MPEG-5 LCEVC

How MPEG-5 LCEVC Can Unlock Ultra HD DTT Deployment?

Author: Thierry Fautier, Managing Director Your Media Transformation

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1. UHD DTT use case.

Digital Terrestrial Television (DTT) has historically served as the network for delivering and creating high-audience linear channels. Today, new broadcast channels in HD are simulcast in UHD over DTT, and we are witnessing that this transition is not without its challenges.
Certain premium live UHD channels, distributed by Multichannel Video Programming Distributors (MVPDs), garner significant viewership, particularly in Europe where SKY and Canal+ hold exclusive rights to soccer matches. Conversely, in the US, Comcast/NBC provided coverage of the last FIFA World Cup in 2160p HDR. It's worth noting that none of these channels are delivered via DTT.
In the US, sports channels are still predominantly broadcast in HD, but there's a noticeable trend toward premium sports leagues migrating to Over-The-Top (OTT) services such as Peacock and Apple TV+, offering content in 1080p SDR. Some services, like Amazon Prime, stream in 1080p HDR, while MAX delivers content in 2160p HDR.
In the US, DTT employs ATSC 3.0 for UHD, but the majority of content remains in 1080p SDR. The full deployment of 2160p HDR will only occur once the ASTC 1.0 service is switched off, though no date for this transition has been announced.
The challenge with UHD over DTT lies in the need for spectrum to attract an audience. Without available spectrum, the widespread adoption of UHD DTT, which caters to the largest audience, becomes unfeasible. This scenario forces content providers to rely on either MVPD or OTT platforms for UHD content delivery. This white paper explores how the current framework for deploying UHD DTT falls short of being optimal and how MPEG-5 LCEVC can address this issue.

How UHD DTT is done today?

UHD DTT world map

We will examine all the various UHD systems deployed and concentrate on a specific system utilizing MPEG-5 LCEVC as an alternative. This solution can be applied to all existing HD systems, except Brazil TV 3.0, as it already incorporates MPEG-5 LCEVC, which will be discussed in a separate white paper.

Traditionally, UHD DTT has been perceived as a simulcast of the already deployed HD service, as outlined in Table 1, leading to a significant bandwidth demand.

Country	HD	Estimated HD bitrate	UHD	Additional bitrate consumed for UHD	UHD overhead vs HD service
US/Korea	MPEG-2/TS	10M/s	HEVC/MMT/ ROUTE	15-20M/s	150-200%
Spain	MPEG-4 AVC /TS	5.5 M/s	HEVC/TS	15-20M/s	300-400%
France	MPEG-4 AVC / TS	5.5 M/s	HEVC/TS	15 M/s for CBR channel 11.2 M/s for stat mux	300% 200%
Germany	HEVC/TS	3M/s	NA	NA	No UHD service planned
Brazil TV3.0			VVC/MPEG-5 LCEVC/IP	10 M/s	NA (2)

Table 1: UHD DTT map

1) for HD base + MPEG-5 LCEVC extension UHD
2) HD VVC is the base later for UHD MPEG-5 LCEVC

From the table provided, we can discern two primary classes:

- Most countries, excluding Brazil, have opted for HEVC for UHD, resulting in bandwidth consumption ranging from 150% to 400% compared to UHD. This is notably inefficient in terms of spectrum usage when compared to viewership.
- Brazil, on the other hand, has embraced VVC+MPEG-5 LCEVC for UHD, consuming only 150% of the bandwidth used for HD encoded in AVC with a TV 2.5 configuration. Additionally, with TV 3.0, Brazil adopts a greenfield approach where both HD and UHD are VVC encoded using MPEG-5 LCEVC, requiring less than 10M/s, making it the most efficient system thus far.

The key takeaway is that employing brute force simulcast, especially using an "older" codec like HEVC for UHD, incurs substantial bandwidth costs and spectrum utilization. A simulcast using a more modern codec such as VVC may consume less bandwidth and could be considered by some countries. However, a true layered scheme utilizing MPEG-5 LCEVC proves to be the most optimal, as both UHD and HD can fit within less than 10M/s, closely resembling the Brazil TV 3.0 scheme and offering backward compatibility.
The second issue pertains to spectrum availability, illustrated through a guided tour of the listed countries:

- In the US, the simultaneous transmission of ATSC 1.0 and ATSC 3.0 restricts UHD transmission to 1080p (SDR) using HEVC encoded at 6-8M/s. This fails to capture consumers' attention, as it only presents a migration from 1080i to 1080p. Moreover, the non-uniformity of HD to UHD up conversion across different TVs, coupled with SDR to HDR conversion, dissuades broadcasters from pursuing this option.
- In Korea, broadcasters have access to a dedicated band for deploying UHD channels, resulting in all UHD content being 2160p60.
- In Spain, while the main channels remain in SD or HD, UHD channels have a dedicated DVB-T2 spectrum.
- In France, similarly, the main channels are in HD, with UHD channels allocated dedicated DVB-T2 spectrum obtained through the re-optimization of HD channel encoding.
- In Italy, the absence of spectrum allocation for UHD precludes the possibility of over-the-air UHD services. Similarly, in numerous countries worldwide, the availability of HD services is not matched by frequencies for UHD, resulting in broadcasters refraining from investing in UHD.

