Embedding Metadata in Analog Video Frame for Distance Education

Arindam Saha, Aniruddha Sinha, Arpan Pal, and Anupam Basu

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 developing countries including India. 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) 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 new 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.**

Index Terms—**Distance education, metadata in analog video, satellite broadcast.**

I. Introduction

The demand for rural distance education in developing countries is increasing which is mainly due to the paucity of teachers. Despite the fact that 7 million people are engaged in the education system in India, which comprises of over 210 million students in 1.4 million schools, a recent report [1] indicates the poor quality of education system in most of the schools in rural India.

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 [2]. 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]. The same report states that 35% of overall India's internet connection has average speed of 256 kbps. 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 [2]-[5] 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 [6]. 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. There are few solutions proposed [7], [8] based on satellite connections however they either need costly specialized hardware setup or not suitable for Indian scenario. The DVB-RCS based solution [7] 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 [8] fails in India and other developing countries due to lack of the required infrastructure.

With the above motivation, we present a novel alternate approach for distance education solution based on the existing television broadcast network which uses a low cost HIP [9] based client box capable of taking analog video-audio as input and providing analog output to the TV. A method to embed the QA and other related data, termed as metadata, is proposed as part of the analog video. The challenge is to make the metadata embedding method robust enough to sustain video compression and digital to analog conversions in the digital TV broadcast.

The 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 payload size capacity for the teletext and the closed caption embedded in the VBI lines is 7175 bits per second per line. However, there is a limit for the number of VBI lines which is of the order of 20-40 lines. The VBI lines already contain teletext, closed captions and electronic program guide (EPG) as per the existing TV broadcast standard. Hence, there is a limit for number of free lines available to send new type of data. 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. In order to extract the question-answers (QA) while using the existing infrastructure of digital broadcast there is a need for

Manuscript received February 7, 2012. This work is done as part of the distance education solution for developing countries like India.

A. Saha, A. Sinha, and A. Pal are with Innovation Labs, Tata Consultancy Services Ltd, India (e-mail: ari.saha@tcs.com, aniruddha.s@tcs.com, arpan.pal@tcs.com).

A. Basu is with Indian Institute of Technology, Kharagpur, India. He is a Professor in the Department of Compute Science (e-mail: anupambas@gmail.com).

specialized software to handle the metadata in the HIP based client box which is responsible to extract the QA from the analog video-audio signal.

The above method also enables the rhetoric questionnaire (RQ) [10] to be broadcasted allowing the sequence of questions to be determined in run-time based on the responses of the user. However, the treatment of RQ is out of the scope of this paper.

II. Architecture

A. System Architecture

In the architecture 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. In the scenario of broadcasting the education content along with the QA, it is required to embed all related information into analog video frame and time multiplex the information along with the tutorial video, so that it can be extracted by the client HIP box from the input analog video-audio signal.

The standard EPG for every TV channel is transmitted as part of the digital MPEG2 transport stream (TS). This EPG information is extracted by the STB and presented to the user. Based on this information the timing for a particular program in a TV channel is known by the user.

The TV channel meant for distance education is selected in the STB. This channel carries various tutorials throughout the day. The HIP box is responsible to detect and record the desired tutorial as selected by the user. In order to achieve this, it is necessary to have a part of the EPG information, containing the broadcasting schedule plan of the tutorials, to be available in the HIP box. Thus the EPG information for the tutorials is also embedded as part of the analog video frames.

In this paper, the analog video frames selected to transmit metadata (QA and tutorial EPG) are termed as special frames. The bits of the metadata are converted to symbols and then inserted as part of the pixels in the special video frame which is described in sub section B and C in this section.

The detailed block diagram of the overall system is shown in Fig. 1. 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 video, as EPG for the tutorials. Finally, it generates the video and audio elementary streams for a particular tutorial using standard video and audio encoders. The procedure is detailed in sub section B and C of current section.
- 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 and the associated QA. The procedure is detailed in sub section D in current section.
- 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 [11] hence not explained in this paper.

