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White Paper

Can JPEG2000 solve the challenge of HDTV Contribution over IP?

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Executive summary

The introduction of High Definition Television (HDTV) results in new increased functionality requirements for broadcast contribution systems. For understandable economic reasons, networks designed for the transport of Standard Definition Television were seldom dimensioned to transport HDTV signals. Legacy installations such as satellite and ATM are expensive and offer limited capacity suitable for HDTV postproduction. A potential solution is the use of IP, however broadcasters and operators need to be confident that IP gigabit networks can provide the Quality of Service (QoS) necessary for carrying uncompressed SDI and do this cost-effectively. For HD it is increasingly clear that it's necessary to reduce the bandwidth required in order to distribute HD over the more cost-effective sub 1 gigabit networks. JPEG2000 is an excellent candidate to reduce the 1.5 Gbit/s HDTV signal to a more affordable bitrate. The advantages of JPEG2000 for contribution of video over IP are low video quality degradation, low latency, large dynamic range and the possibility of rebuilding content to provide a lower bit-rate through extraction of data - by contribution, we mean the backhaul of programming to studios or play-out facilities. This layered structure also provides the possibility to adapt forward error correction (FEC) to avoid video degradation.

The Challenge: HDTV demands new Contribution systems

The demand for High Definition (HD) consumer equipment is growing considerably. The number of HDTV sets in the world's homes is projected to reach 106 million by the end of 2010 - around three times the 2005 figure (Informa Media and Telecom, HDTV, 09/2005). HDTV transmissions are now well advanced in Australia, Japan and North America and in Europe major satellite and cable broadcasters are to start offering HDTV programming in 2006. This means that in order to stay competitive, all broadcasters with ambitions for mass market appeal will be pushed to offer HD content offerings. This not only influences the required functionality of studio equipment, but also poses new requirements for contribution systems. To summarise - to compete content providers need to equip their infrastructure to ensure that it is HD compatible.

Up to now, MPEG-2 compression at bitrates in the range 10 to 15 Mbit/s have been used for contribution links, whether the distribution medium is by satellite or telecom network. Delivery of HDTV signals requires bitrates about 4 times higher than for SD signals and such bitrates will often not be supported by current contribution systems. The undeniable conclusion is that an upgrade of the contribution infrastructure is required. This also provides a good opportunity for rethinking the whole contribution architecture and as the Quality of Service levels of IP networks are now high enough to satisfy the most demanding broadcaster, IP is a good and economically viable alternative. IP achieves this through the combination of modern IP router technology such as MPLS and by advanced Forward Error Correction schemes in the video to IP Gateways, these advantages are being quickly understood leading to IP quickly gaining ground in the video contribution arena. Capex costs are reduced as network operator can save considerable amounts by using equipment designed for voice over IP and data rather than investing in specialised and expensive ATM based video networks. In addition, operational costs are reduced as it is no longer required to have highly trained specialised staff with the skills base to operate and maintain both ATM and IP networks.

It's also much easier to develop increased functionality in-house if you're running an IP network.

Based on all of the above facts, we believe it's now clear that IP based networks will increasingly become the preferred network protocol for HDTV contribution purposes.

In addition, for events that require a high quality input to the postproduction process, MPEG-2 does not offer a satisfactory solution. The image quality is degraded in the compression, the dynamic range is cut off to 8 bits and IB GOP structure limits the editing. As for SDI there is the possibility to transport HDSDI uncompressed, but this breaks the 1 Gigabit price barrier and will be costly. So, for HD contribution the key question is: How to fit a 1.5 Gigabit HD SDI stream into the 1 Gigabit IP pipe?

The Solution: JPEG2000

The answer to the question is the same whether the contribution is over a satellite or fibre system. Some kind of compression is required: up to now, MPEG-2 4:2:2 has been the main compression technology for contribution purposes, but considering the deficits mentioned above, is it the ideal technology for contribution today?

