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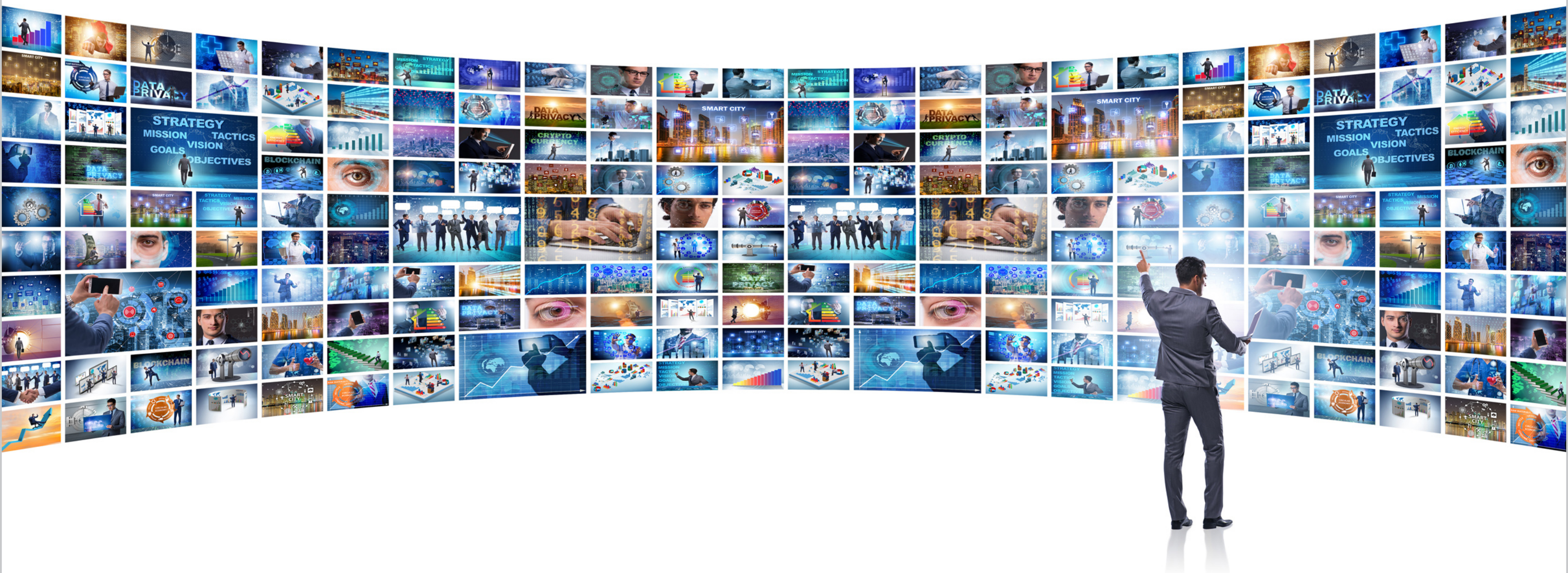
HITACHI
Inspire the Next

Software-Based DTV Encoding



WHITE PAPER

COMARK
Communications

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Contents

Abstract

The purpose of this white paper is to review the benefits of software-based encoder solutions with respect to the current ATSC 1.0 DTV standard as well as the future capabilities in Next Generation Broadcast Television (NGBT) systems.

Introduction

Comark Digital Services (CDS) has a mission to help broadcasters with navigating the FCC repack with new ATSC encoder solutions in addition to showing the migration to ATSC 3.0. CDS is your partner for ATSC 3.0 strategy, product selection, system design, and end-to-end implementation. It's a big job, but now there is a company that can assist you through a successful and cost-effective transition.

This white paper will provide an overview of the new software-based encoder solutions that are currently available for deployment in ATSC 1.0 as well as NGBT. The paper will provide historical background on the evolution of encoder technologies, show the capability of new software-based encoders, discuss transition in strategies for NGBT / ATSC 3.0 as well as the trade-offs of cloud based vs. bare metal / COTS server implementations.

Historical Background

The ATSC standard was introduced in 1996 and was the world's first all-digital, end-to-end system for the distribution and delivery of high definition television images. ATSC 1.0 was built on cutting-edge MPEG technologies for both video coding, compression, and the transport of the digital signals between subsystems of the distribution chain. From an encoder perspective, ATSC 1.0 was designed to support resolutions of 480i (480 lines x 720 pixels wide) for Standard Definition (SD) programs as well as 720p (720 lines x 1280 pixels wide) and 1080i (1080 lines x 1920 pixels wide) for High Definition (HD) program content with a 16:9 display aspect ratio (wide screen). ATSC supports many frame rates, including 29.97, 30, 59.94 and 60 frames per second (FPS) as well as progressive and interlaced scanning.

First Generation MPEG-2 Encoding

Early commercially-deployed MPEG-2 encoders were installed on dedicated ASIC / rack mounted hardware platforms and would only process / output a Single Program Transport Stream (SPTS) for each video program. Multiple encoders relied on a separate multiplexer (MUX) platform to generate the Multi-Program Transport Stream (MPTS). Some of the very first encoders required hardware platforms (4 to 5RU) per video program. Early ATSC 1.0 deployments would have 1HD + 1SD programs maximum due to the processing limitations of the MPEG-2 encoders as well as the capital equipment costs.

Second Generation MPEG-2 Encoding

MPEG-2 encoder technology has improved tremendously since the inception of ATSC 1.0. Second and third generation encoders were reduced to 1RU platforms. With the introduction of more powerful encoding algorithms and new "digi-nets", broadcasters have deployed solutions with 1HD and 3 to 4SD programs in a single ATSC RF channel. These 1RU platforms, many of which are currently in use today, still rely on dedicated hardware platforms. Encoders have taken advantage of higher performance platforms that have reduced bit rates and lowered product pricing.

Encoding Algorithm Improvements

While ATSC 1.0 limits broadcaster's Over-The-Air (OTA) signal to MPEG-2, the encoding industry has marched forward with newer technologies to better utilize the available bits in any given network. MPEG-2 has been superseded by H.264 (also known as MPEG-4 part 10) and more recently H.265 (also known as High Efficiency Video Codec or HEVC). Each generation of encoding standards has effectively doubled the coding efficiency or conversely requires half the bit rate of the previous generation for a given picture quality / video quality (VQ), as shown in the chart below:

