Pro-MPEG Code of Practice #2
May 2000

Operating Points for MPEG-2 Transport Streams on Wide Area Networks

1. Background

The Pro-MPEG Forum has already made recommendations for a set of *operating ranges* [ref 1] which are intended as an aid to achieving maximum interoperability. For the Wide Area Network it is useful to specify a set of specific *operating points* for encoders and decoders, and network adaptor devices. These should be based on practical considerations of bandwidth, current best practice and maximising interoperability.

Founded on work carried out in 1998 and 1999 to discover which parameters are significant in achieving interoperability, a set of operating points has been drawn up. An early version of this definition was tested in the form of a 'reference stream' for MPEG-2 television over ATM and shown at IBC in September 1999. An upgraded draft was put before the Pro-MPEG Forum on October 20th 1999 and reviewed by the ATM working group. Subsequent email review and input from the working group has yielded the current version, which represents what is believed to be a concensus of views from the above bodies. It is assumed that previous granularity issues (in the TS) are now no longer a problem due to improvements in products.

2. Scope

It is recognised that there are many different mechanisms and interfaces to be considered for carriage of MPEG audio and video over a Wide Area Network. This document addresses the direct mapping of MPEG TS into:

- An ATM (Asynchronous Transfer Mode) network
- PDH/SDH (Plesiochronous Digital Hierarchy/Synchronous Digital Hierarchy)
- Satellite

transmission channels for contribution applications. Although there are circumstances where commonality between operating points for the live streaming case and the file-transfer case will be helpful, that consideration does not play a part in the selection of suitable values here. The transport of professional television over IP networks is for future consideration.

Mapping of pre-compressed streams: For interfaces such as SDTI, mapping from the active content CP-MPEG-TS (and possibly CP-MPEG-ES) to the network protocol must be defined in order to achieve a bit-rate efficient implementation. Note that, where all of the above assume an encoder feeding the WAN and a decoder receiving from the WAN, either end could in reality be replaced by studio equipment already operating in the compressed domain.

3. Operating Point Parameters

The starting points for the selection of recommended operating points are:

- bit-rates based on available channels and current usage, and
- decisions based on options included in the Appendix.

Audio bit-rates specified so far are 256 kbit/s, MPEG layer 2 compressed, 384 kbit/s, MPEG layer 2 compressed and uncompressed according to SMPTE 302M, requiring 2.388969 Mbit/s.

The required TS multiplex bandwidth has been derived using a software tool kindly made available by Barco. It makes allowance for the carriage of tables as data but additional data channels have been excluded from these operating points. The table on page 6 of this document lists the operating points selected to far.

The following is an initial list of parameters whose values have already been chosen. Revisions may be necessary as work proceeds and as more applications are found where interoperability of MPEG-2 codecs over a wide-area network is important. Commonality between the wide-area network and other contribution and distribution networks has been identified and incorporated wherever possible.

The appendix gives a set of arguments (Pros and cons) for and against the adoption of various parameters. The decisions quoted in this document are based upon these arguments.

Additional operating points will need to be defined in the future. The quoted points are useful starting points for supplier/customer agreement and as the basis for limiting the number of tests necessary to ensure that interoperability has been achieved. The list is split between transmission technology and MPEG.

4. Transmission Technology

4.1 ATM Network

The physical connection to the network is made using:

- multimode optical fiber (62.5/125 µm, SC connectors), OC-3/STM-1 (155.52 Mbit/s).
- single-mode optical fiber (9/125 µm, SC connectors), OC-3/STM-1 (155.52 Mbit/s)
- Coaxial cable G.703, BNC connectors, E-3 (34.368 Mbit/s)
- Coaxial cable G.703, BNC connectors, DS-3 (44.736 Mbit/s).

The adaptation layer is AAL-1 with FEC. The VPI/VCI are not mandated (0/32 to 0/511 is the preferred range so as not to interfere with ATM Forum defined values 0/0 to 0/31 which would otherwise interfere with signalling, ILMI and OAM flows). Different values for outgoing and incoming are preferred. Correct operation without a control channel is preferred. Any IP data channel(s) carried are to use separate VPI/VCI.

