



# DVB Transport Streams

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## Understanding the Multiplex

22 June 2012

# Multiplexing Streams



- TV has always involved multiple streams of information.
- With the advent of Digital Media Systems we get the opportunity to combine (multiplex) streams together, making better use of the available bandwidth, and allowing more services.
- In a typical Digital TV system we have several streams to combine and separate out again...
  - Video
  - Audio
  - Subtitles
  - Metadata about the current and future content (titles, information, start and stop times)
  - Metadata about where to find other content (frequencies other programmes are broadcast on).
  - Access Control Information (keys to decrypt any Encrypted Audio and Video)
- In addition we can also combine multiple programmes together in to one single multiplex
- And we can have other services such as Digital Teletext (MHP)

# DVB - *A Digital TV Broadcast Standard*



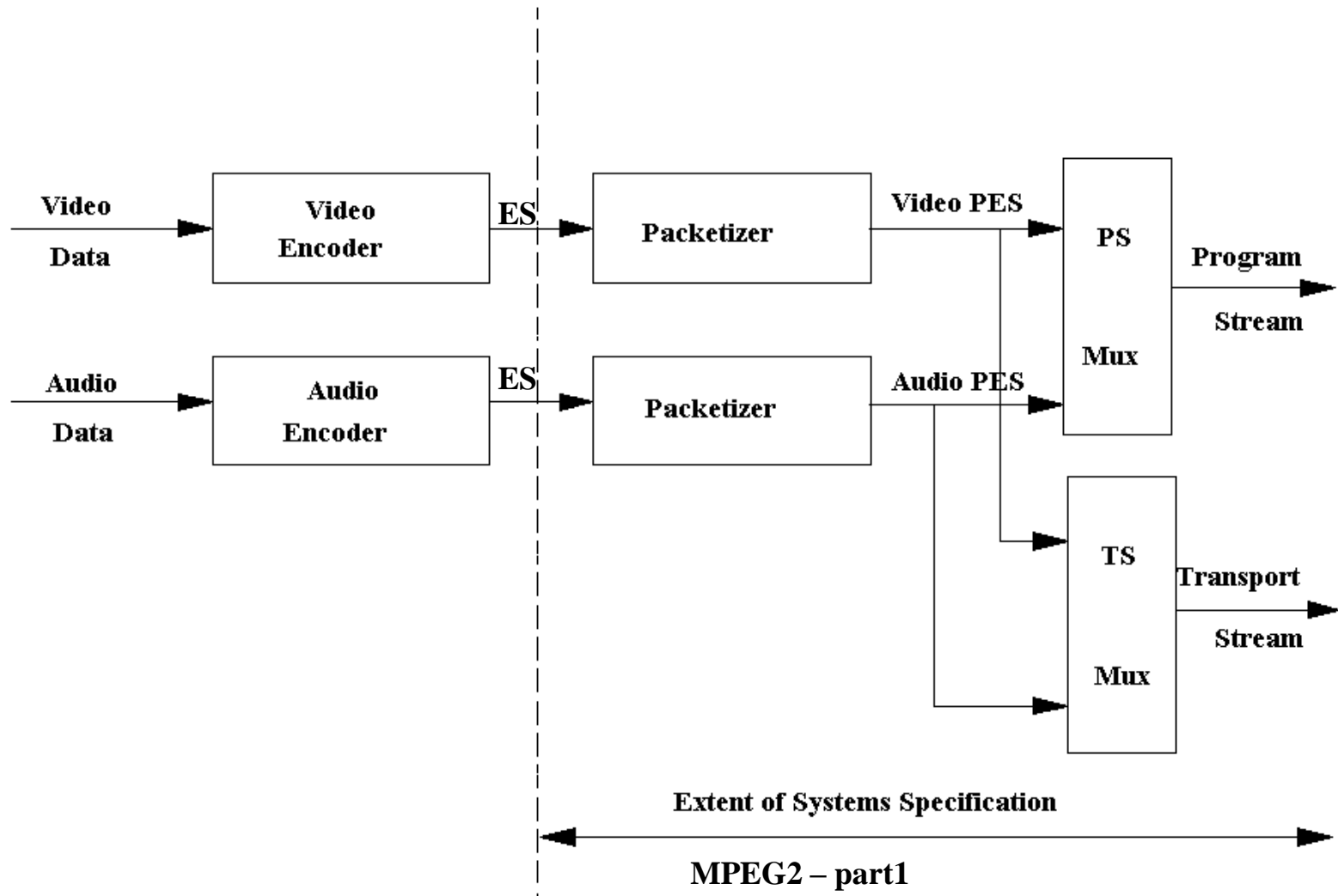
- DVB Project is an industry-led consortium of over 300 companies
- The DVB Project was launched on 10<sup>th</sup> September, 1993
- In 1995 it was basically finished and became operational
- There are several sub-standards of the DVB standard
  - DVB-S (Satellite) – using QPSK – 40 Mb/s
  - DVB-T (Terrestrial) – using QAM – 50 Mb/s
  - DVB-C (Cable) – using OFDM – 24 Mb/s
- We now have the second revisions of these standards DVB-S2, DVB-T2 which increase the maximum bitrate and reliability
- **These three sub-standards basically differ only in the specifications to the physical representation, modulation, transmission and reception of the signal. The data stream (Transport Stream) is the same.**
- **The material that follows applies to all of them.**

# MPEG2 - *A Standard for Digital Content*



- In 1994, MPEG has published the ISO/IEC-13818, also known as MPEG-2
- MPEG-2 was the standard adopted by DVD (Digital Video Disk or Digital Versatile Disk) and Digital TV
- It is designed for video compression between 1.5 and 15 Mbps
  
- MPEG-2 part 1 (Systems) describes the two container formats...
  - Program Stream
  - Transport Stream