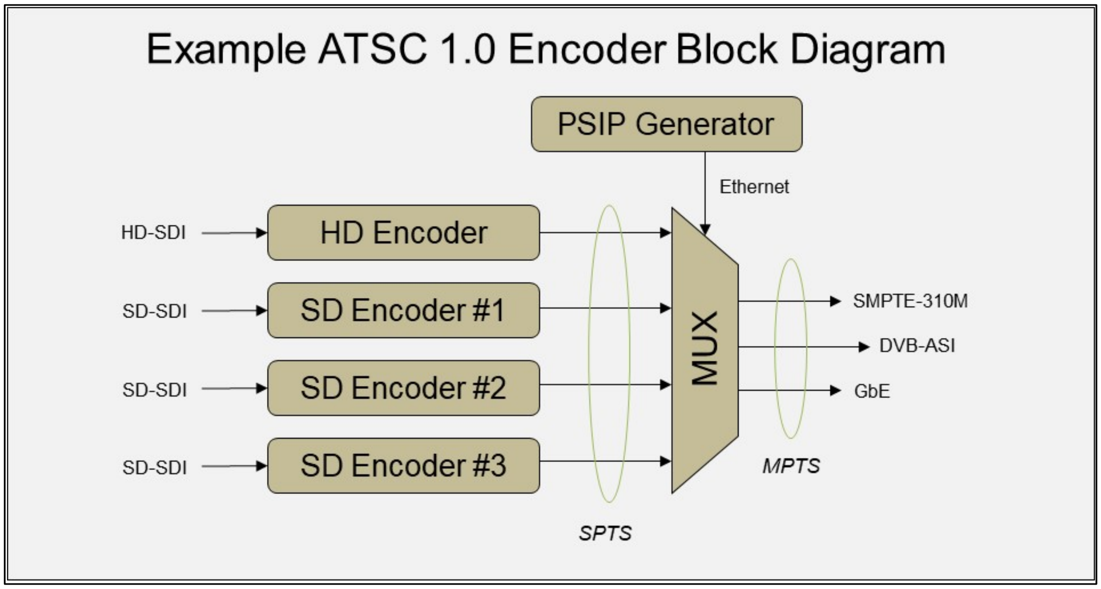
Coder Technology	HD apx. Bit Rate	SD apx. Bit Rate
MPEG-2	10Mbps	4Mbps
H.264	5Mbps	2Mbps
HEVC	2.5Mbps	>1Mbps

Physical Interfaces

Let's take a minute to discuss the physical interfaces between encoder(s) and other subsystems in the DTV encoder / transmitter facility. The most common interfaces in use are shown in the table below:

Interface Standard	Details	Common Usage
Serial Digital Interface (SD-SDI), SMPTE 259M	Uncompressed digital, 270Mbps data rate	Camera output / encoder input for 480i
HD-SDI, SMPTE 292M	Uncompressed for High Definition, 1.5Gbps data rate	Camera output / encoder input for 720p & 1080i
Asynchronous Serial Interface (DVB-ASI)	Asynchronous serial digital interface for MPEG-2 TS	Encoder output, MUX input / output, Exciter input
SMPTE 310M	Synchronous serial digital interface for MPEG-2 TS	Older STL (MUX output, Exciter input)
GbE / 1 GigE Ethernet, IEEE 802.3-2008	Gigabit per second packet switched network via RJ-45	Ethernet packet distribution via computer networks

A typical ATSC 1.0 MPEG-2 encoder system block diagram is on the following page. Generally, the program encoder video input is either SDI or HD-SDI. Some encoding systems still offer dedicated NTSC video inputs, such as our LEX-2000 encoding platform. The SPTS output of an MPEG-2 encoder is generally ASI to the MUX. The MUX Multiple Program Transport Stream (MPTS) output interface has evolved over the last 20 years. Originally, Studio-to-Transmitter Links (STL) incorporated SMPTE 310M all the way to the transmitter's DTV exciter input. SMPTE 310M has been replaced by ASI on newer STL systems. Many newer encoder solutions offer an IP GbE Ethernet interface.



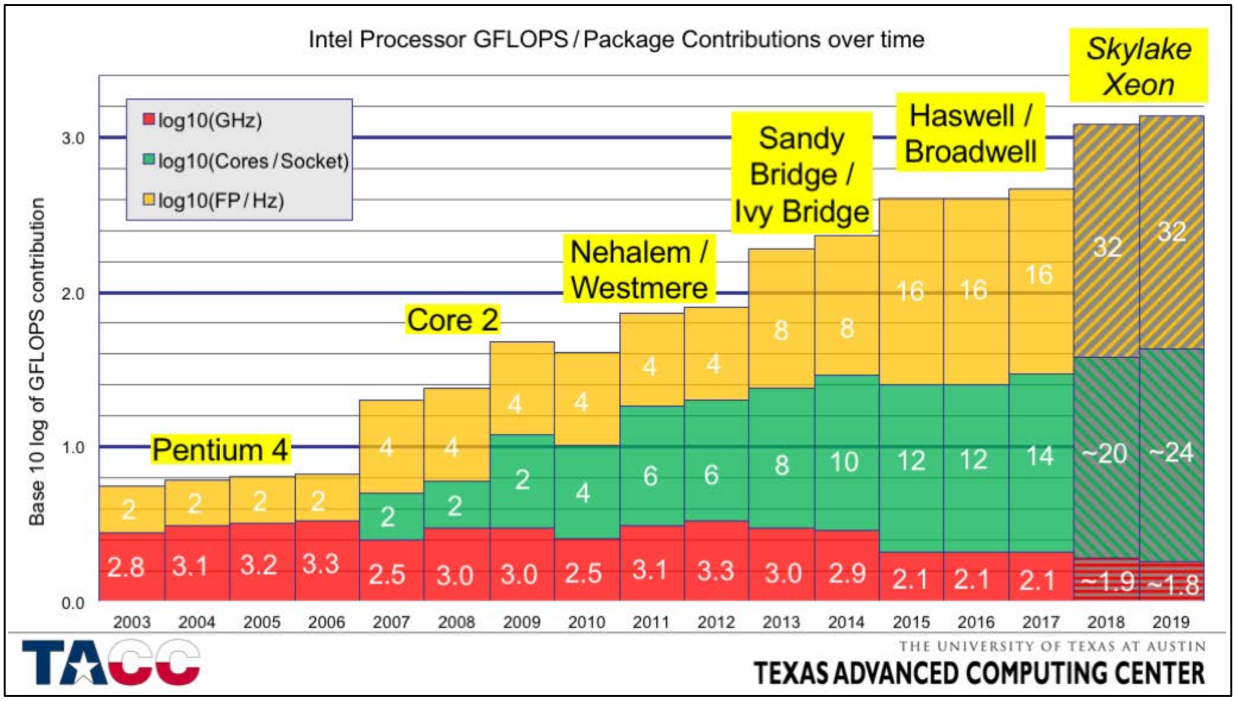
The LEX-2000 (rear panel shown below) is an all-in-one encoder / MUX platform that uses ASIC technology for signal processing. The LEX-2000 is a very cost effective platform that was designed for LPTV systems as well as backup / disaster recovery applications. This encoder incorporates many of the standard system interfaces (SDI, HD-SDI, NTSC, ASI, GbE, DVI) for maximum implementation flexibility.

Rear Panel - LEX-2000 Hardware Based Encoder

Purpose built hardware platforms were originally required to provide the best performance for processing DTV signals, given the complex and time sensitive relationship between audio, video, and metadata. These platforms also included many of the previously reviewed input / output interfaces that are very specific to audio / video signals and are very different from what is used in the IP world of computers.

Over the last decade, general purpose computers and servers based on Intel / AMD processors and COTS hardware have been augmenting computing functions with specific acceleration engines to enable more efficient handling of media signals. Only recently have general purpose CPU's been powerful enough to compete with the power footprint and density capabilities of an Application Specific Integrated Circuit (ASIC) or Field Programmable Gate Array (FPGA). However, there have always been challenges to meet the stringent real-time requirements for processing audio and video signals.

