Analytical Analysis Of Implementation Issues And Its Practical Applicability In DVB-NGH Single Frequency Networks

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Abstract

The role of the television has huge impact on the 21st century and basically the televisions either make use of SFN single frequency networks (SFN) or multi frequency networks (MFN) and both these networks are ideal for meeting the practical requirements either in local and global services. Another important drawback in these two networks are these two networks consumes huge amount of spectrum. The single frequency networks (SFN) main approach is it radiates the same amount of signal both in terms of time and frequency and 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. A novel approach has been proposed in this paper where high equipped next generation mobile broadcasting standard digital video broadcasting—next generation handheld for providing global and local contents in SFN topologies: hierarchical modulation (H-LSI) and orthogonal local services insertion (O-LSI) techniques. H-LSI uses hierarchical modulation to transmit local services on top of the global services in areas close to the transmitters, by transmitting the local services in the low priority stream and the global services in the high priority stream. The O-LSI scheme specifies groups of OFDM subcarriers in specific OFDM symbols for the exclusive use of particular transmitters to transmit local services. For both techniques, the transmission of local content through the whole SFN network can be scheduled in a way that different local areas do not interfere with each other. In addition to the description of both H-LSI and O-LSI schemes, the applicability of these approaches in terms of network topologies, implementation issues, and performance evaluation are analyzed.

KEYWORDS: single frequency networks (SFN), Multi frequency networks (MFN), OFDM, DVB-NGH, hierarchical modulation, local services, orthogonal local services insertion

1. INTRODUCTION

The DVB-NGH (Next Generation Handheld) standard is the mobile evolution of the European standard Digital Terrestrial Television (DTT) for the second generation DVB-T2 (Terrestrial 2nd generation). The DVB-T2 was submitted to ETSI in 2008, and will be taken into operative use during 2010. This second generation system provides about 50% increase of physical layer capacity compared to the previous standards.

DVB-T2 is in its first stage targeting for fixed reception. Providing the same or better capacity increase for portable, mobile and handheld broadcasts (DVBNGH), require new technical concepts.

For this reason, DVB-NGH has been thought to be the mobile broadcasting standard reference worldwide, with better performance in terms of capacity and coverage to the existing mobile technologies, such as, the first mobile DTV generation

standard DVB-H (Handled), the hybrid terrestrial-satellite mobile DTV standard DVB-SH (Satellite to Handhelds), or cell broadcast standard MBMS (Multimedia Broadcast Multimedia Services).

One of the main advantages of DTT networks is the possibility of deploying SFNs by the use of Orthogonal Frequency Division Multiplexing (OFDM) with a sufficiently long Cyclic Prefix (CP). The receiver usually receives multiple signals coming from different SFN transmitters with different channel attenuations and time delays, which exhibits a severe artificial multipath effect. All the signals from the different transmitters should arrived inside the CP interval in order to be considered constructive to the wanted signal. SFNs are ideally suited for global services because of the need of a single frequency channel and due to the mutual support of the signals from the different transmitters, the so-called SFN gain.

However, if local services are transmitted, they have to be transmitted across the whole network, including regions where they are not required. This leads to a significant waste of capacity if the proportion of local content is large. On the other hand, using a MFN approach, the full channel capacity is available for the content transmitted within each cell. The main drawback is that more spectrum is required compared to the SFN approach. An ideal solution to transmit global and local content in SFN networks should retain all SFN advantages for global services.

The transmission of local services should be spectrally efficient and using any subset of sites of the network, while their coverage area (Local Service Area, LSA) is restricted to the specific areas where local content is to be consumed. In order to achieve this, the SFN principle has to be violated partially, e.g., for a short period of time or a limited frequency range. The main problem is that different local services transmitted within a single frequency cause interference. Thus, in areas where the signals of two or more sites transmitting different local services are strong, successful reception of local services may not be possible. However, for local services a reduced coverage area

compared to global services may be acceptable for some use cases (e.g., urban areas), although for some uses cases the required coverage can be the same as for global services.

