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ULTRA HIGH DEFINITION TV OVER IP NETWORKS

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ABSTRACT

The audiovisual media production industry is investigating the possibility of migrating from purpose-made equipment using speciality interfaces such as Serial Digital Interfaces (SDI) and AES3 digital audio, to an IT-based packet network infrastructure. At the same time, the development of new formats such as Ultra High Definition TV (UHDTV) is creating demand for higher throughput and new studio interfaces.

The conclusion from a demonstration setup of UHDTV over IP is that the carriage of UHDTV video streams is definitely possible using existing IP network infrastructure. However, it requires proper management of the network to ensure integrity of the video in the presence of other traffic.

This article will be of interest to system designers and integrators who wish to experiment with the transport of uncompressed and “beyond HDTV” video over IP networks.
INTRODUCTION

The audiovisual media production industry is seriously investigating the possibility of migrating from purpose-made equipment using speciality interfaces such as Serial Digital Interfaces (SDI) and AES digital audio, to an IT-based packet networks infrastructure.

In parallel, the industry is working on the development and standardization of so-called “beyond High Definition Television (HDTV)” formats. This work will provide a combination of higher pixel resolution, higher frame rates, higher dynamic range and wider colour space than HDTV, collectively referred to as Ultra High Definition TV (UHDTV). A direct impact of these future formats is the higher throughput requirement for carrying the uncompressed signal, and thus the need for new high performance studio interfaces. Therefore, it is timely for media organisations to gain knowledge from experiments with those alternative interfaces, in order to verify that they can continue running their daily business, while increasing flexibility and eventually generating operating cost reductions.

The purpose of this article is to share facts and knowledge gained from a demonstration setup of UHDTV over IP, developed for the EBU UHDTV “Voices and Choices” Workshop that took place in November 2013, at the EBU headquarters in Geneva.

The resulting conclusion from this demonstration is that the carriage of UHDTV video streams is definitely possible using existing IP network infrastructure. However, it requires properly configured Quality of Service (QoS) protocols within the network to ensure precedence of critical video traffic over other traffic. This then enables a successful workflow migration from traditional SDI-based to an all-IP environment.

This article will be of interest to system designers and integrators who wish to experiment with the transport of uncompressed and beyond HDTV video over IP networks. In addition, the overall goal is to share our findings with both technical broadcast and IT experts, as this industry learns how to bridge these two domains of technology that have traditionally been kept separate.

DEMO SET UP

CONTENT FLOW DIAGRAM & DISPLAYS

Figure 1: Data Flow Diagram of the UHD over IP Demo
As seen in Figure 1, content flows from the source playout server, through the SDI over IP gateways, across the IP network, to the receiving SDI over IP gateways, and finally to the display. Not shown on this diagram, but illustrated in Figure 2, are the multiviewers, which were connected to the SDI matrix routers for 'before and after' video quality comparisons. The diagram also indicates where additional background IP traffic was injected to investigate what happened to the UHDTV video when the network was overloading beyond its normal capabilities.

**Figure 2: Displays used in Demo Setup; TV Logic 56” UHDTV screen (L) and Asus 24” LCD screens (R)**

**EQUIPMENT USED IN SETUP**

The following equipment was used in constructing the demo:

**Playout Server:** Video Clarity ClearView Extreme 4K including:

- 2 x AJA Video Card with 2x3G-SDI outputs
- Sync Generator: AJA GEN10

**SDI-to-IP Encapsulators/Decapsulators:**

- Cisco Digital Content Manager (DCM) IP Video Gateway
- Nevion Ventura VS902

**IP Network:** 2 x Cisco Nexus N3548

**SDI Matrix Routers:** BlackMagic Design Videohub

**UHDTV Display:** TV Logic LUM-560W - 56” LCD UHDTV Professional Monitor

**Multiviewer:** Decimator MD-QUAD

**Multiviewer Displays:** ASUS VG248QE - 24” LCD Monitors

**Waveform Monitor:** Omnitek OTR 1000
BASEBAND VIDEO

VIDEO FORMAT & PLAYOUT
For the demo, the format of the video content was 3840 horizontal pixels by 2160 lines at 50 or 60 progressive frames per second (depending on the available test material) with 10-bit pixel depth and a 4:2:2 sampling structure. This corresponds to the UHDTV1 format in the SMPTE 2036-1 standard [1].

