Digital television

The DVB transport stream

- The need for a general transport stream
- DVB overall stream structure
- The parts of the stream
  - Transport Stream (TS)
  - Packetized Elementary Stream (PES)
  - Program Specific Information (PSI -> ESG)
Digital broadcasting, service delivery model

Networks
- Satellite
- Cable
- Terrestrial

Multiplexes
- Transponder 1
- Transponder 2
- Transponder 3
- Transponder T
- Channel 1
- Channel 2
- Channel C

Services
- Bouquet
- Service 1
- Service 2
- Service 3
- Service 5

Components
- Video
- Audio 1
- Audio 2
- Data
Standards

• MPEG standard (ISO-13818-1) defines ways of multiplexing more than one stream (video, audio and data) in order to produce one program

• Used by -
  – DVB
  – DVD
  – HDTV

• Provides basic framework for integrated video, audio and data services

• ETS 300 486 gives PSI documentation (for DVB)
MPEG-2 Systems Layer
(Transport Stream)
DVB transmitter

- A program consists of one or more elementary streams, which may or may not be MPEG encoded
- Possible to have streams with private data
- 2 schemes for the multiplexing process
  - Program Stream
  - Transport Stream

FEC – Forward Error Correction
• Program Stream
  – Primarily intended for storage and retrieval from storage media
  – Grouping of video, audio, and data elementary streams that have a common time base
  – Each program stream consists of only one program
  – Useful in error free environments
    • Large packet size
    • Packets size may be variable (hard for decoder to predict start and end of packets)
  – DVD standard uses the MPEG-2 Program Stream
Transport Stream

• Multiplexes various PES into one stream along with information for synchronizing between them
• Short, fixed length packets 188 bytes (4 byte header + adaptation field or payload or both)
• Constraints for forming transport packets:
  – First byte of PES packet must be first byte of transport packet payload
  – Each transport packet must contain data from only one PES packet
Role of transport stream

• General bit-stream that transports all programming information
• Transports all the information that a particular service provider transmits (on a certain frequency)
• Minimize processing effort in order to
  • Retrieve coded data from one stream
  • Extract transport stream packets of one or more programs, from one or more transports and output a new transport stream
• Enable to transport a program stream over a lossy environment, then recover a valid identical stream.
Transport Packet Structure

188 bytes

- 8: sync_byte (sync the decoder -47hex-start of TP)
- 1: transport_error_indicator
- 1: payload_unit_start_indicator (PSI or PES packet)
- 1: transport priority (useful in scalable MPEG2)
- 13: PID(13 bit id for each stream)
- 2: transport_scrambling_control
- 2: adaptation_field _control
- 4: continuity_counter(counts packets of PES)

- 8: adaption filed length
- 1: discontinuity_indicator
- 1: random_access_indicator
- 1: ES_priority_indicator
- 5: various flags (PCR_flag...)
- PCR (if PCR_flag is set) (system time clock, every 0.1sec, sync decoder and encoder time)
- other fields depending of which flags are set
- stuffing bytes
Overall transport stream
Sync byte – always hex 47 (bin 1000 1111)
Transport error – error during transport
Payload start (PES or PSI data)
Transport priority
PID (13 bits : dec value 0-8192, hex 0-1FFF)
Transport scrambling (only payload): 0 or 1,2,3
Continuity pointer: Increases modulo per PID basis
## PID values

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Program association table (PAT)</td>
</tr>
<tr>
<td>1</td>
<td>Conditional access table (CAT)</td>
</tr>
<tr>
<td>2 to F</td>
<td>Reserved</td>
</tr>
<tr>
<td>10</td>
<td>Network information table</td>
</tr>
<tr>
<td>11</td>
<td>Service description table (SDT), bouquet information table (BAT) and stuffing table (ST)</td>
</tr>
<tr>
<td>12</td>
<td>Event information table (EIT) and stuffing table (ST)</td>
</tr>
<tr>
<td>13</td>
<td>Running status table (RST) and stuffing table (ST)</td>
</tr>
<tr>
<td>14</td>
<td>Time/date table (TDT), time offset table (TOT) stuffing table (ST)</td>
</tr>
<tr>
<td>15 to 1F</td>
<td>Reserved for future use</td>
</tr>
<tr>
<td>20-1FFE</td>
<td>Video / audio / private data</td>
</tr>
<tr>
<td>1FFF</td>
<td>NULL packets</td>
</tr>
</tbody>
</table>
Adaptation field (1)

