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Joint EBU – SMPTE Task Force
on
Time Labelling
and
Synchronization

User Requirements & Request for Technology

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User Requirements and Request for Technology

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1 Foreword

The Society of Motion Picture and Television Engineers (SMPTE) and the European Broadcasting Union (EBU) have formed a new Joint Task Force to examine and standardize future needs for timing and synchronization in moving picture and related industries. Current methods of timing and synchronization for television, audio and other moving picture signals rely on standards that have been in place for over 30 years. These standards are becoming increasingly inappropriate for the digital age with, for example, networked content sharing and the higher frame rates appropriate to HDTV, UHDTV and other image formats. They now impose unacceptable limitations for the future and must be replaced by new time-labelling and synchronization technology.

The Task Force has begun by collecting User Requirements (hereafter, “UR”) from broadcasters and the media and entertainment industries. This document represents these UR and is presented as a Request for Technology (RFT) to invite responses and proposals from any interested party.

The Task Force will evaluate responses to this RFT against its UR. The outcome of this process will be a set of specifications that will be passed to the appropriate SMPTE Technology Committees for due-process standardization.

Examples for target users of the new technology are:

- TV Production and postproduction organizations.
- TV Broadcasters.
- Film producers and associated industries.
- Consumer products such as Camcorders, editing systems.
- Any industry segment where forensic time stamping may be important.
- The image and sound archiving industry.
- Producers of TV and related industry commercial content.
- Medical related industries.
- Audio recording, production and archiving industries.

This list is not exhaustive and it is merely illustrative of the potential widespread use of the new technologies. Additionally it should be noted that it is anticipated that not all industry segments will use all aspects of the new technologies, but that each industry segment will choose its necessary core set of parameters.

2 Schedule of feedback to the Request for Technology

Vendors and developers of technological solutions, systems and products (hereafter, “Respondents”) are invited to study this document and to respond to the Task Force with firm technology proposals replying to the needs set out in the UR.

A response form is provided in Annex F for the purpose. This should be completed and e-mailed to both the co-chairs* of the Task Force not later than 1st. May 2008.

Respondents are reminded that, to be considered for standardization, all submissions must comply with **SMPTE IP policy**, available at:

http://www.smpte.org/standards/SMPTE_IP_Policy_01_27_2007.pdf.

Respondents to this RFT must declare any patents known or believed to be essential to the implementation of the proposed technology, whether or not owned or controlled by the respondent. Where such patents are owned or controlled by the respondent, the submission must be accompanied by a statement of willingness to offer RAND licensing.

It is recognized that Respondents not currently involved in broadcast technology may have initial difficulty in interpreting this RFT. Respondents are invited to contact by email the co-chairs* who will attempt to assist with background information, additional explanations, etc.

Responses to the RFT may address some or all of the UR set out in this document. Additionally, concept proposals are welcomed even if the Respondent does not have the resources to provide a complete solution.

In this document, for each set of issues, the keywords "shall", "must" and "shall not" indicate essential requirements strictly to be addressed. The keywords "should", "should not" and “preference” indicate requirements or issues that it is recommended be addressed, and for which it is intended to provide solutions provided they are practicable. The keywords "encourage", "may" and “optional” indicate further requirements or issues for which solutions may be desirable. While respondents are expected at minimum to address the essential requirements related to the area(s) of their responses, it is recognised that no single technology solution can be expected to fully address all the issues that are described in the RFT. The final selection of technologies is likely to be a combination of solutions that meet all essential requirements, and that in addition offers the best overall balance between functionality/extensibility and cost/practicability as judged by consensus within the Task Force.

The Task Force will evaluate responses against its UR, and a selection of the technologies, judged as appropriate by consensus within the Task Force, will be made. The selected technology proposals will be drafted into preliminary standard documents for final standardization work by the SMPTE.

The anticipated time schedule is as follows.

- Responses to the RFT received by the co-chairs not later than 1. May 2008.
- Questions about the RFT sent in via e-mail will receive written responses until 15 April 2008.
- Initial evaluation period: 1 May - 1 June 2008
- Presentation and discussion of proposals with Respondents will be done at the Task Force’s 4th. open meeting, to be held on 4,5,6 & 7 June at the IRT in Munich. (Duration and timing of presentations will be directly communicated to Respondents).
- Start of technology selection and preparation of a "request for standardization": 1 July 2008.
- Hand-over to SMPTE formal standardization work after IBC 2008 but latest November 2008.

3 The issues being addressed

There are three separate but related issues that need addressing. The first two concern the analogue “colour black” (or “black and burst”) synchronization signal and SMPTE 12M timecode

*The co-chairs of the Task Force are Hans Hoffmann (hoffmann@ebu.ch) and Peter Symes (psymes@smpte.org) signal have been the mainstay of analogue TV system design for many years. Changes and extensions have been made to keep both these reference signals relevant to evolving digital technology and the expanding number of image formats that need be supported. The ability to further extend the life of these analogue synchronizing and timecode signals is very limited. It is now time for a re-evaluation of technology offerings to address, for the longer term, needs to have accurate time keeping, to have a reference signal that can support many image formats (including UHDTV) and support significantly higher frame rates.

The third issue relates to the binding of Metadata to Essence. Current TV production systems can all handle and process Essence with minimal loss and distortion. The same is NOT true for any Metadata, such as a Time Related Label (TRL), that is associated with the Essence. Bindings between Metadata and Essence are currently fragile at best and are mostly constrained to recording devices. Other system elements tend to discard the Metadata. In future system designs some mechanism is required to retain such binding.

- Future TRL should be bound to Essence more robustly
- SMPTE 12M is currently used both for distribution of time and as a data format for a time label; a future system should provide for time distribution as a function of the sync signal.

3.1 Synchronization signal

Almost all TV systems now in use have relied upon the analogue colour black signal to derive their synchronizing information. Digital component systems, both SDTV and HDTV, have also used this analogue reference signal to generate their digital clocks, albeit with some degree of complexity. A new reference signal is required to address the expanded industry needs described herein.

3.2 Timecode

The SMPTE 12M analogue timecode data structure was developed over 30 years ago and it cannot support TV frame rates beyond 30[1] frames per second. Today, systems with frame rates of 48, 50, 60, 150 and 180 fps are in common use. SMPTE 12M based solutions cannot support editing at single frame resolution at frame rates above 30 fps, nor can they support cross-conversion of frame rates and variable frame-rates.

Standards for time-related labelling within file formats (e.g. MXF/AAF) are in widespread use and a consistent approach for labelling both file-based Essence and physical signals is needed.

3.3 Timecode Label Binding

The binding of the SMPTE 12M timecode label to a given TV frame is currently very fragile. Perhaps the most common example of this binding is the use of a linear track on a VTR or audio recorder or via VITC in a video signal. The SMPTE has an extensive suite of standards that allow for the carriage of 12M timecode over various interfaces, but the result is a patchwork solution; there was never system-wide architecture to support robust binding. Today's bindings can be broken at almost any point in the production process.

Responses to this RFT may not provide solutions to all these problems, but the label should be designed to facilitate binding to both Essence and to transports. Respondents are encouraged to suggest mechanisms to effect this binding.

[1] SMPTE 12M-2008 provides limited support for 50 and 60 Hz operation

4 Overall System Concept

This RFT addresses both the requirement to synchronize television equipment, audio recording devices and other systems and the requirement for labelling television frames and other media access units with time-related data.

The two requirements are linked insofar as the synchronization system is required to carry information from which “time of day/date” can be derived, and this information may be used to create the data for the label when a time-of-day label is required.

It may, therefore, be preferable that the data formats concerning time for synchronisation and for labelling are identical or closely related so that the same algorithms may be used for human-readable displays, etc. In other respects the synchronization and time-labelling systems are independent.

The overall goal of this project is to provide new designs that offer robust solutions for the future. Although interfacing or translation to current systems will inevitably be required, this must not be allowed to constrain the forward-looking solutions.

4.1 Synchronization systems

The synchronization system envisaged would define a “synchronization signal” of some form that is conveyed by some mechanism from a (usually small) number of master generators to a (potentially large) number of slaved generators (hereafter, “slave(s)”).

Each master generator must be capable of deriving both frequency and time information from some global reference such as GPS and it must indicate via the synchronization signal the state of its lock with respect to the global reference.

On receipt of the synchronization signal, a slave shall be able to lock both the frequency of its oscillator and the phase of derived signals so as to be able to generate one or more signals conforming to television or other (e.g. audio) standards. The synchronization signal is required to convey informationthat will allow time of day and date to be calculated at the slave.

The synchronizing system will be used in various environments. There may be an advantage to a proposal that supports multiple transports. In some environments reliable performance is critical to operation and the system proposed must support architectures with full redundancy.

Appropriate transport(s) shall be described in sufficient detail to validate the proposal.

4.2 Data structure for a Time Related Label (TRL)

This RFT seeks proposals for a data structure of a TRL that may be used to associate time-related information with television frames and other media access units. The TRL shall be capable of carrying time-of-day information that may optionally be derived from the synchronization signal discussed in this RFT. In other applications the TRL may carry time-related information that does not relate to time of day (for example, a programme with leader may be labelled such that the programme start is at 01h00m00s).

Where multiple recordings of the same event are made, such as in multi-camera recording or separate recording of audio and video, applying TRLs to the multiple streams allows them to be brought into correct time-alignment for post production or for replay with correct lip sync.

The TRL may be used to index specific access units in video, film frames and audio signals such as AES3, and to provide controlling information in, for example, editing procedures. It may also be used to provide controlling information in other time-sensitive procedures such as animations, lighting changes, robotics control, etc.

The TRL is abstract in nature and should not require any specific transport. The definition of the label may however be influenced by the constraints of known transport mechanisms and requirements for binding as discussed below.

4.3 TRL Binding and transport issues

Definition of all possible transports and bindings is not within the scope of this RFT. However, there are specific requirements in a number of areas, as discussed in various sections of this document Respondents to this RFT are encouraged to submit suggestions for robust binding.

For the TRL, it is important to recognize that there are two distinct areas for consideration. The label will potentially be used on a wide range of transports; relevant constraints and binding mechanisms shall be described in sufficient detail to validate the proposal. In addition, there are specific requirements to bind the label to the Essence in applications where it cannot be transported with the Essence. It is recognized that there is no “magic solution” to solve all problems on legacy equipment, but Respondents should discuss approaches to maximize robustness in legacy environments. Proposals should provide for robust binding in future systems.

5 General user requirements

5.1 Intellectual property rights

See paragraph 2 concerning “Reasonable and Non-Discriminatory” (RAND) licensing terms.

5.2 Software platform

Users shall be free to make their own software implementations of the standards without dependence on a particular operating system or hardware platform. Respondents should not propose solutions that rely upon features of specific operating systems or hardware platforms.

5.3 Transition to use of the new standards

Respondents are encouraged to consider the transition from current to new standards and to suggest means to achieve this in broadcast production plant with infrastructure based on current standards.

5.4 Continued availability

The proposed technology shall have a high likelihood of continued availability, or availability of backward-compatible technology, for the foreseeable future.

6 User requirements for a sync system

6.1 Introduction and limitations of current systems

The operation of a television facility requires that individual items of equipment be synchronized so that the signals produced are all derived from a common timebase, and may be phased to be synchronous at points in the chain. Different processes and video standards require different precisions of synchronization of the TV signals. For example, switching in a routing system generally requires synchronization to within 5 microseconds, but mixing of composite analogue signals requires synchronization to within about 0.5 nanoseconds.

Examples of the limitations of current systems:

No deterministic synchronization of all signals

The most obvious limitation is that there is no deterministic way to synchronize audio systems with 59.94 Hz video systems. The optional 10-field reference described in SMPTE 318M can make synchronization consistent within the domain of a single reference generator, but there is currently no way to ensure that multiple generators will initialize with the same phase relationship. A method to solve this issue was evolved (see the note below) but has not been implemented.

No multi-standard capability

Many facilities operate both 50 and 59.94 Hz (or 24 Hz and 25 Hz) equipment. With current reference signals, it is necessary to distribute separate reference signals for each frame rate standard.

Reliance on unsuitable frequencies

The subcarrier frequencies used in the colour black reference signals have no relevance in the digital world, and are not good frequencies to support simple derivation of master clocks.

Signal Bandwidth

Colour black is not a robust signal as it has a very wide bandwidth (25 Hz to about 5 MHz) and, therefore, requires complex equalization for long paths. A signal with small (percentage) bandwidth would provide better performance.

Note on previous work:

The SMPTE previously drafted a document SMPTE 404M “SMPTE Epoch” to define a point in time, corresponding to the origin for International Atomic Time (TAI) and Coordinated Universal Time (UTC). This document has not been formally published, but will be made available to recipients of the RFT.

The intention was to define the phase of all necessary systems at a single point in time, so that their phase could be determined at any future time. This phase alignment has been so defined for many standards.

Respondents are not required to utilize this approach for synchronization. However, if this concept is proposed use of the SMPTE 404M epoch is encouraged, but not required if there are benefits in the choice of an alternate epoch.

