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Transmission of the CAP Protocol through the ISDB-T Standard

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ABSTRACT

Early warning systems have had a significant impact on society by providing timely information to mitigate the effects of natural disasters. To enhance early warning capabilities, researchers are exploring the use of digital terrestrial television systems to broadcast alerts across large urban and rural areas. In this research project, the aim is to integrate the global early warning protocol CAP (Common Alerting Protocol) into the existing ISDB-T standard, alongside the standard's Emergency Warning Broadcasting System (EWBS). This integration will enable the creation of a hybrid system, allowing various global emergency alert devices that utilize the CAP protocol to be activated through the Digital Television signal. To achieve this, a CAP to EWBS translator was developed as part of the design proposal prior to transmission. Additionally, transmitters compliant with both the full-seg and one-seg ISDB-T standards were designed to support the CAP protocol. These transmitters utilize SDR (Software-Defined Radio) cards of the Adalm Pluto type. The CAP protocol, encoded in XML format, was transmitted through the ISDB-T transport stream using the DSM-CC data transmission protocol. By incorporating the CAP protocol into the ISDB-T standard and utilizing the DSM-CC data transmission protocol, this research project aims to enhance the early warning capabilities of digital terrestrial television systems.

1. Introduction

Traditionally, Early Warning Systems (EWS) have been implemented to alert the population about potential natural or man-made phenomena and mitigate their impacts [1-2]. To achieve this, various systems have adopted global protocols or developed their own protocols for emergency risk reduction [3-7].

In Ecuador, the ISDB-T International standard is being used for digital terrestrial television implementation. This standard, originating from Japan with Brazilian modifications, is widely adopted in South America [8-9]. The International ISDB-T standard includes an Early Warning Broadcasting System (EWBS) that utilizes area codes to deliver emergency information at the regional level, allowing for targeted alerts within specific areas [10-12].

However, relying solely on the EWBS system within the International ISDB-T standard poses limitations in terms of receiver compatibility and the replication of emergency alerts. As a result, there is a proposition to integrate global alert protocols for emergencies. One widely adopted international protocol is the Common Alerting Protocol (CAP), which interfaces with diverse technologies such as telephony, radio, fax, emails, and websites [13]. Hence, the objective of this article is to incorporate the CAP protocol into the International ISDB-T standard, thereby enabling hybrid digital terrestrial television standards to swiftly and effortlessly transmit emergency messages on a global scale.

The CAP protocol offers an open and non-proprietary digital message format for all types of alerts, utilizing XML for programming, which leads to reduced costs and operational complexity by providing a unified software interface for numerous existing warning systems [14].

The TV 3.0 project is a regional initiative led by Brazil that aims to develop and enhance the television transmission standard to provide viewers with a more advanced and enriched experience. It began in July 2020 and has been divided into several phases to achieve its objectives [15].

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The first phase of the project involved inviting organizations from around the world to submit proposals for the six components of the TV 3.0 system: over-the-air physical layer, transport layer, video coding, audio coding, subtitles, and application coding [16]. A total of 36 responses were received from 21 different organizations. Similar proposals were merged to simplify testing and evaluations in the next phase [17-23].

The second phase took place during the years 2021 and 2022, focusing on comprehensive testing and evaluations of the proposed technologies and components for the TV 3.0 system. Currently, the third phase of the project is underway and is expected to last approximately two and a half years. A final decision on the over-the-air physical layer technology is anticipated in April 2024, with corresponding technical specifications being drafted from May to August 2024. Concurrently, research and development (R&D) activities are being conducted for the transport layer and application coding, including the development of adaptations, extensions, tools, and test suites. These activities will take place from March 2023 to August 2024. The official launch of the TV 3.0 system is expected to occur in 2025, offering viewers an enhanced television experience and a wide range of services and functionalities.

