On the implementation of a Laboratory of Digital Television according to the ISDB-Tb standard

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ABSTRACT

This paper summarizes the implementation process of the Digital Television (DTV) Laboratory of the University of Cuenca according to the open television broadcasting ISDB-Tb standard, adopted by Ecuador in 2010. The Laboratory arises as a research and testing environment for Digital Television DTV signal transmission and interactive applications. The goal of this article is to document the aspects that have been considered to simulate a real DTV scenario where: a Transport Stream (TS) is first generated, then transmitted through the communication channel and finally, received in televisions using an ISDB-Tb receiver. The TS is formed by combining DTV audiovisual content and interactive applications. Therefore, it facilitates the development and testing of new services and allows taking full advantage of the characteristics of the new DTV adopted format.

Keywords: Terrestrial digital television, digital television laboratory, Ginga-NCL, interactive applications, user behavior registering, ISDB-Tb, applications server, Electronic Program Guides.

RESUMEN

Este artículo resume el proceso de implementación del Laboratorio de Televisión Digital (DTV) de la Universidad de Cuenca, que surge como un entorno confiable de experimentación e investigación que hace uso de las características asociadas al estándar ISDB-Tb adoptado por Ecuador en el año 2010 para la transmisión de señales de televisión abierta. El objetivo de este artículo es documentar los aspectos que se han considerado para simular un escenario real en el que un Transport Stream (TS) formado por contenido audiovisual y aplicaciones interactivas, primero se genera, para luego transmitirse a través del canal de comunicaciones, y finalmente ser recibido en una televisión con receptor ISDB-Tb. Así, se facilita el desarrollo y la experimentación de nuevos servicios aprovechando el nuevo formato de DTV.

Palabras clave: Televisión digital terrestre, laboratorio de televisión digital, Ginga-NCL, aplicaciones interactivas, registro de actividad del usuario, ISDB-Tb, servidor de aplicaciones, guía de programación electrónica.

1. INTRODUCTION

As one of the most important means of communication invented in the twentieth century, television arose as a novel and different technology that was quickly adopted by people. The use of television became very popular, changing people habits and becoming part of human culture. This device is present practically in every home all over the world. Nowadays, even in the Era of Internet, television still stands as the first source of information and entertainment, which is not surprising since traditionally open TV signals can be received for free.

Following the global trend seen in recent years, about switching television broadcasting technology from analog standards to digital ones, Ecuador as many other countries in the region, adopted in 2010 (Supertel, 2010) the *ISDBT-Tb*[1] standard (DiBEG, 2007): *Integrated Services Digital Broadcasting, Terrestrial, Brazilian version*, also known as SBTVD or *Brazilian Digital Television System* (Sistema Brasileiro de Televisão Digital) (ABNT, 2007). New digital television standards incorporate significant improvements over the classic analog signal, for example, related to image and sound quality, as well as the possibility of the inclusion of interactive applications that will let Digital Television Users (*DTV* Users) to enjoy the TV watching experience as never before. Interactivity includes education services, shopping, e-commerce, contests, weather services, electronic voting, electronic program guide, etc. (Alulema, 2012). Moreover, the electromagnetic spectrum is exploited in a better way, as pointed out by Nakahara et al in (Nakahara *et al.*, 1996) since the adoption of the *ISDB-Tb* standard facilitates an increase of the number of broadcasting channels and supporting reception during mobility. Also, the bandwidth assigned to current TV stations (6 Mhz in the case of Ecuador) will let them to broadcast simultaneously multiple programs and services.

In Ecuador, the analogue switch-off process will be performed in three stages given at specific dates: i) by the end of 2016 for the Metropolitan Districts of Quito and Guayaquil; ii) by the end of 2017 for cities with more than two hundred thousand inhabitants; and finally, iii) by December 31 of 2018 for the rest of the country. This transition process implies challenges that society will have to overcome, and an opportunity for universities for doing research focused on exploiting all the advantages associated to the use of this new technology in the development of new knowledge. Currently, public and private TV stations are already working on the transition stage, while some are already broadcasting in the new format. In its efforts to contribute and to be part of this change, the University of Cuenca (Universidad de Cuenca) started supporting research work regarding Digital Television transmission technologies and the development of interactive applications through the creation of the *Digital Television and Web Semantic Research Group*.

The following sections describe the requirements, equipment and goals considered for the implementation. Section 2 presents the general description and requirements of the laboratory by considering the current situation of the *DTV* in the country. In Section 3, the laboratory architecture is analyzed in detail by describing the hardware and software products employed at each stage and how they interact. Section 4 presents the results as to the current state of the laboratory implementation. Finally, Section 5 presents the conclusions obtained from the development of this work, pointing out the future features that will be incorporated to the laboratory.

2. LABORATORY DESCRIPTION

This project aims to implement a *DTV* broadcasting infrastructure that allows signal propagation testing and that facilitates interactive applications development. There are three important contributions of this work: i) the generation, transmission and reception of *DTV* signals according to the *ISDB-Tb* standard, which stand as the main goal of this implementation; ii) the development of an application for *DTV* user activity logging and, iii) the implementation of an application server. The additional specific functions that have been defined out of the scope of signal transmission are aimed to expand the functionality of the laboratory.

For the transmission stage (i), the broadcasting signal is generated from pre-recorded audiovisual content which is coded and packaged in addition to interactive applications and electronic program guide information. Moreover, transmission parameters such as modulation type, throughput, power, frequency and bandwidth can be monitored and tuned. To test interactivity, a return channel has been

[1] http://www.dibeg.org/

enabled for user information retrieval. This scenario simulates a real environment on which it is possible to perform several experiments and tests. Since the laboratory fulfills the current government regulation, the *ISDB-Tb* standard is used. The technical features of the ISDB Tb standard are briefly presented in Section 2.1.

