A Revolutionary Digital Broadcasting System: Achieving Maximum Possible Use of Bandwidth

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Abstract

In a broadcast system incorporating both advanced video codecs and high-efficiency broadcast transmission technology, ten or more HDTV broadcast channels within one 6-MHz physical channel may be realized. To achieve this level of efficiency, a broadcaster could choose to manage the multiple channels of broadcast content in the same manner as cable and satellite systems operators do today. A better choice would be to employ advances in technology which enable scalable broadcast reception, drawing on a wide range of functionality and performance ranging from mobile phones to very large screen television. The system would be designed to deliver the maximum amount of high-quality content of all forms to a variety of receiving devices within a single service. Such a service would satisfy consumer demand for a viewing and listening experience that is even greater than that offered by the promise of ATSC 2.0.

1. Introduction

Next-generation broadcast technologies promise increased transmission capabilities. An advanced delivery system not only will enable increased channel capacity, it will bring forth the possibility of new user experiences. When next-generation broadcast television services are introduced later this decade, the following features can be expected to be included:

A) **Super HDTV and Eyewear-free 3DTV.** Market penetration of advanced display technologies such as Super HDTV (4K by 2K resolution) and eyewear-free 3DTV will provide an effective adoption path for broadcast services tailored to such technologies. Eyewear-free 3D and Free Viewpoint Television are being developed by ISO/IEC JTC1 SC29 WG11.

B) **Higher Efficiency Codec** The next-generation video codec, called High Efficiency Video Codec (HEVC), is being developed now by JCT-VC, a group which teams the experts in ISO/IEC JTC1 SC29 with those in ITU-T SG16 WP3. Significantly more efficient and higher compression rates are achievable through these technologies than with current AVC (ISO/IEC 14496-10 | ITU-T Rec. H.264).

C) **High-Bandwidth Internet.** As explored within ATSC Planning Team 3, improvements in wide-area network infrastructure, including widespread use of fiber optics, enable broadband services capable of delivering full resolution IPTV service to television viewers.

D) **High-Powered Mobile Devices.** Mobile devices with increasing intelligence and computing and graphics power are becoming commonplace. Coupled with various broadcast systems, these devices create an essential and necessary component in the daily lives of many individuals.

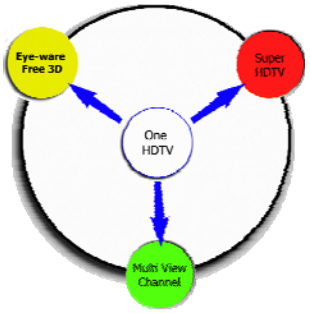
The following sections illustrate some of the broadcast service use cases that can be realized using these technological advances.

2. Effective Use of Broadband Services

Compared with the current broadcast system, the next-generation broadcast system is expected to provide a greater amount of usable bandwidth. In parallel, advancements in codec technology are expected to enable highly efficient video transmission. One conceivable result, for example, is that 6 MHz of bandwidth will be sufficient to transmit ten channels of high-definition (1080i or 720p) programming. Thus it is possible for a

broadcaster to introduce multi-channel programming services more similar to those offered by cable and satellite operators. It is quite desirable for next-generation terrestrial broadcast to offer added value by increasing the total amount of video content within a single 6 MHz transmission channel. This paper presents a next-generation broadcast television service as an effective means to deliver three new types of services, Super HDTV, eyewear-free 3DTV and Multi-view TV with Portal. Figure 1 depicts the enhanced user experiences available with various new TV technologies.

Figure 1: Video experience expansion



2.1 Use Case 1: Super HDTV

Tom enjoys the 100-inch large-screen DTV in his living room. Although he loves the quality of his big display when watching programs in 1080i or 720p resolution, one day he happens upon a program offered by XBC called World Heritage Journey that is offered in Super HDTV. He is captivated and thrilled by the breathtaking beauty of the intricate coral of the Great Barrier Reef.

By 2020, expectations are that TV display resolution will increase two-fold. Frame rates of 120 Hz exist today and higher frames rates are possible. The average size of living room televisions is predicted to increase. Thus, to take the advantage of the larger display's characteristics and to obtain optimal large screen picture quality, a new TV service may be envisioned. A Super HDTV service with a resolution of 3840x2160 and 60Hz progressive frame rate is expected to enhance the viewing experience. Super HDTV, as noted above, compared with current broadcast HDTV, contains twice the horizontal and vertical information. Super HDTV cannot be delivered in a 6 MHz channel with today's technologies, even using AVC (ISO/IEC 14496-10 | ITU-T Rec. H.264). However, with the advent of HEVC technology, it becomes possible to transmit a Super HDTV service within one 6 MHz channel. A Super HDTV service offers a true home theater experience for those viewers who own a 100 inch DTV screen in their living room.

