Course Description

Triveni Digital: MPEG101 with PSIP overview
This course is a two part overview of the basic elements that make up the MPEG2 Transport Stream. This course of instruction covers detailed Transport, Video and Audio PES layer service impacting non-compliant issues. Key metrics like Continuity Counter errors, MDI, PCR Timing, Buffering, Metadata (PSI & PSIP) and GOP and their relationship to the TS layer is explored in detail. A Program Specific Information Protocol (PSIP) overview is added.
Course Sections Part 1

- Encoding Basics
- Transport Stream Elements
- Multiplexor Functions
- Metadata
- MPEG Timing Elements and Lip Sync considerations
- Decoder Buffering Functions
Part 1

MPEG2 Encoding Elements
Digital Compression starts at the MPEG encoder

MPEG2 or MPEG4 CODECS (Coder Decoder Algorithm) can be carried in an MPEG2 Transport Stream

The encoder filters noise in the input signal and compresses baseband video & audio or uncompressed digitized video/audio/data

Video and Audio, and sometimes Data elements are encoded into a sequence of frames

A frame is a single image from a video or audio sequence

In most countries, one frame occurs every 33 milliseconds

Each frame is encoded in one of three ways:
I Frames

- **I-picture: intra-picture** encoding, similar to jpeg encoding (exploiting spatial redundancy).
  - A digitized picture of *everything* in the camera frame
  - Highest amount of data of all other frame types
  - ‘Group Of Pictures’ always start with an I frame or **Anchor** frame
  - B & P frames are calculated or based off of the I frame
  - “I” stands for “Intra” coded
P Frames

- **P-picture. predictive** encoding, using motion adjusted deltas from a previous reference frame (exploiting temporal redundancy).
  - Compressed using data referenced from closest preceding I or P frame.
  - P frames encode the **changes or differences** in motion thus saving bitrate
  - GOP (Group of Pictures (frames) with back-to-back P frames usually indicate fast motion as the data rate is rapidly changing
B Frames

- **B-picture. bi-directional** encoding, using motion adjusted deltas from a previous and a future frame (exploiting temporal redundancy).
  - Uses Data from preceding and following I & P frames
  - Depends on data before and/or after in video sequence
  - Cannot calculate from another B frame
  - Further reduces bitrate requirements for encoding

- ALL professional encoders attempt to filter noise out of the input before the encoding process
MPEG-2 Video Encoding (Contd.)

Example 1. Panning Camera

I-picture  B-picture  I-picture

Example 2. Moving Object

I-picture  B-picture  I-picture
MPEG-2 Video Encoding

Group of Pictures = GOP

- Series of encoded frames consisting of a single ‘I’ frame with P & B frames
- A GOP begins with an ‘I’ frame and ends with last frame before the next ‘I’ frame
- All frames within the GOP depend directly or indirectly on data from the I frame
- Relationships between GOPs:  OPEN or CLOSED
- Closed GOP is self-contained.  No dependence on data outside GOP
- Open GOP can use data from I frame of following GOP
- Advanced system use GOP-less structures use P/B Frames only.  No I frames
MPEG-2 Video Encoding

Typical GOP Structures

Typical low motion GOP sequence:
- I Frame: 216.6 Kb
- P Frame: 49.9 Kb
- B Frame: 83.45 Kb

Typical high motion GOP sequence:
- I Frame: 183.2 Kb
- P Frame: 59.9 Kb
- B Frame: 44.5 Kb
MPEG-2 Video Encoding (Contd.)

- Encoder emits sequence of encoded frames (Aud & Vid or Data)
- Sizes of encoded frames vary based upon compression
- Encoded frames are packed into packetized elementary stream (PES) packets
- PES packets are packed into MPEG-2 transport packets (All packets for single video or audio or data stream have same PID value) and output from the encoder
- Overall compression ratio at this layer is 50:1 or more
- Can be quite an efficient process and allows for multichannel services in the same transport bandwidth!
AC-3 Audio Encoding

- Audio **frames**, each 32 milliseconds in length, are encoded.
- Encoded frame size depends only on bitrate.
- Encoded frames are packed into **packetized elementary stream** (PES) packets.
- PES packets are packed into MPEG-2 transport packets. (All packets for single audio stream have same **PID** value.)
ATSC/ SCTE Audio Formats

- ATSC uses AC-3 audio encoding, with up to 6 audio channels: left, right, center, left surround, right surround, low frequency enhancement.
- The full set is often called 5.1 audio.
- The sampling rate is always 48 kHz.
- The encoded bit rate may be up to 384 kbps.
- AAC, MPEG1 Audio codecs are also commonly used.
MPEG2 Transport Stream Elements
MPEG Transport Basics - PSI metadata

- MPEG Transport Stream Basics
  - Packet header
- PSI Tables metadata
  - PAT
  - PMT
- Elementary streams
  - Encoding
  - Buffering
  - Synchronization
A Special Use Case of *MPEG-2 transport stream*

Other types of systems use MPEG packets such as Cable Modems (DOCSIS) and Banking systems among others.

Digital Video and Audio require very discrete timing information to be present along with the and inside the MPEG2 packets.

May contain multiple *virtual channels*

- **Video channels**
  - A video stream
  - One or more audio streams
  - Possibly one or more data streams

- **Audio channels**
  - One or more audio streams
  - Possibly one or more data streams

- **Data-only channels**, One or more data streams
MPEG-2 Transport Stream

- Made up of 188-byte transport packets, each with 4 byte header & 184 byte payload
- Each packet contains any ONE kind of information—audio, video, data, PSI, …
We say transport packets have multiple interleaved *elementary streams* -- audio, video, data, PSI, ...