The current state-of-the art DTT system, DVB-NGH (Digital Video Broadcasting – Next Generation Handheld, will allow exploring the viability of inserting local services in SFNs in a way that has not been possible before. DVB-NGH is the handheld evolution of the second generation digital terrestrial TV standard DVB-T2 (Terrestrial 2nd Generation), and one of the main technical innovations introduced with respect to DVB-T2 is the efficient provisioning of local content in SFNs. DVB-NGH has adopted two complementary techniques with small network overhead to transmit local content in SFNs, known as Hierarchical and Orthogonal Local Service Insertion (H-LSI and O-LSI, respectively).

The first technique uses Hierarchical Modulation (HM), which generates each QAM symbol from two bit streams with different robustness levels (global content is transmitted within the so-called High Priority (HP) bit stream, whereas the local content is inserted into the Low Priority (LP) stream). HM was adopted for the first time for DVB-T (Terrestrial), and it was also adopted for the mobile broadcasting system Media FLO and DVB-SH (Satellite to Handhelds), although it has never been commercially deployed yet. With O-LSI technique, a set of OFDM (Orthogonal Frequency Division Multiplexing) sub-carriers within the NGH frame structure are allocated to transmit local services. The transmitters of each LSA transmit local content using a subset of these sub-carriers. This concept is similar to the auxiliary stream insertion specified in the DVB-T2 transmitter signature standard. O-LSI is a novel technique for which no previous studies or performance results are available in the literature.

2. RELATED CONTENT

In the history of broadcast networks, the 1990s remain one of the most important milestones, since they mark the technology leap from analogue to digital. In the process of digitizing the

traditional analogue broadcast systems, the family of Digital Video Broadcasting (DVB) standards has become the reference not only for digital television but also for data, sound and multimedia broadcasting world-wide.

DVB is a family of standardized technologies designed to facilitate broadcasting over terrestrial, cable, satellite and mobile communication systems, and to permit a large degree of user interaction. DVB standard development is at the charge of the DVB Project, an international industry-led consortium of around 250 broadcasters, manufacturers, network operators, software developers, regulatory bodies and others in over 35 countries. Specifications agreed by the DVB Project are then approved and published by a Joint Technical Committee (JTC) of European Telecommunications Standards Institute (ETSI), European Committee for Electro technical Standardization (CENELEC) and European Broadcasting Union (EBU).

DVB specifications cover a large variety of applications, but the most representative are satellite, cable and terrestrial transmissions. The DVB-S system for digital satellite broadcasting (1993), based on Quaternary Phase Shift Keying (QPSK), is still used by most satellite broadcasters around the world for direct-to-home television services. The DVB-C [2] system for digital cable networks (1994) is centered on the use of 64 Quadrature Amplitude Modulation (QAM), and can, if needed, convey a complete satellite channel multiplex on a cable channel. Intended to cope with different noise and bandwidth environments, including multi-path, the digital terrestrial television system DVB-T (1997) is so far one of the most widely adopted and deployed digital terrestrial transmission standards.

Due to the European analogue switch-off and increasing scarcity of spectrum, DVB drew up Commercial Requirements for more spectrum-efficient and updated standards, leading to a second generation of standards with increased capacity. DVBS2 (2005) provides higher modulation orders (16 and 32 Amplitude Phase Shift Keying (APSK)), adaptive modulation and coding and a very powerful forward error correction (FEC).

DVB-T2 includes increased capacity, robustness and the ability to reuse existing reception antennas. The first version was published in 2009, and the latest update (2011) included the T2-Lite subset for mobile and portable reception. Already deployed since 2010 (UK) DVB-T2 is promised to meet a big market success. So far 47 countries worldwide are considering DVB-T2 services.

Following the users request for mobility, technical specifications directed to handheld receivers also emerged. DVB-H (2004) is an enhancement of DVB-T designed to enable the efficient delivery of IP-encapsulated data over terrestrial networks using multi-protocol encapsulation and time slicing. DVB-SH (2010) is a satellite system with an optional terrestrial component allowing the use of a hybrid satellite/terrestrial mode. DVB-SH is designed to use frequencies below 3GHz (typically around 2.2GHz) in order to deliver video, audio and data services to vehicles and handheld devices.

