MEDIA OVER IP

A PRIMER TO APPLYING IP TO VIDEO WORKFLOWS

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INTRODUCTION

Compressed video signals transported via IP are now an essential element of broadcast infrastructure. This paradigm originated more than a decade ago in distribution applications, where underlying connectivity challenges could be improved with techniques imported from IT networking environments. In this scenario there remained islands of broadcast-specific, SDI-based functionality alongside IP, adding complexity to the workflow.

A simplified broadcast infrastructure that seamlessly combines light and heavy compression techniques with uncompressed signal flows over IP simply wasn't possible… until now.

Recent developments in network technology are leading to the replacement of SDI-dependent products with IP solutions capable of moving high-bitrate, uncompressed signals alongside compressed signals. SDI still has its place, and will for some time, but only when legacy or surrounding infrastructure demands its use.

In the Big Broadcast Survey 2015 Market Report, 46% of respondents identified IP networking and content delivery as important to the future of their business. The primary catalyst for their interest is the ability to create a more agile and flexible technology infrastructure that can be repurposed for future services.[1] Greater solution agility allows operators to deal with rapidly changing market dynamics. When systems are no longer commissioned for specific formats, core areas of media functionality can then embrace enterprise techniques like virtualization and software-defined networking (SDN). Live broadcast workflows are the main beneficiaries of these advancements, with the resulting bandwidth and processing gains leading to the availability of all-IP delivery chains for all video formats, including Ultra HD.

The efficiencies and CAPEX and OPEX benefits of IP-based workflows hold an obvious attraction for broadcasters. To realize these benefits requires technical clarity on the issues fundamental to adopting media-over-IP workflows, and that is the principle aim of this ebook: provide a common-sense look at the available technologies for migrating to an all-IP workflow.

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of respondents identified IP networking and content delivery as important to the future of their business.

1. 2015 Devoncroft Big Broadcast Survey

TRACKING THE IP REVOLUTION

The application of compressed video over IP networks began in distribution and is now actively employed throughout ingest and content creation workflows.

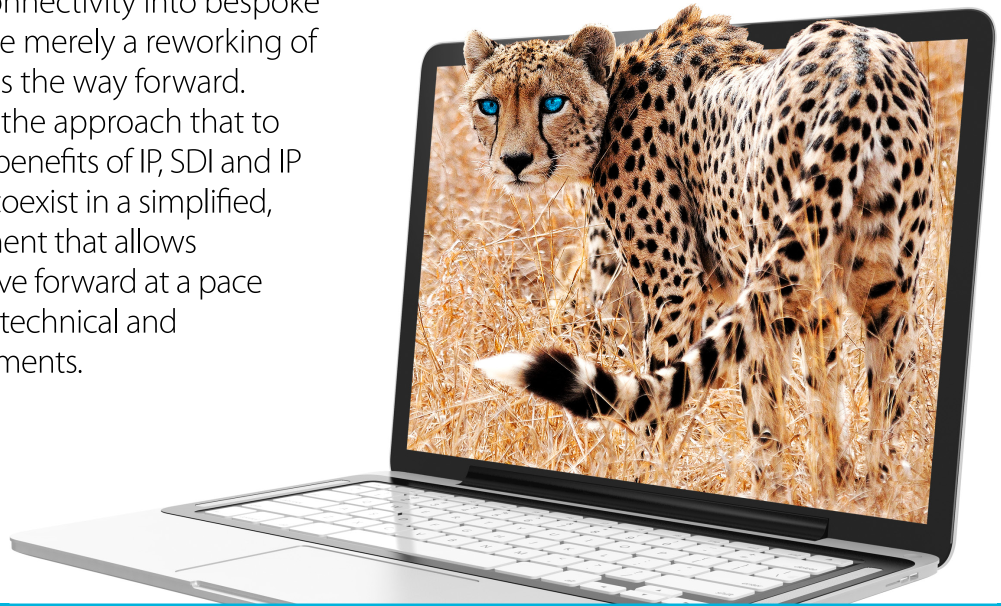
Before IP, a form of SDI known as ASI (asynchronous serial interface) dominated compressed video distribution. This format for carrying MPEG transport streams was very much a compromise solution between the synchronous world of video and the asynchronous domain of IP networking, yet the shift from ASI to IP transport was one of the first major transitions towards adoption of IP network-based solutions in video infrastructure. This revolutionary step required that IP networks possess the same redundancy, resilience and non-blocking behavior of legacy broadcast products and solutions. The use of multiprotocol label switching (MPLS) networks, seamless packet switching and robust error protection were also vital elements to guarantee the quality of service (QoS) demanded for professional video transmission.

