IP Transmission over ISDB-T_B

Gustavo de Melo Valeira, Cristiano Akamine, Edson Lemos Horta, Fujio Yamada, and Rodrigo Eiji Motoyama

***Abstract*—This paper presents a new application of the Integrated Services Digital Broadcasting - Terrestrial version B (ISDB-T_B) digital television system to transmit data in the Internet Protocol (IP) format encapsulated in the MPEG-2 Transport Stream (MPEG-2 TS). The use of this encapsulation technique ensures compatibility of the ISDB-T_B multiplexing system, allowing the transmission of IP packets. The proposed application is unidirectional, i.e., there is no return channel and the protocol used in the IP packets is the User Datagram Protocol (UDP).**

***Index Terms*—Digital Television, Integrated Services Digital Broadcasting - Terrestrial version B (ISDB-T_B), User Datagram Protocol (UDP).**

I. Introduction

In Brazil, the digital terrestrial television system used is a modified version of the Japanese system called Integrated Services Digital Broadcasting - Terrestrial (ISDB-T). This version is called ISDB-T_B, and the main differences are, video (MPEG-4 part 10 or H.264) [1], audio (MPEG-4 HEAAC) [2], middleware (Ginga based on Java or NCL) [3], and the use of high VHF and UHF bands [4].

The ISDB-T_B system can offer reliability for both high-quality transmission of image and sound in fixed receivers, and in mobile receivers. Due to its flexibility, it is also possible to transmit multimedia content [5].

The transmission of data or multimedia content may be performed in one hierarchical layer or multiplexed with other services, such as audio, video, etc.

There are other systems that transmit data in IP, such as Digital Video Broadcasting - Handheld (DVB-H) and Internet Protocol Television (IPTV). DVB-H is a terrestrial standard that uses the IP protocol for applications in portable receivers [6]. IPTV is based on the current IP network, i.e. using the broadband connection for transmitting digital television services [7].

This article proposes data transmission using User Datagram Protocol/Internet Protocol (UDP/IP) format encapsulated in an MPEG-2 Transport Stream for the ISDB-T_B digital TV system. This encapsulation ensures compatibility with the transmission system and with the IP receiver. The transmission of IP packets can be used in digital terrestrial television for streaming and downloading various types of services, for example, audio/video in different encoding formats, music, web pages, free games, and applications directly to a computer. To maintain convergence between these different forms of media, one ISDB-T_B Full-segment demodulator with IP output is in development. This receiver will receive the ISDB-T_B signal and decapsulate the MPEG2-TS, distributing the output signal in UDP/IP format. The output is connected to a computer, and the computer receives data in UDP. In Section II, a quick review of the ISDB-T_B system is made. Some services that use the IP protocol are discussed in Section III. Details of the protocols to be used in ISDB-T_B are shown in Section IV. Finally, in Section V, the conclusions are presented.

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II. ISDB-T_B System

The ISDB-T_B digital television system is flexible, allowing the use of different services on a single television channel with a bandwidth of 6 MHz. The modulation used is Band Segmented Transmission - Orthogonal Frequency Division Multiplexing (BST-OFDM), where the channel is divided into thirteen segments of 6000/14 = 428.6 kHz each. These segments are distributed in up to three hierarchical layers called Layers A, B, and C. The layers may have different robustness, allowing different services (mobile, fixed and/or portable) on the same channel. The useful bandwidth used by ISDB-T_B is 6/14 * 13/14 = 5.57 MHz of the 6 MHz available. For this reason it can be said that the 6 MHz channel is divided into fourteen parts, thirteen of which are used [4] [8].

The parameters in common with the BST-OFDM system is the size of the Inverse Fast Fourier Transform (IFFT) (Mode 1, 2 or 3), and the guard interval (1/32, 1/16, 1/8 and 1/4). The convolutional encoder rate (1/2, 2/3, 3/4, 5/6 and 7/8), the time interleaver length, and the modulation are specific to each layer, changing the robustness and bit rate between layers [4]. There is also the 1seg service, a layer that occupies one segment and is used to transmit the low definition video to portable receivers.

