

# UBLive-264MP: An H.264-Based Solution on the DM642 for Video Broadcast Applications

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## White Paper

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## Introduction

Broadcast video applications are currently undergoing a transition where more and more content is produced and diffused in digital format as opposed to the traditional analog format. The transition is fuelled by the flexibility digital video offers in handling video content at all stages from production to transport/storage to decoding/display. The infrastructure needed to enable this “digital” transformation is being put in place at a rapid pace, allowing both content providers and service providers to significantly expand their market reach over the next few years.

Service providers in the broadcast industry face an unprecedented competition for viewers. In a landscape that was previously dominated by the cable industry, satellite and Digital Subscriber Line (DSL) companies are now also competing for the same customers. The competitive landscape is driving service providers to develop ways to differentiate their services and to adopt new solutions for the production and delivery of digital video. Customers would like to receive more channels for a given service, implying the need for a more efficient use of the available transmission bandwidth. At the same time, consumers are becoming more demanding in terms of the video quality they expect to see on their TV monitors, requiring sophisticated video pre-processing at the broadcasting side. Despite their increasingly stringent video quality requirements, customers still demand that the cost of service be as low as possible.

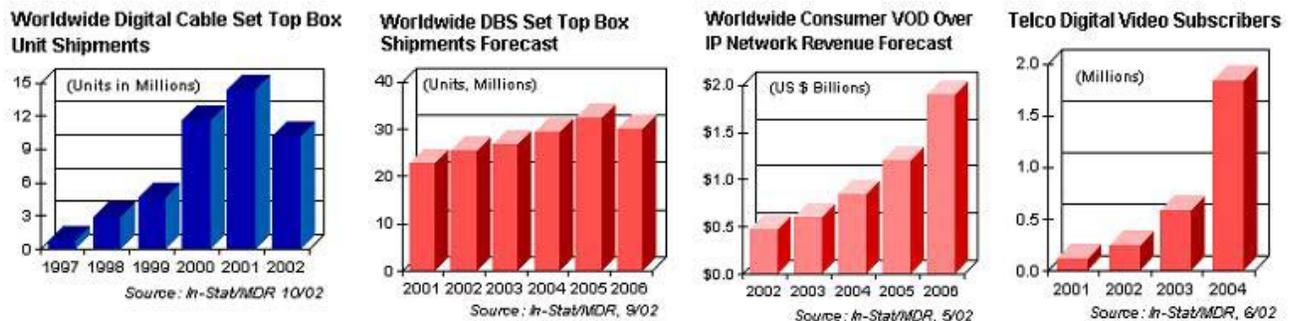
MPEG-2 Part 2 is currently the visual coding standard of choice for the broadcast video industry, operating at bit rates from around 3 to 10 Mbps. The emerging H.264 visual coding standard is set to revolutionize this industry by presenting a viable alternative to MPEG-2 video. H.264 allows encoders to achieve more than 50% savings in bandwidth as compared to MPEG-2, hence its strong value proposition. However, H.264 is a substantially more complex standard than MPEG-2 video, and both the H.264 encoders and decoders are expected to be much more demanding in terms of computations and memory than the MPEG-2 counterparts. Moreover, being in the last phase of development, H.264 has still not been fully tested, implying that further technical changes might be needed before the specification is deemed to be final.

UBLive-264MP, UB Video’s H.264-based video processing solution on Texas Instruments’ TMS320DM642 digital media platform for the broadcast video market, addresses in an effective way all of the above problems. UBLive-264MP achieves excellent video quality at rates as low as 1 Mbps through motion-compensation filtering, effective use of the H.264 Main-Profile standard features, and subjective-quality optimizations. UBLive-264MP is not only algorithmically optimized, but is also extensively optimized for the fully programmable (low-cost) DM642 digital media processor, which allows fast updating of the software as H.264 is being finalized.

The objective of this paper is to introduce UBLive-264MP as well as explain the benefits it offers to the fast-changing broadcast video market. An overview of the broadcast video market is first presented, followed by a presentation of the emerging H.264 Main-Profile standard. The video-related challenges that are facing the broadcast digital video market are then discussed, followed by a detailed description of UBLive-264MP, as well as a discussion of UB Video’s current UBLive-264MP demonstration software.