The early incarnations of broadcast IP headends sowed the seeds for the standardization of compressed video protocols, and triggered the development of forward error correction (FEC) schemes like SMPTE 2022-1/-5 to enable the reliable carriage of media data over IP. There have since been concerted efforts to extend the scope of IP workflows to lightly compressed and uncompressed video transport. Hardware-based codecs such as JPEG 2000 and AVC-I offer light compression performance and the ability to edit encoded content, leading to their adoption in many IP-centric production environments; however, widening the reach of IP techniques and solutions into the realm of video delivery requires compression schemes that can be implemented in both hardware and software.

For all-IP delivery network workflows, light-compression codecs such as VC-2, TICO® and Sony's LLVC are all potential enablers. So is the SMPTE ST 2022-6 protocol for transporting uncompressed signals over IP networks. With any of these standards, broadcasters can operate within a mixed environment consisting of both compressed and uncompressed video, one in which an all-IP interconnect facilitates the operational savings that are already the bedrock of the larger enterprise sector. Synchronous video switching goes a long way to the deployment of this all-IP infrastructure, but timing, control, metadata and the ability of the network to function according to the requirements of live media are the wider ambitions for broadcasters and service providers alike.

Reliable carriage of live media also necessitates buffering, error correction and genlock schemes to overcome the inherent weakness of packet-based IP networks. This reality has led to the development of virtualized IP networks; more specifically, SDN approaches in which the network control layer is decoupled from bespoke hardware to optimize the entire network for the demands of video.

As with any revolution, the speed of IP adoption is not consistent across global markets. Some operators are simply more ready than others to embrace advanced IP video workflows. In addition, some vendors propose that harnessing IP connectivity into bespoke solutions that are merely a reworking of SDI techniques is the way forward. Harmonic takes the approach that to fully exploit the benefits of IP, SDI and IP transport must coexist in a simplified, hybrid environment that allows operators to move forward at a pace that meets their technical and financial requirements.



MIGRATING FROM COAX TO IP: WHY NOW?

> *"IP is the only way to have a flexible, friendly and economically sustainable video ecosystem with reduced equipment demands, standards conversions, cabling, space and power."*
>
> ***- Massimo Bertolotti, head of engineering, Sky Italia***

SDI VS. IP FEATURE COMPARISON

SDI	IP
	
Guaranteed bandwidth	Best effort/prioritized
Deterministic	Probabilistic
Static circuit connections	Dynamic/routed
Single signal	Multi-signal
Synchronous timing	Asynchronous timing
Real time	Non real-time/jitter reorder
Low latency	Variable latency/utilization
Error-free	Packet loss/retransmission/FEC
Point to point	Any to any

No 24/7 broadcaster is going to move from traditional coax-based SDI infrastructure to IP overnight. SDI is simply too embedded — especially for production and playout applications — so the transition will be gradual. The industry has made similar transitions before; for instance, when moving from analog to digital and from SD to HD. In each case, most broadcasters constructed islands of the new technology and routed appropriate workflows into and out of them. Media over IP will be no exception.

What has happened recently to drive the adoption of IP throughout the delivery chain?

1

The increased use of standard IT networking technologies, solutions and practices in media environments. As programmers and service providers have realized the benefits of employing technologies previously found primarily in data centers — IP switches and routers, for instance — they've looked for windows of opportunity for these systems to impact baseband video ecosystems. Transporting large files without the need to encode and decode them multiple times to accommodate SDI islands offers clear workflow efficiencies, but requires an SDI-to-IP bridge. Several technologies provide this capability, including SMPTE ST 2022-6. Moving lightly compressed content over transport stream via proprietary codecs, such as TICO and LLVC, is also viable, but may not be suitable for all applications.

2

The growing demand to reduce total cost of ownership (TCO) of broadcast infrastructure. Software-based media processing applications running on commercial off-the-shelf (COTS) servers delivers on this front. Function integration — the ability to combine previously discrete functions on a single platform — is a key benefit of software-based media processors, resulting in lower overall business costs through significant CAPEX and OPEX savings.

3

Flexible, scalable workflows are now a key requirement for most programmers and content providers. Broadcast, cable, satellite and IPTV services must co-exist with video on demand (VOD) and over-the-top (OTT) services to allow customers to watch content on any device at any time. New, more-efficient codecs such as HEVC are arriving, prompting the desire to adopt them without the need for a forklift upgrade of the headend. And, of course, Ultra HD content distribution is coming soon, requiring that programmers and service providers gain the ability to efficiently transport real-time, high-bitrate signals.

