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Novel Approach in Distance Education using Satellite Broadcast

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Abstract. Limited infrastructural support and lack of adequate teachers demand for a distance education system which can be used to augment the learning of students especially in rural areas of India and other developing countries. We propose novel technological methods to create a solution for distance education which uses existing wide spread satellite broadcast TV network. The solution has two additional components namely a content creator in the broadcast end and a low cost Home Infotainment Platform (HIP) [2] device in the user end. Apart from the video and audio, the associated metadata related to the question-answers (QA) and Electronic Program Guide (EPG) of the tutorials are also transmitted from the broadcast end. A method is proposed to embed the metadata as part of the video frame so that it is accessible in the analog input of the HIP client box. A detailed analysis on the effect of noise demonstrates the sustainability of the metadata in the analog video frame for the existing end to end TV broadcast network.

Keywords: Distance Education, Satellite Broadcast, Metadata in Analog Video.

1. Introduction

A recent report [1] indicates the poor quality of education system in most of the schools in rural India. This is mainly due to the paucity of teachers which leads to a demand for the distance education in India and other developing countries. One major challenge in distance education lies in sharing the tutorial (video-audio and associated question-answer (QA)) with the individual students or may be with the classrooms in the rural schools. In this paper we present a method for distance education which is based on the TV broadcast network available in abundance even in the rural areas of developing countries.

The most popular methods used for distance education is based on the broadband internet protocol (IP) connections [11]. However, India holds 143rd position globally in the average connection speed, which is 0.8 Mbps in Q3 of 2010 as reported by Akamai Technologies in [1]. Moreover, most of the broadband internet connection is available in cities and urban areas. Although recently, wireless broadband connection is peaking up, the situation in rural areas remain pale due to lack in development of infrastructure. Thus the available solutions for distant learning [4], [6], [7], [11] fail to address the development of rural India.

On the other hand, there are more than 100 million Indian television users of which 70% are using pay TV in the form of analog cable or digital satellite connection [15]. The local cable operators occupy 90% of the market share in pay TV which clearly indicates the dominance of analog client terminals in the households. The DVB-RCS based solution [10] requires Satellite Interactive Terminals (SITs) in the client end which is a costly solution for an individual student. The interactive solution based on satellite IP over DVB [12] fails in India and other developing countries due to lack of the required infrastructure.

With the above motivation, we present a novel architecture for the transmission of tutorials, where the low cost HIP [2] device is used in the client end to enable the questions and their associated answers along with video-audio, using the existing infrastructure of digital TV broadcast as shown in Fig. 1. The desired tutorial is selected by the user which gets automatically recorded in HIP upon detection of the broadcast time for the same. The student can then consume the content in off-line mode.

In order to associate the reference answers to the corresponding questions, or to relate a QA to a particular tutorial session, there is a need for metadata. The standard method of embedding the metadata related to teletext and closed captions in the lines of vertical blanking interval (VBI) is disclosed in the CEA 608 standard. The VBI lines already contain teletext, closed captions and electronic program guide (EPG) as per the existing TV broadcast standard. However, there is a limit for the total number of VBI lines which is of the order of 20-40 lines; hence the number of free lines available to send a new type of data is limited. Moreover, at the receiver end, decoding the embedded data of different types using the existing systems requires the support for specialized hardware devices. Thus, in this paper the metadata is embedded in the pixels of the video plane by constructing the symbols for every input bit. As the analog signal is prone to interference noise, we also present a noise analysis for different types of symbols.

Initially we present the system architecture in section 2 explaining the broadcast and the client end. The metadata creation and multiplexing with tutorials are explained in section 3. Experimental results on the robustness to noise are presented in section 4 followed by the conclusion of the paper in the final section.