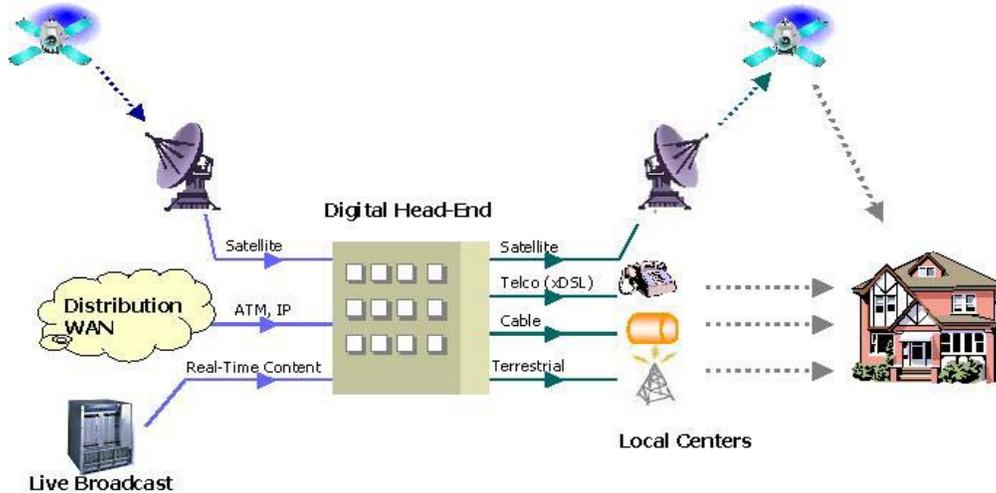
## Broadcast Video Market: Overview

The broadcast video industry has been going through major changes in the last 30 years. In the early days, transmission was "through-the-air" terrestrial broadcast to television sets equipped with antennas. The widespread adoption of cable technology in North America in the 1970's marked the first major shift from the terrestrial broadcast technology. In the 1990s, Direct Broadcast Satellite (DBS) service, with its wider channel selection and its availability outside existing cable service areas, significantly challenged cable operators' market penetration. More recently, telecommunication companies have entered the broadcast video market by offering Digital Subscriber Line (DSL) services, which use the existing telephone copper wire infrastructure. Through this infrastructure, which connects virtually every home or business, many telecommunication companies plan to transform traditional voice networks into high-speed connections for high-revenue integrated services. Now, even greater changes are fuelled by consumer demands for more programs, improved video quality, increased interactivity and new high-speed data services such as e-commerce and Internet access. All forecasts indicate that the broadcast video market is set to grow at a fast rate in the coming years as more services are made available by the service providers (see Figure 1).



**Figure 1: Sample forecast data for the broadcast market**

As shown in Figure 2, a typical broadcasting network consists of production and distribution networks through which content gets delivered to regional digital Head-Ends. A digital Head-End is a central point of processing that performs digitization and other content encoding and transcoding/transrating as necessary and prepares combined television channels for retransmission to local offices throughout a wide area network. At the local site, where local programming and advertisement are inserted, and repackaging/branding of content is done, a broadcasting network such as DBS, cable, terrestrial or DSL encompasses the last mile to the consumers' homes. The digital stream, coming into the home, gets decoded using either a Set Top Box decoder connected to a conventional TV or a digital Television set with an integrated decoder.



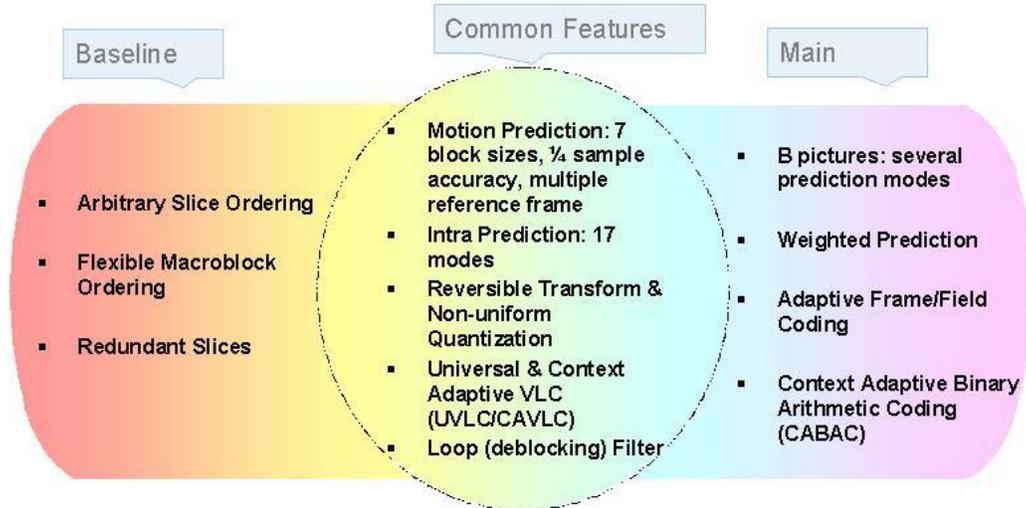
**Figure 2: A typical broadcasting system**