THE BENEFITS OF UNCOMPRESSED WORKFLOWS

Enhanced flexibility and agility of the broadcast plant	Cable reduction via statistical multiplexing of multiple signals
Reduced CAPEX through increased use of COTS hardware	Easier monitoring of video signals
Support for transmission of richer metadata	Flexible distribution via private and public cloud
Simplified infrastructure via a single Ethernet fabric for all media formats and codecs	A single multiresolution fabric for SD, HD, compressed and uncompressed content, with an easy upgrade path to UHD

Adapted from "Demonstration of COTS Hardware for Capture, Playback and Processing of SMPTE ST 2022-6 Media Streams" by Thomas Edwards, VP Engineering & Development, FOX Network Engineering & Operations

IP-ENABLING MEDIA TECHNOLOGIES

For media over IP to become viable industry-wide, adherence to standards is essential. Proprietary or in-house protocols may work on a limited basis, but do not provide the overall flexibility and security required to serve the full spectrum of video playout and distribution applications. There are a number of options currently under consideration for transporting video over IP networks; here's a quick look at a few of them, some standardized and others currently in development.

PRODUCTION CODECS

AVC-I – AVC-I is a light-compression variant of the MPEG-4/AVC codec. It was standardized in 2005, emerging from the MPEG-4 AVC production standard as a low-latency option for video contribution applications. Intra-only codecs such as AVC-I are more efficient than long-GOP options when enough bitrate is available, low end-to-end latency is a decisive requirement, streams have to be edited, or the application is sensitive to transmission errors.[2]

JPEG 2000 – JPEG 2000 is a light-compression codec created by the Joint Photographic Experts Group to improve the performance of the original JPEG standard. Based on wavelet compression technology, a JPEG 2000 architecture lends itself to a wide range of uses, from portable digital cameras to advanced pre-press, medical imaging and other key sectors. At high bitrates, artifacts become nearly imperceptible with JPEG 2000, leading to its wide acceptance in production applications.

MEZZANINE CODECS

LLVC – LLVC (Low Latency Video Codec) is a light-compression technology developed by Sony to support the requirements of 4K 60p transmission over 10-Gbps Ethernet. With visually lossless 3:1 compression, this format is expected to enhance Sony's IP Live Production system, making live studio and sports broadcasts more efficient and less expensive. [3] The codec is currently being reviewed as a SMPTE Registered Disclosure Document (RDD).

TICO – TICO compression was developed for HD and UHD infrastructure by the TICO Alliance, a consortium of industry manufacturers, OEM providers, broadcasters, electronics brands and technology companies. Announced at the 2015 NAB Show, it provides visually lossless compression up to 4:1 and enables UHD and HD content to be transported over legacy SDI infrastructure and modern IP production and contribution networks.

VC-2 – SMPTE ST 2042-1 (VC-2), also known as Dirac Pro, is an intra-frame family of codecs that spans contribution to UHD distribution to post production. Developed by the BBC, VC-2 is non-proprietary and royalty-free, and offers high quality with low complexity and latency. A lossless compression ratio of 2:1 is available, and bitrates are configurable from 10-200 Mbps for transport over ASI and IP.

ENCAPSULATION TECHNOLOGIES

AVB – Audio Video Bridging (AVB) refers to a group of specifications that allow time-synchronized, low-latency production content to be handled over IEEE 802 networks.

ASPEN – ASPEN was developed by Evertz as a format for encapsulating uncompressed UHD/3G/HD/SD over MPEG-2 transport streams (TS). When combined with existing SMPTE standards such as ST 302 (audio over TS), ST 2038 (ancillary data over TS) and ST 2022-x, ASPEN offers broadcasters a flexible method of transporting video, audio and data over scalable IP networks. Ultra-low latency with independent video, audio and ancillary data flows also makes ASPEN appropriate for production workflows.[4]

NMI – Sony's Networked Media Interface (NMI) combines SMPTE ST 2022 video transport standards with SMPTE timing and SMPTE ST 2059 synchronization protocols to support live production of video using IP networks.

SMPTE ST 2022-x – The SMPTE ST 2022 family of standards deals with the transport of various types of media signals over IP, along with optional FEC. Only parts 5 and 6 are applicable for uncompressed media; the others (except for Part 7) address MPEG-2 TS-based media, which is typically compressed. Each part was drafted for long-haul service; as a result, switching is a challenge and needs supplementary timing and control standards to work within an IP ecosystem.