JPEG2000, which was established as an international standard in January 2001, is an image compression standard which has a number of compelling advantages for contribution. At the heart of JPEG2000 is wavelet-based compression methodology that imparts a number of benefits over the discrete cosine transform (DCT) compression methods used in MPEG compression. More details about JPEG2000 in a second, but first let's note that Digital Cinema Initiative (DCI) has formally adopted JPEG 2000 as the standard format for digital delivery of all motion pictures to theatres. The movie studios wanted perfect quality, and after an exhaustive codec shoot-out JPEG 2000 was far and away the winner.

The Details: JPEG2000 offers a feature set ideal for Contribution of HDTV over IP

JPEG2000 is a wavelet based compression technology which provides for a number of benefits over Discrete Cosine Transform (DCT) compression methods such as MPEG-2. The compression process is composed of the following three steps: wavelet transformation, quantization and entropy encoding.

The input picture is transformed by a set of wavelet filters and thus pixel information is transformed into wavelet coefficients which are grouped into several sub-bands. Each sub-band contains wavelet coefficients that describe a specific horizontal and vertical spatial frequency range. For simplicity, only two levels of transform are shown in the diagram below. The first transform level results in sub-bands LH1, HH1, HL1, and LL1. Only sub-band LL1 is passed on for further filtering, generating the next transform level and creating sub-bands LH2, HH2, HL2, and LL2. The main difference compared to DCT compression is that the wavelet transform is done over the complete picture in one transform and not by blocks by 8x8 pixels

Coefficient modelling and coding is done per code block generated for each sub-band. The actual compression is achieved by truncating and/or re-quantizing the bit streams contained in each code block. After the data has been quantized into a finite set of values, it enters the entropy encoding process which gives additional compression.

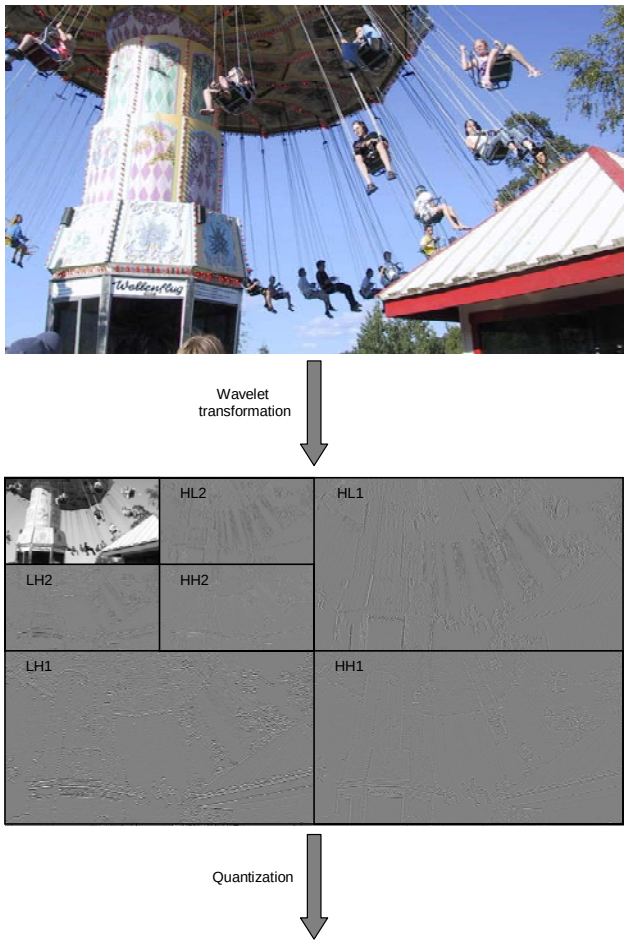

Figure 1. TVG430 HD-SDI to IP Video Gateway

Intra-frame

JPEG2000 is an intra-frame based encoding scheme. Unlike DCT-based compression methods such as MPEG-2, MPEG-4 and VC.1 which encode using P or B -frames and motion vectors to build the frames in-between I-frame's, JPEG2000 encodes each frame independently. This is a great advantage for editing, as the video signal may be cut at any place.

Video quality

Another advantage with JPEG2000 is that it offers a tool set suitable for high-quality video. Whereas the driving force for MPEG-4 has been to deliver a good video quality at low bitrates e.g. for TV over DSL lines by improving the temporal prediction, the driving force behind JPEG2000 has been to produce a standard with high quality compression of single pictures. This requirement fits well with really high video quality applications such as Digital Cinema and also for broadcast contribution.