Field length
Discontinuity indicator
Random access indicator – helps random access
Elementary stream priority (e.g. Video Intracoded slice)
Stuffing bytes – fill the transport packet to 188 bytes
Adaptation field (2)

Program clock reference – intended time of arrival
Spliced – signed counter for splicing
Private data length – up to transport
Extension length
Packetized Elementary Stream (PES)

- Result of the packetization process
- The payload is the data bytes taken sequentially from the original elementary stream
- No specific format for forming the PES packet
  - Entire video frame in one PES packet (but need variable size frames)
  - Fixed size packets
- PES headers distinguish PES packets of various streams and also contain timestamp information
PES and Elementary streams

Elementary stream (Video)

PES = packetized elementary stream
Syncronization

• In PES
  • Presentation Time Stamp (PTS)
    • when an access unit should be displayed in the receiving end
      • at least every 100 ms
  • Decoding Time Stamp (DTS)
    • When it should be decoded (but presented later)
• Program Clock Reference (PCR)
  • 33 bit value, update frequency 90 kHz
  • Used for syncronizing receiver and transmitter
  • Per program, but several programs may share one common clock reference
Transport Stream Generation

Elementary stream (Video)

PES packet Header

Data

Header

Payload

Adaptation Field (used for stuffing here)

Transport stream
Program Specific Information (PSI)

• PSI transport packets - used by decoder to learn about the transport stream
  – Program Association Table (PAT)
    • Contains complete list of all programs in the transport stream along with the PID for the PMT for each program
    • Transmitted in transport packets with PID 0
    • Program number 0 point to the NIT
  – Program Map Table PMT
    • contains the PID for each of the channels associated with a particular program
Program Specific Information (cont.)

– Network Information Table NIT
  • Optional and contents are private (not part of MPEG standard) - can be used to provide useful information about the physical network such as channel frequencies, service originator and service name
  • Conditional Access Table CAT
  • must be sent when the elementary stream is scrambled
  • provides details of the scrambling system in use and provides the PID values of the transport packets that contain the CA information (exact format for this information is not specified)
PSI Data

The PSI data provides information to enable automatic configuration of the receiver to demultiplex and decode the various streams of programs within the multiplex.

Important

• Program Association Table (PAT)
• Conditional Access Table (CAT)
• Program Map Table (PMT)
• Network Information Table (NIT)
Program association table – TS PID=0
Program map tables – TS PID=from PAT
Network information table

Program association table (PAT)
PID: hex 0

<table>
<thead>
<tr>
<th>Program</th>
<th>NIT PID: hex 33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program 0</td>
<td></td>
</tr>
<tr>
<td>BBC 1</td>
<td>PID: hex 320</td>
</tr>
<tr>
<td>BBC 2</td>
<td>PID: hex 200</td>
</tr>
<tr>
<td>Channel 4</td>
<td>PID: hex 220</td>
</tr>
<tr>
<td>Channel 5</td>
<td>PID: hex 235</td>
</tr>
<tr>
<td>etc.</td>
<td>etc</td>
</tr>
</tbody>
</table>

Program map table (PMT)
of Channel 4: PID: hex 220

<table>
<thead>
<tr>
<th>PCR_PID</th>
<th>PID: hex 218</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video</td>
<td>PID: hex 110</td>
</tr>
<tr>
<td>Audio English</td>
<td>PID: hex 121</td>
</tr>
<tr>
<td>Audio Spanish</td>
<td>PID: hex 115</td>
</tr>
<tr>
<td>ECM</td>
<td>PID: hex 108</td>
</tr>
<tr>
<td>etc.</td>
<td>etc</td>
</tr>
</tbody>
</table>
### Kanavaniput antenniverkossa