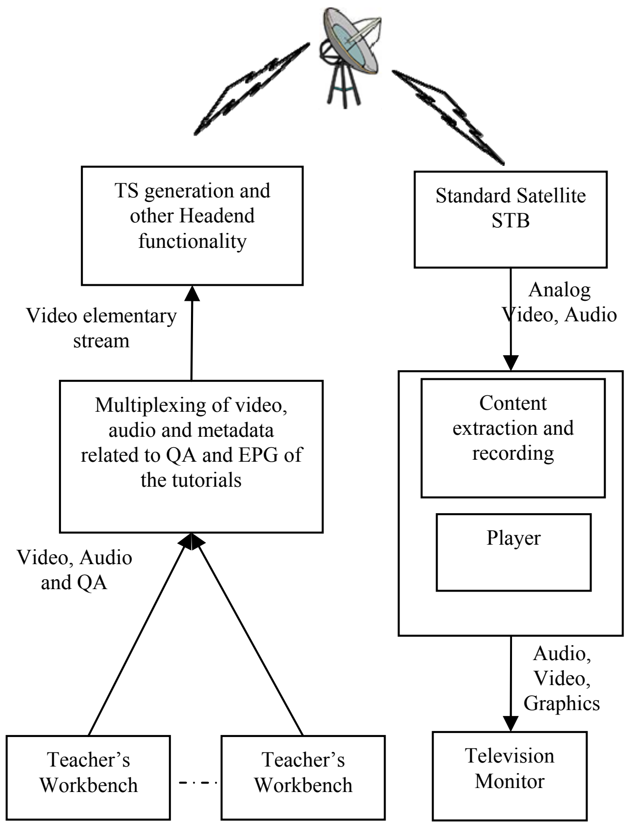
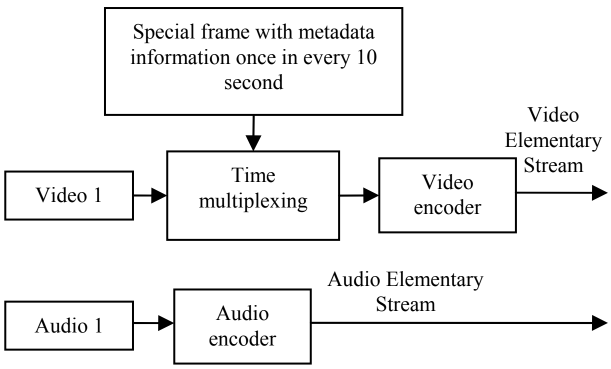


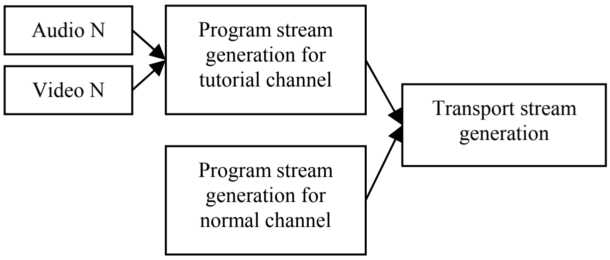
Fig. 1. Architecture for Distance Education using Satellite Broadcast.

B. Broadcast Content Creation

The video, audio, Q&A and EPG are multiplexed to create the broadcast content.



(a)



(b)

Fig. 2. Content Creation in Broadcast – (a) Video, audio and metadata multiplexing to create elementary stream, (b) Generation of transport stream (TS).

The detail of the multiplexing is shown in Fig. 2(a). A special video frame is multiplexed once in every 10 second along with the tutorial video. The special frame contains the QA and the EPG related information in the form of metadata. The standard tutorial video frame rate is 25 frames per sec (fps). Thus for every 250 frames one extra special frame is inserted. The details of the metadata embedding process in special video frame are given in this section. The multiplexed video is encoded using a standard video encoder (MPEG2) and the audio is encoded using the audio encoder (AAC) to generate the elementary streams as shown in Fig. 3(a). The TS is generated from the video and audio elementary streams as shown in Fig. 3(b).

Usually the QA is occasionally present within the tutorials; hence an indicator bit in the special frame indicates the presence of QA session. Once the QA session starts the indicator bit will be set to "true" and all the questions, the difficulty level of the each question, their options, correct answer and the duration for displaying the question are inserted in the form of metadata in the special frame. The syntax for the QA and EPG are given in sub section 5 and 7 of this section.

A. 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.

1. Barcode – indicator for the special frame
2. Pilot pattern – synchronization point for the payload of the metadata
3. Indicator bit for the presence of QA
4. Details of the QA whenever required
5. Present time stamp
6. Tutorial id and name of current video stream
7. Tutorial ids of the future ones and their start time (EPG)

This section provides the detailed information on the metadata creation, insertion and extraction process. It also provides the details of different types of metadata including barcode, pilot patterns, QA and EPG.

B. Barcode

The barcode present in the special video frame contains the following information.

1. Symbol definition (8 bit).
2. Pilot bit length (8 bit).
3. Pilot bit pattern (48 bits approx).
4. Pilot bit start location X, Y (16+16 = 32 bits).
5. It is assumed that every line will start at X point in the special frame.
6. Length of the data inserted in a line from point X (16 bits) in the special frame.
7. QA contained in current special frame or not.(1 bit)
8. QA offset in no. of lines from top.(15 bits)
9. EPG offset in no. of lines from top.(16 bits)

Thus total barcode payload is 144 bit or 18 char.