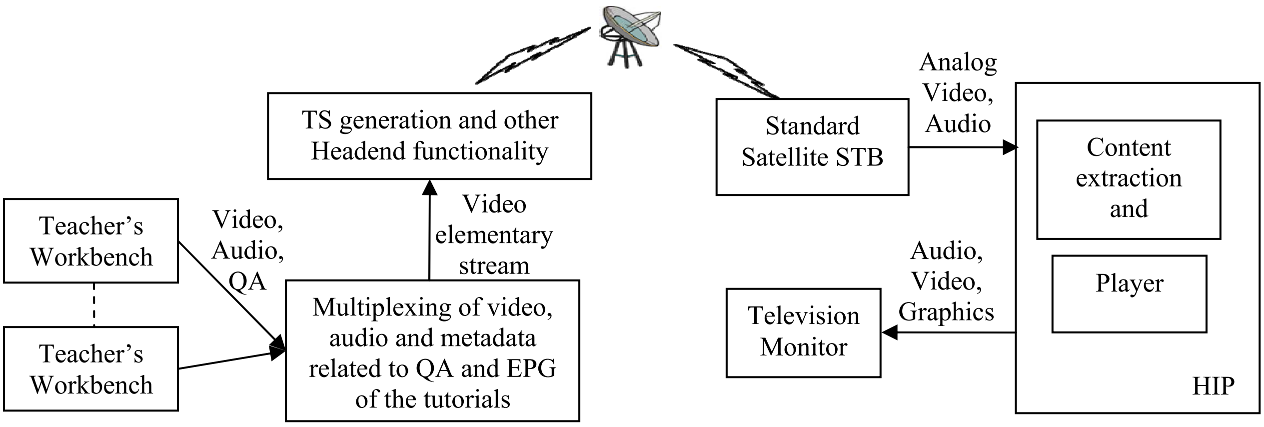

Fig. 1: Architecture for Distance Education using Satellite Broadcast

2. System Architecture

The system architecture for the distance education solution is based on the existing standard TV broadcast network as shown in Fig. 1. A standard STB receives the satellite signal and generates the analog video and audio that are available as input to the HIP box to extract the tutorial and the QA. In this paper, the analog video frames selected to transmit metadata (QA and tutorial EPG) are termed as special frames. A brief of each of the functional blocks are described below:

- Teacher's Workbench – This module creates the video, audio and question-answer (QA) for individual tutorial sessions which are sent to the "Multiplexing of Video and Metadata" module.
- Multiplexing of Video and Metadata – This module multiplexes various tutorials at different broadcast time. It also embeds the QA for each tutorial as part of the specials frames of the same video. The schedule for all the tutorials is also embedded in the special frame of the video, as EPG for the tutorials. The special video frame is multiplexed once in every 10 second. Finally, it generates the video and audio elementary streams for a particular tutorial using standard video (MPEG2) and audio (AAC) encoders.
- TS Creation and Broadcast – This module creates the transport stream (TS). This is a standard module in digital transmission and no change is done. The TS is then broadcasted via satellite.
- Standard STB – This is a standard set-top box which takes the broadcast input, demodulates and extracts the transport stream, decodes the video, audio and generates the analog video and the corresponding analog audio. The standard STB is reused without any change.
- Content Extraction and Recording – This module takes the analog video and records the desired tutorial in AVI format and the associated QA as HTML files.
- Player – This module plays the AVI file and shows the HTML files for questions. It also takes the user inputs for answers to the questions and compares with the correct answer to show the results to the user. The details are given in [14] hence excluded from the scope of this paper.

3. Metadata Multiplexing

The data apart from the video that is inserted in the video pixels of the special frame is termed as metadata. This is used to multiplex QA and the EPG in a single analog video channel. Following information are stored as part of the metadata.

- Barcode – This is the indicator for the special frame. This contains the symbol definition, pilot pattern definition, presence indicator for QA, offset for QA and EPG data from the pilot pattern.
- Pilot pattern – This is the synchronization point for the payload of the metadata. This is inserted in the video pixels as symbols after the barcode.
- QA – This contains the details for the questions, their options to be displayed, duration for which the question is to be displayed and the correct answers.
- Present time stamp – This is the reference time stamp for the current special video frame.
- EPG – This contains the names, IDs, duration and time-to-live for all the tutorials in the next 24 hrs.
- This section provides the detailed information on the metadata creation, insertion and extraction process. It also provides the details of symbol creation and the pilot pattern.

3.1. Insertion Process

The metadata is inserted in the pixels of the special video frame in the form of symbols which are generated from the pilot bits and the metadata bits. The symbol generation process is given in section 3.3. The barcode, pilot bits and metadata are inserted in hierarchical manner. The barcode is inserted in the special frame containing information related to symbol and pilot patterns. Followed by the barcode, the special frame contains the pilot pattern, QA and EPG related data metadata as shown in Fig. 2.

