THE BROADCASTER'S GUIDE TO SMPTE 2022: APPLICATIONS IN VIDEO CONTRIBUTION AND DISTRIBUTION

SMPTE 2022 is a standard way to encapsulate high performance video signals for transport over IP networks. Covering both compressed and uncompressed standard definition and high definition video, the standards allow equipment from multiple manufacturers to work together seamlessly. The ongoing, widespread adoption of SMPTE 2022 has enabled broadcasters to transport error free video throughout the studio and across managed IP networks. This guide gives an overview of the standard and provides information about some of the key areas where this technology is already being applied today.

Introduction

Proprietary systems for transporting video have existed since the dawn of the television age. It's difficult to walk into a broadcast facility more than ten years old that doesn't have some piece of proprietary video transport equipment tucked away in a corner. Many of these units are single vendor solutions, which become obsolete as soon as the supplier stops supporting them or moves on to a new generation.
Fortunately, new standards have now been introduced that allow these old technologies to be phased out in favor of standards-based products that offer interoperability and long-term support from multiple vendors. Leading the way is SMPTE 2022, a series of standards based on work from the Video Services Forum (VSF) and SMPTE that focuses on professional quality video delivered over IP networks.
First introduced in 2007, the SMPTE 2022 standard originally focused on compressed video carried in MPEG-2 transport streams. The standard has since been expanded to cover uncompressed video, audio, and data at speeds up to 3 Gbps and beyond. Today, numerous manufacturers have implemented this technology in a wide array of products. To understand why, it helps to look at the many benefits provided by the SMPTE 2022 suite of standards, including:

- SMPTE 2022 is a global standard that has been deployed by broadcasters around the world.
- It supports video formats from all of the different television systems, including 525 and 625 line SD systems, 50 Hz and 60 Hz progressive and interlaced HD signals, and compressed signals employing the MPEG-2 TS (Transport Stream) container format.
- Many different manufacturers currently produce products that utilize SMPTE 2022 technology for compressed and uncompressed video applications. Some products are offered on a standalone basis, whereas others incorporate SMPTE 2022 technology within more complex devices.

- SMPTE 2022 was designed to address the challenge of using IP for all types of media content while at the same time coping with errors that may occur during transmission. Because errors in IP networks normally cause the loss of entire packets, and not just single bit errors, traditional error correction schemes used on satellite and other links simply won't work. The row/column error correction scheme of SMPTE 2022 is fairly well-suited for lossy packet networks.

Typical applications

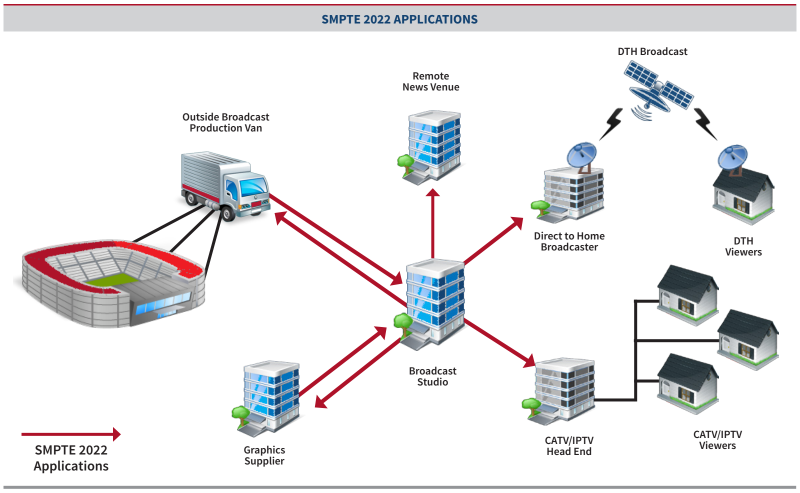
Long haul contribution and backhaul

Video contribution is the process of transmitting high-quality video from a remote source (such as a sports arena) to a broadcast facility for production and distribution. Backhaul is the process of taking a fully produced linear video channel (such as from a local broadcast affiliate) and sending it to a national or regional television delivery provider, such as a satellite TV, CATV, or OTT operator. Typically, backhaul and contribution links are relatively few in number, can sometimes cover long distances, and tend to focus on low-delay, high-quality video signal formats.