C. Symbol Creation

The metadata embedded in the pixels of video frames undergo following operations during the process of TV broadcast, which change the values of the pixels.

1. Video encoding (MPEG2) during broadcasting.
2. On the receiver side, after the MPEG2 decoding in the STB, the digital pixels (YUV) are converted to analog (CVBS) by the STB as shown in Fig. 1.
3. The client HIP box receives the input analog signal (CVBS) and converts to digital (YUV) for further processing.

In the above operations, the values of different pixels change which makes it challenging to extract the metadata embedded in the pixels of video frame. It is also seen that each pixel value has a biasing effect on the adjacent pixels due to the video encoding and digital to analog conversion. 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 due to offset the effect of gamma in TV display [12]. Accordingly, the symbol definitions for one byte, two bytes and three bytes are chosen and shown in Table I. The effect of noise on the robustness of the symbols is analyzed in section VI. The information on the chosen symbol definition is put in the barcode.

TABLE I: DIFFERENT TYPES OF SYMBOL DEFINITIONS FOR EACH INSERTED METADATA BIT

Symbol Length	Bit - 0	Bit - 1
One Byte	0x11	0xEB
Two Byte	0x8011	0x80EB
Three Byte	0x801111	0x80EBEB

The insertion process for a three byte symbol is shown in Fig. 3.

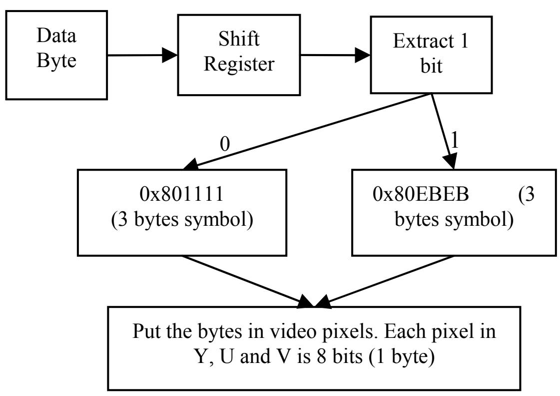


Fig. 3. Metadata Insertion Process for Three byte Symbol.

A comparison of the payload capacity for barcode and different types of symbols as a function of pixels occupied by them is shown in Table II.

TABLE II: COMPARISON OF PAYLOAD CAPACITY (IN BITS) FOR BARCODE AND DIFFERENT TYPES OF SYMBOLS

Size in Pixels	Barcode	One byte symbol	Two byte symbol	Three bytes symbol
60 x 60	152	3528	1800	1200
80 x 80	624	6272	3200	2133
100 x 100	1072	9800	5000	3333
120 x 120	1840	14112	7200	4800
140 x 140	2568	19208	9800	6533

As the payload capacity of barcode is small compared to 3-byte symbol, it is used to send very low volume yet critical information related to the pilot pattern and the offset of QA and EPG payloads. This allows the design to support the use of dynamic pilot pattern and change in symbol length on the fly to support changing noise conditions of the satellite channel.

A. Pilot Pattern

The pilot pattern is inserted to obtain the synchronization point for the metadata payload. It is seen that pixel location, at which the pilot symbols are inserted in the transmitter, gets shifted by one or two pixels when received by the HIP client box. The reason for the shift is mainly attributed due the fact of digital to analog (CVBS) conversion by the digital receiver followed by the CVBS to YUV pixel conversion by the HIP client box.

Hence the synchronization point for the payload is determined by matching the pilot pattern with the received pixels. This matching is based on energy detection using a matched filter [13], [14] and is realized using the cross-correlation technique as shown in Eqn. 1.

$$y(t) = \sum_{i=0}^{N-1} p(i)\, r(t-i) \qquad (1)$$

where r(t) is the received pixels and r(t-i) is the ith shifted pixel in raster scan. The pixel values corresponding to the pilot symbols are p(i) and N is the number of pixels occupied by the pilot symbols.

The pixel point Pt 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.

$$Thr = 0.75 * \sum_{i=0}^{N-1} p(i)\, p(i) \qquad (2)$$

The chosen pilot pattern is based on a row of Hadamard matrix [15] 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.

B. Tutorial Related EPG

The special frame contains the following information for each tutorial for next 24 hrs in the EPG.

