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A DVB-Compliant Electronic Cinema Solution

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Abstract

This paper describes a DVB-compliant HDTV transmission system for Electronic Cinema applications. Such applications include classical film projection as well as live event transmissions into cinema theatres. The concept has been successfully proven within the CyberCinema ESPRIT project under the lead of the European Audiovisual Center, Babelsberg, Germany.

The CyberCinema demonstrator has shown the feasibility of electronic film distribution via satellite to cinemas. A demonstration including five cinemas allover Europe has been set up in October 1998 showing outstanding picture quality and verifying the robustness of the DVB-compliant transmission system.

In this paper we will focus on the HDTV codec „Universal Coding System“ used within this project and the implementation of DVB compliant in-band signalling using DVB Service Information (SI).

Introduction

Electronic Cinema is an exciting new area with a number of innovative applications beyond the classical film projection. An Electronic Cinema network forms a virtual community between people located at different cinema sites participating in events like sports games, pop concerts etc., projected in high resolution quality.

The system concept we propose is a broadcast-oriented concept with the inherent capability of live transmission in high definition quality. The concept allows for both offline-transmission of digitised and compressed movies with local storage on dedicated servers as well as and live transmission of MPEG-2 HDTV signals leading to an outstanding quality sufficient for large screen projection.

A first demonstrator of this concept has been successfully set up and tested within the CyberCinema funded by the European Commission within the ESPRIT framework.

System Overview

The Electronic Cinema Solution we propose is based on at least one playout center which acts as a scheduler for the content to be transmitted. The playout center generates program information by means of DVB-compliant event information tables. Each individual cinema site, equipped with a satellite dish and a Server-PC, may select from an Electronic Program Guide the events it wishes to participate in. Participation in an event is two-folded: In case of a movie transmission the appropriate action is either record onto a local tape drive or immediate processing by directly feeding an MPEG decoder. MPEG-2 signals corrsponding to live events will usually be directly fed to the UCS decoder.