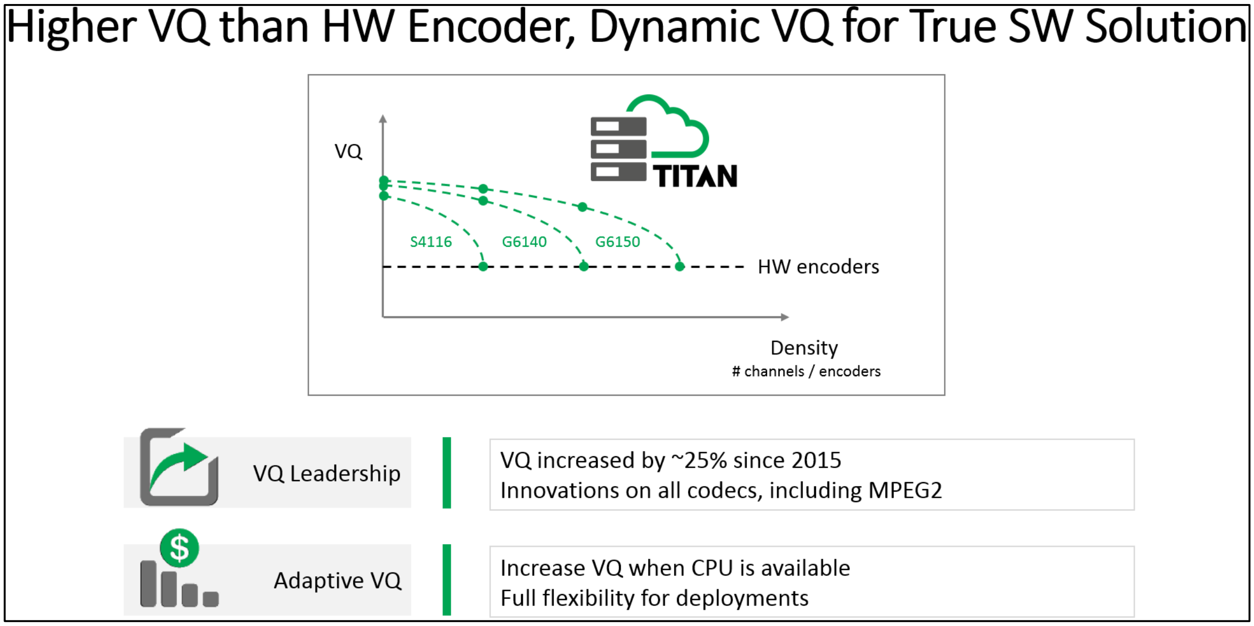
In the last few years, the pace of improvements in computational efficiency and understanding of prioritized multi-threading inside the operating system (usually some variant of Linux) have overcome the challenges of the past, making it now possible to very reliably perform the standard decoding, encoding, and transcoding of audio / video content.



There has also been a move within the broadcast industry to leverage the performance of the ubiquitous 1 / 10 / 100 Gbps IP interfaces in the computer world to transport audio / video signals. According to the SMPTE web site: “SMPTE ST 2110 Professional Media Over Managed IP Networks suite of standards is a major contributing factor in the movement toward one common Internet Protocol (IP) based mechanism for the professional media industries.” This will further enable the use of COTS hardware from the computer industry for all broadcast processing as well as transport applications.

Moving from Hardware to Software Encoding Technology

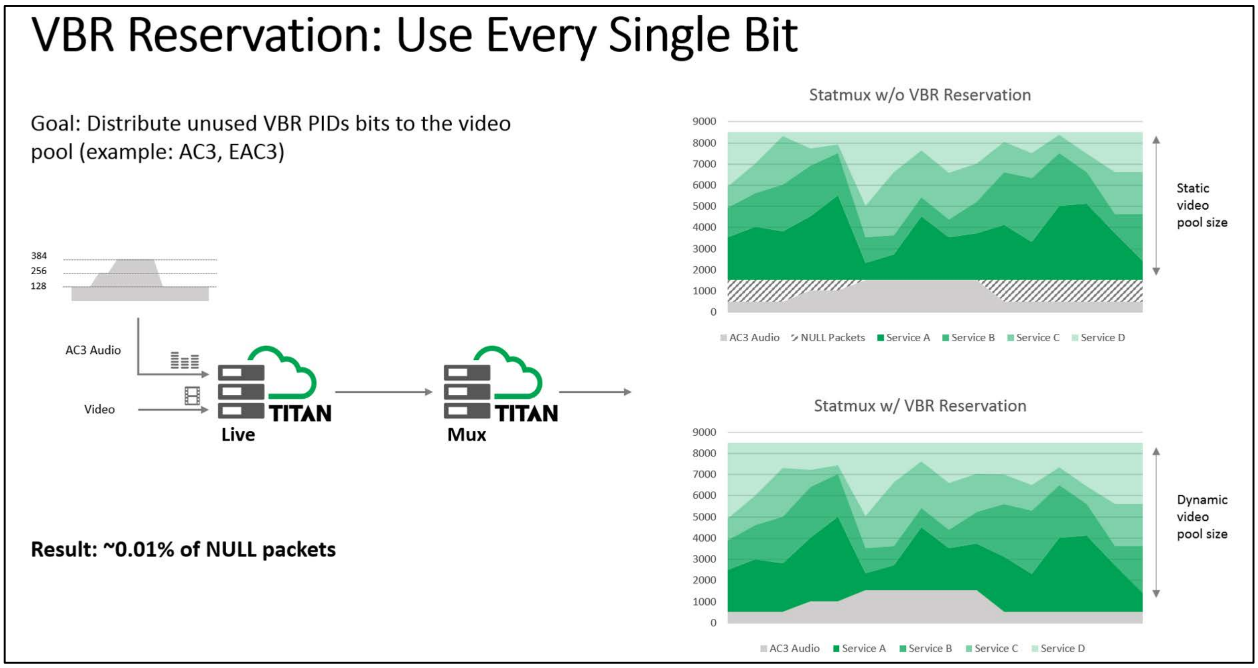
With the advent of faster CPU's and the intellectual property that is the foundation of TITAN Live, encoding has been able to move from FPGA to general purpose CPU. This allows the encoding solution to run on premise, virtually, in the cloud, or in a hybrid fashion. There is no “proprietary hardware box” to ship around anymore.



The TITAN Live development team has also taken what it’s learned from AVC and HEVC development to backport into its original MPEG-2 development for HE-MPEG-2 (High Efficiency MPEG-2). The TITAN Live solution boasts up to 20% MPEG-2 efficiency increases over older legacy MPEG-2 ASIC based solutions. Our pure software encoder is elastic, meaning that the software automatically adapts to the available CPU resources.