1. Ascii name of tutorial (50 chars = 400 bits)
2. Tutorial ID (32 bit)
3. Duration remaining of the tutorial (32 bit in seconds)
4. Time to live (TTL) for the tutorial (32 bit in seconds). This is the time remaining before the tutorial starts airing.

In case a particular tutorial is yet to be aired, then the "duration remaining" for the tutorial provides the total duration of the tutorial. The currently broadcasted tutorial will have the TTL value as 0 and the "duration remaining" will be the remaining broadcast time for the same to terminate.

If we assume that the duration of tutorials are 1 hour each, then there can be information for 12 tutorials.

Thus the EPG needs (400+4+64+32+32+32)*24 = 13536 bits.

C. Video Audio Related Metadata

The information required to extract the video and audio is present in the special frame in every 10 sec. Each special frame will have the tutorial ID of 32 bits length for current tutorial.

D. QA related Metadata

During the QA session, the information on the questions and related answers are inserted in the special frame. It contains the following information:

1. Question header
2. Question payload length
3. Question is in ascii characters. There may be 256 characters (approx)
4. Answer header
5. Answer payload length
6. Options for the answer. This may be 256 characters (approx) for each option.
7. Correct answer
8. Duration for displaying the question

The number of bits occupied by the QA depends on the texts present in the questions, their options and its correct answers. On average it is seen to occupy 8000 bits for each QA.

E. 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 as shown in Fig. 4.

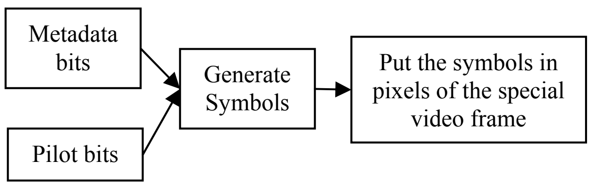


Fig. 4. Multiplexing of metadata in pixels of special video frame.

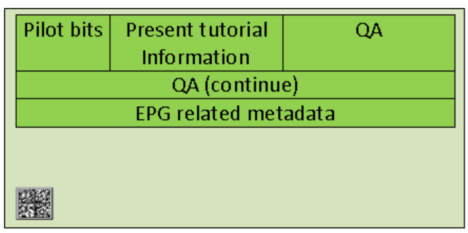


Fig. 5. Layout of the video frame for Special frame.

The barcode, pilot bits, metadata, video and audio 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 related metadata and EPG related data as shown in Fig. 5.

F. Extraction of Tutorial

At the receiver end, the metadata is first extracted from the special frame in HIP box. This metadata provides the QA and EPG information. The content extraction and recording process is done by the following steps as shown in Fig. 6.

1. Detects the special video frame
2. Extracts the EPG from the special video frame
3. Extracts the required tutorial based on user selected input and the tutorial time information present in EPG
4. Extracts the QA and generates the HTML frames for questions.
5. Encodes the video with H.264 and audio with NB-AMR
6. Generates the multiplexed AVI file
7. Generates a metadata file linking the questions for the HTML files and the AVI file. This is useful during the playback of the tutorial.

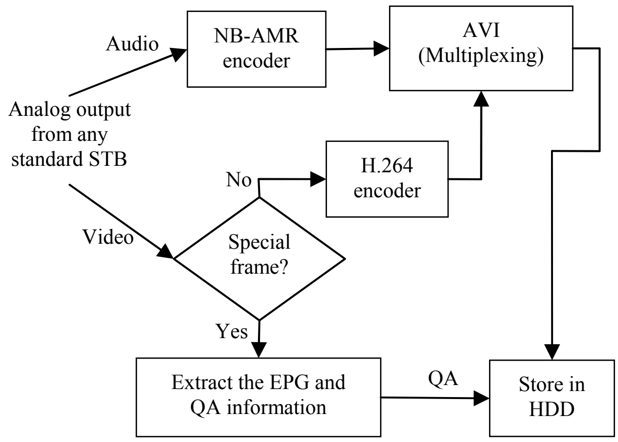


Fig. 6. Content Extraction in HIP Client Box for Satellite Broadcast.

G. Extraction Process

The barcode and metadata extraction process in special frame is shown in Fig. 7. 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, which is described in pilot pattern section. Once the pilot symbols are detected then the QA and EPG related information are extracted.

III. Selection of Required Tutorial

Initially, when HIP starts for the first time, it gets the EPG information from the special frame. The detection of the special frame is based on the barcode as detailed in extraction section. The EPG is extracted within 10 seconds which is the interval for the special frame. This creates a list of tutorials available for next one day. User chooses one tutorial for recording from the list. After user selection, HIP will get a coarse idea to the time frame of the broadcast for the required tutorial from the EPG. If the selected tutorial broadcast time is later than current time then HIP goes to power save (sleep) mode. Once the scheduled time arrives, then it starts extracting the metadata information for the current tutorial and as soon as it finds the matching tutorial ID then HIP starts recording the tutorial along with the QA data. It stops recording at the end of the tutorial.