Within the TV 3.0 project, the implementation of an Advanced Emergency Alert System (EAS) has been identified as a crucial component. The EAS is designed to provide efficient and effective emergency alert notifications to the public through the TV 3.0 platform. It utilizes the Advanced Emergency Alerting (AEA) system based on ATSC 3.0, which is structured in an XML document called the Advanced Emergency Alerting Table (AEAT). This system enables broadcasters to transmit detailed emergency information, including text messages, images, and multimedia content, to inform and adequately prepare the public during emergency situations. Decision trees and protocols have been established to handle different types of alerts, including required alerts, optional alerts, and emergency action notifications, based on priority levels defined in the AEAT [22].

During the transition to digital television, there are still countries in the region that have not completed this process but have digital transmitters that can be utilized to send early emergency alerts through the broadcasting signal. This includes rural areas where television signals are available, as well as locations with Internet access. The research group has been working on projects related to the transmission and reception of emergency alerts using the EWBS system, which is part of the adopted ISDB-T standard in the country [24].

Additionally, the CAP protocol is a global protocol that is part of ATSC 3.0 and will be integrated into the TV 3.0 system. This protocol is used in other global communication mediums as well. Hence, there is a need to demonstrate that through the ISDB-T transport stream structure, it is possible to transmit any type of data, but this requires the implementation of specialized receivers. In this context, this article proposes a method to include the CAP protocol in the ISDB-T system, which is within the standard of the transport layer, and demonstrates its functionality in conjunction with the physical layer of the ISDB-T receiver according to the ISDB-T standard, which requires a special module. To achieve this, the design and implementation using software-defined radio are proposed.

This proposal and innovation aim to expand the capabilities of the ISDB-T system to enable the transmission of emergency alerts using the CAP protocol. By demonstrating the feasibility of this integration, it is expected to improve the efficiency and effectiveness of emergency alert systems in the context of digital television, contributing to the safety and well-being of the population.

This article is structured as follows: Section 2 outlines the methodology employed for information encryption and decryption. Section 3 presents the results obtained from the study, and Section 4 provides the concluding remarks.

2. Methodology

The aim of this study is to incorporate the CAP protocol into a Transport Stream (TS) flow and design a test scenario utilizing Software-Defined Radio (SDR) in both the transmission and reception stages.

To insert the CAP protocol in a TS stream, it is proposed to use the DSM-CC (Digital Storage Media Command and Control) standard. This standard allows the CAP Protocol to be transmitted cyclically using files, directories, services, and event streams through the data and object carousels [25-26].

For the test scenario in the transmission and reception stages, the cost-effective SDR Adalm Pluto will be utilized. This compact and easily transportable device serves various functions in the realms of education and research. The SDR Adalm Pluto operates in conjunction with the GNU Radio software, which is an open-source program compatible with multiple platforms. It allows for modular programming and simplifies the creation of pre-programmed Python blocks for signal transmission or reception [27].

2.1. TS Design

To use the DSM-CC in the International ISDB-T standard, the AIT table must be added to the PSI/SI tables; this table provides complete information about data transmission, the required activation status of the applications carried by it, etc. The data in the AIT table allows the transmitter to request that the receiver change the activation state of an application [28-32].

Within the PSI/SI Tables is the PMT table, which contains all the elements that make up the TS stream, such as audio, video, data, and the AIT table in the Elementary Stream field.

In each Elementary Stream field, some descriptors help to complement the description of each element of the TS stream, which is why the following descriptors are included in the AIT table: the Data Components descriptor and the Application signaling descriptor. These descriptors will indicate the type of application to be used within the TS flow. Its conformation is shown in Figure 1.

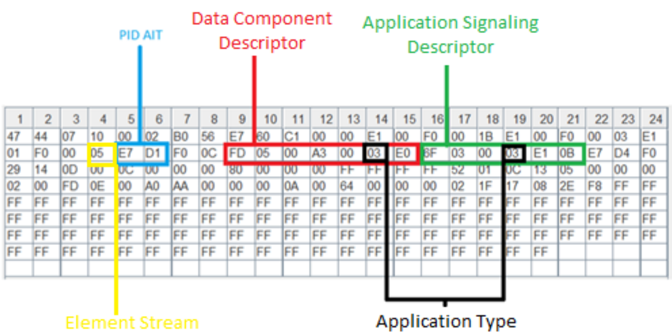

Figure 1: AIT Table Descriptors within the PMT Table

The descriptors for the DSM-CC section element are the TAG Association descriptor, the Identifier descriptor, and the Carousel Identifier descriptor. These descriptors mention the use of the data carousel within the TS stream. Its structure is presented in Figure 2.

