In this framework, this paper investigates in Section 2 the two different spectrum sharing models utilized and elaborates in Section 3 on a mobile TV network based on DVB-H standard, able to operate as a cognitive radio system. Finally, Section 4 concludes this paper.

2. Spectrum sharing models

This section is dedicated in order to analyze two spectrum sharing models that were investigated as two potential approaches, which could be utilized in the proposed mobile TV network:

- The Spectrum Commons; represents an extreme point of view, in which the relationship between primary licensed systems (i.e. DVB-T networks) and secondary unlicensed systems is assured by controlling levels of interference, instead of fixed spectrum allocation, promoting spectrum efficiency without QoS guarantees;

- The Secondary Spectrum Market; involves the sale of spectrum for applications that require sporadic access, establishing a secondary market for the lease and auction of spectrum between primary and secondary systems.

2.1 Spectrum commons

Spectrum commons model promotes spectrum efficiency without control of the resource sharing and no spectrum manager is available to preside over the spectrum allocation. This model is most suitable for low power, short range secondary systems. The experience of the recent past in the wireless ISM bands has shown that innovation and openness to new entrants is facilitated when these have to fulfil the technical rules ensuring good coexistence but do not need to negotiate with existing systems. However, despite the fact that unlicensed spectrum promotes efficiency through sharing, QoS cannot be guaranteed. This is a serious problem for some applications. Sensing techniques for reliable detection of TV White Spaces and coexistence mechanisms for interference avoidance are the main technical challenge. Defining spectrum policies and etiquette rules to promote fairness and avoid the "tragedy of the commons" (Pogorel, 2007) are key challenges.

2.2 Secondary spectrum market

Spectrum commons model promotes sharing, but does not provide adequate QoS for some applications. For applications, that require sporadic access to spectrum and for which QoS guarantees are important, licensed spectrum with real-time secondary markets may be the best solution. Trading allows systems to directly trade spectrum usage rights, thereby establishing a secondary market for spectrum leasing and spectrum auction. This model has the potential to enable small companies to enter the spectrum market, have access to "Digital Dividend" and be charged based on spectrum utilization, thus boosting competition and innovation in the telecommunications sector.

Unlike today's unlicensed bands, primary and secondary systems would coordinate directly, making it possible to protect QoS. In this explicit coordination, the license holder runs an admission control algorithm, which only allows secondary system access to spectrum when QoS of both primary and secondary ones are adequate. The license-holder also uses an intelligent frequency assignment algorithm for determining the frequency at which a secondary system should be allowed to operate and the economics of such transactions, which provides incentives to maximize spectrum utilization. Secondary systems dynamically request access to spectrum when and only when spectrum is needed.

The trading of secondary use may occur through intermediaries such as a spectrum manager (i.e. spectrum broker). In general, the mechanisms of searching for a match between primary and secondary systems largely rely on types of services, access characteristics, and service levels requested by secondary systems. The access types could consist of a long-term lease, a scheduled lease, and a short-term lease or spot markets.

3. Mobile TV network with cognitive radio features

TV spectrum that will be released after Digital Switchover (i.e. Digital Dividend), is proposed to be utilized for the provision of additional wireless broadband networking services, high definition digital terrestrial television services (HDTV), cellular telephony services and interactive mobile TV services (CEPT Report 25, 2008). In particular, interactive mobile TV services, that are provided utilizing converged cellular and terrestrial broadcasting networks, are currently of a great interest. Simultaneously, cellular and broadcasting network operators are looking for a new intermediate common market, that is not fully identified but which could combine features of their present offers. Until now, the introduction and take-up of mobile TV services in European Union has been slow, while Europe's competitors have progressed significantly. Unless Europe takes concrete action immediately, it risks losing its competitive edge. In addition, the unavailability of spectrum was considered the largest barrier to the launch of mobile TV services, hence the Commission called upon Member States to make spectrum available for mobile broadcasting as quickly as possible, including in the UHF band (i.e. 470-862 MHz) as it becomes available. In this context, this section of the paper elaborates on the description of an interactive mobile TV network, able to operate with a cognitive radio approach, exploiting TV White Spaces under two spectrum sharing models (i.e. spectrum commons, secondary spectrum market).

TV White Spaces are well suited for mobile TV applications due to superior propagation conditions, as well as due to the relatively low frequencies which facilitate both low cost and low power designs. At the same time, the wavelength of signals in the band is sufficiently short that resonant antennas can be constructed at a size and shape that is acceptable for many portable devices. The proposed mobile TV network is based on a DVB-H system, able to operate in TV White Spaces, enhanced with cognitive radio features. The DVB-H system is able to operate as an unlicensed secondary system only if no interference is caused to other licensed primary systems (i.e. DVB-T systems), operating in UHF band.

The overall concept for the proposed cognitive radio network is depicted in Figure 2 below, indicating a secondary system (i.e. DVB-H network) exploiting the available TV White Spaces via a Spectrum Broker. In this configuration, the light blue and yellow footprints represent DVB-T broadcasting coverage areas (i.e. primary systems), that operate as licensed spectrum holders in areas A and B respectively. The white footprint represents the coverage area that the secondary broadcasting system wishes to establish, by exploiting possible available TVWS delivering linear and/or interactive mobile TV services with a cognitive radio approach and under a non-interference basis to the primary systems. The secondary system is utilizing a DVB-H platform that negotiates via a spectrum broker with other secondary systems, operating as a cognitive radio broadcasting network. In this configuration, mobile TV terminals are able to communicate with DVB-H platform via different return channels, requesting interactive multimedia content provision.

