ATSC Planning Team 4 – Future Broadcast Ecosystem Technologies: PT-4 Report Summary on Video – 2018/2019

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1. INTRODUCTION

In August 2018, the ATSC Board of Directors created Planning Team 4 (PT-4) to consider the prospects and potential impact of Future Video Technologies. After several months of valuable discussions, the Board elected to expand the scope of PT-4 to encompass future technologies including video and beyond. (See https://www.atsc.org/subcommittees/planning-team-4-future-video-technologies/.) This report summarizes the discussions and findings of PT-4 relating to video technologies.

2. BACKGROUND

PT-4 organized its work effort on video into three inter-related tasks:

1) Future Codec Projections – potential advances such as coding efficiency, latency, functional capabilities, timelines, etc.
2) Future Video Formats/Services – possibilities such as 8K, very high frame rate, point clouds, Augmented Reality (AR), Virtual Reality (VR), etc.
3) Industry Evolution – considerations in evolving the future ATSC 3.0 ecosystem, such as broadcast signals, receivers, MVPD systems, OTT, etc.

Over the following nine months, 15 detailed contributions were extensively reviewed and discussed by over 70 members of PT-4. The findings and opinions expressed in its report are a consensus of the participants' conclusions.

PT-4's report was presented to the Board as a PowerPoint presentation at its Strategic Planning meeting in July 2019. The following sections of this paper provide a concise summary and overview of PT-4's discussions, perspectives, and opinions. The PowerPoint contains a substantial amount of supporting information and has deeper technical and rationale details than can be presented in this overview. PT-4's report is available to all ATSC members and we encourage their review and consideration of its detailed work.

3. FUTURE CODEC PROJECTIONS

Looking at the history of video codec development of the past ~30 years and the current work plan of the MPEG/JVET group, it is reasonable to expect that the efficiency of video codecs will continue to advance in the foreseeable future. However, there will always be fundamental tradeoffs among video resolution, channel capacity/transmission bitrate, and picture coding artifacts that will need to be balanced in the constraints that are applied to standards for specific applications (e.g., ATSC for broadcasting) and in the configurations of those standards that are implemented by users.

History suggests that new codec generations develop on ~7–9 year cycles and that each new codec generation reduces bit rate by ~40–50%. History also suggests that the performance of a given codec can continue to improve for ~10–20 years.

The current MPEG work plan for the next-generation VVC (Versatile Video Coding) codec is targeting ~50% efficiency improvement over HEVC and standard completion in 2020. MPEG is also working on the EVC (Essential Video Coding) codec, that seeks core profile performance similar to HEVC, using a core set of royalty-free coding tools planned for completion in 2020; and a simple, transparent licensing structure for a more efficient main profile promised within two years after publication.

Improvements in video compression require additional tools and options that can be invoked to encode the picture with the fewest bits. In order to incorporate new encoding tools, each new generation of video codec has a new syntax/bitstream — they are NOT backward compatible with previous generation decoders. History suggests that video codec changes are often accompanied (or triggered by) a change in video format; e.g., the change from SD to HD formats also triggered the change from MPEG-2 (H.262) to AVC (H.264) in many MVPD systems, and also in the change from DVD to Blu-ray discs.

The goal of providing a backward-compatible enhancement to a video service by using a legacy codec as a Base Layer and a new codec as an Enhancement Layer has been contemplated for decades. In practice, such attempts have been unsuccessful due to the quality/bitrate limitations of the legacy codec relative to transmission channel capacity. There are no developments that we are aware of that suggest that this will change.

As video coding efficiency advances and encoding computation increases become more difficult, it is possible that video codec development may become increasingly optimized toward specific applications. Given this possibility, future codec considerations for ATSC standards should include requirements driven by broadcast operations and business models, particularly in requirements such as compression efficiency and latency, which ATSC should communicate to MPEG and other codec developers in appropriate liaisons.

History suggests that improvements in codec efficiency alone may be insufficient to trigger market adoption in the one-to-many broadcast ecosystem, where broadcast services using a new (non-backward-compatible) codec are not receivable by legacy receivers and an entirely new user base must be started and grown; this in turn requires a new set of capabilities that are compelling to consumers. The result is an observation that we have dubbed "the codec conundrum*:* new codecs ALONE don't drive the marketplace … but new codec adoption is essential to avoid industry obsolescence". So, what will be the drivers for new codecs adoption?

4. FUTURE VIDEO FORMATS AND SERVICES

In retrospect, HD content production and delivery, and the development of consumer HD flat panel displays were wonderfully symbiotic. ATSC 1.0 delivered widescreen, high definition pictures and surround sound that were a leap from the NTSC analog standard. Can it happen again? — will CE manufacturers and Content/Broadcast upgrade cycles/market drivers align like that in the future?

