Overview of MPEG-4 Visual Coding Standard

Weiping Li

WebCast Technologies

li@webcasttech.com

WebCast Tech

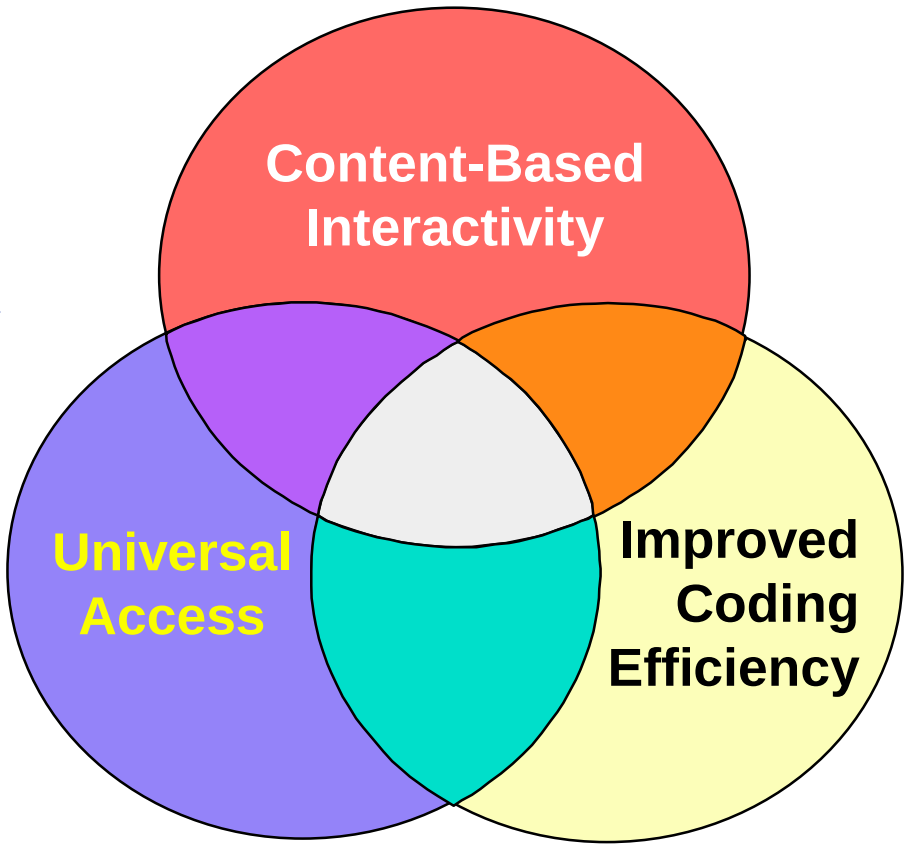
MPEG Standards and Applications

- MPEG
  - Moving Picture Expert Group
  - ISO/IEC JTC1/SC29/WG11
- MPEG-1
  - Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbit/s
  - Video CD (VCD)
- MPEG-2
  - Generic coding of moving pictures and associated audio information
  - DVD, DTV
- MPEG-4
  - Coding of audio-visual objects
  - Multimedia, Interactive, Scalable, Internet, Wireless

Three Objectives of MPEG-4

Video Content Creation

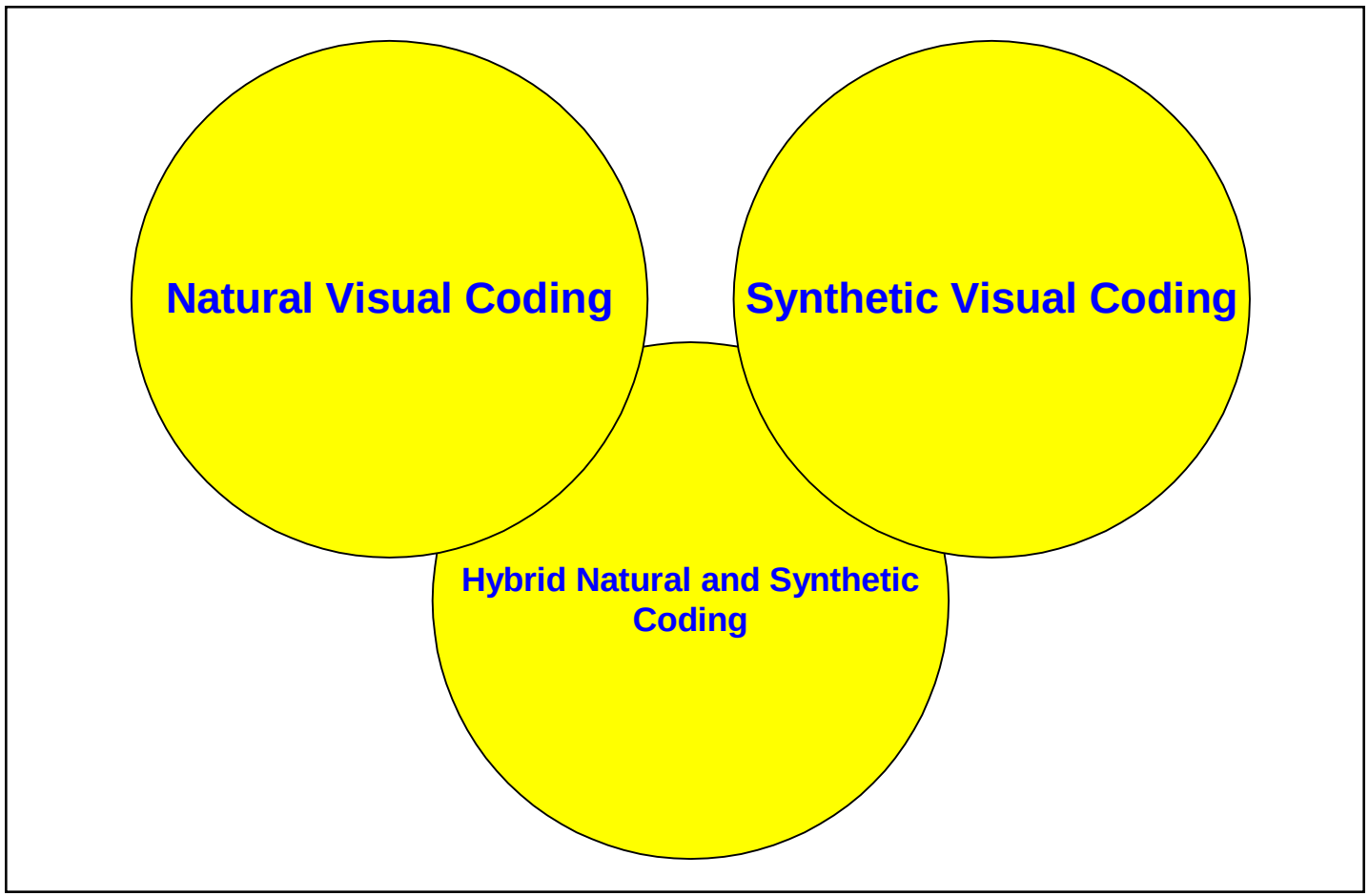
Video Games



Best Video Delivery
for All Possible
Channel Conditions
e.g.
Wireless Video
Internet Video

Better Quality
Lower Bit-Rate

MPEG-4 Visual Coding



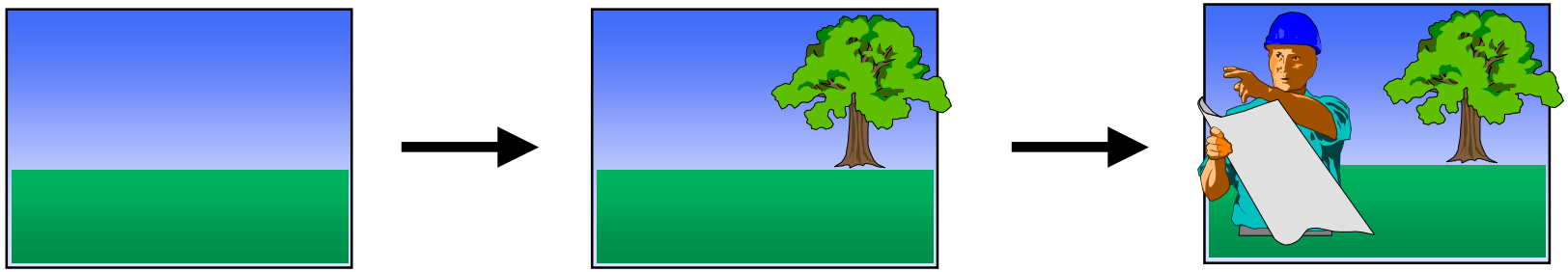
Improved Coding Efficiency

- MPEG-1
  - VCD
  - Bitrate: 1 – 1.5 Mbps
- MPEG-2
  - DVD, DTV
  - Bitrate: 2 – 6 Mbps
- H.263
  - Video Phone
  - Bitrate: 64kbps – 1.2Mbps
- MPEG-4
  - Wireless, Internet
  - Bitrate: 5kbps – 8Mbps

- Compare Coding Efficiency
  - Better Quality at Same Bitrate
  - Lower Bitrate at Same Quality
- MPEG-4 vs. MPEG-1
  - MPEG-4 at 300kbps
  - MPEG-1 at 1.2Mbps
- MPEG-4 vs. MPEG-2
  - MPEG-4 at 2Mbps
  - MPEG-2 at 4Mbps
- MPEG-4 vs. H.263
  - MPEG-4 at 16kbps
  - H.263 at 64kbps

