End-to-End Digital Video Broadcasting Test-bed

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Abstract

This article presents the research and development activities on digital video broadcasting carried by the Mobile Communications Group of the iTEAM research institute of the Universidad Politécnica de Valencia. iTEAM is a full member of the DVB standardization forum, and is actively participating in the standardization process of the next generation mobile TV standard DVB-NGH. iTEAM's DVB facilities include a complete end-to-end DVB-T/H/SH/T2 lab, and a DVB-T/H pilot at the main campus of the Universidad Politécnica de Valencia. iTEAM has developed a proprietary multi-standard DVB encapsulation, simulation, and measurement platforms. On-going work aims at upgrading the platforms with the second generation digital terrestrial television DVB-T2 standard.

Keywords Digital video broadcasting, digital TV, mobile TV.

1. Introduction

This article presents the research and development activities on digital video broadcasting carried by the Mobile Communications Group of the iTEAM research institute of the Universidad Politécnica de Valencia. iTEAM is a full member of the DVB (Digital Video Broadcasting) standardization forum, where it is actively participating in the standardization process of the next generation mobile TV standard DVB-NGH. iTEAM's DVB facilities include a complete end-to-end lab and a test pilot at the main campus of the Universidad Politécnica de Valencia. The laboratory supports the following technologies: DVB-T (digital terrestrial TV standard), DVB-H (mobile terrestrial TV standard), DVB-SH (mobile satellite TV standard), and DVB-T2 (second generation digital terrestrial TV standard). The pilot supports DVB-T and DVB-H. iTEAM has a proprietary multi-standard DVB encapsulation, simulation, and measurement platforms, which is currently being upgraded to DVB-T2.

2. Overview DVB Technologies

2.1. DVB-T

DVB-T (Terrestrial) is the first generation European standard for the transmission of digital terrestrial TV (DTT). DVB-T has been adopted by many countries worldwide. It is planned that DTT services completely replace analogue TV in many European countries by latest 2012. Several European countries such as Luxemburg, the Netherlands, Finland, Andorra, Sweden, Norway, Switzerland, Belgium, Germany, Denmark and Spain have already completed the analogue switch off. Spain stopped the transmission of analogue TV signals in April 2010. DVB-T employs OFDM (Orthogonal Frequency Division Multiplexing) modulation, which makes it very resilient against multi path propagation. OFDM usage allows as well the deployment of SFN (Single Frequency Networks) networks that achieve a very high spectral efficiency. However, DVB-T was designed for fixed and portable reception and generally does not provide enough robustness in mobile environments since it does not implement time interleaving.

2.2. DVB-H

DVB-H (Handheld) is the evolution of DVB-T for the provision of mobile TV services. DVB-H reutilizes the physical layer of DVB-T and implements several modifications in the link layer in order to adapt the transmission to mobile devices. Contrary to DVB-T, DVB-H encapsulates the video, audio and data information into IP datagrams that are transmitted in a busty manner known as time slicing. By doing this, it is possible to achieve power saving figures up to 90%. In order to counteract the impairments of mobile reception (in particular fast fading), DVB-H also implements MPE-FEC (Multi Protocol Encapsulation - FEC) protection at the link layer. Commercial DVB-H services are already on air in more than ten countries in Europe, South East Asia, and Africa.

2.3. DVB-S/S2

DVB-S (Satellite) is the first generation European standard for the transmission of satellite services. At present, DVB-S is the most popular system for the transmission of digital satellite services with more than 100 million receivers deployed around the world. Contrary to DVB-T, DVB-S employs TDM (Time Division Multiplexing) modulation that is better suited than OFDM for satellite transmissions. The high peak to average power ratio of multi carrier modulations such as OFDM forces the on board high power amplifiers to operate quite below the saturation point (for which the transmitted power is maximized) in order to avoid non linear distortions. Single carrier modulations like TDM can operate closer to the saturation point and therefore may provide better spectral efficiency. The FEC mechanisms implemented in DVB-S are very similar to those of DVB-T and thus, DVB-S does not achieve a good performance in mobile scenarios.

DVB-S2 is a second generation standard designed as an evolution of DVB-S for the transmission of satellite services. It implements a new FEC scheme based on LDPC+BCH codes that achieve a better performance against noise and interference. However, DVB-S2 was also designed for fixed reception and does not incorporate time interleaving. Because of this, a protection mechanism in the link layer called LL-FEC (Link Layer FEC) has been standardized in order to improve mobile reception.