Packets belonging to the same elementary stream are identified by *packet id* (PID) in packet header (same color in our illustrations).

These three packets are the same color. They have the same PID and belong to the same Elementary stream.
MPEG-2 Transport Stream - Header Fields

Noteworthy fields:

1) Sync Byte – Find packet boundary

2) PID – Used to identify stream type while multiplexing/ de-multiplexing the TS stream

3) Continuity Counter – Identify packet loss

4) PCR stamp in adaptation field – Clock sync
MPEG-2 Elementary Stream

- Header (4 Bytes)
- 188 Bytes

- Sync Byte
- PID
- Continuity Counter
- Adaptation Field (Optional)
- PES x
- Optional Fields
- Stuffing Bytes
- PCR

- Only PTS on Audio PES packet

Adaptation Field on Video PID's Only

Or other Payload (Pat, PMT, PSIP, etc)
MPEG Header Fields: **Sync Byte**

- When a "decoder" first tunes, all it sees are a stream of 0’s and 1’s
- The "decoder" must first identify the beginning of packets before it can interpret the stream
- The "decoder" uses the **Sync Byte** field to do this

```
01010001111010010101101010001100011110010111000
```

Decoder: Receiver or set top box

MPEG Data Prior to Packet Sync
MPEG Header Fields: Sync Byte (Contd.)

- The Sync Byte of a packet is always 0x47 (Hexadecimal) or 01000111 (Binary)

- The decoder looks for strings of zeros and ones which match the pattern of the sync byte (see red below)

```
010100011101000111101001010110101000111010001110011110010111
(0x47)(0x47)
```

010100011110100101101001010110101000111010001110011110010111
0011110010111 (0x47)
MPEG Header Fields: Sync Byte (Contd.)

- Once the decoder finds a 0x47 in the stream, it looks 187 bytes down the stream, and looks for another 0x47.
- If it finds three Sync Bytes in a row, then the Decoder has Found Sync and assumes packet boundaries from then on.
- Each packet is tested for 0x47 as soon as it arrives. If a packet arrives with an incorrect sync byte, the decoder starts over. This is called “SYNC LOSS”.

### Found Sync

```
0x47  187 bytes  0x47  187 bytes  0x47  187 bytes  Packet 188 bytes
```

### Sync Lost

```
Packet 188 bytes  Packet 188 bytes  0x32  11010101010111011010101010001
```
MPEG Header Fields: Sync Byte (Contd.)

- If you don’t have Packet Sync, the decoder cannot find packet boundaries. You will not be able to decode at all.

- Packet Sync problems typically occur in hardware at packet boundaries during format converters, edge devices, demodulators etc:
  - ASI to SMPTE-310
  - ASI to Gig-E
  - ASI to Microwave or QAM
  - Satellite to ASI
MPEG2 Multiplexor Functions
The Digital Pipe “A Contiguous Bitstream”

MPEG-2 Transport Stream

184-Byte Payload

4-Byte Packet Header

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PI Ds Defined – Example ATSC Bitstream MUX

PSIP Tables

Data channel

Data-enhanced Audio/Video channel

Audio/Video channel

MPEG-2 Transport Stream

Multlexer

PSIP Generator

Data Server

Audio Encoder

Video Encoder

PIDs Defined – Example ATSC Bitstream MUX

PAT

PMT

Audio

Data

Null

Video

PSIP
PI Ds Defined - Example Digital Cable Bitstream

MUX

Video/Audio channel

Audio Encoder

Video Encoder

Video/Audio channel

Audio Encoder

Video Encoder

Video/Audio channel

Audio Encoder

Video Encoder

Video/Audio channel

Audio Encoder

Video Encoder

MPEG-2 Transport Stream

PAT

PMT

Null

CAT

Video

Audio

Multi-plexer
Typical System Block Diagram

Transmitter

- Baseband Video, Audio & Data In
- MPEG Encoder
- MPEG Encoder
- MPEG Encoder
- MPEG Encoder
- PSIP Generator
- EPG Data In
- MUX
- ASI to SMPTE-310 Converter
- XMTR
- DTV Transmitter

Receiver

- Decode Circuits
  - Video
  - Audio
  - Data
- DTV Receiver (8VSB or QAM)
- DTV Decode Circuits
- De-MUX
- RCVR
- Video
PIDs in the PIPE "Multiplexed PES Streams"

- **MPEG-2 Transport Stream**
  - **Virtual Channel:** Program 3
    - 1-Video and 2-Audios
  - **Virtual Channel:** Program 4
    - 1-Video and 3-Audios
  - **PSIP metadata:** MGT, STT, VCT, EITs, RTT

- **PIDs & Descriptors**
  - 0: PIDs & Descriptors that apply to the entire transport stream
  - 1
  - 2
  - 150
  - 151
  - 152
  - 260
  - 261
  - 262
  - 263
  - 8187
  - 7680
  - 7690

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When a set top box first receives a Transport Stream, it demultiplexes that stream based on PID.
**MPEG Header: Continuity Counter & CC Errors**

- The continuity counter is a 4 bit field in the header which increments by 1 each time a packet comes out on a specific PID:

  All Packets PID 0x52

  ![Diagram](image1)

- When a PID ‘skips’ one value of the continuity Counter, we call it a ‘Continuity Error.’ This means one or more packets were lost.

  ![Diagram](image2)
MPEG Header: Continuity Counter (Contd.)

Identifies WHEN we lose Packets, but not HOW MANY!

