White paper

Thomcast

B.R.T. Technology

For MPEG-2 video stream
bit rate transcoding

Multimedia and Digital Systems Unit

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Abstract

In the emerging full digital broadcast world, video compressed materials tend to be the standard element handled by all operators involved in the chain.
Video compressed materials are the result of an initial MPEG2 video encoding process, carried out by content providers or initial multiplex operators. This process is done with specific configuration parameters, among which the video bit rate is one of the most important as it fixes the overall quality as a compromise with the bandwidth necessary to carry - or store - the compressed material.

Operators who want to reuse this already available MPEG2 material, e.g. for secondary distribution or storage, may need to modify this incoming video bit rate value (i.e. reduce or smooth it) just to get a result with an acceptable lower quality and that copes with their system bandwidth or storage capacity constraints.

The purpose of this white paper is to introduce the Bit Rate Transcoding (**B.R.T.**) technology developed by Thomcast to address this need.

The aim of this technology is to provide an answer to the following situations:

- An archived master video material is often encoded at a very high bit rate (more than 10 Mbits/s) in order to preserve the maximum quality. When this video has to be broadcast, as the typical allocated bit rate is between 3 and 5 Mbits/s only, a bit rate down-transcoding operation is needed.

- In a secondary TV broadcasting station, which receives one or more programs and retransmits them through a channel with a lower available bandwidth, the original bit rate of the programs should be reduced; otherwise, some of the programs will have to be dropped.

- A similar case is a transponder diffusing a Multi Program Transport Stream generated by a statistical multiplexer, where each program is encoded with a variable video bit rate. If some of these programs have to be injected in another distribution network or stored on a server, a variable to constant bit rate transcoding operation may be necessary. This constant bit rate program can be remultiplexed easily with others, or requires less storage capacity than the former one. Otherwise the program will have be stored at the peak bit rate value.

- A digital TV or video program producer or distributor may want to provide electronic catalogues or preview versions with intentionally lower video quality or resolution, and distribute them to his customers before they decide to buy the normal quality programs. In that case, he will need to perform a transcoding operation on the original MPEG-video material to generate a lower bit rate MPEG video sequence of the exactly same contents.

Introduction

Digital video, including digital TV and digital multimedia materials, is taking more and more place in our private life and commercial activities because of its multiple advantages over the traditional analog TV and video cassettes and also because of the additional services it can provide. In the near future, it will replace the analog video as the analog color television replaced black & white in the past.

This evolution is the result of the development of several different technologies. The international MPEG-2 standard is a combination of different recent technologies in order to provide an optimal compromise between image quality, encoding/decoding complexity and the bandwidth needed for the distribution of these images. Using this standard, high quality video transmission only needs 3-5 Mbits/s of bandwidth.
Moreover, using the last high performance digital signal modulation and transmission technologies, multi-programs streams may be transmitted over one single program analog TV channel.
Finally, the MPEG-2 standard allows also an efficient storage of video materials, e.g. one high quality movie of two hours duration can be stored in a single DVD of 4Gbytes capacity.

Beyond the possible variations (DVB, ATSC, …), this international standard is today widely accepted and chosen for analog to digital transition in the broadcast world.

However, as the use of digital format for video materials is growing, the question of reusing these materials can be raised. Each sequence is first encoded with a specific format according to the initial constraints such as images quality, channel's bandwidth or storage media's capacity. When these compressed materials are to be reused (e.g. after their primary distribution) in different conditions, the initial encoding format may not meet the new requirements and a conversion is then necessary.

Bit Rate Transcoding or transrating is a conversion process that is mostly needed when:
- the capacity of the new transmission channel is lower,
- the storage capacity is critical,
- an intentional video quality degradation is necessary.

The transrating operation of a program applies essentially to the manipulation of the video stream, which represents the most of the bit rate in a program. Audio and other data only represent a small percentage. For example, in an one-audio/one-video TV broadcasting program, the stereo audio is encoded at a bit rate of 384Kbits/s at most (usually less than 256 Kbits/s) while the video is encoded at 3 to 4,5 Mbits/s which leads to a total program bit rate of about 3,5 to 5 Mbits/s.