2.4. DVB-SH

DVB-SH (Satellite to Handheld) is the European standard for the provision of mobile TV services by means of a hybrid satellite and terrestrial network. The satellite component provides nationwide coverage while the terrestrial component reinforces the signal in urban scenarios. The terrestrial component operates exclusively with OFDM, but the satellite component can transmit either with OFDM or TDM. TDM modulation is better suited for satellite transmissions. The physical layer of DVB-SH is improved with respect to DVB-H by means of turbo codes and long time interleaving profiles, achieving a better performance in both fixed and mobile scenarios. It implements time slicing in order to allow power saving in the user terminals. In order to counteract the characteristic long fades of satellite reception, DVB-SH incorporates the possibility of long interleaving at the physical layer and at the link layer by means of MPE-iFEC (Multi Protocol Encapsulation inter burst FEC). Currently, there are two DVB-SH satellites in orbit covering Western Europe and the USA, which are being used to validate the performance of the DVB-SH satellite link. Commercial services are expected to start late 2010.

2.5. DVB-T2

DVB-T2 is the second generation European standard for the provision of digital terrestrial television. It is the most advanced DTT system. DVB-T2 was originally designed for the transmission of high definition TV (HDTV). It achieves up to 70% more capacity than DVB-T. Based on the same FEC scheme employed in DVB-S2, it implements a series of improvements such as a very flexible time interleaving or the use of rotated constellations. Because of this, DVB-T2 achieves a good performance in both fixed and mobile terrestrial scenarios. DVB-T2 can also provide per service QoS by means of PLPs (Physical Layer Pipes). This characteristic allows the accommodation of different user cases (fixed, portable or mobile) in the same frequency channel. MIMO techniques requiring more than one receive antenna are not implemented in DVB-T2 in order to maintain backwards compatibility with existent antenna installations. However, a MISO technique based on the Alamouti code is introduced in DVB-T2. Although time-frequency slicing is also included in DVB-T2, its usage is optional and will probably not be used extensively in commercial networks. The first commercial DVB-T2 transmissions started in UK in December 2009, and more countries are expected to follow during 2010.

2.6. DVB-NGH

DVB-NGH is the acronym received by the second generation mobile TV European standard. The standardization process of DVB-NGH started at the end of February 2010, and is currently under way. The standard is expected to be completed by the end of 2011. DVB-NGH will probably rely on MIMO technology (with several transmit and receive antennas) and time frequency slicing in order to further improve the performance of DVB-T2. It is expected that the video, audio or data net throughput will be maximized by decreasing the transmitted overhead in the form of packet headers and metadata. The extensive usage of SVC (Scalable Video Codec) is also expected to become an important addition. SCV allows the video to be transmitted as a base layer along with several enhancement layers that improve the frame rate, resolution or quality of the base layer. By means of SVC it is possible to improve the efficiency of the network and achieve graceful degradation.

iTEAM is a full member of the digital TV standardization forum DVB

iTEAM's DVB facilities include a complete end-to-end DVB-T/H/SH/T2 lab, and a DVB-T/H pilot at the main campus of UPV

3. iTEAM DVB facilities

3.1. DVB Lab

The iTEAM research institute has a complete end-to-end DVB-T/H/SH/T2 laboratory. The laboratory is mainly used to evaluate the performance of the different technologies. The most commonly used assemblies schemes are depicted in Figure 1.

The DVB encapsulation platform is the content provider of the information that is going to be transmitted. It consists of a stream writer device, together with the DVB encapsulator that is being developed by the iTEAM (Section 4.2), to generate the transport streams for the different DVB technologies. The generated DVB transport stream is then modulated and transmitted by the DVB-T/H/SH/T2 laboratory modulator by two possible transmission schemes.

The first transmission option makes use of a DVB-T/H modulator which generates IQ base-band signal that be connected with the channel emulator. This device is able to simulate different transmission channels in different reception conditions, providing a RF up converted signal. The second transmission option consists of a physical layer simulator developed by iTEAM (Section 4.3). This simulator generates by software "offline" (no real-time) DVB base-band signals, giving also the possibility to emulate the radiofrequency channel "offline". The generated IQ base-band signals are finally transmitted by an IQ Player available in the laboratory. This device acts as a frequency up-converter and transmits the baseband signals generated with a physical layer simulator in RF. The iTEAM has already developed a DVB-T/H/SH physical layer simulator, and is currently working on the DVB-T2 technology.

