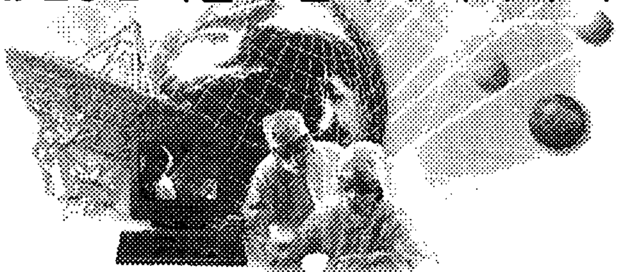
MPEG-2 Visualization:

MPEG-2 기술의 분석과 시각적 이해



1999. 11. 12.

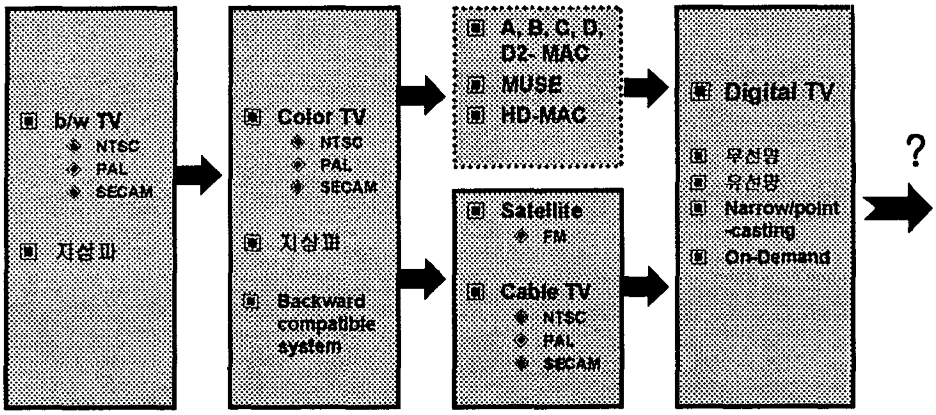
정 주 홍

무선 · 방송기술연구소/방송기술연구부

ETRI
한국전자통신연구원

목차

개요: TV의 변천



-매체의 다양화
- HDTV의 등장

- 반도체 기술의 발달
- All-digital TV

개요: Analog→Digital

■ **Analog Color TV Systems: NTSC, PAL, SECAM**

◈ **Similarities:**
- Backward compatible with b/w TV systems
- Chrominance high with frequency interleaving

◈ **Differences:**
- Color bandwidth
- Color modulation method
- Stereo/Bi-lingual systems

■ **Digital TV Systems: ATSC, DVB, ISDB**

◈ **Similarities:**
- Video compression method is MPEG-2 Video
- Multiplexing and transport method is MPEG-2 Systems

◈ **Differences:**
- Audio Compression method
- Modulation method

개요: Digital Television

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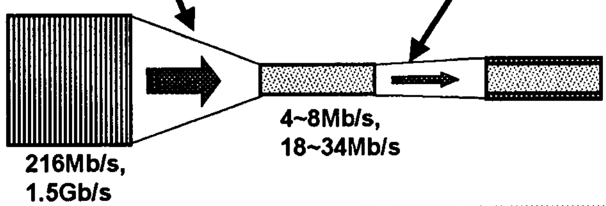
- AS a branch of Digital Communications
  "Efficient and Reliable" Transport of Information

Source Coding:
- Governed by Rate-Distortion Theory
- Redundancy Reduction
- Lossy and Lossless Data Compression

Channel Coding:
- Channel Capacity
- Error Protection
- Additional Redundancy/Complexity



디지털 방송과 MPEG-2

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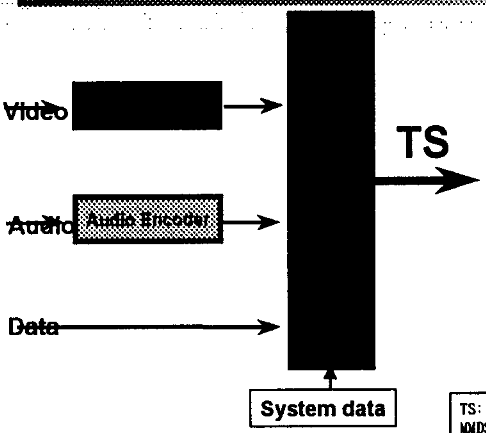


- **Wireless Networks**
  - Satellite
  - Terrestrial
  - MMDS
  - LMDS
- **Cabled Networks**
  - B-ISDN
  - HFC
  - FTTH, PON
  - FTTC, xDSL

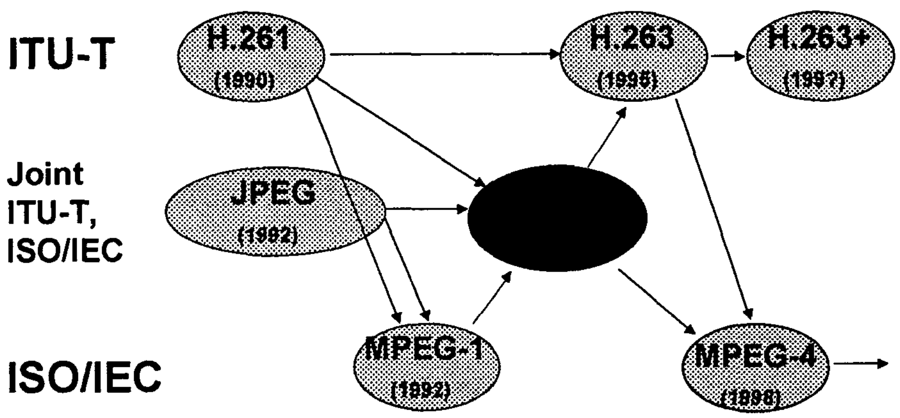
* MPEG-2 Video and Sytems Spec. are the singel worldwide standard for Digital Television Broadcasting.