- Packet loss causes many other kinds of analysis to ‘reset’ or give bogus results for other TS area measurements.
- Any analysis based on an average over many packets will automatically reset when it encounters continuity problems.
- Since a continuity error mean ‘some packets’ have been lost, frequent continuity errors should be one of the FIRST things you look for when conducting MPEG analysis.
Three main monitoring and troubleshooting lessons:

- **Fix Continuity Problems first**
  - Continuity errors create bogus alarms in other areas
  - Until you resolve the continuity problems, it will be very hard to determine if you have other problems in your stream

- To Be Discussed

- To Be Discussed
MPEG2 Metadata Functions
Metadata

- Data about included data is metadata and orchestrates the decode process
- Describes contents (i.e. label on a can of soup)
- Metadata tells the decoder which kinds of information are contained in each PID, and which PID’s go together.

- There are two kinds of Metadata
  - Program Specific Information (PSI) - Tables in the stream defined in the MPEG standards
  - Program and System Information Protocol (PSIP) - Tables defined in ATSC A/65

Later In This Presentation (Detailed in Part 2)
PSI Tables (MPEG-2 Tables)

- **PAT** - Program Association Table
  - Appears in PID 0x0000
  - Identifies MPEG-2 *programs* in transport stream and gives PIDs for their PMTs
  - The PAT is on PID 0x00. This is the first PID or ‘Base PID’ a MPEG decoder looks for

- **PMT** - Program Map Table
  Identifies elementary streams in program (virtual channel), and gives their PIDs.
**MPEG-2 Program Specific Information (PSI)**

- Gives very basic tuning information:
  - **PAT** (Program Association Table): one for entire transport stream; identifies “programs” (virtual channels) in stream and gives PIDs for PMTs.
  - **PMT** (Program Map Table): one per “program”; identifies elementary streams in “program” and gives their types (audio, video, etc.) and PIDs.

- Supports tuning by physical channel number and MPEG-2 program number.

- PSI Table Intervals in the Transport stream
  - PAT should be present at every 100ms
  - PMT should be present at every 400ms
MPEG-2 PSI Tables (Contd.)

PAT (always on PID 0x0)
Station TSID
PMT 1 -> On PID 0x30
PMT 2 -> On PID 0x40
PMT 3 -> On PID 0x50

PMT 1
Video PID 0x31
Audio PID 0x34
Audio PID 0x35
PCR_PID 0x31

PMT 2
Video PID 0x41
Audio PID 0x44
Audio PID 0x45
PCR_PID 0x41

PMT 3
Video PID 0x51
Audio PID 0x54
Audio PID 0x55
PCR_PID 0x51
PSI via PID assignments and descriptors tells the decoder that these PIDS go together to make up a program.

- Decoder: Receiver or Set top Box
- "WXXX Channel Video" PID 0x31 Program 1
- "WXXX Channel Audio" PID 0x34 Program 1
Graphical View of PAT/PMT

Program 2
PID 0x0002
Elementary streams found in this PMT

Program 3
PID 0x0003
Elementary streams found in this PMT

Descriptor
Defines Additional Stream Characteristics

Elementary streams found in this PMT

(PID 0x0000)
MPEG2 Timing Elements
Audio-Video Synchronization

- Audio, video are encoded independently, must be synchronized during the Playout process.
- MPEG has to allow for distances and signal processing between the Encoder and Decoder, and still allow for correct decode of the transport stream.
- Lip Sync Issues can occur when timing issues occur!
How to Assure Audio/Video Sync?

- In order for the audio and video Elementary Streams to remain in Sync, the Encoder Clock and the Decoder Clock must remain in sync.

- The next few slides will demonstrate how this happens and what components to check when it fails...
Encoder Inserts PCR

- When the encoder creates a stream of packets, it embeds the current value of its 27 MHz clock into the stream.
- This time reference is called the **PCR: Program Clock Reference**.
- MPEG demands that one **PCR** packet appear in the stream every 100ms.
**Decoder Consumes PCR**

- When the decoder gets a packet containing a **PCR** timestamp, it adjusts its 27Mhz clock accordingly.
PCR Timestamp Issue

- What could conceptually cause PCR timestamp issues?
  - Encoder possibly time stamped incorrectly
  - Decoder possibly failed to consume time stamps
  - PCR packet was accidentally “lost” in transmission

- When PCR time stamps go awry, we have “PCR jitter”
**PCR Jitter Defined**

**PCR Jitter is:**
- Difference between
  the *Actual* Value of the PCR time stamped by encoder
  and
  the *Expected* Value of the PCR as calculated by decoder based on the clock rate and the time at which the PCR value is received.
- **PCR Jitter spec:** 500ns
PCR Rate (Frequency) Offset

**PCR Frequency Offset is:**

- Difference between
  
  the clock frequency calculated at decoder based on actual PCR values received
  
  and
  
  an “ideal” 27 MHz clock, which is the clock rate dictated by the MPEG-2 standard

- **PCR Frequency Offset Spec:**  +/- 810 Hz
**PCR Intervals, Jitter and Rate**

**PCR spec summary:**
- Transmit interval: 100 ms
- Jitter: no more than 500 ns
- Rate: 27 MHz +/- 810 Hz

- Most streams seen in the field are compliant, but every now and then extreme jitter shows up.