As long distance IP networks become more cost-effective, and as their performance improves to more closely mirror that of private leased line services, more broadcasters will migrate their contribution and backhaul video circuits towards managed IP networks. This trend will be particularly apparent in terrestrial point-to-point services that replace dedicated satellite circuits.

Facility infrastructure

Transporting video signals inside a broadcast facility used to be the exclusive domain of SDI and HD-SDI transmitters, receivers, and video routers. Today, the compelling benefits of having a single converged infrastructure for many different types of signals are encouraging more broadcasters to migrate towards IP-based technologies. For this to work, signal sources and destinations must be able to communicate using a common standard for encapsulating video into IP packets, such as SMPTE 2022.



Program distribution

Transmitting fully produced, linear television programming (i.e. a broadcast or cable TV channel) to viewers is usually a two- (or more) step process. First, the content must be distributed to a provider such as a local broadcaster, a cable TV system, an IPTV/OTT provider, or a satellite service. From there, the signals are distributed to individual viewers. In the distribution link, high-quality compression formats are typically employed to help ensure acceptable end-of-line quality for signals that are transcoded before delivery to viewers.

Three trends are enhancing the economics for IP-based distribution systems. First, many delivery providers, including major IPTV/OTT providers such as AT&T U-verse, major CATV systems such as Comcast, and both major home satellite TV providers are concentrating their super head ends into fewer locations. This allows them to reduce the amount of equipment and the staffing levels needed for multiple head ends, and makes it more cost-effective for program originators to use terrestrial IP links to distribute their signals to this relatively small number of destinations. Second, more local television operators are moving to centralized playout/master control systems to reduce equipment and personnel costs. These control/playout facilities (which can each manage dozens or hundreds of local broadcast channels) become another good location for IP-network-based delivery. Third, the number of niche/special interest channels continues to grow rapidly, as program producers continue to churn out content for specialized audiences. With limited viewership, these channels may not generate enough revenue to pay for a satellite transponder, but may be cost effectively delivered using IP technologies to reach targeted delivery providers.

Content exchange

Sharing video and audio clips between rival broadcasters has a long history in television news. In some cases this is mandated when a news source limits the number of cameras permitted at a specific event; in other cases, favors are done by one organization in anticipation of those favors being returned in the future. Sports leagues also encourage short clips from one broadcaster to be shared with others for summary and wrap-up coverage. For these exchanges to work effectively, it is important that both sender and receiver use compatible technology. This is the role of SMPTE 2022, which has helped broaden the pool of devices that can be used to quickly and cost-effectively exchange live and near-live content over IP networks.

Seven Parts of SMPTE 2022

Unlike some other SMPTE and IETF specifications, SMPTE 2022 consists of multiple parts that have been developed over many years. Collectively, they all focus on technologies related to high performance video traffic over IP networks, and are primarily used for contribution and distribution applications. Taken individually, each part of SMPTE 2022 defines a specific function, which can be used as needed to accomplish a task.

Parts are important because they define the features that are used to create the packet stream and therefore determine the required capabilities of the device that receives the stream. In other words, whatever parts of the SMPTE 2022 standard that are used to transmit the signal must also be supported at the signal reception sites. This same concept applies to standards like AVC (MPEG-4) and MPEG-2, where any of the almost 30 parts of the standard used by the encoder must be implemented in the decoder to fully decode the MPEG compressed transport stream. Also note that some parts of SMPTE 2022 are interrelated, such as the SMPTE 2022-5 being designed to work with SMPTE 2022-6. The following paragraphs define the various parts of SMPTE 2022 and describe how they are related to each other.