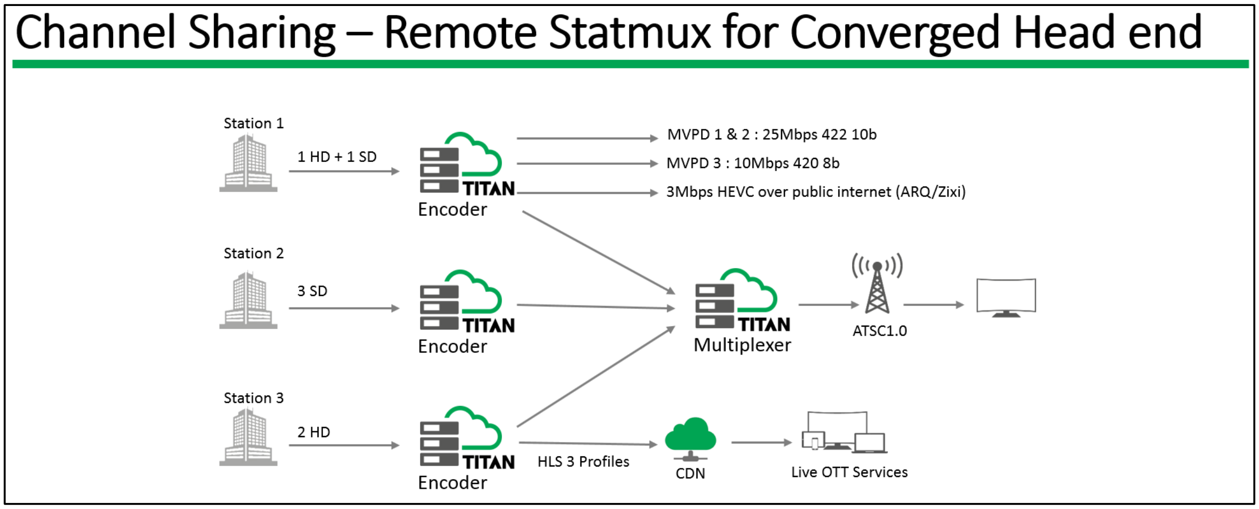
ATSC 1.0 Software-Based Encoding Capabilities

Some of the legacy MPEG-2 encoders for ATSC are CBR (Constant Bit-Rate). With the advent of faster CPU's, the TITAN Live codec, and the TITAN statistical multiplexing algorithm, the VQ of the final product can look much better than it ever has before. Not only is TITAN Live varying the video bit-rate based upon scene complexity, the algorithm also monitors unused bits that could be used for video in a process termed VBR Reservation. For example, as audio bit-rates fluctuate, we will use the unused audio space for video, maximizing the Transport Stream (TS) payload.



The TITAN Live software-based solution has also been developed with the capability to enable Remote StatMUX, in which a MUX may be at a transmitter and encoders can be at different geographical locations with different network latencies. This allows for higher VQ (by not having to re-encode at the transmitter site) and lower CAPEX (by not spending more on encoding services).

A pure software solution paired with remote StatMUX enables users to be flexible in how they deploy solutions. The Encoder and MUX can both run on the same server as an appliance, in addition each one can be run on different servers in different locations or they can be run virtually in common cloud service providers.



Broadcasters want to add value to their existing ATSC 1.0 infrastructure by adding channels or adding new ways of reaching consumers. The TITAN Live ATSC 1.0 solution is not a “me too” solution. In fact, the same system can enable a broadcaster to serve their linear MPEG-2 distribution, as well as give them capability to serve AVC / MPEG4 OTT and provide an HEVC upgrade path for ATSC 3.0. One system that fits the needs of today and tomorrow.

- ATSC 1.0 Remote StatMux – Flexible for repack or potential re-architecture
- ATSC 1.0 VBR Reservation – Uses the bits more wisely, increase VQ or add more channels
- Built-in Packager for simultaneous OTT streaming – HLS, DASH, smooth streaming, RTMP
- ATSC 3.0 ready – The system is HDR HEVC ATSC 3.0 ready whenever the broadcaster is
- TITAN Live world class VQ with in-house PhD Video Algorithm staff
- 100% software solution so you can control how and where you want to run it
- A full ATSC 1.0 system with SDI, ASI, and ATSC 3.0 capability that can run in 1RU rack space

Transitioning SW encoder for NGBT

Broadcasters that are deploying new ATSC encoder solutions today have to keep an eye on what is coming down the road tomorrow. NGBT, also known as ATSC 3.0, provides broadcasters with even more flexibility and efficiency to do more within their spectrum resources. NGBT takes advantage of the newest, most advanced video codecs, including HEVC.

Software encoding solutions are ideally suited for broadcasters transitioning to NGBT, since the encoding engines are flexible enough to accommodate multiple output formats (MPEG 2, H.264, and HEVC) from a single encoding platform providing customers with:

- A common primary feed to everyone in the format desired by the end customer, adding higher or lower bit rates and quality depending on their commitment
- Primary feeds at different rates to different parts of the network dependent on congestion or other network factors
- Additional lower bit rates and mobile formats as mobile devices and playout requirements evolve

TITAN Live provides all this flexibility on the output formats without the need for any additional licenses.

HDR / HFR / WCG

There are a lot of discussions in broadcasting about using NGBT to deliver "better pictures" to the end users. There are five elements that define video picture quality including:

1) Display resolution (SD, HD, 4K / UHD, or 8K)
2) Frame rate (29.97, 30, 59.94, 60, 119.88, and 120 interlace / progressive FPS)
3) Color depth (8 / 10 / 12 bits per sample)
4) Image brightness range (SDR / HDR)
5) Color gamut (RGB vs BT.2020)

The graphic on the next page shows the impact of varying each of the five items above and the resultant picture improvement for the end user. It should be noted that increasing the picture's resolution, frame rate, and color depth (items 1, 2, and 3 above) requires significantly more bits when moving from SD to HD to UHD. For example, a 2160p UHD image (2160 lines x 3840 pixels) provides four times the resolution of 1080p HD (1080 lines x 1920 pixels). This increase in resolution simply requires more bits (bandwidth) in the broadcast TV station's 6MHz RF channel. It should also be noted that 4K is not exactly the same as UHD in terms of resolution:

- 4K is 2160 lines x 4096 pixels (which is a digital cinema standard, 21:9 aspect ratio)
- UHD is 2160 lines x 3840 pixels (4 x resolution of HD)
- 8K is 4320 lines x 7680 pixels (16 x resolution of HD)

Conversely, broadcasters that utilize HDR and WCG technologies will improve picture clarity (using metadata) without much additional penalty to the payload of the HD resolution. Hence some broadcasters are looking to use ATSC 3.0 / NGBT to provide 1080p + HDR + WCG as the best compromise between bandwidth usage and better pictures.

Technologies employed in the studio (image capture and post-production) need to properly process and format the video signals from the onset. The rest of the video distribution workflow must be video aware to properly process and transmit better pictures.

High Dynamic Range (HDR), High Frame Rate (HFR), and Wide Color Gamut (WCG) are technologies that can be used in ATSC 3.0 / NGBT that enhance picture quality for the end user. Better pictures can be achieved with higher video resolutions (SD vs. HD vs. 4K / UHD) as well as with HFR and WCG technologies.

Prior to 4K / UHD, ITU-R Recommendation BT.709 was released around 1990 to specify the High Definition TV (HDTV) standard that is currently in use within the US. BT.709 includes features such as 16:9 wide screen format, specific frame rates, 1080i and 1080p resolutions, in addition to 8 or 10-bit color samples.

