Copyright Protection Scheme for Digital Television Content

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Abstract

We have developed a copyright protection system aimed at empowering the content provider to dictate the terms for free-to-air digital TV recording. The system proposes embedding copyright instructions into MPEG2 content to be telecasted so that the complying set top boxes would not be able to bypass the terms such as expiry period of recording or prohibition of recording of any specific program. After the expiration of the program recording rights, as determined by the telecaster, any recorded program is deleted. The system also uses encryption to prevent content copying to external storage devices.

Keyword: Digital television copyright protection, self-destructive recording.

1 Introduction

Digital TV is becoming more popular in Australia, USA, Europe and in South East Asia due to its clarity in video and sound as well as its potential to provide interactive Television experience. All major TV networks in Australia are currently broadcasting in digital formats with few already telecasting for limited hours per day in more feature-rich High Definition (HD) with Dolby Digital sound track.

However, this truly unique experience can only be fully realized only if content providers agree to telecast material such as latest Hollywood movies over their networks. As has been reported recently, Hollywood major movie producers raise copyright issues in releasing their movies to be shown on free airwaves due to potential of perfect reproduction of their material by the end users [1], [2]. This has been a fact of life in its limited exposure to digital TV in Australia.

Currently a handful of digital TV enthusiasts are capable of recording digital TV content to hard disks for later viewing or copying. Unless some mechanism is brought forward to curtail this copyright violation(s) (from the movies producers perspective) ordinary consumers tend to loose more. The major producers may decide to lower the quality of their telecast so that reproduction would be lower than DVD quality. However, this issue can be tackled by video content copyright management scheme

that address many facets of this problem. The content provider would be in a position to change the authenticated set top providers list regularly through control information, there by removing any threats to the misuse of digital content. The proposed system would address the above issues of duplication of the content recorded from free-to-air, over-the-internet, satellite and cable digital TV receivers. The system would record the intended program with a time stamp as indicated by the content provider. This time stamp determines the lifetime of the recorded program and would delete it at the end of its life expectancy. The system hardware is setup in such a way that the recoded encrypted material would not be retrievable by removing the storage device (hard disk drive) to an external device.

2 The Worldwide Digital Television Adoption

All digital TV variants can carry both standard definition television (SDTV) and high definition television (HDTV). All early SDTV television standards were analog in nature, and SDTV digital television systems derive much of their structure from the need to be compatible with analog television. In particular, the interlaced scan is a legacy of analog television. Attempts were made during the development of digital television to prevent a repeat of the fragmentation of the global market into different standards (i.e. PAL, SECAM, NTSC). However, the world could not agree on a single standard, and hence there are two major standards in existence: the European DVB system and the US ATSC system, plus the Japanese system ISDB.

Most countries in the world have adopted DVB, but several have followed the US in adopting ATSC instead (Canada, Mexico, South Korea). Korea has adopted ISDB for satellite mobile broadcasting. There could be other specialized high-resolution digital video formats in the future for markets other than home entertainment. Ultra High Definition Video (UHDV) is a format proposed by NHK of Japan that provides a resolution 16 times greater than HDTV.

In current practice, HDTV uses 1280x720 pixels in progressive scan mode (abbreviated 720p) or 1920x1080 pixels in interlace mode (1080i). SDTV has less resolution (704x480 pixels with NTSC, 768 x 576 or 1024x576 with PAL), but allows the bandwidth of a DTV channel (or "multiplex") to be subdivided into multiple sub-channels. The TV stations can use subchannels to carry multiple broadcasts of video, audio, or any other data, and can distribute their so-called "bit budget" as necessary, such as dropping one sub-channel down to a lower resolution in order to make another one available to show a wide-screen movie. Often, this is done automatically, using a statistical multiplexer.