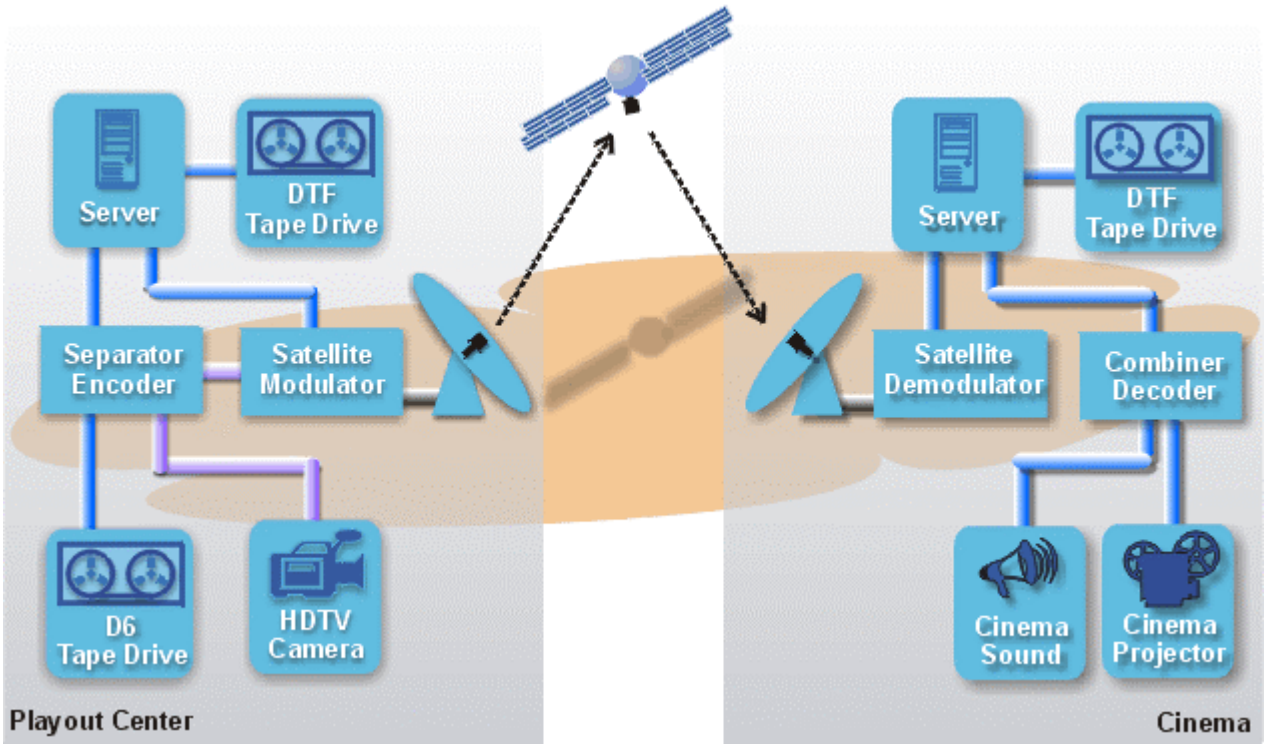

Figure 1: *System Diagram*

Fig. 1 shows the end-to-end system diagram. Regarding the source material, two cases are considered: *Movies*, digitized by a film scanner and *live sources* like the output signal of an HDTV studio. The HDTV standard currently used is the EUREKA95 standard (1250/50/2:1), other upcoming standards may be applied. Since HDTV MPEG-2 (e.g. ML@HP) codecs are not widely available yet at a reasonable price, a solution called „Universal Coding System“ is used within our project. The basic idea behind is to split the HDTV signal by a special signal processing unit into four independent SDTV signals for compression. The four SDTV signals will be compressed synchronously according to MPEG-2 MP@ML and the resulting elementary streams will be multiplexed into a single MPEG-2 transport stream (TS). The TS will be transmitted and, on the receiving side, de-multiplexed into four video streams which will be decoded by four decoders. The output of those decoders will be re-combined to an HDTV signal. Details of this codec will be given in the next chapter.

Dedicated Servers, based on standard Windows NT computers, have been developed for the playout center and the electronic cinema sites. The servers are equipped with a DVB I/O board which is able to generate and receive synchronous DVB compliant bitstreams.

The bottleneck we have figured out is currently the projection system. Electronic projectors are able to illuminate screens up to about 12 meters sufficiently. Commercially available projectors map the incoming signal to a native internal resolution of maximum 2000 by 1500

pixels. So the overall resolution is limited by the resolution of the projector rather than the HDTV codec. Upcoming new projection technologies, like the laser display, might overcome this problem in the future.

Universal Coding System UCS

The MPEG-2 coding standard which was finalised at the end of 1994 covers all aspects of possible video applications, ranging from TV distribution and audio-visual communication services to the storage of video sequences. The standard itself is laid out as a generic standard. This means that the standard is not related to a fixed application but it gives room for a number of different functionalities which are suitable in an optimal manner for certain types of applications. By freely choosing the compression factors and the appropriate coding profile and level, it is possible to reach the optimal picture and sound quality for the available data rate in a special transmission service.

Due to the strong demands for cheap equipment for the distribution and receiving of digital TV programs, up to now the only available chipsets on the market are for the MPEG-2 Main Level. This Main Level is very often combined with the functionalities of the Main Profile that takes into account the characteristics of standard TV distribution. The predominance of this type of MPEG-2 chips (MP@ML) leads to the fact that also other applications which normally need more complex functionalities have to be implemented by using these MP@ML-chips to stay cost efficient.