As part of the evolution of the DVB family of standards, the newest emerging member is DVB-NGH, a terrestrial system with an optional satellite component allowing the use of a hybrid terrestrial-satellite mode. DVB-NGH is targeted for the new generation handheld (NGH) terminals. From a standardization point of view, the main technical choices were frozen at the end of 2011. Currently under drafting, the DVBNGH specifications are to be released current 2012 (current target is September) and are expected to complement 3rd generation (3G) and beyond 3G telecom networks and offer superior performance with respect to existing DVB-H.

3. MOTIVATION

DVB-NGH is based on DVB-T2 physical layer specification, but introduces several advanced mechanisms and techniques that allow the transmission of high definition TV services. This thesis aims to investigate study and develop the new physical layer for the new handled generation of terrestrial TV standard. The main objective of this thesis is focus on how these

mechanisms enhance the new physical layer in compare to T2 physical layer.

4. NETWORK TOPOLOGIES FOR LSI IN DVB-NGH

The principle of SFNs with global and local services for H-LSI and O-LSI is shown in the Figure 1. All transmitters employ a common frequency, f_{com}, to transmit both global and local services. For global services, a coverage gain within the Global Services Area (GSA) is achieved due to a statistical gain by exploiting the signal diversity and a power gain by the combination of the received signal strengths (SFN gain). Local services are only provided in the three depicted LSAs. For H-LSI, the coverage of the local services is limited to the areas surrounding the transmitters. This may be acceptable for some use cases (e.g., when the transmitter is located within a city). In this case, signals from different LSAs act as interference if the insertion took place at identical time instances.

A solution to avoid interferences between LSAs is to time share the hierarchical transmission mode, e.g., on a frame-by-frame basis. Time sharing slots can be reused between transmitters that are sufficiently far apart. Time sharing leads to a reduced capacity available for local content that can be inserted at each LSA. The main advantage of O-LSI is that it is possible to provide local services across the whole network with basically the same coverage as the global services, not necessarily only in the vicinity of the transmitters as the first approach of H-LSI. Hence, this technique is suitable, for example, for local news or advertising as temporal window in a global service. The right side of Fig. 1 shows the coverage level for global and local services in an SFN with O-LSI. In the overlapping zones between adjacent LSAs, global services experience an SFN gain whereas local services do not, but the receivers can decode more than one local service.

5. HIERARCHICAL MODULATION FOR LOCAL SERVICES INSERTION IN DVB-NGH SFNS

5.1 Concept

DVB-NGH supports hierarchical 16QAM and 64QAM modulation for the insertion of local services, where the global services employ a QPSK or 16QAM modulation, and the transmitters inserting local services add an additional QPSK constellation on top of the global QAM constellation, containing the local service. For the global service, the hierarchically modulated QAM symbols "look" like noise, requiring an increase in CNR (Carrier-to-Noise Ratio). This effect diminishes with distance from the local service inserting transmitter as shown in Fig. 2. Since the local service is mapped to the low priority bits of the constellation, the effective CNR of the local service is smaller compared to the global service.
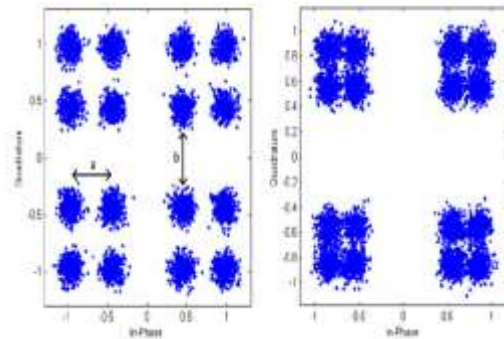

Figure 1: Received signal constellation in a network comprising two transmitters, one transmitting the global service only using QPSK, the other one transmitting both global and local stream using hierarchical 16-QAM; left: receiver is close to the local transmitter, right: receiver is distant from the local transmitter and near to the nonhierarchical transmitter.

5.2 Implementation Aspects

DVB-NGH re-uses the PLP (Physical Layer Pipe) feature of DVB-T2. A PLP is a logical channel carrying one or multiple services. Each PLP may use a different modulation scheme and code rate within the same transmission channel to meet different reception conditions (e.g., portable indoor or rooftop reception). In DVB-T2, each transmission frame comprises two types of PLPs, known as Type 1 and Type 2 [3]. PLPs of Type 1 are transmitted in a single burst (slice) within each frame,

whereas PLPs of Type 2 are transmitted in multiple subslices within each frame.