The use of Switched Virtual Circuits (SVCs) has clear benefits and ATM Forum UNI version 3.1 or later should be used.

188 byte packets are used to map the MPEG into the ATM payload area; TS FEC provided in 204 byte mode is not appropriate and may indeed increase the liability to errors, and hence error monitoring FEC at the transport-stream point is not possible. The power of the FEC in the Adaptation Layer is believed to be appropriate for MPEG over ATM. Methods for presenting network performance measures to the user are under consideration.

Encoders need to deliver a constant bit-rate without peaks in the output rate and low drift in order that networks receive the negotiated bit-rate at all times. If this cannot be guaranteed, either a higher bitrate must be negotiated or potential loss of cells will need to be tolerated by decoders.

4.2 PDH/SDH

The following table lists PDH/SDH rates applicable in various territories. Channel aggregation may be employed to achieve more useful rates for professional television. These numbers may be used (after deduction of overheads) to determine which operating points can be accommodated at which PDH/SDH rates.

Name	Territory	Rate (Mbit/s)
E-3	Europe	34.368
DS-3	US, Japan	44.736
E-4	Europe	139.264

As per Digital Video Broadcasting standards [ref 2], [ref 3], the Pro-MPEG Forum Operating Points here defined call for the use of ATM framing for carriage of an MPEG TS over SDH and PDH fixed links.

Operating points which map the TS directly to PDH/SDH may be defined in the future.

4.3 Satellite

The interface into a modulator for a satellite uplink is ASI. LVDS is not supported by the Pro-MPEG Forum. This ASI should carry 204 byte MPEG packets of TS but this can be 16 null bytes or 16 bytes FEC. 188 byte packets is not supported. FEC, if present, should be carried to the corresponding point on the downlink. The modulator must also supply error correction. Currently, only QPSK modulation has been defined – more efficient modulation schemes may be adopted in the future.

Encapsulation of the signal into ATM cells prior to submission to the satellite transmission system should be considered and may be added to the available operating points in the future.

5. MPEG

- For Pro-MPEG applications, 4:2:2 professional profile is specified. Tests have shown that 4:2:2 profile yields a better picture quality than 4:2:0 for the VES rates considered here.
- The full range of PID values should be selectable at encoder and decoder except for reserved values [ref 4]. This provision is for maximising interoperability rather than for its DVB use of channel multiplexing.
- All encoders and decoders must support PAT/PMT tables. Other tables might be used, and the decoder must be able to accept/discard these tables but still continue to operate.
- The decoder must support any quantization matrix sent in the stream.
- The decoder must accept both Field and Frame encoding (Field encoding can be used to get a lower delay and to optimise the picture quality during scenes with heavy movement).
- Buffering: the decoder must be compliant with the MPEG standard, especially for the 4:2:2@ML profile. Thus the minimum buffer size must be 9,437,184 bits.
- If encryption is used, the encoders and decoders must support open, standardized encryption schemes, such as the DVB-DSNG Encryption specification [ref 5], [ref 6], to ensure seamless interoperability.
- PCR jitter [ref 7] must be kept within the limits of the MPEG standard and a decoder must be able to decode a signal fulfilling these requirements. The objective must be to attenuate any network jitter to levels which are comparable with the requirements of contribution-quality analogue composite video. The values quoted are (related to the 27MHz parallel clock):
  - at set-up
  - maximum slew
  - maximum error

A suitable target for timing stability is given in the table below. This applies to the SDI clock and was originally derived from the PAL subcarrier specifications.