The user activity logging application (ii) has been created to record the *DTV* user's behavior and watching television habits. This information could be analyzed and used in the domain of the generation of personalized audiovisual content, for example through the use of recommender systems, such the one documented in Avila *et al.* (2014) and Saquicela *et al*, (2013). Recommender systems could make use of semantic information obtained from both the analysis of the user profile, as described in Espinoza-Mejía *et al.* (2014) and from electronic programming guides enriched with external resources such as the one documented in Saquicela *et al.* (2013) to fully exploit the advantages of *DTV*, therefore, the need for a user's activity capturing platform. The development of DTV applications requires the use of a software layer or *Middleware* between the application code and the run-time infrastructure, as described in De Mello Brandao *et al.* (2010) that in the case of the *ISDB-Tb* standard corresponds to Ginga-NCL[2] and Lua scripting.

To store the information related to the *DTV* applications and users' activity, a server is incorporated to the laboratory infrastructure (iii) so that, other systems could be able to access to it by simple querying a MySQL database.

2.1. ISDB-Tb standard main features

The "Integrated Services Digital Broadcasting Terrestrial, Brazilian version" (ISDB-Tb) is a digital television standard, which is adapted from *ISDB-T* (Japanese standard) to the needs established by Brazil. It is also known as *Sistema Nipo-Brasileño de Television Digital Terrestre (SBTVD*). This standard supports: high definition television (*HDTV*), standard definition (*SDTV*), simultaneous digital transmission for reception of fixed and mobile devices, and finally interactivity (Supertel, 2010).

The main differences between the Japanese standard and the Brazilian are: i) the use of *H.264/MPEG-4 AVC* as a video compression standard whereas the *ISDB-T* uses *H.262/MPEG- 2*; ii) the use of 30 frames per second for mobile device reception instead of the 15 used by the Japanese standard; and iii) the incorporation of Ginga NCL as a powerful middleware that is used for interactive application development.

The audio compression and coding scheme denotes the use of two possible options: first a Multi Channel 5.1 transmission *using MPEG-4 AAC@L4 –Advanced Audio Coding*, Level 4 or *MPEG-4 HE-AAC v1@L4 -High Efficiency AAC*, Version 1, Level 4; and second: a Stereo transmission with the *MPEG-4 AAC@L2 -AAC* Level 2 or *MPEG-4 HE-AAC v1@L2 -HE-AAC*, Version 1, Level 2. For portable service, the *MPEG-4 HE-AAC v2@L2* is used, as described in (Técnicas, 2008).

ISDB-Tb makes use of a Transport Stream (TS), as a transport protocol that supports data, audio and video simultaneous transmission. This standard supports multiple versions of the same program or even multiple programs that can be transmitted using the same bandwidth that the one used for analogue television. For example, we think about a scenario where a TV user might be watching a sports game and being able to switch to different points of view belonging to several cameras. Among the main features of the TS, synchronization and multiplexing are the most important. Deeper analysis of these features can be found in (DiBEG, 2007).

The *ISDB-Tb* standards employ a *BST-OFDM* (Band Segmented Transmission- Orthogonal Frequency Division Multiplexing) modulation, in the *VHF* or *UHF* frequency band, according to the current national regulation of each country.

2.2. Specific laboratory functions and requirements

EiTV suggest in (EiTV, 2014) a complete platform for a Laboratory of Digital Television for production, transmission and reception of interactive services, shown in Fig. 1, which has been considered as a reference for this implementation: this figure shows four basic building blocks which

[2] http://www.gingancl.org.br/en

have been adapted in this project to perform specific functions and requirements defined as part of the laboratory services. Some of these functions and requirements may be shared by more than one block and are described as follows:

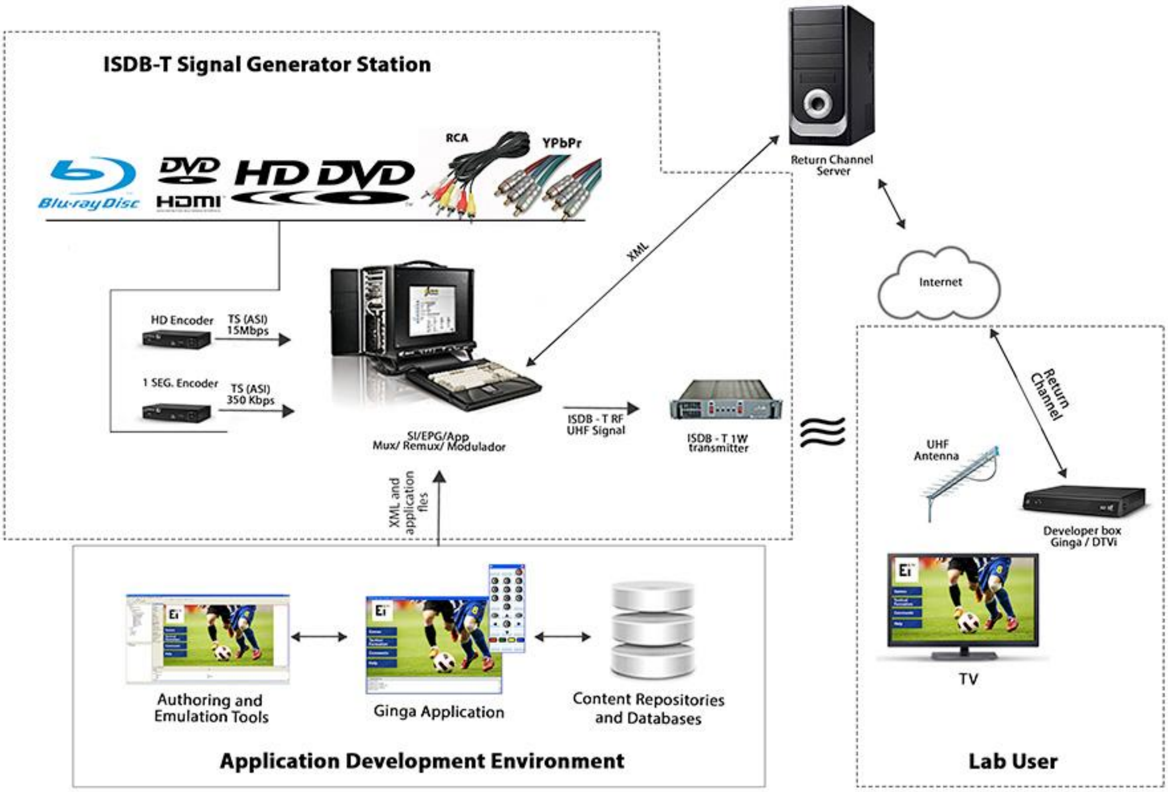

Figure 1. Laboratory Architecture ISDB-Tb suggested by EiTV (2014).

- *Interactive digital TV generator station*: Named as *ISDB-T Signal Generator Station*; this block deals with the generation and transmission of audiovisual content and applications, including:
  - Audiovisual content and Ginga applications multiplexing.
  - Audiovisual content and data: coding and multiplexing.
  - Audiovisual content, data and Ginga applications transmission and synchronization under the *ISDB-Tb* standard.
  - Radio-frequency signals amplification for wide area broadcasting.
- *Interactive Services Provider or Return Channel Server:*
  - An interactive application and information storing resource manager.
  - Access to a return channel through *LAN* or *WAN* network.
  - Access to a database and interactive external services.
- *Applications Development Environment:* In addition to the functions of before mentioned block it has:
  - Ginga-NCL development environment.
  - Set-top-box (*STB*) emulation tools.
- *User Lab or User Environment:*
  - Audiovisual content, data and Ginga applications reception under the ISDB-Tb standard.
  - Access to a return channel through a *LAN* or *WAN* networks.
  - Access to a database and interactive external services.

3. LABORATORY DESCRIPTION

Figure 2 shows the architecture implemented for the laboratory, which has been designed following the recommendations presented in Cochancela & Gutiérrez (2013) and Alencar (2009).

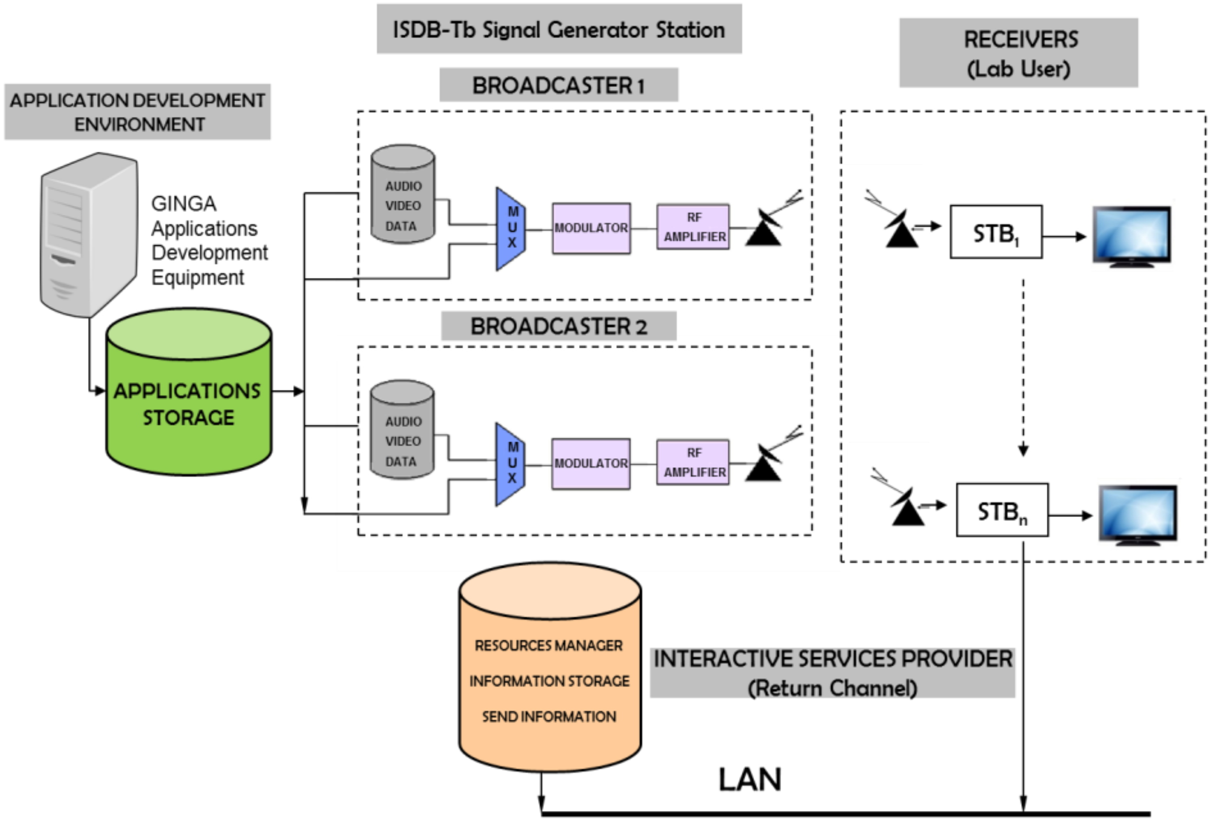

Figure 2. Implemented Laboratory Architecture ISDB-Tb: (Medina & Villa, 2014).