Video bit rate is the number of bits used to represent a one second image sequence. This parameter has a direct relationship with the bandwidth needed to transmit the compressed video or with the necessary capacity for storing it. As a consequence, it is a very sensitive economic criterion. It is also one of the most important parameters for the final image quality. A higher encoding bit rate will result in a higher video quality and vice versa.

Transrating is an operation which aims to convert a valid MPEG-2 video stream, knowing or not its incoming bit rate, into a new valid MPEG-2 video stream with a different bit rate

(variable or constant in time), without changing the visual content or the display duration of the video sequence.

An up-conversion of the compressed video stream rate may be easily performed by adding padding bytes. A down-conversion is much more complicated: Due to the algorithms involved (and specified by the MPEG-2 standard), simple modifications of the data in the compressed representation domain cannot result in a valid MPEG video stream.
A simply coupled MPEG video decoder and encoder solution may perform transrating. But we will see in the next section that this solution is not efficient regarding economic and performance criteria.

As any other equipment and service, the highest quality to cost ratio must be provided so that operators may be able to integrate the solution into their system with a limited budget and then make profits with it.

The real time B.R.T. technology developed by Thomcast is very attractive in the sense that it offers:
- architecture optimization and cost effectiveness,
- low image quality degradation,
- low end to end delay.

This technology is very promising as it can be used in a wide range of applications where digital TV and video are manipulated.
Below is a non exhaustive list of the potential applications (Fig.1):

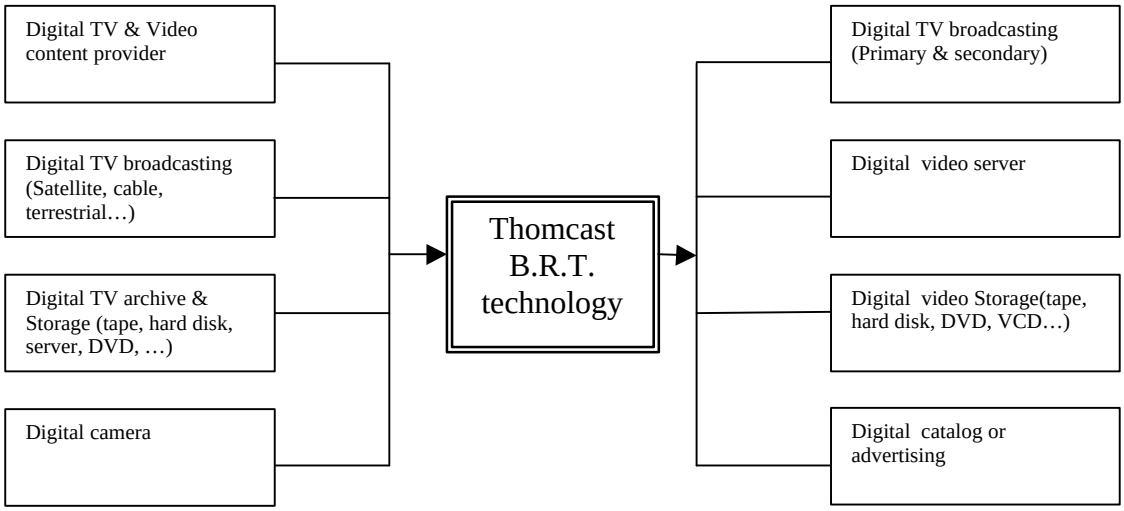

Fig.1 Applications of the Thomcast B.R.T. technology

In the following sections, the current technology for video bitrate transcoding is presented, as well as the limits of the simple decoder/encoder solution. Thomcast solution is then presented, followed by the road map of products implementing the BRT technology.

Video transrating: what today's technology offers

The easiest method to perform a video bit rate transcoding operation is to use a standalone decoder cascaded with a standalone encoder as shown in the figure 2. With the control of the encoder, the desired bit rate may be produced. Both high quality decoders and encoders are already available today.

