The Pro-MPEG Forum Interoperability Tests

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Executive Summary

Between 21st and 28th February 2001, eight manufacturers, members of the Pro-MPEG Forum, took part in interoperability tests. The tests were conducted on behalf of the Pro-MPEG Forum by BTexact (formerly British Telecom Research Labs), who are also members. Fourteen Operating Points were used as the test-points, based on the Code of Practice devised by the ATM Working Group in the Forum. Six different video rates were tested, and uncompressed as well as compressed audio was tested. No interoperability problems were seen in the tests which included compressed audio. Where uncompressed audio was included, a marked improvement in compliance with the Code of Practice, and therefore interoperability, was seen compared with previous tests.

Background

The first-listed objective of the Pro-MPEG Forum is to "promote the interoperability of MPEG-2 equipment....". One of the Working Groups set up in the Forum addresses the needs of the Wide-Area Network, and ATM (Asynchronous Transfer Mode) interconnection in particular. Several manufacturers who are members of Pro-MPEG make terminal equipment for such networks, be they MPEG-2 encoders, MPEG-2 decoders or ATM adaptors. As a very concrete step towards improved interoperability, tests have been run during July 2000 [1] and most recently February 2001. Both sets of tests were based on a Pro-MPEG Code of Practice: "Operating Points for MPEG-2 Transport Streams on Wide Area Networks" [2].

Operating Points Code of Practice

The 'ATM' Working Group in Pro-MPEG authored the Operating Points document which was approved and published by Pro-MPEG in May 2000. It was written with the intention of meeting users' requirements and, to this end, several representatives of the broadcasters in Pro-MPEG were involved. It is essentially a practical document, covering different applications from Satellite News Gathering at 7.5 Mbit/s (video-rate) up to 80 Mbit/s for High Definition Television. The bit-rates required for video-content, audio, transport and physical medium are spelled-out because it had been felt that these are often mis-quoted when talking informally about service provision. Many of the bit-rates correspond to those in use internationally. All operating points specify 4:2:2 sampling structure. Both 525 and 625 line systems are included.

The Operating Points specified cover transmission over ATM and Satellite networks. They are intended as a starting point for service provision, clarifying the engineering required in order to meet the specified user need. Another objective of the Code of Practice is to provide the basis of a test specification for checking interoperability. All 14 of the standard-definition operating points were used as test-points in the interoperability tests conducted by BTexact.

Audio

Audio considerations feature highly in Pro-MPEG priorities and more than half of the variations between operating points are solely because of differences in the requirements for audio. Thanks to the standardisation activities of the DVB (Digital Video Broadcasting) group, MPEG-compressed audio is available on all encoders and decoders presented for these interoperability tests. A user-requirement for uncompressed audio has been accepted by Pro-MPEG, and recommended by the Forum to SMPTE [3] and there is an uncompressed-audio operating point for each of the video rates listed.

The SMPTE standard for carriage of uncompressed audio over MPEG Transport Streams is SMPTE 302M, dated 1998 and 2000(draft) [4]. It is anticipated that codec manufacturers track the finalised version of 302M; this is the audio standard specified for uncompressed in the Operating Points Code of Practice.

Dolby-E is a relatively new audio transport mechanism for carrying multiple channels of compressed audio over a path designed for one uncompressed stereo pair. Although not part of the Operating Points code of practice, Dolby-E's compatibility with SMPTE 302M was thought to be a useful additional feature to include in these tests.

Vendor Involvement

Invitations were sent out to the whole membership of Pro-MPEG. It was anticipated that many of the MPEG-2 encoder and decoder manufacturers would wish to participate, as well as makers of the adaptor units required to convert compressed video into ATM streams, since this was the selected interconnect to be used during the tests. It had been decided by the organisers that a minimum commitment of 6 manufacturers would be needed for the tests to be worthwhile. In the event, the following 8 manufacturers expressed interest and took part in the tests:

Maker Product(s)

Thomson	MPEG-2 encoder, MPEG-2 decoder, ASI to ATM adaptor
TandbergTV	MPEG-2 encoder, MPEG-2 decoder, ASI to ATM adaptor
BarcoNet	MPEG-2 encoder, MPEG-2 decoder, ASI to ATM adaptor
Tiernan	MPEG-2 encoder, MPEG-2 decoder, ASI to ATM adaptor
Scopus	MPEG-2 encoder, MPEG-2 decoder
Sony	MPEG-2 decoder, ASI to ATM adaptor
ATecoM	ASI to ATM adaptor provided for BarcoNet use
ADVAoptical	Cell-Ace ASI to ATM adaptor provided for Scopus use.