The Laboratory architecture includes at least two independent Broadcasters, so that, user activity related to TV channel switching can be registered. Moreover, to facilitate the interoperability between different web services, a server is also incorporated to the architecture. Finally, two distinct TV receivers represent correspondingly, the possible scenarios of a regular TV user: one watching a modern high definition *LCD TV* with an embedded *ISDB-Tb* compatible tuner and, another user watching a classic standard definition *CRT TV* with an *ISDB-Tb* compatible *STB* receiver/converter attached to it. It can be noted that the Return Channel block holds communication only with the Lab User block, since no operations related to the Broadcasters have been planned up to this point of the implementation. The following subsections describe each block.

3.1. Interactive digital TV generator station

As mentioned in Section 2, the *DTV* signals generated at this point are formed by pre-recorded audiovisual content which is processed before transmission along with other data or applications to form the Transport Stream (*TS*). The open source software application OpenCaster[3] that works under the Linux OS has been used for managing functions such as content serving, Electronic Program Guide *EPG* generation, multiplexing and synchronization. Figure 3 shows the architecture of this block, also identified as *The Broadcaster*.

[3] http://www.avalpa.com/the-key-values/15-free-software/33-opencaster

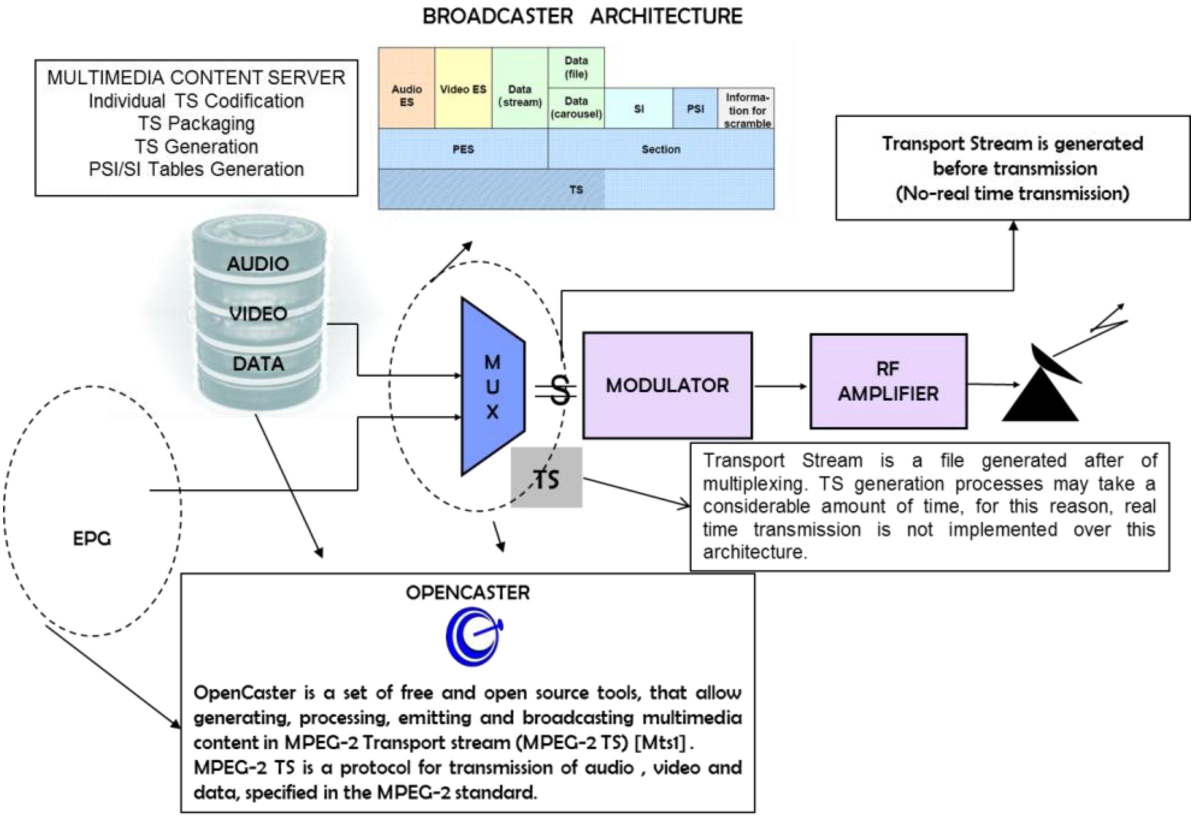

Figure 3. Broadcaster Architecture (Medina & Villa, 2014).

Since the *TS* is generated before transmission, it should be mentioned that at this point, it is not possible to modify the TS on real time due to the use of platforms based on different Operating Systems (Linux and Windows) for coding and broadcasting. Therefore, the need for processing and generating new *TS* in case of a new transmission is required. The *TS* is generated in a computer able to run the following applications:

- OpenCaster: for audiovisual content, data and *EPG* codification.
- Ffmpeg: A set of tools for audio and video converting.
- Python interpreter: For coding *PSI/S*[4]*I* tables.
- VLC Media Player: User for transport flow testing tasks.

Figure 4 shows how the broadcasting process is currently performed and the needed equipment. Once the TS is created in one computer, a second computer running the Windows OS, makes use of the *StreamXpress*[5] application which communicates via the USB port with a *DTU-215* modulator interface card which generates the RF signal from the content stored in a high capacity external hard drive attached to the computer. This application allows monitoring of the *PSI/SI* tables coded in the *TS*, as well as managing transmission parameters such as: output power, modulation type, frequency, bandwidth, etc. Additionally a 36 dB signal booster has been included before the antenna input to expand the system coverage area. Each Broadcaster shares the same configuration described in this section.