The ISDB-T_B system can be separated into the following blocks: source encoder, multiplexer/re-multiplexer, and modulator as in Fig. 1 [4] [8].

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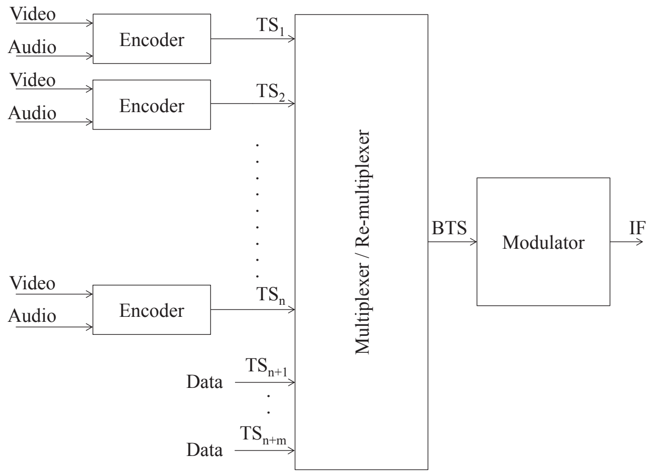

Fig. 1. Block diagram of ISDB- T_B

A. Source Encoder

Studio audio/video signals must be encoded in H.264 video standard [1] and audio MPEG4 HE-AAC v1 or MPEG4 AAC-LC for High Definition Television (HDTV) or Standard Definition Television (SDTV) and MPEG4 HE-AAC v2 for 1seg [2]. The MPEG-2 Transport Stream (MPEG2-TS) [9] is used at the output of encoders to maintain compatibility with the multiplexer/re-multiplexer, which uses the serial interface called Asynchronous Serial Interface (ASI) for transmitting MPEG2-TS. The TS packet size is 188 bytes, and its structure is shown in Fig. 2 [9] [10] [11].

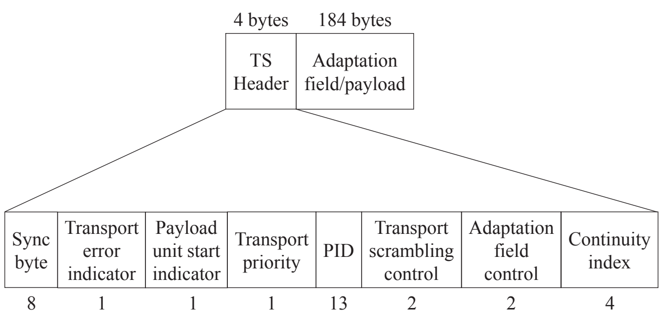

Fig. 2. TS packet structure, indicating the size in bits of each field

The most important header fields are Sync Byte and Program Identification (PID). Sync byte has a fixed value $(47)_h$ and indicates the beginning of the TS packet. The PID identifies the program that is inside the packet, such as audio, video, and closed caption, etc. This parameter is important for the re-multiplexer to correctly filter the PID for audio and video, Program Clock Reference (PCR), and data from each encoder.

B. Multiplexer / re-multiplexer

All TS data encoders and data carousels are re-multiplexed, resulting in an output of 204-byte TS packets. This output signal is called the Broadcast Transport Stream (BTS) because its bit rate is constant and equal to four times the sampling frequency of the IFFT modulator. The bit rate is then equal to $4 \times 512/63 = 32.507937$ Mb/s [12].

The final sixteen bytes of the BTS, i.e., the dummy byte, has a counter and a packet layer identifier [13], and can optionally have a Reed Solomon block code (RS) shortened to (204,196,4) with a correction capacity of up to 4 bytes in a TS packet.