TS: Transport Stream
MMDS: Multi-channel Multipoint Distribution System
LMDSL: Local Multipoint Distribution System
HFC: Hybrid Fiber-Coax
FTTH: Fiber to the Home
FTTC: Fiber to the Curb(Kerb)
PON: Passive Optical Network
xDSL: Digital Subscriber Line(ADSL,HDSL,VDSL, PowerDSL)

MPEG-2 Video:

ISO/IEC 13818-2

Data Compression Standards

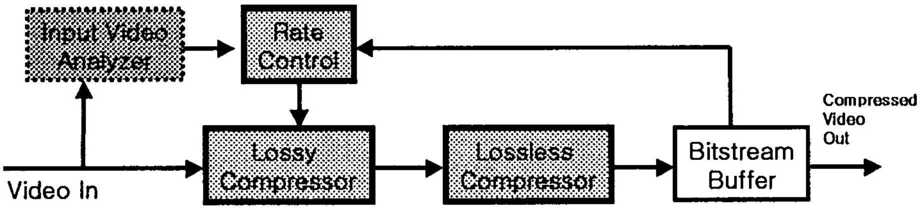


JPEG: Joint Photographic Experts Group
MPEG: Moving Pictures Experts Group

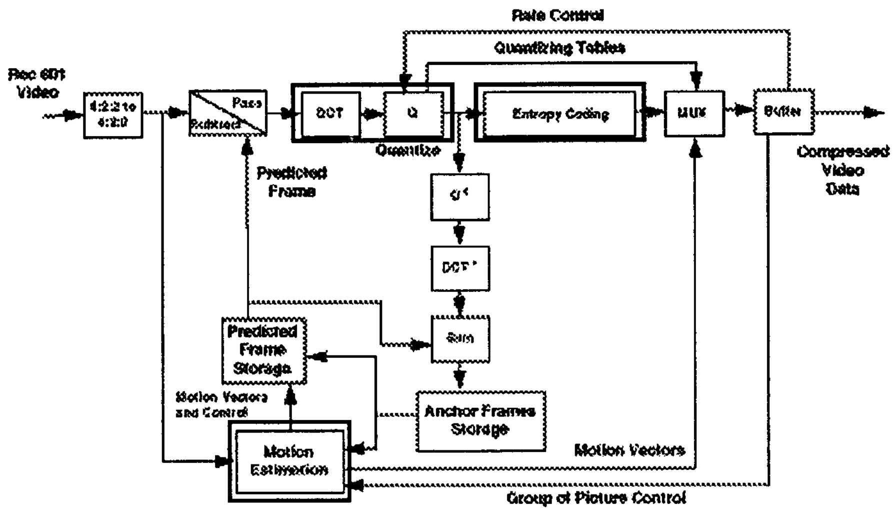
MPEG-2 Video Encoding

■ **Lossy Compression**
- ◆ **Temporal redundancy elimination: Motion compensated prediction**
- ◆ **Spatial redundancy elimination: Discrete Cosine Transform**
- ◆ **Linear/Non-linear Quantization**

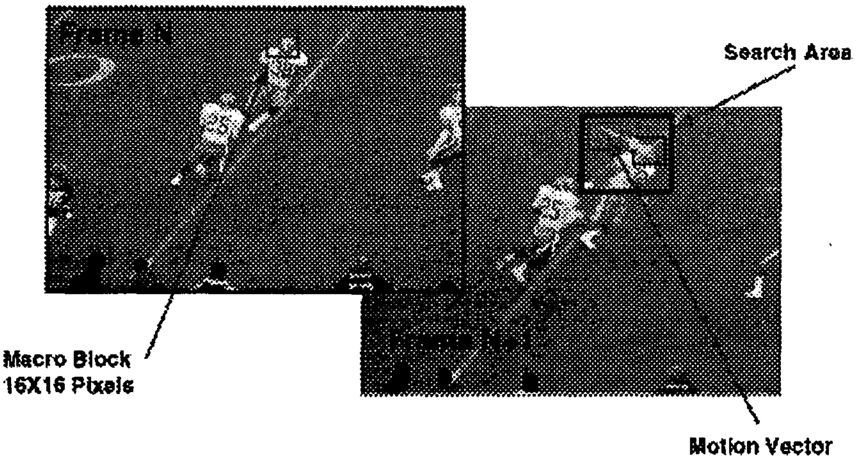
■ **Lossless Compression**
- ◆ **2D-VLC(Huffman Coding): (Magnitude, Zero-Run Length)**



MPEG-2 Video Encoding:



Temporal Redundancy Elimination



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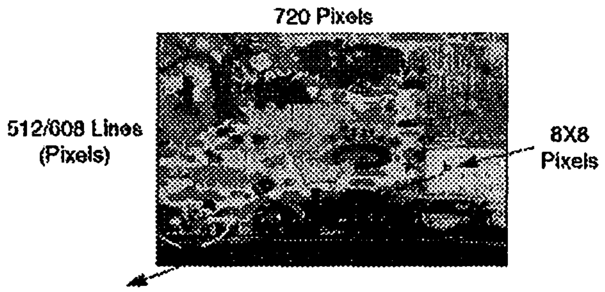
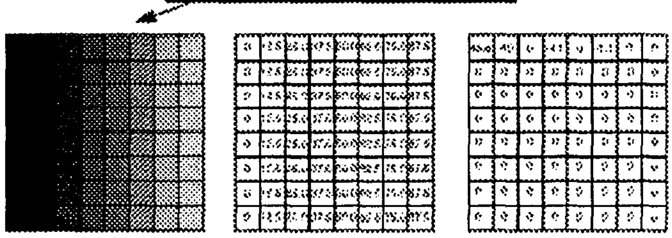
Spatial Redundancy Elimination





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MPEG-1 v.s. MPEG-2

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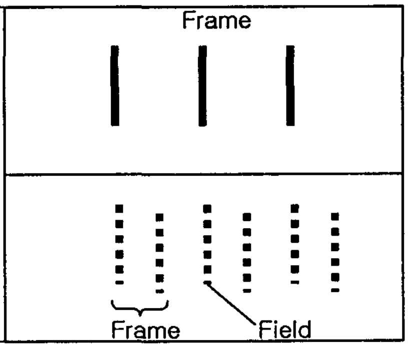
- **MPEG-1**
  - ◆ **MC-DCT + 2D-VLC**
  - ◆ **Frame based**
- **MPEG-2**
  - ◆ **MC-DCT + 2D-VLC**
  - ◆ **Field/Frame based**



MPEG-2 can handle interlaced picture well.