TIMING

SMPTE ST 2059-x – The new SMPTE ST 2059 family of standards addresses the timing of systems (and devices) based upon IEEE 1588 PTP. The move to PTP permits operators to circumvent the need for genlock synchronization and time-code wiring in IP-centric facilities, and to begin a coherent migration from SD/HD-SDI to IP for media transfer (often using ST 2022-5/-6).

NETWORK INFRASTRUCTURE

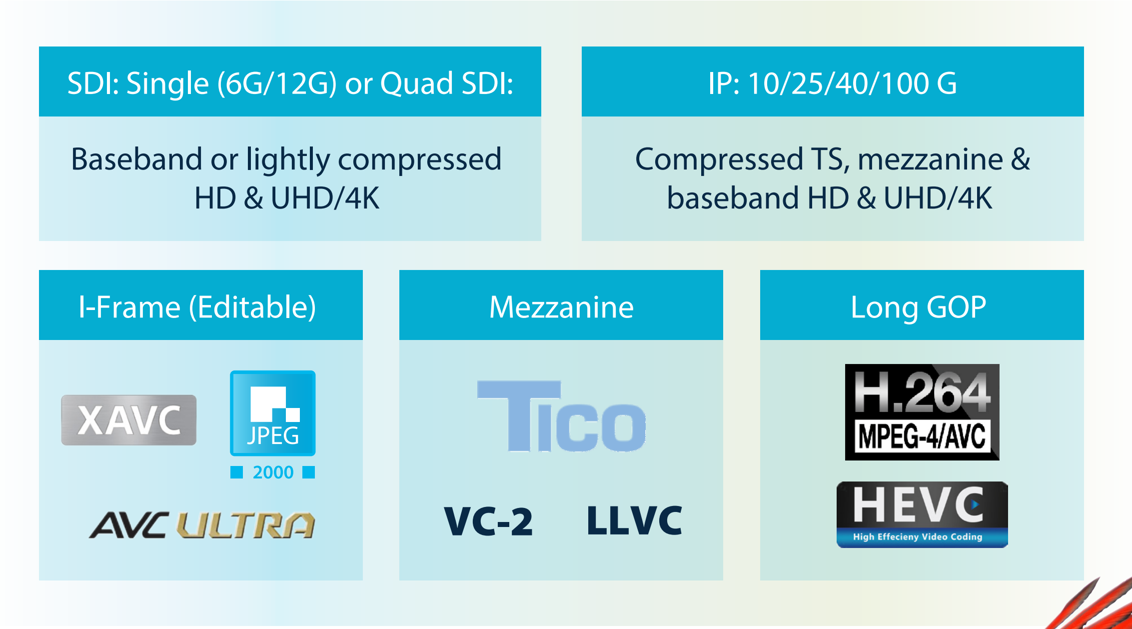
SDN – SDN is an emerging architecture that decouples the network control from hardware-level packet-forwarding functions. One of its key aspects is that switching decisions can be made at the switch level to allow the network to be controlled and optimized for non-blocking carriage of video. An SDN standard is currently being defined by the Open Networking Foundation (ONF) in cooperation with the work of the European Telecommunications Standards Institute (ETSI) on NFV (network functions virtualization).

NFV – NFV decouples the network functions, such as network address translation, firewalling, intrusion detection, domain name service and caching, from proprietary hardware appliances so they can run in software. It utilizes standard IT technologies that run on high-volume service, switch and storage hardware to virtualize network functions, and is applicable to any data plane processing or control plane function in both wired and wireless network infrastructures.[5]

2. http://ateme.com/IMG/pdf/avc-i_for_broadcast_contribution_by_pierre_larbier_ateme_cto_-_october_2011-2.pdf
3. https://blog.sony.com/press/sony-collaborates-with-evertz-on-ip-interoperability-and-development-of-its-networked-media-interface/
4. http://www.evertz.com/resources/ASPEN
5. https://www.sdxcentral.com/resources/nfv/whats-network-functions-virtualization-nfv/

PROFESSIONAL INTERFACING

A look at some of the interface and format options for migrating from SDI to IP.



For media over IP to become viable industry-wide, **adherence to standards** is essential.

