VBrick

MPEG-2 Transport vs. Program Stream

White Paper

"What is the difference between Program Stream and Transport Stream, and why do we currently only support the Transport Stream format?" Well, this topic is going to lengthy! I've included more detail than usual, so we'll start with a brief discussion. If you are interested in the detail, I'll provide some of that too.

We are talking about how MPEG-2 is delivered, NOT how it is encoded. So whether a video is Transport Stream or Program Stream has nothing to do with the quality of the video encoding or the MPEG-2 GOP structure. The format for delivery is independent of the content.

Why are there two formats? Well, because there are conflicting applications. If you want to save MPEG-2 to a file on your computer, you are not very concerned about transmission. If you want to transmit MPEG-2, you are not very concerned with file format. Happily, the MPEG-2 standards address both.

Unfortunately, we have some trouble with language. The word "Program" could mean "what I'm watching on TV", or it could mean "a channel", or it could mean "a specific format". We are talking about the format, and to avoid confusion, I'll try to use the word "content" when talking about the MPEG-2 audio/video. But you need to be aware that different industries use the term "Program" in different ways!

It is very important to point out that "Program Stream" has a very specific meaning. MPEG-2 has two different multiplexing schemes: Program Stream and Transport Stream. The Program Streams are mostly used in storage applications. Broadcast usage commonly uses the Transport Stream format. If you have one content channel (one program), it does NOT imply that the stream that carries the program would be a Program Stream. In broadcast usage it would be a so-called Single Program Transport Stream (as defined by ISO 13818-1): a multiplexed collection of concatenated Program Streams without beginning or end. VBrick currently only supports Transport Stream which is superior to Program Stream for streaming applications.

- An MPEG-2 Program Stream contains one, and only one, content channel. A Program Stream is like a single-passenger car without shock absorbers: drive it on a smooth road.
- An MPEG-2 Transport Stream can contain one or more content channels. A Transport Stream is like a high end car or bus: it can carry one or more passengers and has a good suspension system that can handle the bumps in the road. VBrick supports Single Program Transport Stream, so this is like a single passenger car with good suspension.
- Authoring tools, such as Adobe, Avid, ULead, Media100, can produce MPEG-2 Program Streams (usually with 3rd party plug-ins). This is because the intended applications are the creation of files for distribution on disk, including DVD. Conversion to Transport Stream format is required for streaming to VBrick. This conversion is easily accomplished with a VBrick software product. Some vendors like to stream Program Streams directly...but this is not a good solution because it is not compliant with the broadcast industry, Set Top Boxes, and is error prone.
- In the DVB (satellite TV) world, a satellite needs to deliver, via radio, one stream to subscribers. That one stream needs to carry many TV channels. To do this, the many channels are multiplexed into a Transport Stream. The receiver actually receives all of the channels at once (it has no choice!), but it only demultiplexes and then decodes the selected content, one at a time, from the delivered Transport Stream.
- When sending MPEG over IP, there is less value in having one Transport Stream that contains multiple content channels. It is more useful, flexible, and uses less bandwidth when each content channel has its own IP multicast address. This leads you to single a content Transport Stream which VBrick supports.

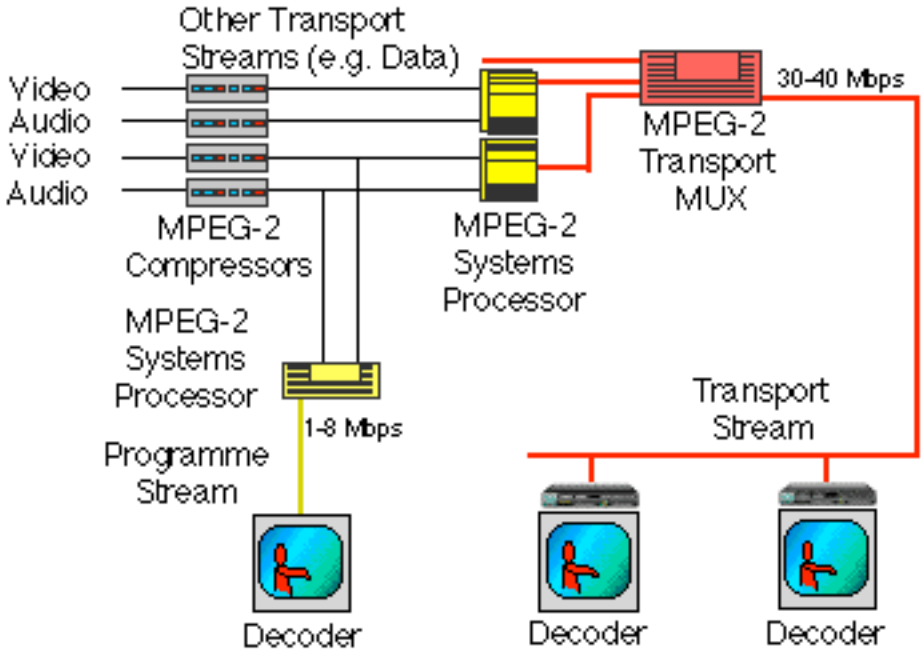
- Commercial broadcasters and cable companies use Transport Stream format for delivery of content to Set Top Boxes. In a mixed, streaming-to-the-desktop, VBrick encoder/decoder, and STB world, it is better to use only one format which takes you to Transport Stream.