HDR technology expands the color range of the image to make the HDR picture seen by a consumer more "life-like". ITU-R Recommendation BT.2100 (aka Rec. 2100 or BT.2100), defines various aspects of HDR video. Rec. 2100 defines two sets of HDR Optical-Electrical Transfer Functions (OETF) which are:

- Perceptual Quantization (PQ) from Dolby SMPTE ST 2084
- Hybrid Log-Gamma (HLG) from NHK / BBC

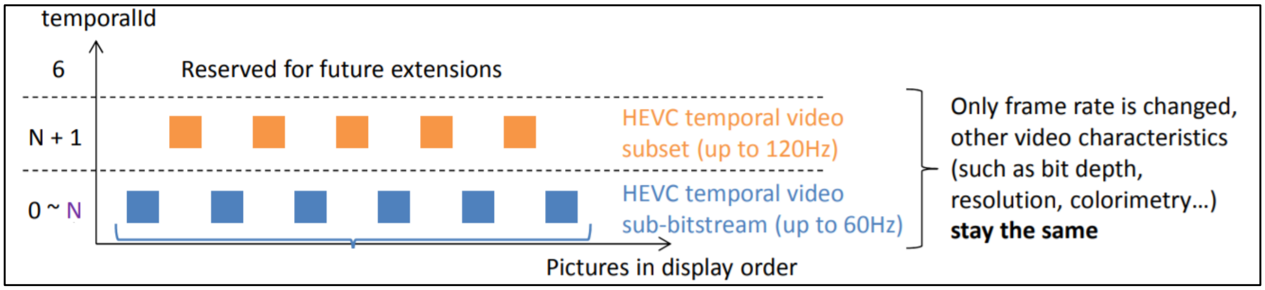
From a broadcasting facility perspective, the TITAN Live encoding system needs to be HDR agnostic, which means it supports all modern versions of HDR with the capability to implement new standards as they are formalized.

Below is a list of HDR standards currently supported by TITAN Live:

Technology	Use cases	OETF	Static Metadata (ST2086)	Dynamic Metadata (ST2094 or ETSI)	SDR TV / STB compatibility	HDR TV / STB compatibility
PQ 10	HDR	PQ	No	No	No	w/ PQ 10 support
HDR10	HDR + metadata	PQ	Yes	No	No	w/ HDR10 support
Samsung HDR10+	HDR + metadata	PQ	Yes	Yes	No	w/ HDR10 support
HLG	SDR / HDR	HLG	No	No	Yes (phase1)	w/ HLG support
Dolby Vision (8.1)	(HDR / SDR) + metadata	PQ / BT.709	Yes	Yes	Yes, with IP/Yes	w/ HDR / SDR support or Dolby
Technicolor (SL-HDR2)	HDR + metadata	PQ	Yes	Yes	Yes, with IP	w/ HDR10 support or Technicolor IP
Technicolor (SL-HDR1)	SDR + metadata	BT.709	Yes	Yes	Yes	w/ Technicolor IP

TITAN Live is a pure software solution that allows HDR updates and additions. We are a leader in HDR working and partnering with standardization bodies, studios, and other manufacturers. Also, beyond the HDR technology, TITAN Live software encoding supports different HDR workflows.

HFR is most important for fast moving sports or content where motion blur can occurr due to fast moving objects. TITAN Live has been developed to support HFR video encoding @ 100 fps and 120 fps with a temporal subset stream. The first PID / stream is encoded as 60 fps, which is capable of being decoded on a standard decoder-display for backwards compatibility. The first and second PID / stream are decoded on capable decoders-displays to output a natively decoded 120 fps video stream.



The TITAN Live offers a better viewing experience for those who can utilize 120 fps with backwards compatibility. Furthermore, 120 fps encoding adds minimal overhead to the base stream and we are working with display manufacturers to ensure interoperability. The benefits of TITAN Live users are simple, even if the 120 fps contents is not widely deployed today, having an HFR-ready solution provides more options moving forward.

WCG is sometimes lumped in with HDR but they are not specifically linked together. A colorspace is a standard that defines a specific range of colors that a given technology can display, with maximum red, green, and blue points. The colorspace can be mapped via X / Y / Z coordinates on a Chromacity diagram. The area inside a given X / Y / Z colorspace is its corresponding “gamut”. A color gamut is well defined so that image captures can be optimally recreated during image presentations on a user’s screen (PC, projector, TV, etc.)

HDTV uses Rec.709 color gamut, using 8-bit depth. WCG (Rec. 2020 color space) is a 72% increase in the available color pallet so that viewers see "redder" reds, "greener" greens, and "bluer" blues more vividly. Thus, images that are using WCG are more life-like. In HDTV, 16.7 million colors were possible, with WCG we have increased the pallet of available colors to over 1 billion.

HEVC vs. AV1

Digital video encoding has evolved from MPEG-2 to AVC / H.264 to HEVC / H.265. Each new iteration of encoding algorithms provides an approximate efficiency gain of 35% over the previous generation. Larger screens demand better images and consumers are looking for better pictures in the form of UHD / 4k content, HDR, and WCG. AVC and HEVC encoding algorithms have also been designed to support these new features. It's a given that HEVC is the current codec of choice within ATSC 3.0. Hence, TITAN Live supports:

- HEVC up to 12-bit encoding (including HEVC Main 10)
- Any resolution for both progressive and interlaced content.
- Built-in packager allows both TS and DASH output

There are multiple benefits for participating stations including:

- Improve the density per Tx by leveraging the combination of HEVC, StatMux, HDR, and WCG
- Simplified workflow by combining HEVC and DASH packaging
- TITAN HEVC encoding is compatible with Scalable HEVC (SHVC), StatMux, HDR, HFR and WCG

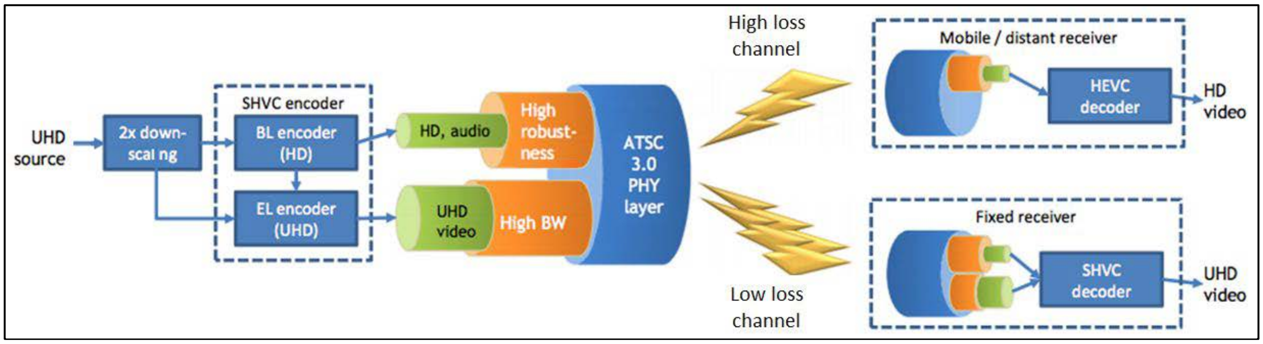
From a technical perspective, better efficiency and better picture quality is always good. However, from a business perspective there are potential issues associated with intellectual property, patents, and royalty fees that could hinder widespread adoption of HEVC. This is where AV1 could potentially come to play. AV1 was recently released (Jan-2018) and is a royalty-free video codec that also promises to boost efficiency over HEVC. So where will all of this end up as broadcaster's implement NGBT? No one knows for sure.