VIDEO PROCESSING OVER IP

All-IP workflows offer the promise of more efficient, less-expensive media processing for everything from OTT to UHD content, making it a better option than SDI for future-proof infrastructure investment. The bitrates for the different video formats transported over a SDI link are outlined below:

Format	Standard	Name	Bitrate (Gbps)
720p, 1080i	SMPTE ST 292	HD-SDI	1.485
1080p	SMPTE ST 372	Dual Link HD-SDI	2.970
1080p	SMPTE ST 424	3G-SDI	2.970
UHD1 30 fps	SMPTE ST 2082	6G-SDI	6
UHD1 60 fps	SMPTE ST 2082	12G-SDI	12
UHD1 120 fps	SMPTE ST 2036	24G-SDI	24

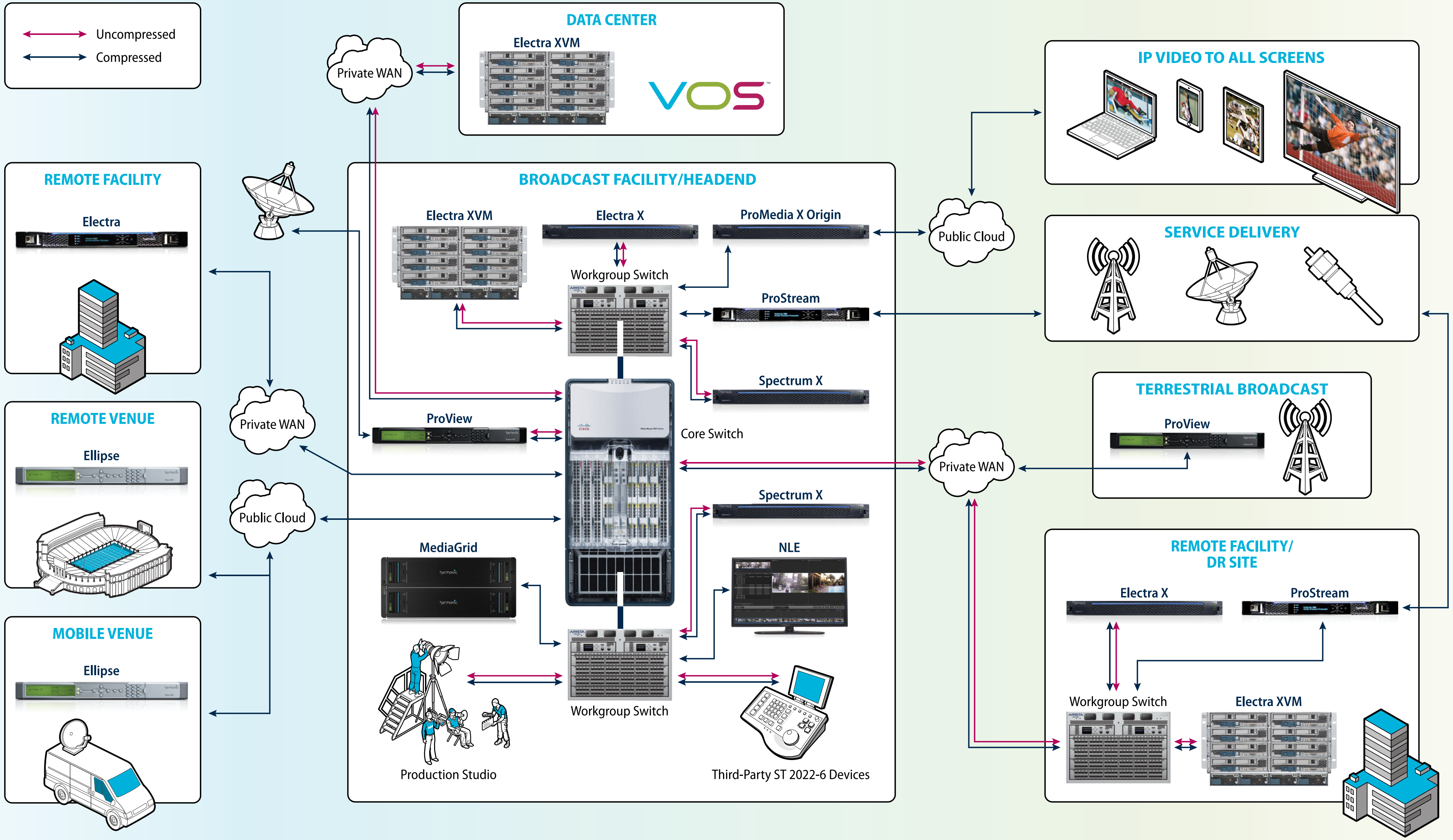
Based on this table, we can see that the carriage of UHD 60-fps content requires 12G-SDI connectivity and therefore cannot be carried over a 10-GbE link; light compression is required to make this possible.