Content-Based Interactivity

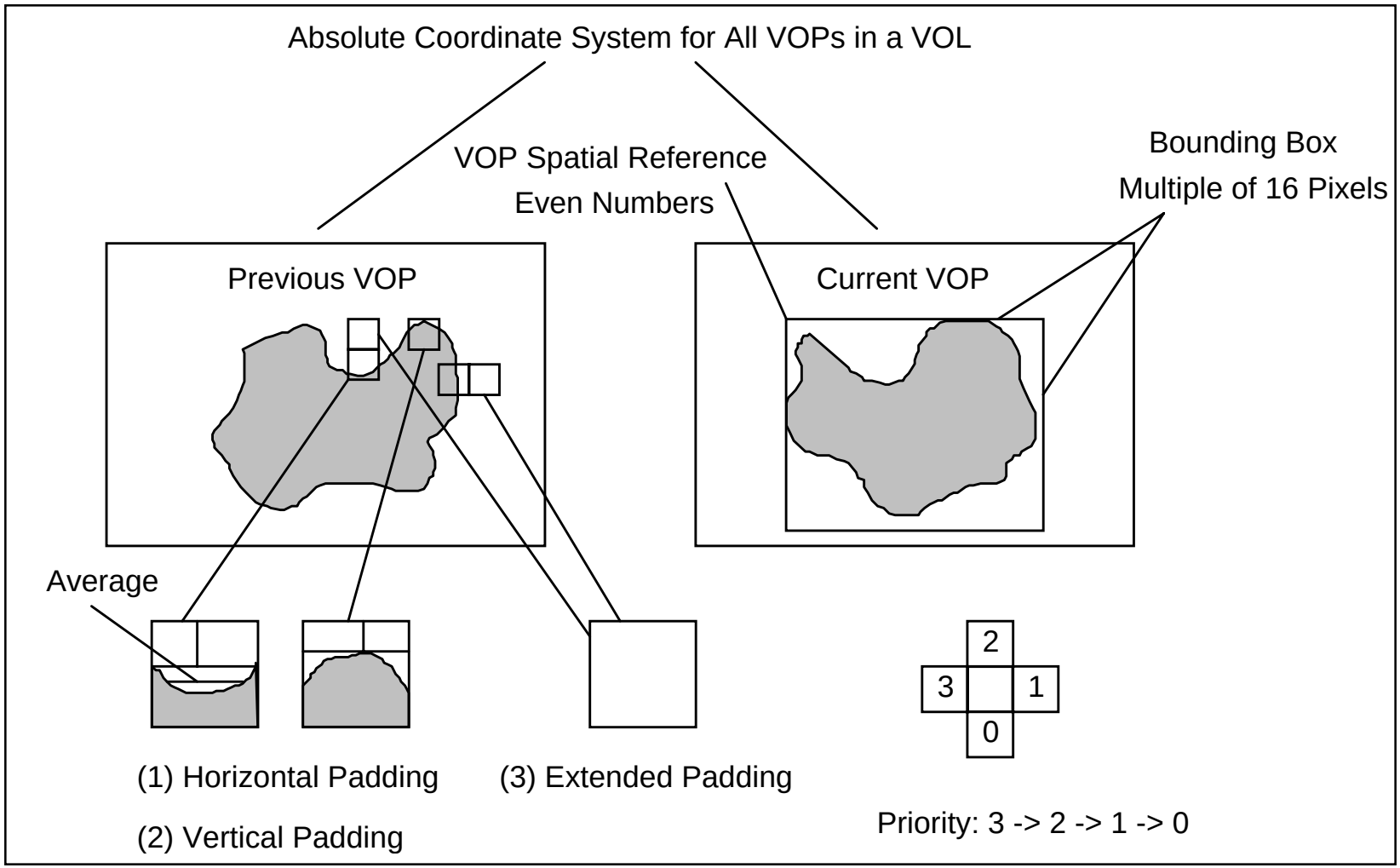
VOP-1



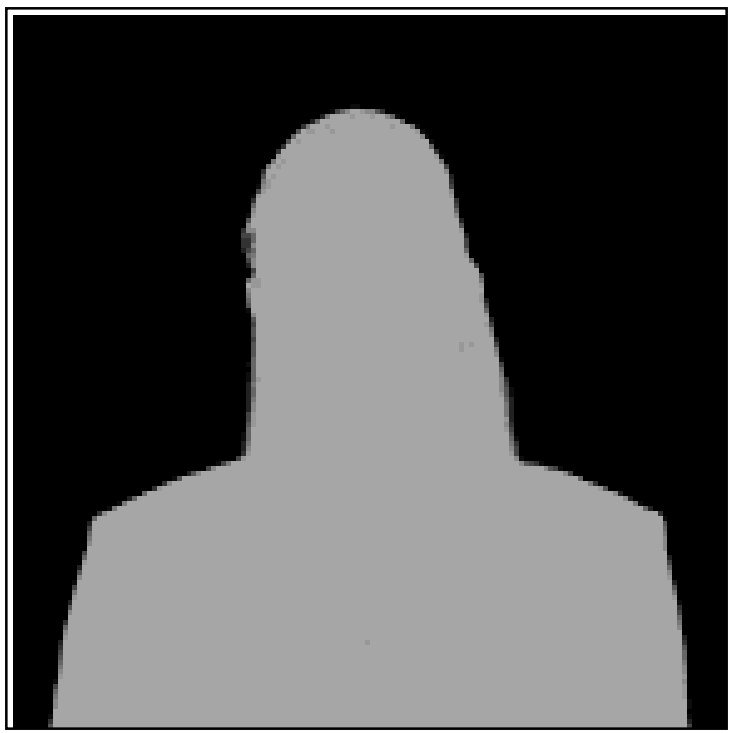
VOP-2

VOP-3

VOP Motion Compensation



Shape & Texture Coding



INTRA Shape Coding

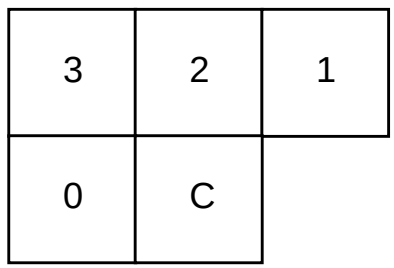
Conditional Entropy Coding

H(X|C) <= H(X)

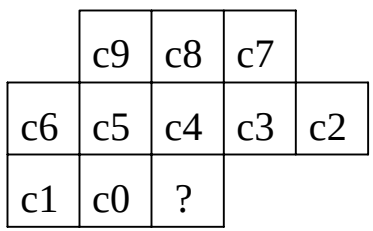
Conditional VLC of Intra BAB Type

Transparent, Opaque, IntraCAE

3 BAB Types and 4 Conditional BABs = 81 Conditional VLC Tables of 3 Entries



Conditional Arithmetic Coding (Fixed Model) for IntraCAE



INTER Shape Coding

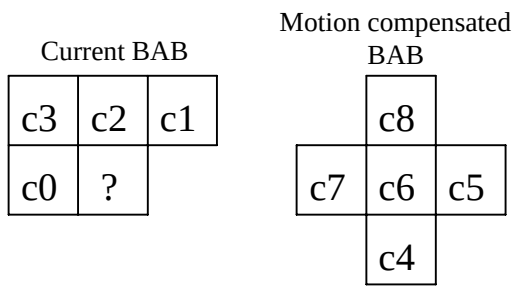
Montion Compensated Conditional Entropy Coding

Conditional VLC of BAB Types

0: MVDs==0 && No Update, 1: MVDs!=0 && No Update, 2: Transparent, 3: Opaque
4: IntraCAE, 5: MVDs==0 && interCAE, 6: MVDs!=0 && interCAE

		bab_type in current VOP (n)						
		0	1	2	3	4	5	6
bab_type in previous VOP(n-1)	0	1	01	00001	000001	0001	0010	0011
	1	01	1	00001	000001	001	0000001	0001
	2	0001	001	1	000001	01	0000001	00001
	3	1	0001	000001	001	01	0000001	00001
	4	011	001	0001	00001	1	000001	010
	5	01	0001	00001	000001	001	11	10
	6	001	0001	00001	000001	01	10	11

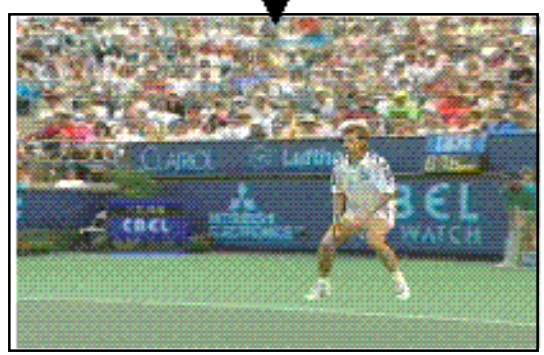
Conditional Arithmetic Coding (Fixed Model) for InterCAE



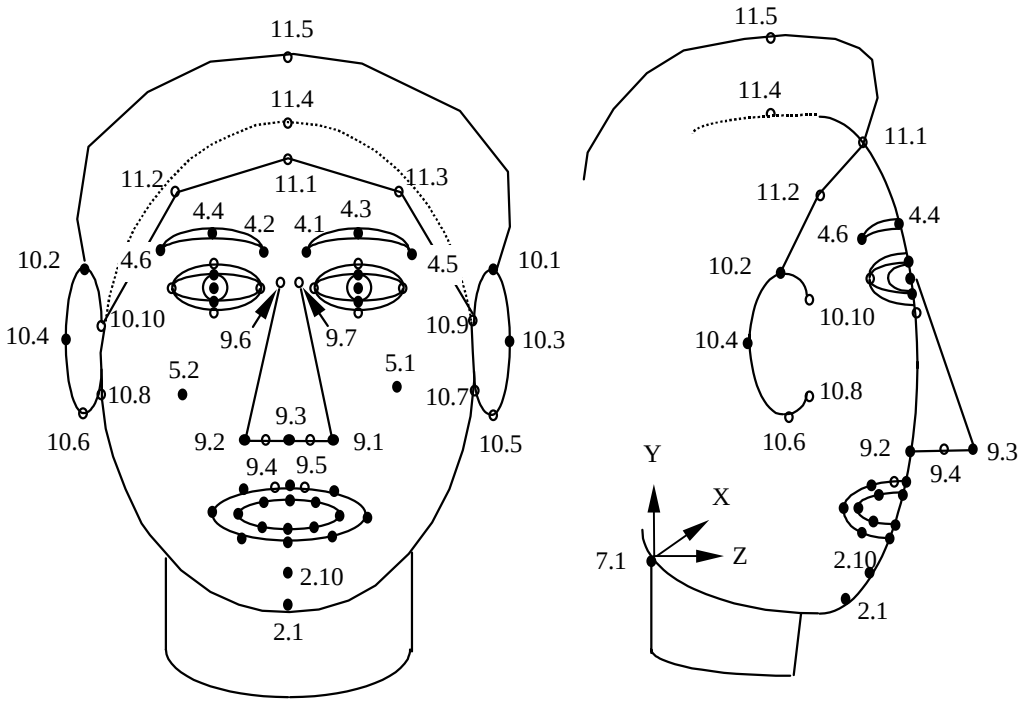
Sprite Coding

- Origins in Computer Graphics
- Long Term Background Objects
- Real Time Rotation, Translation, Zooming