**Here’s Why**
What in your network facility could cause PCR timestamp issues?

Three of the most common are:

- It can happen any time you MUX streams
- It can happen at the source encoding
- It can happen on any IP link – due to network lag
PCR Packet Spacing Before Muxing

- Note the Number of Packets between each PCR packet in each Input Stream

<table>
<thead>
<tr>
<th>PID</th>
<th>Packet Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x31</td>
<td>2 Packets</td>
</tr>
<tr>
<td>0x41</td>
<td>1 Packet</td>
</tr>
<tr>
<td>0x51</td>
<td>0 Packets</td>
</tr>
</tbody>
</table>

Video 0x31

Video 0x41

Video 0x51

Transport Stream MUX
PCR Packet Spacing After Muxing

Note that the **PCR** packet spacing has changed!

<table>
<thead>
<tr>
<th>PID</th>
<th>Old Spacing</th>
<th>New Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x31</td>
<td>2 Packets</td>
<td>8 Packets</td>
</tr>
<tr>
<td>0x41</td>
<td>1 Packet</td>
<td>5 Packets</td>
</tr>
<tr>
<td>0x51</td>
<td>0 Packets</td>
<td>2 Packets</td>
</tr>
</tbody>
</table>
Muxing Causes PCR Jitter

- When we MUX multiple streams together, the spacing between the PCR packets in each stream CHANGES.

- The physical shift results in a TEMPORAL shift as well, throwing the time stamps off.

- The TEMPORAL shift in PCR values is referred to as “PCR jitter.”
Muxing Causes PCR Jitter (Contd.)

- The MUX has to RESTAMP all the PCR values to correct for the change in the packet spacing – THIS IS VERY HARD TO DO

- The more services on the output, the harder it is to restamp

- The fewer ‘null’ packets at the output, the harder it is to restamp
What in your network facility could cause PCR timestamp issues?

Three of the most common are:

- It can happen any time you MUX streams
- It can happen at the source encoding
- It can happen on any IP link – due to network lag
PCR Jitter From Incorrect Encoding

- If the MPEG encoder’s parameters are set up incorrectly, you can introduce jitter at the source.

- This is relatively rare, however:
  - If a national programmer sent it’s stream up to the bird with jitter in it, the result would effect all receive sites!
  - Re-encoded streams at the headend may also create PCR jitter.
  - Local broadcast streams could create PCR jitter at the encoder.
What in your network facility could cause PCR timestamp issues?

Three of the most common are:

- It can happen any time you MUX streams
- It can happen at the source encoding
- It can happen on any IP link - due to network lag
The MPEG encoder and MPEG decoder use a 27Mhz ‘clock’ to encode/decode incoming audio and video.

The clock is actually a ‘counter’ which advances every 1/27000000 seconds.
The Encoder and Decoder Clock

- The MPEG encoder and MPEG decoder use a 27Mhz ‘clock’ to encode/decode incoming audio and video.
- The clock is actually a ‘counter’ which advances every 1/27000000 seconds.
The Encoder and Decoder Clock

- The MPEG encoder and MPEG decoder use a 27Mhz 'clock' to encode/decode incoming audio and video.
- The clock is actually a 'counter' which advances every $1/27000000$ seconds.
MPEG2 Decoder Buffering Functions
Presentation Time Stamp - PTS

- Each Frame is marked with a PTS - “Presentation Time Stamp” – a positive number
- The value of the PTS is set to the value of the Encoder Clock when the frame is encoded
As packets flow into the Decoder, a space in memory is set aside for them, one buffer for each PID.
Reconstruction of Frames From Buffer

- Packets form Video and Audio Frames in the buffer

Decoder

27Mhz Clock

1, 2, 3, 4.....

MPEG Packets

Buffer 1 Pid 0x31 Video

<table>
<thead>
<tr>
<th>F1</th>
<th>F2</th>
<th>F3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTS 500</td>
<td>PTS 675</td>
<td>PTS 950</td>
</tr>
</tbody>
</table>

Buffer 2 Pid 0x34 Audio

<table>
<thead>
<tr>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTS 200</td>
<td>PTS 990</td>
</tr>
</tbody>
</table>
The Magic of Decode

- When the value of the Decode clock MATCHES the PTS on the frame, that frame is sent to the decode hardware.

**Diagram:**

- Decoder
  - 27Mhz Clock
  - MPEG Packets
  - PTS 500
  - PTS 675
  - PTS 950
  - PTS 990

- Decode Hardware
  - F1
    - PTS 200

- Buffer 1 Pid 0x31 Video
  - F1
    - PTS 500

- Buffer 2 Pid 0x34 Audio
  - F2
    - PTS 990
Another Frame Goes to Decode Hardware

- Next Frame

Decoder
27Mhz Clock
= 500

MPEG Packets

Decode Hardware

F1
PTS 500

Buffer 1 Pid 0x31 Video
F2
PTS 675
F3
PTS 950

Buffer 2 Pid 0x34 Audio
F2
PTS 990
One More Frame Heads to Decode

- And the next frame...

Decoder
27Mhz Clock
= 675

MPEG Packets

Decoding
Hardware
F2
PTS
675

Buffer 1 Pid 0x31 Video
F3
PTS
950

Buffer 2 Pid 0x34 Audio
F2
PTS
990
Audio and Video Buffers

- Receiver must buffer audio and video frame data until presentation time.
- If data appears too late in the transport stream, buffer underflow results.
- If data appears too early in the transport stream, buffer overflow results.
- Either condition results in garbled play or incorrect synchronization.
- Different decoders/receivers may respond differently to the same underlying buffer violations.
MPEG-2 Transport Synchronization

System Time

Presentation Time Frame 0
Presentation Time Frame 1
Presentation Time Frame 2
Presentation Time Frame 3

Video Frame Video Frame Video Frame Video Frame

Audio Frame Audio Frame Audio Frame

Presentation Time Frame 0
Presentation Time Frame 1
Presentation Time Frame 2

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MPEG-2 Transport Synchronization

System Time ➔ PCR Clock True ➔ PCR Clock True

VPTS ➔ VPTS ➔ VPTS ➔ VPTS

Video Frame | Video Frame | Video Frame | Video Frame

Audio Frame | Audio Frame | Audio Frame

APTS ➔ APTS ➔ APTS
Summary: Audio/Video Sync

- **PCR** values help the Encoder Clock and the Decoder Clock to remain in sync.