ST 2022-1:2007

"Forward Error Correction for Real-Time Video/Audio Transport Over IP Networks" defines row/column FEC (Forward Error Correction) for IP video streams. Along with Part 2, this standard has been widely implemented. Row/column FEC works by grouping IP video packets into logical rows and columns, and then appending one FEC packet to each row and each column. In the event that one packet is lost from a row or a column, the data in that packet can be perfectly recreated using the contents of the FEC packet in conjunction with the other packets in the row or column. This method works quite well, and allows the packet stream to survive lengthy bursts of lost packets.

ST 2022-2:2007

"Unidirectional Transport of Constant Bit Rate MPEG-2 Transport Streams on IP Networks" specifies how constant bit rate compressed video signals that are encoded within MPEG-2 transport streams are encapsulated into IP packets. This standard covers the transport layer (RTP and UDP) as well as comments about timing and buffer sizes.

SMPTE 2022 Standards

DATE	STANDARD	PARTICIPANTS
Feb. 2005	COP3R2 Multicast 20 Mbps Streams	Aastra DV, C-COR, Path 1, IneoQuest, Qvidium, Tandberg TV, Thomson, Tut Systems
Feb. 2006	COP3R2 Multicast 20 Mbps Streams	Aastra DV, BT, Path1, Qvidium, Sencore, Tandberg TV, Thomson Grass Valley, Tut Systems, T-VIPS
Feb. 2007	COP3R2 Multicast 20 Mbps Streams	Harris, Path1, Tandberg TV, Thomson Grass Valley, T-VIPS
Feb. 2011	2022-5 and 2022-6 270 Mbps Streams	Artel, Media Links, Thomson Grass Valley
Feb. 2012	2022-5 and 2022-6 1.5, 3 Gbps Streams	Macnica, Nevion, Xilinx
Feb. 2013	2022-5 and 2022-6 1.5, 3 Gbps Streams	Evertz, Macnica, Nevion, Xilinx
Feb. 2013	2022-1, 2022-2, 2022-7 20 Mbps Streams	Cisco, Evertz, Nevion, Xilinx
Feb. 2014	TR-01 (2022-1, 2022-2) HD Video using JPEG 2000 at 80 Mbps	Artel, Barco Silex, Ericsson, Evertz, Imagine Communications, IntoPIX, Media Links, Macnica, Nevion, Xilinx

ST 2022-3:2010
"Unidirectional Transport of Variable Bit Rate MPEG-2 Transport Streams on IP Networks" defines IP packets for variable bit rate MPEG-2 transport streams that are constrained to have a constant bit rate between PCR messages (called piecewise-constant). This standard has not yet been widely implemented.

ST 2022-4:2011
"Unidirectional Transport of Non-Piecewise Constant Variable Bit Rate MPEG-2 Streams on IP Networks" is similar to Part 3, except that it removes the constraint on bit rates being constant between PCR messages. This standard has not yet been widely implemented.

ST 2022-5:2013
"Forward Error Correction for High Bit Rate Media Transport Over IP Networks" expands on Part 1 to allow larger row/column FEC combinations to support signals with bit rates up to 3 Gbps and beyond.

ST 2022-6:2012
"Transport of High Bit Rate Media Signals over IP Networks (HBRMT)" specifies a way to transport high bit rate signals (including uncompressed 3 Gbps 1080p video) that are not encapsulated in MPEG-2 transport streams.

ST 2022-7:2013
"Seamless Protection Switching of SMPTE ST 2022 IP Datagrams" describes a way to send two matching streams of packets from a source to a destination over different paths, and have the receiver switch automatically between them. This allows a perfect video signal to be reconstructed at the receiver as long as both paths do not fail simultaneously.

JPEG 2000

Particularly for long-haul network applications, broadcasters often use multi-generation capable, visually lossless compression technologies to achieve a balance between circuit cost and bandwidth, latency, image quality, and hardware link cost. Technologies such as JPEG 2000 (J2K) and AVC-I are often used to transmit signals using 4:2:2 color space with 10 bit sampling. Single frame or lower end-to-end delay is achieved using Intra-frame (I-frame) or sliced encoding methods. Although both compression methods are available in the marketplace, many broadcasters have chosen to deploy J2K for both technical and economic reasons.