MPEG-2 Coding Scheme

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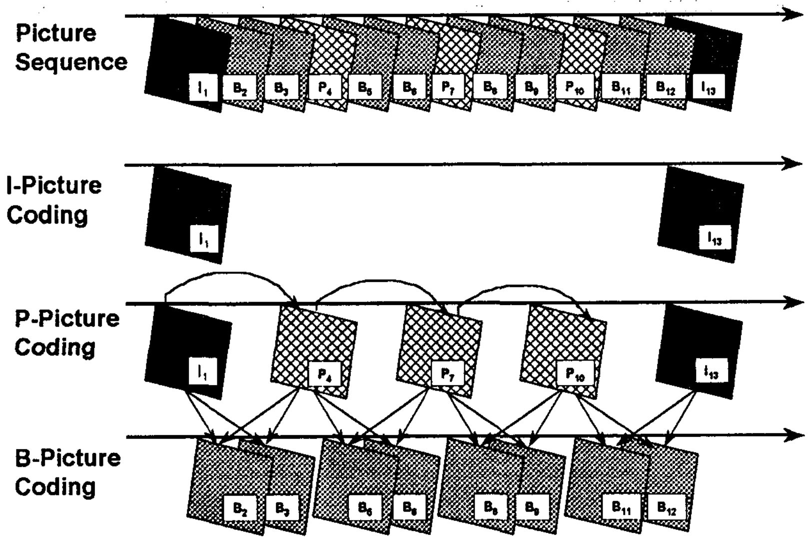
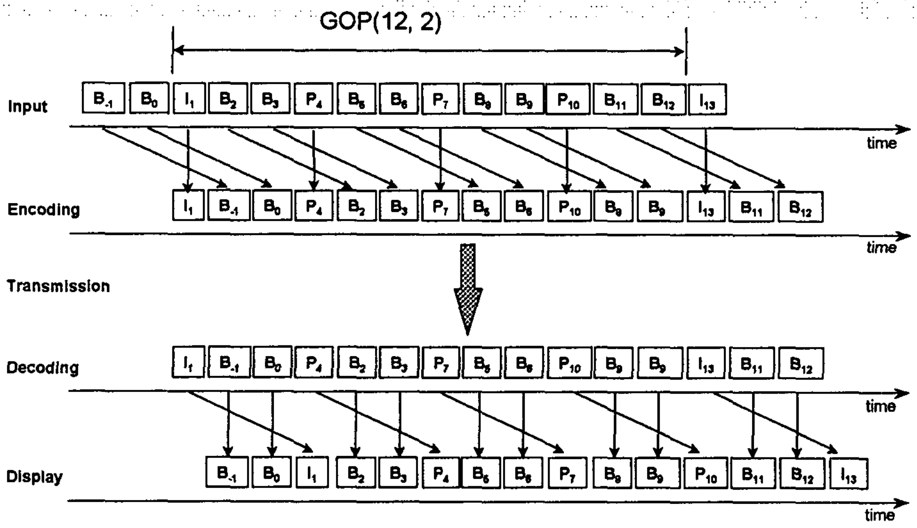


MPEG Processing Order



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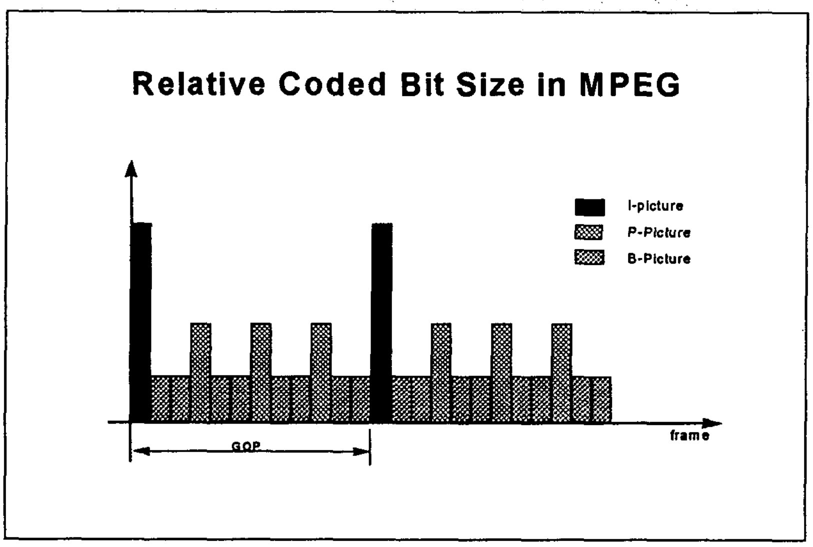
MPEG-2 Traffic



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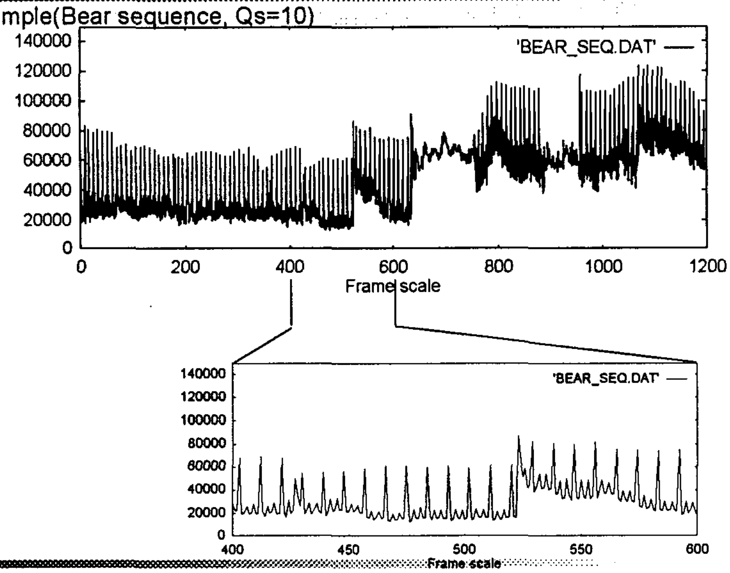
MPEG-2 Traffic Characteristics:

An Example(Bear sequence, Qs=10)



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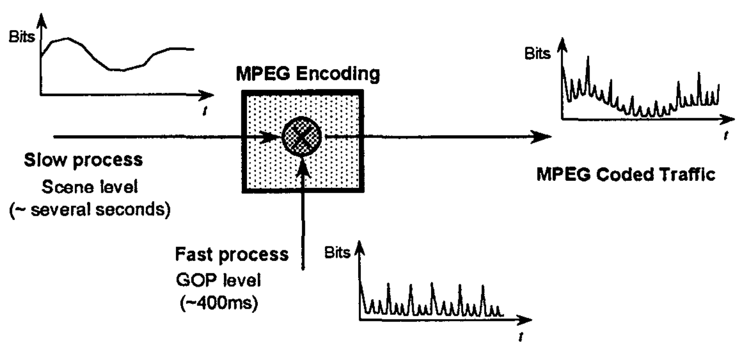
MPEG-2 Traffic Characteristics