Finally, the RF signal is received, registered and processed by the DVB measurement system developed by the group (Section 4.1), which also extracts the transmitted information for its analysis or visualization. Furthermore, the measurement system can control all the devices that are part of the laboratory measurements, changing their configuration when needed, and bringing the possibility of completely automate the measuring process.

3.2. DVB Pilot

At the beginning of 2009, the iTEAM installed a DVB-T/H pilot at the main campus of the Universidad Politécnica de Valencia. The pilot basically consists of a DVB-T/H encapsulation platform and a professional transmitter with two sector antennas. The coverage map of the pilot and its basic scheme can be seen in Figure 2. The transmission frequency assigned to the pilot corresponds to the UHF Channel 36 (594 MHz).

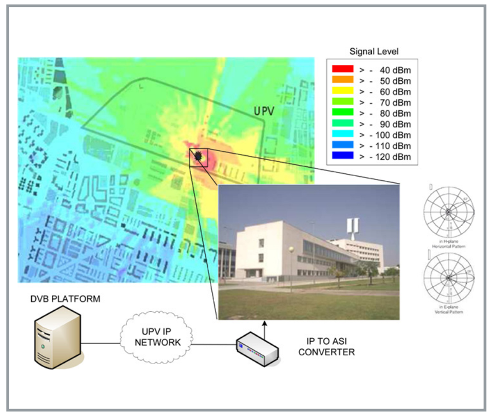

Figure 2. *Coverage and basic scheme of the DVB-T/H pilot.*

Nowadays, the MCG group exploits the pilot to take vehicular and pedestrian DVB-T/H field measures in the university area, employing the DVB measurement system described in Section 4.1. These measures permit to evaluate the performance of DVB-T/H technologies and the quality of service experienced by users. The iTEAM aims to evaluate new applications and services in the near future, including the possibility of transmitting DVB-T2 signals.

4. DVB development activities

4.1. DVB Measurement System

The iTEAM is developing a DVB measurement system to ease the real-time acquisition of measures process in a DVB network. The system can be employed form making field measurements or laboratory measurements for DVB-T/H/SH/T2 technologies. iTEAM is also developing an independent DVB-T/H measurement system installed on a PDA, to ease the acquisition of indoor measures.