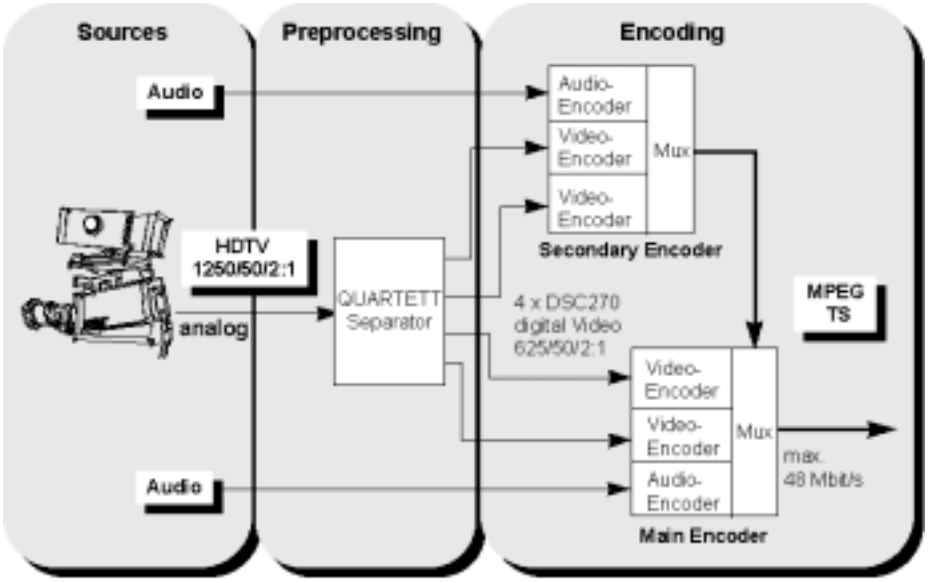

Figure 2: *UCS Transmitter*

Deutsche Telekom was faced with this situation when it started a project dealing with high quality video conferencing using HDTV picture format. So, in co-operation with MATRA Communications (now Thomcast) and other companies a system [1] was designed that takes advantage of the availability of the MPEG-2 chips for the processing of HDTV sequences and gives additional flexibility by using the same equipment for the coding of multiple standard

TV programs or stereoscopic programs (3DTV). The components and the input and output signals for the transmitter are shown in **Fig. 2**.

For the encoding of HDTV images using MP@ML-chips, a pre-processing has to be done in order to split up the HDTV image in several parts of appropriate size that can be handled by the standard encoding equipment. With the **Separator** analogue HDTV signals are digitised and split into four data streams. Each of these signals belongs to one quarter of the original image and is output as a serial D1-signal (DSC270) which transmits frames of 720 x 576 pixels at a clock rate of 270 MHz. Afterwards, these data streams are fed into two cascaded encoder systems, each one compressing two quadrants of the HDTV image. Both systems are implemented in VME-cabinets that are housing, beside the controller board, the boards for video and audio coding and the transport stream multiplexer. Each encoder delivers the MPEG-2 Transport Stream output signal in DVB-PI parallel signal format either ECL or LDVS level. The **Main Encoder** is equipped with an additional input board for accepting the transport stream coming from the **Secondary Encoder**, thus implementing the ability to cascade the two systems. For an easy configuration and maintenance of the whole system both cabinets can be connected to a PC-based external controller operating under Windows95™.

The final transport stream with a maximum data rate of 48 MBit/s is delivered by the main encoder at a DVB-compliant interface. So, for lower data rates it can directly be fed into appropriate transmission equipment such as modulators in a cable head-end or in satellite uplink stations.