1.2 Use Case 2: Eyewear-Free 3DTV

Bill has been interested in 3DTV for some time and immediately bought an Eyewear-Free TV when he first learned of their availability. With the combination of soccer broadcasts in 3D and his glasses-free TV, Bill is thrilled by the feeling of actually being on field of play.

In 2010, for the first time, the market offers 3DTV consumer displays. These sets require eyewear to enjoy the 3D effect. Cable and satellite services already offer 3D broadcast content and channels. The 3D work by ATSC Planning Team 1 is predicated on preserving full resolution and compatibility within the constraints of the existing 2D terrestrial broadcasting system. Looking farther into the future, the goal of TV manufacturers is to realize eyewear-free 3DTV. Eyewear-free 3DTV is possible for stereoscopic images. A more realistic display requires encoding and rendering of multiple viewing angles. Based upon these requirements, the MPEG 3DV (3D Video Coding) group has initiated research into coding methods for 3D multi-view video signals. Although the number of views required to realize multi-view 3D at a suitable quality level is unknown, through application of the HEVC codec it is plausible to think that an eyewear-free 3D service can be delivered within a 6 MHz channel.

2.3 Use Case 3: Multi-view plus Portal

XBC is broadcasting a car race and in addition to the typical program view provides sub-channels that can switch among six cameras placed at key points along the race course. The video feed from each sub-channel shows the location of one of the vehicles in real-time. A seventh sub-channel shows a course map, while another is a Portal channel, for a total of eight sub-channels. From the Portal sub-channel, the viewer can access pages

containing featured programs, weather forecasts, news programs, and the like. Jenny can enjoy channel surfing while watching the main sub-channel program. Paul watches the car race by switching between the main program and each camera view of the car race.

We consider Super HDTV and eyewear-free 3DTV to be the future direction of high-end video services. On the other hand, television viewers may want to view a 2D HDTV program from a variety of perspectives (Multi-view). If the 6 MHz bandwidth could contain up to ten HD programs, providing Multi-view programs might be possible. For example, a baseball broadcast could provide views from the bleachers behind home plate, first base, third base, and the outfield, and also an aerial view. If the program is a car race, the views could be from various locations along the race course. As the number of viewpoints increases, this capability should provide features such as video of discrete locations and panoramas. One video channel not only can provide a single view as well multiple views, but by the use of broadband internet can also provide alternate programming and content. Each broadcaster occupying a physical channel can operate an internet Portal channel. In conjunction with each and every video channel containing multiple views, it is desirable to also achieve HDTV broadcasts carrying interactive applications such as the Triggered Declarative Objects (TDO) envisioned in the ATSC 2.0 New Work Item Proposal. These features are viable without the introduction of any particular new technology. Figure 2 shows an example of a screen with a multi-view Portal.

Figure 2: Example of Multi-View Portal

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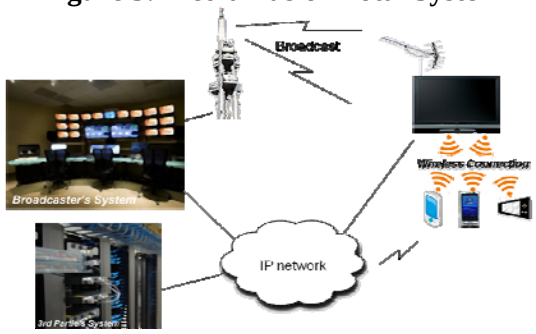
3. Service use case achieved with integration of converged media

Current broadcast services are divided among fixed DTV and Mobile DTV devices, and there is no correlation between the two. Future convergence entails integration of fixed and mobile devices. Moreover these devices will proceed to simultaneously integrate broadcast and internet services. The result is an evolving sophisticated and versatile integrated media broadcast service. The work in ATSC in ATSC 2.0 and Planning Team 3 can be extended to describe use cases for an advanced "media fusion" service. Figure 3 shows an overview of a media fusion transmission system framework.

Figure 3: Media Fusion Total System



3.1 Use Case 4: Fixed and Mobile Convergence

Daniel turns on his living room TV with the TV control application on his Mobile device. The device reviews his program preferences and makes reservations for the programs he wants to record. Next, Daniel checks currently-airing shows and chooses an interesting program. When it starts, an icon representing an interactive application (TDO) linked to the TV program appears on-screen. Daniel interacts with the icon and the TDO is shown on the screen. But since his wife, Nancy complains the TDO is obstructing the program, Daniel uses his mobile device to hide the TDO on the TV and then enables the TDO on his mobile device. Additionally, because the TDO is linked to the program, the mobile device receives related streaming content and Daniel watches TV while glancing at the streaming content.