MPEG-2 Multiplexing

The MPEG-2 standard allows two forms of multiplexing:

- **MPEG Program Stream** A group of tightly coupled PES packets referenced to the same time base. Such streams are suited for transmission in a relatively error-free environment and enable easy software processing of the received data. This form of multiplexing is used for video playback and for some network applications.
- **MPEG Transport Stream** Each PES packet is broken into fixed-sized transport packets forming a general purpose way of combining one or more streams, possibly with independent time bases. This is suited for transmission in which there may be potential packet loss or corruption by noise, or / and where there is a need to send more than one program at a time.

Combining Elementary Streams from encoders into a Transport Stream (red) or a Program Stream (yellow).



The above illustration shows a classic MPEG system model, where the audio and video codecs are independent. Obviously, VBrick does the audio/video encoding and multiplexing in one unit. To the extent a multichannel Transport Stream is desired, a Transport Stream Mux can assemble the required format.

The Program Stream is widely used in digital video storage devices, and also where the video is reliably transmitted over a network (e.g. video-clip down load). *Digital Video Broadcast (DVB)* uses the MPEG-2 Transport Stream over a wide variety of underlying networks. Since both the Program Stream and Transport Stream multiplex a set of PES inputs, interoperability between the two formats may be achieved at the PES level.

MPEG Transport Streams

A transport stream consists of a sequence of fixed sized transport packet of 188 bytes. Each packet comprises 184 bytes of payload and a 4 byte header. One of the items in this 4 byte header is the 13 bit *Packet Identifier (PID)* which plays a key role in the operation of the Transport Stream.

The format of the transport stream is described using the figure below (a later section describes the detailed format of the TS packet header). This figure shows two elementary streams sent in the same MPEG-2 transport multiplex. Each packet is associated with a PES through the setting of the PID value in the packet header (the values of 64 and 51 in the figure). The audio packets have been assigned PID 64, and the video packets PID 51 (these are arbitrary, but different values). As is usual, there are more video than audio packets, but you may also note that the two types of packets are not evenly spaced in time. The MPEG-TS is not a time division multiplex. Packets with any PID may be inserted into the TS at any time by the TS multiplexer. If no packets are available, it inserts null packets (denoted by a PID value of 0x1FFF) to retain the specified TS bit rate. The multiplexer also does not synchronise the two PESs, indeed the encoding and decoding delay for each PES may (and usually is) slightly different. A separate process is required to synchronise the two streams.

Transmission of the MPEG-TS

Although the MPEG TS may be directly used over a wide variety of media (as in DVB), it may also be used over a communication network. It is designed to be robust with short frames, each one being protected by a strong error correction mechanism. It is constructed to match the characteristics of the generic radio or cable channel and expects an uncorrected Bit Error Rate (BER) of better than 10-10. (The different variants of DVB each have their own outer coding and modulation methods designed for the particular environment.)

The MPEG-2 Transport Stream is so called, to signify that it is the input to the *Transport Layer* in the ISO *Open System Interconnection (OSI)* seven-layer network reference model. It is not, in itself, a transport layer protocol and no mechanism is provided to ensure the reliable delivery of the transported data. MPEG-2 relies on underlying layers for such services.