Multiplexes can even reduce their overall bit budget and digital bandwidth, in order to reduce the transmission bitrate and make reception easier for more distant or mobile viewers. Today most viewers receive digital television via a set-top box, which decodes the digital signals into signals that analog televisions can understand, but a slowly growing number of TV sets with integrated receivers are already available. Access to channels can be controlled by a removable smart card, e.g. via the Common Interface (CI) standard. Some signals carry encryption and specify use conditions (such as "may not be recorded" or "may not be viewed on displays larger

than 1m in diagonal measure") backed up with the force of law under the WIPO Copyright Treaty and national legislation implementing it, such as the US Digital Millennium Copyright Act.

Another flavor of digital TV that is appearing is Interaction Digital teletext which, is an enhanced teletext service based on XHTML and CSS. Many countries, including Finland, use Multimedia Home Platform DVB-MHP for digital teletext. An alternative is the MHEG-5 platform used terrestrially in the UK. Digital teletext is supposed to provide interactive services, but for this a separate "return path", such as a telephone line or Internet connection is required. ISDB has adopted ARIB STD-B24 for interactive services. ISDB has labeled interactive services as data broadcasting. ARIB STD-B24 system is base on BML. BML is modified XML language for data broadcasting. ISDB has been providing EPG, news, weather forecast, traffic information, stock market conditions, educational program, interactive game program, TV shopping via the internet etc.

3   The DVB-T System Overview

The DVB-T system specification for terrestrial digital television was approved by ETSI in February 1997 [3]. As with the other DVB standards, MPEG-2 sound and vision coding forms the basis of DVB-T. Under DVB-T system, Australia uses a transmission scheme based on Coded Orthogonal Frequency Division Multiplexing (COFDM), which allows for the use for either 1705 carriers (usually known as `2k'), or 6817 carriers (`8k') [3]. In this method, concatenated error correcting is used. The `2k' mode is suitable for single transmitter operation and for relatively small single frequency networks with limited transmitter power. The `8k' mode can be used both for single transmitter operation and for large area single frequency networks where the guard interval is selectable. Moreover, the `8k' system is compatible with `2k' system. The data carriers in the COFDM frame can use QPSK and different levels of QAM modulation as code rates, in order to trade bit rate against irregularity. The DVB-T compliant signals can also be carried over cables. However, the DVB-T specification is part of a family of specifications covering also satellite (DVB-S) and cable (DVB-C) operation.

All above schemes use MPEG-2 coding for video and audio MPEG-2 type of multiplexing. They have common features in the error protection strategy. The main difference is the modulation method which is specific to the relevant bearer (satellite, cable or terrestrial) [4]. The available data capacity is also different, as higher bit rates are offered on cable and satellite. Moreover, the Australian DVB-T specification also supports High Definition Television transmission and Dolby Digital AC-3 surround sound specification. As well as providing much improved picture and sound quality, a digital TV signal also uses the RF spectrum (airwaves) very efficiently. In the 7 MHz space (width) occupied by an analogue TV channel, up to five equivalent digital SDTV signals can be allowed [5].

MPEG audio has a long and successful worldwide history in consumer electronics, computers and is the audio standard for DVB-T Digital Television systems. Moreover,

MPEG2 audio provides 5.1 multi-channel sound, stereo with surround sound, stereo and mono.
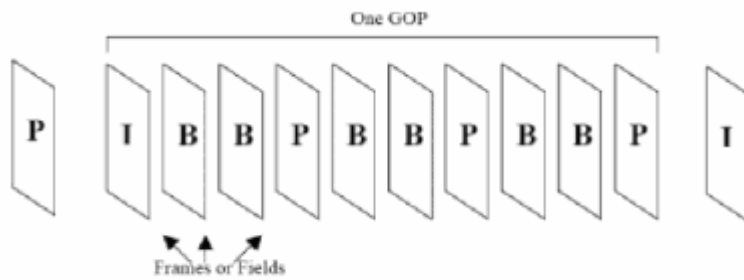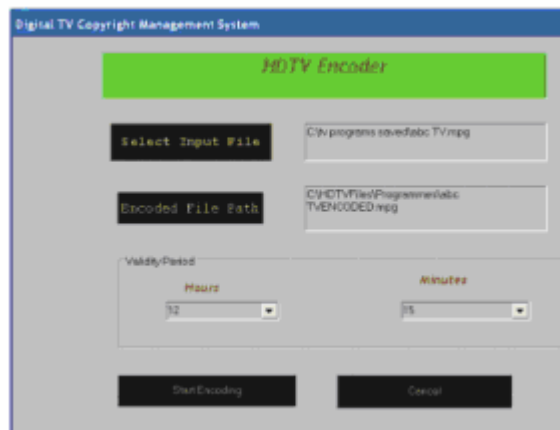