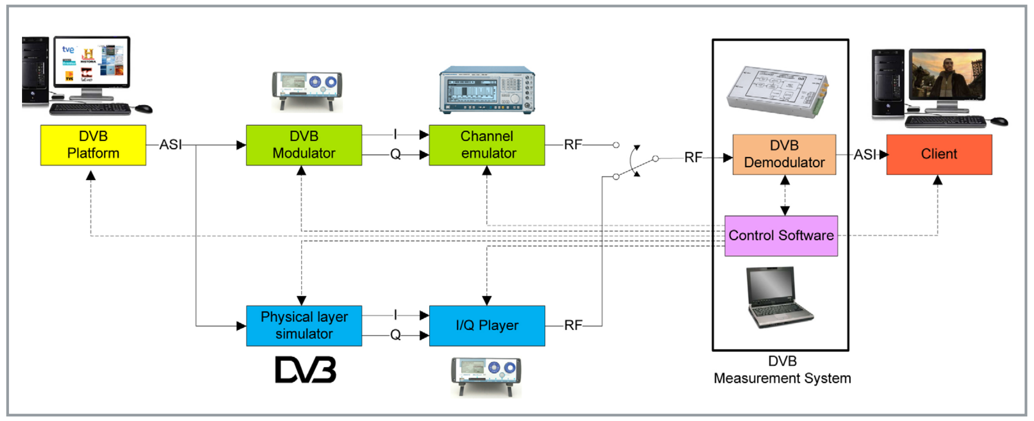

Figure 1. *Common assembly of the components of the DVB laboratory.*

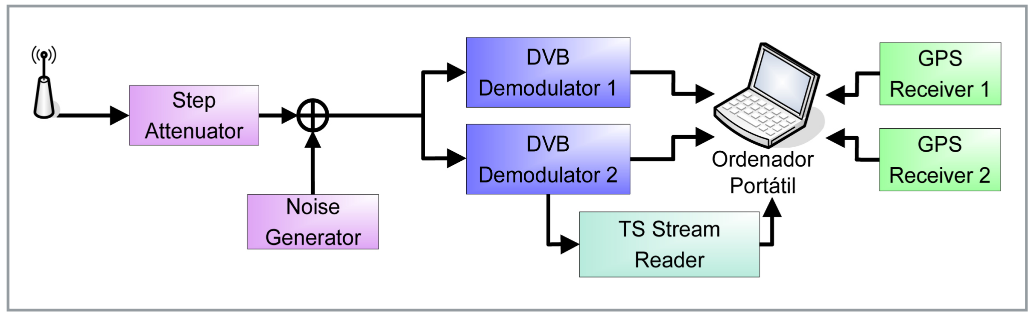

Figure 3. *Generic architecture of the DVB measurement system for making field measurements.*

The general architecture setting of the DVB measurement system for making field measurements is depicted in Figure 3. It consists of one or several DVB receivers which demodulate the received signal, and a GPS receiver. The transport stream adapter is employed to process the streams demodulated by the DVB demodulator, while the step attenuator and the noise generator are used to modify the detected CNR. The iTEAM DVB measurement system incorporates two professional DVB-T/H receivers, one professional DVB-SH receiver, and one professional DVB-T2 receiver.

When making laboratory measurements, the DVB signal demodulators are directly connected to the rest of the components of the DVB laboratory, as can be seen in Figure 1. The system is capable of controlling and automating the different devices that integrate the DVB laboratory: the DVB platform, the modulator, the I/Q player, the channel emulator and the physical channel simulator. It also simplifies the later processing of the stored information, including the option of generating coverage maps.

The system application software, installed in a laptop, reads all the physical layer information (RSSI, CNR, MER, etc) and the link layer information (FER, MFER, MiFER, etc.) provided by the DVB receivers. This information is then stored synchronously with the GPS speed and position data. When using the TS adapter, a vector with the reception state of each TS packet (correct / incorrect reception) is also stored together.

The main applications of the DVB measurement system are: coverage studies and calibration of the propagation models considered on a network, evaluation of quality of service experienced by users and optimization of the data transmission of these technologies. In addition to the iTEAM's DVB facilities, the measurement system has been successfully employed in DVB-T measurement campaigns in Valencia, and in the first DVB-SH laboratory and field trials organized in Spain in 2009 as part of the FURIA project.

4.2. DVB Encapsulation Platform

In a DVB system, the encapsulator is the responsible of generating the MPEG-2 transport stream by taking into account the information and multimedia data provided by the content servers. Basically this implies protocol adaptation, signalling, and FEC schemes at link and application layers.

iTEAM is cworking in the development of a multi-standard DVB encapsulator that could be used for different DVB standards. The encapsulator runs over a conventional PC station with GNU/Linux O.S. within a special Java Virtual Machine oriented to real time applications. The encapsulator already supports DVB-T/H/SH, and it is being extended to DVB-T2. In Figure 4, a block diagram of the encapsulator is depicted. The building blocks are described next.

The signalling block provides information to discover and locate services within the MPEG-2 streams.

The signalling block is divided into two blocks: the PSI/SI and the ESG blocks. The PSI/SI block deals with the signalling in terms of MPEG-2 services. The ESG block provides location information at IP level.

The encapsulation block encapsulates PDUs of the network level (IP datagrams) iteratively into PDU's of lower layers until the physical layer

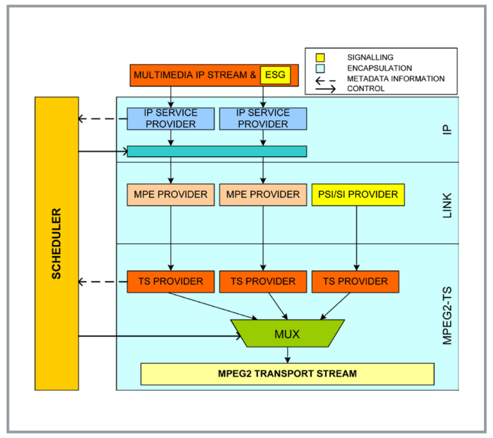

Figure 4. *DVB encapsulator block diagram.*

iTEAM participates in the main R&D projects on DVB at national (FURIA) and international (ENGINES) level

iTEAM is actively participating in the standardization process of the next generation mobile TV standard DVB-NGH

is reached. This generic block can be used for DVB-T, DVB-H and DVB-SH by instancing the corresponding PDUs. Within this block, there is the FEC block which is used to provide the MPE-FEC and MPE-iFEC protection schemes.

