Fundamental of Digital Video Coding

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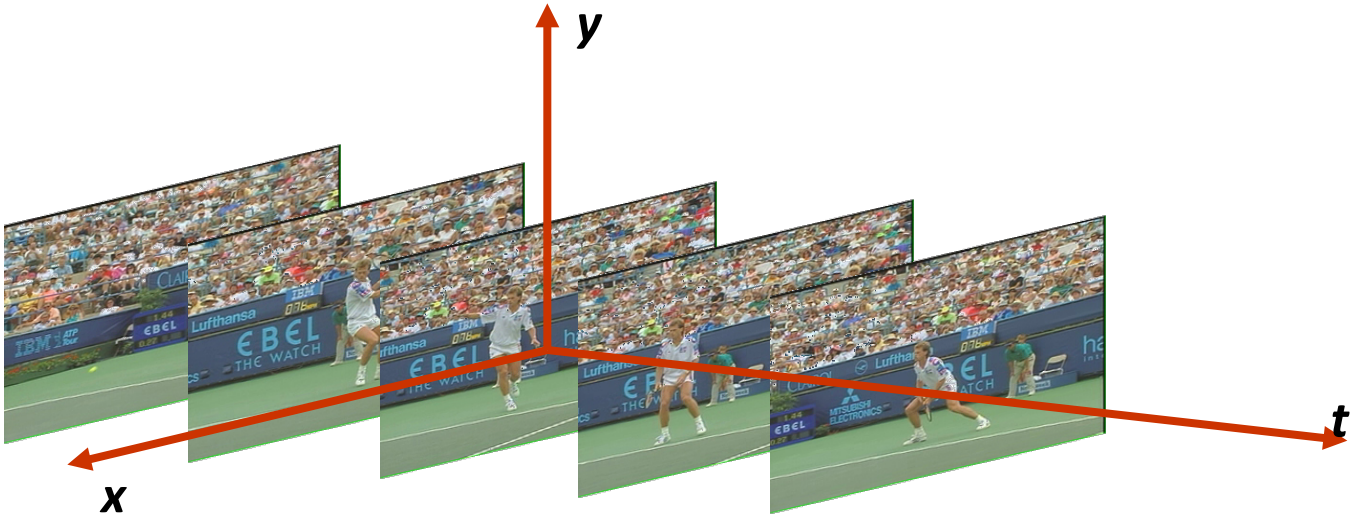
Outline

- **Digital Video Representation**
  - **Application scenarios of video coding**
  - **Theoretical basis of video coding**
  - **Digital video formats**
- **Current status of digital video/image coding standards**
  - **Standard activities**
  - **Brief description of standards**