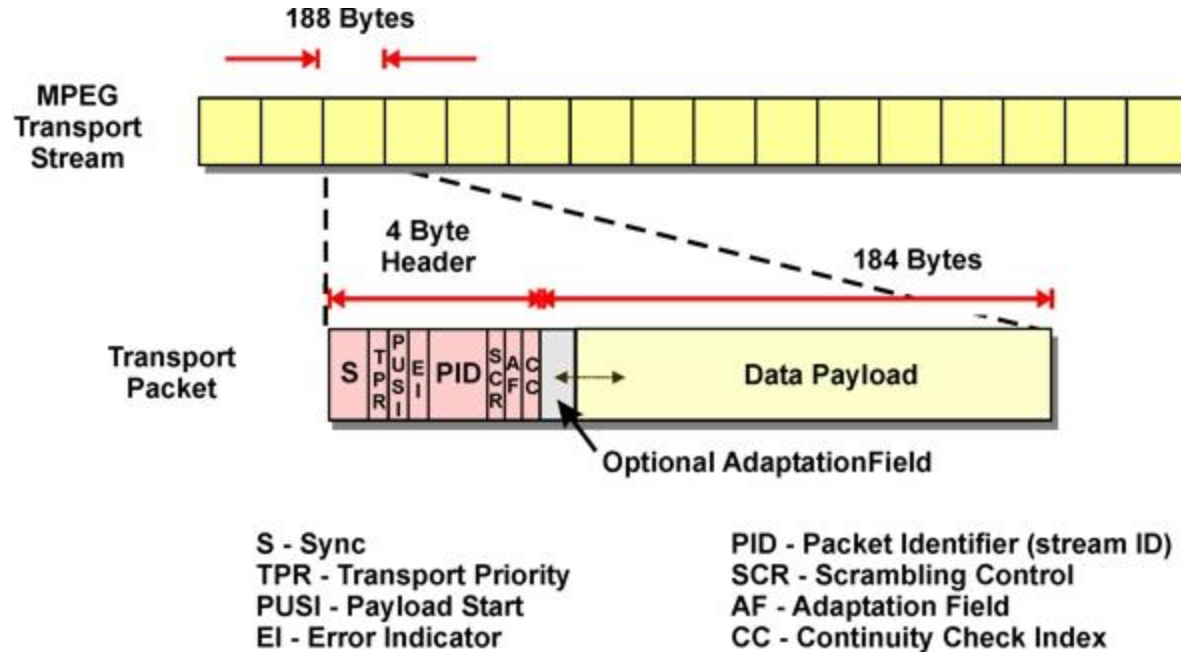
# Model for MPEG2 Systems



- Used for File Based Playback
- Combines one or more Packetised Elementary Streams (PES), which have a common time-base, into a single stream
- Designed for use in relatively **error-free environments** and suitable for applications which may involve software processing
- Programme stream packets may be of variable and relatively great length
- **One Programme per Stream**

- Used for Streaming
- Combines one or more Packetised Elementary Streams (PES) with one or more independent time bases into a single stream (sometimes called multiplex)
- Elementary streams sharing a common time-base form a programme
- Designed for use in environments where **errors are likely**, such as storage or transmission in lossy or noisy media
- Synchronisation points are added to the data
- Error correction is done.
- **Multiple Programmes per Stream**

# MPEG2 Transport Stream



- Sync byte 0x47, and PUSI helps with recovery from errors
- PIDs indicate which stream the data comes from.
- Payload size varies (184 bytes only is no Adaptation Field)



# The MPEG-2/DVB Multiplex

## (expanding the concept of a Transport Stream)



- A multiplex is a Transport Stream with a **bouquet of PIDs** containing several channels (television, radio, data etc), basically is a collection of programmes
  - This bouquet contains two classes of information...
    - **PES** - Audio data, Video data, Subtitling Data (i.e. usually content)
    - **Sections** – DVB Service Information (metadata) containing the description of the contents of the transport stream
  - Based on the DVB-SI, the decoders can select the correct PIDs of the desired programme in order to decode them
- A Transport Mux contains...
    - Transport Packets that contain either...
      - SECTIONS holding DVB-SI information (metadata)
      - or PES which contains...
        - ES holding the AV data stream (Compressed Audio / Video)

# DVB Service Information

## *(The Meta Data)*



- Program Specific Information (PSI)
  - Program Allocation Table (PAT) & Program Map Tables (PMT): identifies and indicates the PIDs of the streams that make up each service
  - Network Information Table (NIT): provides information about the physical network
  - Conditional Access Table (CAT): provides information on the CA systems used in the multiplex; the information is private and dependent on the CA system
- Additional Service Information
  - Event Information Table (EIT): contains data concerning events or programmes such as event name, start time, duration, etc. Fundamental to generating your EPG – Electronic Program Guide.
  - Bouquet Association Table (BAT): provides information regarding bouquets
  - Service Description Table (SDT): describes the services in the system e.g. names of services, the service provider, etc
  - Running Status Table (RST): gives the status of an event (running / not running)
  - Other tables: TDT, TOT, ST, SIT, DIT
- DVB-SI information is repeatedly broadcast typically at a rate of 10 times a second (varies)

# MPEG2 / DVB PID Allocation



- PAT always has PID = 0 (zero)
- CAT always has PID = 1
- EIT always has PID = 18
- The PMTs have the PIDs specified in the PAT
- The audio, video, PCR, subtitle, teletext etc PIDs for all programmes are specified in their respective PMT

Table	PID value
PAT	0x0000
CAT	0x0001
TSDT	0x0002
reserved	0x0003 to 0x000F
NIT, ST	0x0010
SDT, BAT, ST	0x0011
EIT, ST	0x0012
RST, ST	0x0013
TDT, TOT, ST	0x0014
network synchronization	0x0015
reserved for future use	0x0016 to 0x001B
inband signalling	0x001C
measurement	0x001D
DIT	0x001E
SIT	0x001F