6.2 Global requirements

The proposal shall provide the functionality and performance specified below.

It is envisaged that the system will comprise one or more master generators within a facility (with the ability to provide rapid and automatic switchover to backup systems in the event of failure). The master generators will emit some form of signal (the “synchronization signal”) that will be distributed to a (potentially large) number of slave systems.

6.2.1 Basic Value and Economy

The proposal should offer significant additional value when compared to the existing colour black system.

In a typical application there will be many more slaves than masters, so cost of implementing basic functions in a slave is particularly significant. In addition, the cost may be influenced by the accuracy and stability requirements of the target application.

6.2.2 Universal Format Support

The synchronization signal must convey sufficient information to generate any appropriately specified video or audio standard. The proposal must define any information that would need to be included in standards to enable the required functionality.

6.2.3 Deterministic Phasing between multiple systems

The system must provide deterministic phasing of all current video and audio standards. It must be able to accommodate potential future standards (e.g. based on arbitrary frequencies) without change to the synchronization signal. Proposals should indicate the parameters that would need to be defined in a future standard to enable such use.

This phasing must be deterministic and repeatable within the specifications listed in this document among multiple slaves from the same master, across multiple masters driving multiple slaves, and across loss and restoration of lock reference and/or power to the synchronization system.

6.2.4 Phase Adjustment capability (informative)

In products utilising this technology it is expected that slaves will provide for manual and/or automatic phase offset from the derived reference phase to account for transmission latencies, etc.

6.3 Frequency reference

6.3.1 External lock

The proposal must provide for master generators that lock to an external reference frequency, and specifically it shall be possible to lock to a global time/frequency reference, such as GPS.

6.3.2 Lock indication

The proposal shall provide information on the synchronization signal about:

- the state of the master such as “locked”, “locking”, “not locked”,
- the quality/grading of the master oscillator and the reference to which it is locked.

6.3.3 Slave lock

The proposed solution must provide a mechanism for slaves to generate an internal master frequency locked to the reference frequency of the master generator.

6.3.4 Frequency accuracy and stability

The actual quality of masters and slaves will be determined by the market, and by advances in technology.

The proposal must support frequency accuracy (at least) sufficient to meet the most stringent of requirements; currently this is the PAL system, requiring accuracy of ±1 Hz at subcarrier frequency, or approximately 0.225 ppm.

Design requirements are otherwise best defined by timing stability, specified below.

6.4 Time reference

6.4.1 Time of day

The synchronization signal shall convey sufficient information to provide a “time of day” clock with date information at the slave. (This time may be used within the time-labelling system described elsewhere in this RFT.) A minimum time resolution of one second is required. Respondents shall indicate the time resolution of their proposed solution.

6.4.1.1 Time Format

Note that use of this time as a datum for system phases may likely require that Time Atomic International (TAI) is used, and that a value of leap seconds be conveyed as a separate data item for derivation of Universal Time Coordinated (UTC) time of day. This approach would also be consistent with the requirement for leap second management (6.4.2, below).

6.4.1.2 Local Timezone and DST

In addition, the synchronization method must convey sufficient information to convey local timezone offset from UTC as well as a Daylight Savings Time (DST) flag which would be used in conjunction with UTC to determine actual time-of-day in a facility. This information would be conveyed as separate data from the time data and managed as described below.

6.4.2 Leap second and DST management

Leap seconds occur at midnight UTC, and this is not a convenient time for a disruption in many areas (for example, it corresponds to “prime time” in the United States). Television organizations require the ability to defer leap second implementation. The proposal must provide for appropriate management of leap seconds. The same requirement applies to Daylight Savings time which is specific to geographic / political region. The proposal must provide for appropriate management of DST.

6.4.3 Extensibility

It is likely that over the required lifetime of this standard there will be the need to transport additional data specific to the extension of the capabilities of the system. The system shall provide a mechanism for extensibility of the transported data to accommodate future requirements. Use of such a mechanism shall not alter in any way the performance of the reference system.

Respondents are encouraged to indicate the extensibility or limitations of their proposal.

Users have suggested that a new synchronising system may be able to provide additional capabilities that assist in automatic timing. Examples of possible functionality include:

- Correction of timing based on information received from equipment with dynamic latency (frame stores, special effects equipment, etc.).
- Correct of timing for dynamic path latency (e.g. a moving wireless camera).
- Auto phasing of new or modified installations.

Respondents are encouraged to discuss possible extensions to the proposed solution.

6.5 Compatibility with legacy systems

It shall be possible for a slave system to generate legacy synchronization signals such as colour black that meet all existing standards. RFT responses should indicate any special requirements for master-to-slave connection that may be necessary to satisfy this requirement.

6.5.1 Repeatability

The proposal shall support that all slaves receiving a synchronization signal from a single master, or from masters locked to the same external reference, shall provide deterministic timing of all derived signals. The outputs shall return to the deterministic state even after restoration of a failed external reference input or a power restoration.

6.5.2 Timing accuracy

Timing accuracy refers to the amount of time variance in the temporal alignment of two or more media signals. These may be the same type of signal, or may be dissimilar, but related (such as 29.97 video and 48 kHz AES3 audio).

Further to requirements indicated in Sections 4.1, 6.1 and 6.2; slaves shall have the following timing requirements:

- Shall be able to lock to a master reference sync signal.
- Shall derive all timing signals for the intended application (digital video, digital audio, analogue video, etc.)
- Shall provide the timing performance required by the application.
- Shall use time information to derive the instantaneous phase of media signals (possibly with respect to the SMPTE Epoch defined in SMPTE 404M).

Accurate timing between the outputs of slaves locked to the same master system shall be achievable for all intended applications. For example, to meet established synchronization limits of digital audio at extended sample rates, a slave timing accuracy within ± 50 ns of the master is required to align multiple slave outputs within 0.1 µs.

This specification provides adequate timing accuracy for horizontal alignment of digital television systems.

It must be noted that this specification is adequate for digital operations, but not for analogue composite video systems. It is accepted that systems performing analogue mixing should have all system elements synchronized to the same master reference within ± 0.5 ns.

Respondents shall indicate the timing accuracy of their proposal.

6.5.3 Timing stability

Timing stability generally refers to short-term timing fluctuations with respect to its nominal value. Stability is generally specified as an integral over time period, which is phase jitter and wander. Phase noise and slow frequency variations of the oscillator generally cause short-term stability issues.

Note: Long-term stability includes temperature effect, ageing, etc. This timing deviation is covered by the timing accuracy specification.

The proposed reference sync system shall allow a slave generator to meet or exceed the timing stability performance specifications required by various types of media systems:

- Analogue composite video systems (as per SMPTE 318M and ITU-R BT.470)

- Digital SD and HD video systems (as per SMPTE 259M, SMPTE 292M and SMPTE 424M for 3 Gbit/s SDI systems)
- Digital AES3 audio systems (as per AES11)
- UHDTV systems (as per SMPTE 435-3)

Respondents should address issues related to timing stability and slave costs (see requirements above), which can be achieved on the slave outputs.

Any constraints on transport mechanisms for the synchonising signal should be detailed in the proposal.

The template showing today's requirements of jitter and wander is included in Annex A, for information.

6.6 Synchronization signal transport considerations

User preference is that the synchronizing system should not necessarily require its own infrastructure dedicated to the distribution of the synchronization signal. This preference could be met by using an infrastructure that is already in place in an existing plant, or that would have to be provided for other reasons in a new plant. If a dedicated distribution infrastructure is required, consideration should be given to a choice of a robust signal optimized for transmission over long distances with little or no need for equalization.

Some example infrastructures are described below as background information, but this should not be taken as an indication that these are the only or preferred transports.

6.6.1 Colour black distribution

For existing TV plants, use of the previously installed distribution for colour black signals may be an option. Note that "green field" plants may have no use for a colour black distribution.

6.6.2 Ethernet

Most items of broadcast equipment manufactured today have at least one RJ45 connector. Wired Ethernet is generally used for configuration, control, and SNMP reporting. If a network is constrained to these functions, and does not carry heavy traffic, it may be possible to use the network for transmission of synchronization information.

If network transport is proposed, RFT responses should describe in detail the requirements for network technology and topology, and indicate performance expectations for various traffic levels.

For this, and other reasons discussed below, the ability to use a network transport for the synchronization signal is desirable. This statement does not imply that a network should be the only, or even the primary, transport mechanism. Attention is drawn to the fact that there is generally a demand for the synchronizing system to be extremely reliable, and to have a high degree of redundancy.

6.6.3 Dedicated SDI distribution

Most production facilities will support distribution of serial digital signals conforming to SMPTE 259M, and/or SMPTE 292M, and/or SMPTE 424M (at nominal bitrates of 270 Mbit/s, 1.5 Gbit/s, and 3.0 Gbit/s respectively). A digital transport in accordance with one of these SMPTE standard specifications could be used to provide a reference sync signal to media devices requiring it.

6.6.4 Dedicated AES distribution

Most production facilities will support distribution of serial digital audio signals conforming to AES3. A digital transport in accordance with AES3 specifications could be used to provide a reference sync signal to media devices requiring it.

6.6.5 Narrow band analogue distribution

It has been shown that a carrier signal using narrow-bandwidth modulation (such as phase reversals) can provide robust operation with minimal equalization as described in 6.1 above.

6.6.6 Distribution range

Existing colour black distribution systems can use coaxial cable lengths of up to about 300 m between amplifiers. Users have indicated requirements for the effective radius of a new synchronizing system of up to 1 km.

- Proposals should indicate effective range and mechanisms that may be used to extend that range.
- Proposals should indicate possibilities for long distance (e.g. inter-city) synchronization or phasing, link requirements and expected performance.

6.6.7 Special transport capability

Many new plants are making increased use of IT infrastructures, although a synchronization system is still necessary for baseband playout operations.

Wireless cameras are used extensively at sporting events; the ability to synchronize, perhaps over a wireless network, would be an advantage. It is recognized that performance, particularly in locking after a disruption, will be dependent on available bandwidth. RFT responses should indicate limitations and anticipated performance parameters.

6.6.8 Multiple transport capability

Although the primary goal of this RFT is to specify a system suitable for audio or television plants it is anticipated that the resulting system may be used in many environments where there are timing requirements. It is likely, therefore, that there will be a wide spread of requirements for reliability and performance versus cost.

Consideration should be given to a system that permits transmission of a common set of synchronizing information over multiple transports, selected by the user according to local needs.

6.7 Locking behaviour

Behaviour on initial lock, and lock following a disruption, is critical for both master and slave. Requirements for slaves depend on the environment and circumstances. It is likely that user-selectable options will be necessary.

6.7.1 Master lock to frequency and time reference

Users may require a fast lock (perhaps 1 minute to stability) on power-up or on manual intervention, but generally, following any loss of lock, re-locking should be constrained to maintain slave master frequencies within the tolerances of the appropriate video standards (slow lock). This is an equipment design issue for a master generator rather than a system requirement, but is included for clarity.

6.7.2 Consistency of frequency and time references

If the proposal utilizes time information to provide phase information (for framing, etc.) the time information conveyed shall always track frequency reference movement during a locking operation. The fact that the time information is not accurate (during a locking operation) shall be indicated on the synchronising signal as described above.

6.7.3 Slave lock

The system shall provide for “crash” lock of a slave, meaning rapid frequency, phase and time lock following any disruption (such as a power loss). Lock time of less than one second is preferred. RFT responses shall indicate lock performance of proposals, with variations and factors determining variation if applicable.

Depending on environment and circumstances, users may choose to limit slaves to slow lock as described above. This is an equipment design issue.

6.7.4 Dynamic and automatic timing (optional)

While timing infrastructures are usually static systems, there are opportunities to solve additional system issues related to dynamic timing. These can include equipment that can exhibit dynamic delay during normal operation (such as a roving wireless camera or vision mixer with DVEs) as well as equipment and systems that can perform self-timing.

RFT respondents should describe any capabilities of the methods proposed to offer solutions to dynamic timing issues, and detail both the specific issues solved and solution proposed.

7 Time Related Labelling (TRL)

7.1 Introduction and limitations of the current system

SMPTE timecode, as defined by the Standard SMPTE 12M, is probably the most used standard in the field of audio and video media. The standard was created in the 1970s to facilitate editing of videotape, but has been applied in many other fields. Essentially, timecode was intended as a label for each frame of video in a sequence, unique to that sequence. It should be noted that, although timecode is capable of carrying a value related to time of day, it is not required to do so, and many applications use arbitrary values unrelated to time of day.

Originally, SMPTE timecode was intended for recording on a linear audio track on a tape machine. It was defined as an 80-bit frame (64-bit payload) that included eight 4-bit BCD values (for tens and units of hours, minutes, seconds, and frames), an equivalent space for “user data”, and a number of flags and control bits. In more recent times, transport for timecode has been defined for the vertical interval of video signals, using ancillary data packets in a digital video signal, and in various file formats.

This RFT seeks proposals for a new time-related labelling system more suited to the needs of digital TV systems, to file based production environments, and systems where much higher frame rates are anticipated, to film applications where frame rates differ from TV frame rates (even arbitrary), and to medical and scientific applications where extremely high frame rates may be employed. This list of applications is not exhaustive by any means, and should only be used as a guideline.