Test Method

The heart of the test setup is the ATM switch. The interconnection needs for these tests are not complex; a 12 port NewBridge Vivid switch was used. Connections to all of the ATM adaptors were *via* Multi-Mode Fiber, STM-1. Permanent Virtual Circuits (PVCs) were established in the switch; these took the form of a broadcast – cells arriving on the first port of the switch (port 1-1) were duplicated and sent to all ports (ports 1-1 to 6-2). A convention was adopted that encoded MPEG was presented to the switch on PVC 0/33 and was delivered on the broadcast to all decoders using PVC 0/34.

The video source used the Serial Digital Interface (SDI) with embedded audio. One of the encoders provided was not designed for embedded audio so a separate de-embedder was used. All of the decoders delivered embedded audio. The program material included high-quality sequences with speech (for lip-sync tests) and some critical material from test-sequences such as 'Barcelona', and 'Mobile + Calendar'. These were played from a D-1 VTR or a full-bandwidth server.

A typical test would have a television source feeding audio and video into all encoders, one of which would be set to one of the Pro-MPEG Operating Points. Its output would be ASI (Asynchronous Serial Interface) and this would be converted to ATM using its associated adaptor, using AAL-1 (ATM Adaptation Layer #1), the recommended layer for transporting professional television. The ATM cells would be presented to the Vivid switch and be broadcast to all ports. All 6 decoders would therefore receive the same stream, *via* their own ATM adaptors. Every one of the decoded output streams was looped in SDI form through a quad-viewer and into a manual switcher for full-screen monitoring and audio monitoring.

Cross-patching was provided between the receive ATM adaptor and the associated MPEG-2 professional decoder. Three operating points were chosen: low (7.5 Mbit/s video), medium (20.5 Mbit/s video) and high (50 Mbit/s video), and each ASI stream was fed to each decoder to look for any incompatibilities at this ASI interconnection point.

Monitoring of the resulting audio and video, and the lip-sync, was done subjectively. In the tests conducted in July 2000 it had been found that in-depth analysis of picture-quality was not worthwhile since it gave no more information on interoperability than a subjective assessment by those present at the tests.

Each encoder was allocated a day on which it was the source feeding all decoders. The encoder would be configured for each of the operating points that it was designed to operate at. Note here that some of the encoders and decoders had SMPTE 302M uncompressed audio capability and others did not. These situations are 'not tested' in the results sheets. None of the decoders possessed more than 2 stereo pairs as outputs. Several of the operating points specify a greater number and so the 2 available outputs had to be manually pointed at the input streams in order to check for compatibility with the audio streams they were being sent.

Results

The results are captured in 3 tables at the end of this document. The primary table shows all encoder to decoder interoperability test results and, at the specific request of some of the vendors, 2 further tables which split the results into compressed and uncompressed audio findings.

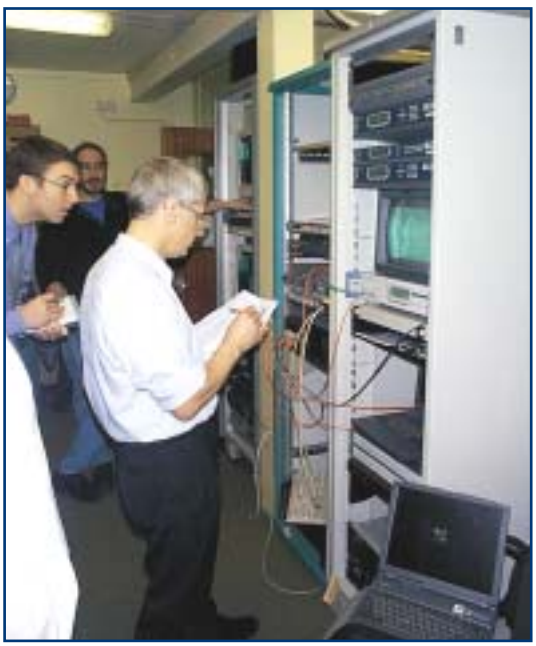
Dashes (---) in the results table indicate 'not tested' or 'not applicable' – typically because uncompressed audio does not feature in 3 of the codecs. Because of this, it may be easier to analyse the results by looking at the split tables (2 and 3).