Digital Video Overview

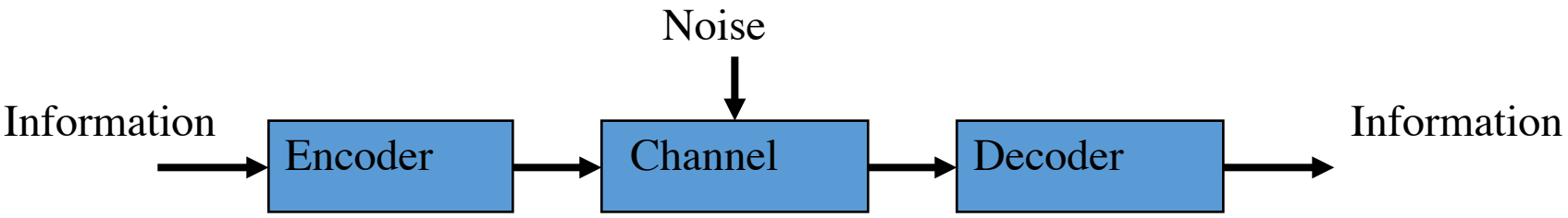
- **Digital Video**

$$f(x,y,t),(0 \le x \le N-1, 0 \le y \le M-1, t = 0, T, 2T, \ldots)$$



Scenario of video compression: transmission

- Communication systems



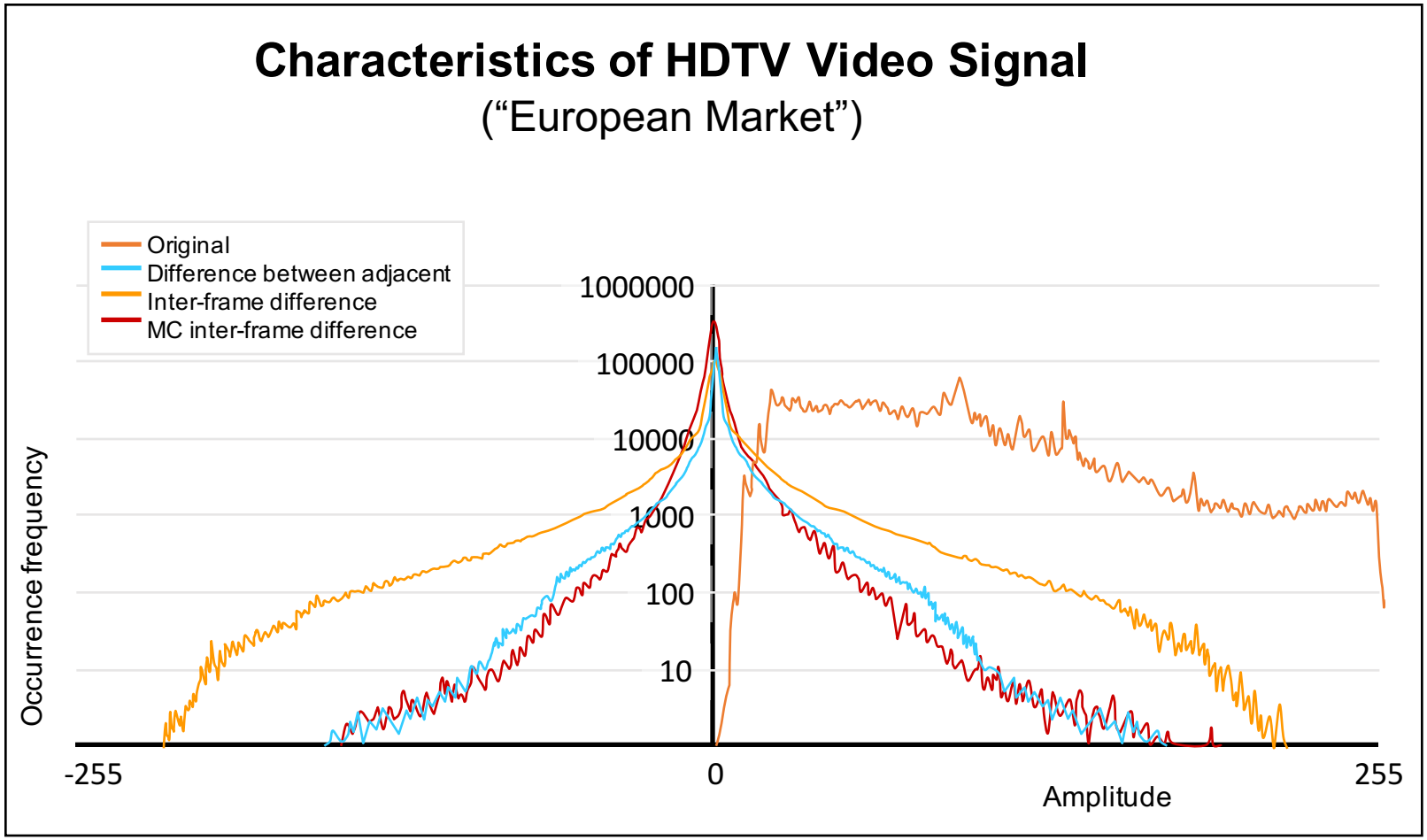
- Encoder
  - Source coding: remove redundancy correctly and keep as much information as possible for given data rate
  - Channel coding: add proper redundancy to protect information
- Channel
  - Capability or bandwidth allow maximum information transmission without information loss: Shanon Model
- Decoder:
  - Recovery information
  - Post processing

Scenario of video compression: storage

- Storage applications: such as DVD

- Encoder
  - To meet the fixed sized storage
  - To obtain maximum quality for a given size
- Almost error free environment
- Decoder
  - Multi-standard format

Characteristics of video signals

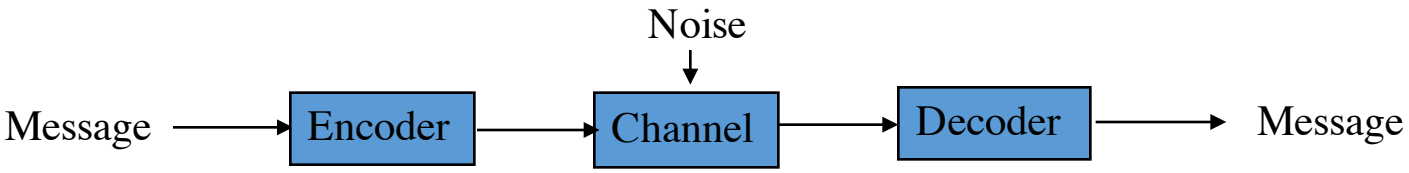


Basic principles of video compression

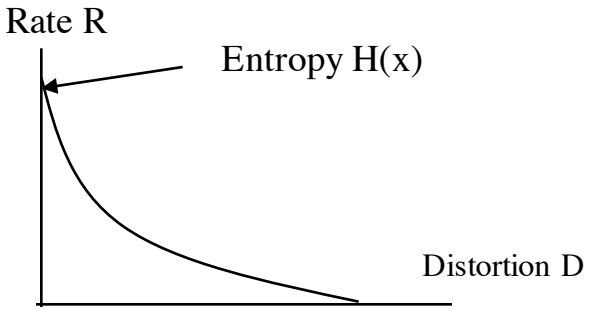
- **Theoretical basis of digital video compression**
  - Remove spatial and temporal redundancy that exist in natural video imagery
    - correlation itself can be removed in a lossless way
    - compression ratio dependent on the nature of images, about 2:1
    - important for medical applications
  - Psychophysical redundancy
    - exploit limitation in human visual system
    - reduced sensitivity to noise in high frequencies (edge of object)
    - save bits in a psychovisually lossless
  - Entropy coding
    - statistical method