The lack of a single link interface specification matching the 12 Gbit/s total bit rate of UHDTV requires its carriage over four aggregated 3G-SDI links, as four separate 1080p 50/60 HDTV video signals.

The playout server presents the source through two video cards, each generating 2 quadrants of the quad HD raster on two 3G-SDI interfaces. This physical separation requires an accurate external reference for proper synchronization of the two video cards.

It should be noted that the 3G-SDI interface comes in various ‘flavours’; Level A, Level B - Dual Link (B-DL) and Level B - Dual Stream (B-DS). Unfortunately, not all products indicate which of the 3G-SDI levels are supported in their specifications and this can cause serious confusion and interoperability issues, as became plain during the staging of the demo.

VIDEO ROUTING
An SDI matrix router was used both to distribute the four HDTV source signals to two different SDI-to-IP encapsulators and to switch between the two IP-to-SDI decapsulators before display. Additionally, the SDI matrix router was used to duplicate the source and decapsulated signals to feed the multiviewers for side-by-side comparison of the input and output video signals.

INTERFACE ENCAPSULATION
Two different SDI-to-IP encapsulators from different vendors were used to generate 2 separate UHDTV streams from the same playout source.

Both the *Cisco DCM IP Video Gateway* and the *Nevion VS902* encapsulated its four 3G-SDI inputs into four individual RTP streams, each running at approximately 3 Gbit/s (i.e. approx. 12 Gbit/s total data rate). The outputs of both vendors’ encapsulation devices consisted of two 10GbE (10 Gbit/s Ethernet) interfaces, each containing two RTP streams (approx. 6 Gbit/s per 10GbE interface).

The *Nevion VS902* used modified firmware to allow four 3G-SDI inputs to be encapsulated in four SMPTE 2022-6 [2] compliant RTP streams using a UDP transport. In order to keep the latency to a minimum, and since the network was simple and in a controlled environment, no Forward Error Correction (as per SMPTE 2022-5 [3]) was added.

VISUAL ASSESSMENT
The *TV Logic* 56” UHDTV display has four 3G-SDI inputs, each providing a quadrant of the overall UHDTV picture. Based on previous experience, it was known that this display requires less than a video line difference in synchronisation between the four HD signal inputs. Therefore, perfect time alignment of the four quadrants and a precise and stable synchronisation was maintained throughout the chain at all times.
IN/OUT COMPARISON
A simple comparison of the original video from the playout server with that carried over the IP path was made using a multiviewer that displayed the same quadrant of video from each path on the same display. While the total latency of the system was not measured, a comparison between the two images exhibited no visible time difference or major horizontal or vertical shift. Since the multiviewer had to compose an image from two different sources, the worst case time difference between the two images must have been less than a video frame (assuming that there was sufficient display buffering).

BIT TRANSPARENCY
The Waveform Monitor was used to make spot checks on the data in the decapsulated stream, comparing it to the source at the pixel level. This confirmed the video signal was not altered in any way during its transport.

NETWORK
NETWORK INFRASTRUCTURE
In view of the aggregate bit rate of the UHDTV source (12 Gbit/s), a native 40 Gigabit Ethernet transport mode was configured in the two Cisco Nexus N3548 network devices that were used. This was done by selecting one of the options in the IEEE 802.3ba standard that supports a ‘four lanes’ model, that delivers serialized data at a rate of 10.3125 Gbit/s per lane. The N3548s support this capability natively by allocating 4 adjacent ports each equipped with 10GbE SFP+\(^1\) to set up the native 40GbE transport without any impact on the delivery of the streams, as shown in Figure 3, overleaf.

EQUIPMENT LATENCY
To fulfil the typical video production requirement of limiting any latency to the bare minimum within the production facility, low latency network devices were selected. In their standard operating mode, the Cisco Nexus N3548 devices are capable of providing sub 250 ns latency between the input and output ports, and even sub-200 ns in specific operating modes [4].