- **PCR** jitter can cause synchronization problems for elementary streams.

- Ensure:
  - **PCR** jitter and frequency offsets are within standard limits.
  - Elementary stream buffers limits are NOT violated.

- Large **PCR** jitter values can cause “Lip sync” error.

- Buffer over- or underflow problems may cause “tiling”, “pixelization”/“macro blocking” errors.
Three Things to Remember (2 of 3)

- Three main monitoring and troubleshooting lessons:
  - Fix Continuity Problems first
    - Continuity errors create bogus alarms in other areas
    - Until you resolve the continuity problems, it will be very hard to determine if you have other problems in your stream
  - Check for PCR jitter
    - PCR jitter can cause packet over- or underflow problems
    - Lip synch errors may also be result of PCR jitter
  - To Be Discussed
Summary: MPEG’s 7 Basic Parameters

Per ATSC standards:

- **PAT** Interval: 100ms
- **PMT** Interval: 400ms
- **PCR** Interval: 100ms
  - Max Jitter: 500ns
  - Max Freq. Offset: +/- 810 Hz

Also check:

- Video Buffer
- Audio Buffer
End of Part 1
Part 2

PSI P Data In the Stream
Course Sections Part 2

• PSI P Background
• PSI P Functions
• PSI P Elements
PSI P Background

- Program and System Information Protocol
- Metadata inserted into broadcast stream
- Enables:
  - Tuning to virtual channels
  - Displaying channel name (on channel changes)
  - Interactive electronic program guides (EPGs)
  - Automatic language selection for audio track
  - Caption decoding
  - “V-Chip” function (parental content blocking)
  - Accurate receiver time-of-day clock setting
  - Redistribution Control
Basic functions of PSI P Tables

- **Branding** – Station call letters and channel number

- **Signaling** – V-Chip data, information about audio and video PID’s, Virtual Channel Table

- **Announcement** – Electronic Program Guide (EPG)
PSI P Elements
Signaling vs. Announcement

**Signaling**
- Information about what is "on now"
- Used to assemble program elements into whole
  - Provides linkages
  - Ex: PMT and/or VCT used to link different components of television program (i.e. video and audio)
- Used to define characteristics of current program (descriptors)
  - Captioning, ratings, redistribution...

**Announcement**
- Information about what will be available in the future
- Program Guide information (name, description schedule)
- Characteristics of future programs (captioning, ratings, redistribution...)
- Typically does not provide linkages between program elements
PSIP Generation Architecture

- Traffic/Program System
- Time
- Remote GUI(s)
- Automation System
- PSIP Generator
- Encoder(s)
- Listing Service
- Staging Server
- MUX
- Firewall

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**PSIP metadata found in the ‘Payload’**

Noteworthy fields:

Payload contains **PSIP, PAT, PMT** metadata
**ATSC PSI-P Tables**

- **MGT** - Master Guide Table  
  - Interval: 150ms  
  - Appears in PID 0x1FFB.  
  - Gives PIDs, sizes, and version numbers of other PSI-P tables (except STT). A directory of all PSI-P tables.

- **STT** - System Time Table  
  - Interval: 1,000ms (1 sec)  
  - Appears in PID 0x1FFB  
  - Gives current UTC time.

- **VCT** - Virtual Channel Table  
  - Interval: 400ms  
  - Identifies and describes virtual channels.

*Details to follow*
**ATSC PSI P Tables (Contd.)**

- **RRT** - Rating Region Table  
  Interval: 60,000ms (1 min)  
  - Describes content advisory system(s) being used to rate events.

- **EIT** - Event Information Table  
  - Gives titles, start times, durations, content advisory ratings of *events* (TV programs).

  - EIT has variable intervals:  
    - EIT-0: 500ms  
    - EIT-1: 3,000ms  
    - EIT-2 & up: 60,000ms

- **ETT** - Extended Text Table  
  Interval: Follows it’s EIT  
  - Gives extended textual descriptions of virtual channels and events.

*Details to follow*
**PI Ds in the Stream**

MPEG-2 Transport Stream

- **PID**
  - 0
  - 1
  - 2
  - 1025
  - 501
  - 601
  - 602
  - 8187

**Program Association Table (PAT)**
- TSID = 4100
- PMT PID = 1025
- program_number = 2000

**Program Map Table (PMT) (section)**
- program_number = 2000
- Video PID = 501
- Audio PID (English) = 601
- Audio PID (French) = 602

**PSIP metadata tables:** VCT, MGT, STT, EITs & ETTs

Montreal/Toronto Seminars

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Transport Stream Decoding

- **PSIP** tables (including **VCT**) give mapping from virtual channel number to the correct PIDS.

- MPEG-2 **PAT** and **PMT** tables also give mapping, but in less useful form.
PSI P from the User’s Viewpoint

- “Where am I?”
  - Channel number, channel name

- “Where am I going?”
  - Channels organized by major/minor groups
  - Enables EPG in the receiver/STB
    - What’s on now?
    - What programs do I want to plan to watch?