A headline result from the operating points which only include compressed audio is a less than 1% failure rate in interoperability. In fact, the only missing 'YES' in these tables was due to a second audio channel having been erroneously disabled for a brief period in the tests. Based on the other findings there is no reason to expect that 100% interoperability couldn't be achieved. It is worth noting that all 'compressed-only' decoders returned silence upon receipt of uncompressed audio. None of them misbehaved in this regard.

Considering only the encoders and decoders designed to support uncompressed audio, there is complete interoperability with only the following reservations:

(1)The BarcoNet Stellar decoder was not able to decode the uncompressed audio from the Tandberg encoder. See further explanation under 'Issues Raised'

(2)The Thomson decoder could not be configured to decode a mix of compressed and uncompressed audio, though the hardware is clearly able to decode both.



A Dolby-E test was conducted after all the other tests. When correctly configured to accept this signal, the Tandberg pair passed it successfully. No other combinations of encoders and decoders would pass the signal.

The ATM adaptor interoperability tests showed an extremely high level of compatibility. Adaptors from Thomson, TandbergTV, BarcoNet (Alcor), Tiernan, ADVA (Cell-Ace) and Sony fed decoders from Thomson, TandbergTV, BarcoNet, Tiernan, Scopus and Sony. Ignoring any interoperability issues already covered in the results tables, five out of the six adaptors presented no problems. The sixth (Sony BDX-N1000) requires network-clocking which was not provided in the test setup. Excess PCR (Program Clock Reference) jitter resulted, which the BarcoNet Stellar decoder was not designed to handle.

Issues Raised

In general, the tests progressed smoothly. Where issues cropped up, some were positive, some negative.

Control of the equipment varied from vendor to vendor. Although there are many commonalities in control mechanisms, be they front-panel control, serial interface, pre-loaded presets or SNMP (Simple Network Management Protocol), there were no 2 devices which could be controlled using the same controller/dialogue. The Pro-MPEG Forum has been actively considering this issue for some time and expects to make concrete proposals in the near future.

The ordering of the audio pairs is only laid down in the input and output SDI streams, not in relation to the MPEG stream. The order could be inferred from the tables in the Operating Points Code of Practice, but this has not been mandated. A convention for the use of audio PIDs (Packet Identifiers) has been suggested whereby the lowest number indicates the primary channel. Use of channels in any given service must be left to the discretion of the broadcast user and it is worth noting down any conventions that have been assumed. This is particularly significant in the allocation of compressed/uncompressed audio pairs and their possible use for multi-channel (e.g. Dolby-E). For the current tests, selection was made manually to ensure correct routing from source to destination.

A 'workshop' environment existed during the days of the tests. Vendor-reps all co-operated and helped with the testing and wished to make progress then and for the future. To this end, and as the result of a series of bi-partisan agreements, pairs of vendors agreed between themselves to record MPEG data streams (as ASI) and take these away on CD for the mutual benefit of interoperability. BTexact was very happy to facilitate this activity; this could point to a future test-method, with individual encoder vendors supplying CDs of their data-streams to the decoder vendors.

One further point arose regarding uncompressed audio. The Sony BDX D-1000 decoder was not designed to handle SMPTE 302M uncompressed audio, but recognised that this stream was not compressed audio or indeed its own native uncompressed format. The audio stream was therefore output in the VBI (Vertical Blanking Interval) portion of the SDI, but its validity was not tested.

As mentioned earlier, the 2 versions (1998 and 2000) of SMPTE 302M have differences which would prevent complete interoperability. Although outside the scope of these tests, results have been reported which show that interoperability in the uncompressed audio has been achieved between BarcoNet and TandbergTV equipments. This involved the use of firmware in both devices with matching implementations of the standards. Reference should be made to these vendors for more information.

In the earlier series of tests (July 2000), an attempt was made to use automated lip-sync testing using the Tektronix VM-700T. Whilst it is believed that any significant lip-sync errors would have been detected using the subjective observation method, an automated method would potentially yield quantitative values which were more repeatable and consistent. In the earlier tests it was not possible to achieve a strong correlation between the input video and audio and so no reliability resulted. Studies are to be conducted to address this issue.

The Future...

Within the Forum, the Wide Area Networking group continues to address interoperability, not only for ATM networks, but also MPEG over IP networks, Vertical Blanking Interval transmission, Networking of the Serial Data Transport Interface and requirements for test and measurement.

As a result of previous successes in Interoperability Testing for Pro-MPEG, BTexact Technologies has agreed to openly offer a future capability through its Broadcasting Solutions facility at Adastral Park, Martlesham, UK. With a launch set for September 2001 at the International Broadcasting Convention in Amsterdam, a range of services including product evaluation and interoperability testing on neutral ground are made available. The facility will be based on a wealth of experience gained from years of test and development in MPEG and related fields.