**Table:**

<table>
<thead>
<tr>
<th>Pääasema ja täytelähetin</th>
<th>Kanavanippu A kanava-numero</th>
<th>Kanavanippu B kanava-numero</th>
<th>Kanavanippu C kanava-numero</th>
<th>Kanavanippu D kanava-numero</th>
<th>Kanavanippu E kanava-numero</th>
<th>Coordinates of Transmitters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitter</td>
<td>Mux A Channel f (MHz)</td>
<td>Mux B Channel f (MHz)</td>
<td>Mux C Channel f (MHz)</td>
<td>Mux D Channel f (MHz)</td>
<td>Mux E Channel f (MHz)</td>
<td>Coordinates of Transmitters</td>
</tr>
<tr>
<td>Anjalankoski</td>
<td>22</td>
<td>27</td>
<td>53</td>
<td>56</td>
<td>59</td>
<td>60 as. 41 min, 27 as. 03 min</td>
</tr>
<tr>
<td>Espoo</td>
<td>32</td>
<td>44</td>
<td>46</td>
<td>53</td>
<td>56</td>
<td>60 as. 10 min, 24 as. 38 min</td>
</tr>
<tr>
<td>Hyvinkää, Musta-Männistö</td>
<td>29</td>
<td>39</td>
<td>57</td>
<td>60</td>
<td>65</td>
<td>61 as. 17 min, 21 as. 42 min</td>
</tr>
<tr>
<td>Karkkila</td>
<td>38</td>
<td>55</td>
<td>58</td>
<td>60</td>
<td>65</td>
<td>60 as. 07 min, 23 as. 29 min</td>
</tr>
<tr>
<td>Lohja</td>
<td>48</td>
<td>70</td>
<td>74</td>
<td>65</td>
<td>60</td>
<td>64 as. 10 min, 25 as. 15 min</td>
</tr>
<tr>
<td>Nummi-Pusula, Hyönälä</td>
<td>47</td>
<td>58</td>
<td>53</td>
<td>53</td>
<td>53</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Sipo, Norrkulla</td>
<td>49</td>
<td>60</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Vantaa, Hakunila</td>
<td>32</td>
<td>44</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Eurajoki</td>
<td>38</td>
<td>61</td>
<td>52</td>
<td>55</td>
<td>55</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
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<td>Kankaanpää</td>
<td>43</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Lavia, Lavianjärvi</td>
<td>24</td>
<td>408</td>
<td>31</td>
<td>31</td>
<td>31</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Vammala, Sävi</td>
<td>46</td>
<td>874</td>
<td>40</td>
<td>60</td>
<td>60</td>
<td>63 as. 37 min, 27 as. 04 min</td>
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<td>Fiskars</td>
<td>32</td>
<td>562</td>
<td>44</td>
<td>46</td>
<td>58</td>
<td>60 as. 07 min, 23 as. 29 min</td>
</tr>
<tr>
<td>Hanko</td>
<td>39</td>
<td>618</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Tamminsaaari</td>
<td>39</td>
<td>618</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Haapavesi</td>
<td>34</td>
<td>578</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Kalajoki</td>
<td>34</td>
<td>578</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Raah, Mestauskiallo</td>
<td>30</td>
<td>546</td>
<td>39</td>
<td>39</td>
<td>39</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Raah, Piehinki</td>
<td>34</td>
<td>578</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
<tr>
<td>Vaala</td>
<td>58</td>
<td>770</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>63 as. 37 min, 27 as. 04 min</td>
</tr>
</tbody>
</table>

### Source

www.digita.fi
PAT -> PMT -> PES
Descrambling transport stream

DEMULT

Descrambler (CSA)

clear stream

Control words (CWs)

μC

Decryption CW

Service_key

Decryption Service_key

Smart Card

User_key

Pocket Card

PCMCIA Card

EN 50221 Standard

CMT-EMM (Service_key encrypted and Conditional Access)

CMT-ECM (CW encrypted)

EMM (Conditional Access)
Other tables in ETS 300 468

Network information table (NIT) - Information on physical network
Bouquet association table (BAT) – List of services for bouquet (EPG)
Service description table (SDT) – Service provider names etc.
Event information table (EIT) – Information on events, start times etc
Running status table (RST) – Status of an event
Stuffing table (ST) – Invalidates old data
Time and date tables (TDT) – Information about present time and date
Time offset tables (TOT) – Information on local time
Other tables in ETS 300 468