Shannon' Model and rate distortion theory

- Shannon's model of communication system



  - How much information included in the message
  - How can the information can be expressed effectively
  - How can the information transmitted correctly over the noisy channel
- Rate distortion function



Fundamental technologies of video coding

- Prediction
  - Reduce the redundancy in the video data
  - Intra frame prediction
  - Inter frame prediction with motion compensation
- Transform
  - Decomposition, not equal energy distribution
- Quantization
  - Reduce the information permitted by human visual system limit
  - Optimized quality according to the frequency sensitivity
- Entropy coding
  - Reduce bit rates according to the statistics of source data
  - Variable run length coding
  - Arithmetic coding

Video representation

Color representation

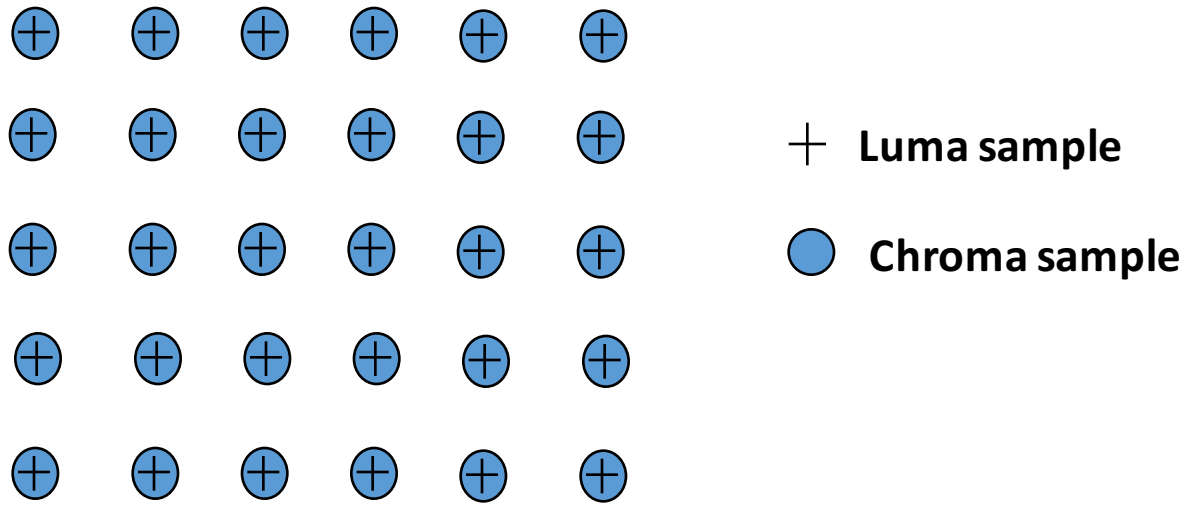
- Colors can be represented by a mixture of three primaries: R, G, B
- Various equivalent color spaces are possible

- Many important color spaces comprise a luminance component and two chrominance components
- Color space standards
  - ITU-RB.601 for SD
  - ITU-RB.709 for HD
  - New standard xvYCC color space IEC-61966-2-4