Proposals should define a data structure suitable for labelling video frames, for labelling appropriate access units of other media types (such as audio), or for labelling related events e.g. theatre lighting. The proposed TRL should, as a minimum be capable of representing a time stamp (including date).

Respondents should be aware that the use of this label is widespread over different applications. Annex D gives some use case examples.

Proposals need not specify transport mechanisms or bindings, but may offer suggestions to validate the proposed TRL. However, the sections below include specific requirements for the ability to transport the TRL, or a useful subset of the TRL, over specific transports; proposals shall address each of these requirements.

Examples of the limitations of the current system:

- No simple relationship with NTSC video (see Annex C)
- No robust solution for frame rates >30 Hz
  SMPTE 12M-2008 includes a mechanism for using the field bit (not present in LTC) to permit identification of frames in 50 Hz and 59.94/60 Hz progressive systems, but this mechanism is at best an interim solution. No support is available for rates higher than 60 Hz, or for arbitrary frame rates.
- No support for “super slo-mo”
- Poor support for audio/video synchronization e.g. with skipped video frames
- Limited to a 24 hour period

7.2 User Requirements

The proposal shall provide the following functionality and performance.

7.2.1 Basic functionality

With the anticipated widespread usage of the TRL, it may be that bandwidth or data space restrictions require use of subsets of the TRL.

7.2.2 Basic structure

Respondents should propose a label as a data structure that is capable of conveying at least a time stamp with date information, or appropriate data that may simply and unambiguously be converted to this information.

7.2.3 Data format

Consideration should be given to using a data format the same as, or easily related to, the time information carried by the synchronization signal discussed elsewhere in this RFT.

Consideration should also be given to using a data format related to the access unit being labelled, for example a frame count.

7.2.3.1 Optimization of Date/Time information

Respondents may consider whether carriage of the most significant bits or elements of date/time information can be optimized by subdivision of the label. It is desirable to get full information from a single label but it is also desirable to minimize the number of bits needed for some applications. The requirements for physical streams and file-based content may differ in this regard.

7.2.3.2 Missing date information

The TRL should include provisions to indicate that the date information is unavailable or not applicable.

7.2.3.3 Labelling over more than 24 h

The TRL should be capable of representing time over a range significantly greater than 24 hours.

7.2.3.4 Sub-divisions of access units

A mechanism is required to label sub-divisions of access units. Respondents should indicate how this requirement is met in their proposals. An example for sub-divisions of access units is a field of an interlaced frame, where the field represents a sub-division of the frame. Another example would be one or more audio sub-frames or frames (perhaps representing different audio channels) within an audio block.

7.2.3.5 Time resolution

The label shall support sufficient time resolution to distinguish between consecutive access units at any arbitrary rate to be specified in the RFT response (e.g. users have indicated interest in capabilities up to 1000 fps and audio sample rates of up to 384 ksample/s, taking also into account the effects of pull-up / pull-down).

Higher speeds may be accommodated by other mechanisms such as, for example, the use of larger access units and sub-division-unit addresses.

7.2.3.6 Rate indication

In many applications is required to determine, for example, frame rates, audio sample rates, or access units.

Respondents should explain the capabilities and limitations of the proposed solution (one possibility is that the information may be derived from the Essence)

7.2.4 Multiple time stamps

The proposal should support a mechanism to permit multiple optional subsidiary time stamps so that (for example) source material time stamps could be associated with (edited) “program” time stamps.

7.2.5 Synchronization of streams

The proposal shall support automated synchronization of associated video, audio and data streams. A significant and current industry synchronization problem is Lip-Sync.

7.2.6 Label Editing

The proposal should support the ability to independently edit any of the time stamps.

7.2.7 Example applications (informative)

User requirements are defined above. The following examples are included to characterize possible applications.

Support for “super slo-mo”

Super “slo-mo” is a process where-by the picture is captured at a much higher rate than the replayed signal. During the slow-motion replay the picture displays much greater temporal resolution than a signal captured at nominal rate.

Variable speed

Some applications e.g. under-cranking and over-cranking may result in continuously varying frame rates.

Event synchronization

Synchronization of labelled streams, and/or events (such as lighting changes).

The process of stratification in archiving

7.2.8 Standards conversion

When a standards conversion is performed, including a conversion that includes a 1/1.001 relationship, the TRL conversion shall be deterministic.

7.2.9 Compatibility with legacy systems

7.2.9.1 SMPTE 12M-2008 from TRL

It shall be possible to deterministically create (using a simple algorithm) a SMPTE 12M-2008 label with equivalent time information compliant to the SMPTE 12M-2008 standard.

At frame rates other than those supported by SMPTE 12M (and SMPTE 12M-2008), each TRL shall be translated to the valid SMPTE 12M time value closest to the time value of the TRL, with appropriate use of the field bit as specified in SMPTE 12M-2008.

7.2.9.2 TRL from SMPTE 12M-2008

Respondents should indicate how to deterministically generate a TRL sequence from a SMPTE 12M (and SMPTE 12M-2008) sequence.

7.2.9.3 Repeatability of transform

When the two transforms above are applied repetitively the derived values shall remain constant irrespective of the number of iterations.

7.2.9.4 Transport / recording in SMPTE 12M environments

Consideration should be given to a representation of the TRL (or a useful subset of the TRL) that could be transported and/or recorded in an environment that does handle SMPTE 12M timecode.

For example, it may be possible to specify an 80-bit representation (64-bit payload) that would be maintained though transports and recorders that are transparent to SMPTE 12M (without being able to process/interpret the TRL).

7.2.9.5 TRL transport in compressed bit-streams

Consideration should be given to a representation of the TRL (or a useful subset of the TRL) that could be transported in bit-streams such as MPEG-TS.

7.2.9.6 Transport over AES-3 streams

Use of the TRL in conjunction with AES-3 transmission of audio, (where reduced bandwidth is a constraint) should be considered.

7.2.10 3:2 pull-down

Respondents are encouraged to suggest how their proposal supports 3:2 and 11:3[*] pull-down applications.

7.2.11 Original frame rate

Consideration may be given to including a data field to indicate the original frame rate and/or video standard.

7.2.12 User data

"User Bits" as implemented in SMPTE 12M are NOT required.

7.2.13 TRL linkage

Consideration may be given to a mechanism to permit association of the TRL with Essence and/or other Metadata by means of some identifier.

7.2.14 Human Interface

TRLs must allow the generation of standardized representation of date and time.

7.3 TRL binding to Essence

Perhaps the biggest challenge in proposing a new technology can be considered to be the binding issues (including binding within file formats). Legacy systems design may rely upon both interfaces and recording devices to maintain the binding between the Essence and the TRL. However, much legacy equipment will only pass on the Essence and will discard other signals that appear on the interface.

See informative Annex B for legacy binding details.

Respondents are encouraged to offer suggestions as to how this situation may be addressed.

7.4 TRL binding to transport and associated system considerations

Respondents are encouraged to offer suggestions as to how binding to transport and the associated system considerations may be addressed.

Examples of system considerations are:

- Media materials and their related frame labels should be transported together to maintain an accurate relationship between them
- Some applications require the carriage of multiple frame labels corresponding to several media types carried by the same transport (e.g. video and several audio streams). Frame labels may need to include a source identifier.

Depending on the type of processing equipment, frame labels may be subject to two kinds of handling: passed transparently (e.g. colour corrector) or be revised (e.g. frame rate converters, editing operations, frame synchronizers when frames are dropped or repeated, DVTRs in override mode, etc.)

[*] 11:3 pulldown is used when converting from 24 fps to 25 fps.

Annex A: Possible synchronization system infrastructure

A.1 Current Jitter and Wander Template

Colour black, together with dedicated SDI and AES distributions of a house timing reference signal may take advantages of existing infrastructures.

The proposal shall be capable of meeting or exceeding the performance specifications shown in the template in Figure A1 below. The primary value of this template is in setting limits on how much jitter and wander is allowed when distributing a house timing reference signal.

It should be noted that these specifications are for the timing reference signal; equipment using this reference may need to implement additional stabilization at high jitter frequencies to meet the alignment jitter specifications of some applications.

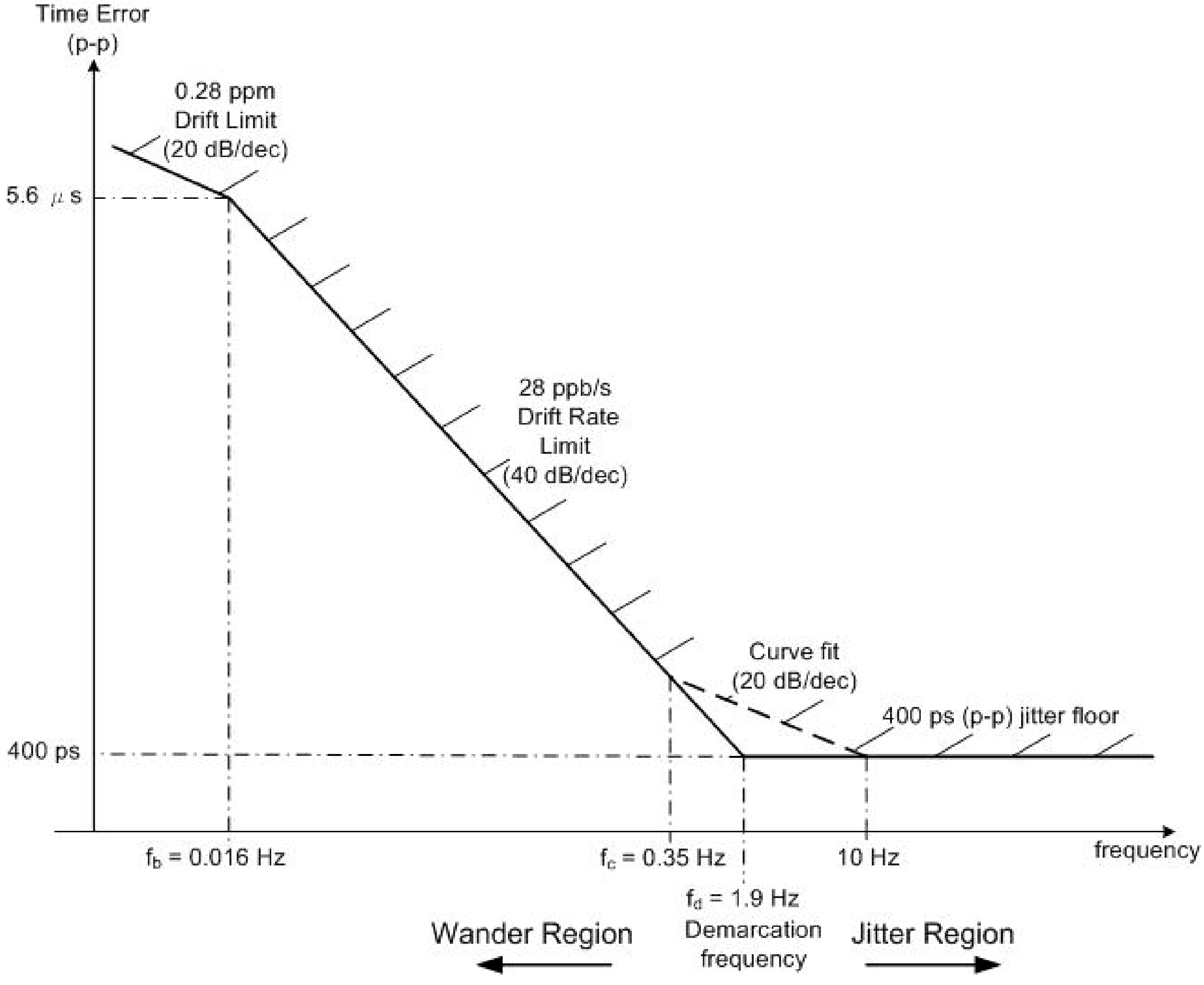

Figure A1: Maximum timing error template

Note: With the lower edge of the SDI timing jitter band specified at 10 Hz (SMPTE 259M), a little curve fitting at the corner is added to reflect real implementations.

A.2 Background

SMPTE 170M and SMPTE 318M recommend that the colour subcarrier frequency not drift any faster than 0.1 Hz/s (0.028 ppm/s for the NTSC subcarrier). Also, in the context of studio quality video, there is an approximate static phase relationship between the sync leading edge and colour-burst, referred to as SCH phase, precluding any significant difference between the subcarrier and H-sync phase wander. This then puts the drift-rate limit of 0.028 ppm/s on the leading edge of H-sync as well.

Drift-rate limits are ±0.028 ppm/s (±0.1 Hz/s) for NTSC and ±0.0226 ppm/s (±0.1 Hz/s) for PAL.

Note: SMPTE 318M specifications: -
Sub-Carrier drift rate = 0.1 Hz/s.
Sync jitter = within 2 ns p-p, (jitter measured over one field)
Burst jitter = within 500 ps p-p. (jitter measured over one field)

The rate of H-Sync frequency drift has the greatest effect on studio quality recording and post-processing equipment and is therefore of primary concern for users of such equipment.