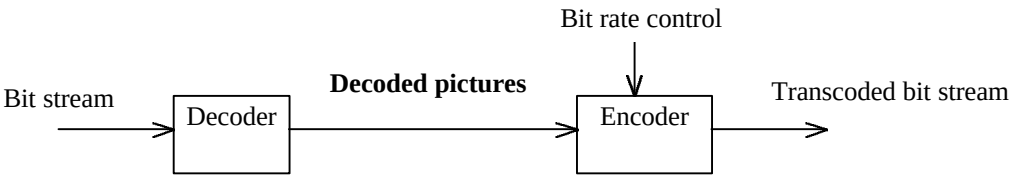

Fig.2 Transrating today's technology

But this trivial solution has some drawbacks:

- *Significant cost* : one complete decoder and one complete encoder are necessary, the latter being expensive due to the processing power needed by the motion estimation.
- *Video quality degradation* : as new encoding decisions will be taken, additional distortions will be introduced each time such a transcoding operation occurs. Experimental results showed that with the picture type changed by the second encoder (the IBP sequence is likely to be different), up to 2dB are lost in the new signal to noise ratio.
- *Necessary processing of the video related components*: If the incoming video stream has got related audio or data components, these have to be processed as well by the chain, which can lead to avoidable audio quality degradation or complex architectures to preserve these data streams.

Some recent solutions have reduced the image quality degradation by introducing a parallel information bus between the decoder and the encoder, which conveys a limited set of the initial encoding decisions. In preserving the GOP structure between both encoding processes, the results are better but these solutions are still expensive and don't address the video related components issue.

In such a context and based on its know-how in video and more generally MPEG-2 processing, Thomcast developed a new technology called **B.R.T.** (for Bit Rate Transcoding) for MPEG-2 video transrating with multiple objectives:

- reduction of global cost,
- image quality degradation optimisation,
- flexibility and robustness.

Thomcast B.R.T. technology overview

The basic principle of the B.R.T. technology is to provide a solution allowing to preserve all encoding decisions and to only requantize DCT coefficients to meet the new bit rate requirement. Experimental results published in scientific papers showed that the modification of the initial encoding decisions is the principal cause of the image quality degradation.

This is only possible if both the decoder and the encoder are embedded in an integrated architecture, i.e. they share the same resources and then may interact instantaneously.

An analysis of the processes involved in the decoder and in the encoder shows that many of them are symmetrical, and can be avoided in a video bit rate transrating operation. For example, the picture reordering stage in the decoder and in the encoder along with the corresponding memory may be removed. Moreover and as a result, no reordering delay is introduced in the operation. In addition, the memory necessary for storing reference pictures may also be shared by both decoding and encoding processes.

The integrated system becomes a single processing module, gathering both decoder and encoder functions, and receiving the video bit stream to be processed and the new bit rate value as shown below in Fig. 3.

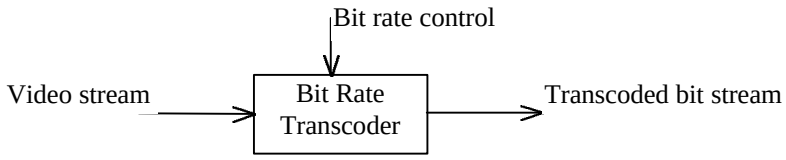

Fig.3 Thomcast integrated transrating solution

To handle the video related components, the B.R.T. technology is embedded in an architecture featuring remultiplexing capability. So they can be processed in parallel, without any modification, with the timing information preserved (components synchronisation).
The block diagram of such a system is shown below (Fig.4).