Digital video formats

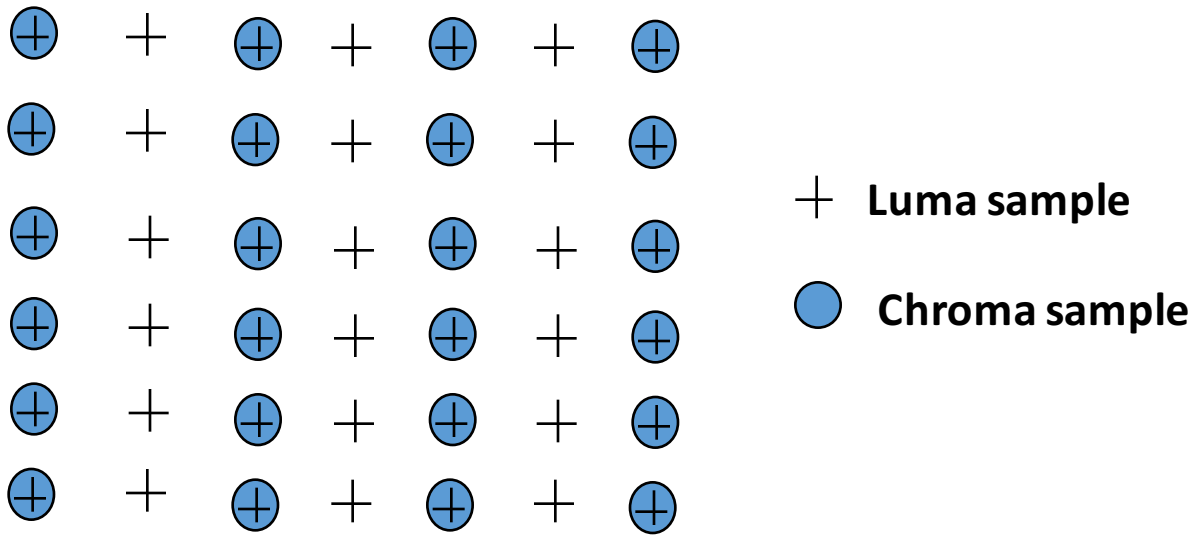
4:4:4 sampling format

- Chroma and luma samples are co-sited



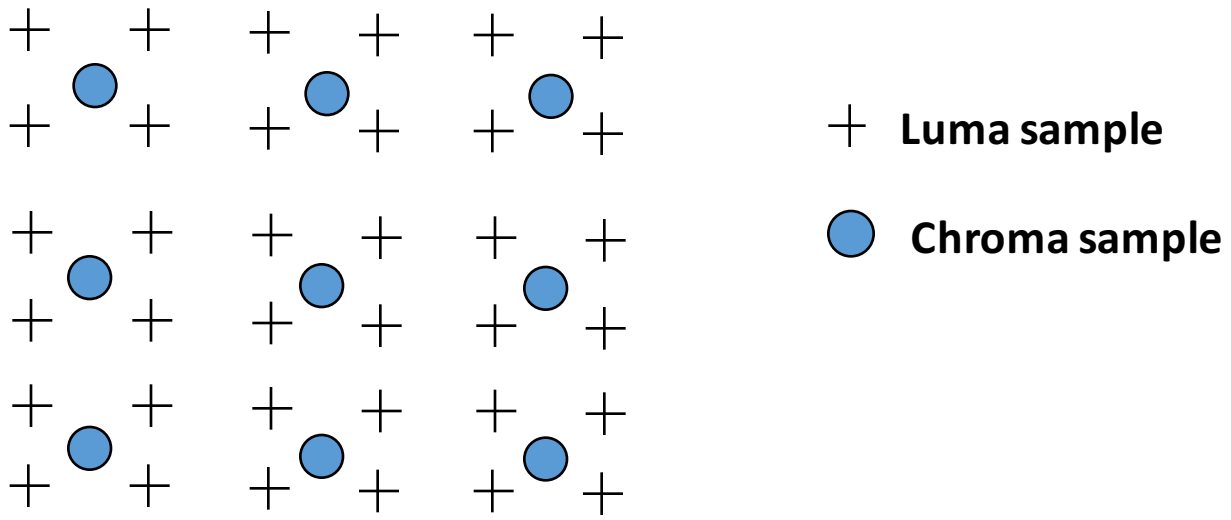
4:2:2 sampling format

- Chroma and luma samples are co-sited
- Chroma subsampled



4:2:0 sampling format

- Chroma and luma samples are not co-sited
- Chroma is subsampled by two both horizontal and vertically

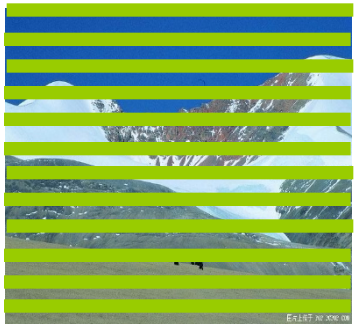


Progressive and Interlace

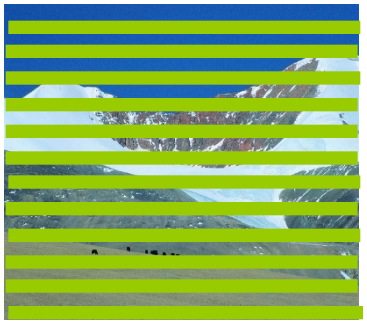
Part Frame scanned (1/60 sec)

Full Frame (1/60 sec)

Odd Field (1/60 sec)



Even Field (1/60) sec)



Full Frame (1/30 sec)

Why compress?

Video Format	Y Size	Color Sampling	Frame Rate (Hz)	Raw Data Rate (Mbps)
HDTV Over air. cable, satellite, MPEG2 video, 20-45 Mbps				
SMPTE296M	265/332/664	1280x720	4:2:0	24P/30P/60P
SMPTE295M		1920x1080	4:2:0	24P/30P/60I
		597/746/746		
Video production, MPEG2, 15-50 Mbps				
BT.601		720x480/576	4:4:4	60I/50I
		249		
BT.601		720x480/576	4:2:2	60I/50I
		166		
High quality video distribution (DVD, SDTV), MPEG2, 4-10 Mbps				
BT.601		720x480/576	4:2:0	60I/50I 1
		24		
Intermediate quality video distribution (VCD, WWW), MPEG1, 1.5 Mbps				
SIF		352x240/288	4:2:0	30P/25P
		30		
Video conferencing over ISDN/Internet, H.261/H.263/MPEG4, 128-384 Kbps				
CIF		352x288	4:2:0	30P
		37		
Video telephony over wired/wireless modem, H.263/MPEG4, 20-64 Kbps				
QCIF		176x144	4:2:0	30P
		9.1		

Examples of Video Compression

Compression requirements for DTV:

- to fit in a 6 MHz television channel
- to satisfy the channel requirement for networks
- to satisfy commercial picture quality