Definitions, equations and template hereafter are derived from parts of two standard documents, the IEEE 1521 and the ETSI TR 101290.

A.3 Definitions

Frequency drift or Frequency accuracy: is the difference between the actual value and the nominal frequency of the clock (e.g. 3.579545…MHz). The term "Frequency offset" is used for static frequency errors.

Using this clock example, the limit is set to ±1 Hz for a master sync generator. Converting this value into relative or normalized units results in $1/(3.579545 \times 10^6) = 0.28 \times 10^{-6}$. This means that the frequency of the clock at any moment should be the nominal ±0.28 ppm. Rating the limit of the frequency offset as relative has the advantage of obtaining a limit valid for any value of frequency for a reference clock used to synthesize the nominal clock of 3.579545 MHz. For example, the frequency error in Hz of a 270 MHz serial clock derived from the 3.579545 MHz system clock can be divided, or normalized, by 270 MHz to determine if the frequency offset is within ±0.28 ppm.

Frequency rate of change, or frequency drift rate: is the "speed" at which the frequency of a clock varies with time. In other words, it is the first derivative of the frequency with respect to time or the second derivative of phase with respect to time.

The limit is set to 0.1 Hz per second for the 3.579545 MHz clock. It can be converted into a relative limit by dividing by 3.579545 MHz, which produces a result of
$0.1 /(3.579545 \times 10^6) = 28\ 10^{-9}/s$.

It means that the maximum rate of change allowed for the clock frequency is ±0.028 ppm/s of the nominal value, or ±28 ppb/s of the nominal value of the system clock frequency. (Note that a billion is taken here as 10^9; in many countries a billion is represented as 10^{12}).

A.4 Equations

Phase noise introduces a phase modulation of the clock sine wave. The waveform of the phase modulation may have any shape that can be analyzed as a composition of sinusoidal waveforms of various amplitudes and phases. Also the clock may be a pulsed signal. In this case the formulas below apply to the fundamental component of such periodic signal.

For example, the equation for a sinusoidal clock with sinusoidal phase modulation can be written as:

$$F_{clk}(t) = A \times \sin[\omega_c \times t + \Phi(t)] = A \times \sin[\omega_c \times t + \Phi_p \times \sin(\omega_m \times t)]$$

Where:

ω_c = nominal angular frequency of the reference sync clock, ($\omega_c = 2\pi \times 3.579545$ MHz);

$\Phi(t)$ = phase noise or phase modulation function;

Φ_p = peak phase deviation in radians;

ω_m = phase modulating angular frequency in units of radian/s ($\omega_m = 2\pi f_m$).

1. The **instantaneous phase** of the clock has two terms as:

$$\Phi_i(t) = \omega_c \times t + \Phi(t) = \omega_c \times t + \Phi_p \times \sin(\omega_m \times t)$$

The **peak phase equation** may be found as:

$$\Phi_p = \omega_c \times T_{max} = 2\pi \times 3.579545 \text{ MHz} \times 200 \times 10^{-12} \text{ s}$$

Where: T_{max} = time error limit of clock edge = 200×10^{-12} s

Note: The SMPTE 318M specifies a T_{max} of 500 ps p-p. Given that real signals will be generated from a slave and in this frequency region the slave is more likely to degrade the quality of the master than improve on it, it makes sense to add a little margin in for slave tracking error. So, a floor limit of 400 ps p-p (or 200 ps peak) is selected.

2. The instantaneous angular frequency, or **frequency drift**, of the clock is found as the first derivative of the instantaneous phase as:

$$\omega_i(t) = d\,\Phi_i(t)/d\,t = \omega_c + \Phi_p \times \omega_m \times \cos(\omega_m \times t)$$

Where: ω_i = instantaneous angular frequency of the clock, in units of radian/s.

Accordingly, for an SMPTE 318M-compliant master clock, the maximum angular frequency deviation from the nominal is:

$$\Phi_p \times \omega_m = 2\pi \times 1 \text{ Hz (in radian/s)}$$

By dividing by ω_m, the **frequency equation** for peak phase error as a function of modulation frequency may be found as:

$$\Phi_p = 2\pi \times 1/\omega_m \text{ (in seconds)}$$

This equation may be normalized by dividing by ($2\pi \times 3.579545$ MHz) to show the time interval error:

$$Tf(\omega_m) = \Phi_p / (2\pi \times 3.579545 \times 10^6) = 2\pi \times 1/(2\pi \times 3.579545 \times 10^6 \times \omega_m)$$

$$Tf(f_m)_{peak} = (10^{-6}/3.579545 \times 2\pi f_m) \times = (44.46\ 10^{-9}/f_m) \text{ (in seconds)}$$

The peak-to-peak value of the TIE is:

$$\mathbf{Tf(f_m)_{p\text{-}p} = (88.92 \times 10^{-9} / f_m)} \text{ (in seconds)}$$

3. The **frequency rate of change**, or **drift rate**, is given by the first derivative of the angular frequency, or the second derivative of the phase as:

$$r_i(t) = d\,\omega_i(t)/d\,t = -\Phi_p \times \omega_m^2 \times \sin(\omega_m \times t)$$

Where: r_i = instantaneous rate of change of the clock, in units of radian/s^2.

From the instantaneous drift rate equation, it can be seen that the maximum peak value of angular frequency drift-rate is ($\Phi_p \cdot \omega_m^2$), which can be compared to the limit set by SMPTE 318M of 0.1 Hz/s.

$$\Phi_p \times \omega_m^2 = 2\pi \times 0.1 \quad \text{(in radian/s}^2\text{)}$$

By dividing by ω_m^2, the **drift rate equation** for peak phase error as a function of modulation frequency may be found as:

$$\Phi_p = 2\pi \times 0.1/\omega_m^2$$

This equation may be normalized by dividing by (2π × 3.579545 MHz) to show the time interval error:

$$Tr(\omega_m) = \Phi_p /2\pi \times 3.579545 \times 10^6 = 2\pi \times 0.1 /(2\pi \times 3.579545 \times 10^6 \times \omega_m^2)$$

$$Tr(f_m)_{peak} = (0.707 \times 10^{-9}/ f_m^2) \quad \text{(in seconds)}$$

The peak-to-peak value of the TIE is:

$$\mathbf{Tr(f_m)_{p\text{-}p} = (1.414 \times 10^{-9}/ f_m^2)} \quad \text{(in seconds)}$$

Note: This equation is represented by a straight line in XY log-log coordinates and is shown in Figure A1. This line indicates a drift-rate limit of 28 ppb/s.

A.5 Mask/Template for a master sync reference signal

A TIE limit mask can be derived from a group of functions representing the limit specifications. The three equations discussed above provide information for the template shown in Figure A1.

Peak phase equation:

$$Tmax = \Phi_p /(2\pi \times 3.579545 \times 10^6) = 200 \text{ ps peak (or 400 ps p-p)}.$$

Frequency drift equation:

$$Tf(f_m)_{p\text{-}p} = 10^{-6}/(3.579545 \times 2\pi f_m) \text{ s} = (88.92 \times 10^{-9}/f_m)$$

Drift rate equation:

$$Tr(f_m)_{p\text{-}p} = (1.414 \times 10^{-9}/ f_m^2)$$

Demarcation frequency f_d :

The demarcation frequency separates the low-frequency spectral components (wander) from the high-frequency components (jitter). As shown in Figure A1, this frequency (f_d) is determined when the drift-rate limit is equal to the maximum time error limit (400 ps p-p). This can be resolved as:

$$(1.414 \times 10^{-9}/ f_d^2) = 400 \text{ ps p-p}$$

$$f_d = 1.88 \text{ Hz}.$$

Break frequency f_b :

This frequency (f_b) is determined when the drift-rate limit intersects with the frequency drift limit. This can be resolved as:

$(1.414 \times 10^{-9} / f_b^2) = (88.92 \times 10^{-9} / f_b)$

$f_b = 0.0159$ Hz.

This break frequency is very low and may not be of practical use.

Corner frequency f_c :

Considering a 20 dB/dec slope for the fitting line, the line equation can be determined at the frequency of 10 Hz:

$(x \times 10^{-9} / 10 \text{ Hz}) = 400$ ps

$x = 4$

So the curve fitting line equation is:

$Tc(f_m)$ p-p $= 4 \times 10^{-9} / f_m$

The corner frequency (f_c) is determined when the drift-rate limit intersects with the fitting line limit. This can be resolved as:

$(1.414 \times 10^{-9} / f_c^2) = 4 \times 10^{-9} / f_c$

$f_c = 0.3535$ Hz.

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Annex B (Informative): Information on TRL binding to Essence

B.1 Types of TRL and their bindings:

TRL in present system use following transmission forms:

- LTC – Longitudinal Timecode Label. Analogue or Digital systems, either SD or HD.
- VITC – Vertical interval Timecode label. Only in Analogue system, SD systems.
- ATC – Ancillary Timecode label. Only in Digital form on SD and HD systems.
- D-VITC – Digital VITC Label. Only in Digital form on SD system

Analogue form - Timecode may be distributed as an audio frequency without any binding. A specific binding happens only when the Timecode information is transported over a specific transport form as indicated above.

TRL binding types

Essentially only two types of bindings of a current TRL to signal Essence exist:

a) A binding based on physical properties of a storage media called here “Media binding”

b) A binding based on insertion of a TRL onto equipment outgoing stream called here “Stream binding”. This binding may use VITC or ATC form.

Acquisition and signal originating equipment

All signals originating equipment (camera, graphics generator, character generator, etc) may or may not provide a TRL on the output stream. The presence of TRL is determined by the equipment and choice of the user. When video stream from those sources is routed to a recorder, the recorder as part of its storage functionality may record incoming TRL if present, or it may record TRL in form of LTC recording. It should be noted that low cost recording equipment may not have operational feature supporting TRL recording.

Signal distribution in a plant.

A distribution of a stream in a studio represents a robust TRL binding for “Stream binding” because signal stream is passed from one point to another without processing. That is applicable also to a routing switcher and other equipment (patch panel) because routing equipment is passing the incoming streams unaltered.

Signal processing equipment.

Majority of processing equipment does not support robust passage/processing of TRL. Primary reason of this limitation is the signal process only operates on part of video stream carrying video Essence; therefore additional signal, as is TRL, located outside the Essence space in a vertical blanking interval, is neglected.

Example of equipment that consistently removes input TRL from the incoming steams is a digital production switcher. Additionally Production switcher manipulates two or more streams at the same time, therefore creates a situations where single “combined” TRL may not be usable after the production effect. As a result the TRL information is not passed on. Another example is a DVE processor, which mostly manipulates the incoming stream in the temporal domain, and the input TRL signal is not passed on due to possible conflict with the original values of the incoming TRL.

For all practical purposes, all stream bindings are of medium or low security due to different features of signal processing equipment and the TRL signal location possibly being in unprotected space.

TRL Recording and Storage

Tape recording of an original source provides a robust environment. TRL signal is (from LTC input or incoming stream) recorded on separate track; however use of a tape recording media is now in decline. Optical disk based systems might accommodate TRL recordings as tape-based recordings.

Recorders may also inserts TRL onto an outgoing stream using a Stream binding which is a prevailing method how to move TRL around a plant. While this process by itself should be robust, majority of studio equipment does not pass or store the incoming TRL therefore it is necessary to classify Stream binding as medium robust and is dependent on the used equipment. Also the stream space where is TRL inserted and transmitted from a recording device is not protected.

System and equipment configuration

TRL (LTC type) may be distributed thru out the plant on a separate distribution thru a low frequency bandwidth network. This is then used to provide a synchronizing TRL source for internal use of various plant processing devices. It should noted that majority of recording devices use TRL in some form, other equipment in the plant may not process or pass the TRL with the exception of distribution equipment.

Processing equipment may deliver TRL on its output based on the input TRL, however some equipment (e.g. switchers and DVE) never processes the input TRL.

A summary of passage and TRL processing is shown in Table B1.