Overall, UHD deployment in many countries faces significant hurdles both in terms of business and technology. The potential of MPEG-5 LCEVC to overcome these challenges will be explored further.

Building a UHD DTT service

We'll commence with the standardization phase, with ATSC for the US/Korea, SARFT in China, ARIB for Japan, Forum SBTVD for Brazil, and DVB for the rest of the world. Typically, it takes around three years, on average, to transition an MPEG standard to a fully ratified standard by a Standard Developing Organization (SDO).

During the SDO process, the decoder chip is assumed to be designed, with no additional delays considered. Following this, TV manufacturers must develop, produce, and sell their TVs. Broadcasters typically contemplate deploying new technology when the installed base surpasses 40% of TVs.

For instance, in the US, with NextGen TV commercially introduced in 2020, the volume ramp-up only reached 40% by 2026, six years post-introduction, with 70% achieved in seven years.

In France, for UHD DTT, technical specifications were finalized in 2018, and regulatory approval from ARCOM was granted in 2023 to commence broadcasting by the 2024 Paris Olympics. TV manufacturers anticipated this decision and began producing UHD sets with DVB T2/HEVC capability from 2018.

Subsequent software upgrades addressed interoperability issues without altering the hardware platform on the AV side.

By 2024, the penetration rate of UHD TVs stood at 70%, achieved over six years, surpassing the previously mentioned 40% threshold. While there's no legal mandate for upgrading deployed TV sets, TV makers at CES'24 announced that new TVs manufactured in 2024 would receive software support for five years. FAVN (French UHD group) tested a few TVs predating 2020 and found no major interoperability issues on recent TV sets, suggesting a five-year backward compatibility consideration.

Overall, from the inception of a new codec to deployment, the process takes approximately 10 years. While this pace doesn't match the speed of the internet, it reflects the operational norms within the broadcast space. We'll explore how MPEG-5 LCEVC can revolutionize this dynamic.

Conclusion

In conclusion, the current method of deploying UHD DTT is not only costly in terms of spectrum but also time-consuming. We doubt many countries will be able to pursue this path in the future, particularly if alternative approaches become available. This presents an opportunity for exploring alternative methods to UHD DTT deployment.

2. MPEG-5 LCEVC features

Background

MPEG-5 LCEVC, which stands for Low Complexity Enhancement Video Coding, has been specifically designed to serve as a codec-agnostic enhancement with reduced hardware or software complexity compared to other full-fledged codecs. LCEVC can be implemented in various ways, including traditional hardware integration on chipsets or at the device driver level, leveraging a combination of CPU/GPU software and hardware blocks already available on-chip. This flexibility enables the updating of existing chipsets to support LCEVC.
The performance of the MPEG-5 LCEVC codec depends on several factors, including the type of base codec used, the type of extension layer utilized, and the operating point selected. As a rough estimate, envision an extension layer utilizing around 20% of the base layer to construct a UHD layer from an HD base layer. Further details will be provided in the subsequent sections.

MPEG-5 LCEVC applied to UHD

In this section, we will examine two scenarios for the base layer:

- HD 1080i/720p SDR (BT 709) encoded in AVC, as commonly done in most countries.
- HD 1080p/720p SDR (BT 709) encoded in HEVC, as practiced in a few countries like Germany and Italy.

At the output of the MPEG-5 LCEVC encoder, the decoded signal must provide up to a 2160p HDR output, accommodating various HDR formats such as HDR10, SL-HDR1, SL-HDR2, HLG, Dolby Vision, and HDR10+, which are standardized by ATSC (HDR10, SL HDR-1), DVB (HLG, HDR10, HDR10+, SL HDR-2, Dolby Vision), and SBTVD (HDR + optional dynamic metadata to support Dolby Vision, SL-HDR-2, HDR10+ for broadcast, and SL-HDR-1/HLG for OTT).
An MPEG-5 LCEVC-enabled UHD encoder must handle two types of inputs:

- Native UHD when the content has been produced in UHD.
- Legacy HD when HD is the source.