LAYER 3 ROUTING
The network was designed using a layer 3 architecture, implying that routing was performed between the different IP subnets. Each Ethernet port of the SDI-to-IP gateways was connected to a separate IP subnet. The same condition was applied between the two Nexus N3548 devices, which were interconnected using a separate IP subnet. The selected network equipment has been designed to perform at full line rate capabilities both at layer 2 (switching) and layer 3 (routing) levels, hence no performance penalty was induced by selecting this approach and we maintained the benefits of a layer 3 topology [4].

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\(^1\) The enhanced small form-factor pluggable (SFP+) optical transceiver supports data rates up to 10 Gbit/s. It is a popular industry format supported by many network component vendors.
MULTICAST

In a real IP network environment, devices that may need to receive the video source data comprise a wide range of products and applications - such as monitors, graphics servers, encoders or test & measurement equipment. These devices may be added or removed dynamically according to operational requirements.

When using a traditional unicast only approach, this would create an additional flow in the network between the source and the receiver and could quickly cause bandwidth scalability issues. On the other hand, a multicast approach requires the sharing of a single common flow from the source, only replicating the multicast IP packets onto additional interfaces when and where a new receiver that is not on the path of the flow, subscribes to the source. This drastically simplifies bandwidth management planning.

Figure 3: Command Line Interface showing that the 40 Gbit/s transport over 10GbE interfaces mode is providing a full line rate of 39.45 Gbit/s
SOURCE SPECIFIC MULTICAST (SSM)

In a traditional multicast environment, sources are identified by the group IP address. Since no identifier is used for the source IP address, this is known as the AnySource Multicast (ASM) model. To enable a receiver to discover the source IP address, a RendezVous Point (RP) is used to initiate the initial setup of the multicast ‘tree’. This may cause additional overhead in terms of delay and bandwidth usage, due to replication of traffic other than on the shortest path between any given source and receiver.

By enabling Source Specific Multicast (SSM), receivers are capable of subscribing to a source by specifying both the group and the source IP address. This provides additional security and filtering capabilities by ensuring that the source is well identified, therefore limiting errors due to mis-configuration. It also simplifies the multicast topology since no RP is required to initiate the session between a receiver and a source. To support this functionally, only the multicast receivers and the directly connected routers need to be configured to support the IGMPv3 protocol enabling these changes; the rest of the multicast network infrastructure is identical to ASM.

QOS

To ensure that the UHDTV multicast sources attained the highest level of priority in the network, Quality of Service (QoS) operation was enabled within the network. IP packets containing the encapsulated SDI payload from the UHDTV service were marked using Differentiated Service Code Points (DSCP), specifically using DSCP 46 to map to the Expedited Forwarding (EF) class, which matches the Priority Queue (PQ) used on the network devices. Priority queuing ensured that the queue scheduler serviced the traffic with the highest priority first.

BACKGROUND TRAFFIC

To demonstrate that network QoS was actually implemented and functional, background traffic was injected into the network. This was done so that the aggregate output of IP traffic would exceed the bandwidth of the 40GbE connection, thereby creating a bottleneck that would require dropping some IP packets. This is where the QoS settings described above were enforced and these ensured that none of the UHDTV packets were delayed or dropped.

To visually prove the point, the processing of the QoS settings on the Nexus N3548 network device connected to the source SDI-to-IP gateways was disabled temporarily to demonstrate the impact on the picture quality. Under those non-QoS enabled conditions, both pairs of SDI/IP encapsulators / decapsulators exhibited video artefacts that would not be acceptable as professional video quality.

While it was observed that the characteristics of those artefacts were not the same for the different vendor equipment paths, no conclusions should be drawn. Implementation details from each vendor, combined with rate loss and loss distribution patterns will all affect how the SDI-to-IP decapsulators attempt to recover from errors. It should be noted that no FEC was enabled on the IP streams since this would have further modified the behaviour of the error recovery process in the decapsulators, and that was not the aim of this demonstration.

When selecting SDI-to-IP encapsulators and decapsulators it may therefore be relevant to test the behaviour of the video (and audio) when the network is not able to deliver all the packets on time, both with and without FEC enabled, as some products may cope better with small packet losses. For instance, the loss of a valid SDI stream with good eye pattern characteristics could cause the loss of synchronisation at the input of the downstream equipment.
CONCLUSION

This article has presented the setup and the findings from a demonstration of the transport of Ultra High Definition video over an IP network.