# MPEG-2/DVB PSI Structure



Program Map Table For Programme 1

Stream 1	PCR	31
Stream 2	Video 1	54
Stream 3	Audio 1	48
Stream 4	Audio 2	49
-----	----	----
Stream k	Data k	66

Table section id always set to 0x02

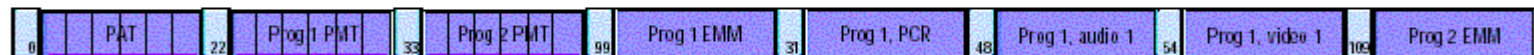
Program Association Table (always PID 0)

Program 0	PID = 16
Program 1	PID = 22
Program 2	PID = 33
-----	----
Program K	PID = 55

Table section id always set to 0x00

Program Map Table For Programme 2

Stream 1	PCR	41
Stream 2	Video 1	19
Stream 3	Audio 1	81
Stream 4	Audio 2	82
-----	----	----
Stream k	Data k	88



Multi-Program MPEG-2 Transport Stream

CA Section 1 (programme 1)	EMM PID (99)
CA Section 2 (programme 2)	EMM PID (109)
CA Section 3 (programme 3)	EMM PID (119)
-----	----
CA Section k (programme k)	EMM PID k

Table section id always set to 0x01

Conditional Access Table (always PID 1)

Private Section 1	NIT info
Private Section 2	NIT info
Private Section 3	NIT info
-----	----
Private Section k	NIT info

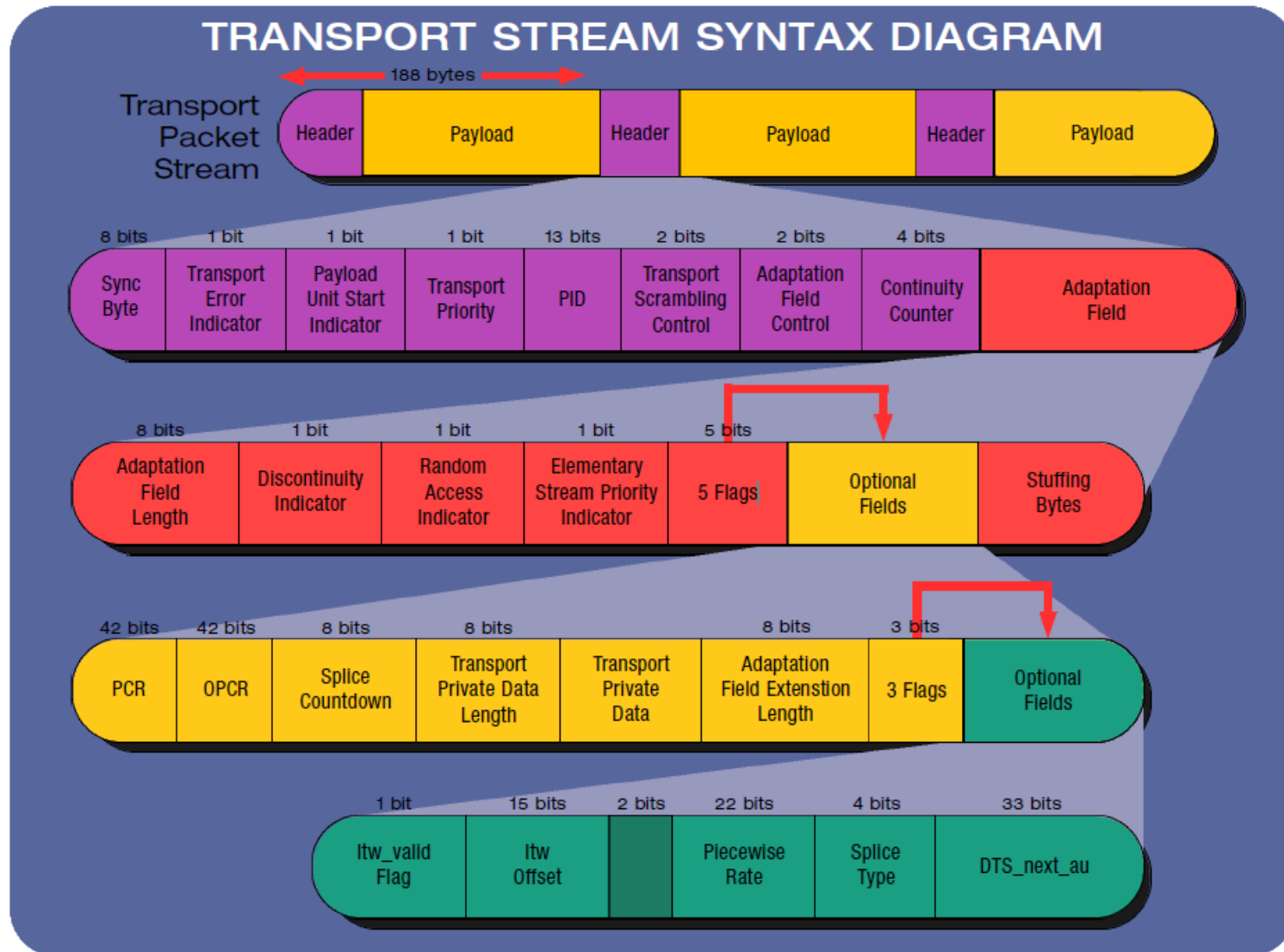
Table section id assigned by system

Network Information Table (always programme 0)  
NIT is considered private data by ISO