There are two well-known facts about the broadcast video market: 1) service providers will have to make a huge infrastructure investment over the next few years to migrate fully to an all-digital service, and 2) competition over subscribers will be very fierce as options of service providers will increase. As a consequence, a broadcast video service provider is constantly seeking ways to differentiate itself from the competition through mainly new technology (e.g., H.264) and better quality-of-service offerings.

MPEG-2 has been the enabling video compression technology behind the success of digital video broadcasting to the home. This technology, coupled with sophisticated digital communications technologies, allowed the service providers to increase the number of channels that can be broadcasted over essentially the same network infrastructure. However, the emerging H.264 standard is poised to double that number, since H.264 encoders are expected to achieve the same picture quality as that of MPEG-2 using less than half of the bandwidth. It is therefore not surprising that major companies in the broadcast video industry are rushing to adopt this standard. In the next section, an overview of the H.264 standard is given. For a detailed description, please refer to [1].

## H.264: Overview

In 1997, the ITU-T Video Coding Experts Group (VCEG) initiated the work on the H.264 standard (formerly known as the H.26L standard). The main objective behind the H.264 project was to develop a high-performance video coding standard by adopting a “back to basics” approach using simple and straightforward design with well-known building blocks. Towards the end of 2001, and witnessing the superiority of video quality offered by H.264-based software over that achieved by the existing most optimized MPEG-4 based software, ISO/IEC MPEG joined ITU-T VCEG by forming a Joint Video Team (JVT) that took over the H.264 project of the ITU-T. The JVT objective was to create a single video coding standard that would simultaneously result in a new part of the MPEG-4 standard (MPEG-4 Part 10 Advanced Video Coding (AVC)) and a new ITU-T Recommendation (H.264).



**Figure 3: Features for the Baseline and Main profiles**

To this date, three major profiles have been agreed upon: Baseline, mainly for video conferencing and mobile applications, Main, mainly for broadcast video applications, and X, mainly for streaming and mobile video applications. Figure 3 shows the common features between the Baseline and Main profiles as well as the additional specific features for each. The Main profile allows an additional reduction in bandwidth over the Baseline profile through mainly Bi-directional prediction (B-pictures), Context Adaptive Binary Arithmetic Coding (CABAC) and weighted prediction. These specific features will be briefly discussed next:

**B pictures:**

B-pictures provide a compression advantage as compared to P-pictures by allowing a larger number of prediction modes for each macroblock. Specifically, bi-predictive coding modes are available for each partition of the macroblock. Here, the prediction is formed by averaging the sample values in two reference blocks, generally, but not necessarily using one reference block that is forward in time and one that is backward in time with respect to the current picture. In addition, "Direct Mode" prediction is supported, in which the motion vectors for the macroblock are interpolated based on the motion vectors used for coding the co-located macroblock in a nearby reference frame. Thus, no motion information is transmitted. By allowing so many prediction modes, the prediction accuracy is improved, often reducing the bit rate by 5-10%.

**Weighted prediction:**

This allows the modification of motion compensated sample intensities using a global multiplier and a global offset. The multiplier and offset may be explicitly sent, or implicitly inferred. The use of the multiplier and the offset aims at reducing the prediction residuals due, for example, to global changes in brightness, and consequently, leads to enhanced coding efficiency for sequences with fades, lighting changes, and other special effects.

**CABAC:**

Context Adaptive Binary Arithmetic Coding (CABAC) makes use of a probability model at both the encoder and decoder for all the syntax elements (transform coefficients, motion vectors, etc.). To increase the coding

efficiency of arithmetic coding, the underlying probability model is adapted to the changing statistics within a video frame, through a process called context modeling.