MPEG-2 and MPEG-4 are limited to 8-bit video and the 4:2:2 profile, however JPEG2000 can allocate more bits per sample e.g. 10 bits video is offered which is in line with SMPTE SD and HDSDI specifications and normal studio practice.

Less visual artefacts

The result of an error in an MPEG-2 stream is often the well known blocking effects. This is a common impairment produced by DCT based compression, it occurs because in MPEG-2 the picture is broken up into small blocks. Bit errors in a JPEG2000 stream create less visual artefacts than MPEG-2 solutions, as the error appear as a short-lived blur in the picture much less visually disturbing than the blocking effects which can also be much longer lasting.

Symmetrical complexity and cost structure

In systems with a small number of encoders and a large number of decoders, it is important to reduce the complexity of the decoders as much as possible at the expense of the complexity of the encoder. Put another way, the encoder can be complex and expensive as long as the decoders are simple and cheap. This is the philosophy behind MPEG-2 and MPEG-4, which are designed for the compressed video to be transmitted to a large number of receivers. The architecture of contribution systems are very different, with the number of transmitters and receivers much more equally matched. The cost and complexity of the transmitter and the receiver should therefore ideally be about the same, with JPEG2000 this is relatively easily achieved, as the same chips are used for encoding and decoding.

Low latency

Reducing latency is crucial for live TV Contribution. In the MPEG compression world, pictures are encoded using information about past and future pictures (the famous P and B pictures in the Group of Pictures) with latency obviously hit hard by reliance on future frames. JPEG2000 compression provides much lower latency as there is no dependency from one picture to the next, in general JPEG2000 produces latency of less than 1.5 frames for encode or decode.

Robustness in case of transmission errors

JPEG2000 is a particularly good choice for contribution of video over IP as it is exceptionally robust to transmission errors. As described earlier, JPEG2000 provides no blocking artefacts and any errors that are introduced are more pleasant to the eye and additionally because JPEG2000 has no error propagation between frames any artefacts are much shorter-lived.

Sustains multiple compressions

One of the challenges of using MPEG2 compression for contribution purposes is the quality degradation at every compression step. The JPEG2000 compression technology sustains multiple compression steps very well and it is robust to pixel shifts.

Conclusion

Contribution of HD content over IP is still in its initial phase, with no defacto standard for the economic transport of HD over IP links. Whereas MPEG2, MPEG4 and VC.1 offer great advantages in distribution to the home, JPEG2000 offers a number of advantages which makes it an excellent choice for IP contribution. These advantages include high video quality, low latency and high robustness to transmission errors.

T-VIPS offering for Contribution of HDTV over IP

T-VIPS have developed a complete solution for Contribution and Distribution over IP. The Connect solution includes products for transport of both compressed and uncompressed video signals over IP infrastructures as well as monitoring and control systems.

TVG430 HD-SDI to IP Video Gateway

In order to transport HD-SDI signals over IP, T-VIPS have launched the TVG430 HD-SDI to IP Video Gateway. The product uses JPEG2000 compression for bit rate reduction of an HD-SDI signal from 1.485 Gbit/s to bit rates between 50 and 200 Mbit/s. Each TVG430 unit may be configured by the user as either a transmitter or a receiver.

The following picture formats are supported:

- SMPTE 274M-2003 System 5: 1920 x 1080/59.94/I
- SMPTE 296M-2001 System 2: 1280 x 720/59.94
- SMPTE 274M-2003 System 6: 1920 x 1080/50/I
- SMPTE 296M-2001 System 3: 1280 x 720/50
- SMPTE 274M-2003 System D: 1920x1080/24/PsF

Figure 2. TVG430 HD-SDI to IP Video Gateway

The IP transport is based on standard solutions including Pro-MPEG code of practice for transport of video over IP, RFC 3550 and IETF draft “RTP Payload Format for JPEG 2000 Video Streams”.