The bottom line is that the flexibility of the software-based TITAN Live solution, along with multiple options for implementation, will allow broadcasters to migrate more easily to future codes as technology continues to improve and evolve.

SHVC

Scalable HEVC or SHVC is an extension that allows simultaneous encoding of different versions of a video organized in layers. Thanks to inter-layer predictions, SHVC provides bit-rate savings over an equivalent HEVC simulcast encoding. TITAN Live supports dual layer SHVC where the video is encoded into a Base Layer (BL) and an Enhancement Layer (EL).

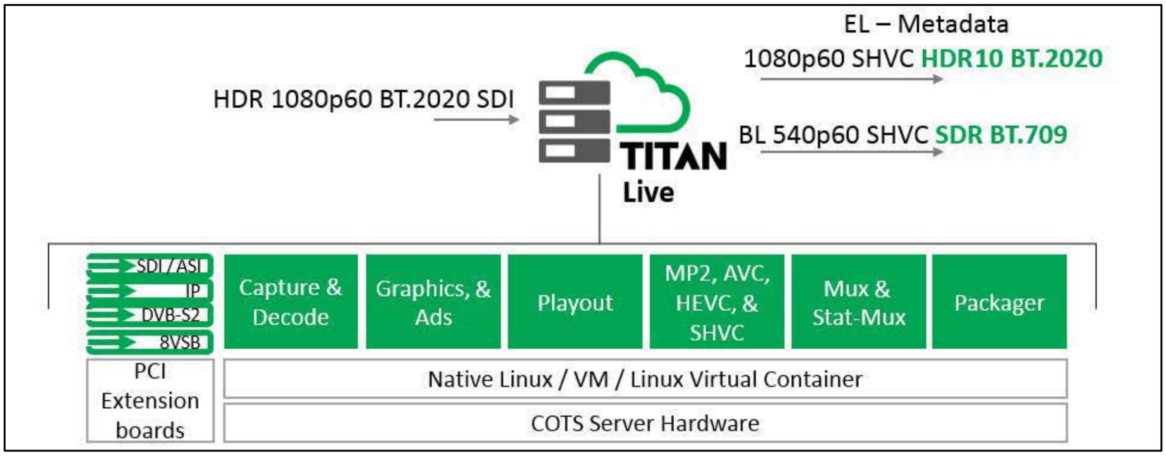
- The BL provides a lower resolution image for use in a high loss channel, providing the capability of deeper penetration / better coverage area
- The EL uses the information in the BL and improves the VQ (via higher resolution) for the low loss channel



TITAN Live provides a user configurable ratio between the BL and EL as well as the support of Scalable HEVC with HDR, StatMux, and WCG. A use case example is shown below:

SHVC / HDR Use Case Example

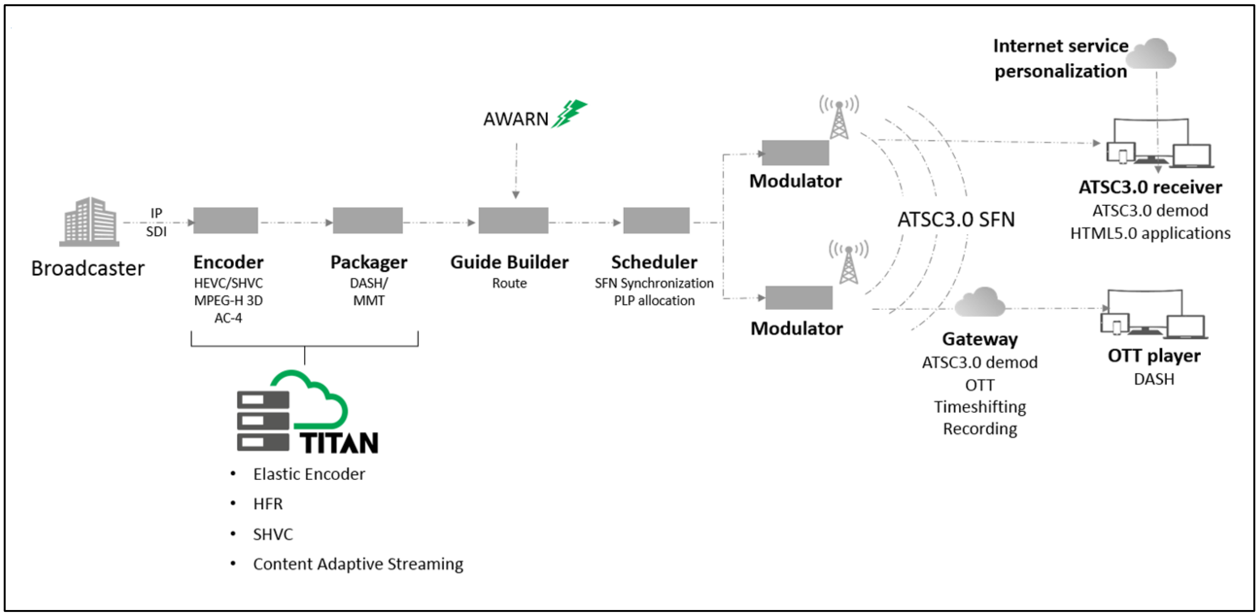
Signal:	Physical IO:	Resolution:	Enhancements:
Input	SDI Signal	1080p60	BT.2020
Output (BL)	IP Stream	540p60 HEVC	SDR BT709
Output (EL)	IP Stream	to 1080p60 HEVC	HDR10 BT.2020



In another SHVC implementation, a broadcaster could also consider a simpler use case where only the temporal scalability is used (without any HDR / SDR or WCG conversion). SHVC provides a couple of very important benefits to broadcasters that implement this technology. First, SHVC can save up to 30% of the bitrate allocation when compared to a simulcast encoding use-case (same video program that is transmitted in two separate resolutions). The second benefit is related to flexibility on bit-rate allocation. TITAN Live can provide ratio configuration between the SHVC BL and EL.