Compression ratio:

- NTSC (or PAL) : 168Mbps -> 6 Mbps, 28:1
  168Mbps -> 4 Mbps. 42:1
- HDTV: 1.188 Gbps -> 19 Mbps, 60:1

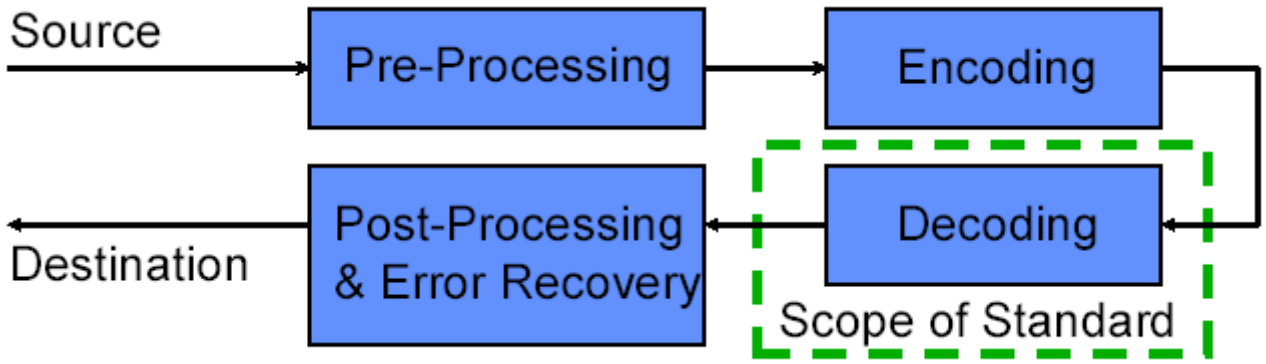
Compression method:

ISO/ITU Video Coding Standards

Note: the above bit rate is required to store 4:2:2 digital video, the active pixels of HDTV are interlaced 1920x1080

The Scope of Video Coding Standardization

- Only restrictions on the Bitstream, Syntax, and Decoder are standardized:
  - Permits the optimization of encoding
  - Permits complexity reduction for implementability
  - Provides *no* guarantees on quality