[4] PSI: Program Specific Information / SI: Service Information.
[5] www.dektec.com/products/Apps/DTC-300/

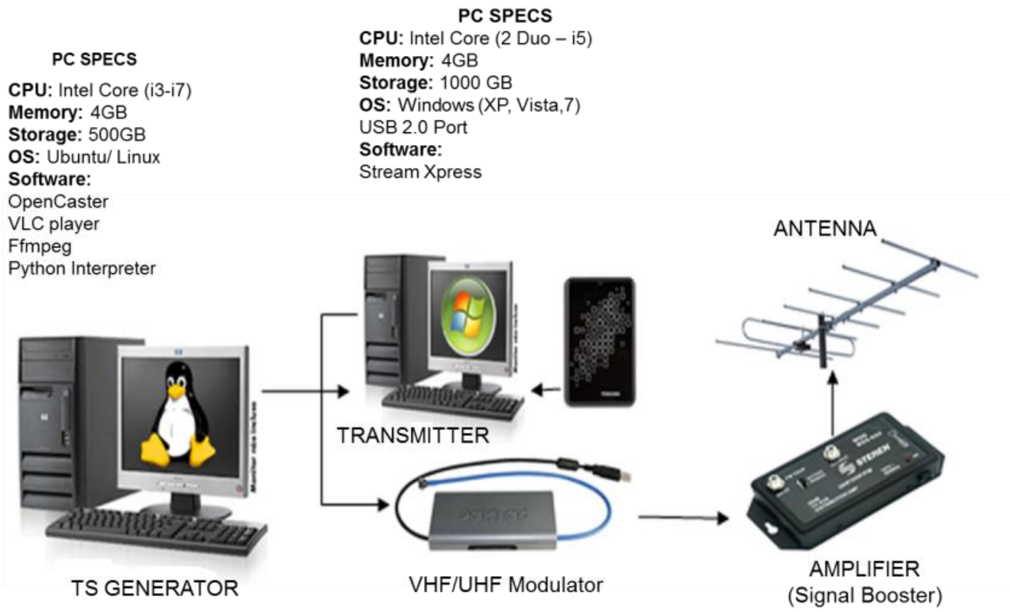

Figure 4. Broadcasting Process (Medina & Villa 2014).

3.2. Applications development environment

This module holds the tools needed for Ginga applications development and storage. Also, it contains software components that allow to simulate applications and to support for accessing the Return Channel through a simple *LAN* Router. The following list details the software components required for this module:

- Eclipse: use for Ginga-NCL applications development and emulator interfacing.
- Lua: allows Lua scripting within applications.
- Virtual STB: used for emulating Ginga-NCL applications.

Figure 5 shows the implementation of this part of the laboratory.

Figure 5. Broadcasting Process (Medina & Villa 2014).

3.3. User Lab: user environment

Figure 6 shows a graphic representation of the two receivers implementation. As previously described, there are two televisions one with an embedded *ISDB-Tb* tuner and another that makes use of a *STB* to decode the *DTV* signal. The *STB* includes an Ethernet port that is connected through a *LAN* router to the Interactive Services Provider (Return Channel), to enable interactivity testing.

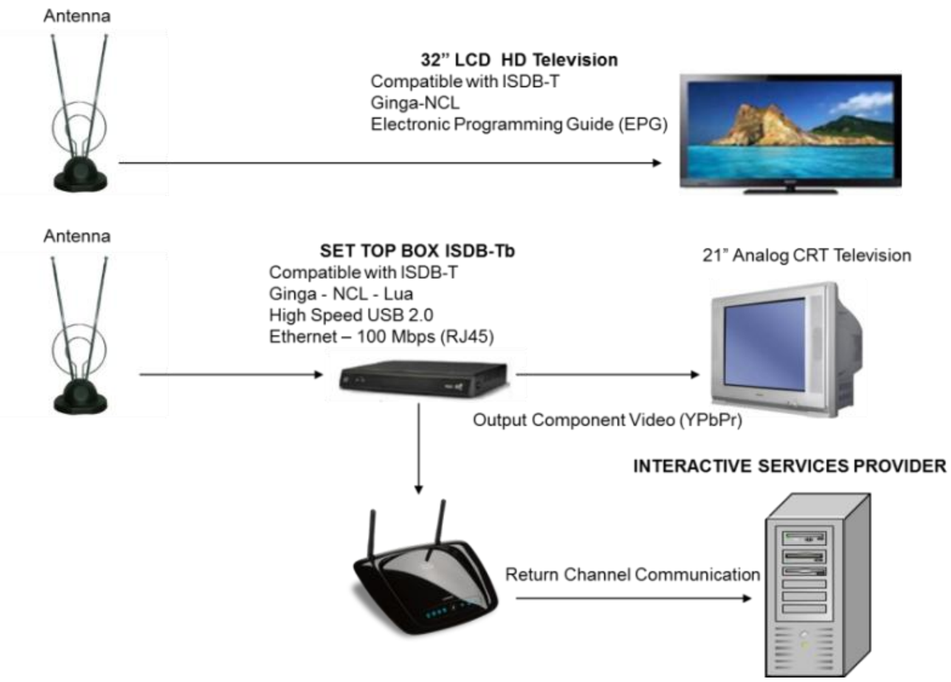

Figure 6. Receivers Implementation (Medina and Villa 2014).