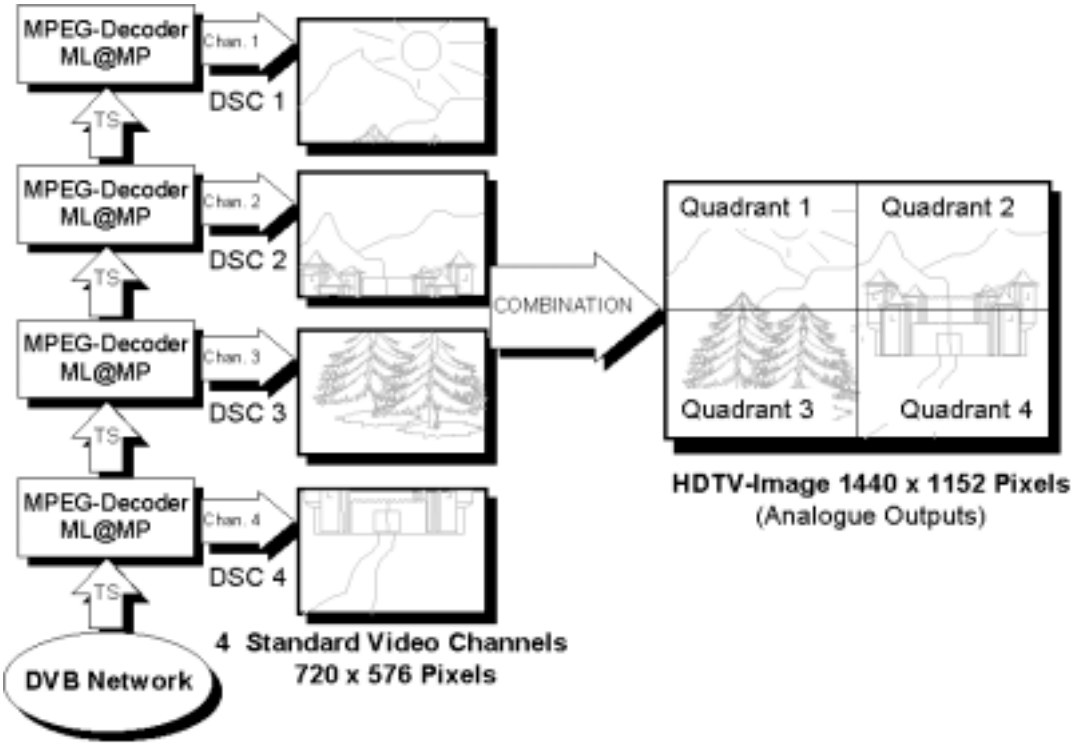

Figure 3 *UCS receiver*

Fig. 3 shows the principles of decoding and recombining the HDTV signal at the receiver site. The incoming transport stream is fed to four MPEG-2 MP@ML-decoders. Each of them processes one of the contained 'programs' marked by the related PIDs (Program Identificators), thus decoding one of the quadrants of the original HDTV image. The four generated video signals (again in DSC270 format) are then reassembled to a complete analogue HDTV signal by the **Combiner**.

The described universal encoding system was implemented as a group of modules that allow the use of consumer-oriented equipment that is available on the market today at reliable prices. Of course the principle of splitting the HD image into several sub-images in the spatial domain demands an absolutely synchronous processing of the resulting signals in every stage of coding and transmission. So, a considerable amount of engineering had to be done to develop this flexible system. The UCS can now handle up to four standard TV programs or one HDTV program in the European HDTV standard. As the channels are strictly synchronous, stereoscopic TV programs can also be transmitted by the UCS. In this case two separate views (left channel and right channel) at standard TV resolution are transmitted to gain a 3D-effect at appropriate displays.

The system can be adapted in short time to the customer's needs and to the characteristics of different transmission channels in a flexible way. In addition the separator/combiner system (developed for Deutsche Telekom and sold under the product name 'QUARTETT' by

ViDiSys Inc., www.vidisys.de) is also perfectly suited for recording and playback of HDTV sequences by multi channel video disk recorders (e.g. Tektronix Profile).

Applying DVB Service Information to Electronic Cinema

DVB Service Information (SI)

The MPEG-2 standard provides means to embed tables carrying Service Information (SI) into Transport Streams (TS). MPEG-2 tables are not continuous streams like audio and video but merely tables of fixed or variable size that are merged periodically into a transport stream. MPEG-2 defines a small set of tables (Program Allocation Table PAT; Program Map Table PMT, Conditional Access Table CAT; Network Information NIT) only. Within DVB, these MPEG-2 defined tables are referred to as Program Specific Information (PSI). PSI contains basic information about the transport stream it is embedded in. The PAT (one per TS) e.g. provides a list of all programs within a TS, in particular a pointer to the PMT of each program. Each program's Elementary Streams (ES) can be referenced by the PMT of that program.

The SI tables defined by DVB [3] in contrast may also contain information about events and services carried by other multiplexes (transport streams). The DVB-SI information can be used for Electronic Program Guides that may use e.g. Event Information Tables (EIT) to display information about upcoming and running events of a DVB system.

Within the electronic cinema framework, we propose EIT tables for automatic content retrieval applications in local cinema servers where upcoming events may be pre-selected for later storage onto tape or disk. Since a TS also contains a time reference this avoids also problems with unsynchronized local and central clocks.

Time and Date Tables (TDT)

The TDT is employed to carry UTC-time and date information. This table has a fixed size and simple structure.

Event Information Table (EIT)

The EIT is considerable more complex in structure and semantic contents. An EIT is made up of one or more events that in turn carry properties like *start_time*, *duration*, *running_status* and one or more event descriptors.

There are about ten descriptors dealing with different topics like Parental Rating or Content classifying. User defined textual information can be applied to short event descriptors or extended event descriptors.

Within one program, at most one event should have the *running*_status set to „running“. For the actual transport stream, there are two schemes to notify about upcoming events: The „present/following“ scheme contains only information about the present and the following event of a program. This scheme is mandatory when applying EITs. Furthermore, „event schedule information“ may be embedded into a TS. These (optional) EIT carry information about a non-limited number of upcoming events of a particular program.

Integration of SI into UCS Transport Streams

Transport Streams generated by the UCS are MPEG-2 compliant bitstreams containing the PAT and one PMT of the HDTV program carried.

Considering an E3 transmission system, each of the four video ES might have a bit rate of about 8 Mbit/s. The multiplexer of the UCS fills the TS with NULL packets up to the output rate that has been configured (34.368 Mbit/s in the case of E3).