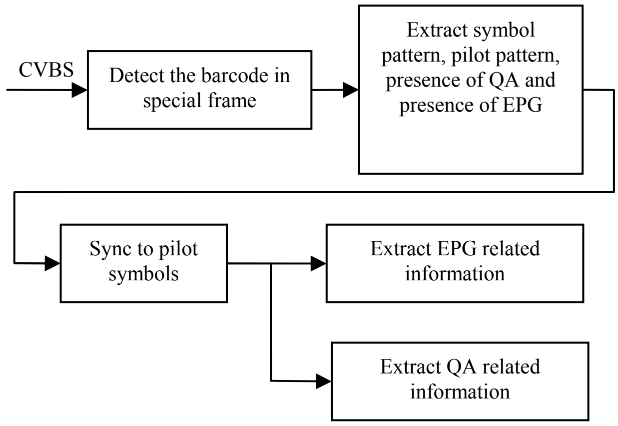


Fig. 7. Extraction process of barcode and metadata in special frame。

IV. Support for Multiple Audio Languages

The language selection in general is done at the digital STB, which is not specific to the tutorial channel but is a general procedure for any TV channel. The STB output is connected to the client HIP box. Thus the analog audio data with desired language is received by the HIP box for consumption by the user. At present the selection of the language for the QA is not supported and is part of the future work.

V. Lip Synchronization

Based on the information available in the EPG, the HIP box is supposed to record the desired tutorial from the start of the same. The audio and video gets broadcasted in the same way for other satellite channel, so the recording will capture the audio and video in a synchronized manner and lip synchronization is well established automatically. This assumes that the lip synchronization exists in the STB output or in the RF analog cable signal.

For some reason (power failure or other reason) if the HIP does not start recording from the start of the tutorial, then it will know the exact time information from where it has started recording, using the EPG information. This time is used to do the lip sync with the audio. This is also true if there is a loss in the video in the middle of the recording.

VI. Analysis on Noise Robustness

One of the major contributions of this paper lies in transmitting current tutorial information 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. The metadata information is initially converted to bits which are then converted to symbols before insertion in the pixels of the video frame as shown in Fig. 4. On the receiver side, the extraction process is based on the detection of barcode and pilot symbols as synchronization points as shown in Fig. 7.

In this section we perform the noise analysis on barcode, effect of symbol length, pilot pattern and the bit error rate (BER) of the received metadata. The results are generated with the MPEG2 encoded stream at 5 Mbps.

A. *Experimental Setup*

The experimental setup is shown in Fig. 8. A DVD player is used to simulate the analog output of STB. The barcode, pilot pattern, QA and EPG are embedded in the special frames and encoded along with the tutorial video. The multiplexed content is added with white noise generated by the "rand" function. The Eb/N0 is varied by varying the strength of noise. The final content (TS) is generated by encoding the noisy tutorial with MPEG2 encoder for video and AAC encoder for audio. The content is decoded by DVD player and passed to the HIP client box. Experimental results are generated by varying the parameters for barcode, changing the symbol length and noise strength.

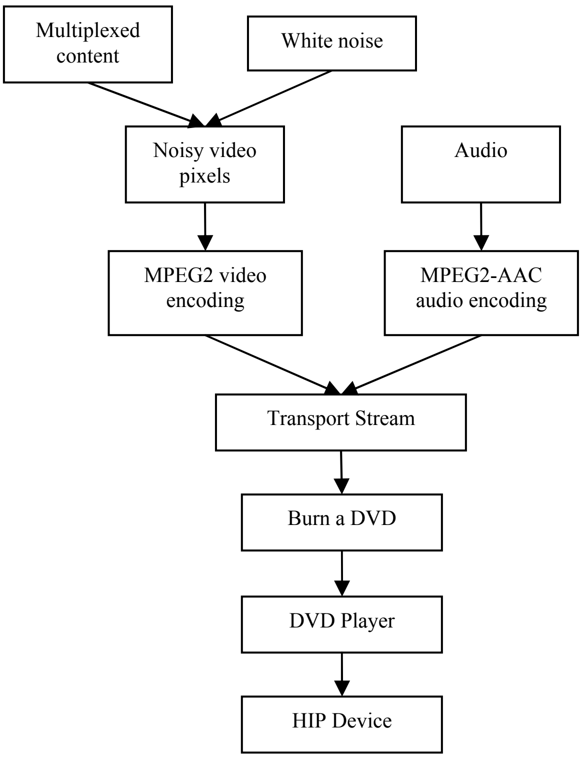


Fig. 8. Experimental Setup for Noise analysis.