A Conceptual Model for MPEG Encoding



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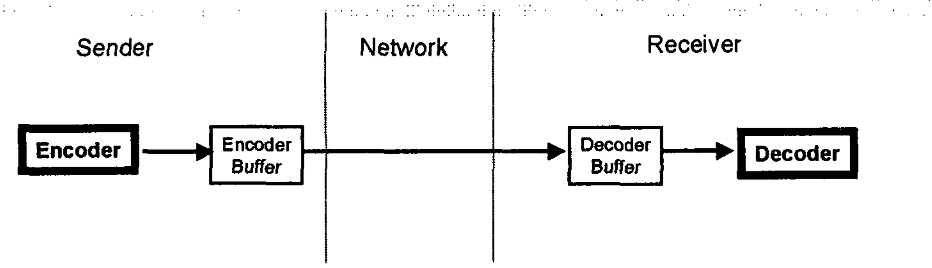
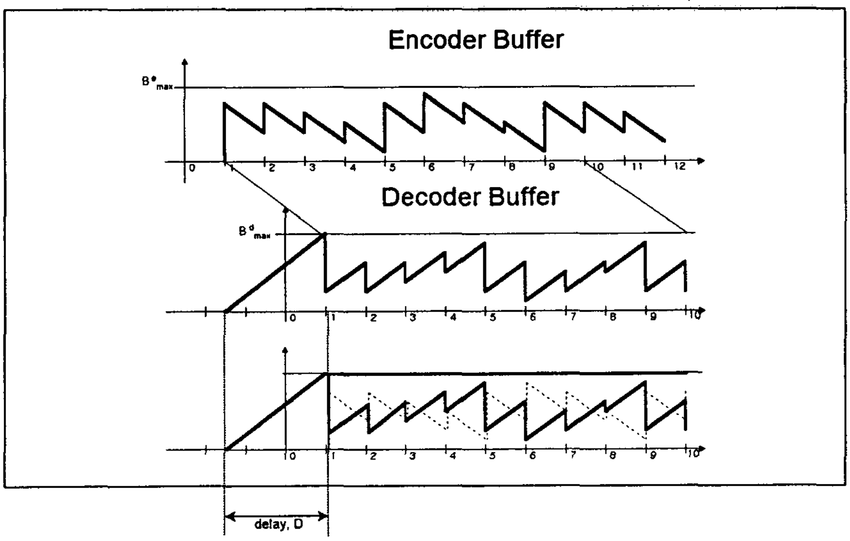
Delay and Buffer Size



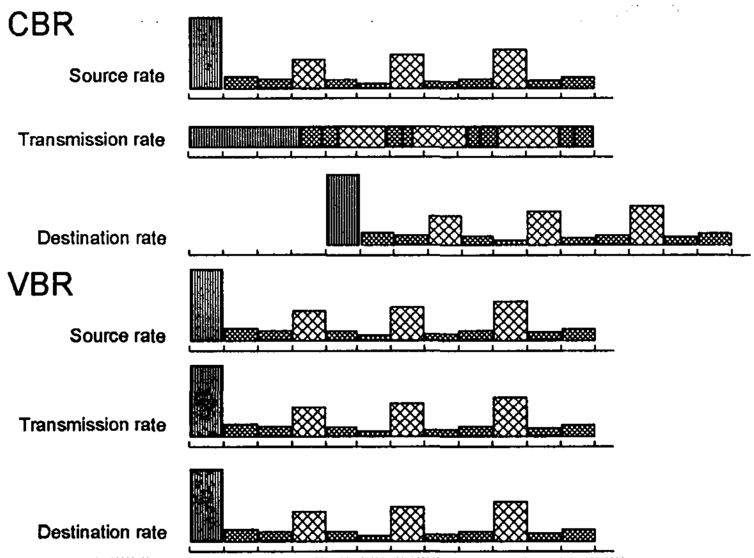
- MPEG needs rather large buffer(SDTV: 1.8Mbits, HDTV: ~8Mbits)

cf. H.261(64kbps: ~8.5Kbits; ~133ms delay)

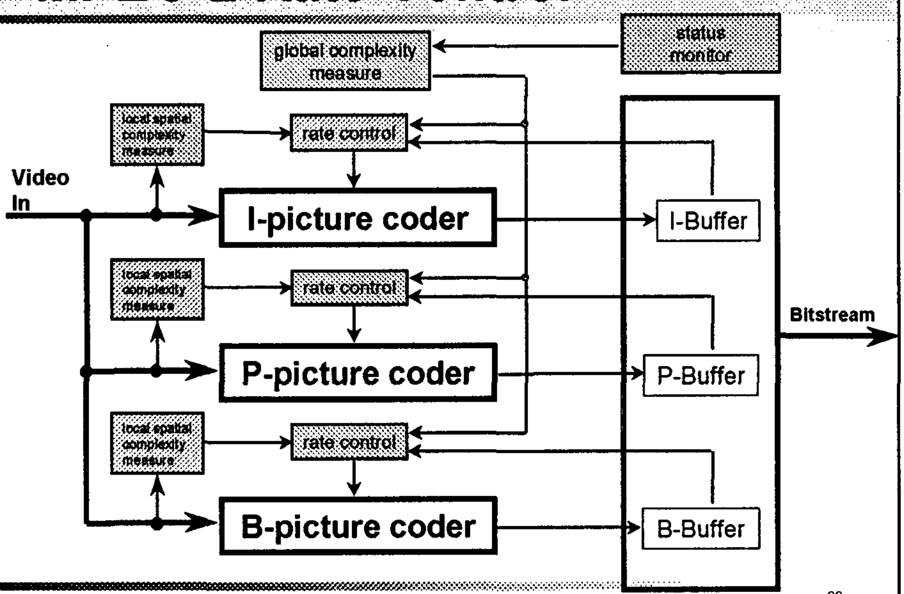
Encoder-Decoder Buffer Behaviour: CBR Case