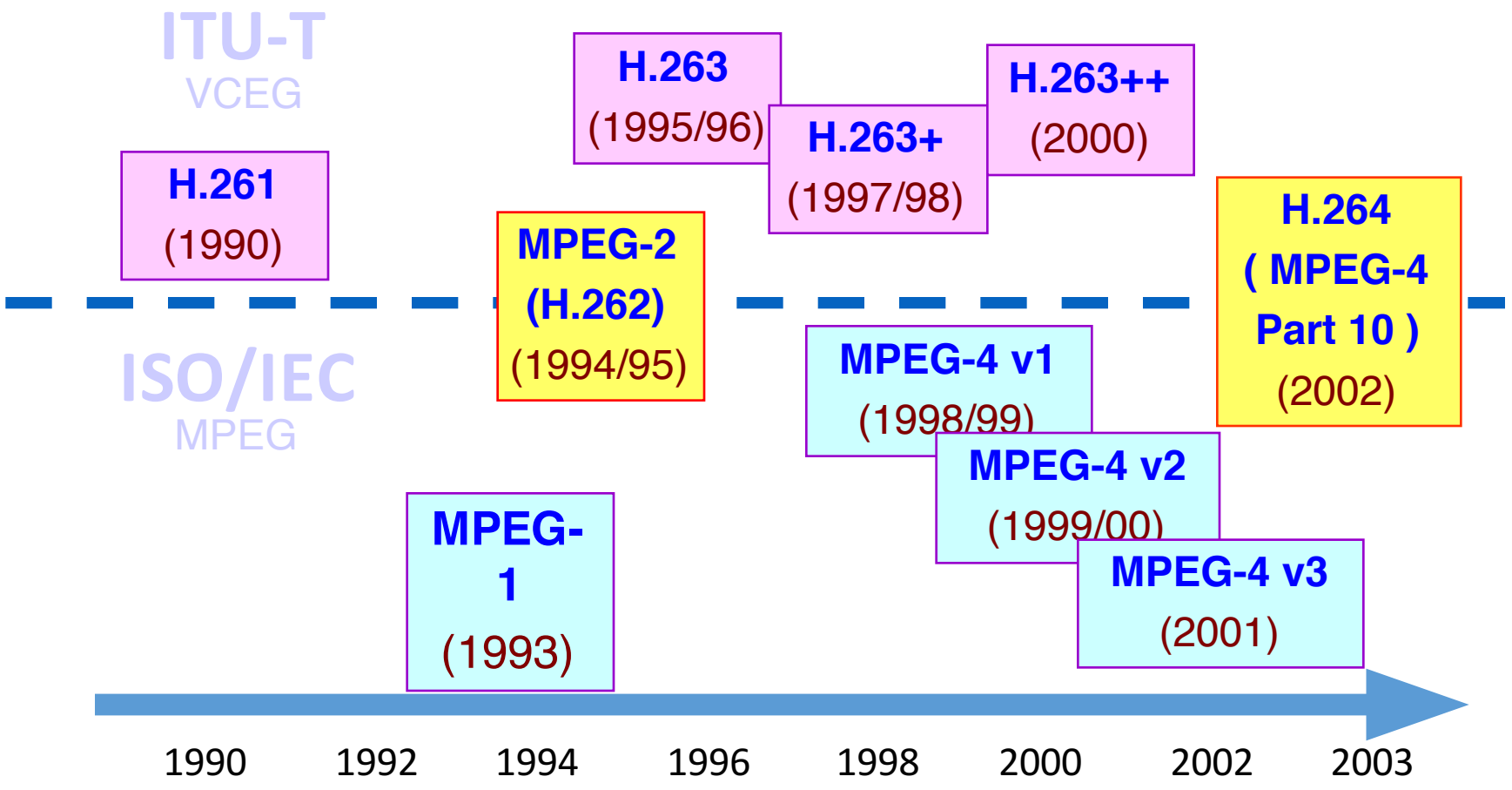
MPEG video standards

- MPEG-1 (1991)
  - Optimized for low rate coding of progressive scanned material at about 1.5 Mbps.
  - System multiplex optimized for error-free channels, primarily digital storage media
- MPEG-2, H.262 (1994)
  - Optimized for low to high rate coding of interlaced and progressive scanned material.
  - System multiplex optimized-for error prone and error-free channels
  - Motion-compensated prediction and DCT transform coding
  - Entropy coding
- MPEG-3
  - Original intended for HDTV coding, dropped when MPEG-2 application domain was extended to HDTV
- MPEG-4 Part 2 (1999)
  - Originally intended for very low bit rate audio/visual coding, change to Object-oriented coding algorithm
  - It may be extended for both low and high bit rate application
- MPEG-4 Part 10 AVC, H.264 (2002)
  - Advanced video coding with coding performance 2 times better than MPEG-2
  - It includes many new coding tools such as multiple reference frames, loop-filter, arithmetic entropy coding, intra frame prediction, integer transform, ..
- MPEG-7 (2001)
  - There is no reason to pick up the series number 7 instead of 5 or 6 or other
  - Intend to set a standard of "Multimedia content description interface" that will specify a standardized description of various types of multimedia information.
- MPEG-21
  - Multimedia framework including DRM, multimedia adaptation ..