The BTS packet sequence of each layer depends on the guard interval, the convolutional encoder rate, the number of segments, and the modulation of each layer. This sequence, termed multiplex frame is repeated at equal intervals that only depend on the guard interval and mode, as can be seen in Table I [4]. Besides the packets of each layer, there are null packets that are generated by the multiplexer, which do not correspond to any hierarchical layer and serve to maintain the constant bit rate 32.507937 Mb/s regardless of the input. Identified in the final 16 bytes of the BTS, the corresponding hierarchical layer of each packet coming from the encoders are configured in ISDB-T_B multiplexer so that the modulator can transmit that packet in the layer correctly.

TABLE I
NUMBER OF PACKETS IN A MULTIPLEX FRAME

Mode	Guard Interval			
	1/4	1/8	1/16	1/32
1 (2k)	1280	1152	1088	1056
2 (4k)	2560	2304	2176	2112
3 (8k)	5120	4608	4352	4224

Because there can be up to three hierarchical layers with different modulation parameters and convolutional encoder rate, the bit rate must be calculated for each of them. With that, the encoder bit rate can be properly configured to not exceed the limit of each layer. It is also worth noting that if data is transmitted, the encoder bit rate should be adjusted so that the sum of these two rates do not exceed the maximum allowed. Equation (1) shows the calculation of segment bit rate [4].

$$bit\ rate = \frac{N_S \times N_C \times M_d \times R_{CC} \times R_{RS}}{T_u \times (IG+1)} \tag{1}$$

The useful time T_u of the OFDM symbol, the number of useful carriers N_c and the Reed Solomon encoder ratio R_{Rs} are calculated by Equations (2), (3) and (4), respectively [4].

$$T_u = \frac{2^{mode-1} \times 63}{250} \tag{2}$$

$$N_c = 2^{mode-1} \times 96 \tag{3}$$

$$R_{RS} = \frac{188}{204} \tag{4}$$

Combining Equations (2), (3), and (4) into (1) results in equation (5), which can be used to calculate the bit rate of each layer or segment.

$$bit\ rate = \frac{N_S \times M_d \times R_{CC} \times 376000}{1071 \times (IG+1)} \tag{5}$$

In Equation (5), the N_s, M_d, and R_{cc}, and GI parameters represent the number of segments, the number of bits per

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symbol, the convolutional encoder rate, and the guard interval, respectively. The number of bits per symbol M_d is 2 for DQPSK or QPSK, 4 for 16QAM, and 6 for 64QAM. As this number increases, the greater the total bit rate, but the distance between these points decreases, decreasing the signal robustness [8].

C. *BST-OFDM modulator*

The BST-OFDM modulation allows the thirteen segments to be distributed in up to three hierarchical layers with different protection against errors. In Table II the transmission parameters for the Brazilian digital television system can be found [4].

TABLE II
CONFIGURATION PARAMETERS IN ISDB-T_B

Mode	1,2 or 3
Guard Interval	1/4, 1/8, 1/16 or 1/32
Partial reception (1seg)	On or off
Total number of segments	13
Maximum number of layers	3
Layer modulation	DQPSK, QPSK, 16QAM or 64QAM
Layer convolutional encoder rate	1/2, 2/3, 3/4, 5/6 or 7/8
Layer time interleaving	0, 400, 800 or 1600 ms (Mode 1) 0, 200, 400 or 800 ms (Mode 2) 0, 100, 200, 400 ms (Mode 3)

It can have up to three layers and these are identified by the letters A, B, and C. When it is used only one layer, this is designated as A. If there are two layers, the layer that has fewer segments is A and the other is B. In this case, the central segments correspond to layer A and the outer layers correspond to layer B. If three layers are used, the layer designated as A has less or an equal number of segments as layer B, which in turn has a lower or equal number of segments compared to C. It is shown in Figures 3, 4, and 5 [4] [14], the identification of the segments and their respective layers, in the case of one, two, and three layers, respectively. Fig. 4 is used in the 1 + 12 configuration (Layer A with one segment and B with twelve segments) and in Fig. 5, the 1 + 3 + 9 configuration (Layer A with one segment, B with three segments, and C with nine segments).