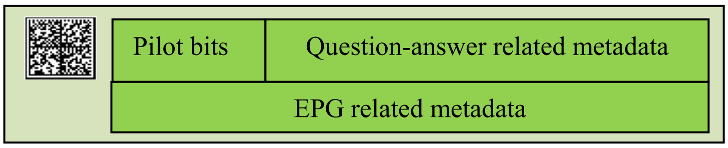

Fig. 2: Layout of the video frame for special frame

3.2. Extraction Process

The barcode and metadata extraction process in special frame is shown in Fig. 3. Initially the barcode is searched in the video frames to detect the special frame. After that the synchronization point for the payload is determined by finding the location of the received pilot pattern symbols. Once the pilot symbols are detected then the QA and EPG related information are extracted.

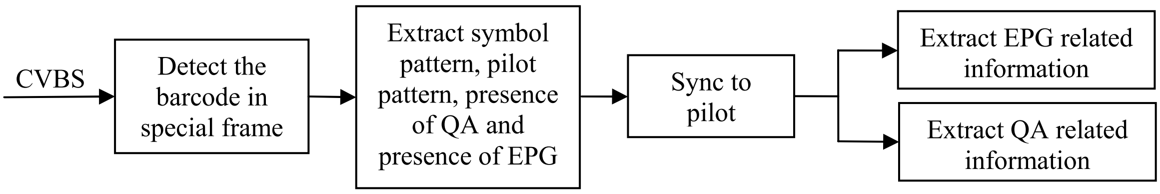

Fig. 3: Extraction process of barcode and metadata in special frame

3.3. Symbol Creation

The metadata embedded in the pixels of video frames undergo video encoding (MPEG2) during broadcasting and digital (YUV) to analog (CVBS) conversions in the receiver, which change the values of the pixels. This makes it challenging to extract the metadata embedded in the pixels of video frame. Hence we introduce the concept of symbol for robust extraction. Each bit of metadata information is converted to a symbol and then inserted in the pixels of the video frame.

The range of values for YUV is 0 to 255 where the middle value is 128 (0x80). For the TV transmission signal, the Y component of each pixel remains within 17 (0x11) and 235 (0xEB) which is mainly to offset the effect of gamma in TV display [16]. Accordingly, the symbol definitions for one byte, two bytes and three bytes are shown below:

Bit – 0 → 0x11 (*one byte*), 0x 8011 (*two bytes*), 0x801111 (*three bytes*)

Bit – 1 → 0xEB (*one byte*), 0x 80EB (*two bytes*), 0x80EBEB (*three bytes*)

One of the above three symbol definitions is chosen for transmitting the pilot bits and metadata. The information on the chosen symbol definition is put in the barcode, which allows the dynamic change in symbol length for changing noise conditions of the satellite channel. The effect of noise on the robustness of the symbols is analyzed in section 4.

3.4. Pilot Pattern

The pilot pattern is inserted to obtain the synchronization point for the metadata payload. This point is determined by matching the pilot pattern with the received pixels which is based on energy detection using a matched filter [5], [8] and is realized using the cross-correlation technique as shown in Eqn. 1,

$$y(t) = \sum p(i) r(t-i) \quad \text{-- Eqn. 1} \qquad\qquad Thr = 0.75 * \sum p(i) p(i) \quad \text{-- Eqn. 2}$$

Where r(t) is the received pixels and r(t-i) is the i^{th} shifted pixel in raster scan. The pixel values corresponding to the pilot symbols are p(i) and sum is done over the number of pixels (N) occupied by the pilot symbols.

The pixel point P_t is detected as the synchronized point for the pilot pattern if the cross-correlation value is greater than a threshold *Thr* which is given by the Eqn. 2. The chosen pilot pattern is based on a row of Hadamard matrix [9] of size *48 bits*. A sample pilot pattern is "110111000100110111000100110111000100110111000100". Thus for the symbol length of 3 pixels the value of N is 48*3=144. The barcode is used to send the pilot pattern which allows the dynamic change in the same during the broadcast.