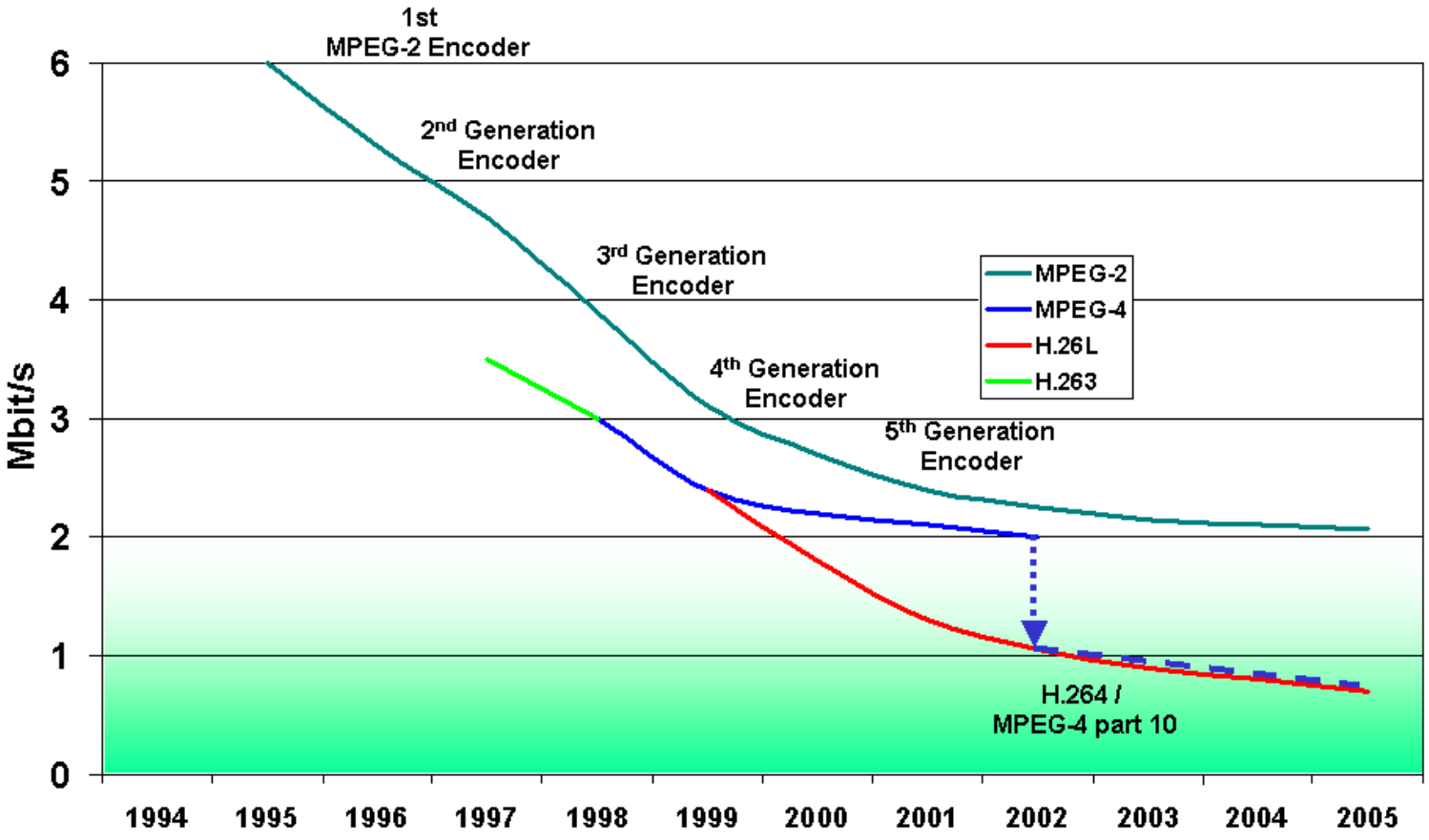
ITU-T Video Coding

- H.261 (1990)
  - DCT-based motion-compensated scheme
  - Target bit rates are from 64Kbps to 1,920 Kbps
  - Used for video conference
- H.263 (1996)
  - Very low bit rate applications
  - Based on H.261 with several added features: unrestricted motion vectors, syntax-based arithmetic coding, advanced prediction and PB-frames
- H.263+ (1998)
  - Including a number of new optional features based on the H.263.
  - These new optional features are added in order to provide improved coding efficiency, a flexible video format, scalability and backward-compatible supplemental enhancement information.
- H.26L
  - Long term project which is looking for more efficient video coding algorithms.
  - H.264 started from H.26L

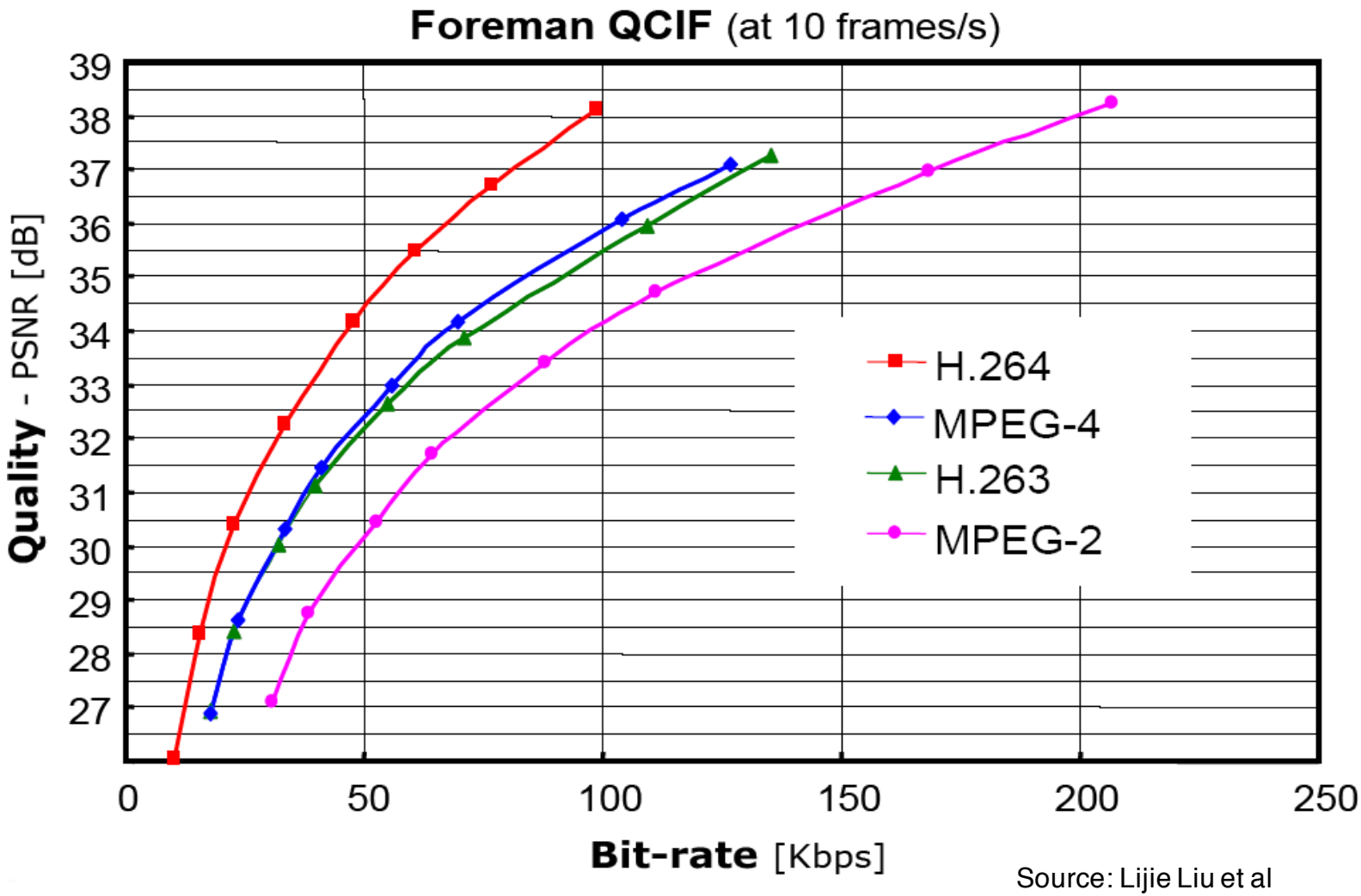
Chronological Table of Video Coding Standards