In DVB-NGH, two new types of PLPs are defined for local service insertion in SFNs, known as Type 3 and Type 4, which are used for O-LSI and H-LSI, respectively [2]. Fig. 3 shows the NGH logical frame (LF) structure showing the different types of PLPs. H-LSI PLPs are transmitted on top of data PLPs of Type 1, being mapped after the common PLPs.

The O-LSI PLPs are transmitted at the end of the frame, after data PLPs of Type 2. Auxiliary streams or padding sub-carriers may exist in-between Type 2 and Type 3 PLPs. With H-LSI the local and global service bits are processed separately in two stages, both containing the typical blocks of the DVB-NGH signal generation as shown in Fig. 4. However, the processing path of the local PLP comprises a special burst builder, which groups the coded local service bits of an integer number of FEC frames and inserts a 64 bit synchronization header at the beginning, building a local service frame. The synchronization header carries the signaling information for local PLP decoding. The value of the hierarchical parameter a and the ID of the global PLP carrying the local PLP are signaled in the physical layer (L1) signaling, since this information is required to extract the local stream.
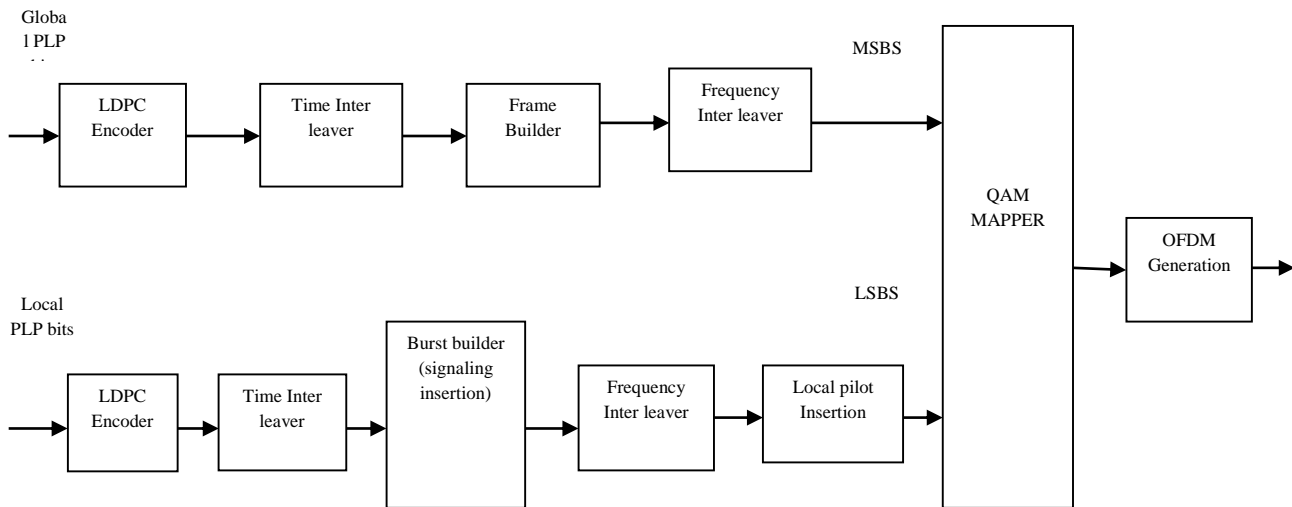
Figure 2: H-LSI transmitter block diagram

6. ORTHOGONAL LOCAL SERVICES INSERTION IN DVB-NGH SFNS

6.1 Concept

With O-LSI a set of dedicated OFDM sub-carriers on dedicated OFDM symbols are reserved for the transmission of local services. Within the same OFDM symbol, the transmitters of different LSAs employ a different subset of subcarriers to broadcast local services, whereas the same OFDM sub-carriers used by the other transmitters are unused. The orthogonality obtained by using dedicated carriers for each local service ensures that no interference between adjacent transmitters occurs (Assuming correct frequency synchronization between SFN transmitters). The general concept of the O-LSI technique for the insertion of local services in an SFN with three LSAs is illustrated here. For the sake of clarity, the picture shows the allocated data subcarriers in one OFDM symbol before frequency interleaving. After frequency interleaving, each set is spread across the complete bandwidth to achieve high frequency diversity, still avoiding interference between transmitters of different LSAs. However, similar to other OFDM systems, the frequency offsets such as Doppler Effect, can affect this orthogonality, resulting in inter-carrier interference (ICI) due to power leakage among subcarriers. In this case, the performance of global and local services in mobile reception is similar to the performance DVB-NGH in

conventional SFN topology and depends on the velocity of the receiver and the robustness of the transmission mode.