4. Analysis of Noise Robustness

One of the major contributions of this paper lies in transmitting current tutorial and associated QA of the tutorials and the EPG in a single analog video channel along with the normal video. All these metadata are multiplexed as part of the pixels in the video frame. This video is further encoded using a standard video encoder MPEG2 before broadcast. It is important to analyze the noise robustness of the metadata embedding process. In this section we perform the noise analysis on the pilot pattern and the effect on bit error rate (BER) of the received metadata for various symbol lengths. The results are generated with the MPEG2 encoded stream at 5 Mbps. The size of the barcode (QR-code [13]) chosen is 80x80 pixels, which allows 100% detection even at E_b/N_0 of 8.25 dB SNR level for a payload size of 144 bits.

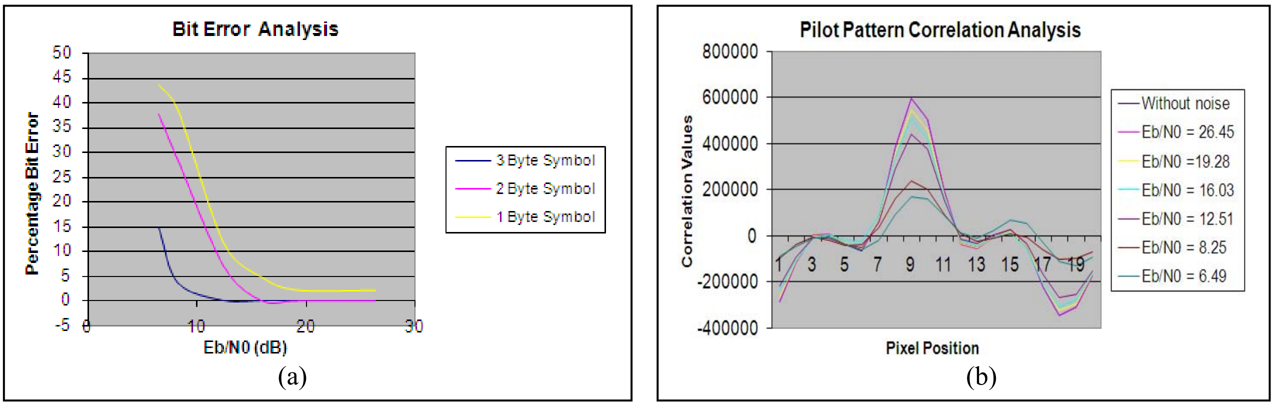

Fig. 4: Noise Analysis on – (a) BER for various symbol lengths, (b) Pilot pattern

4.1. Symbol Length

As described in section 3.3, the symbol length can vary from one pixel to three pixels. The bit error rate (BER) against different noise levels for various symbol lengths is shown in Fig. 4 (a).

The plot shows the average percentage bit error with noise. The plot shows there are some amount of error present with E_b/N_0 of 16 dB for 1 byte symbol and no bit error even with E_b/N_0 of 16 dB for 3 byte symbol. This graph also shows the robustness of 3 byte symbol.

4.2. Pilot Pattern

The noise response of the pilot pattern generated with 3 byte symbol is demonstrated in Fig. 4 (b). This plots the correlation values for different noise level. This graph shows a sharp peak which gives the matching of pilot pattern detection. Now this peak goes down as noise increased. Even at E_b/N_0 of 8.25 dB the peak is visible and able to detect pilot pattern successfully.

After all this analysis we come to a conclusion that 3 byte symbol is the best option for this type of data transmission and hence used in our solution.

5. Conclusion

In developing countries like India and other similar countries, the IP based broadband penetration in rural area is minimal compared to the analog TV usage. Thus in this paper we propose an architecture based on existing satellite TV broadcast network to support distance education using a low cost client HIP box which also works with the analog cable RF connection. In order to support the QA session as part of the tutorial and provide the user an input on the progress score, the metadata are inserted as part of the analog video frames. This metadata includes barcode, pilot pattern, QA and EPG related to the tutorials. The bits of the metadata are converted to symbols and inserted in the pixels of the special video frames. The barcode is used to detect the special frame and the pilot pattern is used to detect the synchronization points for payload pixels of the metadata. EPG allows the user to select the desired tutorial in HIP box. The selected tutorial is recorded by the HIP box which is later consumed by the user using the player on the box. A detailed noise analysis is performed to demonstrate the feasibility of the proposed solution. Further work is being done in multiplexing multiple tutorials in spatial and temporal domain to support lot more tutorials in a single TV channel and analyzing their acceptability and effect in overall broadcasting business.

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