An Example of Sprite Coding

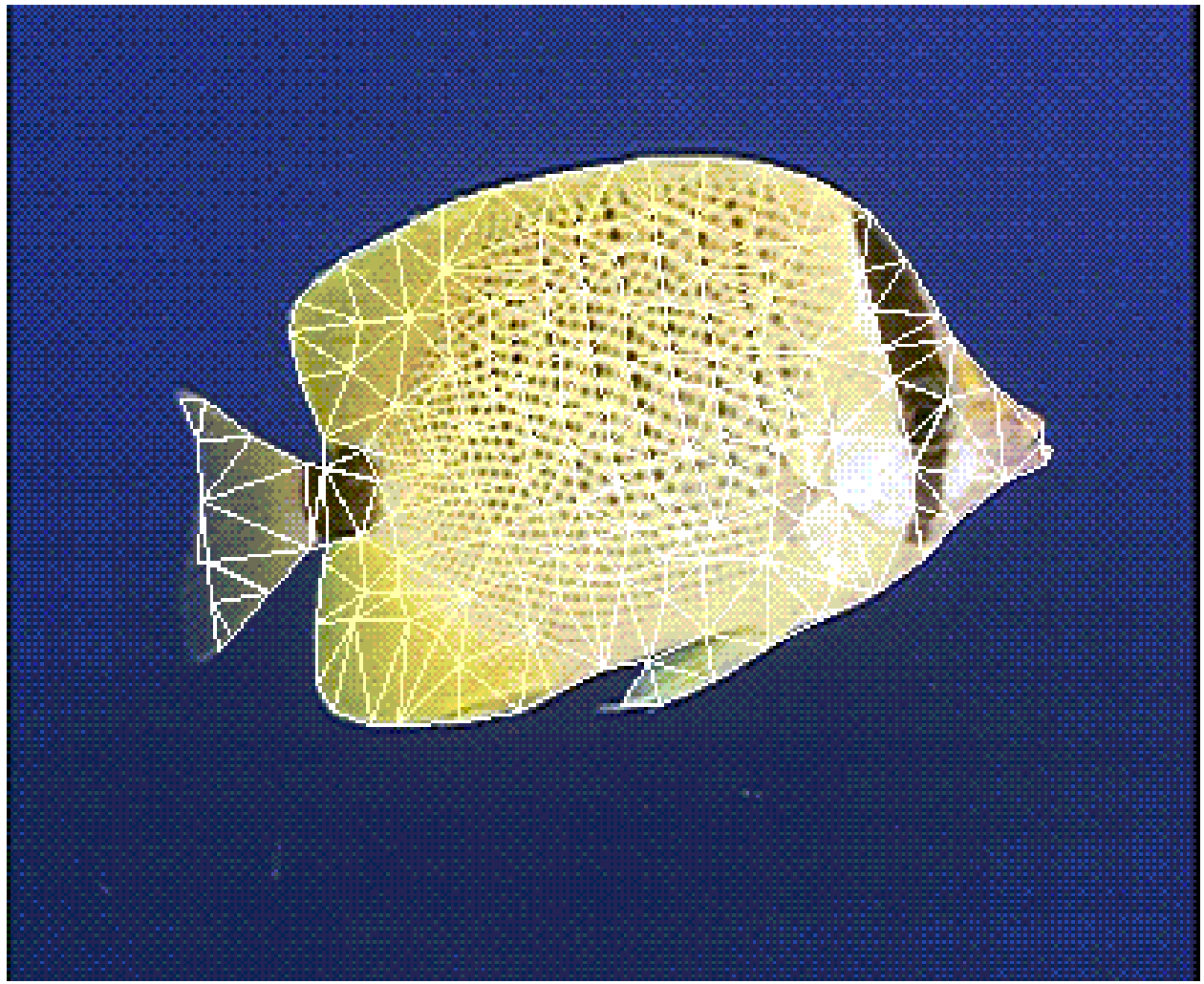


Face Animation



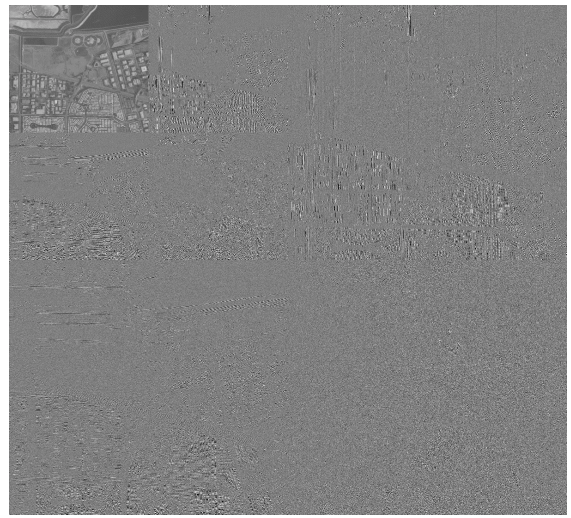
- Points involved in FAPs
  - Feature points