The scheduler block manages the encapsulation times of each service and the moments for their transmition to the MPEG-2 stream. It is the most critical for an efficient usage of the bandwidth. The encapsulator has been developed in Java, and runs over the special Java Real Time System virtual machine. The reasons for this are: integration with Java content server providers already developed in our group, and to accomplish time restrictions requirements of the standards taked into account.

4.3. DVB Physical Layer Simulation Platform

The multi-standard DVB physical layer simulation platform is an end-to-end transmission chain which simulates DVB technologies. The platform combines a set of hardware and software blocks which produce cost saving in comparison with a transmission chain form by only hardware equipment. The DVB physical layer simulation platform takes into account the physical layer signaling and the RF modulation of the simulated system as it can be seen in Figure 1. The simulation platform has been developed in Matlab for DVB-T/H/T2 and in C++ for DVB-SH.

Several studies can be carried out with the developed platform, for example at the first stages of DVB development technologies, where there are no receivers available, system performance can be analyzed. Other studies are comparison performance of different real receivers, coverage maps, performance evaluation of higher system layers and user experience evaluation amongst others. The encapsulation platform already supports DVB-T/H/SH, and the support of DVB-T2 is ongoing.

5. DVB Research Activities

5.1. Physical Layer Performance Modeling

Simulations are an essential tool in analysis of the performance of communication systems. With simulations different systems can be compared and the parameters of transmission systems or receiver algorithms can be tuned to maximize performance. The main issue of physical layer simulations is the computational inefficiency to simulate a large amount of bits. For that, the goal of this research activity is to provide practical and efficient error models that allow approximating the physical layer performance according to time-variant reception conditions as the received signal strength and receiver velocity.

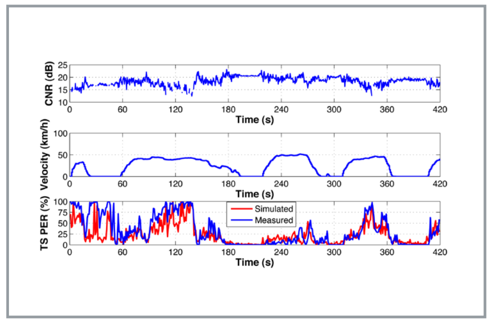

Figure 5. *DVB-H field measurement and corresponding simulation results. Transmission mode FFT 8K, GI 1/4, 16-QAM 1/2.*

The performance model developed at iTEAM uses a four-state aggregated Markov model to approximate the error behavior of receivers operating in varying reception conditions. To develop performance Markov models it is necessary to obtain using laboratory measurements or physical layer simulations statistics corresponding to a given transmission scenario. The advantage to use laboratory measurements is that the performance predicted is the hardware receiver performance. Once error traces at the physical layer are obtained it is possible to reproduce the quality experienced by the measuring terminals for any type of service emulating the upper layers in software (time-slicing, FEC mechanisms and protocol decapsulation).

As an example, Figure 5 shows validation results (in terms of MPEG-2 TS packet error rate) obtained by comparing simulations using performance models developed at iTEAM with field measurements for DVB-H with 16-QAM modulation mode, 1/4 OFDM guard interval length, 8K FFT length, and 1/2 physical layer convolutional code rate performed at DVB pilot of the Universidad Politécnica de Valencia (Section 3.2). It is illustrated the good fitting between the measured and simulated packet error rates.

5.2. DVB Platform Research Lines

In addition to the basic functionalities, there are some advanced features that the encapsulator can perform in order to optimize the usage bandwidth, the protection, etc. These are current research topics covered in these concrete lines: transmission with statistical multiplexing, Scalable Video Coding (SVC) with hierarchical modulation, and zapping time analysis.

Statistical multiplexing is thought to exploit the bandwidth available and improve encoding schemes by taking advantage of the variability of video rate.

Scalable Video Coding joint with hierarchical modulation: drawing that in scalable video coding there is a critical base layer referenced for other quality extender layers; it is preferable to protect more robustly this base layer than the

others. One way to do it is by using hierarchical modulation to transmit the different video layer streams.