Table B1: Analyses of TRL use in present systems

No	Use case	Signal process	TRL Binding and location	Issues with currently used solution (12M)	TRL Binding Reliability /TRL presence/Robustness
1	Camera head (studio) + CCU	May or may not include any form of TRL on the output video stream	SB	TRL might be added at the output of the camera CCU in form of VITC/ATC or provide a separate LTC output	Medium
2	Stand alone Camera	May or may not include any form of TRL on the video output stream	SB	TRL might generated and added at the output of the camera in form of VITC or ATC on the output stream	Medium
3	Camcorder (ENG)	Usually accommodating VITC or TRL during the recording on the recording media (tape, disk, memory)	SB	Recorded TRL has no Linkage to a studio environment (free running), however TRL recorded on Media may be in form of VITC or ATC, depending on type of equipment	Medium
4	Character Generator and Graphics Generator	May or may not include a TRL on the output video stream	SB	Output stream TRL depends on operational features of equipment	Medium

No	Use case	Signal process	TRL Binding and location	Issues with currently used solution (12M)	TRL Binding Reliability /TRL presence/Robustness
5	Slide Store, Film Chain	May or may not include TRL on the output video stream	SB	Output TRL depends on operational features of equipment	Medium
6	Signal distribution process, Routing Switcher	Distribution of video stream containing VITC or ATC on a studio network	SB	None - Secure passage of TRL due to lack of signal processing of the input video stream and TRL	High
7	Production switcher, Master Control Switcher	Signal processing of several video streams containing input TRL (ATC type or VITC type)	SB	All production switchers during a production effect will destroy incoming TRL by either not passing thru input TRL or modifying (combining) TRL value	Low
8	Signal process (Synchronize r, TBC, compression encoder, etc.)	Correction/process of incoming video stream containing TRL after a distribution	SB	Few equipment provide secure passage of the TRL on the processed video stream	Low
9	Digital Video Equipment (DVE)	Usually temporal processing of a one or more video streams containing TRL	SB	Known equipment destroy input TRL during the selected process, no output TRL	Low
10	Tape recording of TRL from an LTC input	Linear recording of TRL on a longitudinal tape track (called LTC track)	PB	Secure due to a common physical media (tape); output TRL present on removable Media and output stream	High
11	Tape recording of TRL from a video stream (recording on a video track)	Recording of a TRL located in a Vertical Blanking Interval (or VITC) into a video track	SB	Vulnerable to loss of input TRL; not all equipment records incoming TRL; output stream may or may not contain locally generated VITC or ATC; equipment feature issue	Medium
12	Disk/Server recording of a TRL from video stream	Recording of a TRL located in a Vertical Blanking Interval – VITC or ATC(TRL recording on a separate space of a disk)	SB	Vulnerable to loss of input TRL; may or may not contain locally generated VITC or ATC on output stream; equipment feature issue	Medium
13	Recording a TRL from a video stream on a Solid State Media	Recording TRL on “memory “stick	SB	Vulnerable to loss of a TRL from the incoming stream; output stream may or may not contain ATC recorded on storage Media ; equipment feature issue	Medium to High

Abbreviations:

TRL - Timecode Label	LTC - Linear Timecode
VITC – Vertical Interval Timecode	ATC - Ancillary Timecode packet
PB - Physical binding	SB - Stream Binding

Analysis Conclusion

Based on the Table 1 it is becoming clear that there is no consistent delivery of TRL on the output streams from equipment to equipment. The only exception is distribution equipment (not IT based) that consistently passes the TRL signal around the plant. Even storage equipment, that records TRL, never consistently processes the incoming TRL to the device. With any future system a major examination of TRL rules in acquisition, processing, storage equipment and overall system shall be needed.

B.2 TRL Binding to Essence stream issues

To maximize the use of TRL for production, the fundamental rule for TRL binding should be:

During all production processing steps, an Essence relevant TRL should not be neglected or erased unless a new TRL is substituted.

System TRL passage requirements

Based on the above rule, the following steps need to be accomplished:

1) The TRL signal should be passed transparently through all system equipment.

2) When 1), above, is not possible, a substitute TRL signal is provided, based on an instant of the stream release.

3) When an incoming stream is processed, the TRL value might be changed according to rules that apply to Essence creation, pending a decision of a User.

Binding methods

The binding methods for a TRL binding to Essence are the following:

a) Securely bind TRL to an Essence output stream in a form of ATC (**Stream binding**).

b) Provide for a separate network on which the relevant TRL may be distributed in the form of LTC. (**Media binding**)

c) In modern systems, video streams may be conveyed as files that provide space for a TRL (**File format binding**)
Note: This binding is highly robust but the robustness is unidirectional and in a round trip the binding may/will be lost.

Binding robustness

To achieve a maximum robustness of the TRL binding, the following guidelines are offered:

- The TRL shall reside on the output stream in a secure, protected space in ATC form.
  (Note: This requirement requires modification of existing standards)
- The TRL may reside within the Essence itself. “Inner ATC form” type 1 or 2
  (Note: Several possibilities exist; partial use of a single line of the relevant Essence (type 1) or partial use of a single Essence word distributed to all lines of an Essence raster/frame (type 2) or use of watermarking).
- All storage/recording devices shall record incoming TRL regardless of which and what form (LTC, VITC, and ATC).

Table B2: User Requirements on binding for future systems

	Environment	TRL Binding type	User requirements	Notes on UR
1	Essence signal origination	Stream	TRL on output stream ATC form	Internally generated TRL to be locked to external TRL source or free running; output TRL located in a protected space
			TRL on output stream - Inner ATC form	
		Media	Provide for ext. TRL form input (?)	
2	Distribution	Stream	TRL on input and output stream in all ATC forms	No processing required, passive passage of signal
		Media	Passage of TRL on separate network	Separate network, unidirectional; duplex type.
3	Production	Stream	Passage of input TRL on output stream, all ATC forms	Relevant TRL processing dependent on equipment type; no loss of input TRL; re-insertion of new output TRL in a protected space, if input TRL is irrelevant
		Media	Provide for ext TRL form input (?)	
4	Storage/recording	Stream	Storage of input TRL, TRL on output stream; all ATC forms	Input TRL storage/recording required; no loss of input TRL; re-insertion of new TRL on output if processing involved
		Media	Storage of TRL from distribution network	Recording TRL on Media

B.3 TRL Binding conclusions

System impact

Requiring that the TRL be securely bound to its video stream (Essence) will have a significant system impact. The majority of current equipment does not pass or generate/regenerate a TRL on its outputs. Consequently the major impact will be mainly in revising existing standards and existing equipment.

Point of TRL insertion and system binding rules

Presently there is an unwritten rule that assumes the attachment of the TRL at the point of first recording. It seems that a better method would be to attach the TRL at the point of origination (camera) instead of at the recording/storage device. A study is also required into what to do with the TRL at every point of the production chain (e.g. during the mixing of two different streams or during DVE effects). These rules need to be established or there is the danger of the loss of the TRL during production.

Carriage of the TRL in audio streams

While this report is primarily video based, it is necessary to take into account the audio capability of the total system. One of the most limiting issues for the TRL size is the carriage of the TRL in a digital audio stream, such as AES3.

An AES3 stream has a very limited capability to accommodate a TRL. Each stream may only use 32 bits for each audio block available from the *C-bit Info Data Block* for TRL. This space of 32 C-bits is available only once every audio block and is repeated every 5 video frames. The *U-bit Info Data Block* has a size of192 bits and this is also repeated once every 5 video frames. A study of digital video recorder standards has shown that neither the C-bits nor the U-bits are carried transparently through recorders, although when a transparent mode of operation is selected in a recorder, the number of bits remaining for audio recording is decreased. It is doubtful that users would exchange the number of audio bits to make a protected space for a new TRL. As to the capability of audio recording/storage devices for transparency of C- and U-bits, no information was collected.

Binding methods and transparency

Media binding is required for removable storage media, so that the TRL is never lost when Media is moved around. However it is possible that use of the Media Binding (separate network) may not survive in a longer term.

Stream binding, using a protected space on the incoming or outgoing stream or even within the Essence itself is anticipated to be the most practical and secure. It seems that the highest security TRL binding may be achievable by using the video Essence stream (frame) itself; however that step might be controversial especially if it involves repeated compression coding. As already mentioned, inclusion of the TRL in the Essence may use different methods (including watermarking) that should be selected on the basis of the overall stream robustness.

A separate issue is the TRL binding transparency and robustness during a contribution and distribution phase of Content. This subject is much closer to the point of a stream release, and whilst important, it is believed that it is outside the scope of the SMPTE/EBU Task Force and surely outside of the scope of the subgroup on binding.

Annex C (Informative): A bit of history on PAL & NTSC timing

In today's television plants, synchronization is most frequently achieved by distributing a "colour black" signal (also known as "sync and burst" or "black and burst") conforming to either the 525-line NTSC or 625-line PAL system for 60 (nominal) or 50 Hz (field rates) environments respectively.

The signals carry a short burst of the subcarrier frequency appropriate to the standard (nominally 3.579545454 MHz for NTSC, 4.43361875 MHz for PAL). The operation of a slave derives both frequency reference and frame/line timing from the colour black signal. This derivation may be from the timing of sync edges or, for higher stability, by averaging zero crossings of the subcarrier burst. These reference signals are described in SMPTE 318M, but it should be noted that some provisions of this standard, such as the ten-field reference, are not widely implemented.

Most master generators make use of a 1 MHz or 5 MHz reference frequency derived from a high-precision oscillator, or from a widely available standard such as a GPS receiver.

One of the complications of associating television signals with time is unique to the NTSC system. In 1953 the Federal Communications Commission decided to change the line and frame rates of the new colour standard by 0.1% from those of the monochrome NTSC system to avoid the need to change audio carrier frequency. This means that the frame rate of nominal 30 Hz NTSC systems is actually 30/1.001 (approximately 29.97 Hz). The impact of this extends beyond NTSC operations alone; operations of digital and high-definition systems in countries that used NTSC are likely to continue to be based on the 30/1.001 Hz frame rate for the foreseeable future. In addition, operation in NTSC-related plants uses other modified frame rates, such as 24/1.001 (approximately 23.98 Hz).

There is, therefore, no convenient correlation of NTSC frames and time-of-day clock. Previous approaches to this problem include "drop frame" timecode as specified in SMPTE 12M.

Note that the decision to offset the line rate of NTSC required the line rate to be a sub harmonic of the 4.5 MHz intercarrier beat frequency. 4.5 MHz is also a harmonic of the PAL line frequency (and both are even harmonics), so there is a convenient frequency relationship between both line frequencies and 4.5 MHz and 2.25 MHz.

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Annex D: Use Cases

D.1 Use case for time labelling in a simple multi-camera and recording application

Introduction

This document forms part of the work of the EBU/SMPTE Task Force on Timing and Synchronisation. Use cases, such as this one, will allow user requirements to be defined with reference to practical examples.

Time labelling

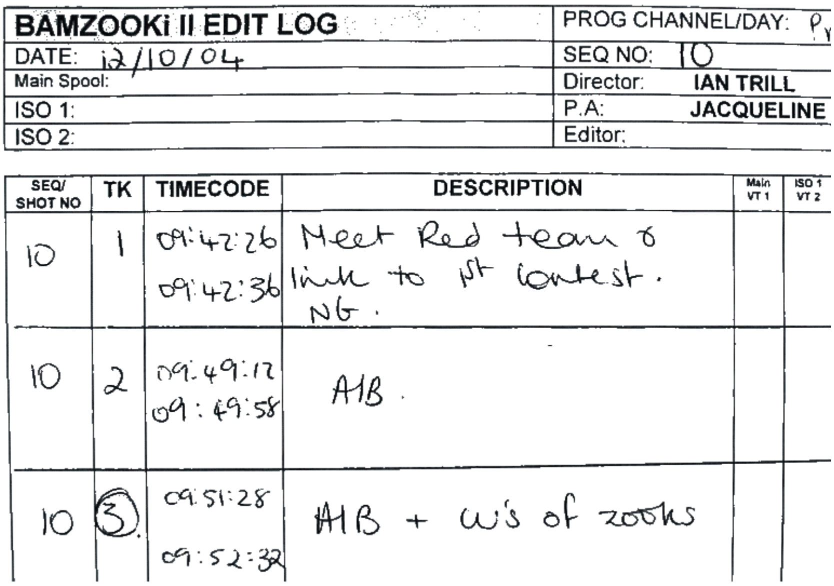
In this context, a time label is a label that can be read or derived for an "access unit" of recorded material (a typical access unit is a video frame) and which identifies the temporal position of that access unit.

Time labelling has a number of purposes, including indexing, time alignment and triggering.

Indexing

Some form of index into recorded material is needed so that reference can be made to instants or sections of interest. The index should be accessible at any point in the production chain. The index needs to be easy for humans to deal with. Something similar to clock time is an example of a human-friendly format.

An example of this kind of use is a production log:



BAMZOOKi II EDIT LOG	PROG CHANNEL/DAY:
DATE: 12/10/04	SEQ NO: 10
Main Spool:	Director: IAN TRILL
ISO 1:	P.A: JACQUELINE
ISO 2:	Editor:

SEQ/ SHOT NO	TK	TIMECODE	DESCRIPTION	Main VT 1	ISO 1 VT 2
10	1	09:42:26 09:42:36	Meet Red team & link to 1st contest. NG.		
10	2	09:49:12 09:49:58	A1B.		
10	3	09:51:28 09:52:32	A1B + w's of zooks		

Time alignment

Where multiple recordings of the same event are made, such as in multi-camera production, there is a need to bring these recordings into temporal alignment so that edits can be made correctly. This alignment can be achieved by matching the time labels of the various recordings.

Triggering of effect or event

It is sometimes necessary to trigger a video or audio effect when the time label of an input stream matches some pre-determined value.