The context modeling provides estimates of conditional probabilities of the coding symbols. Utilizing suitable context models, given inter-symbol redundancy can be exploited by switching between different probability models according to already coded symbols in the neighbourhood of the current symbol to encode. The context modeling is responsible for most of CABAC's 10% savings in bit rate over the Baseline entropy coding method (universal and context adaptive VLC).

## Broadcast Video Industry: Current Challenges

Digital broadcast video service providers need to overcome significant technical hurdles in order to differentiate their services in the market. From a video coding perspective, there are three major challenges that the industry has to deal with; namely making efficient use of the available bandwidth, ensuring high-reproduction video quality, and providing a cost-effective embedded decoder solution. Another challenge is that the H.264 Main Profile standard, while holding the promise to help improve the bandwidth-quality tradeoffs, is still not final, and may in fact change quite significantly over the next few months. Each of these four challenges is discussed in more detail in the following:

- ◆ **Efficient Bandwidth Utilization:**

A key differentiating factor for service providers is the number of channels that can be accommodated over a given transmission bandwidth, which in turn affects the amount of generated revenues. For the different service providers, whether based on cable, satellite, or DSL services, a more efficient use of the transmission bandwidth could translate into making available more channels to the customers, or providing additional services, hence enhancing the service providers' service offerings. For some broadcast video applications, such as video over DSL, the available bandwidth is already very limited, implying that bandwidth savings would be even more needed. However, any savings in the bandwidth allocated to the broadcasting of digital video should not come at the expense of video quality, as customers expect the service to provide the same broadcast video quality they are used to, or even better. Therefore, the only available solution is that the most effective compression tools be used.

- ◆ **Broadcast Video Quality:**

Viewers used to the superior quality produced by DVD players will not accept any broadcast video that does not measure up to that level of quality. Providing broadcast video quality at a limited channel bandwidth (i.e., 1.5Mbps for DSL channels) for the Standard-Definition (SD) resolution (720x480) can therefore be quite challenging, particularly when the video content is characterized by action sequences with significant amount of motion, scene changes as well as fades and dissolves. Moreover, for most broadcast video applications, the video quality could be significantly affected by the presence of spatial and temporal noise. In such a case, the encoder would end up spending valuable bits coding noise that would otherwise be spent on coding the actual content, often yielding very objectionable artefacts such as contouring and blocking especially in bright areas. Therefore, pre-processing the source video to remove noise is critical to insuring a high-level of video quality.

- ◆ **Decoder complexity:**  
The H.264 standard is significantly more complex than any of the previous video coding standards. Motion compensation, for instance, makes use of 7 block sizes from 16x16 down to 4x4. Consequently, the H.264 decoder is expected to be significantly more demanding in terms of computations and memory requirements. Any decoder should be able to handle all “legal” bit streams (i.e., worst-case scenario), making the decoder implementation even more complicated. Moreover, the development of an embedded decoder implementation where the internal memory size is limited is a challenging task. For example, when performing motion compensation on a macroblock coded using bi-directional prediction, the decoder must refer to multiple reference frames in both directions. Transferring the appropriate macroblocks for motion compensation can slow down the decoder significantly as memory transfers may become too demanding in terms of cycles.
- ◆ **H.264 Main Profile: Status**  
The H.264 Main Profile standard is in the last stage of development and changes to the standard may still be possible. The H.264 standard has also not yet gone through extensive testing. As a result, broadcast infrastructure companies are currently looking for solutions that are fully programmable in order to be able to quickly adapt to the evolving standard.

## UBLive-264MP

UB Video’s UBLive-264MP solution consists of three components: a Pre-processing tool, an Encoder and a Decoder. This solution is based on the H.264 Main profile, which has a number of features that make it suitable for broadcast video applications. UBLive-264MP was designed to address all the major video processing challenges (discussed above) that face the broadcast video industry. In the following, the three components of UBLive-264MP solution and how they address the different challenges are discussed.

### **Pre-processing**

One of the challenges in broadcast video is the presence of noise that may potentially lead to objectionable artifacts. UBLive-264MP applies motion-compensated filtering to reduce noise in successive video frames. Motion-compensated filtering reduces noise in the temporal direction while taking into account its trajectory in previous video frames. This pre-processing not only achieves good performance in terms of reducing the occurrence of artifacts, but it also results in bit savings, leading to a better overall video quality.