The capabilities of next-generation intelligent mobile devices are expected to include

downloadable applications for TV remote control. Communications among TVs and mobile devices is possible by way of the internet for connections through infrared, wireless LAN, and the remote environment. All the existing remote control functions such as power On/Off, channel selection, etc. are accommodated in this way as well. Additionally with a mobile device, it is possible to display program guide information for fixed and mobile services, to select programs, to set recording schedules, and to perform similar functions. These capabilities are achievable independently of the broadcast service. Furthermore as a broadcasting service, the control functions mentioned above through integration into a mobile device can realize the following features:

- A TDO application associated with a broadcast program targeted for a fixed device can be moved to a mobile device.
- A TDO running on a mobile device can enable the customer to view related streaming and downloadable content on the mobile device.
- Personalized services for each member of the household can be enabled through the ATSC 2.0 concept of Preferences Demographics and Interests (PDIs) stored on a mobile device.

Figure 4 shows an example of a mobile device and a TV link service screen.

Figure 4: Mobile TV Link

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ATSC NWIP for ATSC2.0

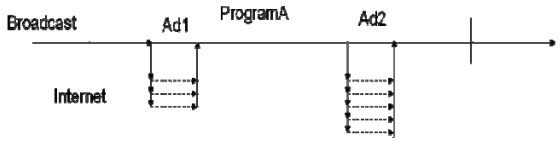
3.2 Use Case 5: Switching Between Broadcast and Internet Streaming

Through further evolutional convergence, it is possible to receive broadcast and internet streaming content and to switch between services or to stored content delivered through an advanced NRT service. The switching itself can be made transparent to the viewer. Below are specific use case examples:

A major electronics retailer is a sponsor of an XBC TV show. This retailer wants to insert a commercial announcing featured products and wishes to direct viewers to stores located nearest to their homes. Carol, who lives in New Jersey, sees a commercial announcing a special offer for televisions and refrigerators available at a local shopping mall. Martin, who resides in Portland, is watching the same program and sees a commercial announcing a special price for a washing machine and air conditioner at a store near his home.

Commercials that are aligned with a viewer's interest or demographics profile can be inserted into broadcast programming. Insertion of commercials can be done through an advanced NRT service and with content downloaded via the internet.

Figure 5: Targeted Ad Insertion



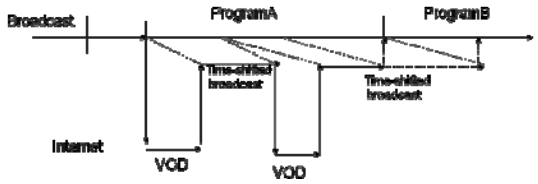
During the XBC morning news, a list of news topics appears on the screen. Alice interacts with the program to learn more about a topic of interest and sees that it is a long-form news segment and that it appears to be one complete news program. Since Alice does not have time to view such a long program, she decides to watch a drama instead.

A streaming interstitial program tailored to a viewer's interest is inserted into a program. In this scenario, the length of the original program varies according to the viewer's preferences. Time-shifted programming is played back directly following the internet streaming interstitial content. The current program may be displayed in a Picture-in Picture (PiP) window to allow the user to return to the main program at any desired time. To support this

use case, improved synchronization management is required to enable seamless switching between internet streaming and broadcast programs.

Figure 6 illustrates a variable-length TV program sequence with broadcast and video on demand services. Program A and B are time-shifted for viewing after VoD playback.

Figure 6: Flexible length program



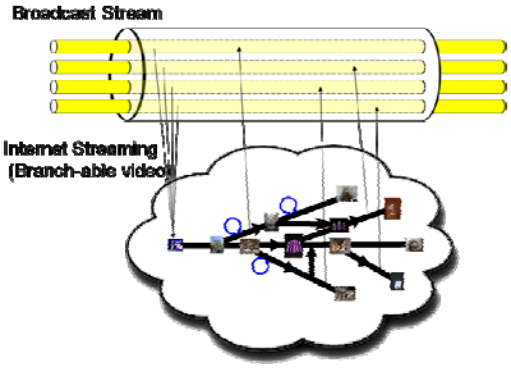
3.3 Use Case 6: Interactive Video Portal Service

The following use case involves an advanced service that is expected to be realized through convergence of broadcast and internet services.

XBC is providing a new concept for a Portal service called "XBC Studio Tours." David navigates from the home page to enter a virtual reality gate called "Studio Tours" that consists of streaming video content. Exploring areas with the virtual studio, he purchases products that are associated with some XBC programs. Along the way, he sees an announcement of a promotional event about a new drama series; the star of the series welcomes him and offers a narrative about the story's background. Just before the actual drama is released, she takes him to a neighboring virtual theater where the drama is shown on a virtual theater screen. In this environment, it is possible to access a "catch up" TV service that allows David to watch any previously-aired episode he chooses. XBC has designed the Studio Tour in an entertaining and engaging manner; the variety of content, information, and activities keep the user's interest.