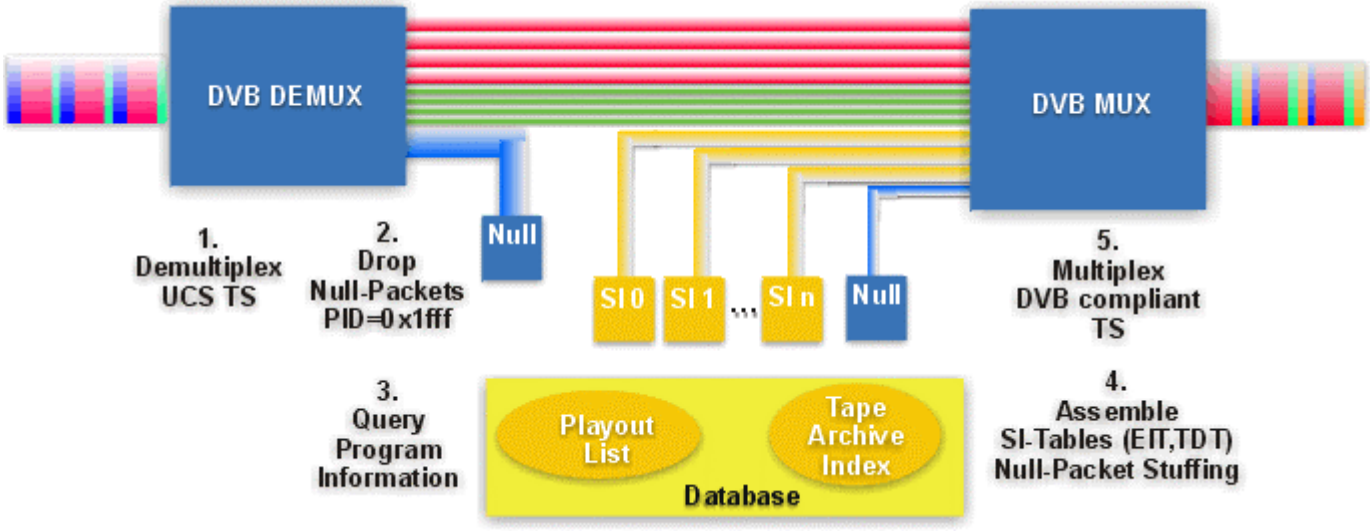

Figure 4: *Integration of Service Information into UCS Transport Streams*

The following strategy (see **Fig. 4**) for including SI information will be applied on the playout center site of the system:

- Demultiplex UCS-TS. The TS is split into its elementary video and audio streams. The null-packet stream is dropped on demultiplexing.
- Query Program Information: a database is provided to maintain information about the tape library content and also to provide program schedules prepared by a Program Editor.

- Assemble SI-Tables and multiplex DVB compliant TS**:** Setup appropiate Event Information Tables (events, descriptors) and TDTs and pass them to the multiplexer. This is an ongoing supervised process since table contents change from time to time.

The multiplexing itself will be done in real-time by a dedicated piece of hardware.

Electronic Cinema Program Editor and Electronic Cinema Program Guide

In the CyberCenter (the playout center) a Program Editor allows to schedule events and controls the transmission. The embedded EITs and TDTs will be used as input for an EPG in the local cinemas, allowing for event pre-selection as described in the section „System Overview“.

Cyber Cinema Demonstrator

In a first demonstrator the feasibility of the concept has been proven. Due to the short time frame for this demonstrator no DVB-SI tables have been merged into the transport streams transmitted. The server implementation on the playout center site feeds the satellite modulator with pre-recorded streams from DTF tapes. On the local cinema site the streams are received and stored onto DTF tapes according to a proprietary outband signalling scheme.

So the emphasis of the demonstrator setup was to prove the general usablity and reliablity of hardware and software devices for operating at a constant bit rate of 34.368 Mbps.

Server hardware components comprise an Intel Pentium-II 266MHz processor, 128MB RAM, Adaptec UW SCSI PCI-adapter, Viewgraphics Dynamo MediaPump PCI-adapter and Sony DTF drives. The MediaPump adapter implements, in our case, two DVB-LVDS interfaces.

The server OS is Windows NT4.0, the demonstrator application provides an easy-to-use GUI interface that was written using MS Visual C++.

Server Implementation (Playout Center)

Demonstrator

The demonstrator application of the Playout Center controls **capture** and **send** processes as described below.