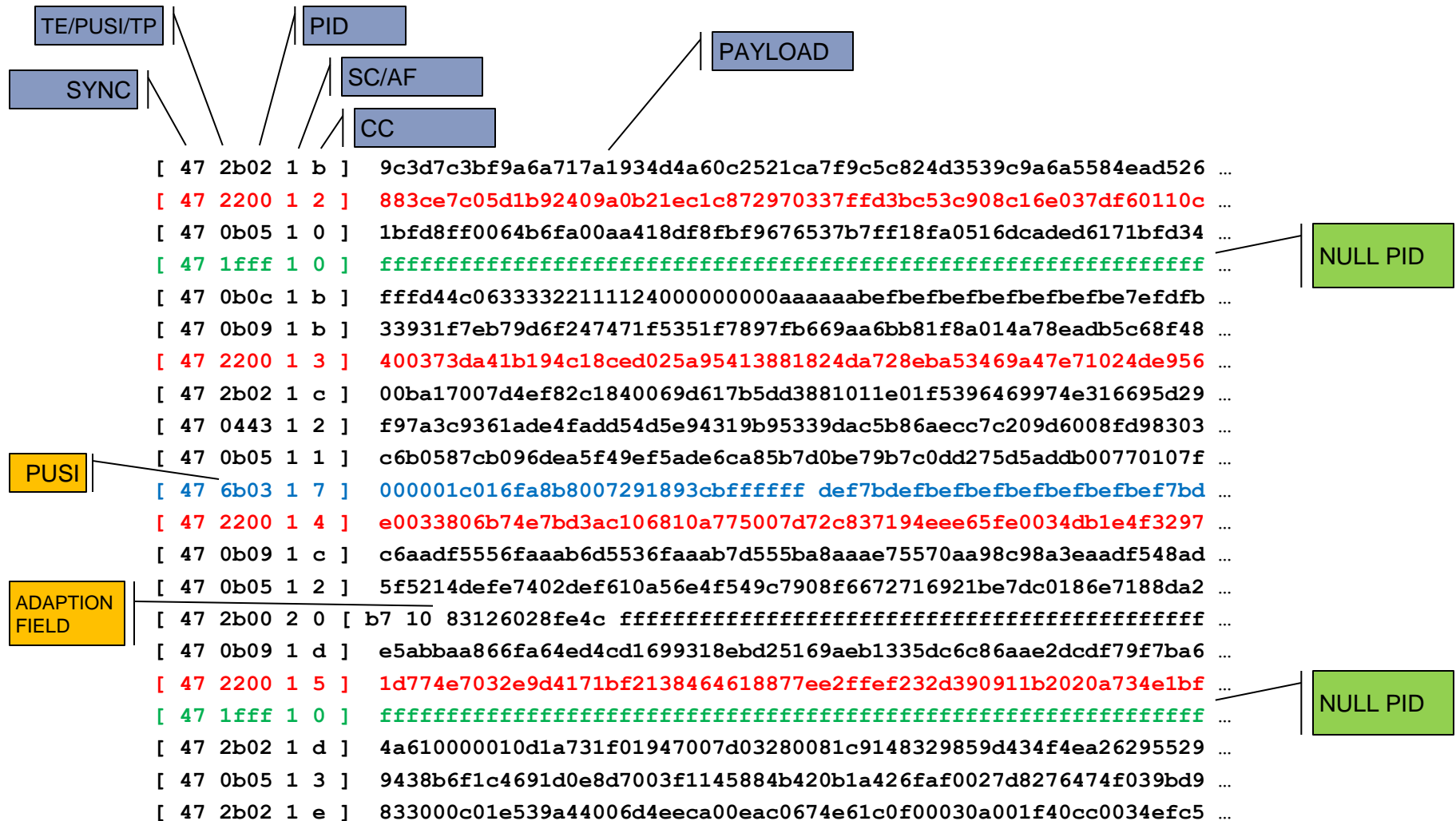
The Nuts and Bolts, or...