Zapping time: the zapping time between channels becomes critical for QoE when using MPE-iFEC with high interleaving depth, which is frequent in DVB-SH. With the encapsulator we can study the impact of this zapping time in the user experience, and test several techniques to smooth it.

5.3. Upper Layer FEC & Cross-Layer Optimization

Physical layer FEC mechanisms are commonly designed to counteract the degradation caused by noise and interference. In every instant they ensure a quasi error free reception as long as the received signal strength is above a certain threshold. However, mobile reception is characterized by slow and fast fluctuations of the received signal strength over time (known as shadowing and fast fading respectively). In order to repair the errors cause by shadowing and fast fading it is necessary to incorporate interleaving mechanisms along with FEC protection. Interleavers perform an averaging of the received signal strength over a period of time referred to as interleaving depth. However, the implementation of long time interleaving at the physical layer involves an increase in the memory requirements, which has an important impact in the hardware complexity and cost of user terminals. On the contrary, the implementation of long time interleaving at upper layers allows the provision of extended interleaving depths with significantly lower hardware requirements. Moreover, upper layer FEC mechanisms can use the general purpose memory of the user terminals for interleaving purposes. Because of this, it is possible to implement long time interleaving at upper layers without the need of additional hardware.

Several upper layer FEC mechanisms have been standardized inside the DVB at the link or application layer, including MPE-FEC, MPE-iFEC, LL-FEC, and AL-FEC. The MCG has been researching upper layer FEC since its incorporation in DVB-H. The main focus of these activities is the performance evaluation of upper layer FEC in the presence of shadowing and fast fading by means of field measurements and dynamic system-level simulations. Another important topic is the cross layer optimization of physical and link layer FEC in order to provide the best protection with the minimum hardware complexity and latency issues.

5.4. Quality of Experience Estimation for Mobile TV Services

In the particular case of video streaming services, the quality of service (QoS) has an important subjective factor. The quality experienced by the users is determinate by a lot of factors, from the physical layer with the errors, to the video decoder with its behaviour in the presence of errors, namely error concealment. In order to study this impact on the users, iTEAM have developed some assistance applications.

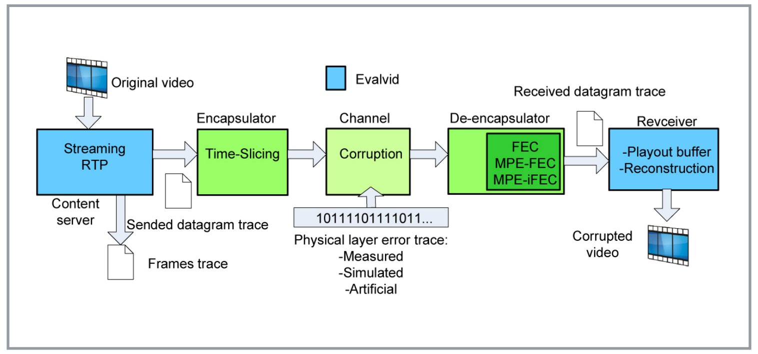

Figure 6. *"Display" block diagram.*

To emulate the quality of a video streaming service, iTEAM has developed a tool called "display", which creates corrupted videos with the same visualization errors as if the original video had been transmitted in a real DVB scenario, and received by a real terminal. These resultant videos are later presented to the users through a web application, in which their opinion is stored in a database for a future study. The "display" parts from a physical layer error pattern to propagate its errors until the video itself. To do it properly, it uses the arrival time of the IP datagrams, their size, the maximum size of the time-sliced bursts, and the cycle time, to emulate its streaming through the network with the objective to determine which MPEG-2 packets of the error pattern affect each datagram. Furthermore, it also can emulate the performance of the FEC mechanisms: MPE-FEC and MPE-iFEC, and provide some objective QoS measurements like PSNR and others belonging to lower layers. The "display" follows architecture similar to a real DVB-H/SH system, which is depicted in Figure 6. Notice that we have used the framework for the quality evaluation of a video streamed through a packet network, named "EVALVID", to deal with the issues above the IP layer.

These tools are being used to study how some issues impacts the quality experienced by the users, and experiment with new techniques in order to relax the needed reception conditions. For example, one aspect of interest is the determination of the biggest amount of errors acceptable for each typical error pattern over time. Another one is the preliminary study of different smooth zapping time techniques, before a final implementation in the DVB platform.