There are multiple dimensions in which "traditional" video can continue to improve, even beyond the current limits of ATSC 3.0. These include: Resolution, Dynamic Range, Color Gamut, Color Sub-Sampling (e.g., 4:4:4, 4:2:2, 4:2:0, etc.), Sample Bit Depth, and Very High Frame Rate. But human visual system analysis concludes that very large displays and close viewing distances are needed to see the differences between HD and 4k; and that does not take into account the excellent up-conversion that is often performed in today's 4k displays. It is currently unclear what improvements will be commercially justified by significant perceived benefits in picture quality that are readily perceived by consumers and easily marketable to them, relative to the additional costs of content production and distribution (especially capacity / data rate) that they will require.

We observe that the adoption history of 4k in the U.S. suggests that rapid advances in consumer display capabilities have outpaced the ability of content producers and OTA/MVPD distributors to keep pace with aligned transitions to new formats. Currently, many feature films continue to be rendered in 2k (i.e., 2048 x 1080) for cinema *and its large screens*. HD remains the prevalent television format, even while 4k/HDR Blu-ray titles are available (the highest quality content available to consumers). Some OTT and MVPD services are also delivering 4k/HDR content. Most recently, 8k televisions are now available in the market and the industry has formed an 8k Association (8kassociation.com); the UltraHD Forum has also updated its most recent Guidelines document (Guidelines v2.1) with some 8k related information.

The discussion of future technical video format parameters and human perception factors raises the question of the goals and motivations for future improvements. It is unclear whether increased realism, more intense rendering of artistic intent, or pure information display density will drive future advances. At the same time, we note that there are new drivers of consumers' display device adoption and that new imaging formats are emerging, driven by VR and CGI applications. These formats will require new codecs and work is underway in both JPEG and MPEG. But it is currently unclear whether such formats are appropriate for broadcast delivery and audiences; there are also many unknowns in the production of such content.

We conclude that new video formats are an important area to "watch" – and that the historical progression from SD to HD may not be precedent for the future.

5. INDUSTRY EVOLUTION

Any consideration of a possible introduction of a new video format, codec, or signal type should begin with an understanding of its degree of non-backward compatibility and its potential impact on already-deployed ATSC 3.0 receivers. Two categories can be identified: 1) the new service/technology is not rendered by legacy devices, but it is gracefully ignored by them; and 2) the new service/technology is NOT gracefully ignored by legacy devices and it interferes with their operation to some degree. Note that in both categories, a non-backward compatible approach means that a new receiver is required to render the new service/technology.

Considering situations in the first category, launching new formats and/or codecs that are not backward-compatible with legacy 3.0 receivers (but are gracefully ignored by them) within OTA signals will trigger a need to deliver simulcast services in order to accommodate both new and old receivers. The problems of evolving a one-to-many broadcast can be considered in two categories: 1) getting "new services' bitstreams" to receivers, and 2) the ability for receivers to handle the "upper layers" represented by those bitstreams (i.e., their ability to decode, process and display new services).

Considering situations in the second category, where new signals or formats cannot be gracefully ignored by legacy 3.0 receivers and may interfere with their operation to some degree, further requires simulcast using different RF channels for the new and old services, just like ATSC 1.0 and analog NTSC, or like ATSC 3.0 and ATSC 1.0. These examples demonstrate that in such situations, careful channel assignment and frequency planning must be performed.

At the highest level, options for any industry evolution scenario depend on spectrum availability. Simulcast in New Spectrum is simplest but may not be feasible. Simulcast within a Shared Spectrum Pool or Simulcast within a Single Channel are probably more likely approaches.

Any in-channel evolution approach benefits from increasing signal capacity / data rate. SFNs are a promising opportunity. Boosting RF signal density throughout a DMA (i.e., increasing received signal strength) enables the use of PHY layer modcods (i.e., modulation and coding combinations) that require higher C/N (carrier to noise ratio) but provide higher data rates. Since the time of the original PT-4 report, the NAB and APTS filed a Petition for Rulemaking on 3

October 2019 requesting that the FCC modify its DTS (Distributed Transmission System) rules related to broadcasters use of Single Frequency Networks and on-channel repeaters.

The constraints imposed by requirements for backward-compatibility have historically proven to limit the efficiency and capabilities of the new system, while simultaneously imposing some degradation on the legacy system.

The ability for receivers to handle new "upper layers" carried by new services' bitstreams — to decode, process, and display those services — seems to be a challenging problem. Early ATSC 3.0 receivers are unlikely to be fully software upgradeable to future-generation capabilities (e.g., VVC codec, new RF transmission waveforms). We may be on the cusp of true software-defined receiver products, but there may be significant variation in software and hardware implementations among products, and the universality of software-defined designs should not be a near-term expectation.