A configuration widely used in São Paulo has two layers, with Layer A for 1seg service and B for high-definition content. The guard interval is 1/16 in Mode 3, with the following configuration in Layer A: one segment, QPSK modulation, convolutional encoder rate of 2/3, and time interleaving of 400ms. Layer B has twelve segments, 64QAM modulation, convolutional encoder rate of 3/4, and time interleaving of 200ms. It is possible with this configuration to also have multiprogramming in Layer B, up to eight programs in SD (Standard Definition) or two programs in (HD) high definition.

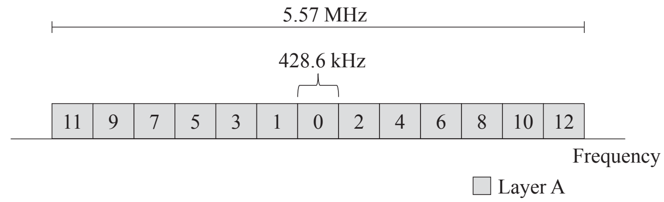

Fig. 3. Segments arrangement in the case of one layer

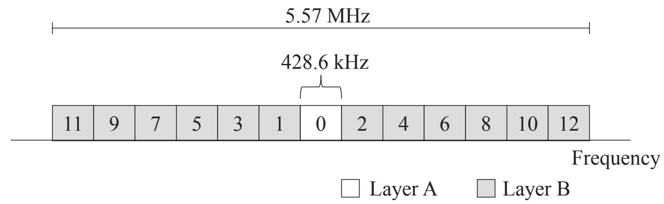

Fig. 4. Segments arrangement in the case of two layers (12 + 1)

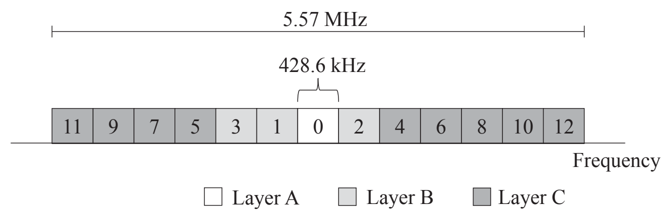

Fig. 5. Segments arrangement in the case of three layers (1 + 3 + 9)

III. IP SERVICES

Some services that use the IP protocol for transmission are Digital Video Broadcasting - Handheld (DVB-H) and Internet Protocol over Television (IPTV).

A. *DVB-H*

DVB-H is a terrestrial system with an application for portable receivers and it is based and compatible with Digital Video Broadcasting - Terrestrial (DVB-T), which is used for fixed receivers. DVB-H was created because the DVB-T system had problems due to the mobility of portable receivers receiving the signal [15] [8]. In this system is transmitted IP datagrams within the Multi-Protocol Encapsulation (MPE) sections with or without the option of using Forward Error Correction (FEC). Using the MPE-FEC resulted in a signal more robust [15]. To reduce energy use in portable receivers, time slicing was developed. This technique consists of transmitting only one service at a time with a high bit rate, i.e. each service is transmitted sequentially at different times. There is an energy saving because the receiver does not need to receive the data all the time. However, to know when data is desired, there is Transmission Parameter Signaling (TPS) that tells the receiver if time slicing and MPE-FEC are being used [8].

B. *IPTV*

IPTV is a system used to transmit digital television services to broadband users, through the IP communication network, i.e. it not uses radio frequency directly. Thus, the content is encoded in the desired video and audio standard to be multiplexed in IP [16]. IPTV is responsible for transmitting videos generated for one or more terminals (users) and

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depending on the programming, this service can be VOD (video on demand) or broadcast [17]. In the first case, the content transmitted by IP has just one destination point, i.e. unicast mode. In broadcast, the mode used is multicast because there are several users who can access this content at the same time. Thus, there is an IP network bandwidth saving by transmitting single content to multiple users.