Basics of Implementing ATSC 3.0

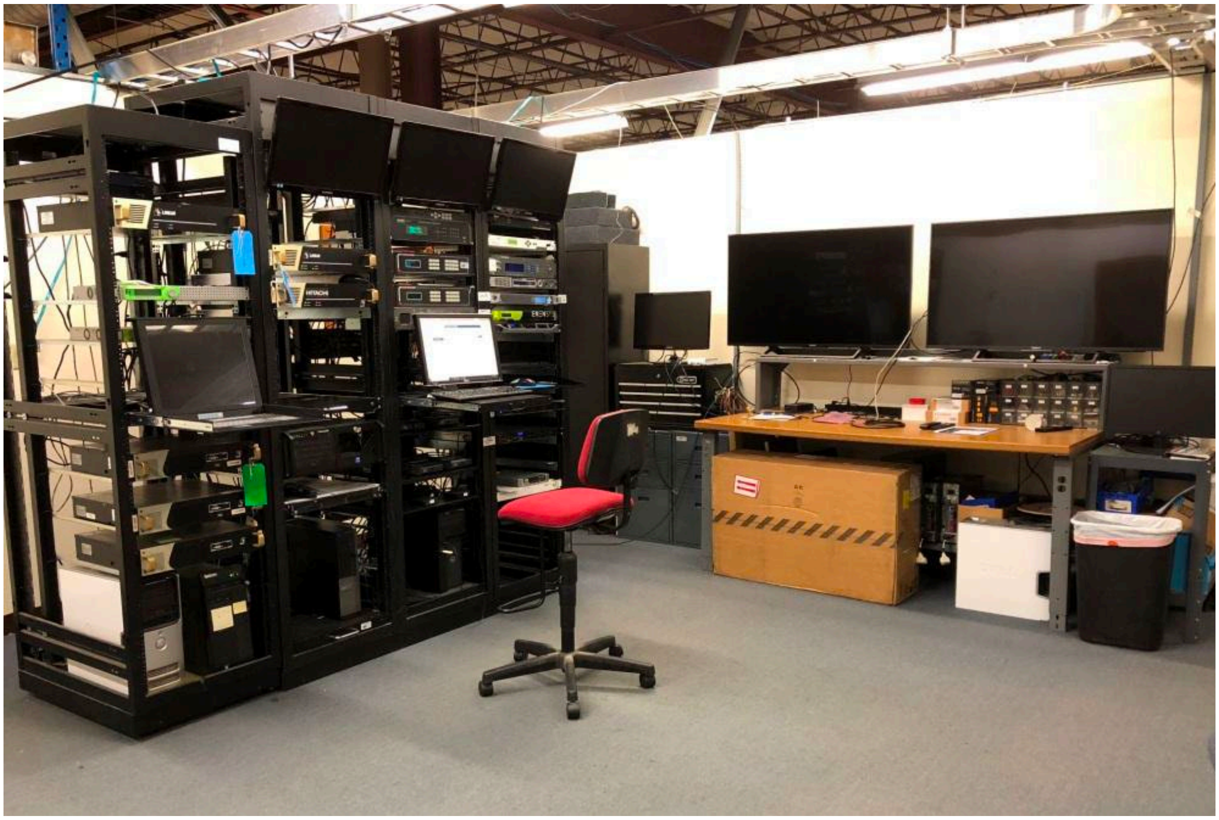
So, you are already on board with deploying a new TITAN Live software-based encoder solution. The next question just around the corner is transitioning this system to ATSC 3.0. OTA stations moving towards NGBT will require additional hardware to implement the ATSC 3.0 standard as seen in the block diagram below. Note that there are options when integrating an end-to-end signal processing chain for NGBT. The info presented here is just one such solution.



The first device is the PACKAGER, which converts the IP streams from the encoder into DASH / MMT. The packager can be implemented on the TITAN Live platform. The next device is a Guide Builder / ROUTE server, which is used to deliver all of the data streams (including video, audio, and captioning). A Scheduler, or broadcast gateway, provides encapsulation and sends the signal via STL to the transmitter's ATSC 3.0 enabled exciter(s). The scheduler is responsible for the setup of Physical Layer Pipes (PLP's), Single Frequency Network (SFN) synchronization, and Layered Division Multiplexing (LDM). Generally, these products are typically installed at the studio or the Network Operations Center (NOC). ATSC 3.0 is a highly capable and complex set of standards and additional details on the ATSC 3.0 standard are available from our separate white paper from Hitachi-Comark.

CDS System Integration

CDS offers a team of experienced broadcast professionals that understand the complex worlds of IT and encoding technologies inside and out. Whether replacing a legacy ATSC 1.0 system or planning a complete ATSC 3.0 rollout, we can guide you through the business and equipment options. CDS can help you select the most advanced and reliable technology, design the system, and integrate it all at our advanced labs in addition to handling the end-to-end implementation.



CDS Integration & Testing Lab located in Southwick, MA

The CDS lab offers broadcasters:

- ATSC 1.0 and ATSC 3.0 system integration capability
- End-to-end capability including 8VSB and OFDM exciters
- Multiple off-air and locally served video sources
- MPEG-2, AVC / H.264, HEVC encoder capabilities
- Various test and monitoring capabilities for TS, VQ, and RF analysis
- GPS and satellite reception capabilities

Our powerful encoding products deliver world-class VQ even in the most challenging configurations. We have optimized solutions for channel sharing and are ATSC 3.0-ready, all at a price that won't break your budget. CDS will bring your project from strategic vision to on-the-air reality.

Cloud vs. bare metal / VM

The "cloud" is one of the hottest topics in the world of broadcast and media at the moment. It seems like every vendor is keen to offer a cloud solution, even if some are not always clear on exactly what it means and where the benefits lie. So the first question for a broadcaster to understand is: What is the cloud?

Gartner defines the cloud as a means of computing which is scalable and elastic. IBM says it meets three key points: the elasticity to scale up and down on demand, a metered service so you pay for use, and the ability to self-provide rather than rely on others to set up services for you. It is important to remember that the cloud is not important by itself. Cloud computing is a part of a much wider technological transformation in the media industry and an important element in achieving the promise of new efficiencies.

Virtualization

When using dedicated hardware platforms for signal processing, each device had a single function. Moving to processes running in software, on standardized hardware, we do not need a platform for each operation. We simply need to have enough processors for peak performance demands, as well as for software processing start-stops. This strategy is known as "virtualization".

When the application is separated from the hardware, each function appears as a Virtual Machine (VM) running on common, shared hardware with some overseeing orchestration layer allocating processors as required. The orchestration layer, the hypervisor, allocates memory, storage, processing cycles, and connectivity as demanded by the application. It can even overlay virtual operating systems if that makes the application layer more efficient.

Virtualization offers reduced CAPEX because you do not need a machine or dedicated hardware platform per function, you simply need to be able to support sufficient virtual machines during the busiest times. Virtualization means you can create a very flexible system architecture because you are not connecting machine-to-machine, but rather simply linking a series of software processes. New workflows, and even completely new functionality, are created simply by defining, in software, which processes need to be applied to content. This allows for the orchestration layer to create virtual machines as it needs them.

Cloud

The principles of virtualization can be applied at a number of levels. You could transform the broadcast machine room into a server farm or you could integrate the media functionality into the enterprise-level IT infrastructure. With an enterprise-level IT infrastructure, processors could be running HR or business process management at one moment and then broadcast encoding or transcoding the next.

This implementation could prove very effective if you have a lot of non-real-time encoding jobs that could be batched to run overnight when IT applications are lightly loaded. Keeping the processing on premises has the additional benefit of keeping content under your roof in an industry where many media companies are still nervous around intellectual property control.