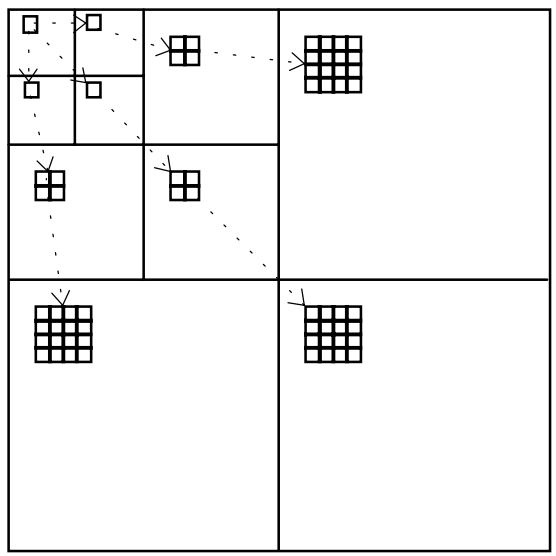
Mesh Coding



Still Texture Coding

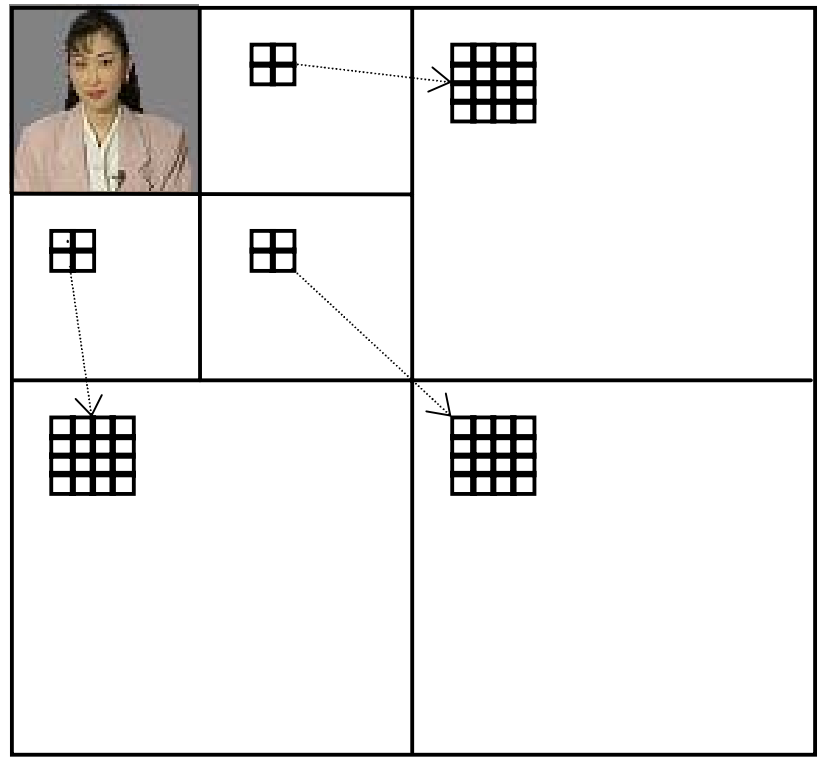
Wavelet Transform





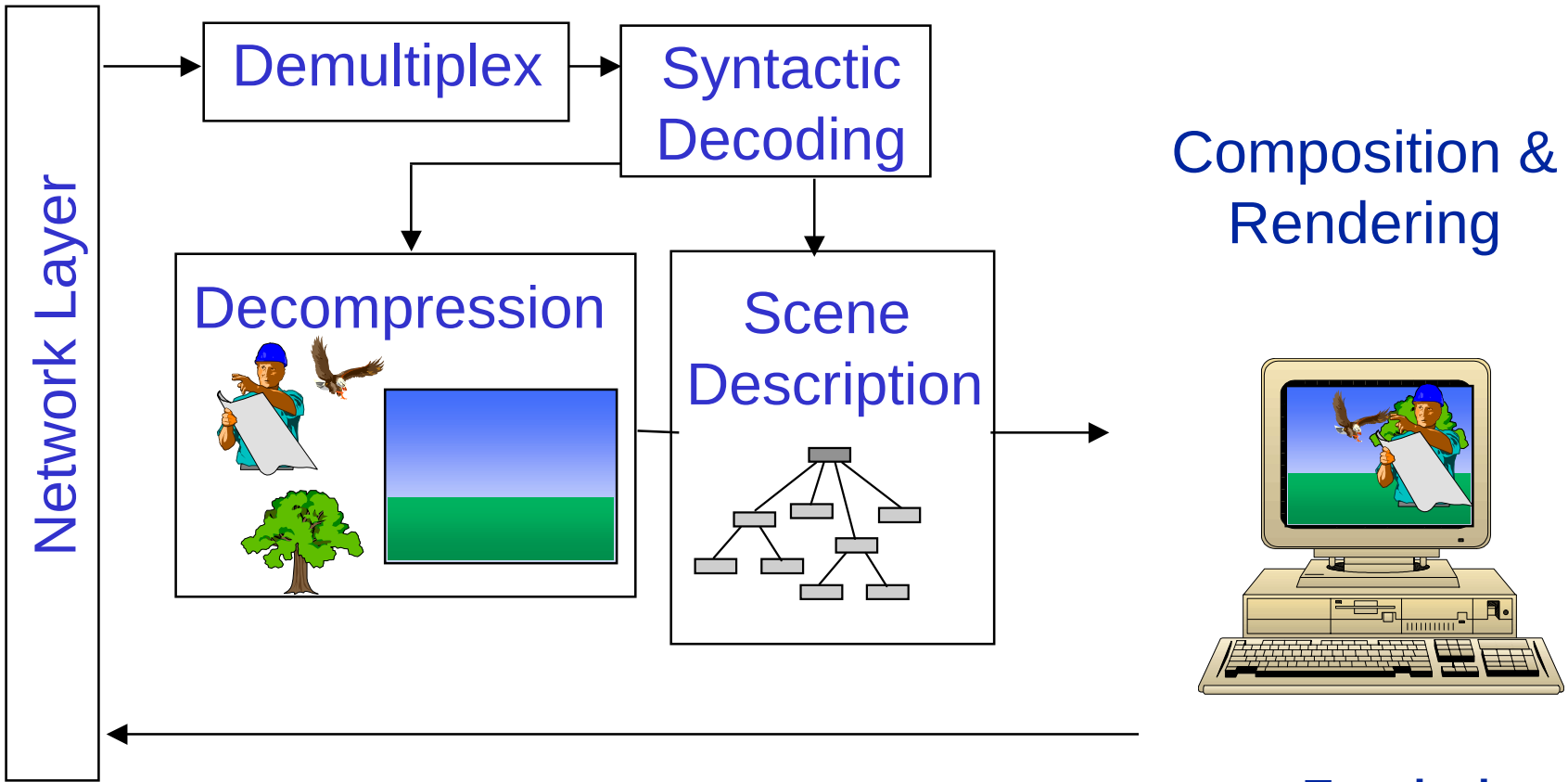
Zero-Tree Coding

Shape Adaptive Wavelet Coding



- **Shape Adaptive Wavelet Transform**
- **Shape Adaptive Zerotree Coding**

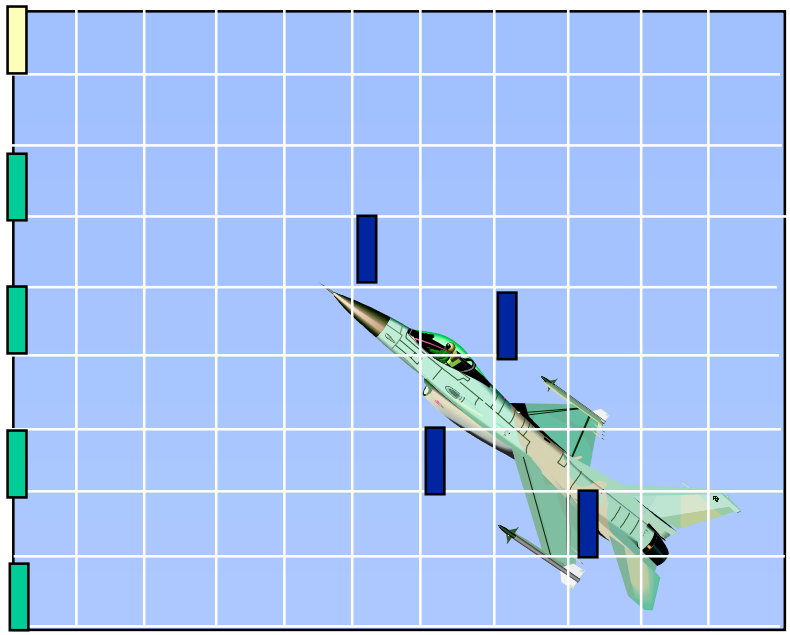
MPEG-4 Terminal Structure



Universal Access

- Deliver and Receive Encoded Video with Best Quality under Different Channel Capacity
- Error Resilience (Recover from Damage)
  - Packet re-synchronization
  - Reversible VLC
  - Data partitioning
- Scalability (Control Damage)
  - Quantization scalability
  - Temporal scalability
  - Spatial scalability