# **THE BITS AND BYTES**

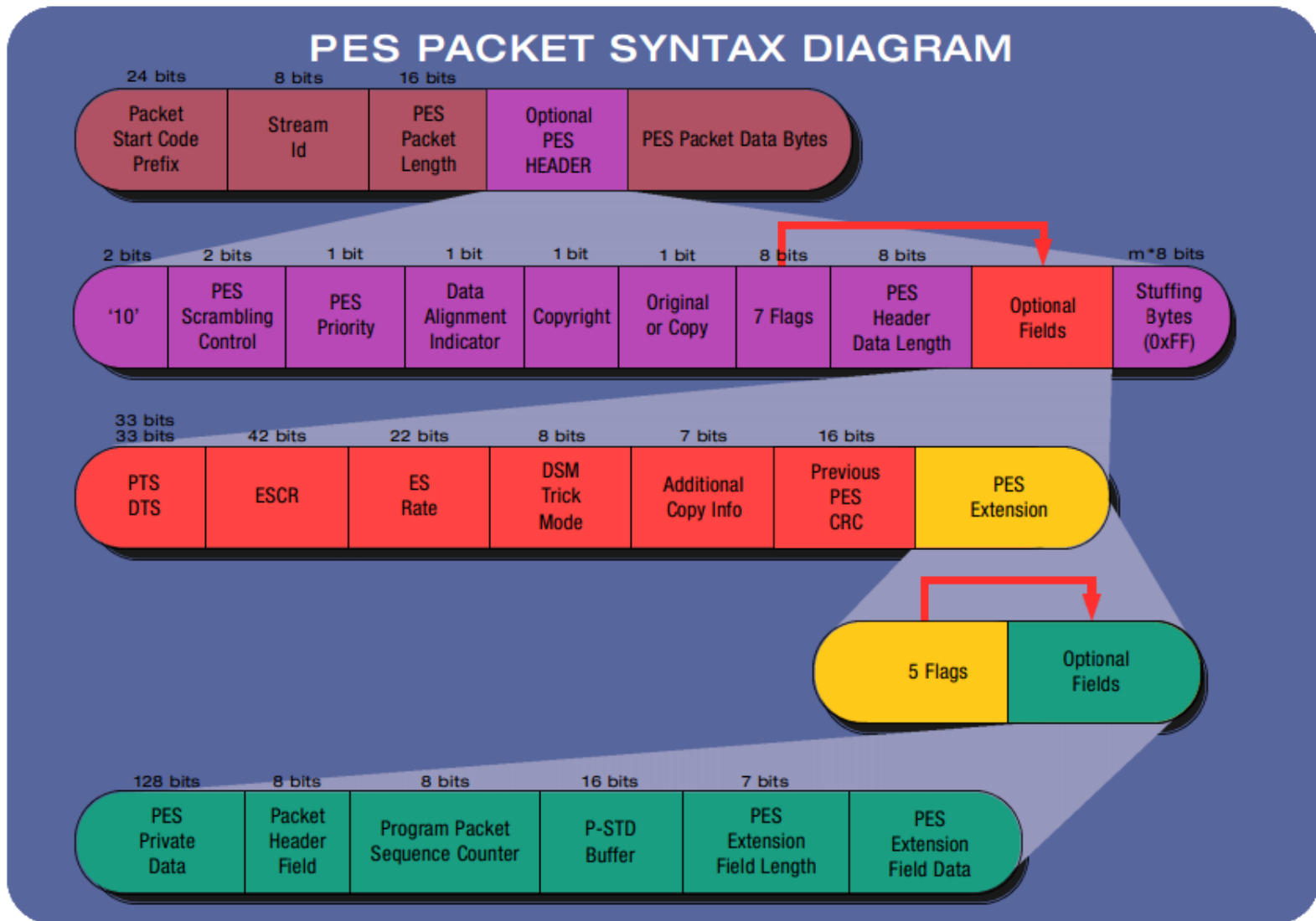
# Transport Stream Packets



# A Transport Stream



# PES Packet Format





# PES in a Transport Stream



```
[ 47 008c 1 d ] 54c87ceba6438a198e6151f450f9e747d14321e85dcf49f56f4c8337330800 ...
[ 47 008c 1 e ] f1f212902e3009c941261b8246b1b71ba2fd52e29ae27d2ee21f369f8a9ce5 ...
[ 47 008c 1 f ] 6b13509b9be76b9e50b7a28aef68000001124b96198b9ec788b8830ee9a845 ...
[ 47 008c 1 0 ] ce1f78f862d6ee353d2e02be3542974515b4e8f9773f701ad684d07d14431b ...
[ 47 008c 1 1 ] 49f061313fbbfba288d81bf94ca7c1f61ef7736aa5615e5d1436df876d0400 ...
[ 47 008c 1 2 ] 8c7d9d7f3d092dc8206a6382c8f0e0b23d095e98408afcc96268a250313a45 ...
[ 47 008c 3 3 [ 9f 00 ffffffff ... ffff ] ] 83a97710b1250ba182e8a210a16a1cafc6b8d589451591b
[ 47 408c 1 4 ] 000001e007fa800000 04b9874901230a6a2864b9298dbb88d2ce1d7 ...
[ 47 008c 1 5 ] 675144f675c43d27d3733080000001155b96238ef644a6418a298da83f7cf3 ...
[ 47 008c 3 6 [ 07 10 0003c8867ebc ] ] 07ff01763b42b5f40f0ea28a4286354e132a551 ...
[ 47 008c 1 7 ] f3707d5515df714f7102125caa662c423685d14420ccfb9849d0eb8c2e0a97 ...
[ 47 008c 1 8 ] cd626a1330800000011843963b1ea82c2a5f38c95450ec10a3ae21622a88b4 ...
[ 47 008c 1 9 ] d330ccc116640c4d42660c4cc10990e287639ed75495056a640c54dcf84dc4 ...
[ 47 008c 1 a ] f6d4c82cc8337330400000011b326b5142ec6faeb1fc7aa990233733146641 ...
[ 47 008c 1 b ] a8463e611f888ef52e8468d35358aa7a641e78d232042b45d320a320f3d699 ...
[ 47 008c 1 c ] 0438818ce9b6a31061f00000011e4b961e1f2e5514330428ca28442c04ccc7 ...
[ 47 008c 1 d ] aaa053ef5c75c40826d73c6a67acccad0e204054ebd1d450c819ee3ed9cf9a ...
[ 47 008c 1 e ] 0529927f5c74aba28660c66ba28540861d308d6f4c818a80a23403ea285416 ...
[ 47 008c 3 f [ 97 00 ffffffffffffffffffffffff ... ffff ] ] f35c4084bbb8820b9844823088e8da285
[ 47 408c 1 0 ] 000001e007fa80800521001fb5f3 5c811169e5d4701d88b3c41b1542352a8 ...
[ 47 008c 1 1 ] 0e993320c23509b88383e845c3e69a408547cc2201d73b60f01fcb9ee84582 ...
```