FORMAL SMPTE STANDARDS FOR IP NETWORKS

SMPTE has certified a range of standards for transporting media over IP networks. Here's a closer look at them.

SMPTE ST 2022-1	Forward Error Correction for Real-Time Video/Audio Transport over IP Networks
SMPTE ST 2022-2	Unidirectional Transport of Constant Bit Rate MPEG-2 Transport Streams on IP Networks
SMPTE ST 2022-3	Unidirectional Transport of Variable Bit Rate MPEG-2 Transport Streams on IP Networks
SMPTE ST 2022-4	Unidirectional Transport of Non-Piecewise Constant Variable Bit Rate MPEG-2 Streams on IP Networks
SMPTE ST 2022-5	Forward Error Correction for High Bit Rate Media Transport over IP Networks
SMPTE ST 2022-6	Transport of High Bit Rate Media Signals over IP Networks (HBRMT)
SMPTE ST 2022-7	Seamless Protection Switching of SMPTE ST 2022 IP Datagrams
SMPTE ST 2059-1	Generation and Alignment of Interface Signals to the SMPTE Epoch
SMPTE ST 2059-2	SMPTE Profile for use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications
SMPTE ST 2071-1	Media Device Control — Framework (MDCF)
SMPTE ST 2071-2	Media Device Control — Protocol (MDCP)
SMPTE ST 2071-3	Media Device Control — Discovery (MDCD)
SMPTE ST 2071-4	Media Device Control — Interface Repository (not published yet)

THE HARMONIC MEDIA OVER IP SOLUTION



IP network design needs to account for security and performance, as well as convenience. The Harmonic media-over-IP solution addresses these concerns with an integrated architecture that allows customers to bridge the gap between baseband and compressed workflows with simultaneous SDI and IP functionality. The Harmonic products that contribute to this hybrid solution are outlined below.

Electra XVM

Leveraging the broad capabilities of the Harmonic VOS virtualized media processing platform, Electra XVM is the industry's first broadcast-ready media processing platform designed exclusively for a VVI. Operating on common hardware platforms in IT data center environments, Electra XVM optimizes the computing power of contemporary Intel-based servers to host a robust set of dynamically deployable media processing applications. Like Electra X2, Electra XVM natively supports compressed and ST 2022-6 IP transport streams, as well as DiviTrackIP statmux over IP.

For more information on Electra XVM, **click here**.

Spectrum X

The Harmonic Spectrum X advanced media server system combines file, baseband and transport stream ingest with comprehensive integrated channel playout (ICP) capabilities, including graphics, branding, DVE, and live switching of baseband and compressed IP sources. The software-based system supports a broad range of SD and HD formats up to 1080p (3G), and is upgradeable to Ultra HD. By providing SDI and ST 2022-6 I/O on the same chassis, Spectrum X eases the migration to IP playout workflows, allowing users to transition away from baseband at their own pace.

For more information on Spectrum X, **click here**.

Electra X2

The Electra X2 advanced media processor is the industry's first fully converged platform for broadcast and OTT delivery of SD and HD content via MPEG-2, AVC and HEVC. With support for ST 2022-6 and the ability to adapt to new codecs via software, Electra X2 serves as the cornerstone of a broadcast facility's migration to IP. Bandwidth efficiency of the broadcast network can be further optimized through Electra X2's tight integration with Harmonic's Emmy® Award-winning DiviTrackIP™ statmux over IP technology. The 2-RU Electra X3 is available for UHD-HEVC Main 10 encoding.

For more information on Electra X2, **click here**.

ProStream with DiviTrackIP
Available in Harmonic ProStream stream processors, DiviTrackIP is an IP-based statmux technology that can support up to 300 ms of WAN round-trip delay, auto-adjust to IP network variations, and form MPEG transport streams with up to 64 channels per pool.

For more information on ProStream, **click here**.

ProMedia X Origin
The ProMedia® X Origin multiscreen media server is used to prepare and deliver broadcast-quality video to consumers anywhere, at any time. The software-based system fully integrates with Harmonic's IP video encoding and transcoding systems for live and file-based workflows, enabling a complete ecosystem for launching new revenue-generating multiscreen services. Integrated packaging-on-the-fly functionality allows multiple streams of H.264 and H.265 video to be selectively combined for any of the most popular HTTP adaptive bitrate protocols.

For more information on ProMedia X Origin, **click here**.