- “How can I get where I want to go?”
  - Direct entry of channel number
  - Navigation on the EPG grid
"...fully implement **PSI P** to the extent that ATSC A/65B requires."

- Required transmission of all mandatory tables and descriptors
  - MGT, TVCT, EIT-0→3, STT, RRT (except region 1)

- Required tables and descriptors must be populated with proper and correct information

- **At least 12 hours** of populated **EITs** (EIT-0 thru 3)
  - **EITs** must contain correct schedule information
  - Each **EIT** contains 3 hours worth of event information

- Major channel rules from **PSI P** (A/65B) adopted

- Correct Major Channel number must be used

- Correct **TSID s** must be used
VCT -- Virtual Channel Concept

- Breaks the link between RF channel number and user’s notion of channel number
  - Analog broadcast → “channel number” was the same as the RF carrier designation
  - Digital broadcast → “channel number” is defined by Virtual Channel Table (VCT)

- One digital TS can include multiple channels of programming

- 8-VSB carrier freq. may have (probably) shifted during transition (June 2009)
**VCT: Two Part Channel Numbers**

- 1\textsuperscript{st} part: “major channel” (Original analog channel)
- 2\textsuperscript{nd} part: “minor channel”
- Broadcasters retain their brand identity
  - Digital services groupable with analog
  - KZZZ has been associated with Channel 7 for years; KZZZ-DT can be found on Channel 7-1
Virtual Channel Table (VCT)

- Has same info as **PAT & PMTs**, plus more.
- Allows tuning by virtual major-minor channel number, rather than physical channel number and MPEG-2 “program” number.
- Allows language track selection.
- Allows channel name to be displayed on channel changes and in EPG.
- ATSC receivers are designed to use **VCT**; may have trouble with **PAT** and **PMTs** alone.
### Virtual Channel Table (VCT)

<table>
<thead>
<tr>
<th>Virtual Channel</th>
<th>Short Channel Name</th>
<th>Major Channel Number</th>
<th>Minor Channel Number</th>
<th>Modulation Mode</th>
<th>Frequency</th>
<th>TS ID (of Virtual Channel)</th>
<th>Program Number (in Stream)</th>
<th>Extended Text Location</th>
<th>Access Controlled?</th>
<th>Hidden?</th>
<th>Hide from Guide?</th>
<th>Service Type (A/V/D)</th>
<th>Source ID</th>
<th>Service Location Descriptor</th>
<th>other descriptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video Stream</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eng Audio Stream</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fre Audio Stream</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(PID 0x1FFB)
**Comparing PAT vs. VCT**

<table>
<thead>
<tr>
<th><strong>PAT</strong> (Program Association Table)</th>
<th><strong>VCT</strong> (Virtual Channel Table)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table ID</td>
<td>Table ID</td>
</tr>
<tr>
<td>Section Syntax Indicator</td>
<td>Section Syntax Indicator</td>
</tr>
<tr>
<td>Section Length</td>
<td>Section Length</td>
</tr>
<tr>
<td>Transport Stream ID (TSID)</td>
<td>Transport Stream ID (TSID)</td>
</tr>
<tr>
<td>Version Number</td>
<td>Version Number</td>
</tr>
<tr>
<td>Current Next Indicator</td>
<td>Current Next Indicator</td>
</tr>
<tr>
<td>Section Number</td>
<td>Section Number</td>
</tr>
<tr>
<td>Last Section Number</td>
<td>Last Section Number</td>
</tr>
<tr>
<td>Program Number</td>
<td>ATSC protocol version</td>
</tr>
<tr>
<td>Program Map PID</td>
<td>Number of Channels in Section</td>
</tr>
<tr>
<td></td>
<td>Short Name</td>
</tr>
<tr>
<td></td>
<td>Major Channel Number</td>
</tr>
<tr>
<td></td>
<td>Minor Channel Number</td>
</tr>
<tr>
<td></td>
<td>Modulation Mode</td>
</tr>
<tr>
<td></td>
<td>Channel TSID</td>
</tr>
<tr>
<td></td>
<td>Program Number</td>
</tr>
<tr>
<td></td>
<td>Extended Text Message Location</td>
</tr>
<tr>
<td></td>
<td>Descriptor Length</td>
</tr>
<tr>
<td></td>
<td>Descriptor ( )</td>
</tr>
<tr>
<td></td>
<td>Source ID</td>
</tr>
<tr>
<td></td>
<td>Service Type</td>
</tr>
<tr>
<td></td>
<td>Access Controlled</td>
</tr>
<tr>
<td></td>
<td>Hidden / Hide Guide</td>
</tr>
</tbody>
</table>
PSIP and PSI Link

Table Information for a Television Broadcast Stream

- **PAT**
  - (On PID 0x0)
  - Station TSID
  - PMT 1 -> On PID 0x30

- **PMT 1**
  - (On PID 0x30)
  - Video PID 0x31
  - Audio PID 0x34
  - PCR_PID 0x31

- **VCT**
  - On Pid 0x1FFB
  - 4-1
  - WXXX
  - Video PID 0x31
  - Audio PID 0x34

PAT and PMT Tables  |  PSIP table
Transport Stream ID (TSID)

- Assigned to be unique
- FCC maintains list of TSID assignments for North America
- Equivalent for analog:
  Transmission Signal ID (also TSID)
  - **VCT** can point to analog transmission or digital Transport Stream
  - Required if **PSIP** references analog services
Simple Reception of 2 Stations