Buffer Delay: CBR vs.VBR



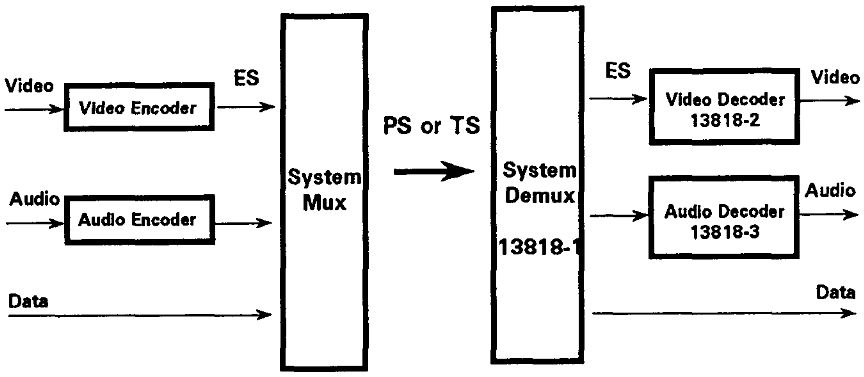
MPEG-2 Rate Control



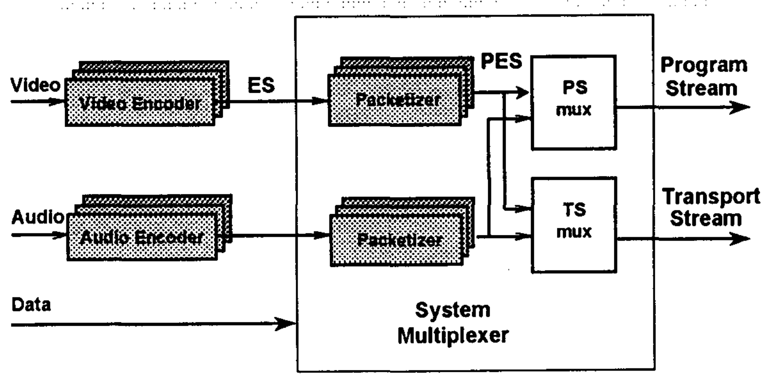
MPEG-2 Systems:

ISO/IEC 13818-1

MPEG Standards

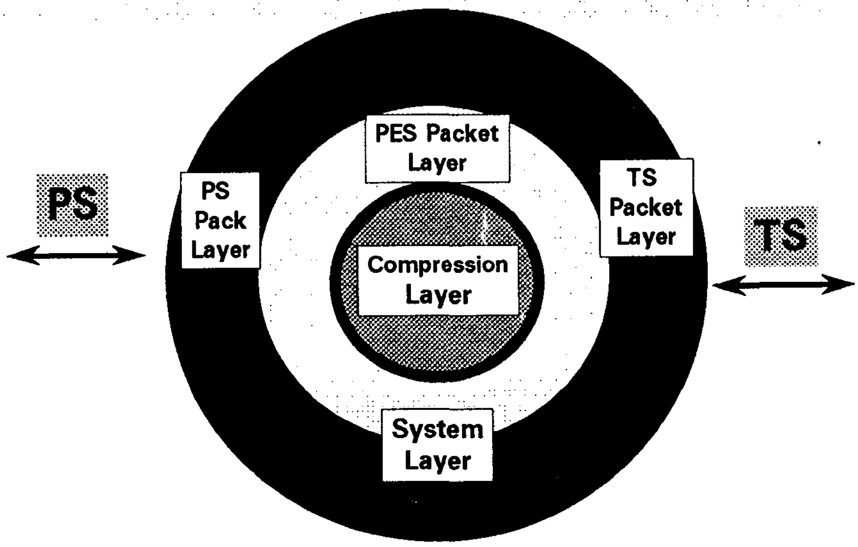


MPEG Systems Standards



ES : Elementary Stream
PES : Packetized Elementary Stream
PS : Program Stream
TS : Transport Stream

MPEG-2 Systems Layers



MPEG-2 Systems Functionalities

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- **Multiplexing(STD-Model)**
  - Multiple Programs
  - Multi-media Multiplexing in a Program
  - Packet Based
  - Transmission Medium Independent
- **Synchronization(Timing-Model)**
  - Absolute Time Identification
  - Synchronized Presentation
  - Buffer Management

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Constant Delay Timing Model :

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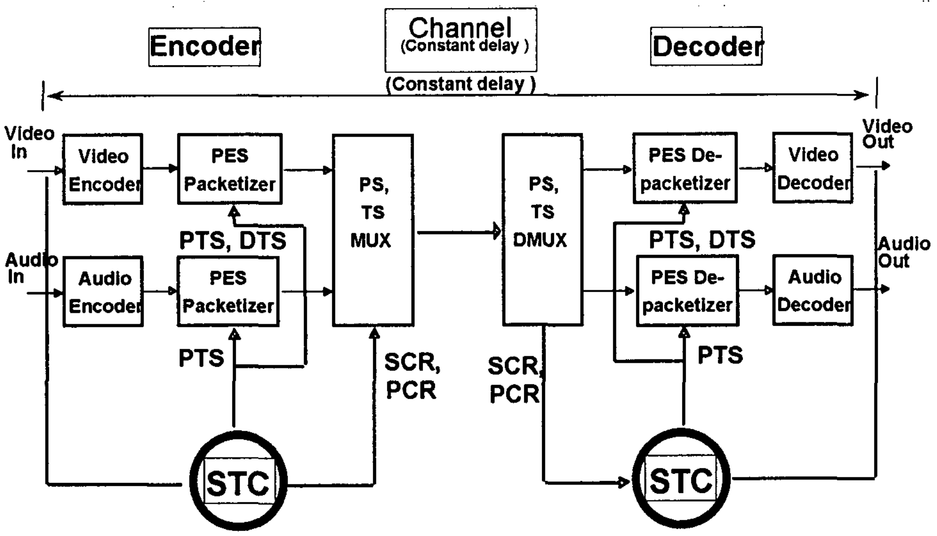
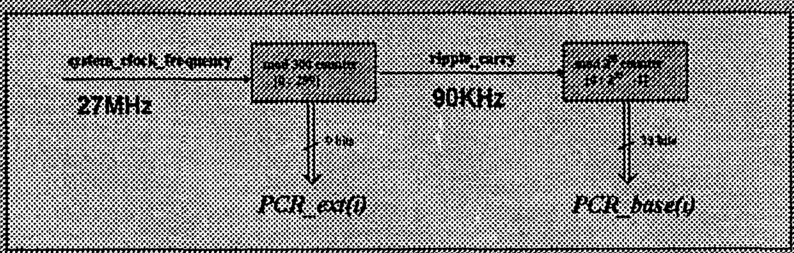
System Timing Model