IV. Proposal

The purpose of this work is to transmit data encapsulated in UDP/IP through the ISDB-T_B system. Fig. 6 shows how the encapsulations are arranged. Within MPEG2-TS, Multi-Protocol Encapsulation (MPE) is used to transmit data in IP/UDP format. Fig. 7 shows the bit structure of the MPE [18]. It can be seen that the MPE is within the MPEG2-TS payload, and, for this reason, a multi-protocol encapsulation packet occupies multiple TS packets.

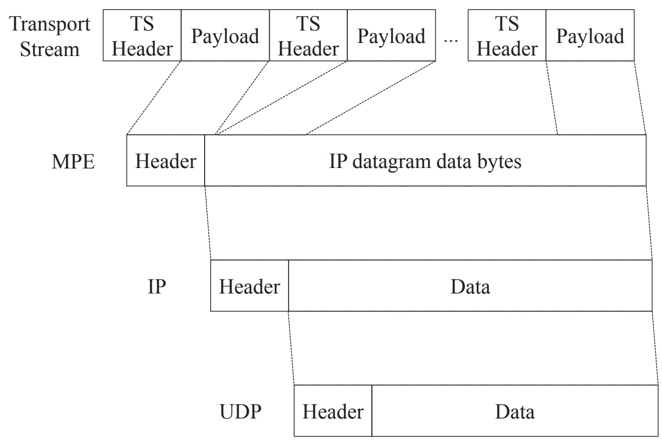

Fig. 6. Encapsulations

An important MPE field is the section length because, with an indication of the section size, it is possible to identify IP/UDP bytes. As for the fields payload scrambling control and address scrambling control, they allow to identify the absence or presence of a private shuffling method of useful information and Media Access Control (MAC) address, respectively [18].

Within each MPE datagram, there is an IP/UDP packet. This protocol contains source and destination address and IP port information. It is desired that the destination IP address is multicast, i.e., to multiple receivers. Thus, it is transmitted in multicast. The identification field of the IP protocol identifies the protocol used after its header; in this case is UDP and the field value is 17. Fig. 8 shows the data structure of IP [19] and UDP [20] packets.

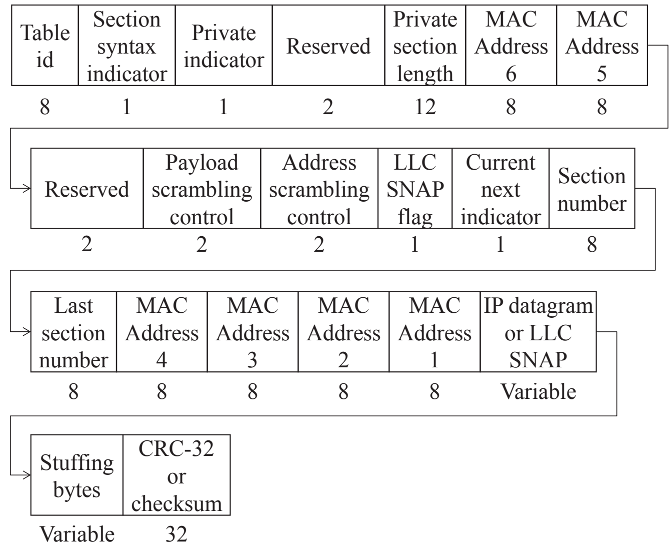

Fig. 7. Structure of Multi-Protocol Encapsulation (MPE), with size indicated in bits