B. *Barcode Noise Analysis*

We analyze the effect of the noise on the payload capacity of a 2D barcode (Quick Response – QR code [11]) is shown in Fig. 9. The pixels occupied by the QR-code are varied to derive the maximum payload it can carry for various SNR (Eb/N0) values.

The QR codes are considered to be equal in width and height. The area covered by the QR codes is plotted in horizontal axis and the maximum decodable payload for different size with different noise level is shown in vertical axis. The figure shows stable characteristics of QR code till Eb/N0 of 12.51 dB. The performance rapidly decreases if the Eb/N0 is less than 12.51 dB and it reaches to 6.89 dB with Eb/N0. Thus the performance of QR code is very robust for Eb/N0 levels above 12.51 dB.

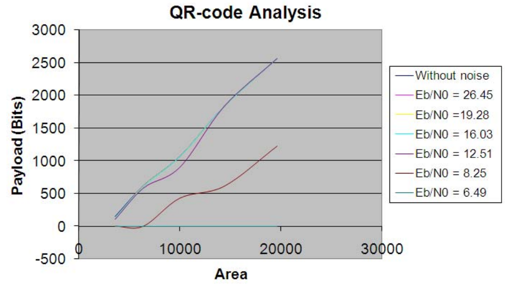


Fig. 9. Noise analysis of QR-code.

C. *Pilot Pattern Noise Analysis*

The noise response of the pilot pattern generated with 3 byte symbol is demonstrated in Fig. 10. 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 Eb/N0 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. The size of the QR code chosen is 80x80 which allows 100% detection even at Eb/N0 of 8.25 dB SNR level for a payload size of 144 bits.

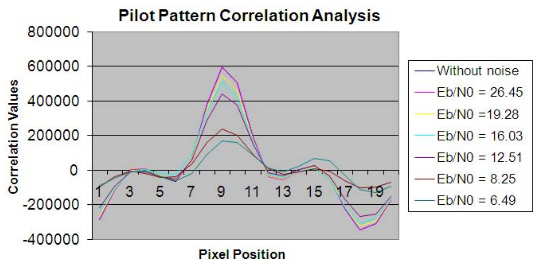


Fig. 10. Noise analysis of Pilot pattern.

D. *Noise Analysis for Symbol*

As described in symbol section, the symbol length can vary from one pixel to multiple pixels. On this paper we analyze the effect of noise for symbol lengths of one, two and three bytes.

Fig. 11 shows the average head-room of symbols of various lengths with different noise level. This is quite obvious that the average head-room will decrease as noise increases and the same is reflecting from the graph. One interesting observation is that the head-room difference between 3 byte and 2 byte symbol is quite large compare to that between 2 byte and 1 byte symbol. This implies 3 byte symbol is quite easily detectable even with high noise level.

The bit error rate (BER) against different noise levels for various symbol lengths is shown in Fig. 12.

The plot shows the average percentage bit error with noise. The plot shows there are some amount of error present with Eb/N0 of 16 dB for 1 byte symbol and no bit error even with Eb/N0 of 16 dB for 3 byte symbol. This graph also shows the robustness of 3 byte symbol.

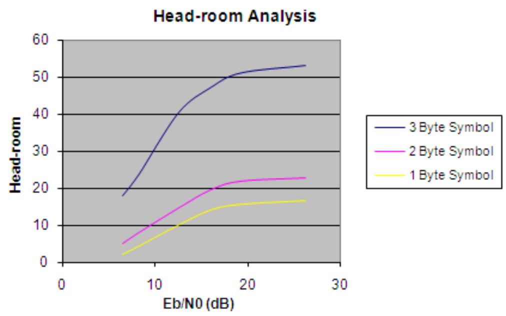


Fig. 11. Noise analysis on various symbol lengths.

A Comparison between barcode and symbol based insertion and their effect of noise is shown in Fig. 13.

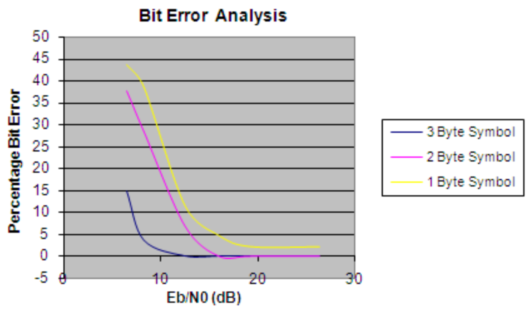


Fig. 12. BER for various symbol lengths.