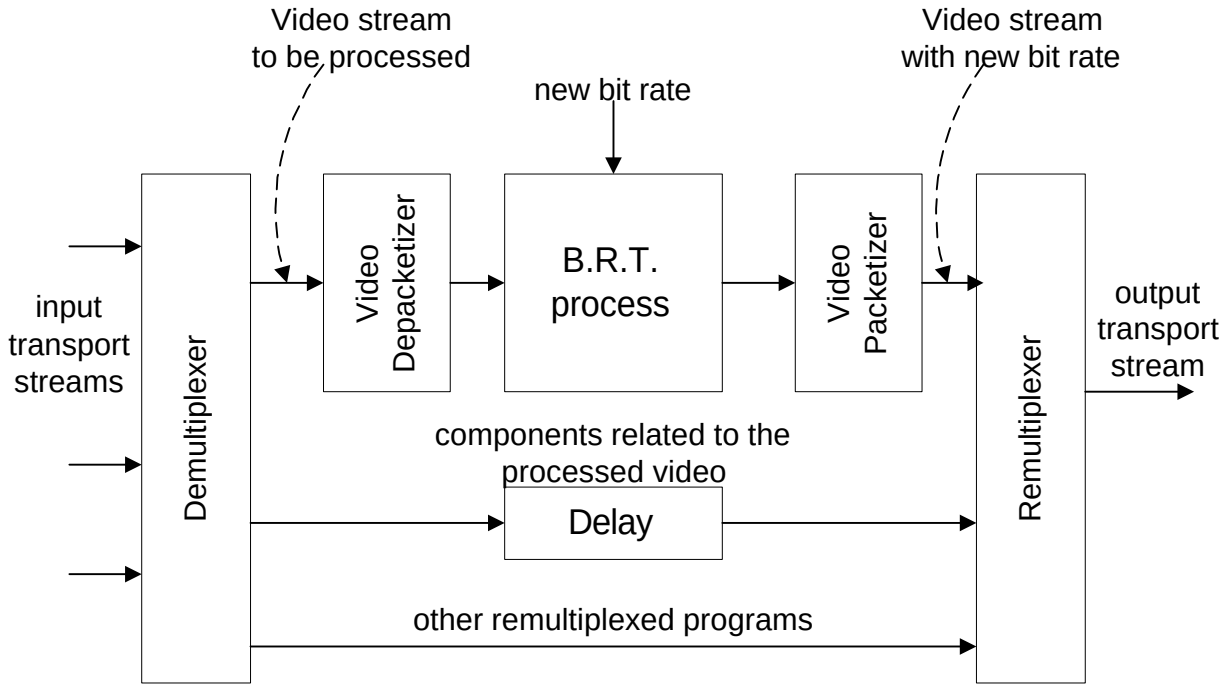

Fig.4 Thomcast MPEG-2 video B.R.T. system

As the targeted applications may differ by the type of video processing involved, two implementations of the B.R.T. technology have been developed:

- on PC stations, to offer the B.R.T. technology as an option to our existing line of video servers,
- on the Amber platform, with a dedicated hardware.

Both platforms conform to the Fig. 4 block diagram:

- our video servers feature the OpenMUX kernel, which is able to perform real time demultiplexing and remultiplexing.
- the Amber platform is built around the well-known Transmux core, dedicated to remultiplexing applications (1U high rackable unit).

Three different algorithm optimizations have been developed, that can run on either platform:

- the first one is dedicated to high quality transrating,
- the second one is optimized for low bit rate generation,
- the third one is a low cost but still very efficient solution.

Main features of Thomcast's B.R.T. systems

- MPEG-2 video compliant
  Thomcast's B.R.T. technology is able to process any valid MPEG-2 video at MP@ML (other profiles under development) and to generate bit streams compliant to the MPEG-2 standard.

- High image quality
  With Thomcast original bit rate control algorithm, the image quality of the transcoded sequence is maximally preserved. Experimental results show that transcoded image quality is very close to that resulted by a single pass encoder at the same bit rate constraints (with only about 0.52dB extra degradation on peak signal to noise ratio). Particular attention is given to the scene changes so that the transition degradation is minimized

- Dynamical bit rate control and VBV conformance
  The bit rate control is performed at picture level. It does not need a priori knowledge on the source bit rate and enables bit rate change at any picture. VBV is guaranteed, i.e. there will be neither underflow nor overflow in the VBV buffer.

- CBR and VBR as input and output
  As a result of our powerful bit rate control algorithm, the B.R.T. system may accept any constant bit rate (CBR) or variable bit rate (VBR) stream as input and generate CBR or VBR according to the user's demand as shown by the Fig.5.