The MPEG TS packet size also corresponds to eight *Asynchronous Transfer Mode (ATM)* cells, assuming 8 byte overhead (associated with the *ATM Adaptation Layer (AAL)*).

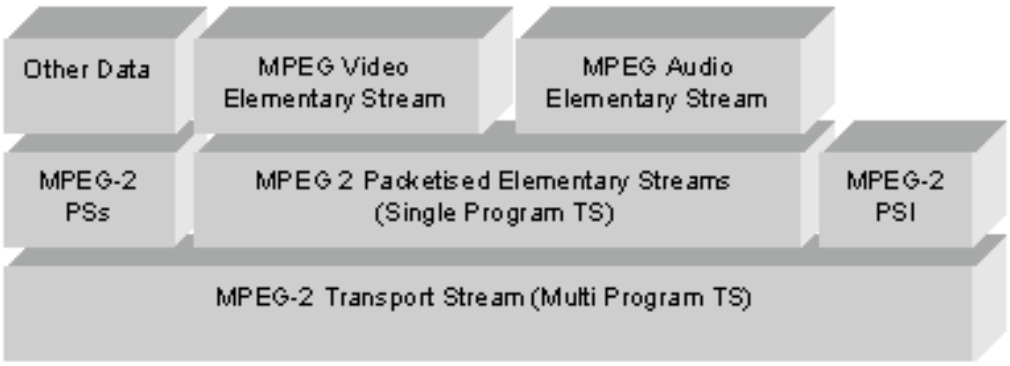
Single and Multiple Program Transport Streams

A TS may correspond to a single TV program, or multimedia stream (e.g. with a video PES and an audio PES). This type of TS is normally called a *Single Program Transport Stream (SPTS)*.

An SPTS contains all the information required to reproduce the encoded TV channel or multimedia stream. It may contain only an audio and video PESs, but in practice there will be other types of PES as well. Each PES shares a common timebase.

In the DVB case, one or more SPTS streams are combined to form a *Multiple Program Transport Stream (MPTS)*. This larger aggregate also contains all the control information (*Program Specific Information (PSI)*) required to co-ordinate the DVB system, and any other data which is to be sent.

Streams supported by the MPTS



Most transport streams consist of a number of related elementary streams (e.g. the video and audio of a TV program). The decoding of the elementary streams may need to be co-ordinated (synchronised) to ensure that the audio playback is in synchronism with the corresponding video frames. Each stream may be tightly synchronised (usually necessary for digital TV programs, or for digital radio programs), or not synchronised (in the case of programs offering downloading of software or games, as an example). To help synchronisation time stamps are sent in the transport stream.

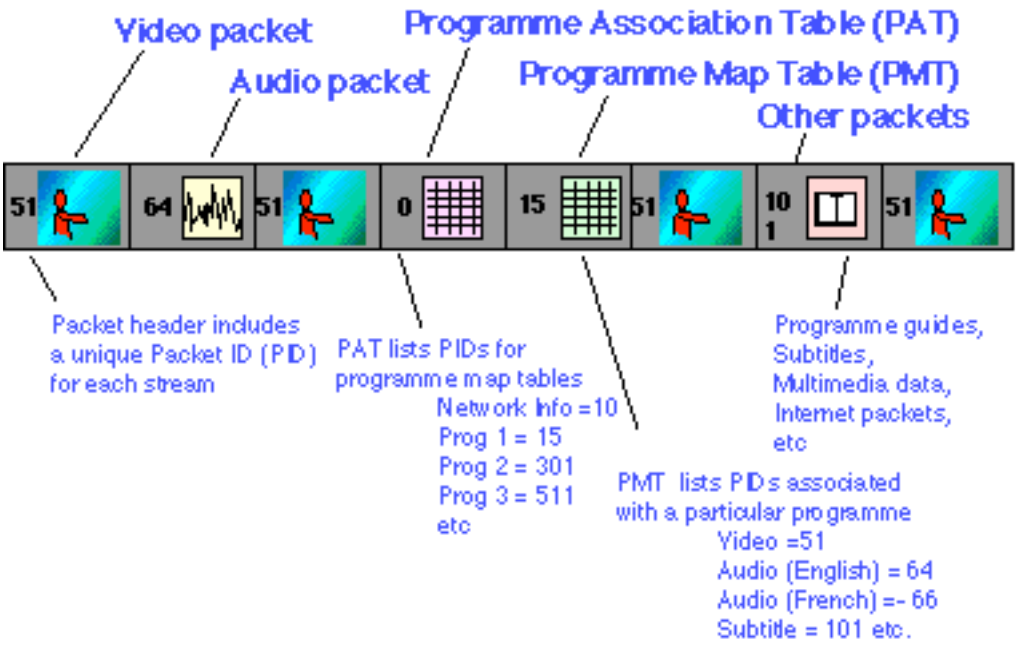
They are two types of time stamps:

- The first type is usually called a *reference time stamp*. This time stamp is the indication of the current time. Reference time stamps are to be found in the PES syntax (ESCR), in the program syntax (SCR), and in the transport packet adaption *Program Clock Reference (PCR)* field.
- The second type of time stamp is called *Decoding Time Stamp (DTS)* or *Presentation Time Stamp (PTS)*. These time stamps are inserted close to the material to which they refer (normally in the PES packet header). They indicate the exact moment where a video frame or an audio frame has to be decoded or presented to the user respectively. These rely on reference time stamps for operation.

Signalling Tables

For a user to receive a particular transport stream, the user must first determine the PID being used, and then filter packets which have a matching PID value. Because VBrick sends a Single Program Transport Stream, we have a special capability to automatically detect the PID and automatically configure the decoder to display the correct content. To help the user identify which PID corresponds to which program, a special set of streams, known as Signalling Tables, are transmitted with a description of each program carried within the MPEG-2 Transport Stream. Signalling tables are sent separately to PES, and are not synchronised with the elementary streams (i.e they are an independent control channel).

DVB Signalling Tables and Transport Layer PIDs



The tables (called *Program Specific Information (PSI)* in MPEG-2) consist of a description of the elementary streams which need to be combined to build programs, and a description of the programs. Each PSI table is carried in a sequence of PSI Sections, which may be of variable length (but are usually small, c.f. PES packets). Each section is protected by a *CRC (checksum)* to verify the integrity of the table being carried. The length of a section allows a decoder to identify the next section in a packet. A PSI section may also be used for down-loading data to a remote site. Tables are sent periodically by including them in the transmitted transport multiplex.

MPEG-2 Signalling Tables

PAT - Program Association Table (lists the PIDs of tables describing each programme). The PAT is sent with the well-known PID value of 0x000.

CAT - Conditional Access Table (defines type of scrambling used and PID values of transport streams which contain the conditional access management and entitlement information (EMM)). The PAT is sent with the well-known PID value of 0x001.

PMT - Program Map Table (defines the set of PIDs associated with a programme, e.g. audio, video, etc.)

NIT - Network Information Table (PID=10, contains details of the bearer network used to transmit the MPEG multiplex, including the carrier frequency)

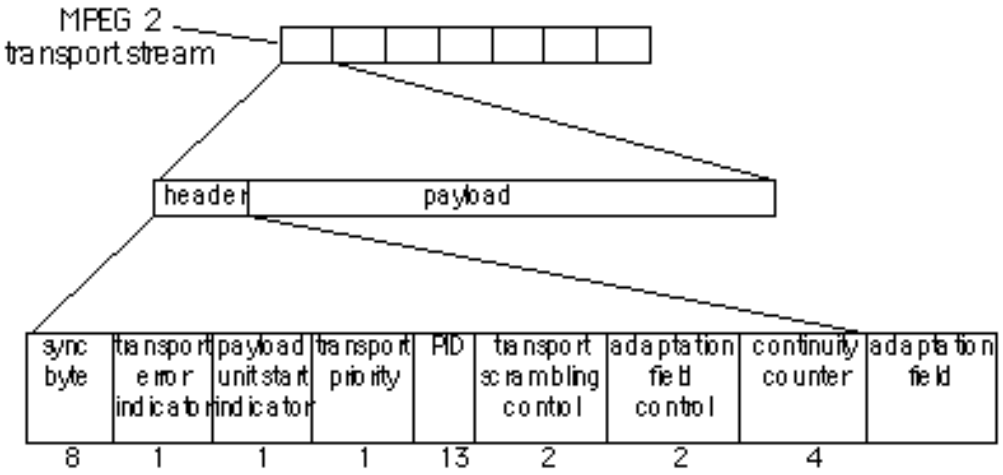
DSM-CC - Digital Storage Media Command and Control (messages to the receivers)

Program Service Information (SI) provided by MPEG-2 and used by DVB

To identify the required PID to de-multiplex a particular PES, the user searches for a description in a particular table, the *Program Association Table (PAT)*. This lists all programs in the multiplex. Each program is associated with a set of PIDs (one for each PES) which correspond to a *Program Map Table (PMT)* carried as a separate PSI section. There is one PMT per program. DVB also adds a number of additional tables. including those shown below.