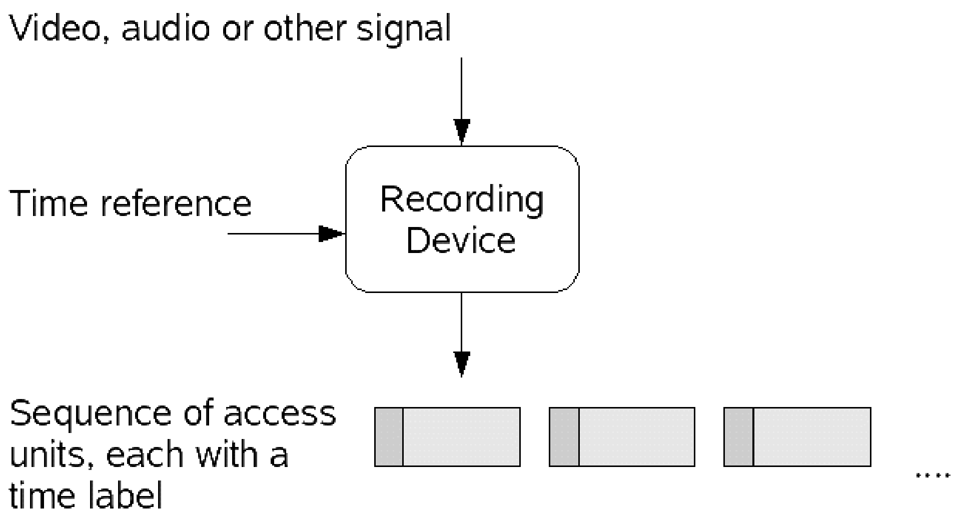
Types of label

Currently used labels include:

- Time of day
- Time increasing from a preset value
- Time representing cumulative recording duration

It would be desirable for a future labelling format to flag the type of time index used.

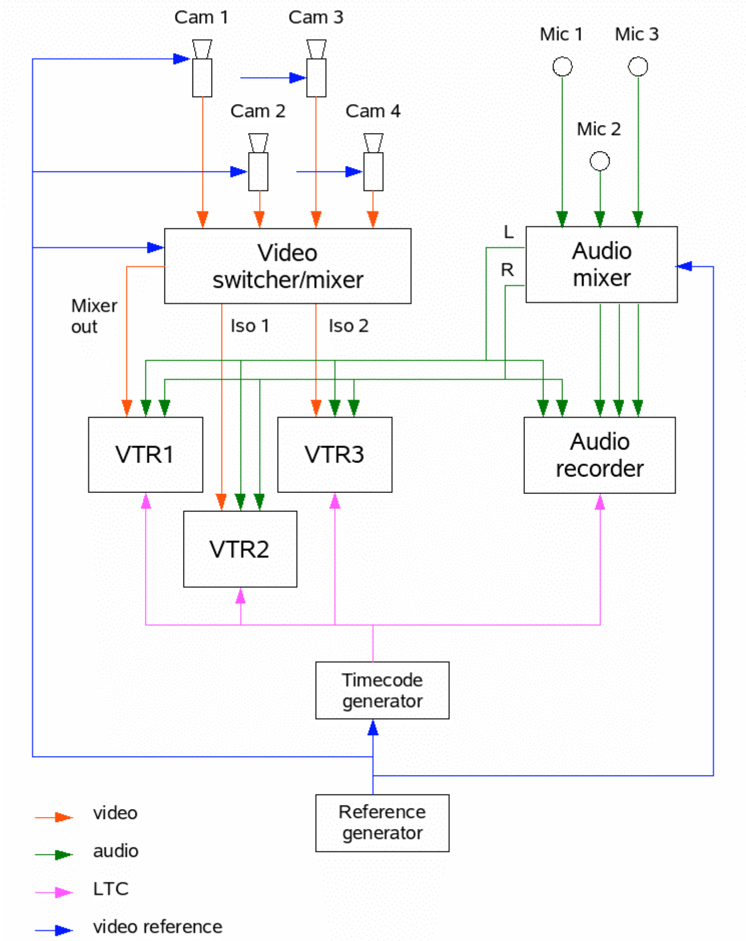
Generic diagram



The recording device is fed with an input signal, e.g. video from a camera. It is also fed with a time reference, e.g. linear timecode (LTC) on an audio cable. As each access unit, e.g. video frame, is recorded, it is given a time label based on the current value of the time reference.

As discussed above, the time labels can be used to align recordings from multiple sources, e.g. multiple cameras.

Multi-camera studio - VTR recording



The diagram shows a studio set up with 4 cameras and 3 microphones. (The microphones might be personal radio microphones on different presenters.)

Video is fed through a video switcher or mixer. The vision-mixed or cut version (shown as "mixer out") is fed to the first video tape recorder (VTR1). Two cameras are selected for recording on a further two VTRs, irrespective of which source is routed to mixer out. These are known as "Iso" (isolated) recordings, shown as "Iso 1" and "Iso 2".

Audio is fed though a mixer to produce a stereo (left/right) pair. This audio mix is recorded on the VTRs and also on a separate multi-track audio recorder. The individual microphone signals are also recorded on the multi-track recorder. This allows for re-mixing during postproduction, if needed.

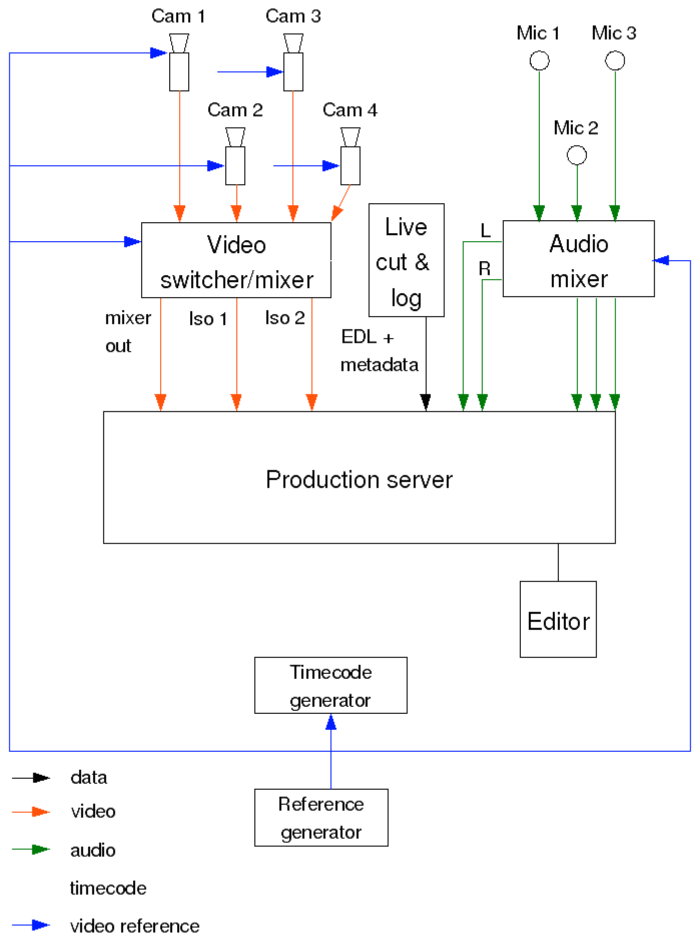
A single source of linear timecode (LTC as an audio signal) is fed to each of the recorders. Typically this would correspond to "time of day". This provides the time reference as shown in the generic diagram above and enables the recorders to apply time labels to the recorded audio and video.

A video reference is fed to each camera and to the audio recorder.

The time labelling should enable the various video recordings to be aligned to frame accuracy and this will be achieved with LTC as long as the cameras are locked to a common video reference.

The time labelling should also enable the audio recorded on the VTRs to be aligned with the audio recorded on the multi-track audio recorder. With the audio recorder locked to a suitable reference signal, this will be achieved to video frame accuracy but probably not to audio sample accuracy, as a small fixed offset is likely to remain.

Multi-camera studio - Server recording



The second diagram shows a similar studio set up, but in this case a production server, providing file-based storage instead of tapes, has replaced the different VTRs. Several non-linear editing applications can have access to the media material stored on the production server. A live cut and log application allows capturing of the live edits and logging (e.g. predefined keystrokes) to an EDL and Metadata.

Video reference is similarly fed to each camera, the audio recorder and the production server. Time code is fed to the production server, and additionally to the video mixer in order to enable frame accurate time labelling with regard to the generated EDL and Metadata.

Note

In the future we need the "time-label" information in the very first part of the signal generation. Therefore it may prove convenient to combine the time reference with the synchronization-signal. This would also simplify the cabling within the studio. This applies to both diagrams.

User inputs (BBC, RAI, NRK, IRT, Multicamera etc).

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Annex F: Reply Form - Response to RFT

Your response to the RFT should be in written form. Your proposal of technology can be either for the TRL or for the synchronization requirement or for both. There is also the requirement to present your proposal to the 4th. Task Force meeting on 4-7 June at the IRT in Munich, Germany. Exact details of the venue, the time of your presentation and other details such as the duration of your presentation will be communicated to you directly after receipt of your proposal.

Your proposal should be attached to an e-mail (e.g. as a PDF) and sent to both the co-chairmen* of the Task Force not later than 1st. May 2008. Should you not be able to meet this deadline, you should nevertheless communicate with both co-chairmen at your earliest opportunity before the deadline to explain your circumstances.

Reponses should also include the completion of the tables overleaf, which comprise the user requirements described in the RFT.

Respondents who are aware of intellectual property believed essential to implementation of the technology proposed should provide details. If the intellectual property is owned or controlled by the respondent the response must include a statement indicating willingness to licence an unrestricted number of implementers on RAND terms. Responders should indicate whether or not it is planned to offer a compensation-free licence.

* The co-chairs of the Task Force are Hans Hoffmann (hoffmann@ebu.ch) and Peter Symes (psymes@smpte.org)

Time Related Labelling:

Section Nr.	User Requirement	Proposed solution meets requirements (Y/N)	Comments

Synchronization:

Section Nr.	User Requirement	Proposed solution meets requirements (Y/N)	Comments

Binding:

Section Nr.	User Requirement	Proposed solution meets requirements (Y/N)	Comments

Annex G: Glossary of Terms

-A-

A/D	Analogue-to-digital conversion.
A/V	Audio/Video or Audiovisual.
AES3	The AES Recommended Practice for Digital Audio Engineering a Serial Transmission Format for Linearly Represented Digital Audio Data. This is a major digital audio standard for serial interface transfer. It is substantially identical to EBU Tech. 3250-E, SP/DIF, IEC 958, EIA CP340 and EIA DAT. These standards describe a uni-directional, self-clocking, two-channel standard based on a single serial data signal. The AES format contains audio samples up to 24 bits in length and non-audio data including channel status, user data, parity and sample validity. The differences between these standards lie in electrical levels, connectors, and the use of channel status bits. The AES3 standard is better known as the AES/EBU serial digital audio interface.
Analogue (video) signal	A (video) signal, one of whose characteristic quantities follows continuously the variations of another physical quantity representing information.
Analogue transmission	A type of transmission in which a continuously variable signal encodes an infinite number of values for the information being sent (compare with "digital").
ANSI	The American National Standards Institute is a US-based organization that develops standards and defines interfaces for telecommunications systems.
API	Application Programming Interface. A set of interface definitions (functions, subroutines, data structures or class descriptions) which together provide a convenient interface to the functions of a subsystem and which insulate the application from the minutiae of the implementation.
Application	A computer program designed to perform a certain type of work. An application can manipulate text, numbers, graphics or a combination of these elements. An application differs from an operating system (which runs a computer), a utility (which performs maintenance or general-purpose chores) and a programming language (with which computer programs are created).
ASCII	American Standard Code for Information Interchange. A coding scheme that assigns numeric values to letters, numbers, punctuation marks and certain other characters. By standardizing the values used for these characters, ASCII enables computers and computer programs to exchange information. Although it lacks accent marks, special characters and non-Roman characters, ASCII is the most universal character-coding system.
Asset	An Asset is any material that can be exploited by a broadcaster or service provider. An asset could therefore be a complete programme file, or it could be a part of a programme, individual sound, images etc.
ATSC	(US) Advanced Television System Committee.