PUSI

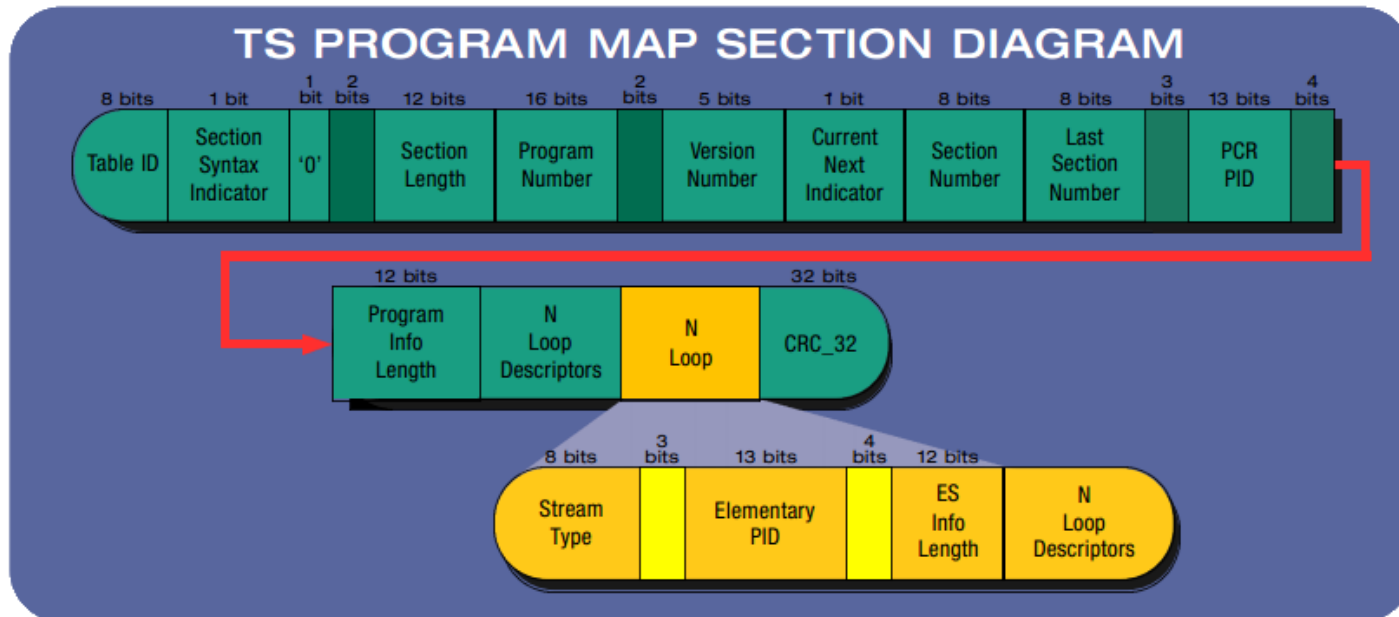
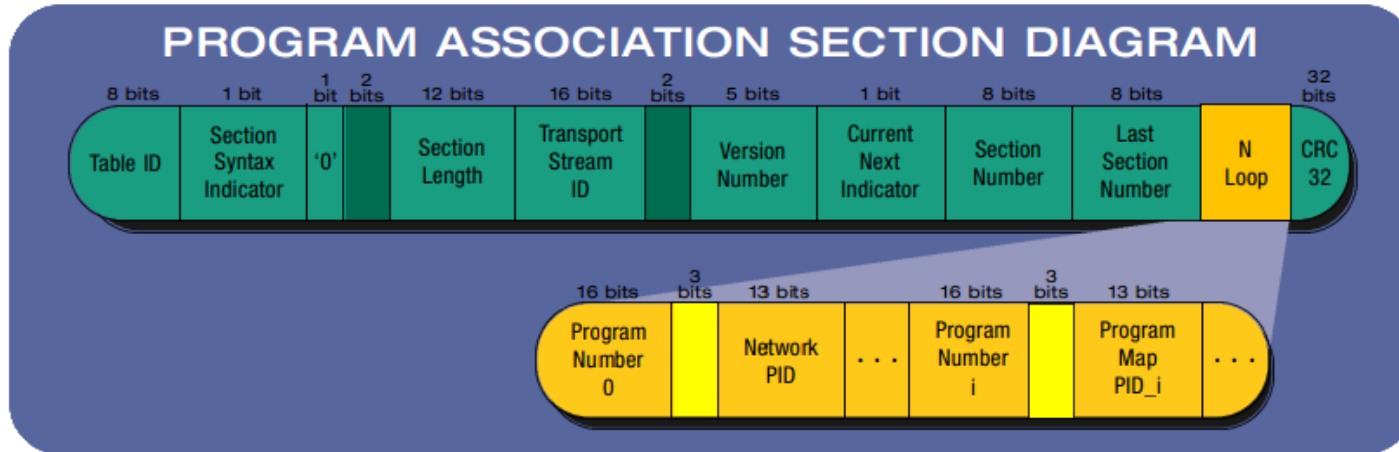
PCR

PUSI

PES is  
padded out  
with an AF

PES is  
padded out  
with an AF

# Section Format





- STMicroelectronics**

# Matching the Broadcast - PCRs



- Data is broadcast at a specific rate
- The STB needs to adjust its clock to match the broadcast and play at the same rate
- This is Clock Recovery
- PCRs are broadcast in the transport stream header (adaption field)
  - It is a 27MHz clock:
    - 33bits of 27MHz / 300 (base – 90kHz)
    - 9bits of 27MHz % 300 (extension)
  - 33bits is chosen so the field will wrap only once a day (26.5hrs)