Derived SDV (SDI) spec	In the requirements listed below, the use of the word 'clock' is intended to indicate the clock signal recovered from an SDI stream at a nominal 270 Mbit/s. Since it will generally be measured at some point where the serial stream has been converted into a parallel stream, the numbers quoted refer to measurements and requirements relative to 27MHz. Figures in square brackets after each requirement are translations of these requirements into a parts-per-million [ppm] figure. **Req 1:** The decoder clock shall have a long-term stability accuracy within 6Hz, [0.222ppm]. **Req 2:** The decoder clock shall achieve the long-term stability figure of req 1 within 2 minutes from the start of a session. **Req 3:** During the first 10 seconds of the start of a new session the decoder clock shall have a rate of change of no more than 6Hz/s, [0.222ppm/s]. **Req 4:** Except for the period given in req 3, the decoder clock shall have a rate of change of no more than 0.6Hz/s, [0.0222ppm]. **Req 5:** The decoder shall produce a resolvable picture within 5 seconds of the establishment of a session. **Req 6:** At no stage will the decoder generate an output clock which deviates by more than 72Hz, [2.66ppm]. **Req 7:** The encoder shall accept any clock deviation up to a limit of 36Hz, [1.33ppm]. **Req 8:** The decoder output clock shall track the encoder input clock, within the limits of req 1 to 4. **Req 9:** Any change to an existing session (eg change of encoder input, break in ATM etc) shall be tracked by the decoder in accordance with req 4 unless the resultant error would incur a lock-up period of more than 1 minute, in which case the tracking should be treated as a new session.

- The decoder should have a facility to ignore optional MPEG parameters and private streams to prevent any misinterpretation where they are used in a proprietary way.

6. Operating Points

Bit rates as follows have been selected as useful for some common applications. An identification convention has been adopted of a number representing the coding rate of the Video Elementary Stream, followed by a number sequence of the form x : y : z, where:

x is the number of MPEG compressed audio pairs, 256kbit/s
y is the number of MPEG compressed audio pairs, 384kbit/s
z is the number of linear uncompressed audio pairs to SMPTE302M, 2.388969 Mbit/s.

Finally, a letter indicating the transport mechanism may be appended.

The actual TS rate required depends to a small extent on the video system (525/625 lines) and the GOP structure. (These differences account for about 20 kbit/s and 1 – 2 kbit/s respectively). To avoid a multitude of TS points, the higher option in each case is selected.

A low-delay mode is available for each operating point and decoding devices must operate correctly with these. For low-delay, the GOP is varied by the removal of B frames. Slice-based refresh for low-delay is under consideration.

Testing for successful interoperability will ideally be performed at each point.

The table gives operating point details and includes a Picture Quality Rating value for each. These values should not be used as the basis for a contract but are given for indication only, to help eliminate illogical options.

Operating Points for MPEG-2 Transport Streams on Wide Area Networks

Op-point	Nominal bit-rate (Mbit/s)	Video ES Mbit/s	GOP	PQR*	Audio: # of pairs 256 kbit/s MP-2	Audio: # of pairs 384 kbit/s MP-2	Audio: # of pairs uncompressed to SMPTE302M	Transport Stream Mbit/s	Satel -lite link	ATM channel Mbit/s	Comments
7.5-1:0:0	8	7.5	12 or 15	4.4	1	0	0	8.448	12.22	9.834	ENG. 4:2:0 case already covered by ISOG. Viterbi of 3/4 used for satellite.
7.5-1:0:1	8	7.5	12 or 15	4.4	1	0	1	10.578		12.313	
10.5-0:1:0	12	10.5	12 or 15	3.6	0	1	0	12.000	17.36	13.968	Viterbi of 3/4 used for satellite.
10.5-0:1:1	12	10.5	12 or 15	3.6	0	1	1	13.790		16.052	
14-0:1:0	15	14.0	12 or 15	3.1	0	1	0	15.000	21.70	17.461	Viterbi of 3/4 used for satellite.
14-0:1:1	15	14.0	12 or 15	3.1	0	1	1	17.384		20.236	
20.5-0:2:0	24	20.5	12 or 15	2.5	0	2	0	22.33	27.69	25.993	As EBU HBR. Sport. Viterbi of 7/8 used for satellite.
20.5-0:2:1	24	20.5	12 or 15	2.5	0	2	1	24.454		28.47	
30-0:0:1	30	30.0	12 or 15	1.9	0	0	1	33.418		38.900	High-quality, even through multi-generations. Fits an ATM DS-3.
30-0:0:2	30	30.0	12 or 15	1.9	0	0	2	35.807		41.681	
30-0:0:3	30	30.0	12 or 15	1.9	0	0	3	38.196		44.462	
50-0:0:2	50	50.0	I-only	2	0	0	2	56.35		65.594	Maps onto in-studio apps. EBU requirement
50-0:0:3	50	50.0	I-only	2	0	0	3	58.74		68.376	" "
50-0:0:4	50	50.0	I-only	2	0	0	4	61.13		71.158	" "
80-0:0:4	80	80.0	long GOP		0	0	4	92.16		107.278	HDTV