Harmonic MediaGrid
Harmonic MediaGrid is a highly scalable, Ethernet-based shared storage system optimized for digital media workflows. Purpose-built to deliver high bandwidth and consistent low latency for video, MediaGrid systems can seamlessly scale to petabytes of capacity and tens of gigabytes per second of throughput. An industry-leading, high-density storage option — up to 504 TB of raw capacity in 5 RU — can reduce rack space by up to 60%, and all compressed and uncompressed file types are supported.

For more information on MediaGrid, **click here**.

Ellipse 3000

Designed for high-end DSNG and live sports broadcasting applications, the Ellipse 3000 family of contribution encoders offers simultaneous RF, IP and ASI outputs. Data transmission on the Ellipse 3200 encoder, which features an integrated DVB-S/S2/DSNG broadcast satellite modulator, enables IP packet transmission via satellite using an MPEG-2 transport stream. Contribution over the Internet, including embedded deep packet recovery technology, is available with the Ellipse 3102 encoder.

For more information on Ellipse 3000, **click here**.

ProView 7100/8100

ProView IRDs assure delivery of pristine video for all content reception applications. With RF, ASI and IP inputs, and ASI and IP outputs, the ProView 7100 and 8100-series receivers simplify the migration to an all-IP headend solution and power the launch of added-value services. Support for advanced content delivery redundancy schemes includes the ability to provide simultaneous primary satellite and backup IP network feeds. Distribution over unmanaged IP networks is available on the ProView 8100.

For more information on ProView IRDs, **click here**.

HARMONIC MEDIA OVER IP PRODUCT SUMMARY

	COMPRESSED		UNCOMPRESSED	
	In	Out	In	Out
Spectrum X Advanced Media Server	X	X	X	X
MediaGrid Shared Storage	X	X	X	X
Electra X2 Advanced Media Processor	X	X	X	
VOS/Electra XVM Virtualized Media Processor	X	X	X	X
Electra 8000/9000 Encoders	X	X		
ProStream Stream Processors	X	X		
Ellipse 3000 Contribution Encoders		X	X	
ProView 7100/8100 IRDs	X	X		

Available Today · Planned · Under Consideration

THE CHALLENGES AHEAD

The topology of a media infrastructure is complex, and when users who are accustomed to SDI with genlock-based timing begin to think about migration to IP networks, they often fail to understand some of the key architectural differences. While the bi-directional nature of IP may be obvious, the need to segregate traffic may not be. Network security is also a key consideration, particularly when that network extends beyond the studio environment.

Even with the construction of IP islands, traditional SDI-oriented users will need to learn several new concepts and terminology. One of these is QoS, an important metric for guaranteeing IP network performance. Since multiple signals share a single IP cable, QoS ensures that media flows get through and less important traffic can be held, when necessary. IP network design also needs to account for security and convenience.

As mentioned earlier, real-time, frame-accurate switching is a particular challenge in IP workflows. ST 2022-6, for instance, was written with long-haul applications in mind, not studio applications; thus, frame-accurate switching of uncompressed IP video streams is only now coming into focus. The ultimate goal is for COTS-based core and workgroup switches to replace bespoke video switchers, a paradigm that is currently cost-prohibitive and lacks the performance required for real-time media processing.

There are other methods, known as packet stitching of AV streams, which can accomplish the goal of frame-accurate switching at the cost of additional devices and/or subsystems, including:

Source Timed Control

- Performed like SDI switching
- Frame-accurate effect
- Buffering at the end point (to cover the transmission time delta between two sources)
- Synchronization required at both sources

Switched Timed Control

- Performed like SDI switching, with the stream switch during VBI
- Frame accurate
- Buffering in the Ethernet switch (to cover the transmission delta from sources to switch)

Destination Timed Control

- Not like SDI switching — the destination assists in "splicing" two streams
- Frame accurate
- Buffering at the end point
- Additional bandwidth required during splice period

Each of these methods requires cooperative resources and sometimes extra bandwidth on the network.

Once content is in the IP domain, many of the techniques used in conjunction with SDI workflows are redundant, and consequently need to be reworked to improve processing efficiency. Specifically, timing and control approaches are being re-evaluated to facilitate the separation of these functions as layers, apart from the signal flow. This approach is consistent with the structure of virtualized enterprise deployments.

CONCLUSION

The media industry is making great strides to adopt IP techniques and infrastructure within the video domain. While IP-based networking has been around for more than a decade, new standards for transporting lightly compressed or baseband video over IP are simplifying infrastructures and opening the door to the deployment of new services, such as UHD.