Capturing Process

The capturing process is initiated by starting **replay** audio from DA-88 tape and video from D6 tape and also starting **capture** from the server application simultaneously (**Fig. 5**). This is a little bit tiresome in that the distance between tape drives and server may be several meters. To solve the problem, begin-of-transmission indication must be achieved. If no video or audio

signal is available the encoder produces a TS containing null-packets only. Therefore the beginning of the recording on DTF tape is triggered by the presence of non-null packets in the transport stream.

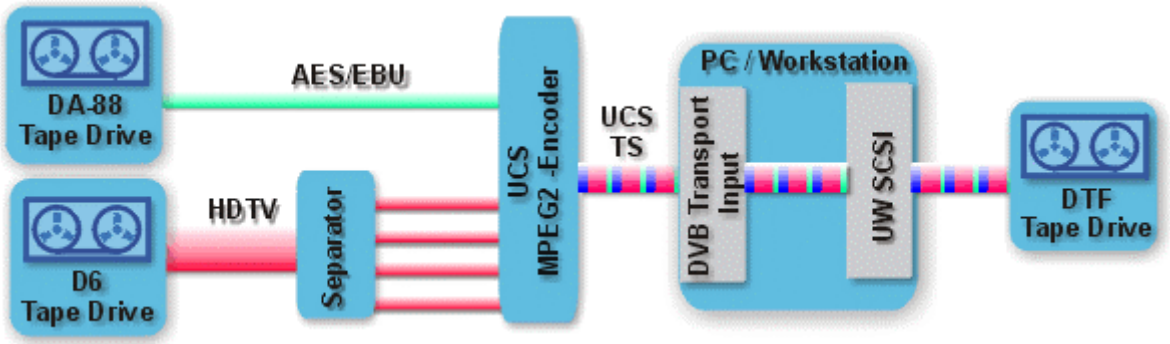

Figure 5: *MPEG2 coding and DTF mastering from D6 video tape and DA-88 audio tape.*

Sending Process

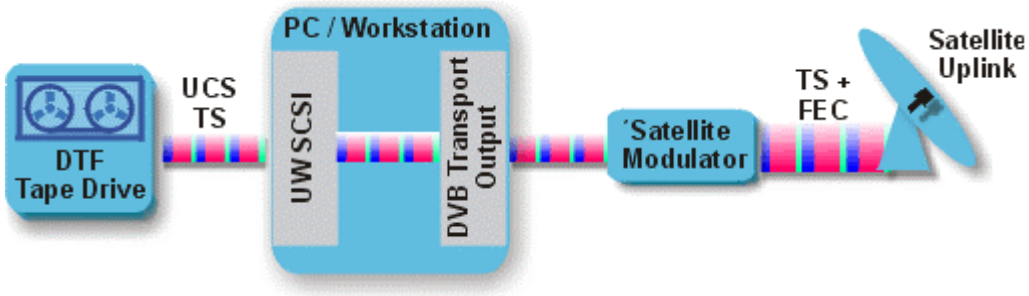

Figure 6: *Movie Broadcast*

The sending process is triggered simply by replaying the DTF tape. The TS is passed directly to the satellite modulator where FEC is added and then the TS is transmitted to the satellite. (**Fig. 6**) Given the server system clock runs properly, a timer can be used to pre-select transmission time.

Proposed Environment

The success of the demonstrator encourages us to announce development activities heading for an integrated broadcasting environment that should be capable to provide basic structures for electronic cinema movie distribution. The first archive extension will maintain about 100 tapes (i.e. 300h of play time).

Two *electronic cinema services* will be introduced that will be mapped to different classified EITs. Classification is applied according to DVB standard that defines four categories of EITs:

1. Actual TS, present/following event information

2. Other TS, present/following event information
3. Actual TS, event schedule information
4. Other TS, event schedule information

Current event information is mapped to an EIT of 1st classification, *program preview* is encodeed with an EIT of 3rd classification.

The playout center will be capable to support broadcasting, tape mastering and database activities simultaneously (**Fig. 7**).

DTF Mastering: The **capture** process is extended by adding a user interface for storing master tape content information to the tape archive database. Tape content information consists of movie related topics like *film title, director, actors, producer, play time, production date, summary* and so on.

Program Editor: The program editor enables the user to assemble a playlist of movies for broadcast and to determine a *program preview* to be integrated with SI. A typical user session for collecting a playlist will look like this:

- Get an empty playlist.
- Put movies to playlist by retrieving data records from tape archive database (*title in alphabetical order, actor, director, etc.*)
- Add the playlist to the *program preview* by assigning a time schedule. In case of a live event define *current event information* to be carried with EIT.