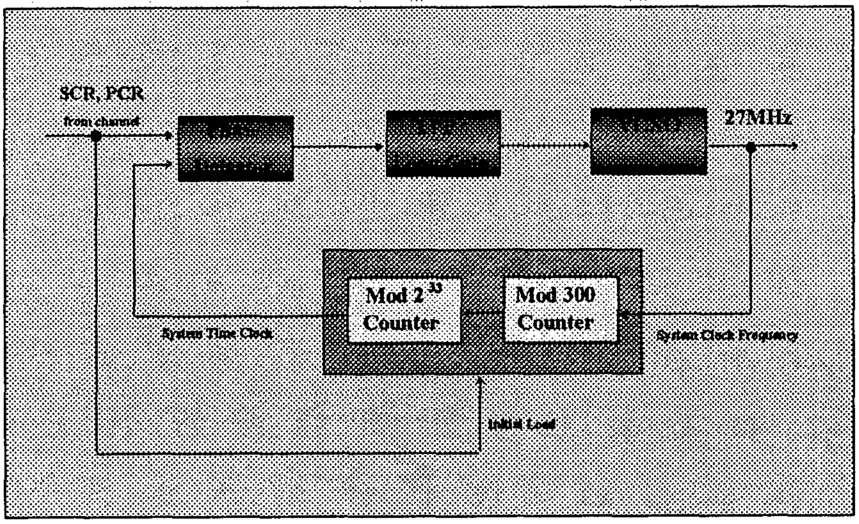


PCR Generation



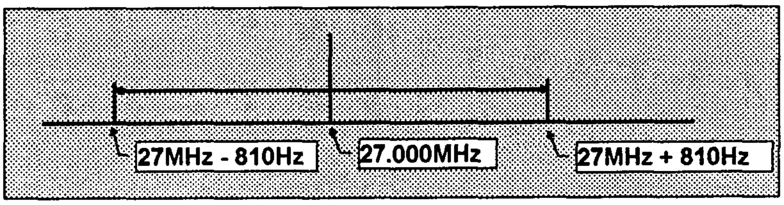
- Why **27MHz** as the STC(System Time Clock) in MPEG-2?
- Why 90KHz as STC in MPEG-1, is it full enough?
  - No Problems with DSM

System Clock Recovery



STC Tolerance Spec.

- Accuracy : 27MHz +/- 30ppm
- Rate of change with time : 0.075 Hz/sec



- System Clock may be locked to the Input Video
- System Clock may be locked to the Input Audio

Time Stamp Coding-I

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- PTS, DTS
  - Reside in the PES packet
  - Intended time for AUs to be presented or decoded
  - Coding interval : less than 0.7sec
- SCR , PCR
  - Sampled value of the encoder **STC** at the time of transmission.
  - Coding interval(**SCR**) : less than 0.7sec
  - Coding interval(**PCR**) : less than 0.1sec

Time Stamp Coding-II

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- PTS, DTS Coding

$$PTS(k) = ((system\_clock\_frequency \times tp_n(k)) DIV 300)\% 2^{33}$$

$$DTS(k) = ((system\_clock\_frequency \times td_n(k)) DIV 300)\% 2^{33}$$

- SCR, PCR Coding

$$PCR(i) = PCR\_base(i) \times 300 + PCR\_ext(i)$$
$$PCR\_base(i) = ((system\_clock\_frequency \times t(i)) DIV 300)\% 2^{33}$$
$$PCR\_ext(i) = ((system\_clock\_frequency \times t(i)) DIV 1)\% 300$$

T-STD Model:

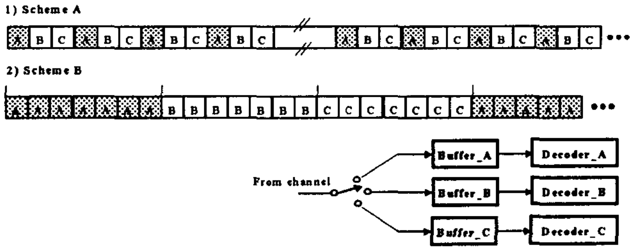
Transport Stream System Target Decoder

T-STD Objectives

- To specify a standard,
  - independent of bit rates,
  - independent of implementations
  - CBR/VBR
- To provide models for
  - data delivery
  - timing
- To specify the virtual platform for MPEG-2 decoder.
- To specify a tool for verification of application correctness.

T-STD Motivations

- **Multiplexing schemes**

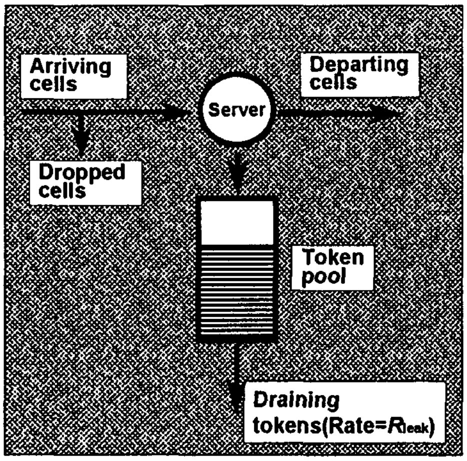


- **The effects of multiplexing schemes on receiving buffer.**
  - What will happen if the **burst duration** is long ?
- **Source traffic control parameters**
  - peak rate
  - average rate
  - burst duration

Leaky Bucket Concept

- The "**Leaky Bucket**" is a useful tool for **traffic policing**
  - To prevent network congestion
  - To detect *the violating cells* of nonconforming sources
- The "**Leaky Bucket**" Parameters :
  - *the **leaky rate***
  - *the **token pool size***
- There are several variants of the "Leaky Bucket".

Operation of the "Leaky Bucket"



LB Operation

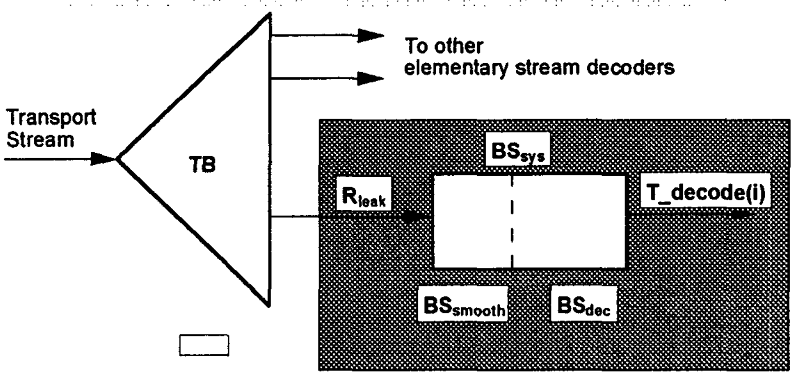
1) ***Tokens*** are drained off at a constant rate from the ***token pool***(at the ***leak rate***).