Acknowledgements

Thanks are extended to the individuals who personally contributed to the successful running of these tests. Thanks also to Rohde & Schwarz [5] for the loan of test-gear, to BarcoNet for the loan of two Vivaldi-II [6] quad-viewer units, to Leitch [7] for the loan of audio embedders, de-embedders and a 12-way SDI-switcher, and to Dolby UK for the loan of a Dolby-E [8] encoder and matching test/monitoring unit.

References

[1] Results from the BTexact-run interoperability test in July 2000:
www.pro-mpeg.org/publicdocs/html/interop.html

[2] Pro-MPEG Code of Practice #2:
www.pro-mpeg.org/publicdocs/pdf/prompeg159.pdf

[3] Operating Ranges recommended to SMPTE as RP 213 and EG 38.

[4] Linear PCM Digital Audio in an MPEG-2 Transport Stream

[5] Rohde & Schwarz: www.rsd.de

[6] Vivaldi quad-viewer units – multiple SDI streams into an SVGA display –
www.barconet.com/downloads/vivaldi%202.pdf

[7] Leitch Genesis modules:
www.leitch.com/support/genesis.phtml

[8] Dolby-E: www.dolby.com/tech/#dolbye

TABLE ONE - Complete results

DECODER	ENCODER: THOMSON	TANDBERG	BARCONET	TIERNAN	SCOPUS
Operating Point: 7.5-1:0:0					
Thomson	YES	YES	YES	YES	YES
Tandberg	YES	YES	YES	YES	YES
BarcoNet	YES	YES	YES	YES	YES
Tiernan	YES	YES	YES	YES	YES
Scopus	YES	YES	YES	YES	YES
Sony	YES	YES	YES	YES	YES
Operating Point: 7.5-1:0:1					
Thomson	YES (comp or uncomp)	YES (comp or uncomp)	YES (comp or uncomp)	---	---
Tandberg	YES	YES	YES	---	---
BarcoNet	YES	NO	YES	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---
Operating Point: 10.5-0:1:0					
Thomson	YES	YES	YES	YES	YES
Tandberg	YES	YES	YES	YES	YES
BarcoNet	YES	YES	YES	YES	YES
Tiernan	YES	YES	YES	YES	YES
Scopus	YES	YES	YES	YES	YES
Sony	YES	YES	YES	YES	YES
Operating Point: 10.5-0:1:1					
Thomson	YES (comp or uncomp)	YES (comp or uncomp)	YES (comp or uncomp)	---	---
Tandberg	YES	YES	YES	---	---
BarcoNet	YES	NO	YES	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---
Operating Point: 14-0:1:0					
Thomson	YES	YES	YES	YES	YES
Tandberg	YES	YES	YES	YES	YES
BarcoNet	YES	YES	YES	YES	YES
Tiernan	YES	YES	YES	YES	YES
Scopus	YES	YES	YES	YES	YES
Sony	YES	YES	YES	YES	YES
Operating Point: 14-0:1:1					
Thomson	---	YES (comp or uncomp)	YES (comp or uncomp)	---	---
Tandberg	---	YES	YES	---	---
BarcoNet	---	NO	YES	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---
Operating Point: 20.5-0:2:0					
Thomson	YES	YES	YES	YES	YES
Tandberg	YES	YES	YES	YES	YES
BarcoNet	YES	YES	YES	---	YES
Tiernan	YES	YES	YES	YES	YES
Scopus	YES	YES	YES	YES	YES
Sony	YES	YES	YES	YES	YES
Operating Point: 20.5-0:2:1					
Thomson	YES (comp or uncomp)	YES (comp or uncomp)	YES (comp or uncomp)	---	---
Tandberg	YES	YES	YES	---	---
BarcoNet	YES	NO	YES	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---
Operating Point: 30-0:0:1					
Thomson	YES	YES	YES	---	---
Tandberg	YES	YES	YES	---	---
BarcoNet	YES	NO	YES	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---
Operating Point: 30-0:0:2					
Thomson	YES	YES	YES	---	---
Tandberg	YES	YES	YES	---	---
BarcoNet	YES	NO	YES	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---
Operating Point: 30-0:0:3					
Thomson	---	YES - any 2 from 3	YES - any 2 from 3	---	---
Tandberg	---	YES - any 2 from 3	YES - any 2 from 3	---	---
BarcoNet	---	NO	YES - any 2 from 3	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---
Operating Point: 50-0:0:2					
Thomson	YES	YES	YES	---	---
Tandberg	YES	YES	---	---	---
BarcoNet	YES	NO	YES	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---
Operating Point: 50-0:0:3					
Thomson	---	YES - any 2 from 3	YES - any 2 from 3	---	---
Tandberg	---	YES - any 2 from 3	---	---	---
BarcoNet	---	NO	YES - any 2 from 3	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---
Operating Point: 50-0:0:4	(video ES lowered to fit TS)				
Thomson	---	YES - any 2 from 4	---	---	---
Tandberg	---	YES - any 2 from 4	---	---	---
BarcoNet	---	---	---	---	---
Tiernan	---	---	---	---	---
Scopus	---	---	---	---	---
Sony	---	---	---	---	---