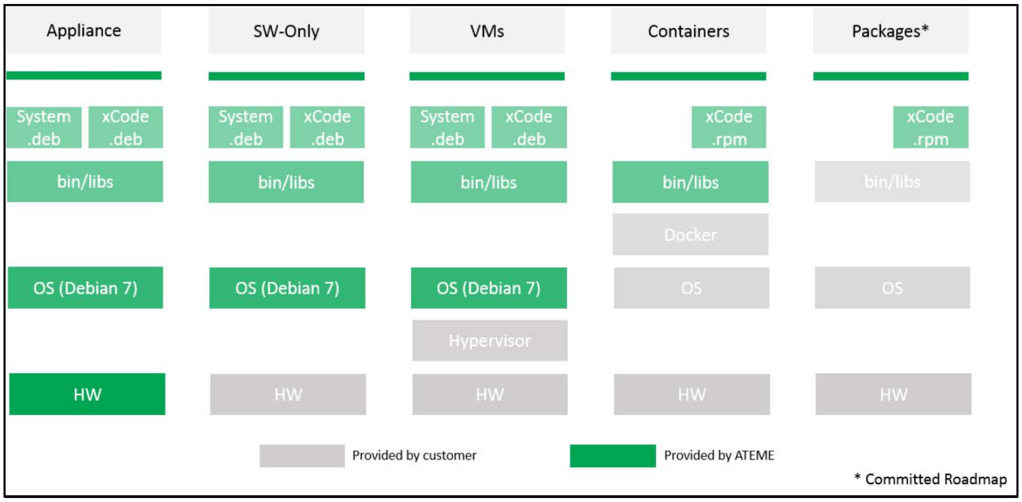
Increasingly, businesses are turning to true cloud-based operations, whereby a third-party service provider takes on the responsibility for providing off-site storage and processing capabilities. This might be a third-party company providing specialist services or it might be a business specializing in the cloud, such as Amazon Web Services (AWS).

The business model is that you pay for storage space and for processing minutes, so you move from the traditional broadcast CAPEX account to a largely OPEX one. This has tremendous implications: you pay for what you need so you have a direct link between a service and the cost of providing it. Cloud computing makes decisions around monetization and commercial viability simple and transparent.

The relationship between a media company and a cloud provider will be defined by a Service Level Agreement (SLA). The SLA will define performance, processing, and availability of content. An agreement should also define the level of security that will be imposed around your content, which you should expect to be very high. For reassurance of cloud-based service, it should be noted that the American CIA uses AWS for its data!

Cloud Encoding

Encoding is a classic cloud computing application. For example, delivery of a new series of dramas or sitcoms will create a big demand for transcoding into multiple formats. The elasticity of a well-provisioned cloud service will mean that a large number of processor cores will be dedicated to the task, then released to other cloud clients upon completion. The result of this hardware abstraction is operational simplicity and a very high performance rate, higher than you could achieve in a traditional architecture through much lower levels of CAPEX. Fortunately, the TITAN Live software-based solution can be deployed in a number of ways depending on the infrastructure requested by the customer, as presented in the diagram below:



The cloud is inherently secure and resilient, with data protection and redundancy defined in the SLA. When new versions of software come along or you want to add new services, the cloud provider will undertake the necessary sandbox testing and verification, allowing you to add them quickly with full confidence. New processes can be integrated quickly through the use of software-defined architectures.

The need to move large files around is currently providing some impediments to cloud migration. However, with the use of file transfer acceleration and the wider availability of high-speed data circuits, this limitation will certainly fade away in the near future. The result of cloud encoding will be an attractive solution to the finance director because of the move from CAPEX to OPEX and the direct correlation between a service as well as the cost of providing it. Cloud encoding is attractive to operational engineers because its elasticity gives a highly responsive solution. Finally, it's attractive to the audience because content will be available to them, on their preferred platform, faster and in higher quality.

Conclusion

Digital TV encoding systems for broadcast television have certainly evolved since ATSC was mandated by the FCC back in 1996. Early MPEG-2 program encoders required a 5RU dedicated hardware platform to process a single HD 1080i program. Today, encoder / MUX systems simultaneously process multiple HD and SD programs for current ATSC 1.0 / MPEG-2 requirements and can easily be deployed using a software-based solution on commercial server platforms. The IT industry continues to advance CPU capabilities as well as IP connectivity speeds and these advances are working their way into the broadcast infrastructure workflow.

The MPEG-2 compression algorithm has been superseded by AVC / H.264, which has been in turn superseded by HEVC / H.265. Each new iteration of encoding algorithm provides an approximate an efficiency gain of 35% over the previous generation, meaning less bits are required and higher resolution images are possible. Moving forward, ATSC 3.0 / NGBT will take advantage of the latest advances in encoding algorithms and picture enhancements such as UHD, HFR, and WCG. Software-based encoder platforms such as the CDS powered by TITAN Live are positioned to deliver both MPEG-2 and HEVC content for today and tomorrow.

Glossary

ASI	Asynchronous Serial Interface
ASIC	Application Specific Integrated Circuit
ATSC	Advanced Television Systems Committee
AVC	Advanced Video Codec
AWS	Amazon Web Services
BL	Base Layer
CAPEX	Capital Expenditure
CBR	Constant Bit-Rate
CDS	Comark Digital Services
COTS	Commercial Off-The-Shelf
DASH	Dynamic Adaptive Streaming over HTTP
DTV	Digital Television
DVB	Digital Video Broadcasting
DVI	Digital Visual Interface
EL	Enhancement Layer
FPGA	Field Programmable Gate Array
FPS	Frames Per Second
GbE	Gigabit Ethernet
Gbps	Gigabits per Second
GHz	Gigahertz
HD	High Definition
HDR	High Dynamic Range
HD-SDI	High Definition Serial Digital Interface
HDTV	High Definition Television
HE-MPEG-2	High Efficiency MPEG-2
HEVC	High Efficiency Video Codec
HFR	High Frame Rate
HLG	Hybrid Log-Gamma
HLS	HTTP Live Streaming
IO	Input/Output
LDM	Layered Division Multiplexing
LPTV	Low Power Television
Mbps	Megabits per Second
MPEG-2	Motion Picture Expert Group
MPTS	Multi-Program Transport Stream
MUX	Multiplexer
NGBT	Next Generation Broadcast Television

NTSC	National Television Standard Committee
OETF	Optical-Electrical Transfer Functions
OFDM	Orthogonal Frequency Division Multiplex
OPEX	Operational Expenditure
OTA	Over-the-Air
OTT	Over-the-Top
PCI	Peripheral Component Interconnect
PID	Program ID
PLP	Physical Layer Pipe
PQ	Perceptual Quantization
PSIP	Program and System Information Protocol
RF	Radio Frequency
RGB	Red Green Blue
RTMP	Real-Time Messaging Protocol
RU	Rack Unit (1.75 in.)
SHVC	Scalable HEVC
SD	Standard Definition
SDI	Serial Digital Interface
SDR	Standard Dynamic Range
SFN	Single Frequency Network
SHVC	Scalable HEVC
SLA	Service Level Agreement
SMPTE	Society of Motion Picture and Television Engineers
SPTS	Single Program Transport Stream
STL	Studio-to-Transmitter Links
StatMUX	Statistical Multiplexer
TS	Transport Stream
UHD	Ultra High Definition
VBR	Variable Bit Rate
VM	Virtual Machine
VQ	Video Quality
WGC	Wide Color Gamut
480i	480 lines x 720 pixels wide resolution interlaced scanned
720p	720 lines x 1280 pixels wide resolution progressive scanned
8-VSB	8 Vestigial Side Band
1080i	1080 lines x 1920 pixels wide resolution interlaced scanned
1080p	1080 lines x 1920 pixels wide resolution progressive scanned