2) when the ***token pool*** is empty, no ***tokens*** are drained from the ***token pool***.

3) If the token pool is not full, an arriving cell enters the network immediately, and at the same time a ***token*** is inserted into the ***token pool***.

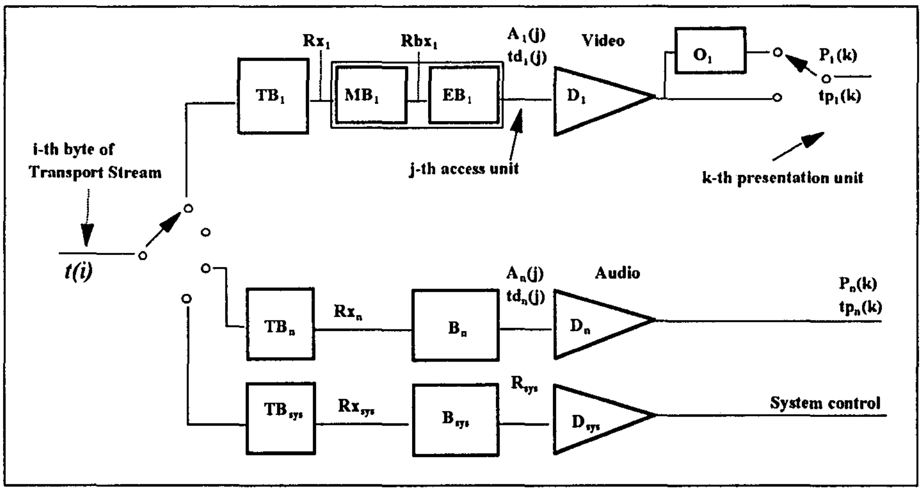
4) The arriving cells that arrive when the ***token pool*** is full are discarded.

Ideal Decoder Model

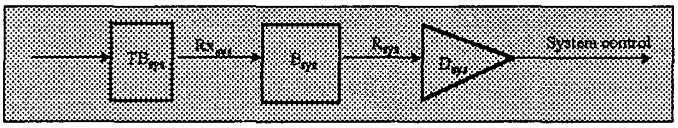


- Items to be specified
  - the size of TB, BS_{sys} (BS_{smooth} , BS_{dec})
  - the leak rate R_{leak}
  - the decoding process(decoding times)

MPEG-2 T-STD Model

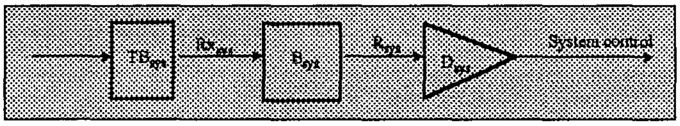


T-STD : System Decoder



- **Transport Buffer**
  - TBS_{sys} : 512 bytes
  - Rx_{sys} rate : 1.0 Mb/s
- **Main Buffer**
  - BS_{sys} : 1,536 bytes
  - R_{sys} rate : max{80Kb/s, *transport_rate(i)**8 bits/byte/500}
- **Buffer management**
  - TB_{sys} *shall not overflow*, and ***shall empty at least once every second.***
  - B_{sys} *shall not overflow.*

T-STD : System Decoder(cont'd)



- **Input Data of the System Decoder**

  Includes TS packets for system information which are used for decoding of the selected program.

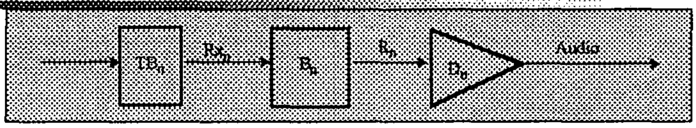
  - PAT

  - CAT

  - PMT

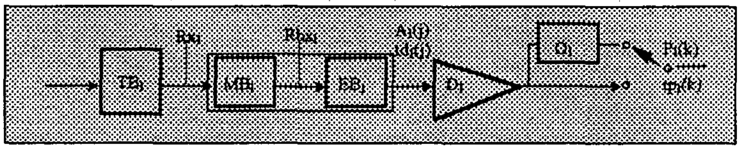
- **Note that the NIT is not transfered to TB_{sys}.**
- **Also note that the EPG or SI are not transfered to TB_{sys}.**

T-STD : Audio Decoder



- **Transport Buffer**
  - TBS_n : 512 bytes
  - Rx_n rate : 2.0 Mb/s
- **Main Buffer**
  - $BS_n = BS_{mux} + BS_{dec} + BS_{oh}$: 3,584 bytes
    ($BS_{dec} + BS_{oh} <= 2,848$bytes)
  - R_n rate :
- **Buffer management**
  - TB_n *shall not overflow,*
    and ***shall empty at least once every second.***
  - B_n *shall not overflow nor underflow.*

T-STD : Video Decoder

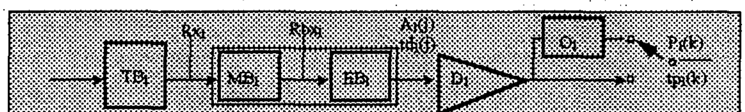


- **Transport Buffer**
  - TBS_n : 512 bytes
  - Rx_n rate : 1.2 * $R_{max}[p,l]$
- **Multiplexing Buffer**

- **Elementary Buffer(i.e. VBV)**

- **Data Transfer from MB to EB**
  - Leak Method
  - VBV Method

T-STD : Video Decoder(cont'd)



- **Multiplexing Buffer**

1) Low & Main Level

$MBS_n = BS_{max} + BS_{oh} + VBV_{max}[p,l]$ - *vbv_buffer_size,*

where BS_{max} = 0.004 seconds * $R_{max}[p,l]$,
BS_{oh} = (1/750)seconds * $R_{max}[p,l]$.

2) H1440 & High Level

$MBS_n = BS_{max} + BS_{oh}$,

where BS_{max} = 0.004 seconds * $R_{max}[p,l]$,
BS_{oh} = (1/750)seconds * $R_{max}[p,l]$.