Fig. 1. Group of Pictures (GOP)

Fig. 2. Screenshot of the copyright data encoder

4   The System Implementation

Digital TV content which is essentially a MPEG2 video stream and a Dolby Digital audio stream [6]. A video stream or a sequence consists of number of Group of Pictures (GOP). These GOPs are intended to allow random access into the sequence.

In our research, our goal was to design and develop a system that would delete a recorded program after the specified validity period. The system doesn't allow recording of any program that lacks the content provider's approval. For example, the telecaster might let any user record and distribute Footy matches and would only let fairly new Hollywood movie to be played back (recorded material) only for two days or non at all in their hard disk and would not play if the hard disk is moved to a different machine.

The above goal can be achieved by inserting some control data into each GOP header which starts with start code namely 000001B8 in 14 hexadecimal. These 32-bit byte-aligned start codes provide a mechanism for searching coded bit streams for commencement of various layers of video. Start codes also provides a mechanism for re-synchronizing in the presence of bit errors. An arbitrary number of zero bytes may precede a start code. The zero bytes can be use to guarantee that a start code occurs within a certain location, or by rate control to increase the bit rate of a coded bit stream. Usually the header carries the time code information, editing information and optional user data. The first encoded picture in GOP is continually an 'I' picture as shown in Fig. 1. This provides an 'I' picture with adequate frequency to permit a decoder to initiate accurate decoding. Furthermore, one of the most usual and efficient GOP structures are 12 frames long and represented as follows: IBBPBBPBBPBB.

4.1 Control Signal Embedding

The control signal is embedded in each GOP after the start code. The control data include time stamp indicating the validity period as well as the recording rights (recording is allowed ore not and a time stamp only if allowed). It is important to embed the control data in every GOP header as a user may want to record a program at any instant. This arrangement ensures system capability to determine the control data at any instant in time as a video stream may pass few GOPs any second. A screenshot of the developed encoder is shown in Fig. 2 and signal embedding is shown in Fig.3.
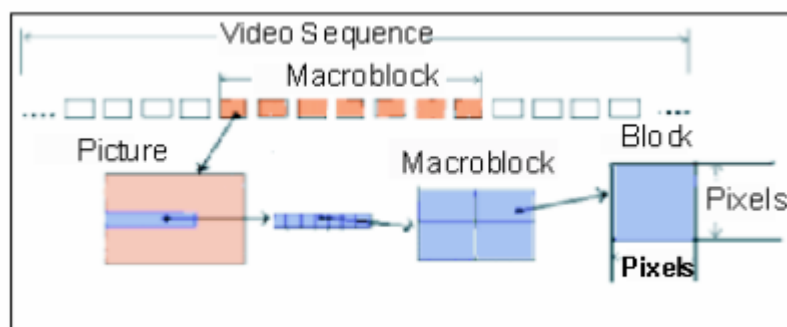

Fig. 3. Control signal is embedded into each GOP of the video stream

4.2 Control Signal Recovery

Once the digital video stream is received, the system reads the program number and the recording rights in every GOP header to determine its recording rights. The set top box can then decrypts the video stream and record it as a newly encrypted version with a time stamp. If the user specifies the set top box to record continuously, the system records different programs with different time stamps as the GOP carries different program numbers and different rights associated with them.