**Physical channel: 41**
**TSID = 0x0303**

- Virtual Channels:
  - 10-1 — WAAAA-DT
  - 10-2 — WAAAA-D2
  - 10-3 — WAAAA-D3

**Physical channel: 29**
**TSID = 0x0501**

- Virtual Channels:
  - 6-1 — WBBB-DT
  - 6-2 — WBBB-D2
  - 25-1 — CSPAN-DT

Signal coverage area
Directional Antenna Example

Physical channel: 41
TSID = 0x0303

Virtual Channels:
10-1 — WAAA-DT
10-2 — WAAA-D2
10-3 — WAAA-D3

Physical channel: 41
TSID = 0x0501

Virtual Channels:
6-1 — WCCC-DT
6-2 — WCCC-D2
6-3 — WCCC-D3
Virtual Channels -- Translators

Physical channel: 43
TSID = 0x0414

Virtual Channels:
8-1 — WDD-DT
8-2 — WDD-D2
8-3 — WDD-D3

Physical channel: 50
TSID = 0x0414

Virtual Channels:
8-1 — WDD-DT
8-2 — WDD-D2
8-3 — WDD-D3
Virtual Channels — Duopoly

Both may transmit EPG data for Ch. 8-1 to 8-6

Physical channel: 43
TSID = 0x0414

Virtual Channels:
8-1 — WDD-DT
8-2 — WDD-D2
8-3 — WDD-D3

Physical channel: 49
TSID = 0x0416

Virtual Channels:
8-4 — WDD-D4
8-5 — WDD-D5
8-6 — WDD-D6
Main PSI P Tables: 40,000 ft view

- System Time Table (STT)
- Master Guide Table (MGT)
- Virtual Channel Table (VCT)
- Event Information Table (EIT)
- Extended Text Table (ETT)

3-hour time slot

Required for Terrestrial Broadcast (first four timeslots EIT-0 thru EIT-3)
PSI/P Tables: The Big Picture

- **MGT**
  - Table Ref 1
  - Table Ref 2
  - Table Ref 3
  - Table Ref 4
  - Table Ref 5
  - Table Ref 6
  - Table Ref 7

- **VCT**
  - VC 1
  - VC 2

- **RRT**

- **PID Z**

- **ETT**

- **EIT-0**
  - Event 1
  - Event 2
  - Event 3
  - Event 4

- **EIT-1**
  - Event 5
  - Event 6
  - Event 7

- **EIT-2**
  - Event 7
  - Event 8

- **EIT-3**
  - Event 7
  - Event 8

- **Hour 0-3**
  - PID A

- **Hour 3-6**
  - PID B
  - PID C

- **Hour 6-9**
  - PID C
  - PID D

- **Hour 9-12**
  - PID D

- **Table Ref 1**
- **Table Ref 2**
- **Table Ref 3**
- **Table Ref 4**
- **Table Ref 5**
- **Table Ref 6**
- **Table Ref 7**

- **Table Ref 8**
- **Table Ref 9**

- **PID A**
- **PID B**
- **PID C**
- **PID D**

- **PID V**
- **PID W**
- **PID X**
- **PID Y**
**Version "Bubbling"**

- MPEG "rule": Any time the contents of a table changes, its version number must increment.
- Application: Each level in a table hierarchy carries the version number of a referenced, lower level table.
- Thus: Any change in a table will bubble upwards.
- Consequence: Any change in a **PSI** *P* table will be reflected by a version change in the **MGT**!
Master Guide Table (MGT)

- **MGT** is the top-level “roadmap”
  - Identifies what PSIP tables are in transport stream
  - Gives PIDs so receiver can find them
  - Indicates when any table has been updated

Table Reference
- Table Type (VCT, EIT-0, etc.)
- PID where table can be found
- Referenced Table Version
- Referenced Table Size
- <descriptors>

(PID 0x1FFB)
Event Information Tables (EITs)

- Describe “events” (TV programs).
- EIT-0 through EIT-127; each covers 3 hour period
- EIT-0 thru EIT-3 FCC required

Event
- Event ID
- Start Time (GPS)
- Duration in Seconds
- Title (multiple languages)
- Extended Text Location

Descriptors
- Content Advisory
- Closed Captioning
- AC-3 Audio
- Broadcast Flag
### EIT Contents

<table>
<thead>
<tr>
<th>Time</th>
<th>Channel 1</th>
<th>Channel 2</th>
<th>Channel 3</th>
<th>Channel 4</th>
<th>Channel 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:00 PST</td>
<td>XYZ News</td>
<td>Movie: Curious George Goes to Miramar</td>
<td>53 Minutes</td>
<td>Adventures in Taxidermy</td>
<td>Scooter</td>
</tr>
<tr>
<td>17:00 PST</td>
<td>Johnny Star</td>
<td>Network News</td>
<td>Celebrity Bowling</td>
<td>Local News</td>
<td>Thunder Car</td>
</tr>
<tr>
<td>18:00 PST</td>
<td>Blue Moon</td>
<td>Movie: Burnout</td>
<td>Celebrity Bowling</td>
<td>Ben’s Lab</td>
<td>Cartoon Tuesday</td>
</tr>
<tr>
<td>19:00 PST</td>
<td>Canine Capers</td>
<td>Classic Cartoon Hour</td>
<td>Movie: Grand Alliance</td>
<td>Gena</td>
<td>Horace Horse</td>
</tr>
<tr>
<td>20:00 PST</td>
<td>Car 45 Where are You?</td>
<td>Movie: Frontier Brain Surgeon</td>
<td>Movie: Round Lake</td>
<td>Medic-Two</td>
<td></td>
</tr>
<tr>
<td>21:00 PST</td>
<td>Classic Cartoon Hour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Additional Channels