Using SDI-to-IP encapsulators / decapsulator pairs from two different vendors, the demonstration showed a stable and bit perfect video stream on the output display; the four progressive HD quadrants were perfectly synchronized. When comparing the final video to its source, a very short latency of less than one video frame was observed.

When adding background traffic to saturate the 40GbE capacity of the ingress switch, the activation of QoS preserved the integrity of the UHDTV video streams.

KEY TAKEAWAYS

It is possible to carry UHDTV video comprising a number of SDI streams over an existing IP network infrastructure that is properly managed.

This requires proper planning of the network and video infrastructure, including IP address planning, multicast configuration, routing of subnets and QoS configuration.

In order to take advantage of the ease of using SDI links, it is highly recommended that the media networks include automated configuration features. In this demonstration, a high level of knowledge of network management was required to manually configure the routing rules and the QoS that provided stable video reception, even when oversubscribing the network with additional background traffic. After the engineering and testing phase, this process could be automated in a number of ways, depending on the management and operational environment in which the network is operated.

The SMPTE Standard 2022-6 “Transport of High Bit Rate Media Signals over IP Networks” [2] currently doesn't support time alignment between multiple streams for UHDTV resolutions. Without a standard synchronisation method, the time alignment of the four HD streams is left to the implementation of the manufacturer of the SDI-to-IP gateways, which implies that interoperability may not be an option.

It must be stated therefore that at this time, there is no standard way to achieve interoperable UHDTV transport over IP.

Network equipment must be designed to keep the end-to-end latency under a few video frames, as required by many applications such as switching between fast moving images in sports events. Low latency switching technology exists and was used as part of this demonstration.

Native 40 Gigabit Ethernet was used to show that there was no impact caused by a multi-lane design. While no single data flow was running at 12 Gbit/s, since the 3G-SDI streams were actually
4 times 3 Gbit/s, this is still a preferred approach that has demonstrated the network capabilities and indicated a future-proof concept.

As mentioned above, 3G-SDI comes in many format ‘flavours’: Level A, Level B - Dual Link and Level B - Dual Streams. It was noted during the demo development, that not all products indicate which 3G-SDI levels are supported in their specifications. When using 3G-SDI interfaces, therefore, the user needs to ensure that all interconnected equipment is using the same format. For more info, see EBU TR 002 [5].

**NEXT STEPS**

This demo has focused on using IP transport for quad 3G-SDI signals. Now that this has been proven to be possible, the feasibility of migrating the full UHD production environment onto an IP network infrastructure must be investigated. This could be done by adding features to this basic demonstration - such as multiple live sources (cameras), time distribution and synchronization of the sources, seamless switching between sources, mixing IP traffic from live sources with other applications such as file-based editing, file transfers, audio, intercoms, graphics generator, camera control, etc.

The question of automated network management and interoperability between network equipment vendors also needs to be investigated.

**REFERENCES**

http://standards.smpte.org/content/st-2036-1-2009/SEC1.abstract.html?ijkey=a886d7db4b1622f6d7fe2ebbce715600a1267f71&keytype2=tf_ipsecsha

http://standards.smpte.org/content/978-1-61482-716-0/st-2022-6-2012/SEC1.abstract?sid=5e7e93aa-6b4c-483d-b185-7bd46b9c3287


https://tech.ebu.ch/docs/techreports/tr002.pdf

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Felix has “grown up” in studios as his parents worked in TV production. His inherited curiosity for technology led him to a diploma in electrical engineering at the École Polytechnique de Montréal completed by a research project at the Massachusetts Institute of Technology. After graduating he began work as a wireless and digital audio expert on international productions, including at Cirque du Soleil. Prior to the EBU, he has worked for national broadcaster CBC/Radio-Canada as engineer in Radio-TV production technologies.

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Adi joined the EBU Technology & Innovation Department in 2007; he is now Senior Project Manager responsible for video and display technology studies and proofs of concept for broadcast applications.

He leads core investigations on UHDTV, including HEVC and High Frame Rates, within the EBU and the Broadcast Technology Futures Group.

In addition, Adi acts as technical advisor to the Eurovision Network where he has been involved in the network technology migration from MPEG-2 to MPEG-4, and establishing operational practices/ trials for new services such as 3DTV and UHDTV for major events.

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