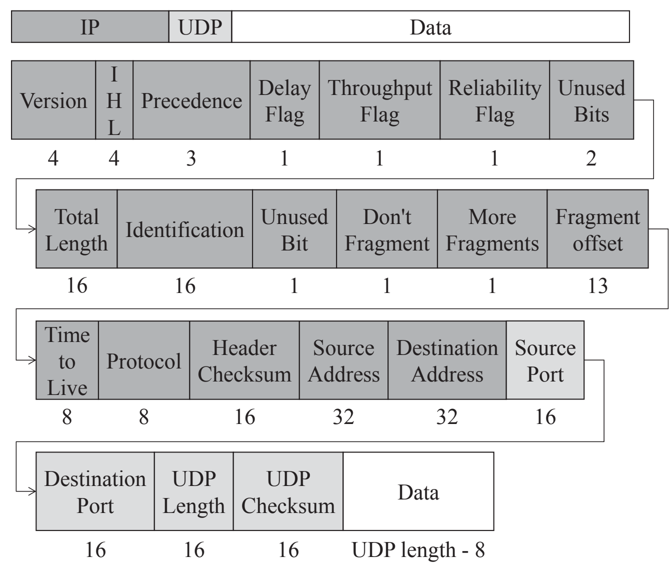

Fig. 8. IP and UDP packet structure, with size in bits. Data sizes in bytes

The block diagram in Fig. 9 shows from IP/UDP data encoding to the computer. Initially files, free games, applications, and audio/video, etc, are encapsulated in the format shown in Fig. 6 and are multiplexed, modulated, and transmitted in the ISDB-T_B standard. The IP receiver demodulates and decapsulates these, and the resulting IP/UDP signal is directed to the Ethernet output connected to the computer. Data received by the computer is processed by a manager, and the updated information is shown on the computer screen. Thus, the IP content transmitted by the ISDB-T_B is available for download or streaming of audio/video. Just updating the computer video codecs allows the computer to decode videos in various patterns, for example, VC-1, Dirac, DIVX, and RMV, etc. transmitted by ISDB-T_B for streaming. The channel exchange is also completed via Ethernet. Fig. 10 shows the IP receiver development board connected to the computer.

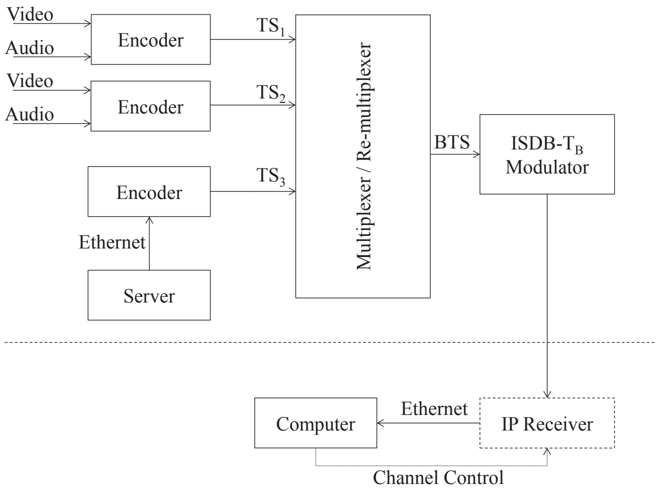

Fig. 9. Block diagram showing the IP transmission of ISDB- T_B

Fig. 10: IP receptor connected to a computer

V. Conclusion

In this study, it was proposed to transmit IP/UDP data over ISDB-T_B, allowing a high bit rate compared with the speed of the Internet currently offered. Informative content can be transmitted through streaming audio/video and files; applications, and free games can be loaded and ran by a computer, only requiring an update in the computer to open certain file types or video.

The useful bit rate when transmitting data in IP/UDP decreases due to the size of the MPE and IP/UDP headers. Using just one hierarchical layer in the most common configuration, the maximum bit rate achieved was approximately 18.6 Mb/s.

This same proposal could be used for an IP USB Full Seg receiver, with the only difference being, that the receiver itself would have an IP output through USB.

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