# Matching the Broadcast - PCRs

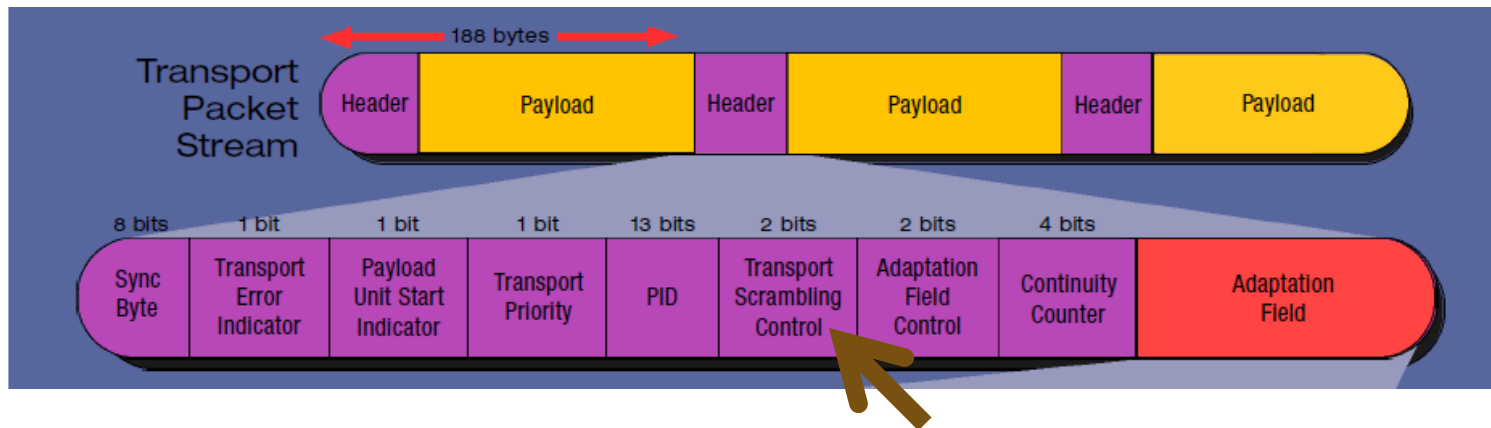


- The packet's arrival time is time stamped on the packet when it arrives.
- The DEMUX presents this timestamp with the PCR when a PCR is received.
- When two PCRs are received the deltas between the PCRs and the two arrival times are checked.
- Clock Recovery is about adjusting the system clock (what creates the arrival time) to keep the deltas the same, and hence matching the broadcast rate.

- Are carried in PES (not sections)
- Timing of presentation is the PTS of the PES (present in the PES header)
- Information is transmitted in graphical format
- Pixel depths of 2, 4 and 8 bits are supported
- Color information is organized in Color Look-Up Tables (CLUT)
- Subtitles are present in a sequence of pages that are going to be overlayed on the associated video image
- A subtitle page contains one or more regions (rectangular areas with specified sets of attributes: position, width, height, depth etc)
- Several regions can be used at the same time (i.e. one region in the bottom of the screen displaying the subtitle, another in one somewhere else on the screen displaying some logo)
- There are different events
  - page update (when only the changed regions from previous page are present)
  - page refresh (when all the data needed to display the page is present)

# CONDITIONAL ACCESS

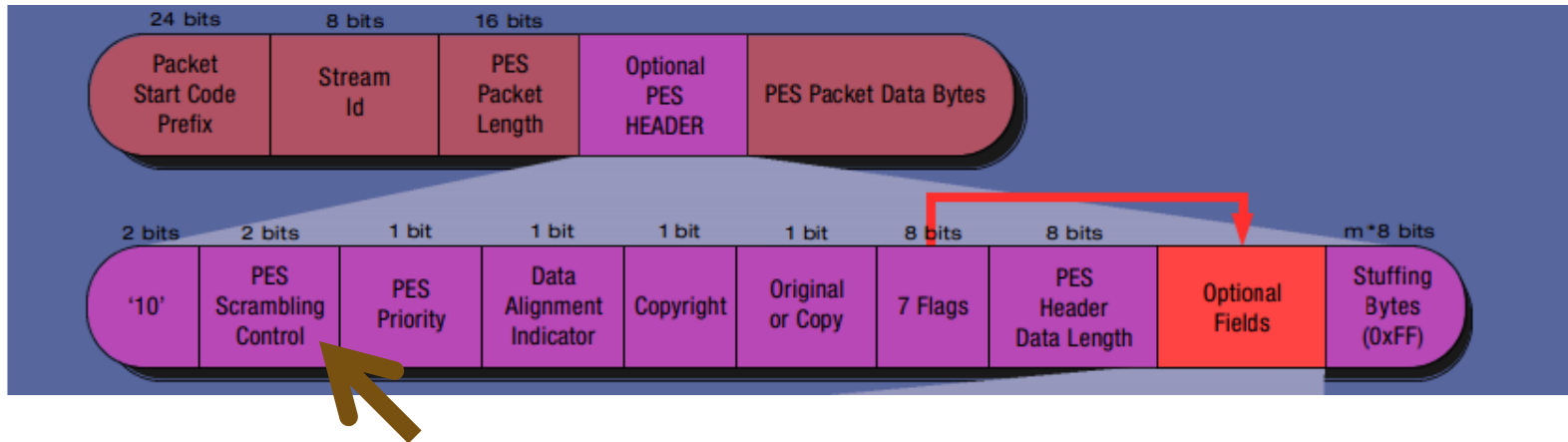
# Transport Level Encryption



- Transport headers (including the adaptation field) are always in the CLEAR
- The 2 “Transport Scrambling Control” bits indicate if the **payload** of the packet is scrambled.
  - '00' = Not scrambled, '10' = Scrambled (with even key), '11' = Scrambled (with odd key), '01' = Reserved
- Payload can be scrambled (encrypted) by a stream cipher (e.g. DVB-CSA) which can encrypt the entire payload whatever size
- Payload can be scrambled by a block cipher (e.g. AES) where you may have a residue (bytes left over) if not a multiple of the block size
  - Sometimes data is left clear at the end or at the start (leading or trailing residue)
  - Often data is encrypted using a residue scheme