-B-

Bandwidth	The frequency range of an electromagnetic signal, measured in hertz (cycles per second). The term has come to refer more generally to the capacity of a channel to carry information, as measured in data transferred per second. Transfer of digital data, for example, is measured in bits per second.
Baseband	Describes transmissions using the entire spectrum as one channel. Alternatively, baseband describes a communication system in which only one signal is carried at any time. An example of the latter is a composite video signal that is not modulated to a particular television channel.
BER	Bit Error Ratio (or Rate).
B-frame	MPEG2 B-frames use bi-directionally-interpolated motion prediction to allow the decoder to rebuild a frame that is located between two reconstructed display frames. Effectively the B-frame uses both past frames and future frames to make its predictions. B-frames are not used as reference frames but for further predictions. However, they require more than two frames of video storage in the decoder, which can be a disadvantage in systems where low cost is of the essence. By using bi-directional prediction, B-frames can be coded more efficiently than P-frames, allowing a reduction in video bit-rate whilst maintaining subjective video quality.
Broadcast	In general terms, a transmission sent simultaneously to more than one recipient. There

	is a version of broadcasting used on the Internet known as multicast. In multicast, each transmission is assigned its own Internet Protocol (IP) multicast address, allowing clients to filter incoming data for specific packets of interest.
Broadcaster (Service Provider)	An organization that assembles a sequence of events or programmes based upon a schedule, to be delivered to the viewer.
BWF	Broadcast Wave File. The EBU has defined an audio file format that contains the minimum information that is considered necessary for all broadcast applications. The file format has been formalised in ITU-R. BR 1352

-C-

CEPT	The Conference on European Post and Telegraph is a European organization that develops standards and defines interfaces for telecommunications systems.
Channel	A means of unidirectional transmission of signals between two points.
Chroma / chrominance	The colour portion of the video signal that includes hue and saturation information. Hue refers to a tint or shade of colour. Saturation indicates the degree to which the colour is diluted by luma or illumination.
Client	Generally, one of a group of computers that receive shared information sent by a computer called a server over a broadcast or point-to-point network. The term client can also apply to a software process, such as an Automation client, that similarly requests information from a server process and that appears on the same computer as that server process, or even within the same application.
Clock	Equipment that provides a timing signal.
Compression	The process of reducing the number of bits required to represent information, by removing redundancy. In the case of information Content such as video and audio, it is usually necessary to extend this process by removing, in addition, any information that is not redundant but is considered less important. Compression techniques that are used include: DPCM, sub-Nyquist sampling, transform coding, statistical coding, sub-band coding, vector coding, run length coding, variable length coding, fractal coding and wavelet coding.
Content	Programme Content can be *Video Essence*, *Audio Essence*, *Data Essence* and *Metadata*. Content can therefore include television programming, data and software applications.
Content provider	A person or company delivering broadcast Content.
CRC	Cyclic Redundancy Check. A common technique for detecting errors in data transmission. In CRC error checking, the sending device calculates a number based on the data transmitted. The receiving device repeats the same calculation after transmission. If both devices obtain the same result, it is assumed the transmission was error-free. The procedure is known as a redundancy check because each transmission includes not only data but additional, redundant values for error checking.

-D-

D/A	Digital-to-analogue conversion.
Data service	A mechanism offered by a broadcaster (service provider) for sending broadcast data to broad cast clients. Such data can include Programme Guide information, WWW pages, software and other digital information. The data service mechanism can be any broadcast process.
Data streaming	The data broadcast specification profile for data streaming supports data broadcast services that require a streaming-oriented, end-to-end delivery of data in either an asynchronous, synchronous or synchronized way through broadcast networks. Data which is broadcast according to the data streaming specification is carried in Programme Elementary Stream (PES) packets which are defined in MPEG-2 Systems. Asynchronous data streaming is defined as the streaming of only data without any timing requirements (e.g. RS-232 data). Synchronous data streaming is defined as the streaming of data with timing requirements in the sense that the data and clock can be regenerated at the receiver into a synchronous data stream (e.g. E1, T1). Synchronized data streaming is defined as the streaming of data with timing requirements in the sense that the data within the stream can be played back in synchronization with other kinds of data streams (e.g. audio, video).
Demarcation frequency	In the context of the sinusoidal spectral content of TIE, it is the frequency that separates the low-frequency spectral components that are best quantified in terms of *wander* from the high-frequency components that are best quantified as *jitter*. This frequency may be explicitly specified by a jitter measurement standard for a particular format, such as bit-serial digital video. If not explicitly specified, a good

	choice for this frequency can be derived from the particular video format's drift-rate (DR) and jitter performance limits in the format specifications. However, since these specifications depend on the level of performance required for the video signal (i.e., video production quality versus video distribution quality), different demarcation frequencies may coexist for a single video format. In any case, the particular frequency used for the measurement should be called out along with the measured wander and jitter data values. *NOTE: Figure A1 illustrates how the demarcation frequency separates jitter and wander specifications.*
Device	A unit of hardware, for example a videotape machine or a server.
Device object	A programming object used to represent a physical, logical or virtual hardware device whose device driver has been loaded into the operating system.
Digital (transmission) channel	The means of unidirectional digital transmission of digital signals between two points.
Digital connection	A concatenation of digital transmission channels, switching and other functional units, set up to provide for the transfer of digital signals between two or more points in a network, in support of a single communication.
Digital demultiplexing	The separation of a (larger) digital signal into its constituent digital channels.
Digital multiplexing	A form of time-division-multiplexing applied to digital channels by which several digital signals are combined into a single (larger) digital signal.
Digital signal	A discretely-timed signal in which information is represented by a number of well-defined discrete values that one of its characteristic quantities may take in time.
Digital transmission	The transmission of digital signals by means of a channel or channels that may assume, in time, any one of a defined set of discrete states.
DSP	Digital signal processor.
DTS	Data Time Stamp.
DVB	Digital Video Broadcasting.

-E-

EBU	European Broadcasting Union. Headquartered in Geneva, Switzerland, the EBU is the world's largest professional association of national broadcasters. Following a merger on 1 January 1993 with the International Radio and Television Organization (OIRT) the former association of Socialist Bloc broadcasters the expanded EBU has 72 active members in 49 European and Mediterranean countries, and 51 associate members in 30 countries elsewhere in Africa, the Americas and Asia.
EPG	Electronic Programme Guide.
Error ratio [error rate]	The ratio of the number of digital errors received in a specified period to the total number of digits received in the same period.
Error, digital error	An inconsistency between a digit in a transmitted digital signal and the corresponding digit in the received digital signal.

-F-

FEC	Forward error correction. A system of error correction that incorporates redundancy into data so that transmission errors can, in many cases, be corrected without requiring retransmission.
Field	A subdivision of a frame containing alternate lines of the frame.
File	An organized collection of related records, accessible from a storage device via an assigned address. The relationship between the records and the file may be that of common purpose, format or data source, and the records may or may not be sequenced.
Frame	An access unit containing all pixels and lines of a single image.
FTP	File Transfer Protocol. A protocol that supports file transfers to and from remote systems on a network using Transmission Control Protocol/Internet Protocol (TCP/IP), such as the Internet. FTP supports several commands that allow the bi-directional transfer of binary and ASCII files between systems.

-G-

Gamma	A nonlinear operation used to code and decode luminance or RGB values into video signals or digital file values
Gbit/s	Gigabit per second. A digital transmission speed of billions of (i.e.10^9) bits per second.
GoP	Group of Pictures. An MPEG-2 GoP begins with an I-frame and extends to the last frame before the next I-frame. The GoP sequence is known as an open GoP if the last frame in the GoP uses the first frame of the next GoP as a reference. Another type of GoP is a

	closed GoP, which has no prediction links to the next GoP and, by definition, always ends in a P-frame.
GPS	Global Positioning System. A constellation of 24 (US military) Medium Earth Orbit satellites that transmit precise microwave signals. Since 1983, the system has been available for civilian use as a widely used aid to navigation worldwide. GPS also provides a precise time reference used in many applications including scientific study of earthquakes and the synchronization of telecommunications networks.
-H-	
HDTV	High Definition TeleVision. Television that is delivered at a higher screen resolution than that of standard definition television.
Host	A device where one or more modules can be connected, e.g. a VTR, a PC ...
-I-	
IEC	International Electrotechnical Commission. Based in Geneva, the IEC is the world organization that prepares and publishes international standards for all electrical, electronic and related technologies.
IEEE	(US) Institute of Electrical and Electronic Engineers. The world's largest technical professional society, with more than 320,000 members. The technical objectives of the IEEE focus on advancing the theory and practice of electrical, electronic and computer engineering, and computer science.
IETF	Internet Engineering Task Force. The IETF is a large open international community of network designers, operators, vendors and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. It is open to any interested individual.
Interface	The common boundary point where two elements connect so that they can work with one another. In computing, the connection between an application and an operating system or between an application and a user (the user interface) are examples of an interface. In C++ programming, an interface is a collection of related methods exposed by a given class of objects. These methods are procedures that can be performed on or by those objects.
Interlacing / interlaced	The technique by which alternate lines (e.g. all even lines) of a television frame are acquired and transmitted or stored as a field, followed by acquisition and transmission or storage of the remaining lines (e.g. all odd lines) as a second field.
Internet	Generically, a collection of networks interconnected with routers. The Internet is the largest such collection in the world. It has a three-level hierarchy composed of backbone networks, mid-level networks and stub networks.
IP	Internet Protocol. The primary network layer of Internet communication, responsible for addressing and routing packets over the network. IP provides a best-effort, connectionless delivery system that does not guarantee that packets arrive at their destination or that they are received in the sequence in which they were sent.
IP Address	An identifier for a network node; expressed as four fields separated by decimal points (e.g. 136.19.0.5.); IP address is site-dependent and assigned by a network administrator.
ISO	International Organization for Standardization, based in Geneva.
Isochronous	A term used to describe signal-timing techniques that require a uniform reference point (usually embedded in the data signal).
ITU	International Telecommunication Union, part of the United Nations, based in Geneva.
-J-	
Jitter	The high-frequency spectral components of the TIE that are generally outside of the phase tracking or synchronization bandwidth of subsequent video processing equipment. TIE spectral components above a specified demarcation frequency are considered jitter. NOTE—SMPTE RP 184-2003 defines several types of jitter for serial digital video signals. In this recommended practice, timing jitter is defined as timing variations with spectral components above a specified frequency, typically 10 Hz or less. Timing variations with spectral components below the specified frequency are termed *wander* and are not addressed by SMPTE RP 184-2003. Short-term non-cumulative variations of the significant instants of a digital signal from their ideal positions in time.
Jitter, delay, latency	See *Latency*
-K-	

kbit/s	kilobits per second. A digital transmission speed expressed in thousand of bits per second.

-L-

LAN	Local Area Network. A network dispersed over a relatively limited area and connected by a communications link that enables each device on the network to interact with any other.
Latency	The time delay inherent in a manipulative process. In particular, the time that it takes to process an input bitstream through a compression and decompression process. Buffering and trans mission can be major contributors to processing delays.
Link	Any physical connection on a network between two separate devices, such as an ATM switch and its associated end point or end station.
Luma	Luma is the weighted sum of gamma-compressed R'G'B' components of a color video. The word was proposed to prevent confusion between luma as implemented in video engineering and luminance as used in colour science. Luminance is formed as a weighted sum of linear RGB components, not gamma-corrected ones. SMPTE EG 28 recommends the symbol Y' to denote luma and the symbol Y to denote luminance
Luminance	A measure of the degree of brightness or illumination radiated by a given source. Alternatively, the perceived brightness component of a given colour, as opposed to its chroma.

-M-

Master	An oscillator or signal generator that is used to control the frequency and timing of other oscillators or signal generators (see *slave*). A Master oscillator itself may receive frequency and timing information from a global clock (e.g. from the *GPS* system)
Mbit/s	Megabits per second. A digital transmission speed expressed in millions of bits per second.
Metadata	Data describing other data.
MJD	Modified Julian Date.
MPEG	Motion Picture Experts Group. MPEG-1 is a standard designed for video playback from CD-ROM. It provides video and audio compression at rates up to 1.8 Mbit/s. MPEG-2 refers to the ISO/IEC 13818 standard, and it provides higher video resolutions and interlacing for broadcast television and high-definition television (HDTV). Both standards were created by the Motion Pictures Experts Group, an International Standards Organization / International Telegraph and Telephone Consultative Committee (ISO/CCITT) group set up to develop motion video compression standards. The MPEG system makes use of three different types of compressed video frames, (I, P and B frames), which are stored so as to enable temporal prediction of missing or incomplete frames as received by the decoder.
MPEG TS	MPEG Transport Stream.
MPI	MPEG Physical Interface.
MSB	Most Significant Bit. In any related grouping of bits (i.e. a *word*), there will be one that quantifies the largest power of 2. This bit is the MSB of the word.
Multimedia	Online material that combines text and graphics with sound, animation or video, or some combination of the three.
MUX	Multiplex or multiplexer. A stream of all the digital data carrying one or more services within a single physical channel. In general terms, a multiplexer is a device for funnelling several different streams of data over a common communications line. In the case of broadcasting, a multiplexer combines multiple television channels and data streams into a single broadcast.