Most Portal services are expected to be realizable through declarative (scripted) applications. This virtual reality use case is achievable through internet streaming. The customer traverses virtual reality by selecting branches leading to entryways of buildings or to interactions with people or objects. This use case could be implemented by a combination of declarative applications and streaming content. Interestingly, this implementation differs from others in the sense that the complete navigation experience is routed through multiple streaming threads, switching between each branch and controlled by attributes of each streaming thread. This ensures excellent navigation performance compared with typical declarative applications and the linkage between broadcast programs and internet streaming is effectively managed. Figure 7 shows the interactive video portal framework concept.

Figure 7: Interactive Video Portal



3.4 Use Case 7: Free Viewpoint TV Service

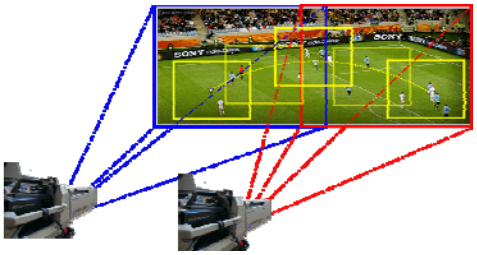
Another cutting-edge application implemented through media convergence is the Free Viewpoint TV service. A Free Viewpoint TV service enables the user access to unfettered and continuous perspective views of the subject matter within a program.

XBC provides a Free Viewpoint TV feature during a live broadcast of a soccer game. Not only does the broadcaster have control over multiple view angles, but the viewer also can access any of the multiple viewing angles of interest. Bill uses his remote control to zoom or pan the entire soccer field to track his favorite player.

The entire bird's eye view of the playing field is captured by multiple, fixed-position high resolution (at least 4K x 2K) cameras spanning the complete soccer field. Each sub-channel view is captured by multiple Super HDTV cameras positioned at different angles. Zoomed or panned views

requested by a given viewer are extracted from the images taken from the appropriate camera, and simultaneous decoding of the multiple sub-channels is performed within the receiver. The client device specifies the desired resolution of the streaming channel. Figure 8 shows an example of a soccer game with the Free Viewpoint TV service.

Figure 8: Free Viewpoint TV Service — Soccer Game



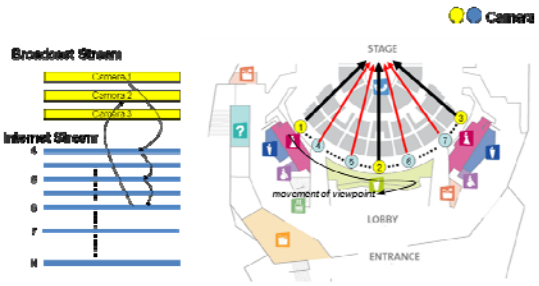
XBC introduces a 360-degree multiple viewing angle system for a travel channel. It allows the broadcaster to deliver the views over multiple sub-channels. Bob enjoys panning across a 360-degree view of a Jeep track in Savanna with his remote control.

This use case configuration is similar to the system used above for the live soccer match and the HDTV resolution is sufficient with the panning function only. In this case, since minor discontinuities can be expected at the border between neighboring sub-channels, a suitable normalization process must be built into the receiver.

Coupled with the Free Viewpoint system, XBC broadcasts a live show originating from the Clark County Government Center Amphitheatre in Las Vegas. Multiple cameras are positioned along the center aisle allowing view transitions from one to another along the aisle. For added enjoyment, Judy adjusts the view to her favorite viewing angle.

Anywhere from ten to one hundred cameras could capture scenes from various angles simultaneously. The user could virtually walk down the aisle by navigating among the set of views using a control device. With 3DV technology [2], interpolation between two adjacent points is performed for smooth perspective transitions. Since many streams are expected to be delivered to the client to implement this system, it should be made scalable. Some camera streams are expected to be sent over the air while others are delivered through the internet. Implementation of synchronized receiving technology and interpolation is required to integrate any two broadcast streams or one broadcast stream with an Internet stream. Figure 9 shows an example of Free Viewpoint TV system applied to a theater.

Figure 9: Free Viewpoint TV System — Theater



4. Conclusion

This paper has shown the use cases and the related technologies that may be employed to deliver the maximum amount of content and quality at the receiving device of all forms of content within a single service. Such services can satisfy consumer demand for viewing and listening experiences that are greater than those offered by the promise of ATSC 2.0.

References

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[3] Fujii, Toshiaki and Tanimoto, Masayuki, Free-Viewpoint TV (FTV) System, Advances in Multimedia Information Processing - PCM 2004, 2005