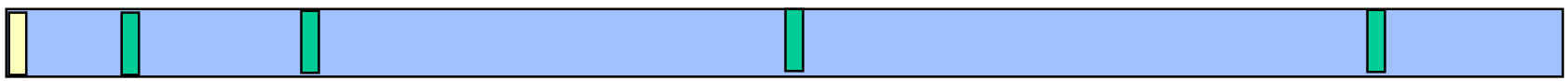
Packet Re-synchronization



Picture Start Code

MPEG-4 Resync Marker

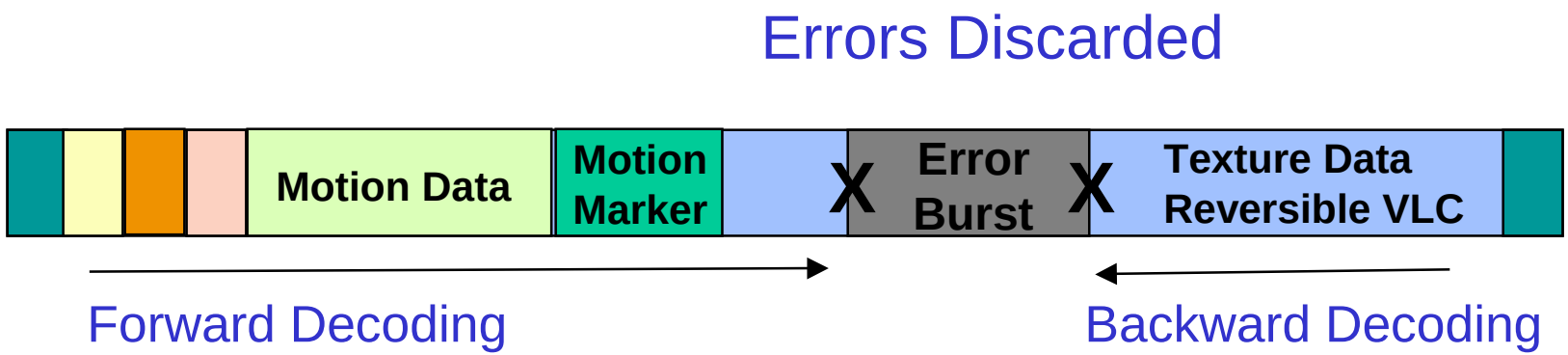
Conventional Re-Sync Marker



Conventional Bitstream

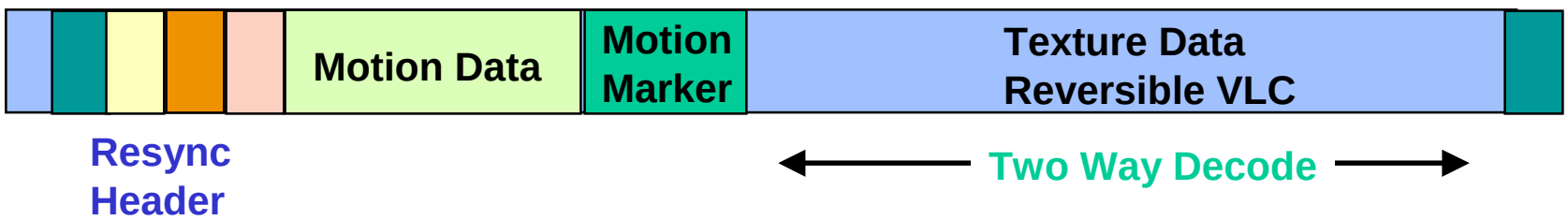
MPEG-4 Bitstream

Reversible VLC



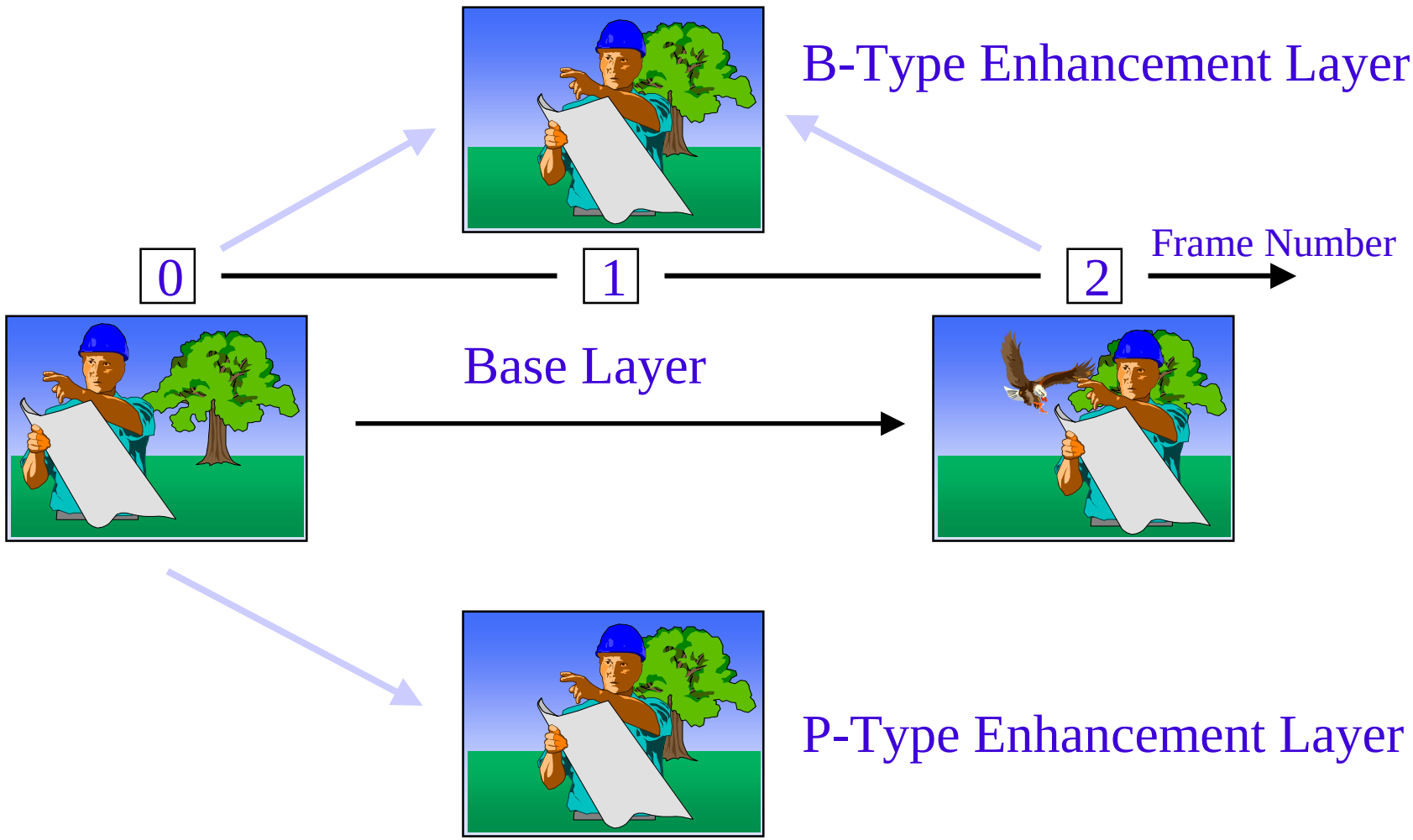
Data Partitioning

- Separate Motion and Texture

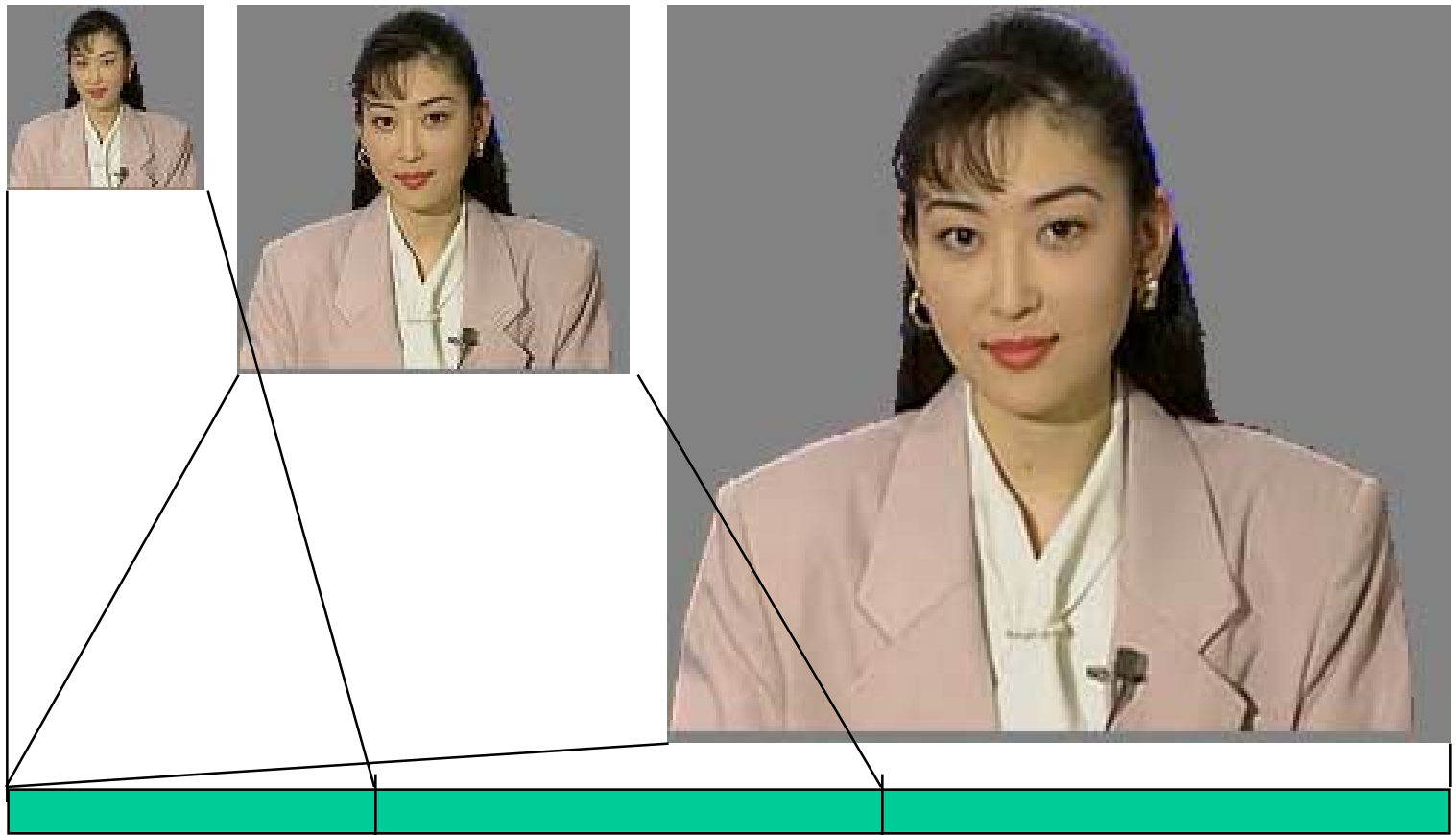


Quantization Scalability

Temporal Scalability



Spatial Scalability



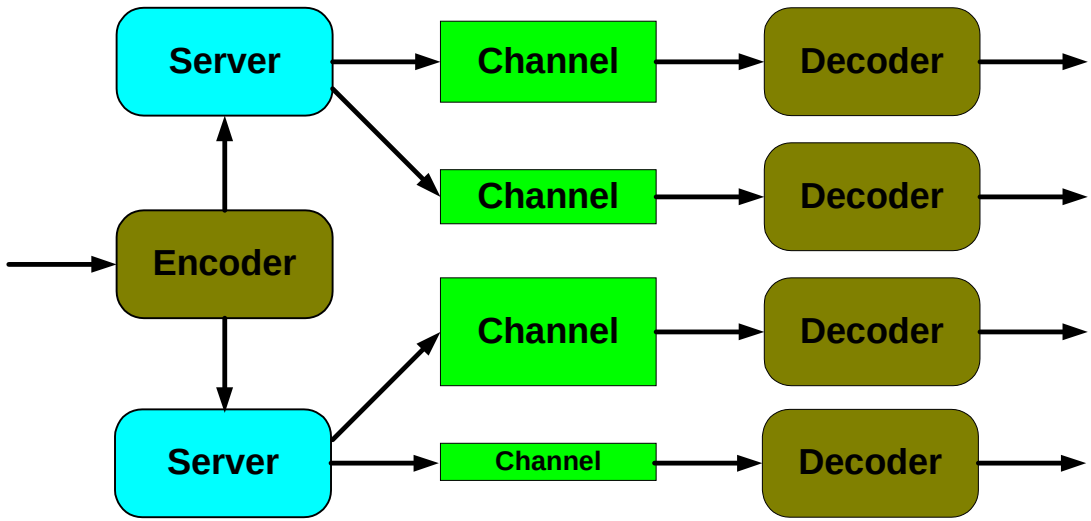
Video Coding for Different Applications

- Video coding for storage
  - VCD, DVD
  - Fixed size
- Video coding for transmission over fixed channel
  - DTV, HDTV
  - Fixed bitrate
- Video coding for Internet transmission
  - Streaming
  - Shared network with a range of bitrates
  - New challenges

Problem: Encoder/Channel Separation

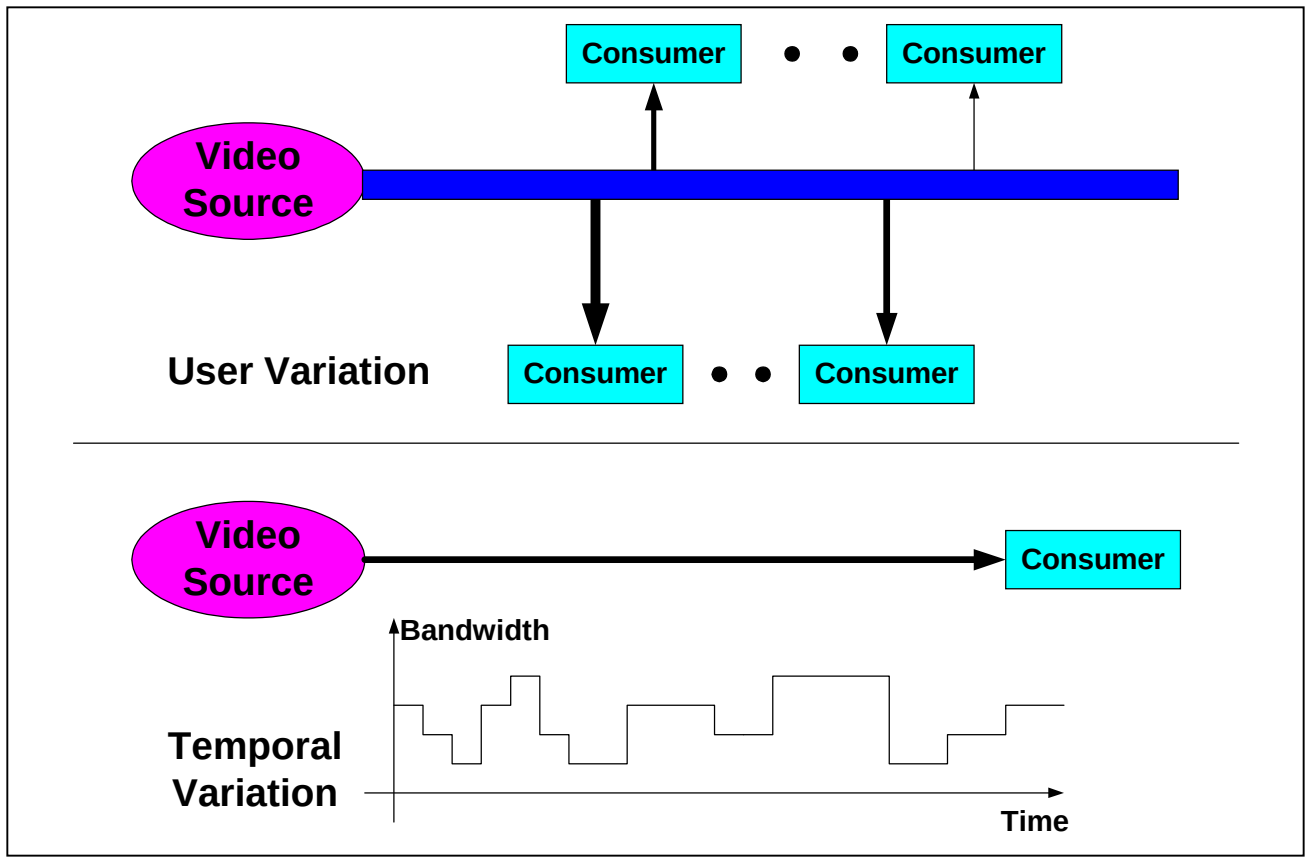
Traditional Model of a Communication System