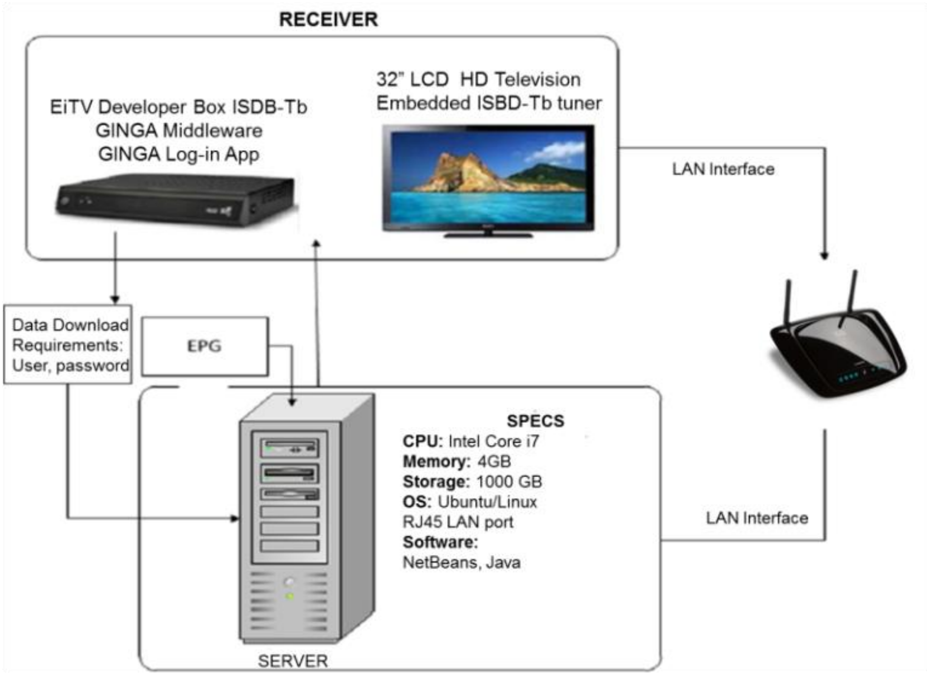

Figure 7. Interactive Services Provider Implementation (Medina & Villa 2014).

3.4. Interactive services provider: Return channel server

This module facilitates data managing and storing for applications running on the *STB*. Figure 7 shows its implementation.

3.5. PSI/SI tables generation

Along with audiovisual content, additional information has to be coded related to signaling in forming the *TS*. Services such as the EPG or interactive applications can make use of information tables that are employed by receivers for decoding operations. In Técnicas (2008) two types of tables are described, which are briefly presented as follows:

- *PSI Tables: Program Specific Information:* which are related to the audiovisual content *Elementary Streams* - *ES* that are multiplexed and transported by the transmission channel so that, they could be synchronously de-multiplexed.
- *SI Tables: Service Information:* which contain information related to the *EPG*, service events and available services. SI Tables might be used for teletext transmission in commercial or informative applications. Transmitted metadata can be used for *Catastrophe Early Warning Systems* and temporal rating measuring tasks. The information that can be recorded in these tables has been used in this implementation for the user activity capture.

3.6. Transport stream generation

Once that the Laboratory Infrastructure has been defined, this section presents the process of generating a Transport Stream formed by multiplexed information related to audio, video, data, *EPG* and interactive applications to be propagated by the RF signal, such as the process described in Villamarin *et al*. (2013), which must be coded in such a way that it could be easily decoded at receivers. Figure 8 shows the coding process where three different parts can be differentiated:

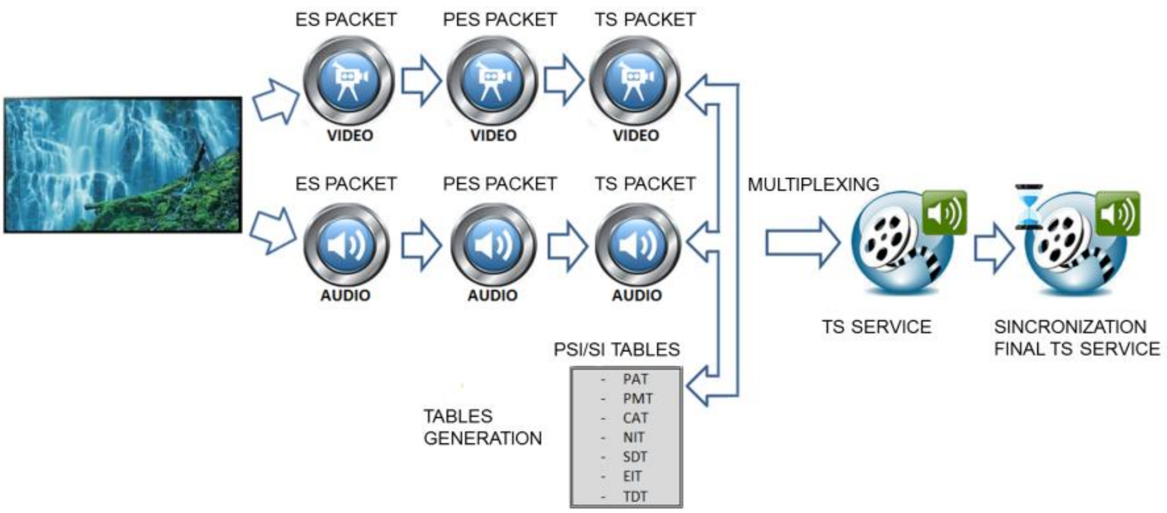

Figure 8. Transport stream generation (Medina & Villa 2014).

Each one of these parts is coded independently in a specific sequence, which are then multiplexed before transmission:

- *Video Coding:* formed by three stages: i) Elementary Stream extraction, where video is separated from a multimedia file, ii) element packaging where ES are encapsulated to create a video buffer of a given size, and iii) video TS forming from packets. Parameters such as identifier, resolution, throughput, quality and bandwidth are added to the content in this stage as well.