6.2 Implementation Aspects

The payload data using O-LSI is transmitted as Type 3 PLP after any preceding Type 1 and Type 2 PLPs in specific OFDM symbols, as shown in Fig. 5. All Type 3 PLP data in a transmission frame is transmitted by a number of consecutive OFDM symbols with the first and the last O-LSI having a denser pilot pattern. The orthogonality among different local content is obtained by dividing the available number of data sub-carriers in each O-LSI symbol into the number of local services areas parts, nLSA. Only one part is then transmitted from a particular transmitter.

When all O-LSI data cells have been introduced, frequency interleaving is performed symbol by symbol. In a similar way to H-LSI, O-LSI PLPs require dedicated pilots for channel estimation. These additional pilots reduce the useful data capacity depending on the number of LSAs in the SFN. The continual pilots, e.g., used for frequency synchronization, are the same for all transmitters in the network.

However scattered pilots must be inserted for each LSA each being frequency shifted by one OFDM sub-carrier, such that the different PPs are orthogonal. Since the scattered PP is repeated for each LSA, the densest patterns PP1 and PP2 are not available for O-LSI to avoid extensive pilot overhead. The reserved O-LSI data and pilot sub-carriers in each LSA are transmitted with an amplitude boosting factor equal to $\sqrt{n}$ LSA, followed by a normalization factor K.

7. FUTURE BROADCASTING

After the successful achievement, since the 90s, of the transition to digital, the international consortium DVB is now concluding the process of renewal of the television broadcast standards, the second generation ones offering performance close to the theoretical limit and a highly flexible configuration.

The DVB-S2

The DVB-S2 system, for satellite broadcasting, is the first second-generation system, defined by DVB in 2003 and is now used by many satellite operators for the deployment of high-definition TV. It was designed for TV and HDTV Broadcast services and for interactive applications for home and professional uses. This system benefits from the latest developments in channel coding and modulation, which guarantee a capacity increase of approximately 30% compared to DVB-S CCM (Constant Coding & Modulation) mode, i.e. fixed transmission parameters. In interactive point to point applications, such as access to the Internet, ACM (Adaptive Coding & Modulation) is used to optimize the modulation and coding scheme according to channel conditions, with a significant increase in transmission capacity.

The DVB-T2

The DVB-T2 system for terrestrial television was defined in 2008 and debuted in 2010 in Britain. In Italy, the Rai Research Centre has begun trials in late 2008. DVB-T2 builds on the technologies already used by DVB-T, primarily the multi-carrier modulation (OFDM) and QAM constellations, extended up to 256 QAM; it combines many innovative features, including the data distribution frame and channel coding DVB-S2 to attain system performance as much as possible close to the theoretical limit. Thanks to an extensive flexibility parameters (guard interval, equalization, differentiated protection per service), the system can be adapted to the characteristics of the transmission channel and the type of service, increasing the capacity up to 50 % in comparison with DVB-T.

DVB-C2

Following DVB-S2 and DVB-T2, the DVB-C2 cable system was born in 2009. Based on the DVB-S2 channel coding techniques and DVB-T2 OFDM, DVB-C2 extends up to 4k-QAM constellations and introduces flexibility in the allocation of available channel bandwidth.