*PQR: Based on Video ES and GOP specified, using PQA-200, Mobile & Calendar sequence and a codec available at BT Adastral Park, October 1999. These values are indicative only and should not be used as the basis for a contract.

Where appropriate, calculations based on a worst-case situation: 525 lines, GOP=12, no B frames. (GOP=12 is typical for 625 line system, GOP=15 is typical for 525 line systems). TS rate always quoted at the 188 byte multiplex, even when 16 bytes of FEC are added afterwards.

7. References

[1] Pro-MPEG Code of Practice #1
MPEG Operating Ranges and Applications

[2] ETSI ETS-300 813 "DVB Interfaces to PDH Networks"

[3] ETSI ETS-300 814 "DVB Interfaces to SDH Networks"

[4] ISO/IEC 13818-1 Generic Coding of Moving Pictures and Associated Audio Information: Systems

[5] EN50221: Common Interface for conditional access and other applications

[6] TS101 197: Technical specification of SimulCrypt in DVB systems

[7] ETR 290: Measurement guidelines for DVB systems specifies PCR jitter requirements in DVB systems

Pro-MPEG Code of Practice #2
May 2000

Operating Points for MPEG-2 Transport Streams on Wide Area Networks

Appendix – Pros and Cons for the decision points

A.1 For an MPEG TS, choice of 188, 204-null or 204-RS

Option:	188	204-null	204-RS
Pros	Lowest possible bit-rate, saves capacity	Same bit-rate as 204-RS so makes modulator clocking easier	Gives distribution QoS: visibility control correctability
Cons	No visibility of transport performance	Wasted bandwidth May provoke further errors	Additional capacity required May provoke further errors

A.2 When using ATM, choice between AAL-1 and AAL-5 adaptation layers

Option:	AAL-1	AAL-5
Pros	Advantages: Error correction CBR rate emulation Higher QoS determination	Low cost of implementation. Lower bitrate required (bigger payload)
Cons	Higher rate required (smaller payload)	No QoS, no time transparency.

A.3 When using an E3 or a DS-3 link, whether to adopt framing (G.832)

Option:	Framed (G.832)	Unframed
Pros	Allows use of SDH management, to give end to end QoS determination	Higher bitrate available
Cons	Capacity needed to implement it	Blind at transport level

A.4 When using a satellite link, which modulation scheme to adopt

Option:	QPSK	8PSK	16QAM
Pros	Standard for DVB	More efficient Most mods/demods will handle	Most efficient of these options
Cons	Least efficient of options		Least popular requires more satellite power/larger dish

A.5 When using a satellite link, which Viterbi coding to adopt

Option:	1/2	2/3	3/4	5/6	7/8
Pros			Most standardised		Most efficient of these options
Cons	Least efficient of these options				

A.6 When using an E3 or a DS-3 link, whether to use ATM encapsulation

Option:	ATM encapsulation	No ATM encapsulation
Pros	Standardised by DVB Error control/QoS if AAL-1 Common output from ATM devices (eg switches) hence simple to implement.	More efficient use of available bandwidth
Cons	Adds to bitrate required and timing-recovery complexity. Same function as 204-RS	Different standard than DVB.

A.7 Use of MPEG or Dolby compression (if any) for the audio

Option:	Compressed audio	Uncompressed audio
Pros	Saves bandwidth Can be same as DVB Audibly satisfactory	Future-proof No cascade problems Standards based if SMPTE 302M Can also carry several compressed formats.
Cons	May not cascade well Archiving problems (‘master’ tapes)	Bandwidth required