4.3 System Recording Manager

The system recording manager is assigned with the task of reading the time stamp of the recorded programs. This is carried out at every hour when the set top box power is on or at the start of every system rebooting. It regularly checks the time stamps to validate the recordings and delete them at the expiry of their rights as indicated in Fig. 4.
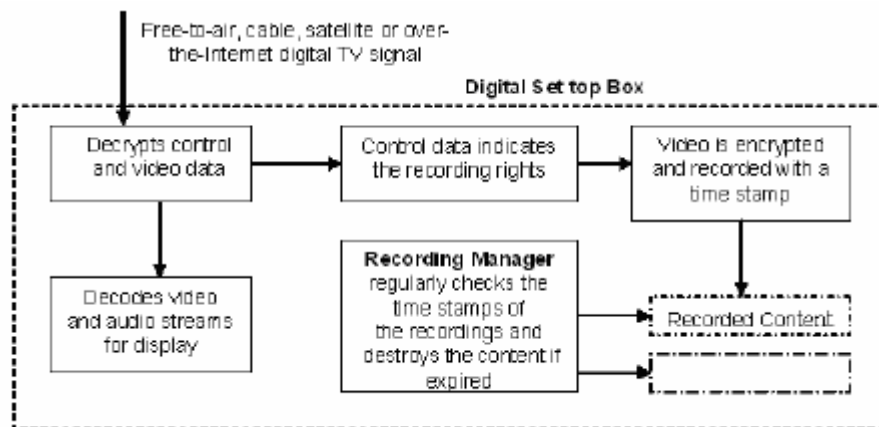

Fig. 4. The overview of the copyright management system in a set top box

5 Experimental Results

Currently the system is implemented using Visual Basic on a Windows XP PC. Initially the three recorded MPEG2 streams, each of 15 minutes duration, have been selected for the experiment. These streams are assigned permanent recording status, no recording status and 1.75hour recording status and are labelled as prog001, prog002, and prog003 respectively. On the receiver side, the system separates the embedded control signal from the video stream. The system now records the program if so desired depending on the rights indicated by the control stream. Currently, the recorded video streams are zipped with password protection so that it is not possible to be removed from the system and played back elsewhere. The system recording

manager opens up the zip archives every hour and reads their time stamps which indicate their life spans and deletes them if they have expired. Out of the three programs we intended to record, only two were recorded as prog002 control data indicates no recording rights. The two recorded programs are of 15minute duration with one having permanent recording rights and other having 1.75 hours of life span. The recording manager performed as expected having deleted the second recording after 2 hours. Fig. 5 shows a screenshot of our implemented system using Visual Basic.

Fig. 5. Screen shot of the implemented system

6 Summary and Conclusions

This proposed copyright management system deters malicious reproduction and distribution of high quality digital TV video content violating copyright laws. It also proposes mechanism to safeguard high quality content delivery to the users without compromising content ownership.

The concepts outlined here can be extended further to develop a interactive digital television system. For instance, much more information such as phone numbers and voting options can be encoded into the mpeg2 bit stream. The settop box may separate phone numbers and voting or program rating options which can then be selected by pressing a button on the remote controller. The ratings and votes can then be transferred from the settop box to a central data collection point with the use of GPRS

enabled mobile phone. This is a simple example of many related technologies that we are currently developing.

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He has published over 40 internationally peer-reviewed research articles and obtained substantial industrial and government grants for research. He has recently been appointed as an OZ reader in Mathematics, Information and Communications by the Australian Research Council (ARC) and has held many internationally accredited positions such as International Liaison Chair for ICIC2005. He has also been a reviewer of many international conferences and journals such as IEEE Transactions on Information Forensics and Security, IEE Proceedings of Vision Image and Signal Processing, IEE Electronics and Visual Communications and Image Representations.