Internet Streaming Applications



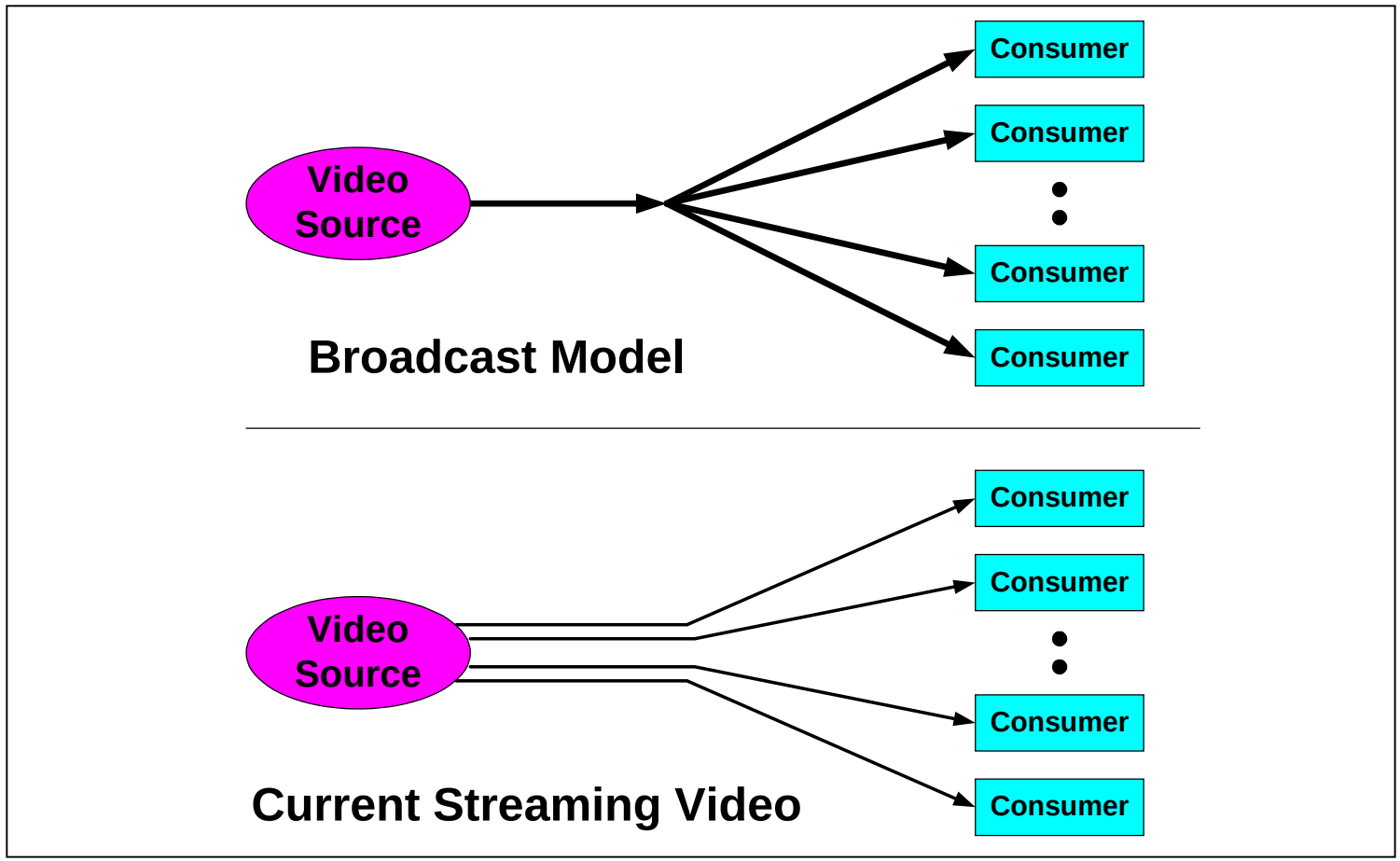
- Basic assumptions of traditional model:
  - Encoder knows channel capacity
  - Decoder is able to process all received bits

Problem: Bandwidth Variation



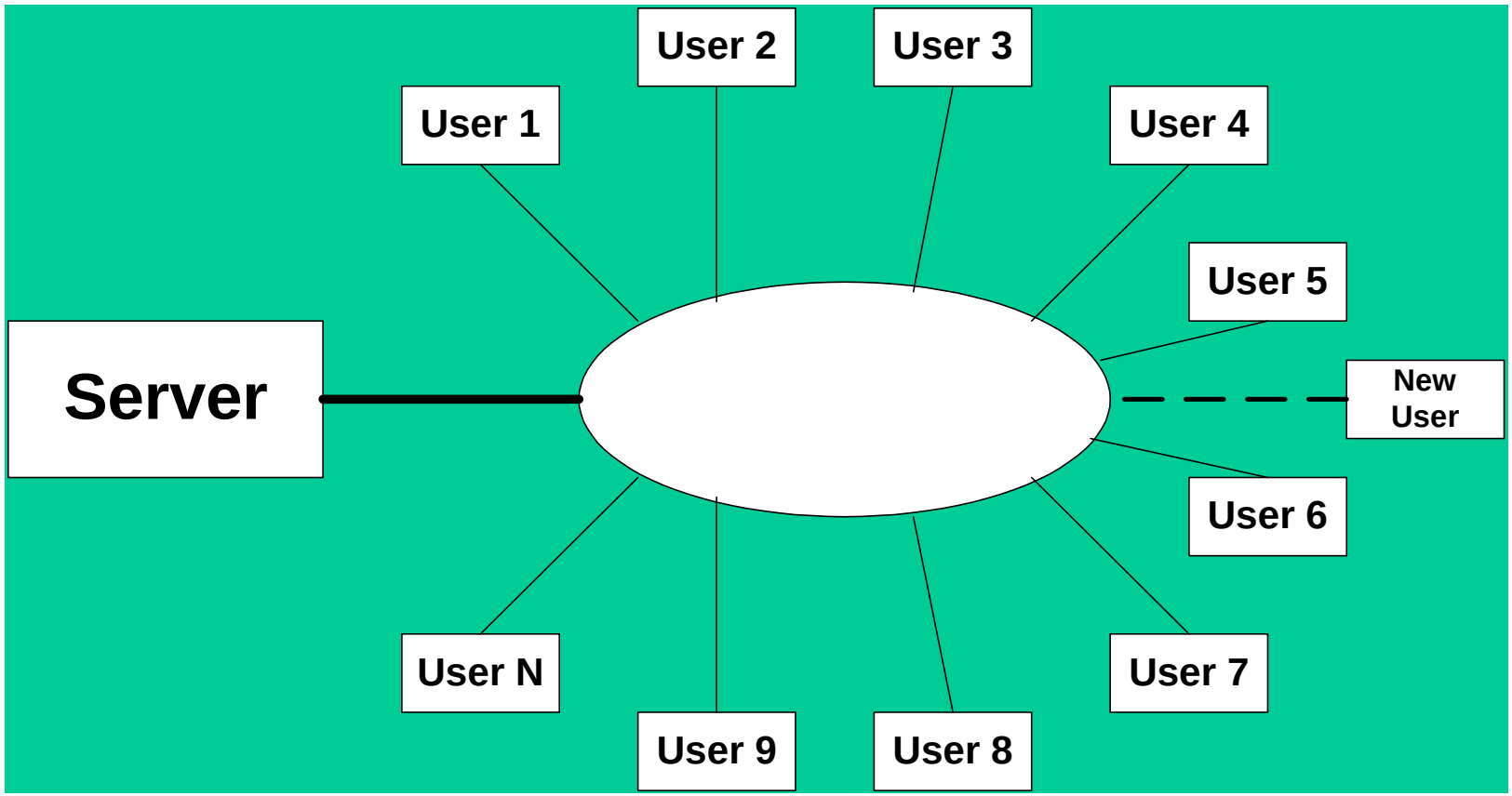
- User Variation: bandwidth varies from user to user
- Temporal Variation: bandwidth varies with time