Coding performance of standards



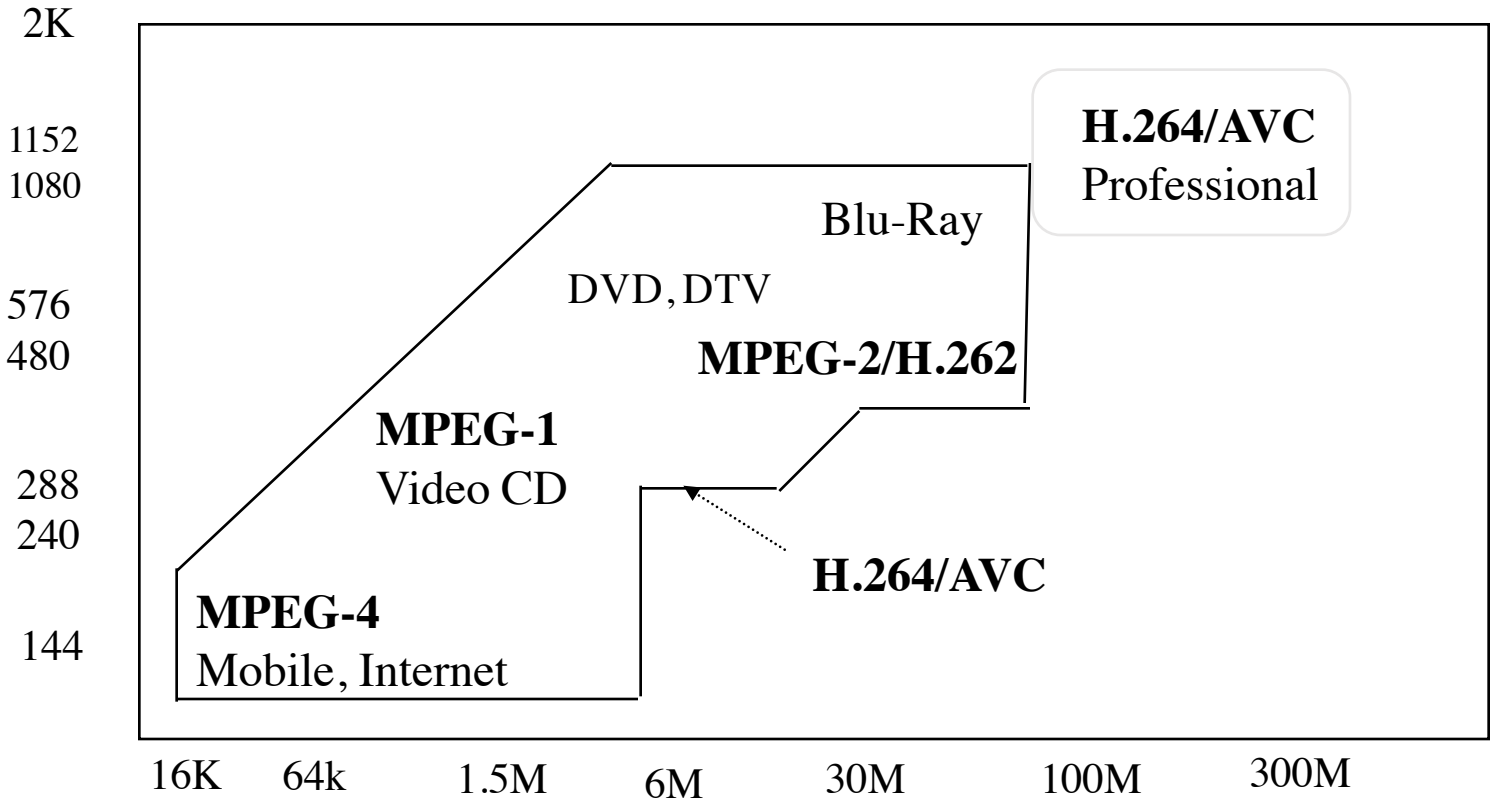
Comparison between standards



Source: Lijie Liu et al

Application scenarios of MPEG standards

- Resolution and bit-rate covered by MPEG videos



JPEG still image coding standards

- JPEG (1992)
  - For still image coding
  - DCT based
  - Moving JPEG
- JPEG2000 (2000)
  - For still image coding
  - Wavelet based
  - Much better coding performance than JPEG
  - Digital cinema and other professional applications

Concluding remarks

- Digital video representation formats
- The purposes of video compression
- Brief introduction of video/image coding standards

Thank You