TABLE TWO - showing those Operating Points which only have compressed audio

DECODER	ENCODER: THOMSON	TANDBERG	BARCONET	TIERNAN	SCOPUS
Operating Point: 7.5-1:0:0					
Thomson	YES	YES	YES	YES	YES
Tandberg	YES	YES	YES	YES	YES
BarcoNet	YES	YES	YES	YES	YES
Tiernan	YES	YES	YES	YES	YES
Scopus	YES	YES	YES	YES	YES
Sony	YES	YES	YES	YES	YES
Operating Point: 10.5-0:1:0					
Thomson	YES	YES	YES	YES	YES
Tandberg	YES	YES	YES	YES	YES
BarcoNet	YES	YES	YES	YES	YES
Tiernan	YES	YES	YES	YES	YES
Scopus	YES	YES	YES	YES	YES
Sony	YES	YES	YES	YES	YES
Operating Point: 14-0:1:0					
Thomson	YES	YES	YES	YES	YES
Tandberg	YES	YES	YES	YES	YES
BarcoNet	YES	YES	YES	YES	YES
Tiernan	YES	YES	YES	YES	YES
Scopus	YES	YES	YES	YES	YES
Sony	YES	YES	YES	YES	YES
Operating Point: 20.5-0:2:0					
Thomson	YES	YES	YES	YES	YES
Tandberg	YES	YES	YES	YES	YES
BarcoNet	YES	YES	YES	---	YES
Tiernan	YES	YES	YES	YES	YES
Scopus	YES	YES	YES	YES	YES
Sony	YES	YES	YES	YES	YES

TABLE THREE - showing those Operating Points which include uncompressed audio

DECODER	ENCODER: THOMSON	TANDBERG	BARCONET
Operating Point: 7.5-1:0:1			
Thomson	YES (comp or uncomp)	YES (comp or uncomp)	YES (comp or uncomp)
Tandberg	YES	YES	YES
BarcoNet	YES	NO	YES
Operating Point: 10.5-0:1:1			
Thomson	YES (comp or uncomp)	YES (comp or uncomp)	YES (comp or uncomp)
Tandberg	YES	YES	YES
BarcoNet	YES	NO	YES
Operating Point: 14-0:1:1			
Thomson	---	YES (comp or uncomp)	YES (comp or uncomp)
Tandberg	---	YES	YES
BarcoNet	---	NO	YES
Operating Point: 20.5-0:2:1			
Thomson	YES (comp or uncomp)	YES (comp or uncomp)	YES (comp or uncomp)
Tandberg	YES	YES	YES
BarcoNet	YES	NO	YES
Operating Point: 30-0:0:1			
Thomson	YES	YES	YES
Tandberg	YES	YES	YES
BarcoNet	YES	NO	YES
Operating Point: 30-0:0:2			
Thomson	YES	YES	YES
Tandberg	YES	YES	YES
BarcoNet	YES	NO	YES
Operating Point: 30-0:0:3			
Thomson	---	YES - any 2 from 3	YES - any 2 from 3
Tandberg	---	YES - any 2 from 3	YES - any 2 from 3
BarcoNet	---	NO	YES - any 2 from 3
Operating Point: 50-0:0:2			
Thomson	YES	YES	YES
Tandberg	YES	YES	---
BarcoNet	YES	NO	YES
Operating Point: 50-0:0:3			
Thomson	---	YES - any 2 from 3	YES - any 2 from 3
Tandberg	---	YES - any 2 from 3	---
BarcoNet	---	NO	YES - any 2 from 3
Operating Point: 50-0:0:4			
Thomson	---	YES - any 2 from 4	---
Tandberg	---	YES - any 2 from 4	---
BarcoNet	---	---	---