- KXYZ-DT (7-1)
  - Movie: Curious George Goes to Miramar
- KXYZ-D2 (7-2)
  - Car 45 Where are You?
- KXYZ-D3 (7-3)
  - Classic Cartoon Hour
- KXYZ-D4 (7-4)
  - In a Jiffy
- CSPAN-1 (72-1)
  - Viewer Feedback
- CSPAN-2 (72-2)
  - Community Focus

### News and More

- Network News
- Capitol Currents
- FCC Report
- DTV Roundtable
- Legislative Agenda
- Party Line
- City Council Today
- Washington Watcher

### Movie Titles

- Curious George Goes to Miramar
- Burnout
- Grand Alliance
- Frontier Brain Surgeon
- Round Lake

### Time Zones

- 16:00 PST
- 17:00 PST
- 18:00 PST
- 19:00 PST
- 20:00 PST

### Additional Information

- 53 Minutes
- Viewer Feedback
- Capitol Currents
- FCC Report
- DTV Roundtable
- Legislative Agenda
- Party Line
- City Council Today
- Washington Watcher
## Electronic Program Guide (EPG)

<table>
<thead>
<tr>
<th>Channel</th>
<th>6:30pm</th>
<th>7:00pm</th>
<th>7:30pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>KXYZ-DT (7-1)</td>
<td>Local News</td>
<td>Ben’s Lab</td>
<td>Thunder Car</td>
</tr>
<tr>
<td>KXYZ-D2 (7-2)</td>
<td>Movie: “Frontier Brain Surgeon”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KXYZ-D3 (7-3)</td>
<td>Movie: “Burnout” (5:00)</td>
<td>Gena</td>
<td>Horace Horse</td>
</tr>
</tbody>
</table>
Extended Text Tables (ETTs)

- **ETT-0** thru **ETT-127**, plus a “channel ETT”
- Text descriptions for channels and events
- May use Huffman coding to reduce bandwidth
- May be in multiple languages
Multilingual Text

- Everywhere text is used
  - Program titles & descriptions
  - Exception: “short” channel name
- Context-sensitive Huffman coding (English lang.)
  - Two tables, one optimized for titles, one for descriptions
  - Compression efficiency is approx. 2:1
- Uses ISO 639 Language coding
System Time Table (STT)

- Clock Time
  - Current GPS time
  - Daylight savings time indicators
Rating Region Table (RRT)

- Defines content advisory system(s) in use
- Defines rating scheme(s) for rating region(s) (MPAA and TV Parental Guidelines in USA)
- Ratings referenced by Content Advisory Descriptors in EITs
PSI P Descriptors

- Descriptors are tag-length-data structures
- Descriptor tag must be a registered value
- Some ATSC-defined descriptors include:
  - Content Advisory
  - Redistribution Control
  - ATSC Private Info
  - Service Location
  - Component Name
  - Caption Service
  - Audio Stream (AC-3)
    - Now carries language
    - Primary audio flag
  - Extended Channel Name
  - ATSC Conditional Access
### PSIP server products hide complexity

#### Table: Event List

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>End Time</th>
<th>Event Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>04:00</td>
<td>120</td>
<td>06:00</td>
<td>Wyatt Earp</td>
<td>The portrait trad defending boot</td>
</tr>
<tr>
<td>06:00</td>
<td>35</td>
<td>06:35</td>
<td>News</td>
<td></td>
</tr>
<tr>
<td>06:35</td>
<td>30</td>
<td>07:05</td>
<td>George Michael Sports Machine</td>
<td></td>
</tr>
<tr>
<td>07:05</td>
<td>60</td>
<td>08:05</td>
<td>Dateline NBC</td>
<td>Stipulations of</td>
</tr>
<tr>
<td>08:05</td>
<td>60</td>
<td>09:05</td>
<td>Meet the Press</td>
<td>(R)Crisis in Yuri Podesta, White</td>
</tr>
<tr>
<td>09:05</td>
<td>55</td>
<td>10:00</td>
<td>Kickin’ It</td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>30</td>
<td>10:30</td>
<td>Endless Youth</td>
<td></td>
</tr>
<tr>
<td>10:30</td>
<td>30</td>
<td>11:00</td>
<td>Game Warden Wildlife Journal</td>
<td>(R)Bison; firea</td>
</tr>
</tbody>
</table>
National Geographic Explorer
6:30 PM - 8:00 PM
NR (Not Rated)
Explorer meets dwellers in Canadian forest. Coyotes, deer, owls, and various small creatures.
End Result - Digital Broadcast Television

*Dish It Up! Italian Style*

Wednesday Afternoon

2:29 PM
Wed 2/7/01

“Dish It Up! Italian Style: Creativity.

TPT 2
TPT Kids
TPT Xtra
TPT You
TPT Wx

Tell it like it is. Tell it like it isn’t. Tell it like it was.

2-0
2-1
2-2
2-3
2-4

TPT 2D
2:30 PM to 3:00 PM
Not Rated
English (Dolby Digital)

Ch 2-5 TPT 2D

4:3 Normal
Antenna A

Family

2/7/01

Dish It Up! Italian Style

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**References**


- *ATSC A/78 Recommended Practice on Bitstream Verification*.

- *www.trivenidigital.com*
Thanks for Attending!

MPEG Technology Seminar
Organized by Incospec

“MPEG 101 with PSI-P Overview”