– *Audio Coding***:** it follows a process very similar to video coding, however, audio buffer size is determined by the *MPEG2*[6] standard, and must be associated to the video they belong to through PSI tables. Parameters such as sampling rate, bandwidth, output audio channels and video synchronization are present as expected.
– *Data*: EPG and Interactive Applications coding: Tables PSI/SI must contain all the information related to the DTV Service to be transmitted.

Once the different parts of the TS are complete, they are multiplexed to create *TS* than must be transmitted at 29958294 bps. In case this throughput cannot be reached by the input content multimedia characteristics, dummy data is introduced to the *TS* for synchronization purposes.

3.7. Implementation challenges

During the Laboratory infrastructure implementation, several challenges had to be faced. The following paragraphs describe the tasks involved in overcoming these challenges and the tools that were used for each one.

The first challenge to overcome was the definition of architecture for the laboratory and its components. We started from the architecture suggested by EiTV (2014), then, after a deep analysis, switched to the architecture shown in Fig. 9 which is very similar to the EiTV one, but shows explicitly the application server integrated with the rest of the infrastructure.

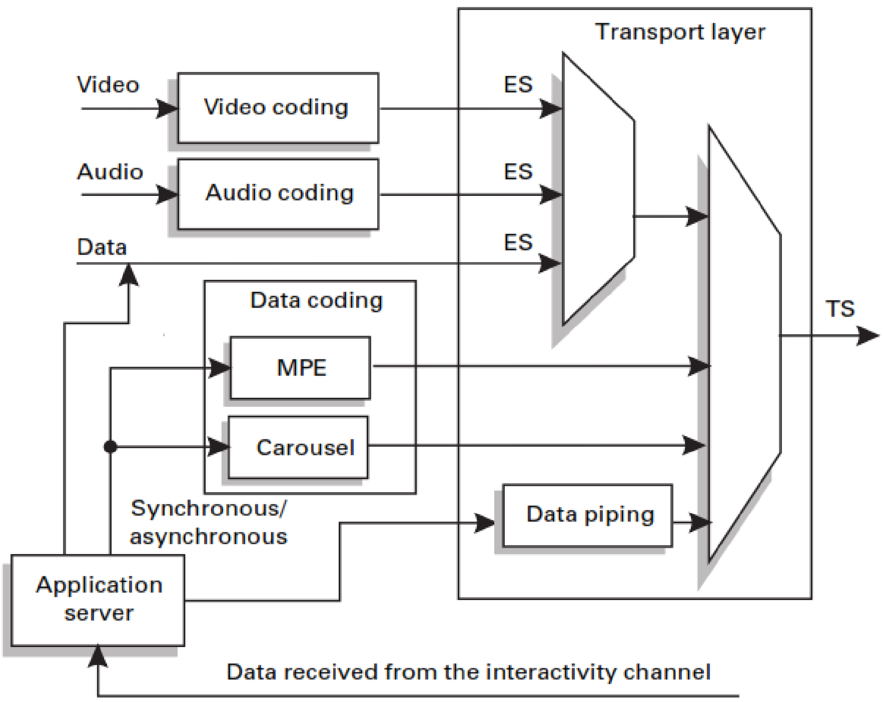

Figure 9. Flow diagram of the data coding, transport layer and interactivity channel (EiTV, 2014).

The architecture and its components could be summarized as follows:
– Multimedia repository
– Transport stream generation
– RF signal generation
– RF signal radiation
– DTV signal reception
– Applications Server

6 www.abdn.ac.uk/erg/research/future-net/digital-video/mpeg2.html

Once an architecture model was chosen, the next step was to define the broadcaster and system components.

As mentioned before, *OpenCaster* executes functions required for the Transport Stream generation; however, it does not allow real time transmission. Moreover, the radio frequency (RF) signal generation is performed by the DTU-215 unit, which was chosen as a well-known and fully tested option in order to speed up the implementation process. The Applications Server implementation, on the other hand, had to be completely defined and developed by the team, since there is not so much available information related to it in the literature. Therefore, the laboratory implementation itself became a challenge due to the lack of documentation of some of its main components.

On implementing the laboratory, there were three tasks that required most the team's attention: i) to learn and be able to generate the TS; ii) to program interactive applications using the Ginga language for testing purposes; and iii) to develop the applications server. The transport stream generation constitutes a process that could be done by following the OpenCaster documentation and some examples found in similar works, such as Villamarin *et al.* (2013). The team learned how to program using the Ginga middleware. The application server was setup as a web server.

As mentioned in Section 3.1, OpenCaster is used for audiovisual content data and EPG codification; however it was originally aimed for the DVB-T[7] standard, deployed mainly in Europe, Africa and Australia. In order to enable the use of OpenCaster for the ISDB-T standard, TeleMidia[8] (Laboratory at the Computer Science Department of Pontifical Catholic University of Rio de Janeiro) developed a freely available patch that was used for this implementation, along with FFmpeg[9], an open source software package that allows MPEG2 audio and video content codification, which was the coding format chosen for testing the developed environment. Nonetheless, the ISDB-T standard supports the use of MPEG4 as well (MPEG-4 AVC /H.264).

On the other hand, although simulation tools have been proven to be very useful for application development, they do not support many of the features a real STB does, which could be noticed for instance, by finding some compatibility problems when making use of the *Information Services* Library. This library is related to the EPG and Broadcaster services and timing data. Moreover, our experience shows that even built in compatible ISDB-T receivers, as the one incorporated in the HDTV LCD TV[10] used for the test, may present some problems during interactive application execution due to the lack of or insufficient Lua libraries. An additional problem to overcome is the real time codification and transport stream generation. As pointed out in Section 3.1, the current laboratory implementation does not support real time broadcasting, so, further research and work must be done in order to reach this goal, as indicated in Section 5.