Table_id distinguishes tables with the same PID (e.g.)
Autotuning

1. Get 1st frequency
2. Tune to frequency
3. Get signal strength
4. Signal present?
   - No: Get next frequency
   - Yes: Get VCT
5. Determine major channel number
6. Optional: Determine minor channel numbers
7. Done?
   - No: Get next frequency
   - Yes: Done
General Streaming Extension (GSE)
Integrated Video, Audio and Data

• MPEG-2 systems layer provides us with a standardized method of providing integrated video, audio and data services

• Currently programs consist of primarily one video channel and possible multiple audio channels

• The data streams are used only to broadcast program related data, like close captioning

• Multiple video streams for the same program (different camera shots of a football game!!)
Integrated Video, Audio and Data (cont.)

- Interactive broadcasts - news broadcast with related URL
- Data download (non interactive) - create PES stream from the data to be broadcast, split into transport packets, use MPEG-2 system layer to generate either a separate Program stream (channel with data only) or associate the data PES with another Program stream (-viewing news broadcast automatically dumps the daily newspaper on your computer...
Integrated Video, Audio and Data (cont.)

- Interactive internet type data - can be inserted in MPEG-2 transport stream without affecting any other data, you will still be MPEG-2 system compliant, it is upto the decoders to figure out if they can handle the data or not (TV v/s PC- we can use the same broadcast)

- Interactive internet type data - must be a “program” and not part of another program - therefore decoder must be capable of tuning to two programs
Sources

European Telecommunications Standards Institute (Sophia Antipolis, France)

Digita, Finland
MPEG-2 Profiles

The profiles are specific subset of the bit stream syntax in the MPEG-2 standard (profile-P@level-L):

- **Main Profile** was designed to accommodate most initial applications of MPEG-2, in terms of both functionality requirements and cost constraints.

- **High Profile** has more functionalities than Main Profile; allows SNR, spatial and an additional type of scalability giving high quality picture quality when all features are utilized in the decoder.

- **Simple profile** is intended for low cost applications; no B-pictures (8 Mbits of memory required).

- **Spatial Scalable Profile** can provide two layer coding with different resolutions on layers (low resolution reproduction and combination gives full-resolution reproduction).

- **SNR Scalable Profile** provides layers with the same pixel resolution by different picture quality (quantization level); the first stream gives a reasonable picture quality and the other stream gives a refinement to the first stream reproduction.
MPEG-2 Levels

A level is a defined set of constraints imposed on the parameters of the MPEG-2 bit stream (profile-P@level-L):

- **Main Level** is to be used by initial applications of MPEG-2. Upper bounds of the sampling density correspond to CCIR601 picture format: 720 x 576 (PAL, 25 Hz) or 720 x 480 (NTSC, 30 Hz)

- **High Levels** are intended for HDTV systems. The High Level supports 1920 pixels per line (1920 x 1152), and the High- 1440 Level 1440 pixels per line respectively (1440 x 1152)