But in the meantime, hardware upgrades in the form of "converter boxes" or multi-tuner "home gateways" and even plug-in "dongles" may be a low-cost way for consumers to extend the lifetime of TVs and other display devices while providing consumer upgrade paths for new codecs and formats. Of course, the performance of such devices may be limited by the capabilities of the legacy consumer equipment they are connected to.

Launching new upper-layer functionality such as new formats and/or new codecs that are not backward-compatible (with legacy 3.0 receivers) within OTA signals will trigger a corresponding need for a simulcast transition (e.g., 3.*x* and 3.*y*) to the new version. Just as ATSC 1.0 provided for the carriage of new services at the MPEG-2 transport stream level, ATSC 3.0 provides a similar functionality at the IP multicast stream level. This can potentially accommodate the introduction of new video formats and/or codecs that will be gracefully ignored by legacy receivers.

In addition, ATSC 3.0 provides new options at both the PLP/LDM level and at the PHY Frame level. In particular, the bootstrap signal and PHY Frame approach of ATSC 3.0 can allow new signal waveforms to be introduced in time slices that co-exist with legacy signals in the same RF channel.

There are many complexities and considerations that will need to be taken into account for any industry evolution scenario. PT-4 strongly cautions that the evolution of ATSC 3.0 should be a carefully considered and planned industry roadmap … NOT chaos unleashed that could confuse and disenfranchise consumers and result in a backlash against broadcasters.

6. CONCLUSIONS

In retrospect, the HDTV Grand Alliance and the ATSC 1.0 standard also envisioned the evolution of technologies and services [see PT-4 report slide 44 – excerpts from Grand Alliance System Specification, 1994]. Despite our attempts with A/72 AVC Codec and A/153 Mobile DTV, we observe that the commercial reality was that ATSC 1.0 *technology* didn't really <u>evolve</u>, although it <u>improved</u> greatly due to MPEG-2 encoding advances. The flexibility provided by the transport layer, PSIP, and support of multiple video formats has enabled the evolution of ATSC 1.0 *services*, including multicasting, channel-sharing, and ultimately the ability to transition to ATSC 3.0.

ATSC 3.0 has all of the flexibility of ATSC 1.0 and then some. ATSC 3.0 provides new PHY Layer extensibility and thorough signaling at each layer. That "Evolvability" facilitates the launch new technologies, but it does NOT inherently provide backward-compatibility or solve the business issues associated with managing non-backward-compatible technology transitions in the marketplace (economics, audience reach, spectrum capacity, MVPD capacity, etc.). It is crucial to understand that *technical "evolvability" of a standard does NOT guarantee evolution of the market.*

These observations point to the need for a carefully planned industry Roadmap for the evolution of ATSC 3.0 services and devices. In developing a roadmap, it is important that careful consideration be given to the benefits and impacts on all stakeholders in the ecosystem, including:

- Broadcasters/Spectrum: The pace and anticipated lifetime of incompatible versions and the shut-off of older versions should be given careful consideration in order to avoid the capacity requirements that would be needed if multiple versions must be simulcast (e.g., 3.*a*, 3.*b*, 3.*c*, 3.*d*, 3.*e*). Note that there are both commercial and regulatory considerations.
- MVPDs: What conversions are required for new versions of broadcast signals to be delivered to legacy subscribers (at different tiers of service and on different platforms)?
- Manufacturers: Product life-cycles, marketable performance, and features; avoiding consumer confusion.
- Consumers: Avoiding consumer confusion and *disenfranchisement* from a plethora of incompatible broadcast services and consumer products should be a paramount consideration.

It seems clear from both historical evidence and economic realities that evolution of ATSC 3.0 will be driven by the business cases NOT by the technology in and of itself.

Many complex and inter-related commercial considerations will be involved in creating and managing an effective Industry Roadmap that will impact all stakeholders. Some of the questions to consider when contemplating a roadmap are:

- How many incompatible versions can be simulcast?
- What triggers the launch of a new version?
- Can Scalable/Base layer play a role? (We note that this is an unproven hypothesis.)
- How is an old version phased out?
- When is an old version shut down? (How many consumers will be impacted?)

PT-4 encourages the ATSC Board and all stakeholders in the broadcast ecosystem to begin to contemplate these issues and to identify additional aspects of industry evolution for discussion and consideration.

7. POST-SCRIPT

The ATSC Board has requested that PT-4 continue its work, with an expanded charter to investigate new technologies that were beyond the scope of the initial effort. We invite all ATSC members to participate in our work.

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