In the case of a native UHD source, a pre-processor will convert the UHD HDR signal to 1080i/720p SDR to feed the base layer to an AVC or HEVC encoder.
For an HD source (1080i/720p), several operations must be performed:

- De-interlacing (if the source is 1080i)
- Up-conversion from HD to UHD
- HDR conversion from SDR source

Table 2 outlines the two major scenarios that need to be supported to generate a UHD signal from an HD source.

Country	Base	MPEG-5 LCEVC		
		Extension layer	HDR conversion	
			Spec	Beta availability
Italy/Germany	1080p SDR HEVC	LCEVC 10 bits	Standard defined Receiver TBD	Demo HDR10
Other DVB countries	1080i/720p SDR AVC	LCEVC 10 bits	Standard defined Receiver TBD	Demo SL HDR-1 & HDR10

Table 2: MPEG-5 LCEVC scenarios for DTT

Application

We present in Table 2 how each system is addressing the scalable coding for different requirements.

System	Scalability approach selected	Status	Use case
ATSC 3.0 (US)	SHVC	Deployed	Mobile (HD)/ OTA (UHD)
Brazil	MPEG-5 LCEVC (green field)	Standardized ('24) Deployed ('25)	New generation of broadcasting system
Japan	Scalable VVC	Standardization stage	Green field 4k/8K scalable
DVB	MPEG-5 LCEVC (backward compatible)	Standardization stage	HD (AVC/HEVC) as base layer to MPEG-5 LCEVC

Table 3: scalable coding systems in the world

We find the DVB system particularly attractive for implementing MPEG-5 LCEVC in UHD DTT, especially considering the numerous countries facing spectrum availability constraints.
In Figure 1, we illustrate the transmission setup involving HEVC HD (SDR) with the MPEG-5 LCEVC extension layer, which facilitates the production of UHD HDR video. It's worth noting that this system remains functional even when the HD content is encoded in AVC SDR.

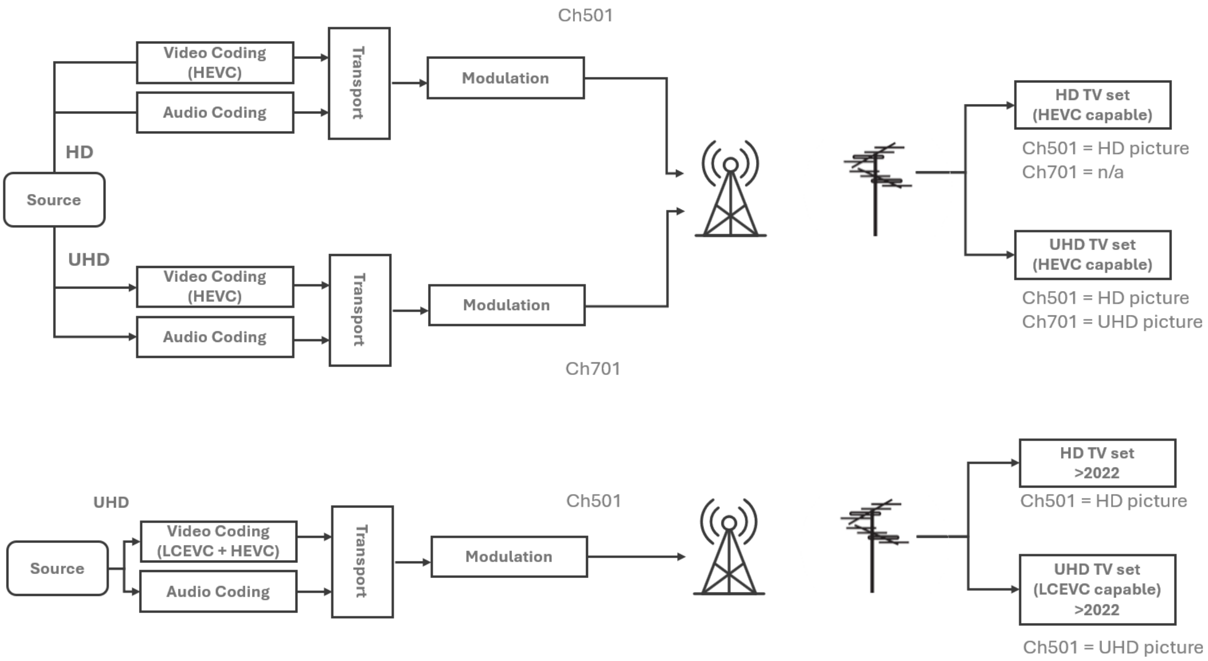

Figure 1: Application of MPEG-5 LCEVC to the transmission of UHD HDR from a HD SDR base layer

Spectrum

As MPEG-5 LCEVC requires approximately 1.5 -3 Mbps of additional layer video bitrate for creating a UHD channel, this spectrum allocation is managed through the "repack" methodology, which can be executed in two main ways:

- Retaining the existing channel lineup while improving compression efficiency by around 20%. This approach, exemplified by France, is challenging as it necessitates significant advancements in compression technology.