- **Low Level** corresponds to the quarter-CCIR601 picture format (SIF)
<table>
<thead>
<tr>
<th>Levels</th>
<th>Profiles</th>
<th>SNR</th>
<th>Spatial</th>
<th>High</th>
<th>Multiview</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4:2:0</td>
<td>4:2:0</td>
<td>4:2:0;4:2:2</td>
<td>4:2:0</td>
</tr>
<tr>
<td>High</td>
<td>Enhancement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bitrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1920 × 1151/60</td>
<td>1920 × 1151/60</td>
<td>1920 × 1151/60</td>
<td>1920 × 1151/60</td>
</tr>
<tr>
<td>High-1440</td>
<td>Enhancement</td>
<td>1440 × 1152/60</td>
<td>1440 × 1152/60</td>
<td>1920 × 1152/60</td>
<td>1920 × 1152/60</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>720 × 576/30</td>
<td>720 × 576/30</td>
<td>1920 × 1152/60</td>
<td>1920 × 1152/60</td>
</tr>
<tr>
<td></td>
<td>Bitrate</td>
<td>60, 40, 15</td>
<td>80, 60, 20</td>
<td>100, 40, 60</td>
<td>100, 40, 60</td>
</tr>
<tr>
<td>Main</td>
<td>Enhancement</td>
<td>720 × 576/30</td>
<td>720 × 576/30</td>
<td>720 × 576/30</td>
<td>720 × 576/30</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>352 × 288/30</td>
<td>720 × 576/30</td>
<td>720 × 576/30</td>
<td>720 × 576/30</td>
</tr>
<tr>
<td></td>
<td>Bitrate</td>
<td>15, 10</td>
<td>20, 15, 4</td>
<td>25, 10, 15</td>
<td>25, 10, 15</td>
</tr>
<tr>
<td>Low</td>
<td>Enhancement</td>
<td>352 × 288/30</td>
<td></td>
<td>352 × 288/30</td>
<td>352 × 288/30</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td></td>
<td></td>
<td>352 × 288/30</td>
<td>352 × 288/30</td>
</tr>
<tr>
<td></td>
<td>Bitrate</td>
<td>4, 3</td>
<td></td>
<td>8, 4, 4</td>
<td>8, 4, 4</td>
</tr>
</tbody>
</table>
## MPEG-2 Profiles & Levels

<table>
<thead>
<tr>
<th>Profile @ Level</th>
<th>Resolution</th>
<th>Maximum Frame Rate</th>
<th>Sampling</th>
<th>Rate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SP @ LL—Simple Profile @ Low Level</strong></td>
<td>176x144</td>
<td>15</td>
<td>4:2:0</td>
<td>96Kbps</td>
<td>Wireless handsets</td>
</tr>
<tr>
<td>SP @ ML—Simple Profile @ Main Level</td>
<td>352x288, 320x240</td>
<td>15, 24</td>
<td>4:2:0</td>
<td>384Kbps</td>
<td>PDAs</td>
</tr>
<tr>
<td><strong>MP @ LL—Main Profile @ Low Level</strong></td>
<td>352x288</td>
<td>30</td>
<td>4:2:0</td>
<td>4Mbps</td>
<td>Set-top boxes</td>
</tr>
<tr>
<td>MP @ ML—Main Profile @ Main Level</td>
<td>720x480</td>
<td>30</td>
<td>4:2:0</td>
<td>15Mbps; limited to 9Mbps for DVDs</td>
<td>DVD</td>
</tr>
<tr>
<td><strong>MP @ H-14—Main Profile @ High 1440</strong></td>
<td>1080i with 1440 pixels/line or 720p with 1280 pixels/line</td>
<td>1080i: 30 or 720p: 30</td>
<td>4:2:0</td>
<td>60Mbps; limited to 25Mbps for DV tape</td>
<td>HDV Potential to move to tape-based at 50Mbps</td>
</tr>
<tr>
<td>MP @ HL—Main Profile @ High Level</td>
<td>1080i with 1920 pixels/line or 720p with 1280 pixels/line</td>
<td>1080i: 30 or 720p: 60</td>
<td>4:2:0</td>
<td>80Mbps; limited to 19Mbps for over-the-air</td>
<td>ATSC 1080i 720p60</td>
</tr>
<tr>
<td><strong>422P @ LL—4:2:2 Profile @ Low Level</strong></td>
<td>720x480</td>
<td>30</td>
<td>4:2:2</td>
<td>50Mbps</td>
<td>Sony IMX using I-frame only</td>
</tr>
<tr>
<td>422P @ ML—4:2:2 Profile @ Main Level</td>
<td>720x480</td>
<td>30</td>
<td>4:2:2</td>
<td>80Mbps</td>
<td>Potential future MPEG-2-based HD products from Sony and Panasonic</td>
</tr>
<tr>
<td><strong>422P @ H-14—4:2:2 Profile @ High 1440</strong></td>
<td>1080i with 1440 pixels/line or 720p with 1280 pixels/line</td>
<td>1080i: 30 or 720p: 60</td>
<td>4:2:2</td>
<td>300Mbps</td>
<td>Potential future MPEG-2-based HD products from Panasonic</td>
</tr>
</tbody>
</table>