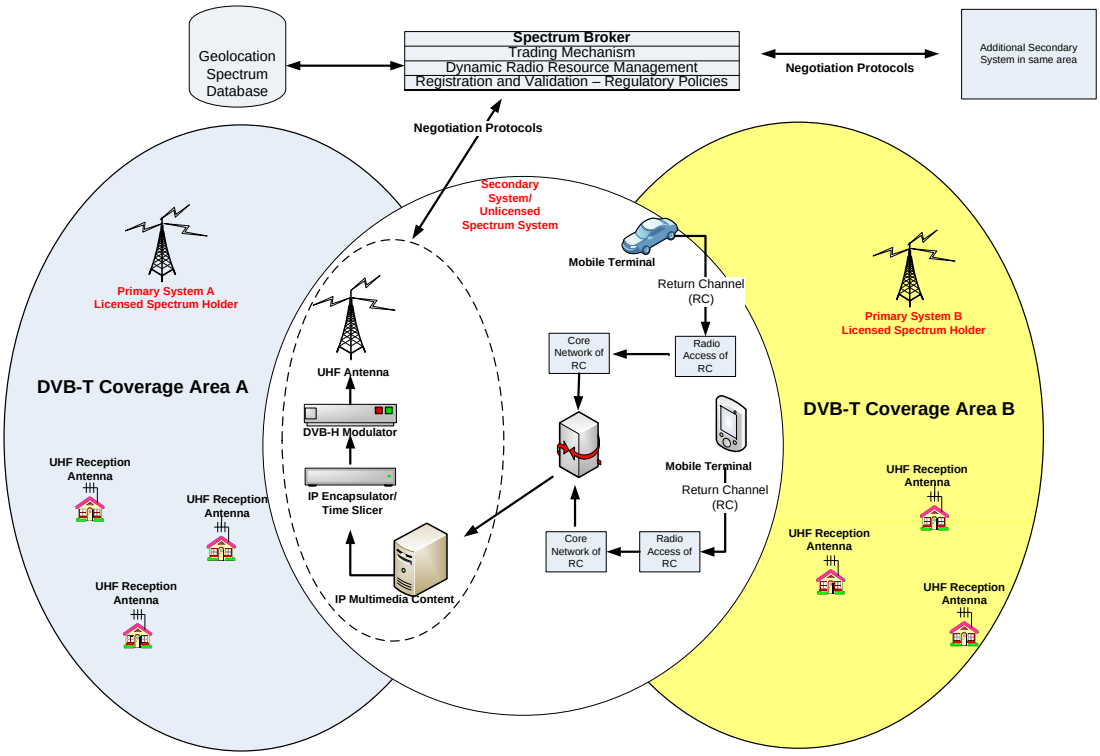

Figure 2 -Mobile TV network configuration in a cognitive radio approach

In the proposed configuration above, the spectrum broker runs an admission control algorithm, which only allows secondary systems (i.e. DVB-H systems), to access spectrum when QoS of both primary and secondary systems are adequate. Spectrum broker entity also utilizes an intelligent frequency assignment algorithm for determining the frequency at which the secondary systems should be allowed to operate and the economics of such transactions, which provides incentives to maximize spectrum utilization. Secondary systems dynamically request access to spectrum when and only when spectrum is needed. The trading of secondary usage in this case is occurred through efficient algorithms incorporated in spectrum broker. In general, the mechanisms of searching for a match between the secondary systems largely rely on types of services, access characteristics, and service levels requested by them. The access types could consist of a long-term lease, a scheduled lease, and a short-term lease or spot markets. Each type requires different discovery mechanisms and applies with different levels of service agreements.

Spectrum broker entity is also able to communicate with a Geolocation Spectrum Database, in order to trade TV White Spaces spectrum between multiple secondary unlicensed systems. According to the frequency availability defined in the database in order to avoid interference with primary systems, spectrum broker assigns spectrum resources that secondary systems are able to utilize for the provision of mobile TV services.

In addition, the return channels in Figure 1, may be able to operate in the TV White Spaces spectrum opportunistically utilizing sensing mechanisms integrated both in the access network and the mobile terminals.

DVB-H services over mobile terminals are expected to trigger new television viewing behaviour patterns among consumer and create a new market for television viewership. However, spectrum allocation by national agencies remains a critical

barrier to the adoption of mobile TV services. In this context and by taking into account the proposed cognitive radio network, TV White Spaces could be utilized as the spectrum, where DVB-H systems may additionally operate. The opportunistic and secondary usage of such systems, as it is proposed in this paper, enables for further technology exploitation, mobile TV services penetration and revenue increase.

4. Conclusion

The transition from analogue to digital terrestrial television releases a significant amount of valuable spectrum in UHF band known as “Digital Dividend”. This spectrum will be available in the form of a “cleared spectrum” of contiguous channels as well as in the form of “interleaved spectrum” (namely TVWS), unused within given geographical locations so as to avoid causing interference to co-channel or adjacent channel DVB-T transmitters. “Digital Dividend” will be utilized for the provision of multiple services, by innovative systems and sophisticated networking technologies that could operate with CR features. In this context, this paper elaborates on the efficient sharing of TVWS by proposing a mobile TV network that is based on DVB-H standard and operates as an unlicensed CR system, accessing TVWS channels via a spectrum broker in order to avoid causing interference to other licensed primary systems (i.e. DVB-T systems). The proposed system constitutes a network solution that alleviates spectrum scarcity problem, by utilizing UHF channels with an optimized approach.

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