Format of a Transport Stream Packet

Each MPEG-2 TS packet carries 184 byte of payload data prefixed by a 4 byte (32 bit) header.



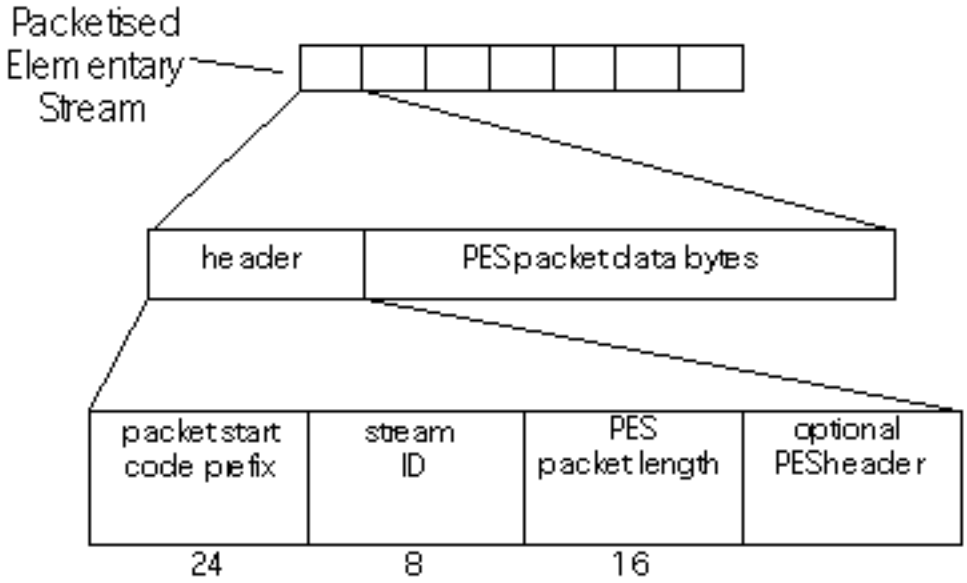
The header has the following fields:

- The header starts with a well-known *Synchronisation Byte* (8 bits). This has the bit pattern 0x47 (0100 0111).
- A set of three flag bits are used to indicate how the payload should be processed.
    1. The first flag indicates a transport error.
    2. The second flag indicates the start of a payload (payload unit start indicator)
    3. The third flag indicates transport priority bit.
- The flags are followed by a 13 bit *Packet Identifier (PID)*. This is used to uniquely identify the stream to which the packet belongs (e.g. PES packets corresponding to an ES) generated by the multiplexer. The PID allows the receiver to differentiate the stream to which each received packet belongs. Some PID values are predefined and are used to indicate various streams of control information. A packet with an unknown PID, or one with a PID which is not required by the receiver, is silently discarded. The particular PID value of 0x1FFF is reserved to indicate that the packet is a null packet (and is to be ignored by the receiver).

- The two scrambling control bits are used by conditional access procedures to encrypted the payload of some TS packets.
- Two adaption field control bits which may take four values:
    1. 01 – no adaptation field, payload only
    2. 10 – adaptation field only, no payload
    3. 11 – adaptation field followed by payload
    4. 00 - RESERVED for future use
- Finally there is a half byte *Continuity Counter* (4 bits)

Two options are possible for inserting PES data into the TS packet payload:

1. The simplest option, from both the encoder and receiver viewpoints, is to send only one PES (or a part of single PES) in a TS packet. This allows the TS packet header to indicate the start of the PES, but since a PES packet may have an arbitrary length, also requires the remainder of the TS packet to be padded, ensuring correct alignment of the next PES to the start of a TS packet. In MPEG-2 the padding value is the hexa-decimal byte 0xFF.
2. In general a given PES packet spans several TS packets so that the majority of TS packets contain continuation data in their payloads. When a PES packet is starting, however, the payload_unit_start_indicator bit is set to '1' which means the first byte of the TS payload contains the first byte of the PES packet header. Only one PES packet can start in any single TS packet. The TS header also contains the PID so that the receiver can accept or reject PES packets at a high level without burdening the receiver with too much processing. This has an impact on short PES packets.