Broadcast Control. The broadcast control is capable to monitor the program database for loading and broadcasting appropriate tapes according to *program preview*. Programs can also be started manually by selecting directly from program database. The broadcasting process described in brief:

Lookup program database for actual preview if any program has to be started. If this is true or a program is started manually, it will encode *current event information* and *program preview* into EIT-SI and start transmission by multiplexing the prepared tables into TS. *Current event information* contains a database record set of the current tape, in case the broadcast is labeled to be a live event contributed by a network, user defined information can be applied.

The broadcast control also multiplexes a TDT with a fixed frequency that carries the current system time. The TDT is updated periodically according to desired time resolution.

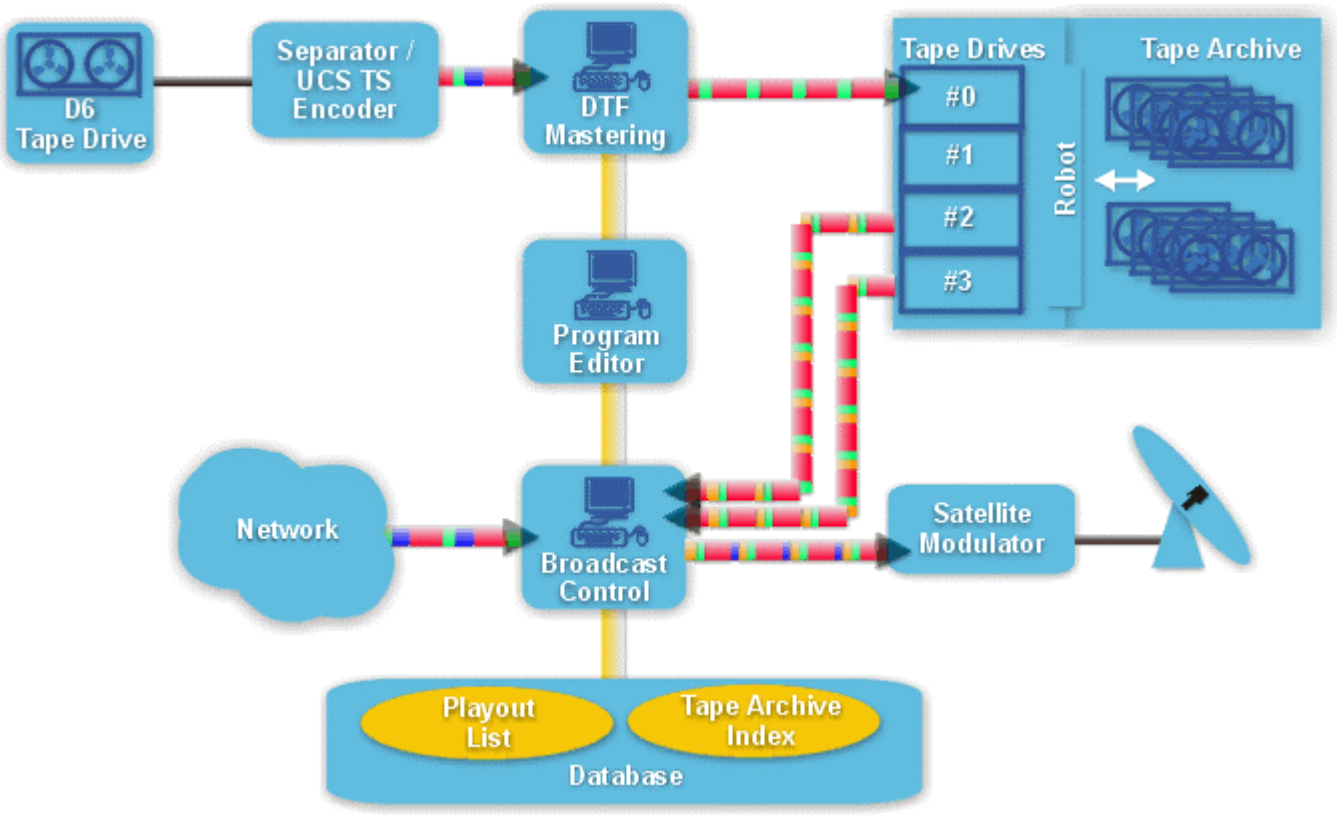

Figure 7: *Proposed Environment of a regular operating Playout and Content Management Center*

Server Implementation (Cinema Sites)

Demonstrator

The demonstrator application of the Playout Center controls **record, receive** and **replay** processes as described below.