Finally ... DVB-NHG

DVB-NGH (Next Generation Handheld) is the newest member of the DVB second generation family and it will be the system for TV on mobile handsets. Expired in February 2010 the call for technologies, the activities for defining the new standard should be completed by 2011. The first commercial NGH devices may be available from 2013. DVB-NGH starts form DVB-T2, already designed in order to correctly operate in the mobile environment, and investigates the possibility of adopting new technologies, specific for the mobile scenario. Among possible new approaches under study, MIMO (Multiple Input-Multiple Output) techniques to improve the performance thanks to spatial diversity offered by multiple antenna systems: the proposed techniques consider 2x2, 2x4, or 4x4 systems, with signals on single polarization or both the polarizations. Finally, for video encoding, the SVC (Scalable Video Coding) profile of H.264/AVC standard is under study: it divides the signal stream in two or more quality levels, with different transmission protection, decreasing for higher levels. This ensures, even in the most critical reception (indoor), a minimum quality of service, increasing with more favorable reception conditions (outdoor).

8 RESULTS
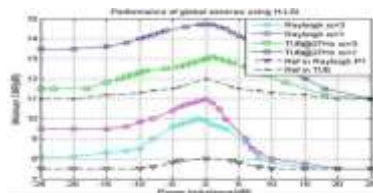
Figure 3: Performance of global services using H-LSI. Hierarchical 64QAM CR 7/15 in Rayleigh and TU6 channels. The dashed lines are the performance of classic 16QAM 7/15
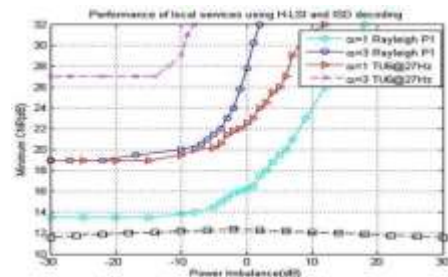

Figure 4: Performance of local services using H-LSI and ISD

decoding. Hierarchical 64QAM CR 7/15 decoding in Rayleigh P1 and TU6 channels. The dashed line is the performance of non-hierarchical 64QAM CR 7/15.
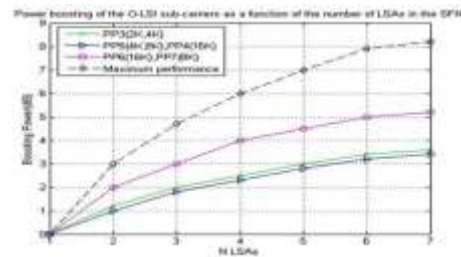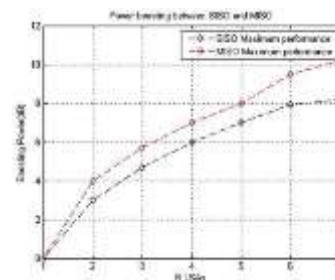

Figure 5: Power boosting of the O-LSI sub-carriers as a function of the number of LSAs in the SFN. The dashed line is the maximum performance without power correction factor K.
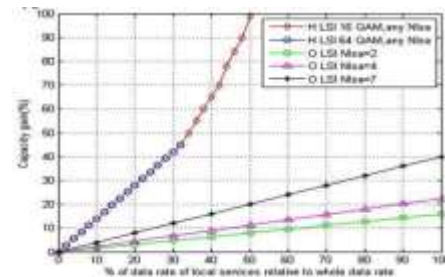
Figure 6: Capacity gain of HM-LSI and O-LSI as a function of the number

of LSAs and the fraction of local services

Figure 7: Power Boosting Between SISO and MISO

9. CONCLUSION

The efficient provision of local services in SFNs with minimum increased overhead was one of the commercial requirements underlying DVB-NGH. This paper has analyzed the implementation issues and evaluated the performance in terms of minimum CNR required for successful decoding and capacity gain of the two complementary technical solutions

adopted, known as H-LSI (based on hierarchical modulation)and O-LSI (using orthogonal transmission mode). Either technique addresses different use cases with a different coverage/ capacity performance trade-off. The optimum transmission technique depends on the target use case and the particular scenario considered (location and power of the transmitters, distribution of the LSAs, etc.). Both solutions preserve the SFN advantage for global services by broadcasting the local content in their respective target areas only, avoiding SFN self-interference between them. Compared with the classic SFN approach, H-LSI offers a high capacity gain for local services while keeping the data rate of the global stream constant, at the expense of a coverage reduction for both global and local services. O-LSI provides local services potentially with the same coverage as the global services with a moderate transmission capacity gain at the expense of reducing the available data rate for global services. By adopting the MISO boosting power is going to increase by which the system performance and transmission speed will increase.

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