When high bit rates are used (80 Mbps and above) and where multiple generations of encoding and decoding are used (as is common in contribution/production environments), J2K-based systems have been shown to have significantly better end-to-end performance compared to AVC-I. From a cost perspective, J2K encoders that support 4:2:2, 10-bit video typically sell for one-half to one-quarter the cost of comparable AVC-I encoders. On the decode side, professional quality MPEG and J2K decoders that support 1080p 4:2:2 10-bit 3G HD-SDI outputs with multiple audio channels are priced roughly the same. Thus, for contribution applications, where the ratio of encoders to decoders is normally 1:1, J2K can offer significant cost savings. Additionally, J2K implementations on FPGA easily adapt as encode or decode nodes whereby MPEG based hardware is typically ASIC specific to encode or decode.

Up until recently, J2K encoders and decoders from different manufacturers were not interoperable. Fortunately the situation has recently changed with the 2014 publication of VSF (Video Services Forum www.videoservicesforum.org) Technical Recommendation TR-01 "Transport of JPEG 2000 Broadcast Profile Video in MPEG-2 TS over IP." This new technical recommendation describes a mapping for JPEG 2000 over MPEG-2 transport streams over IP with FEC, drawn from multiple standards produced by SMPTE, MPEG, and other organizations. Rather than defining a whole new scheme for video compression and encapsulation, TR-01 defines a common operating point within existing standards, thereby permitting true JPEG 2000 interoperability for the first time. Demonstrations of equipment from multiple vendors supporting TR-01 were done at the VSF's VidTrans2014 Technical Conference.

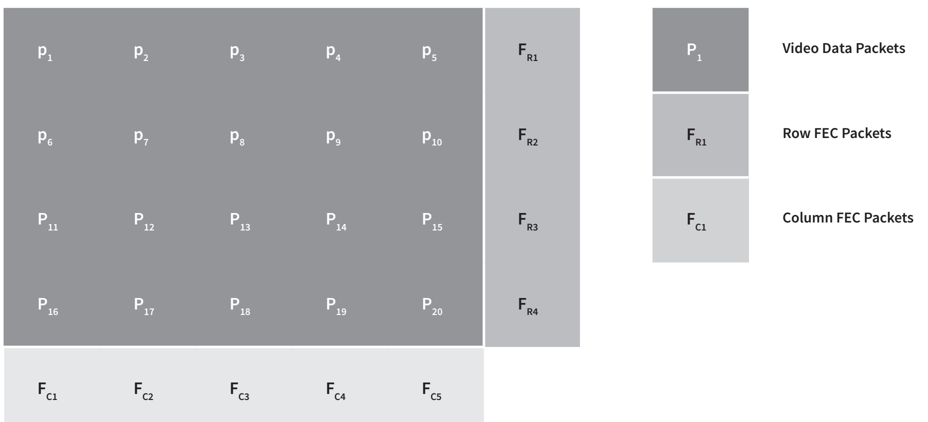
Forward error correction (FEC)

Forward error correction covers a wide range of technologies that implement a single, powerful idea: adding extra information to a data stream that can be used to fix errors that occur in transmission. This extra data is specifically designed to allow the receiver to both determine if errors have occurred and to correct them. At the output of the receiver, the extra data is removed, so that the stream returns to its original form. Many different forms of FEC are used in broadcasting, depending on the type of circuit being used and the types of errors that can occur.

In IP networks, the primary error mechanism is out of order and lost packets. Many IP and Ethernet protocols use checksum or CRC data within each packet header that indicates whether or not any of the data bits making up the packet have changed value during transmission. If one or more bits have changed, then an error is assumed and the entire packet is discarded. The SMPTE 2022 standard standard rides on top of RTP which corrects for out of order packets (re-ordering) and uses a row/column FEC to correct packets that are lost in transmission.