### **Encoder**

Existing broadcast systems are generally based on video coding solutions that make use of the MPEG-2 coding standard. The emerging H.264 standard is poised to become the enabling technology that would address the bandwidth utilization problem. Compared to MPEG-2, H.264 promises an average reduction in bit rate by more than 50% for a similar degree of encoder optimization at most bit rates and for the same subjective video quality. The savings in bit rate are the result of a number of techniques, including the use sophisticated intra prediction, multiple block sizes and multiple reference frames in motion estimation, more advanced B-picture coding and highly efficient Context-Based Adaptive Binary Arithmetic Coding.

UB Video's UBLive-264MP, a result of three-year research and development effort involving various algorithmic and subjective optimizations, achieves the best possible video quality at a given bit rate. From an algorithmic point of view, the encoder typically selects modes from a large number of possibilities in coding each macroblock. Every macroblock can be partitioned in a number of different ways, and each partition can use different reference frames as well as the common single reference block prediction (i.e. P-pictures) or bi-prediction (B-pictures). In order to achieve efficient implementation of the encoder, UB Video has developed rate-distortion optimized motion estimation and mode decision algorithms that provide excellent quality-complexity tradeoffs. To further enhance the video quality, UB Video has also developed new algorithms that take into account the perception limitation of the human visual system.

### **Decoder on the DM642**

Since the H.264 standard is still under development and expected to stabilize only next year, broadcast infrastructure companies are looking for a programmable chip solution that is powerful enough to handle the processing power associated with such a complex decoder. UB Video's highly optimized H.264 Main profile decoder software running on the Texas Instruments' TMS320DM642 Digital Media Processor represents a very compelling solution. This solution currently presents the world's only embedded real-time broadcast-quality H.264 Main profile decoder for SD resolution.

The TMS320DM642™ Digital Media Processor (DM642) is the highest-performance fixed-point DSP from Texas Instruments. The DM642 DSP core delivers the highest performance at the lowest power consumption of any available DSP in the market to date. With its 600Mhz processing power in production today and an aggressive process technology roadmap for continued higher clock rates, this DSP is most suited to overcome the complexity and computational requirements of H.264 and to deliver high-quality full-screen video for most broadband video applications. The DSP core processor has 64 general-purpose 32-bit registers and eight highly independent functional units - two multipliers and six arithmetic logic units (ALUs) with VelociTI.2 extensions. The VelociTI.2™ extensions in the eight functional units include new instructions to accelerate the performance in video and imaging applications and extend the parallelism of the VelociTI™ architecture. The DM642 uses a two-level cache-based architecture and has a powerful and diverse set of peripherals. The Level 1 program cache (L1P) is a 128-Kbit direct-mapped cache and the Level 1 data cache (L1D) is a 128-Kbit 2-way set-associative cache. The Level 2 memory/cache (L2) consists of a 2-Mbit-memory space that is shared between program and data space. L2 memory can be configured as mapped memory, cache, or combinations of the two.

The UBLive-264MP decoder is optimized to provide full frame (30 fps) decoding performance for SD resolution video. This was achieved through algorithmic optimizations that take full advantage of the DSP capabilities. This hardware/software solution offers an attractive and viable option for a new generation of Set Top Boxes featuring enhanced flexibility through the programmability offered by the DM642 Digital Media Processor. Adopting this solution will certainly help service providers roll out their H.264 compliant products in the very near future.

## UBLive-264-MP Demonstration Software: Description

UB Video's UBLive-264MP demonstration software runs on the TMS320DM642 Network Video Developer's Kit (NVDK) board from Texas Instruments. A block diagram of the demo is shown in Figure 4. The NVDK is a platform where real-time API decode function calls are done and where algorithms are tested for compliance. The way the UB Video demonstration software works is as follows: A bit stream is parsed by the decoder and YUV 4:2:0 frames are output (see Figure 5). The resolution of the frame is 720x360 for Y and 360x180 for chrominance components. The vertical resolution (360) is due to the wide screen DVD content that is used. Once a frame is decoded, it goes through a post-processing stage as shown in Figure 6. The chrominance vertical lines are duplicated leading to YUV 4:2:2 resolution and then a transformation to packed format is done followed by a 3:2 pull-down operation to up-sample the frame rate to 30 frames per second. Each frame is delivered to the board display hardware for output to a television.

For more information on UBLive-264MP, please visit [www.ubvideo.com](http://www.ubvideo.com).