In order to cope with packet loss on the network, the TVG430 includes forward error correction (FEC). The product provides recovery from wide out-of-order packet reordering, packet loss concealment to reduce visual impairment for uncorrected packets and configurable receiver latency in order to match expected network jitter, latency variations, FEC settings and out-of-order range. The FEC proposal is based on PRO-MPEG code of practice #3.

T-VIPS Connect

In order to supervise and manage contribution networks, T-VIPS offer T-VIPS Connect, an easy-to-use application to configure and supervise video connections between sites. In addition, the application provides easy administration and supervision of video transport and processing equipment in the network.

The main functionality of T-VIPS Connect is easy set-up and tear down of contribution connections. The operator doesn't have to care about IP addresses and UDP ports, all he has to do is to set up the connection from one input port to an output port and the application will ensure that the equipment is configured accordingly. Instead of configuring all the encoding and transport parameters, the operator can select to use a pre-defined profile for the connection.

T-VIPS Connect also provides device supervision and maintenance. All sites and devices are registered by the application and the application will monitor all devices and show equipment status and health. In case of an alarm from any of the devices, the application will immediately notify the operator by raising an alarm. In addition, all events are logged.

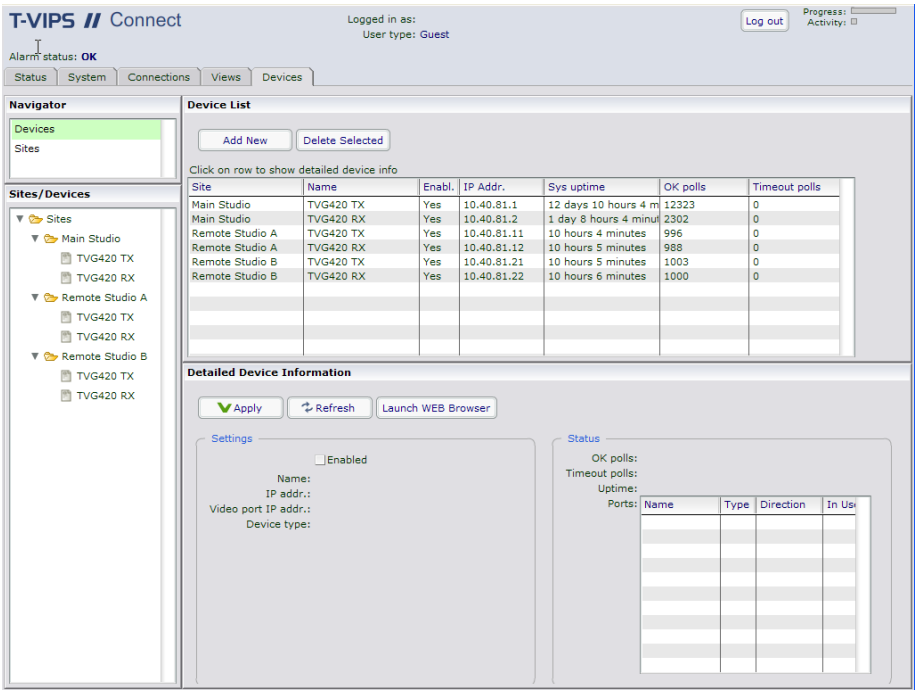

Figure 3. Graphical user interface T-VIPS Connect

T-VIPS Connect provides a ‘northbound interface’ based on SNMP and XML for integration into an overall Network Management System.

T-VIPS Connect is a server application including a central database with web-based remote control. The server will typically be placed centrally with the application providing web-based clients. This means that there is no need to install client software on the PCs operating the server remotely; only standard web browsers such as Internet Explorer are required. In order to provide a fast and user-friendly user interface, the graphical user interface of T-VIPS Connect is based on Rich Internet Application (RIA) technology using Macromedia FLASH.

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About T-VIPS

Headquartered in Oslo, T-VIPS AS is a Norwegian technology company with new products and solutions for the growing professional Video over IP transport market. T-VIPS provides solutions for broadcast contribution, studio-to-studio media exchange, in-house signal distribution and routing, post-production, live event coverage and primary distribution. The company is funded through investments from the leading Scandinavian VC funds Northzone Ventures and Selvaag Venture Capital.

For further information, please visit: www.t-vips.com

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