-N-

Network	In computing, a data communications system that interconnects a group of computers and associated devices at the same or different sites. In broadcasting, a collection of MPEG2 Transport Stream multiplexes that are transmitted on a single delivery system, e.g. all the digital channels on a specific satellite or cable system.
NCITS	National Committee for Information Technology Standards. NCITST11 is responsible for standards development in the areas of Intelligent Peripheral Interface (IPI), High-Performance Parallel Interface (HIPPI) and Fiber Channel (FC).
NTSC	National Television System Committee, which originated the NTSC standard for analogue tele vision signals in North America, and which has also been adopted in Japan and parts of South America. The NTSC system is based on a power supply frequency of 60 Hertz (Hz) and can dis play 525 scan lines at approximately 30 frames per second. However, non-picture lines and interlaced scanning methods make for an effective resolution limit

	of about 340 lines.
-O-	
Octet	A group of eight binary digits or eight signal elements capable of representing 256 different values operated upon as an entity (also known as a “word” or “byte”).
Operating system	Software responsible for controlling the allocation and usage of computer hardware resources such as memory, CPU time, disk space and peripheral devices.
Opportunistic band width	Bandwidth granted whenever possible during the requested period, as opposed to guaranteed bandwidth which is actually reserved for a given transmission.
OSI	Open Systems Interconnection. This refers to the ISO/OSI seven-layer model for standardizing communications.
Over-crank	A technique in Image acquisition where frames are captured at a higher than nominal rate so that reproduction at the nominal rate provides a slow-motion effect. The term is derived from the use of manually cranked film cameras.
-P-	
Packet	A unit of information transmitted as a whole from one device to another on a network. In packet-switching networks, a packet is defined more specifically as a transmission unit of fixed maximum size that consists of binary digits (bits) representing both data and a header contain ing an identification number, source and destination addresses, and sometimes error-control data.
Packet Switching	A switching technique in which no dedicated path exists between the transmitting device and the receiving device. Information is formatted into individual packets, each with its own address. The packets are sent across the network and reassembled at the receiving station.
PAL	Phase Alternation by Line standard. The analogue television standard for much of Europe except France, Russia and most of Eastern Europe, which use SECAM. As with SECAM, PAL is based on a 50 Hertz (Hz) power supply frequency, but it uses a different encoding process. It displays 625 scan lines and 25 frames per second, and offers slightly better resolution than the NTSC standard used mainly in North America and Japan. The PAL bandwidth is 5.5 Megahertz (MHz).
Partial Transport Stream	Bitstream derived from an MPEG-2TS by removing those TS packets that are not relevant to one particular selected programme, or a number of selected programmes.
PCM	Pulse Code Modulation. A process in which a signal is sampled, and each sample is quantized independently of other samples and converted by encoding to a digital signal.
PDH	Plesiochronous Digital Hierarchy.
PES	Packetized Elementary Stream.
Physical Layer	The first of the seven layers in the International Organization for Standardization's Open Systems Interconnection (OSI) model for standardizing communications. It specifies the physical interface (e.g. connectors, voltage levels, cable types) between a user device and the network.
PID	Packet Identifier.
Plesiochronous	The essential characteristic of time-scales or signals such that their corresponding significant instants occur at nominally the same rate, any variation in rate being constrained within specified limits. Two signals having the same nominal digit rate, but not stemming from the same clock, are usually plesiochronous.
PLL	Phase Locked Loop.
Plug and Play	A design philosophy and set of specifications that describe changes to hardware and software for the personal computer and its peripherals. These changes make it possible to automatically identify and arbitrate resource requirements among all devices and buses on a computer. Plug and Play specifies a set of application programming interface (API) elements that are used in addition to existing driver architectures.
Point-to-point	A term used by network designers to describe network links that have only one possible destination for a transmission.
ppb/s	Parts per billion per second
ppm/s	Parts per million per second
PRBS	Pseudo Random Binary Sequence.
Programme	A concatenation of one or more events under the control of a broadcaster, e.g. a news broadcast, entertainment show.
ps	Picosecond (0.000000001 s)
PSI	MPEG-2 Programme Specific Information (as defined in ISO/IEC 13818-1).

PTS	Presentation Time Stamp.
Pull-down	(as in 3:2 pull-down) A technique applied in (nominal) 60Hz environments for the transfer of film to video where one film frame (at 24fps) is converted to two fields (in interlaced standards) or frames (in progressive standards), and (following “pull-down” of the film) the next frame is converted to three fields or frames.
Push model	A broadcast model in which a server sends information to one or more clients on its own schedule, without waiting for requests. The clients scan the incoming information, save the parts they have been instructed to save, and discard the rest. Because the push model eliminates the need for requests, it eliminates the need for a back channel from the client to the server. The push model contrasts with the *pull model*, in which each client requests information from a server. The pull model is more efficient for interactively selecting specific data to receive, but uses excessive bandwidth when many clients request the same information.

-Q-

QAM	Quadrature Amplitude Modulation.
QoS	Quality of Service. The ATM Forum, for example, has outlined five categories of performance (Classes 1 to 5) and recommends that ATM's QoS should be comparable to that of standard dig ital connections.
QPSK	Quadrature Phase Shift Keying.
Quantizing / quantized	A process in which a continuous range of values is divided into a number of adjacent intervals, and any value within a given interval is represented by a single predetermined value within the interval.
Query	A request that specific data be retrieved modified or deleted.

-R-

Reference clock	A clock of very high stability and accuracy that may be completely autonomous and whose frequency serves as a basis of comparison for the frequency of other clocks.
RFC	Request For Comment.
RFT	Request for Technology.
RMS/rms	Root Mean Square.
Router	A device that helps local-area networks (LANs) and wide-area networks (WANs) to connect and interoperate. A router can connect LANs that have different network topologies, such as Ethernet and Token Ring. Routers choose the best path for a packet, optimizing the network performance.
RTP	Real-time Transport Protocol. RTP permits real-time Content transport by the inclusion of media-dependent Time Stamps that allow Content synchronization to be achieved by recovering the sending clock.

-S-

S/N (SNR)	Signal-to-Noise Ratio. The amount of power by which a signal exceeds the amount of channel noise at the same point in transmission. This amount is measured in decibels and indicates the clarity or accuracy with which communication can occur.
Sample	A representative value of a signal at a chosen instant, derived from a portion of that signal.
Sampling / sampled	The process of taking samples of a signal, usually at equal time intervals.
Sampling rate	The number of samples taken of a signal per unit of time.
SDH	Synchronous Digital Hierarchy. International version of SONET that is based on 155Mbit/s increments rather than SONET's 51Mbit/s increments.
SDTV	Standard Definition TeleVision. Television service providing a subjective picture quality roughly equivalent to current 525-line or 625-line broadcasts.
Server	A computer or other device connected to a network to provide a particular service (e.g. print server, fax server, playout server) to client devices connected to the network.
Slave	An oscillator or signal generator that receives its synchronizing information from another oscillator or signal generator (see *master*)
Slip	The loss or gain of a digit position or a set of consecutive digit positions in a digital signal, resulting from an aberration of the timing processes associated with transmission or switching of a digital signal.
SMPTE	Society of Motion Picture and Television Engineers. The Society was founded in 1916, as the Society of Motion Picture Engineers. The T was added in 1950 to embrace the

	emerging television industry. The SMPTE is recognized around the globe as a leader in the development of standards and authoritative, consensus-based, recommended practices (RPs) and engineering guidelines (EGs). The Society serves all branches of motion imaging including film, video and multimedia.
SONET	Synchronous Optical NETwork. A set of standards for the digital transmission of information over fibre optics. Based on increments of 51Mbit/s.
Station	An establishment equipped for radio or television transmission.
STM	Synchronous Transfer Mode/Synchronous Transport Module. In ATM, a method of communications that transmits data streams synchronized to a common clock signal (reference clock). In SDH, it is "Synchronous Transport Module" and is the basic unit (STM-1 = 155Mbit/s, STM-4 = 622Mbit/s, STM-16 = 2.5Gbit/s) of the Synchronous Digital Hierarchy.
Streaming	A collection of data sent over a data channel in a sequential fashion. The bytes are typically sent in small packets, which are reassembled into a contiguous stream of data. Alternatively, it is the process of sending such small packets of data.
Streaming architecture	A model for the interconnection of stream-processing components, in which applications dynamically load data as they output it. Dynamic loading means data can be broadcast continuously.
String	Data composed of a sequence of characters, usually representing human-readable text.
Symbol rate	The number of signal elements of the signal transmitted per unit of time. The baud is usually used to quantify this, one baud being equal to one single element per second.
Synchronization	The process of adjusting the corresponding significant instants of signals to make them synchronous.
Synchronous	A term used to describe a transmission technique that requires a common clock signal (or timing reference) between two communicating devices to co-ordinate their transmissions.
Synchronous network	A network in which the corresponding significant instants of nominated signals are adjusted to make them synchronous.

-T-

TCP	Transmission Control Protocol.
TCP/IP	Transmission Control Protocol/Internet Protocol. A networking protocol that provides reliable communications across interconnected networks made up of computers with diverse hardware architectures and operating systems. The TCP portion of the protocol, a layer above IP, is used to send a reliable, continuous stream of data and includes standards for automatically requesting missing data, reordering IP packets that might have arrived out of order, converting IP datagrams to a streaming protocol, and routing data within a computer to make sure the data gets to the correct application. The IP portion of the protocol includes standards for how computers communicate and conventions for connecting networks and routing traffic.
TDM	Time-division multiplexing. Multiplexing in which several signals are interleaved in time for transmission over a common channel.
Telecommunication	Any transmission and/or emission and reception of signals representing signs, writing, images and sounds or intelligence of any nature by wire, radio, optical or other electromagnetic sys tems.
TFTS	The Joint EBU/SMPTE Task Force for Time Labelling and Synchronization.
Time Interval Error (TIE)	Time variations in the periods of adjacent cycles or pulses. TIE quantifies the timing perturbations of a video signal's synchronization information. Perturbations are caused by phase noise, crosstalk, add/drop of bits or bytes in Networks, etc. TIE caused by phase noise in telecommunications and broadcast applications are called jitter or wander depending on the frequency of the noise.
Timing recovery [timing extraction]	The derivation of a timing signal from a received signal.
Timing signal	A cyclic signal used to control the timing of operations.
Transmission	The action of conveying signals from one point to one or more other points.
Transparency, digital transparency	The property of a digital transmission channel, telecommunication circuit or connection, that permits any digital signal to be conveyed over it without change to the value or order of any signal elements.
Transport layer	The fourth of the seven layers in the International Organization for Standardization's Open Systems Interconnection (OSI) model for standardizing communications. The Transport layer is one level above the Network layer and is responsible for error detection and correction, among other tasks. Error correction ensures that the bits

	delivered to the receiver are the same as the bits transmitted by the sender, in the same order and without modification, loss or duplication. The Transport layer is the highest of the three layers (Data Link, Network and Transport) that help to move information from one device to another.
TS	Transport Stream. A TS is a data structure defined in ISO/IEC 13818-1 for the MPEG-2 Transport Stream. It is the basis of the ATSC and DVB standards.
TV	Television.
-U-	
Under-crank	A technique in Image acquisition where frames are captured at a lower than nominal rate so that reproduction at the nominal rate provides a fast-motion effect. The term is derived from the use of manually cranked film cameras.
UHDTV	Ultra High Definition Television
UML	Unified Modelling Language. The UML is a language for specifying, visualizing, constructing and documenting the artefacts of software systems. It assists the complex process of software design, making a "blueprint" for construction.
Unicast	A point-to-point networking model in which a packet is duplicated for each address that needs to receive it.
Upstream	One-way data flow from the broadcast client to the head-end.
URI	Uniform Resource Identifier. Also known as a URL.
URL	Uniform Resource Locator. URLs are short strings that identify resources on the WWW: documents, images, downloadable files, services, electronic mailboxes and other resources, etc. They may be thought of as a networked extension of the standard filename concept, in that not only can you point to a file in a directory, but that file and that directory can exist on any machine on the network, can be served via any of several different methods, and might not even be something as simple as a file.
UTC	Universal Time Co-ordinated.
U-U	User-User
-V-	
VBI	Vertical Blanking Interval. The time period in which a television signal is not visible on the screen because of the vertical retrace (that is, the repositioning of the trace to the top of the screen to start a new scan). Data services can be transmitted using a portion of this signal. In a standard NTSC signal, perhaps 10 scan lines are potentially available per channel during the VBI. Each scan line represents a data transmission capacity of about 9600 baud. In 625-line systems, about 20 scan lines are available in the VBI.
VBR	Variable Bit-Rate. A type of traffic that, when sent over a network, is tolerant of delays and changes in the amount of bandwidth it is allocated (e.g. data applications).
VC	Virtual Circuit. A generic term for any logical communications medium.
VHF	Very High Frequency.
VHS	Video Home System.
Virtual LAN	A logical association of users sharing a common broadcast domain.
-W-	
WAN	Wide Area Network. A communications network that connects geographically separated areas.
Wander	The low-frequency spectral components of the TIE that are generally within the phase tracking or synchronization bandwidth of subsequent video processing equipment such that the peak time variation of the significant instances from the ideal is not meaningful. TIE spectral components below a specified demarcation frequency are considered wander and are measured in terms of frequency Drift Rate, or Frequency Drift, as opposed to units of time. Long-term non-cumulative variations of the significant instants of a digital signal from their ideal positions in time.
WWW	World Wide Web / the Web. A hypertext-based, distributed information system created in Switzerland and used for exploring the Internet. Users may create, edit or browse hypertext documents on the Web.
-X-	
XTP	eXtended Transport Protocol. A network-level interface appropriate for file transfer. XTP can operate in a “raw” mode in which it encompasses both the Network and Physical layers, or it can operate on top of IP. XTP in raw mode achieves some

	efficiency and has the possibility of using features of the underlying physical media (such as the QoS for ATM) that is not possible when XTP is used on top of IP.
-Y-	
YUV	True-colour encoding that uses one luma value (Y´) and two colour difference values (UV).