6. References

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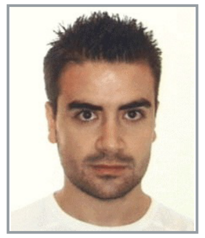
7. Biographies

David Gómez-Barquero is currently a post-doc guest researcher at the Fraunhofer HHI research institute of Berlin, Germany. He received a double M.Sc. degree in Telecommunications engineering from the Universidad Politécnica de Valencia (UPV), Spain, and the University of Gavle, Sweden, in 2004; and a Ph.D. in Telecommunications from UPV in 2009. During his doctoral studies he was a guest researcher at the Royal Institute of Technology, Sweden, the University of Turku, Finland, and the University of Braunschweig, Germany. He also did an internship at Ericsson Eurolab, Aachen, Germany. His main research interests are in the area of mobile multimedia broadcasting, in particular radio resource management, forward error correction, and network planning issues in DVB and MBMS systems. Currently, he is the chairman of the special interest group on hybrid cellular and broadcasting networks in the COST2100 action, and he is actively participating in the standardization process of the next generation mobile broadcasting DVB-NGH standard.

David Gozálvez received his M.S. degree in electrical engineering from the Universidad Politécnica de Valencia (UPV) in 2007. He was the recipient of the Cátedra Telefónica prize for his Master Thesis in the same year. Currently he holds a PhD student Grant from the Spanish Government to research on transmission optimization of DVB broadcasting systems. In 2008 he undertook an internship in NOMOR research (Munich, Germany) and in 2009 he was a guest researcher in the University of Turku. He has collaborated in the FURIA project investigating the utilization of upper layer FEC mechanisms in DVB-H and DVB-SH broadcasting systems. He collaborated with Qualcomm for the development of a DVB-T prototype receiver optimized for mobile environments. David Gozálvez is an active participant in the standardization process of DVB-NGH inside the CCI (Constellation, coding and interleaving) and MIMO working groups.

Pablo Olivas received his M.Sc. degree in telecommunications from the Universidad Politécnica de Valencia (UPV) in 2008. His final thesis was awarded by the Official College of Telecommunication Engineering. During 2008 and 2009 he worked as a R&D Engineer in the Mobile Communications Group (MCG) of the Telecommunications and Multimedia Applications Institute (iTEAM) In Valencia (Spain). In this period, he collaborated in the FURIA project in the designing and development of DVB measurements systems. He currently works in the Institute for Communications Technology (IfN) of TU Braunschweig (Germany).

Fernando Camaró Nogués received his M.Sc. degree in telecommunications from the Universidad Politécnica de Valencia (UPV) in 2008. From 2008, he has been working as a R&D Engineer in the Mobile Communications Group (MCG) of the Telecommunications and Multimedia Applications Institute (iTEAM) in Valencia (Spain). During this period, he has actively participated in the spanish FURIA project in QoE topics related to video streaming services. His interests and activities focus on DVB encapsulation platform architectures, QoE and QoS related topics for video streaming services, and scalable video codecs utilization in broadcast systems.



Pedro Fernando Gómez Molina studied Telecommunications Engineering and received the M.Sc. Degree from the Universidad Politécnica de Valencia (UPV), Spain, in 2008.

His M.Sc. thesis was award-ed by the Cátedra TECATEL prize of UPV and the COIT prize of the Official College of Telecommunications Engineers of Spain. He joined the Institute of Telecommunications and Multimedia Applications (iTEAM) in February 2008 and is currently working as an R&D engineer at the Mo-bile Communications Group in UPV. Actually, his research focuses on physical layer modelling in DVB systems. He collaborates with other companies in the study and research of DVB technologies. As a fruit of this collaboration, he participates in several R&D projects. Can be noted his participation in the FURIA (FUtura Red Integrada Audiovisual) project where he developed a DVB-H/SH system level simulator.

Jordi Puig Bou was born in Castellón, Spain, on March 16, 1985. He received his M.Sc. degree in Telecommunications engineering from the Universidad Politécnica de Valencia (UPV), Spain, in 2009. He is currently working as an R&D engineer at the Mobile Communications Group in UPV. His research focuses on the study of statistical multiplexing techniques in the new second generation broadcasting standards, DVB-T2 and DVB-NGH.

Narcís Cardona
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