Row/column FEC works by arranging groups of packets into logical rows and columns, and then adding a FEC packet to each row and each column. For example, a 5 row, 20 column FEC scheme would add 5 row FEC packets and 20 column FEC packets to every 100 data packets. With this extra data, it becomes possible to correct burst errors of up to 20 packets in length and even replace packets that are completely missing. However, there are limits to what can be corrected, in that only one error per row or per column can be corrected.

SMPTE 2022 Row/Column FEC



Like any technology, row/column FEC has advantages and drawbacks, and may not be suitable for every application. There is a tradeoff between the error rate, the amount of extra bandwidth needed for the FEC data, and the consequences of uncorrected data errors. Using the previous 5/20 example, 25 FEC packets that would be added to every 100 data packets, representing a 25 percent FEC overhead. FEC also introduces delay, primarily in the receiver where the rows and columns need to be reassembled and then processed to recover any missing data. If the error rates are low enough and the consequences not too bad, a user may decide to skip using FEC altogether. Managed data networks used inside broadcast facilities are typically maintained to have extremely low error rates, arguably making the extra processing and bandwidth consumed by FEC unnecessary. It may even be possible to operate in-house networks without FEC, as is commonly done with SDI signals.

Conclusion

Since the introduction of SMPTE 2022, a whole new world of interoperability has opened up for sending video over IP networks. Today, equipment can be purchased from one manufacturer and connected to products from another with impunity. This provides a great deal of flexibility and for broadcasters who may want to operate their own private networks or exchange content with a variety of other sources. By covering a full gamut of applications, from low speed, highly compressed MPEG transport streams all the way up to three gigabit 1080p video and beyond, SMPTE 2022 is an excellent choice for many different broadcast applications.

CHOOSING ROW AND COLUMN FEC DIMENSIONS

Row and column FEC that is defined in SMPTE 2022-1 and 2022-5 is a powerful technique for correcting errors in packet networks. However, choosing the right settings for both row and column size can be a bit tricky due to the tradeoffs involved. On the one hand, large matrices can handle longer bursts of packet loss, and have lower relative overhead. On the other hand, large matrices will increase the end-to-end delay of the system. Here are a few tips for deciding the right amount of FEC to use.

- Try to estimate the duration of a typical error burst. Then, calculate the number of packets that would be affected by that burst, and try to set the row length to be larger than that number. For example, consider an uncompressed HD-SDI signal using 2022-6 encapsulation, which would generate around 135,000 packets per second. To protect against a 2 msec burst error, the FEC row length would need to be at least 270 (2 msec at 135 packets per millisecond).

- The number of FEC columns used has a major impact on the total amount of FEC overhead of the stream. If column length is set to 4 packets, then the stream will have at least 25 percent overhead (one FEC packet for each column with 4 packets). If the column size is set to 10, then the FEC overhead will be closer to 10 percent (assuming long rows are used).

- Row and column sizes are limited to 1020 packets for 2022-5 and 255 packets for 2022-1.

- To avoid excessive delay being introduced by FEC, determine how much time it will take to send one entire set of rows and columns. This can be calculated by multiplying the row size by the column size, and dividing that by the number of packets per second. For example, again consider an HD-SDI stream consisting of 135,000 packets per second for just the video data. If a row size of 270 packets is used in combination with a column size of 10, then the receiver would normally receive and store a full matrix of (270*10) = 2700 video packets and their associated FEC before trying to correct all the errors that occurred. At the video data rate of 135,000 packets per second, the delay due to the buffering in the receiver* would be (2700/135000) = 0.02 or 20 msec, which is longer than the duration of a video frame in a 60/59.94 progressive scanned video signal.

*Note that the transmitter does not need to buffer a full set of rows and columns before transmission; the FEC values can be accumulated on the fly during the encapsulation process. Also note that the delay in the receiver could possibly be reduced by calculating the column FEC values as they arrive with the last row of each column, assuming that no more than one packet is corrupted in each column.

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About Artel
Our mission is to be a world-class manufacturer and provider of innovative IP- and fiber optic-based media transport solutions serving the global broadcast, telecommunications, and related markets.

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