- Consolidating channels by merging them, reducing the total number of channels. This method, observed in the US, involves transforming, for instance, five channels into four.

In practical terms, the transition in France involved migrating from six multiplexes to five of the same capacities, resulting in a bandwidth saving of approximately 16%. This was achieved by upgrading to newer encoder generations, which provided improved compression efficiency. It's important to note that if the encoder fails to attain the targeted compression gain, the alternative option is to decrease the encoding bitrate, which may introduce additional artifacts, necessitating quality validation through trials.

3. MPEG-5 LCEVC benefits

The primary benefits of MPEG-5 LCEVC compared to a traditional approach include:

- Reduced Bandwidth Requirement: MPEG-5 LCEVC typically requires only 20% of the bandwidth of the existing HD signal to deliver a UHD stream. For example, with an AVC base encoded at 7 Mbps for 1080i/720p SDR, the extension MPEG-5 LCEVC layer would be approximately 1.5 Mbps. Similarly, for a 1080p SDR HEVC base encoded at 5 Mbps, the extension MPEG-5 LCEVC layer would be approximately 1 Mbps. These figures are approximately 10 times smaller than the current values used in a simulcast deployment.

- Versatile Implementation: MPEG-5 LCEVC can be implemented at the device driver level on existing video System-on-Chips (SOCs) as well as in hardware in the next generation of chipsets. This capability places TV manufacturers in a unique position to deploy a distinctive new feature on their latest shipping models, enhancing their competitiveness in the market.

We provide in figure 1, a representation of MPEG-5 LCEVC savings.

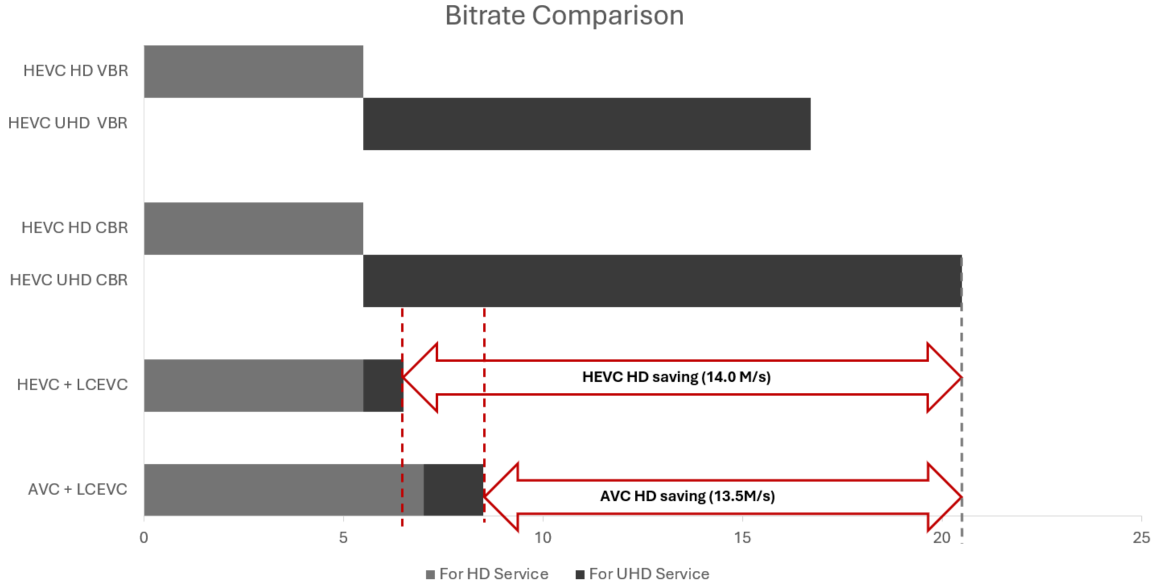

Figure 2: MPEG-5 LCEVC savings

Indeed, leveraging MPEG-5 LCEVC with a legacy HD base layer represents the most optimal solution. The additional bandwidth required for this setup typically ranges from 1.5 to 3 Mbps, which stands in stark contrast to the 15 to 20 Mbps required for a UHD simulcast using HEVC as deployed in current setups. This significant reduction in required bandwidth underscores the efficiency and effectiveness of MPEG-5 LCEVC, making it a highly favorable option for UHD content delivery.