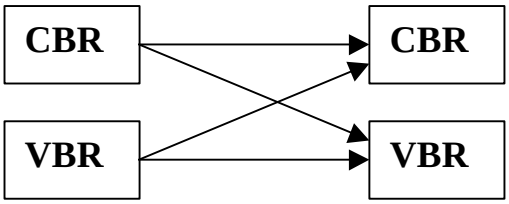

Fig.5: bit rate conversions supported by the Thomcast's B.R.T. technology

- Low cost:
  Thanks to the optimization of the B.R.T. algorithms, the system needs much fewer resources than a decoder/encoder solution does. The computational complexity and the needs on memory for operation are minimized. For some versions of the algorithm, a PC with an Intel processor running at 266MHz is sufficient for processing one video stream in real time.

- Low processing delay:
  The end to end processing delay may be crucial in real time transmission systems. As explained in the previous sections, the decoder/encoder solution introduces a non controllable and long delay because of the picture reordering operations. With our system this variable factor is removed. Only the necessary processing time and the VBV management time are needed.

- Different degrees of complexity to meet different applications requirements:
  Three solutions were developed for meeting different applications' needs:
  - Very low cost solution
    This solution is designed for the video manipulators for whom production cost are crucial and for whom the maximum image quality is not an absolute necessity. This may be the case for electronic advertising or network video diffusion.

    It should be noted that even with its simplicity, this solution is still a high quality solution, since it introduces only a 0.2dB extra degradation on the image quality compared to a high quality solution.

  - High quality solution
    This solution is designed for the applications where maximum image quality should be obtained. This is the case of digital TV distribution and broadcasting or video servers.

  - Very low bit rate generation
    This solution is designed for converting digital TV materials to very low bit rate applications such as internet video distribution, video CD distribution etc.

- Real time:
  The solutions are being implemented into Thomcast's Digital TV real time processing systems such as the SAPPHIRE video servers and the AMBER stream processors (remultiplexers).

Product road map

At IBC ’99 the B.R.T. technology will be demonstrated for the first time, running on our SAPPHIRE server platform.

SAPPHIRE is a family of PC-based MPEG video stream servers. The actual version of SAPPHIRE is able to record in real time MPEG transport streams and play live or stored program according to a play list or in live mode. Programs may be delayed, spliced and edited. With the introduction of the B.R.T. technology, SAPPHIRE will be able to transcode the bit rate of the video programs being recorded or during play-back.

- Transcoding during record will permit lower storage capacity, especially in case of variable bits streams that have to be recorded at their peak rate.
- Transcoding during play-back will offer the possibility to play previously stored high quality video programs (i.e. encoded using high bit rates) with a lower bit rate to meet distribution channel bandwidth.

The B.R.T. technology will be available on SAPPHIRE early 2000.

OpenMux® is a new generation MPEG-2 DVB PC-based software, operating as a real-time gateway for a wide range of broadcast and multimedia applications. It provides the most efficient way to multiplex in real-time a single transport stream from a wide range of heterogeneous sources, live or stored. The introduction of the B.R.T. technology will make OpenMux® even more powerful. The bandwidth of the output channel will be more efficiently used so that more programs may be multiplexed into one MPEG transport stream.

The B.R.T. technology will be available on OpenMux® early 2000.

The implementation of the B.R.T. technology on the AMBER remultiplexer is also under development. The AMBER remultiplexer is based on the proprietary and patented TransMux technology which features a highly integrated and powerful remultiplexing architecture, built around a dedicated ASIC. It is able to take up to 8 MPEG-2 DVB or ATSC compliant transport streams and multiplex selected programs into a new DVB or ATSC transport stream with different output formats. It features many characteristics including service deletion and insertion, input descrambling, output scrambling, dynamic configuration changes, opportunistic data injection etc. With the B.R.T. technology implemented, this 1U high rackable unit will perform real time video bit rate reduction or smoothing on incoming programs.

The B.R.T. technology will be available on the Amber platform Q2 2000.

For further information please contact:

THOMCAST
Caroline Godard
Multimedia and Digital Systems Unit
8, rue Jean-Pierre Timbaud
78180 Montigny-le-Bretonneux
Tel: 33 1 34 90 36 87
Fax: 33 1 34 90 36 71
Caroline.godard@thomcast.thomson-csf.com
www.thomcast.thomson-csf.com