4. RESULTS

As a result of the implementation of the laboratory, Fig. 10 shows the successful transmission of audiovisual content through channel 8.2, which we have called *Universidad de Cuenca*. Channel Information, such as the name of the multimedia file broadcasted is also shown so that, demonstrating the usefulness of the system.

Additionally an interactive application developed for user activity logging has been successfully transmitted through the *RF DTV* signal, as shown in Fig. 11 which presents the application interface for user authentication.

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[7] www.dvb.org
[8] www.telemidia.puc-rio.br/
[9] www.ffmpeg.org
[10] esupport.sony.com/LA/p/model-home.pl?mdl=KDL32BX359

Figure 10. A Digital TV signal received in an LCD TV (Medina & Villa, 2014).

Figure 11. An interactive application received in an LCD TV (Medina & Villa, 2014).

5. CONCLUSIONS AND FUTURE WORK

This paper summarizes the implementation of a Laboratory of Digital Television under the *ISDB-Tb* standard at the University of Cuenca. This implementation response to the need for a reliable and complete testing environment for research purposes in the fields of digital television signal broadcasting and the development of interactive applications that exploit the advantages incorporated by the adoption of the ISDB-Tb standard in Ecuador.

The Laboratory Infrastructure presented in this article demonstrates that it is possible to recreate a real life environment by making use of easily reachable equipment and software. This infrastructure is aimed to simulate scenarios where interactive applications will operate in the near future. Although at this point of the implementation, the transport stream generated cannot be transmitted in real time, it is expected that further research will lead to implementation improvements that allow real time transport stream modification and transmission. At the same time, this infrastructure can be employed for low cost community TV stations implementation, as suggested in (Medina & Villa, 2014). This is an initiative that has been promoted by the Ecuadorian government which has assigned 34% of the available electromagnetic spectrum for community broadcasting services.

As a result of the work presented in this article, we can conclude as well, that further government regulation is needed in order to standardize the minimum hardware and software requirements for the HDTV equipment to be imported to the country that will be used as HDTV receivers and for interactive application execution. With the creation of the Laboratory of Digital Television, this group of researchers expects that new research lines will be fully exploited to generate new knowledge at this point of the incipient era of DTV in the world.

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REFERENCES

ABNT, 2007. Associação Brasileira de Normas Técnicas. Digital terrestrial television - Transmission system. *ABNT/CEE-085 Televisão Digital*.

Alencar, M.S., 2009. *Digital Television Systems.* Cambridge: Cambridge University Press.

Alulema, D., 2012. La Televisión Digital Terrestre en el Ecuador es interactiva. *EIDOS*, 1(5), 12-19.

Avila, J., X. Riofrío, M. Espinoza-Mejía, V. Saquicela, K. Palacio-Baus, H. Albán, 2014. Análisis de la influencia de las propiedades semánticas en los sistemas de recomendación. *Revista Politécnica*, 34(2):68-76**.**

Cochancela, M., A. Gutiérrez, 2013. *Diseño de un Laboratorio de Televisión Digital para la transmisión de señales con multiprogramación, contenidos interactivos y guía electrónica de programación (EPG)*. Tesis de pregrado, Facultad de Ingeniería, Universidad de Cuenca, 236 pp.

De Mello Brandao, R.R., G.L. de Souza Filho, C.E.C.F. Batista, L.F. Gomes Soares, 2010. Extended features for the Ginga-NCL environment: Introducing the LuaTV API. *Proceedings of 19th International Conference on Computer Communications and Networks (ICCCN),* 6 pp.

DiBEG, Digital Broadcasting Experts Group, 2007. ANNEX-AA Structure of ISDB-T system and its technical features. ISDB-T technical report. Disponible en *http://www.dibeg.org/techp/ feature/ANNEX-AA.pdf,* 15 pp.

EiTV, 2014. Entretenimiento e Interatividade para TV Digital. 2014. Descargado de *http://www.eitv.com.br/ es/solucoes/laboratorio-isdb-t-dtvi* el 25 de Agosto 2014.

Espinoza-Mejía, M., V. Saquicela, K. Palacio-Baus, H. Albán, 2014. Extracción de preferencias televisivas desde los perfiles de redes sociales. *Revista Politécnica,* 34(2), 59-85.

Medina, J., C. Villa, 2014. Implementación de un Laboratorio de Televisión Digital que cumpla el Estándard ISDB-Tb. Tesis pregrado, Facultad de Ingeniería, Universidad de Cuenca, 156 pp.

Nakahara, S., S. Moriyama, T. Kuroda, M. Sasaki, S. Yamazaki, O. Yamada. Efficient use of frequencies in terrestrial ISDB system. *IEEE Transactions on Broadcasting,* 42(3), 173-178.

Saquicela, V., M. Espinoza-Mejía, J. Mejía, B. Villazón-Terrazas, 2013. Reduciendo la sobrecarga de información en usuarios de televisión digital. *Proceedings of the Workshop on Semantic Web and Linked Data,* 6 pp.

Supertel, 2010. Informe para la definición e implementación de la televisión digital terrestre en el Ecuador. Superintendencia de Telecomunicaciones. Disponible en *http://www.supertel.gob.ec/pdf/publicaciones/informe_tdt_mar26_2010.pdf*.

Técnicas, Associação Brasileira de Normas, 2008. Multiplexação e serviços de informação (SI). *ABNT NBR 15603-1: Televisão digital terrestre*.

Villamarin, D., M.A Illescas, G. Olmedo, R. Lara Cueva, 2013. Generating a transport stream for digital terrestrial television system in conformance with ISDB-Tb standard.*IEEE Colombian Conference on Communications and Computing (COLCOM 2013),* 1-5.