Problem: Reach Large Audience



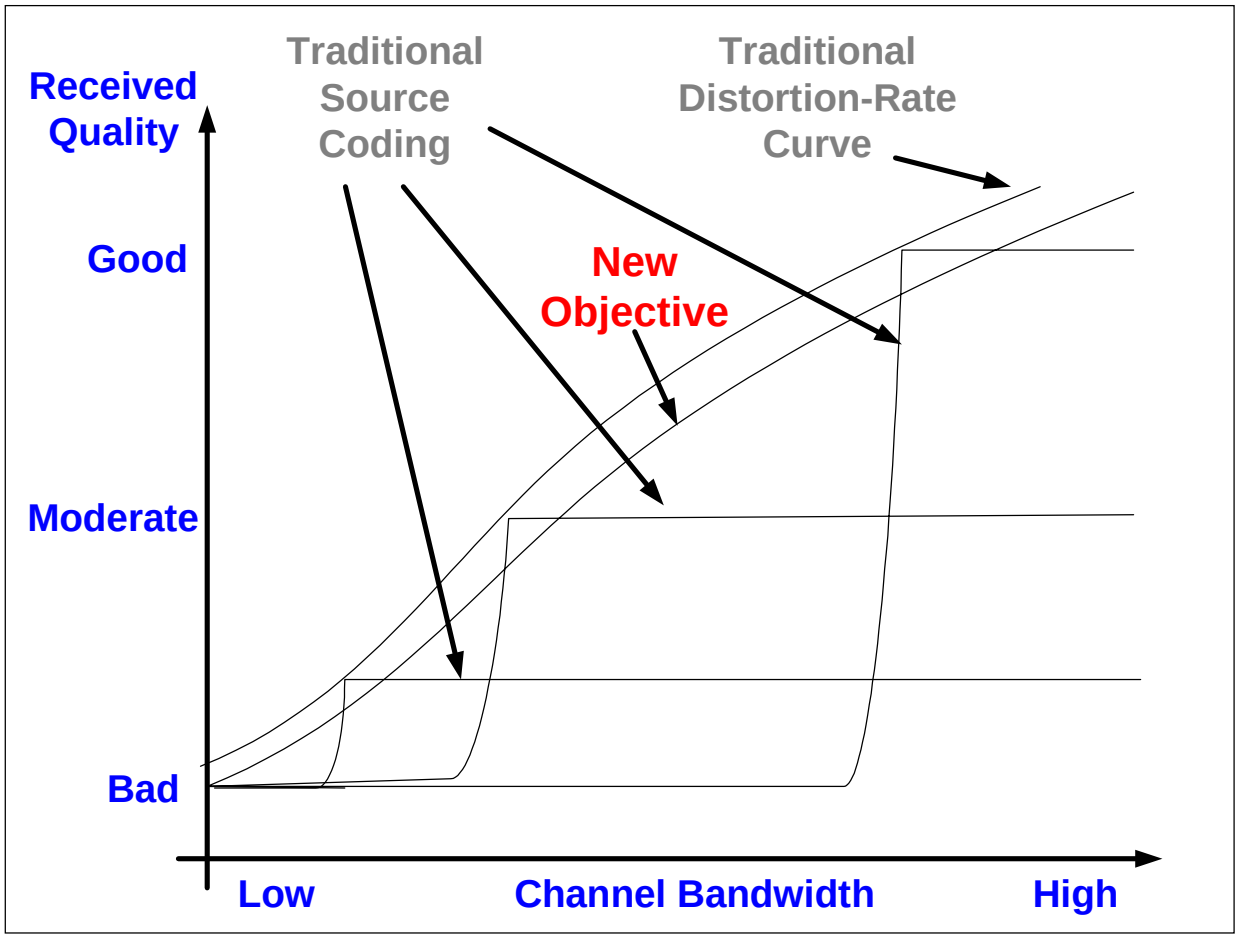
- VCD, DVD, DTV, and HDTV are efficient for broadcast
- Current streaming video is inefficient for broadcast

Problem: User Access



- New user cannot access server when current N users have used up server bandwidth

New Objective for Video Coding

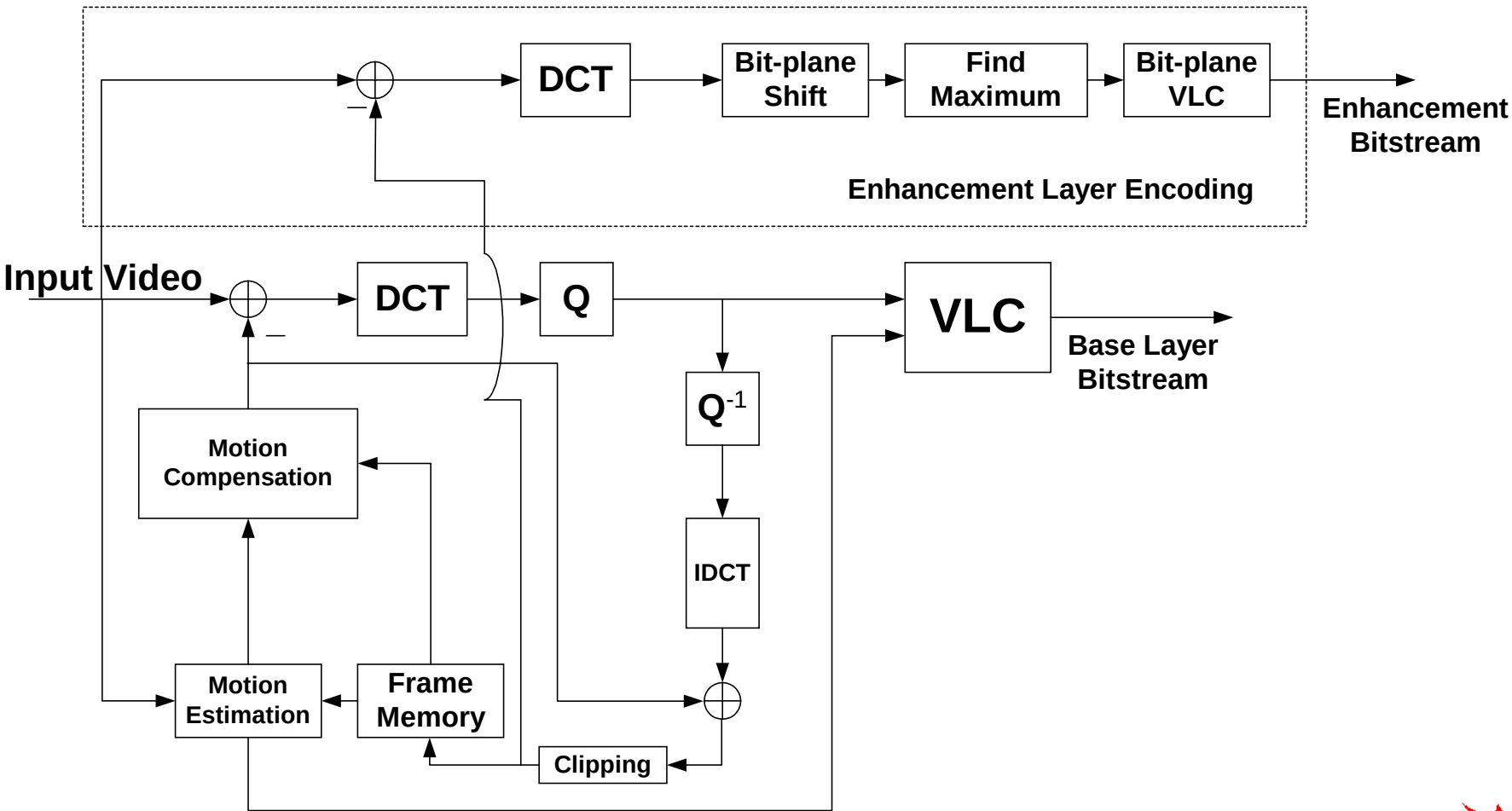


- Make digital video behave similarly to analog video while maintaining the advantages of digital video over analog video

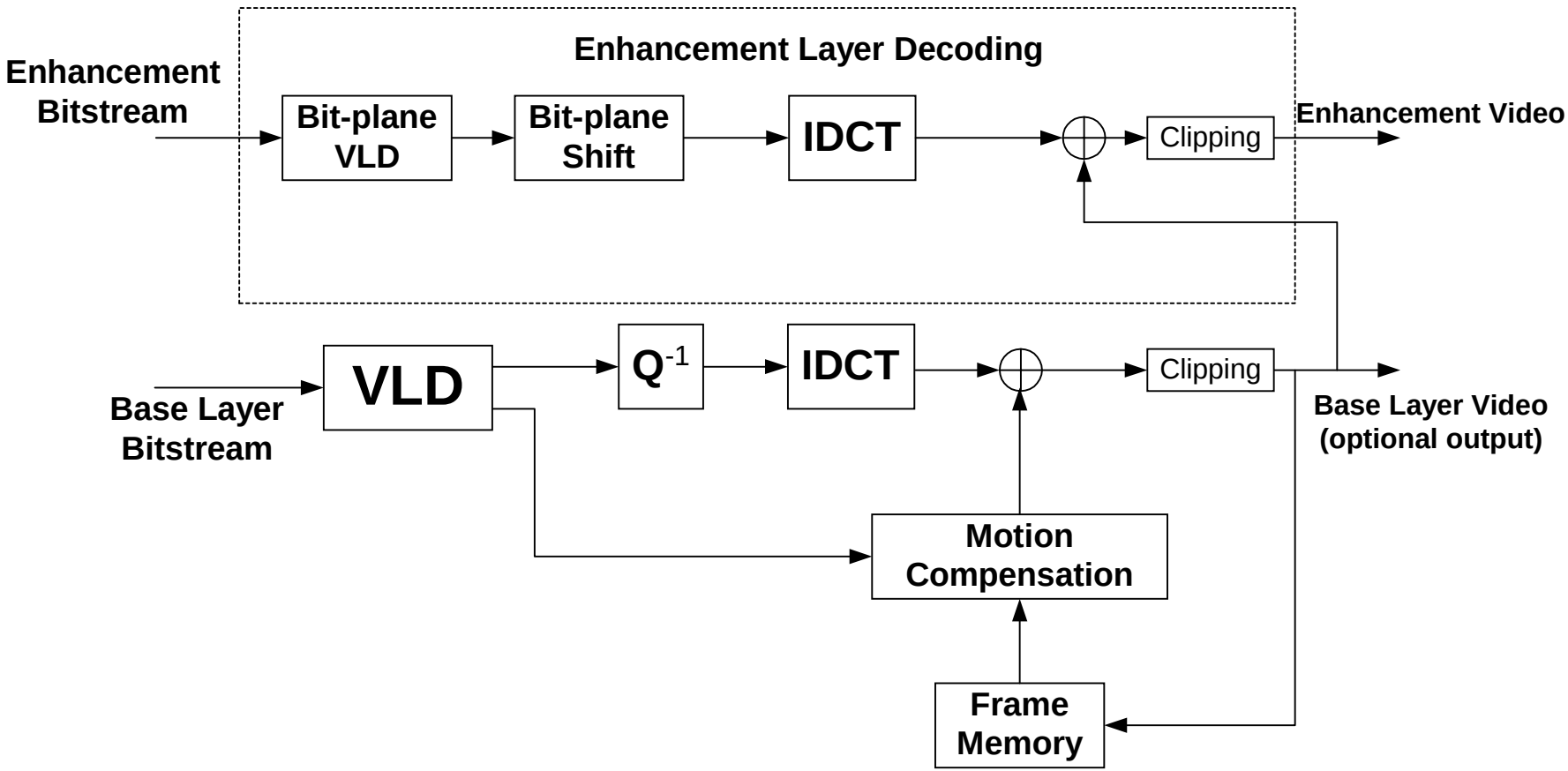
Fine Granularity Scalability in MPEG-4

- Motion compensated DCT coding in base layer to reach lower bound of bitrate range
- Bitplane coding of DCT coefficients in enhancement layer to cover bitrate range
- Enhancement layer bitstream may be truncated into any number of bits per frame
- Decoder may ignore some enhancement bits
- Reconstructed video quality proportional to number of decoded bits