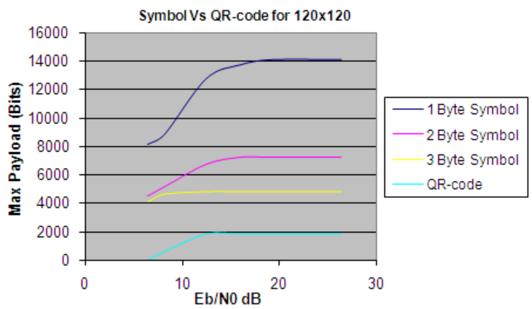


Fig. 13. Comparison of QR-code and various symbol lengths.

The plot shows the comparison between barcode and symbol based insertion with noise. This shows though the payload is quite big for 1 and 2 byte symbol but not so robust with noise and 3 byte symbol is quite stable and robust with noise. The QR-code also not as stable as 3 byte symbol and payload also quite less compared to 3 byte symbol. Hence we have used the QR code to transmit the dynamic information which is very small in size.

VII. Future Work

In the distant education environment, the tutorials are in the form of audio visual contents; need to be broadcasted with the support of local language and curriculum guidelines. In a country like India, it becomes a great challenge to support multiple states, each having their own curriculum and language, using a limited number of broadcast channels. Considering 6 tutorials (classes) per state, 2 languages per tutorial and 22 states, it comes to 264 tutorials, which requires 264 broadcast tutorials. Even if each tutorial is of 1 hour duration, it requires 11 channels to broadcast all the tutorials in 24 hours of a day. This is an infeasible proposition considering the economic structure of India and scarcity of available satellite bandwidth. Thus there is a need to design a system which will reuse the standard broadcast infrastructure and standard receivers to support the above requirement within 2 to 3 broadcast channels.

Instead of transmitting only a single tutorial in a broadcast channel, spatial and temporal multiplexing can be performed to further reduce the broadcast cost for each tutorial with a penalty in the visual quality. A user study needs to be performed to generate a model that characterizes the spatial and temporal multiplexing with the mean opinion score (MOS) of the video quality as perceived by the user. The user model can further be used to provide a trade-off between the cost for airing a tutorial and the price a user agrees to pay for the same.

In practical scenario the noise gets added in RF signal whose behavior needs to be analyzed by creating the actual broadcast setup. Moreover, the effect of other encoding standards (H.264) on the robustness of metadata retrieval for different bitrate needs to be analyzed.

VIII. 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. Barcode is used to embed certain critical and low bandwidth information related to pilot pattern and symbol pattern which makes the design flexible, whereas the 3-byte symbol is used to embed the metadata payload which can sustain less than 10 dB of E_b/N_o. 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.

References

[1] Report on "State of the Internet" Akamai Technologies, http://www.akamai.com/stateoftheinternet/ Q3 2010.

[2] P. Basu, A. H. Thamrin, S. Mikawa, K. Okawa, and J. Murai. Internet technologies and infrastructure for asia-wide distance education. In Proceedings of International Symposium on Applications and the Internet (SAINT'07), 2007.

[3] B. B. De Franco and H. C. Oliveira, "A Communication Architecture For E-Learning And T-Learning Integration," IADIS International Conference, pp.- 334-338, ISBN 978-972-8924-68-3, 2008.
[4] F. B. Brown and Y. Brown, "Distance Education around the World," Chapter One of book "Distance education: strategies and tools" By B. D. Willis, ISBN-10: 0877782687, 1994.
[5] G. Arger, "Distance education in the third world: Critical analysis on the promise and reality," Open Learning, vol. 5, no. 2, pp.9–18, 1990.
[6] S. Murray, "India digital TV forecasts," Digital TV Research, http://www.ekmpowershop4.com/ekmps/shops/broadbandtv/india-digital-tv-forecasts-1-5-users-132-p.asp, 2011.
[7] N. G. V. Kumar, M. Sarkar, V. Agarwal, B. P. Chaniara, S. V. Mehta, V. S. Palsule, K. S. Dasgupta, "Digital Video Broadcast Return Channel via Satellite (DVB-RCS) Hub for Satellite Based ELearning," *International Journal of Multimedia & Its Applications*, vol. 3, no. 1, pp. 133-143, 2011
[8] P. Galajda, S. Marchevsky, J. Gamec, M. Gamcova, and S. Pillar, "Infrastructure For Packet Based E-Learning Services Provided Via Satellite," *Acta Electrotechnica et Informatica*, vol. 9, no. 1, pp.74-80, 2009
[9] A. Pal, C. Bhaumik, M. Prashant, and A. Ghose, "Home Infotainment Platform", Proc. of International Conf. on Ubiquitous Computing and Multimedia Applications, (UCMA2010), Miyazaki, Japan, June 2010.
[10] S. Wattamwar, T. Oberoi, A. Jindal, H. Ghosh, and K. Chakravorty, "A Novel Framework for Distance Education using Asynchronous Interaction", ACM MM MTDL 2011
[11] "QR Code Standardization", http://www.denso-wave.com/qrcode/qrstandard-e.html.
[12] "Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios", Recommendation ITU-R BT.601-7, 03/2011
[13] D. Cabric, A. Tkachenko, and R. Brodersen, "Spectrum sensing measurements of pilot, energy, and collaborative detection," *in Proc. Military Commun. Conf. (MILCOM)*, pp. 1–7, 2006.
[14] J. Proakis, Digital Communications. New York: McGraw-Hill, 2001
[15] J. Seberry, B. J. Wysocki, and T. A. Wysocki, "On some applications of Hadamard matrices," *Metrika*, vol. 62, pp. 221–239, 2005.