1) Integration

Different levels of integration are required for MPEG-5 LCEVC implementation in a TV set. Firstly, at the codec level, integration must occur at the System-on-Chip (SoC) level. There are various implementations of MPEG-5 LCEVC at this stage:

- Driver-level integration: Software (SW) running on the CPU or GPU of the SoC.
- Hardware integration: Dedicated hardware embedded in the next generation SoC.

On the head-end side, integration with encoder vendors is necessary. Currently, V-Nova has signed integration agreements with leading encoding companies such as Harmonic and ATEME. These agreements facilitate the incorporation of MPEG-5 LCEVC into their encoding solutions. Notably, public MPEG-5 LCEVC UHD proof-of-concepts (POCs) were demonstrated by these companies in 2022/23, showcasing the viability and potential of this technology.

2) Adoption

In terms of timing for MPEG-5 LCEVC adoption, V-Nova has been collaborating with System-on-Chip (SoC) manufacturers for several years. It is anticipated that by 2025, major SoC manufacturers will have a General Availability (GA) version ready to support both AVC and HEVC base layers for delivering UHD HDR content on TVs. This indicates a significant step forward in the integration and adoption of MPEG-5 LCEVC technology within the television industry.

4. Next steps

There are different steps to come to a deployment.

a. **DVB Standard:**

First, we need DVB to ratify MPEG-5 LCEVC as one possible option to deploy a broadcast system.

b. **National standard:**

To consider MPEG-5 LCEVC as part of a DTT deployment in Italy, several parameters need to be defined:

- Base Layer Codec: Italy needs to decide whether to use AVC or HEVC as the base layer codec for its DTT deployment.
- Input Resolution: Determine the input resolution for the base layer codec, which could be 1080i/720p or 1080p.
- Output Resolution: Define the desired output resolution, which could be UHD (2160p) HDR.
- HDR Format: Specify the HDR format to be used, such as HDR10, HLG, or Dolby Vision.
- Bitrates: Determine the target bitrates for both the base layer codec and the MPEG-5 LCEVC enhancement layer.
- Encoding Scheme: Decide whether to use Constant Bitrate (CBR) or Variable Bitrate (VBR) encoding for the DTT deployment.

Once these parameters are defined, Italy can proceed with the implementation of MPEG-5 LCEVC as part of its DTT infrastructure, enabling more efficient and cost-effective delivery of UHD HDR content to viewers.

c. **Trial:**

Here is a check list of things that need to be prepared for a trial:

- Identify TV Sets: Select TV sets that are ready to support a UHD DTT MPEG-5 LCEVC trial. These TVs should be equipped with the necessary hardware or software to decode MPEG-5 LCEVC-enhanced signals.
- National Specification Subset: Choose a subset of the national specification to be implemented in the trial. This subset should include key parameters such as base layer codec, input and output resolutions, HDR format, bitrates, and encoding scheme.
- Encoder Upgrade: Upgrade existing encoders to support MPEG-5 LCEVC and run a trial using spare units. This allows broadcasters to use their current infrastructure while testing the new technology.
- Trial Goals: The trial's objectives include assessing the stability of the platform on both the encoder and TV sides, evaluating video quality across different operating points, and testing various modulation configurations, especially T1/T2 mix options.

d. **Plug fest:**

After a successful trial, need to organize a plug fest under the umbrella of the technical arm of the regulator, such as the Ultra HD Forum Italia in Italy. This event brings together different encoder manufacturers to test their products against commercial TV sets.

e. **Regulation:**

Obtaining regulatory approval for commercial deployment is key. This may involve securing the regulator's stamp of approval and addressing any spectrum reallocation required to accommodate the additional 1 Mbps needed for MPEG-5 LCEVC deployment.

5. Conclusion

In this white paper, we've evaluated various options for transmitting UHD over DTT, and the most compelling solution emerges as MPEG-5 LCEVC, particularly when ensuring backward compatibility for legacy TV sets. Brazil has pursued a more innovative approach with its TV 3.0 system, implementing a green field deployment with VVC as the codec alongside MPEG-5 LCEVC.

MPEG-5 LCEVC significantly reduces bitrate requirements, making UHD DTT feasible even in scenarios where spectrum availability is limited. V-Nova, the creator of MPEG-5 LCEVC, stands as the natural partner to deliver UHD over DTT, offering a pre-integrated ecosystem encompassing encoders, chipsets, TV sets, and STBs, thereby bringing UHD DTT to a wider audience.