Option Transport Packet Adaption Field

The presence of an adaptation field is indicated by the adaption field control bits in a transport stream packet. If present, the adaption field directly follows the 4 B packet header, before any user payload data. It may contain a variety of data used for timing and control.

One important item in most adaption packets is the *Program Clock Reference (PCR)* field.

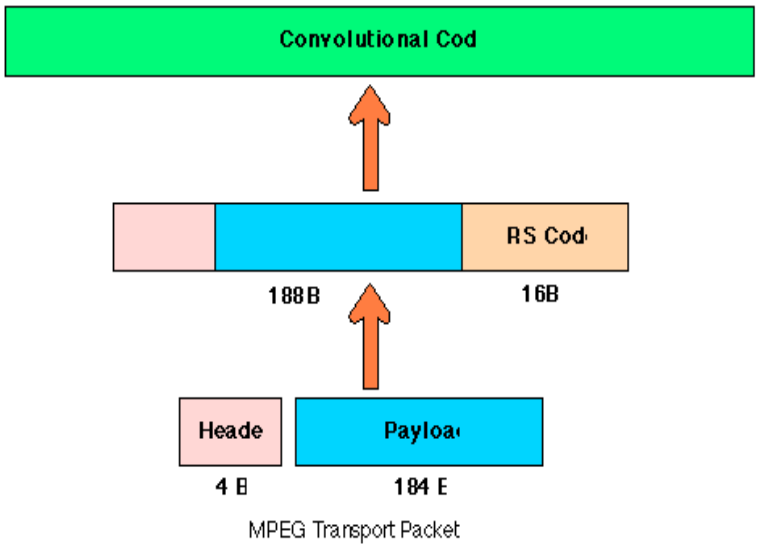
Another important item is *splice_countdown* field. This field is used to indicate the end of a series of ES access units. It allows the MPEG-2 TS multiplexer to determine appropriate places in a stream where the video may be spliced to another video source without introducing undesirable disruption to the video replayed by the receiver. Since MPEG-2 video uses inter-frame coding a seamless switch-over between sources can only occur on an I-frame boundary (indicated by a splice count of 0). This feature may, for instance, be used to insert a news flash in a scheduled TV transmission.

One other bit of interest here is the *transport_private_data_flag* which is set to 1 when the adaptation field contains private data bytes. Another is the *transport_private_data_length* field which specifies how many private data bytes will follow the field. Private data is not allowed to increase the adaptation field beyond the TS payload size of 184 bytes.

DVB Satellite

DVB transmission via satellite (often known as DVB-S), defines a series of options for sending MPEG-TS packets over satellite links. The DVB-S standard requires the 188 B (scrambled) transport packets to be protected by 16 bytes of Reed Solomon (RS) coding which VBrick does not currently support.

MPEG Transport Service Encoding Specified by DVB-S



The resultant bit stream is then interleaved and convolutional coding is applied. The level of coding may be selected by the service provider (from 1/2 to 7/8 depending on the intended application and available bandwidth). The digital bit stream is then modulated using *Quadrature Phase Shift Keying (QPSK)*. A typical satellite channel has a 36 MHz bandwidth, which may support transmission at up to 35-40 Mbps (assuming delivery).

About VBrick Systems, Inc.

VBrick is the leader in Enterprise IP Video solutions, with over 6,000 corporate, education and government customers and 60,000 installations worldwide. VBrick solutions work over standard IP networks and the Internet to deliver rich media communications that connect people everywhere – from employees and customers, to partners and shareholders. Our comprehensive product suite and end-to-end solutions are used in a wide range of live and on-demand applications including meeting and event broadcasts, distance learning, digital signage, TV distribution, video surveillance, and Web-based marketing campaigns. Headquartered in Wallingford, CT, VBrick's products and services are available through industry-leading value-added resellers.

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