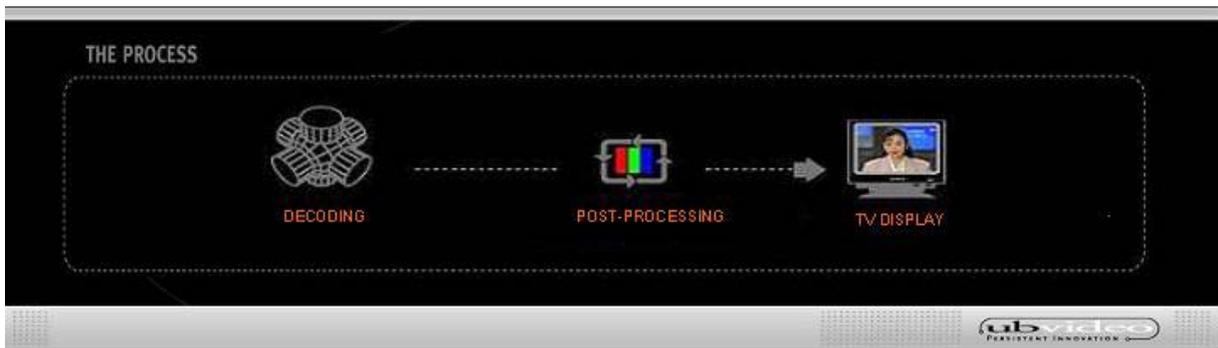


Figure 4. Block diagram of the UBLive-264MP demo.

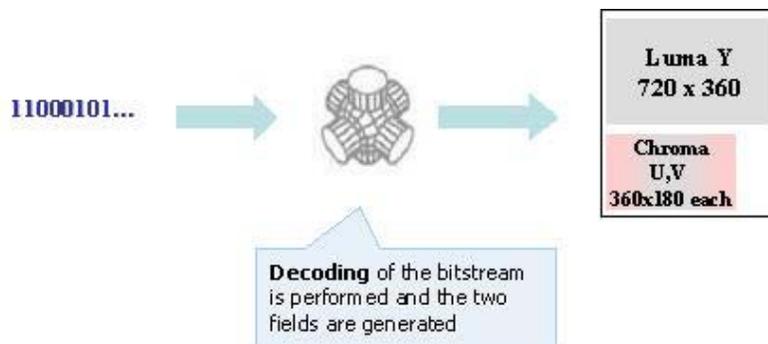


Figure 5. Decoding process

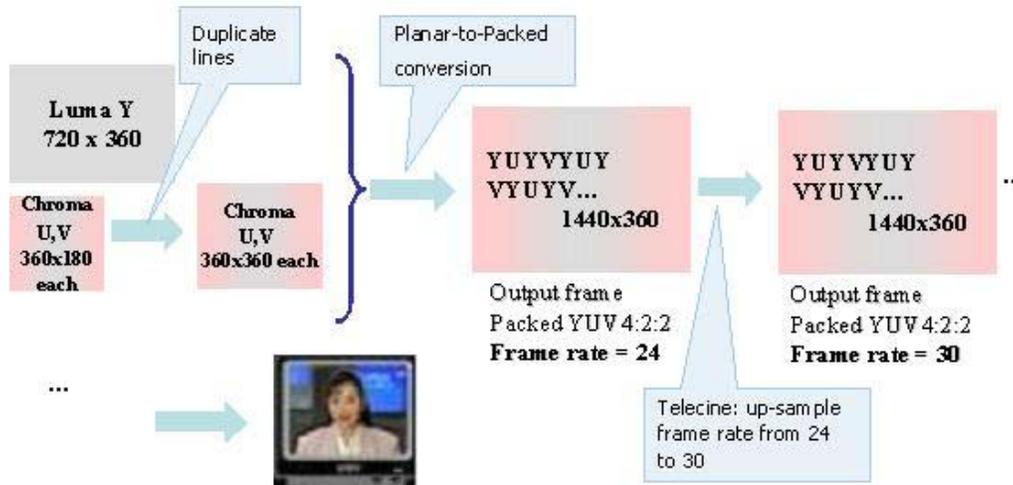


Figure 6. Post-processing process

## References

- [1] Emerging H.26L Standard: Overview and TMS320C64x Digital Media Platform Implementation. UBVideo Inc. [www.ubvideo.com](http://www.ubvideo.com).