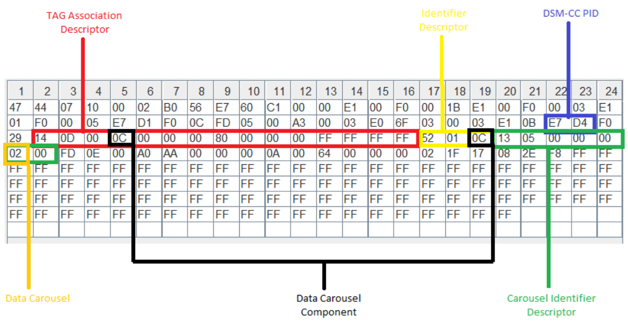

Figure 2: DSM-CC descriptors within the PMT table.

Next, the information that must go in the AIT table is presented, where the type of application is inserted, which must be the same as that shown in the PMT table; in turn, three descriptors are inserted, the first being the protocol descriptor transport indicating the use of data carousel. Second, the application descriptor suggests the priority of the data carousel in the TS flow. Finally, there is the application name descriptor, where the name of the CAP file is inserted in the ASCII code. These values can be seen in Figure 3.

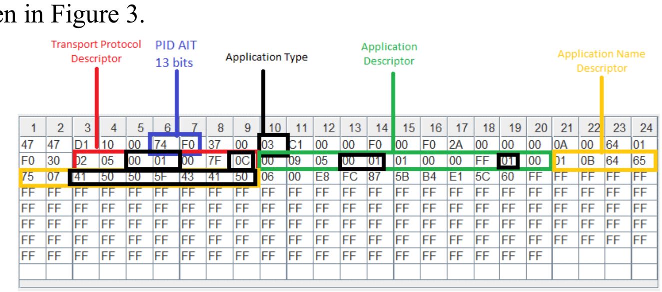

Figure 3: Components of the AIT table.

The TS flow and the DSM-CC section containing the multiplexed CAP protocol will be obtained with an audio and video signal.

2.2. Design of the Transmission and Reception System

With the generated TS stream, we build the transmission system in the GNU Radio software. The transmission system diagram with the GNU Radio software is presented in Figures 4, 5, and 6, and the description of each component is established in Table 1.

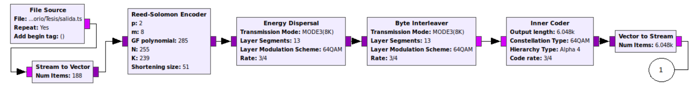

Figure 4: Transmission System in GNU Radio - Coding

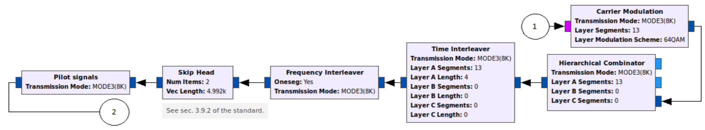

Figure 5: Transmission System in GNU Radio - Modulation

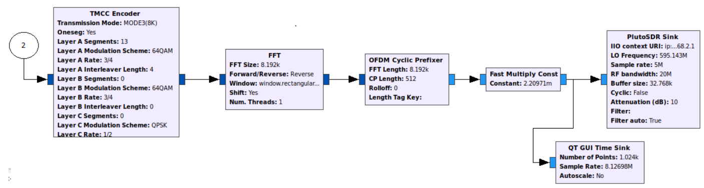

Figure 6: Transmission System in GNU Radio - Configuration

Table 1: Description of each Block of the Transmission System

Block	Description
FILE SOURCE	Read a stream from a file.
STREAM TO VECTOR	Converts an item stream to a GNU Radio block stream.
REED SOLOMON ENCODER	Create a Reed Solomon scrambler according to the standard.
ENERGY DISPERSAL	Implements an energy disperser compliant with the standard.
BYTE INTERLEAVER	Inserts a byte interleaver according to the standard.
INNER CODER	Create an internal encoder with puncturing.
VECTOR TO STREAM	Converts the GNURadio block stream to an item stream.
CARRIER MODULATION	Modulates the carrier with the parameters of Mode, number of segments, and modulation scheme.
HIERARCHICAL COMBINATOR	Divide the content to be transmitted into hierarchical layers.
TIME INTERLEAVER	Implementation of a Fornet interleaver as specified by the standard.
FREQUENCY INTERLEAVER	Performs frequency interleaving.