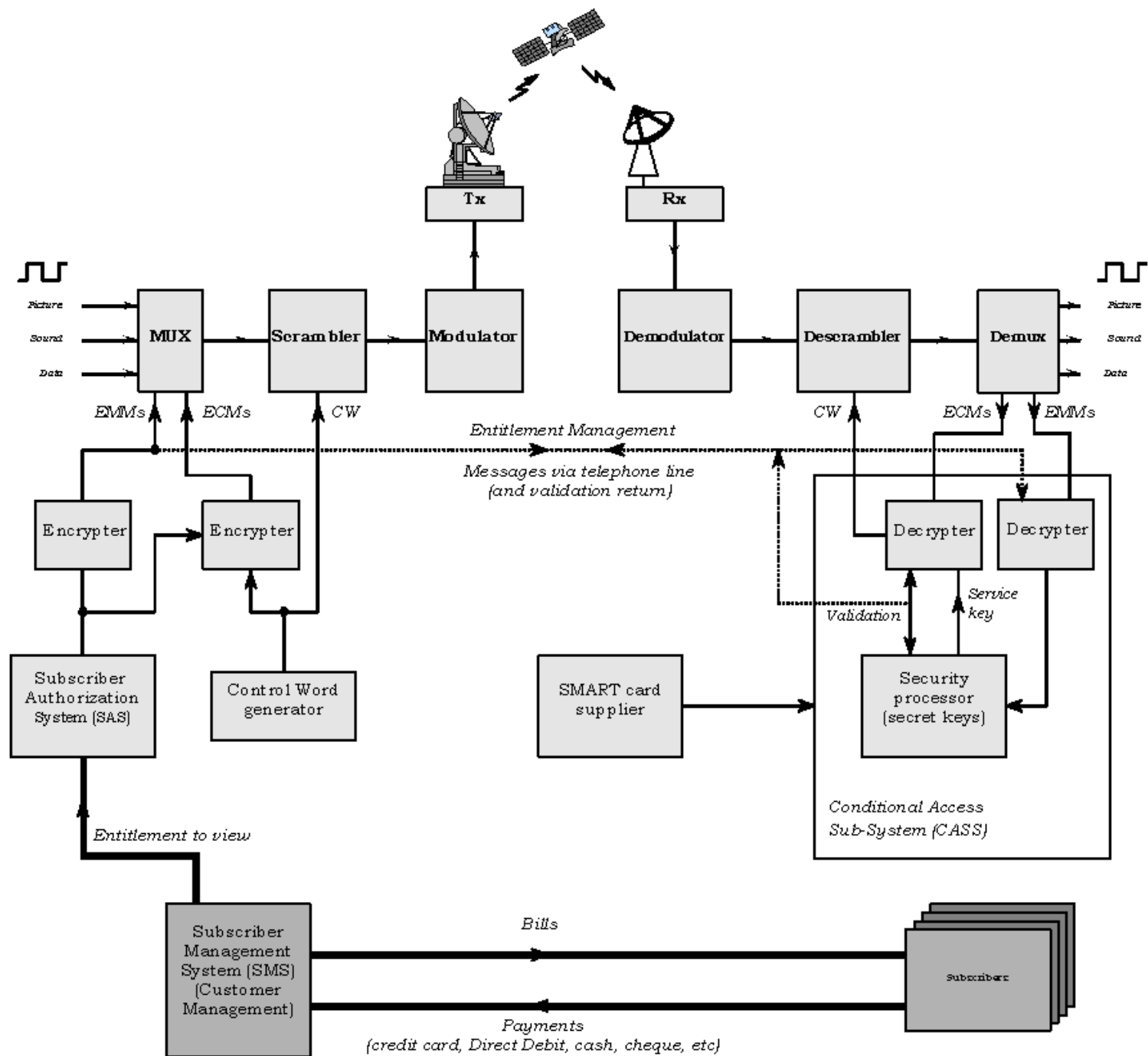


# PES Level Encryption



- Transport Headers are always in the CLEAR (and SC bits are '00')
- PES headers (including any optional fields) are always in the CLEAR
- The 2 “PES Scrambling Control” bits indicate if the **payload** of the PES packet (“PES Packet Data Bytes”) is scrambled
  - '00' = Not scrambled, '10' = Scrambled (with even key), '11' = Scrambled (with odd key), '01' = Reserved
- PES level scrambling is not often used

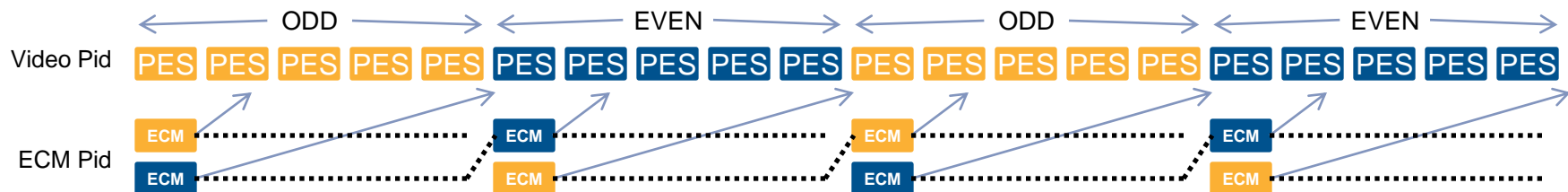
- Entitlement Control Messages (ECM) are the encrypted keys used to decrypt the content (video)
  - The keys are called Control Words (CWs)
- Entitlement Management Message (EMM) effectively holds the key to decrypt the ECMs
  - This key is called the Common Key (CK) or Service Key
- Different CA vendors will process (encrypt) EMMs differently to protect against hackers
  - Typically a smart card is used
  - And may other schemes



# Key Periods



- AV data is encrypted with a key (CW) that is changed frequently (typically once every 5-10 seconds). We call this time a key period.
- Two keys (ECMs – the encrypted CWs) are repeatedly broadcast for each key period.
  - One for the current period (to improve channel change time)
  - One for the next period (to avoid a disruption of video)
- Key periods are labelled ODD and EVEN, as we swap between them.
  - The current scrambling period is indicated in the Transport Header's 2 Scramble Control bits. '00' = Not scrambled, '10' = Scrambled with even key, '11' = Scrambled with odd key, '01' = Reserved.



- MPEG2 Systems Specification...
  - ISO/IEC 13818 (part1) <http://www.iso.org>
  - A handy quick reference Poster...  
<http://www.tek.com/poster/mpeg-poster-dvb>  
(or google “tektronix mpeg poster pdf”)
- The MPEG2 Systems Specification can (and is) used to encapsulate other encoded streams such as H264, Dolby Digital, etc.
- In some new physical layer specifications, e.g. DVB-T2 impose new rules on the SI (service information) sections
- **Although they should, streams do not always comply to the DVB Specification and DEMUXes sometimes have to “bend the rules” to maximise playback possibilities**