Record

The recording process can be determined by adjusting a timer or can be launched manually by clicking the record button of the VCR-like DTF control. The incoming TS is written to tape (**Fig. 8**).

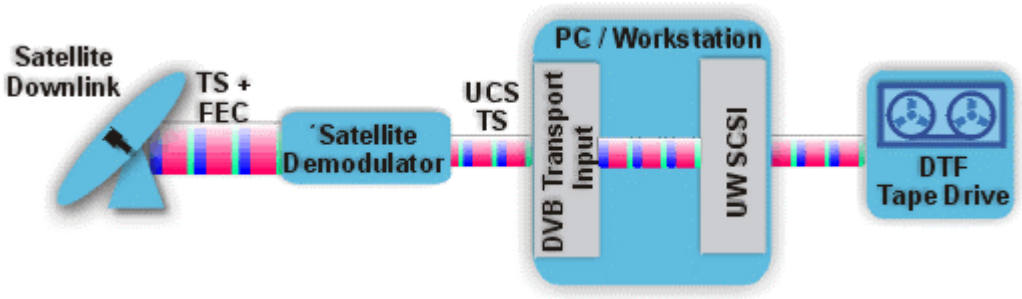

Figure 8: *Recording movie at cinema*

Replay

Film projection is started by replaying the DTF tape drive (**Fig. 9**).

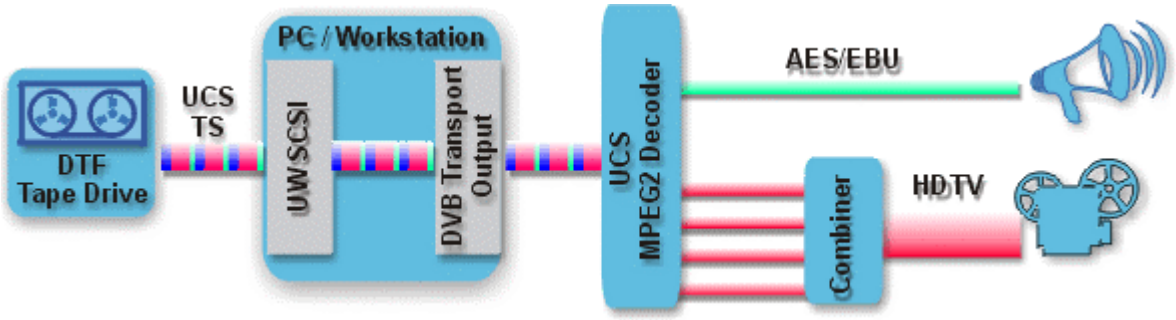

Figure 9: *Replay for projection*

Receive

The receiving process can be considered to be in TV mode in that you watch the broadcast program immediately on arrival. Hence the **receive** bypasses recording to DTF and just diverts the DVB input to the DVB output for projection. For now this only saves the need for unplugging the server from DVB input and connect the demodulator to the decoder directly. But if regular operation of electronic cinema will be established, also some scrambling will be involved that has to be undone on receiving.

Proposed Environment

The hardware at the cinemas will differ only slightly compared to the demonstrator environment. Regular operation requires additional decryption hardware and authorization facilities like smart-card devices. This is due to further investigations and developments.
Software enhancements are related to processing incoming transport streams in real time:

- *Current event information* related to the movie actually broadcasted is displayed.
- EITs are scanned for *program preview* entries which are passed to the electronic program guide (EPG) The operator may now select events from a list presented by the EPG in order to program the tape device for recording.

- Recording is started either manually or is triggered by evaluation of TDT which are matched against the programmed time.

Conclusions

In this paper a system concept for Electronic Cinema has been proposed. The applications that can be realised with this concept include digital movie projection as well as real-time transmission of live events in high definition quality. The concept is DVB-compliant in terms of DVB-SI usage that allows for in-band signalling of upcoming events and an Electronic Cinema Program Guide implementation.

A first implementation of the concept has been successfully proven within the CyberCinema project. The feasibility of transmitting digitised movies and live events on the same DVB-compliant network has been demonstrated.

Further development will include the implementation of a dedicated Conditional Access system as well as the enhancement of the server components in order to set up a consistent content management in the playout center and an easy-to-use, intuitive and reliable software for the cinema operator.

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Figures