Block	Description
SKIP HEAD	Remove information considered junk from the header.
PILOT SIGNALS	Establishes pilot signals by the standard.
TMCC ENCODER	Block that encodes the TMCC carriers.
FFT	Implements the fast Fourier transform.
OFDM CYCLIC PREFIXER	Adds a cyclic prefix and performs pulse shaping on OFDM symbols.
FAST MULTIPLY CONST	Multiply the input by a constant to have the desired size.
PLUTO SDR SINK	Block that transmits the signal through the Adalm Pluto.
QT GUI TIME SINK	Graphically presents the transmission.

With these blocks, the SDR Adalm Pluto is connected, and for this software to recognize it, the IP address: 192.168.2.1 is put in the PLUTO SDR SINK block.

For the receiving system, a new program is created in GNU Radio. The reception system diagram is shown in Figures 7, 8, and 9, and the description of each component is established in Table 2.

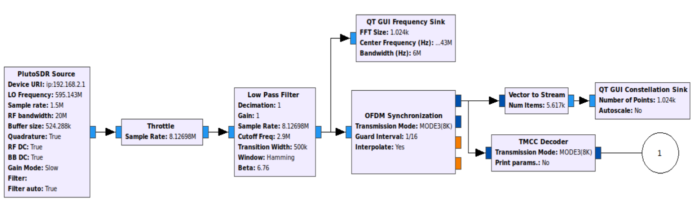

Figure 7: Reception System in GNU Radio – Configuration

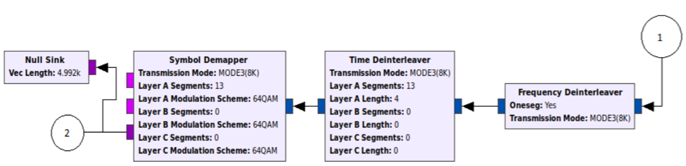

Figure 8: Reception System in GNU Radio - Demodulation

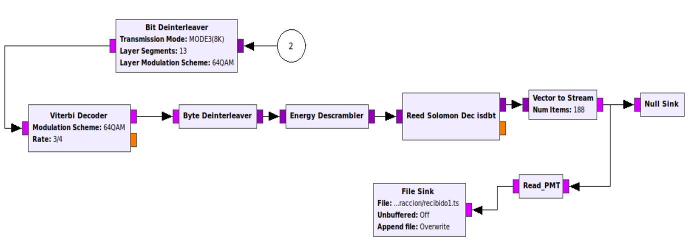

Figure 9: Reception System in GNU Radio - Decoding

Table 2: Description of each Block of the Reception System.

BLOCK	***DESCRIPTION***
PLUTO SDR SOURCE	Receive the signal from Adalm Pluto.
THROTTLE	Indicates the sample rate to use.
LOW PASS FILTER	Create a low pass filter to get the signal from the TS file.
QT GUI FREQUENCY SINK	Graphically indicates the shape of the signal.
OFDM SYNCHRONIZATION	Specifies OFDM information such as Mode, Guard Interval, and interpolation.
QT GUI CONSTEALLATION SINK	Graphically indicates the constellation of the system.
TMCC DECODER	Decodes TMCC carriers.
FREQUENCY DEINTERLEACER	Performs frequency interleaving.
TIME DEINTERLEAVER	Specifies a Forney interleaver as specified by the standard.
SYMBOL DEMAPPER	Removes the symbol map on each carrier and then generates a serial keyword.
BIT DEINTERLEAVER	Performs a bit of interleaving.
VITERBI DECODER	Implements a Viterbi decoder on the signal.
BYTE DEINTERLEAVER	Implements a Forney byte deinterleaver as specified by the standard.
ENERGY DESCRAMBLER	Specifies a power decoder as specified by the standard.
REED SOLOMON DEC ISDBT	Receives 204-byte blocks and performs a Reed Solomon decode.
VECTOR TO STREAM	Transforms the GNU Radio blocks to an elementary stream of 188 bytes for each packet.