3) MPEG-1 CPBS

$MBS_n = BS_{max} + BS_{oh}$ + vbv_max - *vbv_buffer_size,*

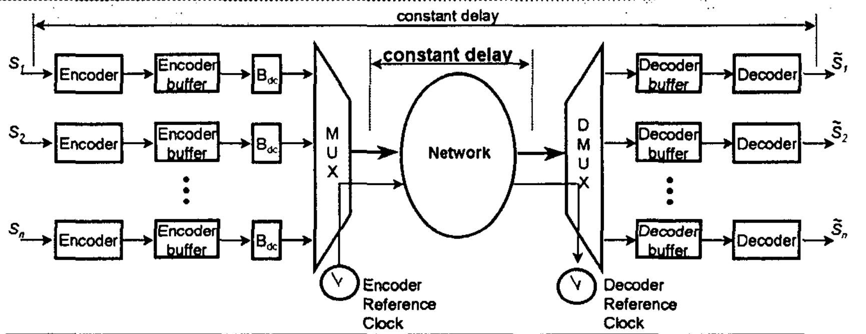
where BS_{max} = 0.004 seconds * R_{max},
BS_{oh} = (1/750)seconds * R_{max}.

TS 주요 시험 대상

- TS 전송 속도
- PSI 정보의 규격 적합성 여부
- 동기 관련 사항
  - PCR 전송 주기 및 지터, PCR 정확도
  - PTS, DTS 전송 주기
- T-STD 모델 관련
  - T-STD buffer overflow/underflow
  - 1 second 규칙 위반
- Syntax, Semantics 적합성
- 허가된 Id(Format_Id, 등) 준수 여부

디지털 방송시스템

System Delay and Delay Compensation

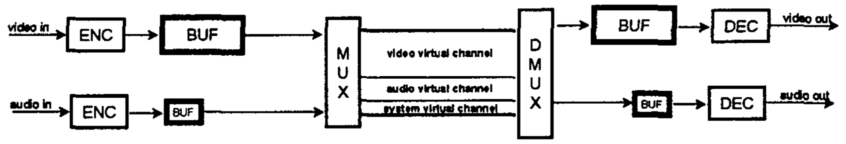


- Decoder reference clock is slaved to that of encoder.
- Decoder buffers are managed by each DTS(Decoding Time Stamp), i.e. the time when a coded unit of a picture leaves the decoder buffer is explicitly defined by DTS.
- **System delay** D_{sys} must be chosen such that,

$$D_{sys} = max\{d_i\ i=1,\ldots,n\}.$$

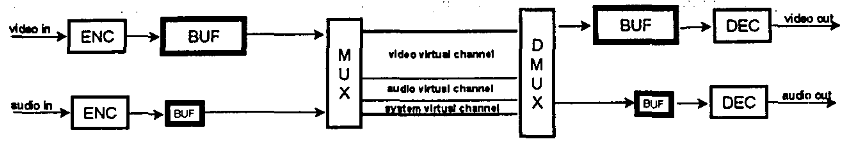
- For each path to have the same delay, **delay compensation** must be done somewhere in the path. When MPEG-2 TS is adopted, it should be done at the sending side.

Delay Difference between Video and Audio



- Assume that the the encoding and decoding delays are zero seconds, and that the transmission is CBR.
- Video Data Transmission
  - video data delay : $delay_{video} = \frac{total\_buffer\_size_{decoder\_video\_path}}{bit\_rate_{video}}$
- Audio Data Transmission
  - audio data delay : $delay_{audio} = \frac{total\_buffer\_size_{decoder\_audio\_path}}{bit\_rate_{audio}}$
- Delay Difference : $delay\_difference_{v-a} = delay_{video} - delay_{audio}$
- *IF the Delay Difference$_{v-a}$ is not zero seconds, what will happen ? and which one is responsible for this ?*

Delay Difference : An Example



- A video stream compliant to MPEG-2 MP@ML with 6Mb/s rate and an audio stream compliant to MPEG-I Layer-II with 384Kb/s bit rate are multiplexed into **Transport Stream**, in this case the **delay difference** can be calculated as follows.

$$delay_{video} = \frac{TBS + 0.004 * R_{max}[p,l] + (\frac{1}{750}) * R_{max}[p,l] + VBV_{max}}{bit\_rate_{video}}$$

$$= \frac{239,888 byte * 8 bits/byte}{6 \times 10^{6} bits/sec}$$

$$= 0.31985 sec$$

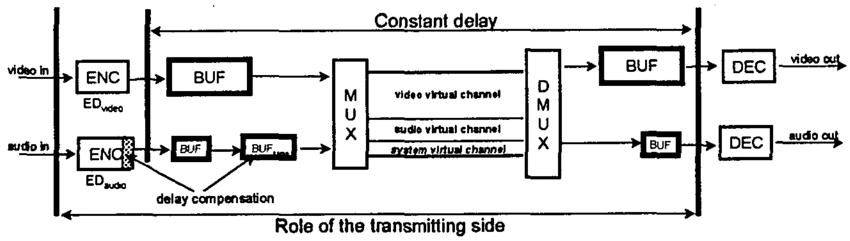
$$delay_{audio} = \frac{4096 byte * 8 bits/byte}{384 \times 10^{3} bits/sec}$$

$$= 0.08533 sec$$

$$delay\_difference_{v-a} = 0.2345 sec$$

- This calculation shows that audio is always decoded **235ms in advance** compared to video in this configuration.

Delay Difference Compensation*



- To compensate the delay difference between the video data and audio data, ***the transmitting equipment must have the functionality to delay the audio data in the case of TS stream.***

- In actual case, the encoding delay is not equal to zero and the encoding delays of video and audio are different.
  For instance, the video encoding delay is 3 to 5 frame times depending on the coding schemes used, and the audio encoding delay is about 2 to 3 audio frame times. If we assume that the video encoding delay is 5 NTSC frame times and the audio encoding delay is 2 audio frame times(e.g. MPEG-1 Layer II, 48KHz sampled audio), the encoding delay difference is about 119ms. This value is too large to be ignored.

  Therefore the encoding delay difference must be compensated in the ***transmitting equipment*** *in actual implementations.*

Summary and Discussions

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- MPEG-2 Encoders has a long way to go for improving the performance.
- MPEG-2 Systems Timing Model and STD-Model violations are found here and there.
- TS analysis techniques are still not matured.

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Visualization Demo.

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Q & A

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