Abstract

The in-band provision of fixed and mobile services and the insertion of local services in Single Frequency Networks (SFN) are two key topics for the optimization of Digital Terrestrial Television (DTT) networks. On one hand, the transmission of mobile TV services requires the allocation of specific bandwidth and dedicated networks to achieve good coverage levels. The costs associated to the deployment of these dedicated networks and the lack of a successful business model have been the main causes of the failure of the first-generation mobile TV technologies. In this sense, the convergence of fixed and mobile paradigms can facilitate the introduction of mobile TV services by allowing the reuse of spectrum, content and infrastructure. On the other hand, neither SFN nor Multi Frequency Network (MFN) topologies used for the current DTT networks are ideally suited for delivery of both global and local services in an efficient way. MFNs enable the efficient transmission of local services but need a significant amount of frequency spectrum. Without violating the SFN principle, local services meant to address sub regions of an SFN must therefore be transmitted throughout the whole network, causing inefficient distribution of local services. Therefore, the efficient provision of global and local TV contents in SFN topologies allow saving bandwidth and guaranteeing an optimal use of the spectrum.

This dissertation investigates technical solutions to optimize the simultaneous delivery of fixed and mobile DTT services and the efficient transmission of global and local services using the same Radio Frequency (RF) channel and network infrastructure. The technical solutions are focused on the European family of standards developed by the Digital Video Broadcasting (DVB) consortium. This include Digital Video Broadcasting- Terrestrial (DVB-T) and Digital Video Broadcasting- Terrestrial 2nd Generation (DVB-T2), as well as the next generation system Digital Video Broadcasting- Next Generation Handheld (DVB-NGH). Nevertheless, the work carried out in this dissertation is of generic nature and can be applied to future evolutions of standards such as the Japanese Integrated Services Digital Broadcasting (ISDB-T), the Future of

Broadcast Television (FOBTV) initiative or the American Advanced Television System Committee (ATSC) 3.0. Our investigations are based on physical layer simulations, laboratory tests and field measurements to assess the performance of the different techniques. Complementary, we analyze the applicability of these solutions by means of coverage estimations in realistic scenarios using a professional DTT network planning tool and information of the current DTT network deployed in Valencia Spain city and the DTT network design of the public TV broadcaster of Colombia.

The provision of mobile broadcasting services is significantly more challenging than traditional fixed services due to the severe propagation conditions of the mobile channel, the utilization of more compact antennas and the reception at ground level. In order to provide good coverage level of mobile broadcasting services with the same DTT networks planned for fixed reception, it is necessary to deploy a dense network with a large number of sites or without deploying additional transmitters, select the more robustness transmission modes at the expense of low bit rates. The transmission modes with services-specific robustness in the same multiplex can be used in order to optimize the coverage and available bit rate of both fixed and mobile services. It is possible in DVB-T by means of the hierarchical modulation, which multiplexes two different streams into the same constellation. In DVB-T2, it can be available through of multiples Physical Layer Pipes (PLP) technique or the T2-Lite profile. Multiples PLP is considered the technical evolution of the hierarchical modulation, where a PLP is a logical channel carrying one or multiple services with independent modulation, coding and time interleaving. T2-Lite is the new profile recently included in the DVB-T2 standard to reduce the complexity of receivers and make possible to efficiently share the capacity of one frequency channel in a time division manner between fixed and mobile services.

In order to improve the reception of mobile broadcasting services in networks planned for fixed reception, we evaluate the combined use of transmission modes that offer services-specific robustness and diversity techniques in the time, frequency, and space domains. Time and frequency diversity is generally achieved by means of Forward Error Correction (FEC) and interleaving, while space diversity is enabled by means of multiple transmit and/or receive antennas. The results show that the incorporation of Time Interleaving (TI) at the physical layer for time diversity, and Single-Input Multiple-Output (SIMO) for space diversity are critical for the performance of mobile broadcasting systems. Upper Layer-FEC (UL-FEC) techniques can be used to enable TI in DVB-T or increase the time interleaving in second generation systems. It can be implemented in generic software in such a manner that ensures that legacy receivers drop it without altering their proper operation. The coverage estimation in real scenarios reveals that the final combination of time and space diversity with

techniques that enable per-service robustness is sufficient to provision mobile services with acceptable coverage level in DVB-T and DVB-T2 networks planned for fixed reception.

The basic principle of SFNs is that all transmitters radiate the same signal synchronized in time and frequency, therefore are especially suitable for global services due to mutual support of the signal by multiple transmitters. However, they are not efficient for transmitting local services because all the content is transmitted throughout the whole network (solution called simulcast). An ideal solution to delivery global and local content in SFN networks should retain all SFN advantages for global services and they are not affected by the local services. Furthermore, the transmission of local services should be spectrally efficient and using any subset of sites of the network, while their coverage area Local Services Area (LSA) is restricted to the specific areas where local content is to be consumed.

Hierarchical modulation (for DVB-T and DVB-NGH) and technical solutions based on temporal or frequency multiplexing (for DVB-T, DVB-T2 and DVB-NGH) are evaluated in this dissertation in order to provide global and local services in SFN broadcasting systems. These solutions keep all SFN advantages for global services, while the coverage area of the local services is restricted to the areas surrounding the transmitters, where generally are located the target population (for example, a city). All solutions offer a transmission capacity gain compared with classic approach to insert local services in SFN such as simulcast. Since the local services are transmitted on top of the global services, the solutions based on hierarchical modulation offer a higher transmission capacity gain than the others solutions.

Using the solutions based on temporal or frequency multiplexing, the local services can have almost the same coverage area as global services. Furthermore, with these solutions the insertion of local services does not affect the coverage of global services. An additional advantage of the frequency multiplexing solution is that there is no interference between transmitters from different LSA because the inserted local content is orthogonal to each other. For the other solutions, a shared time-division manner can be used in order to maximize the coverage area of local services avoiding interferences between adjacent transmitters. However, when the solutions based on hierarchical modulation are used, the coverage of global and local services suffers a reduction compared to the equivalent constellation in non-hierarchical mode due to the inter-layer interference. In general, each technique addresses different use cases with different coverage-capacity performance trade-off, such that they will allow exploring the viability of inserting local services in SFNs in an efficient way.

ABSTRACT