BLOCK	***DESCRIPTION***
READ PMT	Block was created to verify the PMT table information mentioning its Elementary Stream types.
FILE SINK	Create a file with the information received.

With the received file, the information from the DSM-CC section is extracted as follows:

1. Look up the PID from the PMT Table and then identify the PID from the DSM-CC section.
2. Compare the PID frame by frame and verify that it matches the PID of the DSM-CC section. When a frame is found with the DSM-CC PID, its content is analyzed.
3. Identify the Table id to indicate if it is a data or control block.
4. Extract the content stored in a TS file as a data block.
5. Being a control block, the type of block is identified.
6. Finally, the number of data and control blocks found is obtained.

Subsequently, the data carousel is extracted, which allows removing the headers of the DBB sections that contain the data. To perform this function, the following steps are followed:

1. The number of modules that were generated in the extraction of the DSM-CC is verified.
2. Each module is analyzed to check if the file still contains information.
3. The message_length segment located in the byte following the table id is analyzed from each frame. This segment will indicate the size of the CAP file.
4. This process is repeated until the beginning and end of the message are stored.

Then, the object carousel is extracted; in this section, the type of file inside the TS is verified, this; case, it will only be a file type file where the CAP file will be obtained in XML format. The steps are the following:

1. The file size generated in the previous function is obtained.
2. The type of file is obtained.
3. Its header is parsed to extract its content.
4. At the end, you will have the extracted content.

3. Results

To verify the operation of the CAP protocol transmission, the TS flow is created with the information from the PAT, PMT, NIT, SDT, AIT, and DSM-CC tables.

Once all these elements have been verified, the signal is transmitted and received with the help of the GNU Radio software and SDR Adalm Pluto, the scenario mentioned in Figure 10.

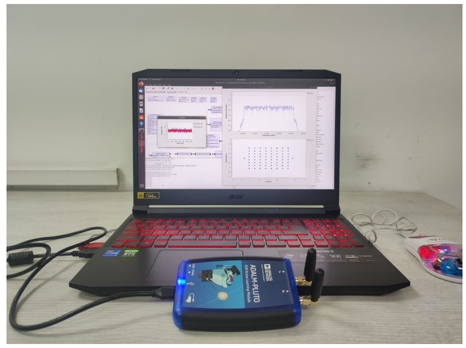

Figure 10: Scenario with GNU Radio and Adalm Pluto.

To check the operation of the communications system, a block called Read PMT was created at the reception; this block will read the information from the PMT and its four elementary Streams: the audio, the video, the AIT table, and the DSM-CC section. This content is indicated in Figure 11.

```
------------------------------------------------------------
PMT
------------------------------------------------------------
PID: 1031 y  in hex: 0x407
Section length: 86 y  in hex: 0x56
Section syntax error: 1 entonces True
CRC-32: [ 23  8  46 248]
Program number: 59232 y en hex: 0xe760
Version Number: 0 y en hex: 0x0
Current next indicator:  1 entonces True
PCR_PID: 256 y  in hex: 0x100
Program information length: 0 y  in hex: 0x0
------------------------------------------------------------
------------------- Information 1 -------------------
Stream Type identifier: 27  in hex: 0x1b : Video ITU Recommendation H.264 e ISO/IEC 14496-10
Elementary Stream PID: 256  in hex 0x100
ES information length: 0  in hex: 0x0
--------------------------------------------------------
------------------- Information 2 -------------------
Stream Type identifier: 3  in hex: 0x3 : Audio  ISO/EC 11172-3
Elementary Stream PID: 257  in hex 0x101
ES information length: 0  in hex: 0x0
--------------------------------------------------------
------------------- Information 3 -------------------
Stream Type identifier: 5  in hex: 0x5 : Seccion
Elementary Stream PID: 2001  in hex 0x7d1
ES information length: 12  in hex: 0xc
--------------------------------------------------------
------------------- Information 4 -------------------
Stream Type identifier: 11  in hex: 0xb :  ISO/IEC 13818-6 (tipo B)
Elementary Stream PID: 2004  in hex 0x7d4
ES information length: 41  in hex: 0x29
--------------------------------------------------------
Stream type identifier: [27, 3, 5, 11]
Elementary Stream PID: [256, 257, 2001, 2004]
ES information length: [0, 0, 12, 41]
```