Yet much of the needed infrastructure to achieve an all-IP workflow is still in flux. SMPTE 2022 is a good starting point, covering not only encapsulation of existing video formats but also FEC and seamless switching of IP datagrams — both essential elements for reliable video carriage over redundant IP networks. Other approaches that allow interoperability within IP networks while retaining core SDI switching capability are currently being deployed, yet these are often proprietary systems that lock users into a closed ecosystem.

The development of SDN architectures shows great promise for enabling high-performance processing and switching of video in an IP network. SDN may well be the catalyst for the adoption of a layered approach to the separation of media, control and timing — a necessary step if video media is to emulate the structure of enterprise networks, where there is a clear separation of applications from underlying processing capability. The move to VVI will lead to even more logical partitioning of processing resource allocation, allowing broadcasters to fully embrace the benefits of running video applications on servers.

While the drive to deploy uncompressed IP workflows has concentrated on the implementation of what are essentially SDI techniques, there remain committed efforts to approach media carriage and processing from a fresh perspective, exploring video in a new light, free of the legacy constraints of SDI — even analog! These initiatives might well yield key efficiency gains in terms of processing and bandwidth, but raise the question: How far from existing SDI-based processing can a facility go and still be compatible with installed infrastructure?

What is certain is that compression has a huge part to play, particularly for the carriage of 4K/UHD over 10G Ethernet. For IP techniques to be used over a wider footprint, new compression techniques must meet the traditional needs of content production, where quality, editability and image manipulation place very different demands on the codecs used for contribution and distribution.

Harmonic is leading the way with an infrastructure for the efficient transport of baseband and IP signals. Adherence to industry standards assures that components in this architecture are interoperable with standard IP networking systems, and paves the way to VVI. The move to realize core functionality in a software-based VVI is already under way with the Harmonic VOS media processing platform.

With its legacy of IP innovation and support for emerging standards, Harmonic is the ideal partner for implementing a complete media-over-IP workflow.

HARMONIC IP INNOVATION

Harmonic possesses a long history of innovation in IP video technology. Here's a look at some of our major milestones.

2000

1st IP edgeQAM **(NSG)**

2001

2002

2003

1st all-IP TV headend and all-AVC headend

2004

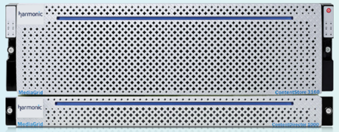
- 1st broadcast encoder with IP-only output **(Ion)**
- 1st broadcast playout server to support standard IT network file system protocols **(Spectrum)**

2005

IP-based geographically distributed, closed-loop statistical multiplexing system **(DiviTrackIP)**

2006

High-performance shared storage via Ethernet **(MediaGrid)**



2007

- **Emmy Winner:** Time Warner Cable's Start Over Service with Ion encoders to generate IP-based ingest streams
- Harmonic powers Abertis with accurate IP dejittering solution for DVB-T SFN-over-IP distribution **(ProStream 1000)**

2008

Introduction of FLEX technology, universal video/audio decoding enabling the all-IP headend **(Electra & Ion)**

2009

1st IP headend-in-a-box, combining multiplexing, scrambling and transcoding **(ProStream 1000 with ACE)**

2010

COMCAST

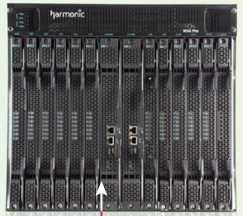
Harmonic powers Comcast Media Center's nationwide, all-IP platform for content distribution

2011

Introduction of new frame-accurate IP dejittering solution, without external reference, for DVB-T SFN-over-IP distribution **(ProView 7100)**

2012

- **Emmy Winner:** The Development and Commercialization of (IP-based) Digital Infrastructure for Local Cable Ad Insertion
- Harmonic powers first public DASH-based IPTV across the Internet trial at 2012 London Olympics
- Introduction of Converged Cable Access Platform **(NSG Pro)**



2013

#1 in IPTV headends, named by MRG

2014

- Introduction of IPTV 2.0 solution for unified all-HTTP adaptive bitrate (ABR) delivery architecture
- Introduction of fully virtualized IP-based media processing platform **(VOS)**

VOS™

2015

- Introduction of contribution solution over unmanaged IP networks with deep-packet recovery for the open internet **(ProView 8100 & Ellipse 3100)**

- Support for uncompressed video over IP **(SMPTE 2022-6)**
- **Emmy Winner:** IP Closed -loop Statistical Multiplexing of Geographically Distributed Encoders

2016

2017

10.30.15