Aniruddha Sinha B.E. in Electronics and Telecommunication Engineering from Jadavpur University, Kolkata, India, in June-1996 and M.Tech in Electrical & Electronics Communication Engineering with specialization in "Integrated Circuits and Systems Engineering" from IIT-Kharagpur, India in Jan-1998. Since 2007, he is associated with the Innovation Labs, TCS, Kolkata, working as a senior scientist R&D in the field of embedded signal processing for ubiquitous applications. Prior to that, he has worked with Motorola, India, in the field of embedded signal processing for mobile phones and set-top-boxes for almost 10 years. He has published more than 15 papers in referred international conferences in which most of them are IEEE sponsored. His current research interest includes context extraction and modeling of user for intelligent human machine interaction. Mr. Sinha is a member of IEEE.

Arindam Saha has received B.Tech. in Computer Science and Engineering from Kalyani University, Nadia, West Bengal, India, in July-2004. Since August-2008, he is associated with the Innovation Lab, TCS Kolkata, working as a researcher in the R&D field of embedded application. Prior to that, he has worked in Tata Elxsi Ltd and Ingenient Technology in the field of embedded domain of set-top-boxes for totally almost 4 years. He has published 2 papers in different international conferences.

Arpan Pal is a B.Tech and M.Tech from Indian Institute of Technology, Kharagpur, India in Electronics and Telecommunications. He has more than 19 years of experience in the area of Signal Processing, Communication and Real-time Embedded Systems. Currently he is with Tata Consultancy Services, where he is leading the TCS Innovation Lab, Kolkata under the theme of Intelligent Infrastructure. His main responsibility is in conceptualizing and architecting assets, and leading a team of researchers for creating solutions and applications in the area of Intelligent Infrastructure like Smart Buildings, Smart Cars and Smart Cities. Earlier he had been with Defence Research and Development Organization (DRDO) of Indian Govt. working on Missile Seeker Signal Processing. He has also worked with Macmet Interactive Technologies, leading their real-time systems group in the area of Interactive TV and Set-top boxes. His area of interests includes Frugal Engineering, Sensor Data Analytics; Interned-of-Things based Applications and HCI for ubiquitous systems. He has more than 30 publications till date in reputed Journals and Conferences along with a couple of Book Chapters. Mr. Pal has filed for more than 25 patents and has three patents granted to him. He serves on the Technical Program Committee of several International Conferences. He is also a reviewer for Elsevier Journal for Signal Processing: Image Communications, EURASIP and Journal of Computer Technology and Applications.

Anupam Basu has received B.E. and M.E degress from Jadavpur University, Kolkata and his Ph.D degree from IIT Kharagpur, India. Presently, he is a Professor in the Computer Science & Engineering Department, Indian Institute of Technology, Kharagpur. He has also been a visiting professor at the University of California, Irvine. His area of research interests includes Artificial Intelligence, with special emphasis to Languages, User Interfaces and Computer Assisted Education. Prof. Basu is a fellow of Indian National Academy of Engineering and an Humboldt Fellow. He has received multiple distinguished awards including the "da Vinci Award" by the Engineering Society of Detroit, U.S.A and Multiple Scelerosis Society of Michigan, U.S.A (2004), National Award for the Best Innovation for the Physically Challenged, Govt. of India (2007), Sir J. C. Bose Memorial Award(2004). He has more than 170 papers in international journals and peer reviewed international conferences.