Figure 11: Content of the PMT Table at the reception

After some time, receiving and transmitting are paused, and the received.ts file is obtained. The steps for removing the DSM-CC section using a Python file are followed to extract the information from this received file, getting Figure 12.

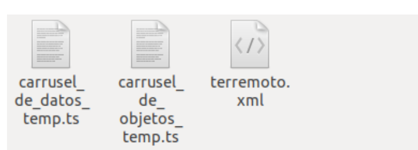

Figure 12: File Extracted from TS Stream.

In the end, the terremoto.xml file is successfully extracted. The cap-validator software checks the CAP file, resulting in a valid file, as shown in Figure 13 [33].

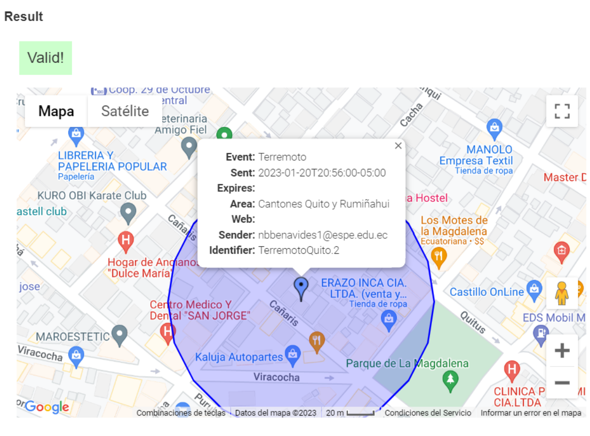

Figure 13. Result of cap-validator software.

The resulting process and the used diagram are shown in the QR code below in Figure 14.

Figure 14: QR code of CAP protocol transmission and extraction display.

4. Conclusions

The present study successfully demonstrated the transmission and reception of CAP protocol data in XML format through the DSM-CC data structure within an ISDB-T transport stream. The utilization of the CAP protocol resulted in the generation of minimal bytes in the DSM-CC, showcasing its efficiency in terms of bandwidth utilization when compared to transmitting an interactive application under the same transmission mode.

By employing GNU Radio and the SDR Adalm Pluto, a robust communication system for ISDB-T with full-seg content was developed. The system exhibited flawless reproduction of audio and video reception, while ensuring the complete download of the CAP file. Furthermore, the implementation of a one-seg reception system using the SDR Adalm Pluto and the DEKTEC DTU 215 modulating card yielded successful results, thanks to the minimal bandwidth requirements of the transmitted CAP file.

To ensure the quality of the CAP file, both during its construction and upon reception in both one-seg and full-seg scenarios, the cap-validator software was employed. This validation process confirmed the accuracy and integrity of the CAP information. Overall, the communications system demonstrated optimal performance and is well-suited to serve as a valuable asset in supporting the EWBS emergency system. By integrating the CAP system into the ISDB-T transport layer platform, emergency authorities and broadcasters can send timely and accurate emergency alerts, ensuring the safety and well-being of the population. The CAP structure, which is both part of ATSC 3.0 and will be part of TV 3.0, aims to provide a powerful tool for public authorities to disseminate news, weather updates, and critical information during emergencies, enhancing the overall emergency response capabilities within the broadcasting industry. Through the proposed approach in this article, the integration of CAP can even be achieved during the transition to digital television using the ISDB-T system, allowing for readiness in any migration to an advanced digital television system in the near future.

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