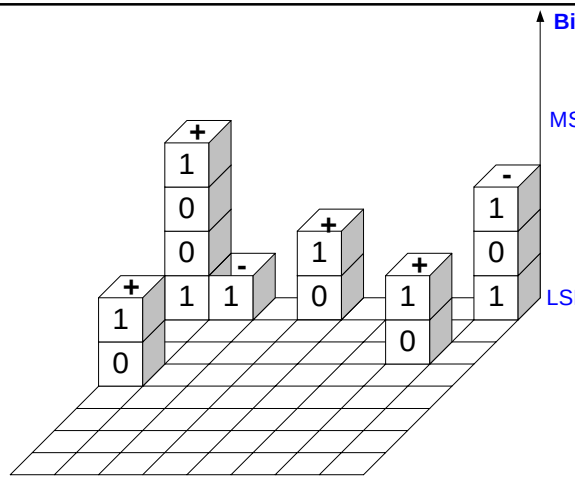
Basic Encoder Structure



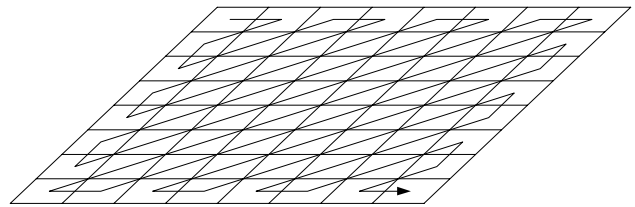
Basic Decoder Structure



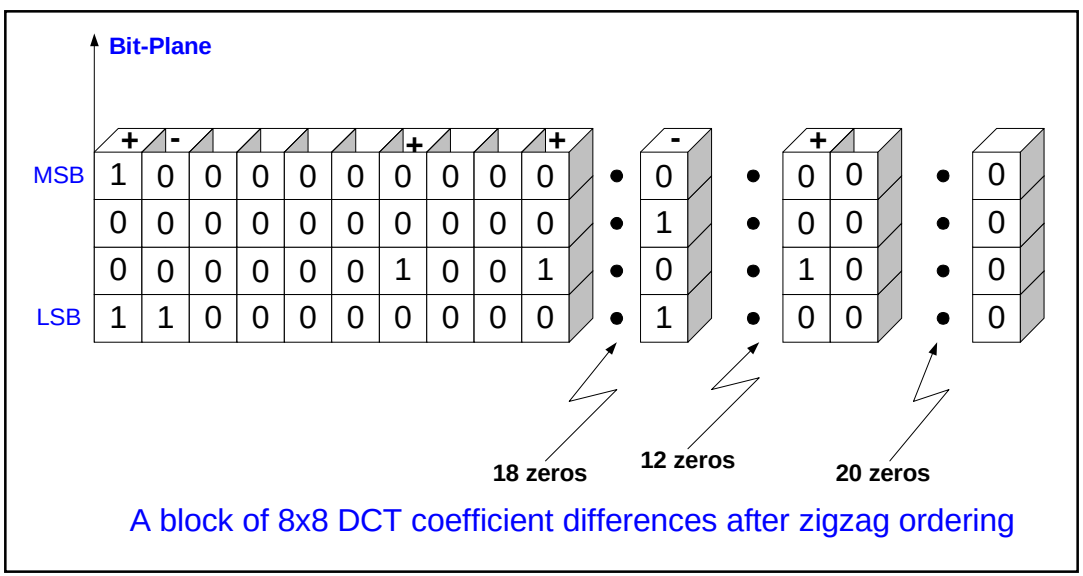
Basic Bitplane Coding Technique



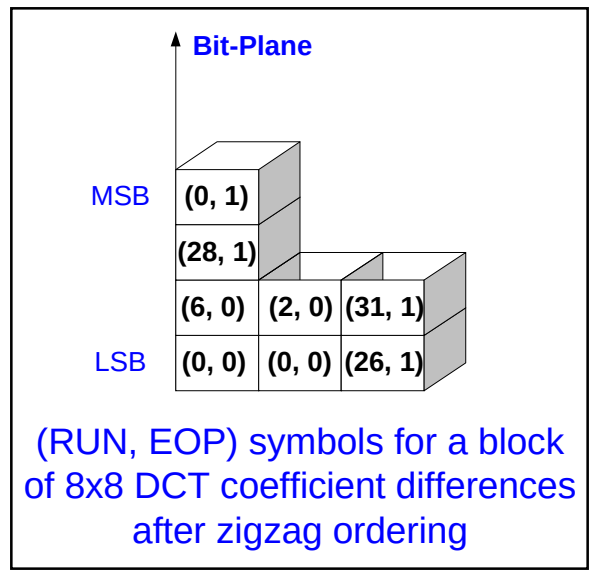
A block of 8x8 DCT coefficient differences



Zigzag ordering of a block of 8x8 DCT coefficient differences



A block of 8x8 DCT coefficient differences after zigzag ordering



(RUN, EOP) symbols for a block of 8x8 DCT coefficient differences after zigzag ordering

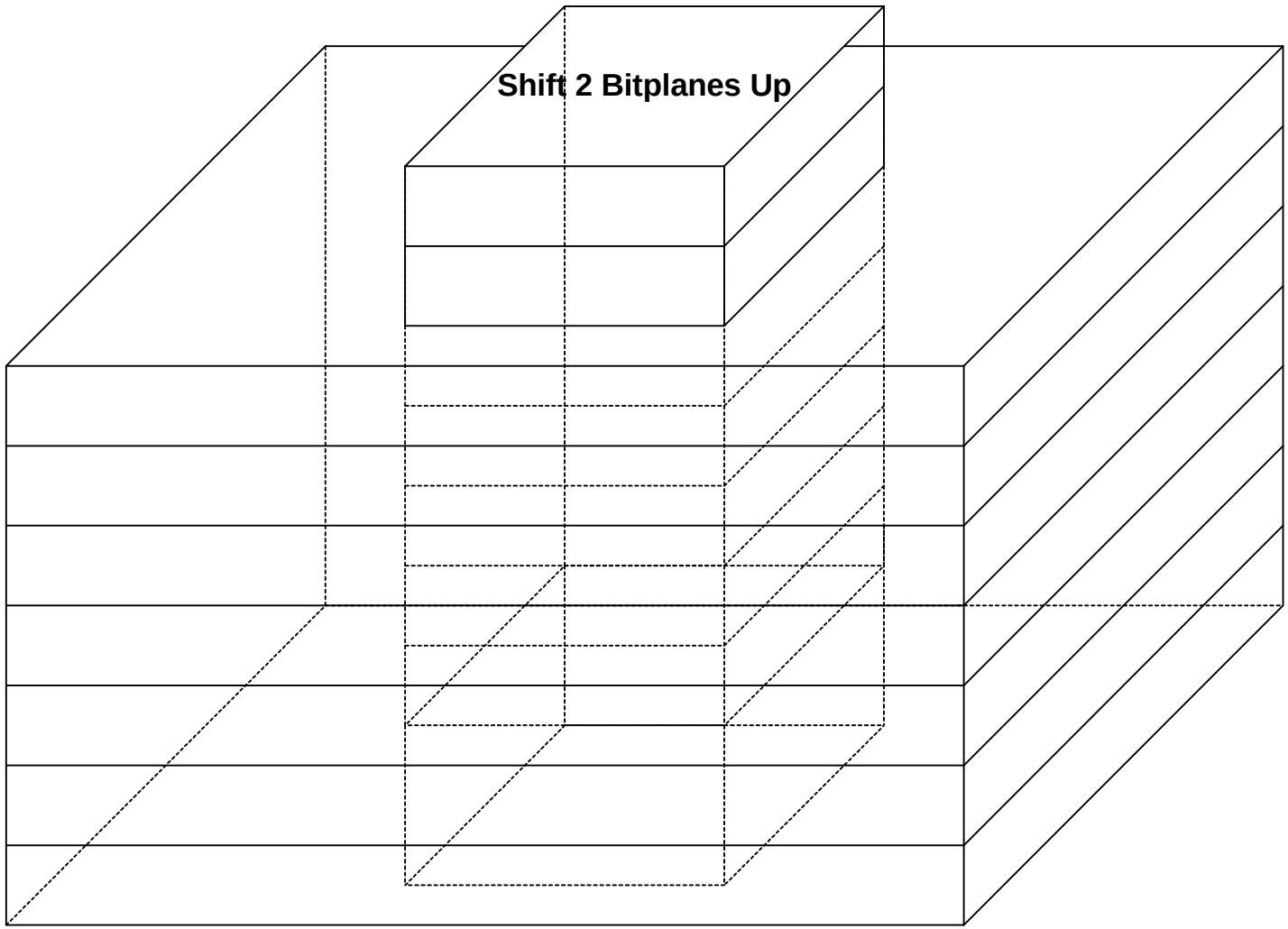
Generate (RUN,EOP) Symbols

- Maximum number of bit-planes in a frame = 6
- Difference of a DCT block after ordering
  - 9, -1, 0, 0, 0, 0, 2, 0, 0, 2, 0, ..., 0, -5, 0, ..., 0, 2, 0, …, 0
- Maximum absolute value in this block = 9 (4 bits)
- Six bit-planes of absolute values
  - 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, …, 0, 0, 0, …, 0, 0, 0, ..., 0
  - 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, …, 0, 0, 0, …, 0, 0, 0, ..., 0
  - 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, …, 0, 0, 0, …, 0, 0, 0, ..., 0
  - 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, …, 0, 1, 0, …, 0, 0, 0, ..., 0
  - 0, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, …, 0, 0, 0, …, 0, 1, 0, ..., 0
  - 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, …, 0, 1, 0, …, 0, 0, 0, ..., 0

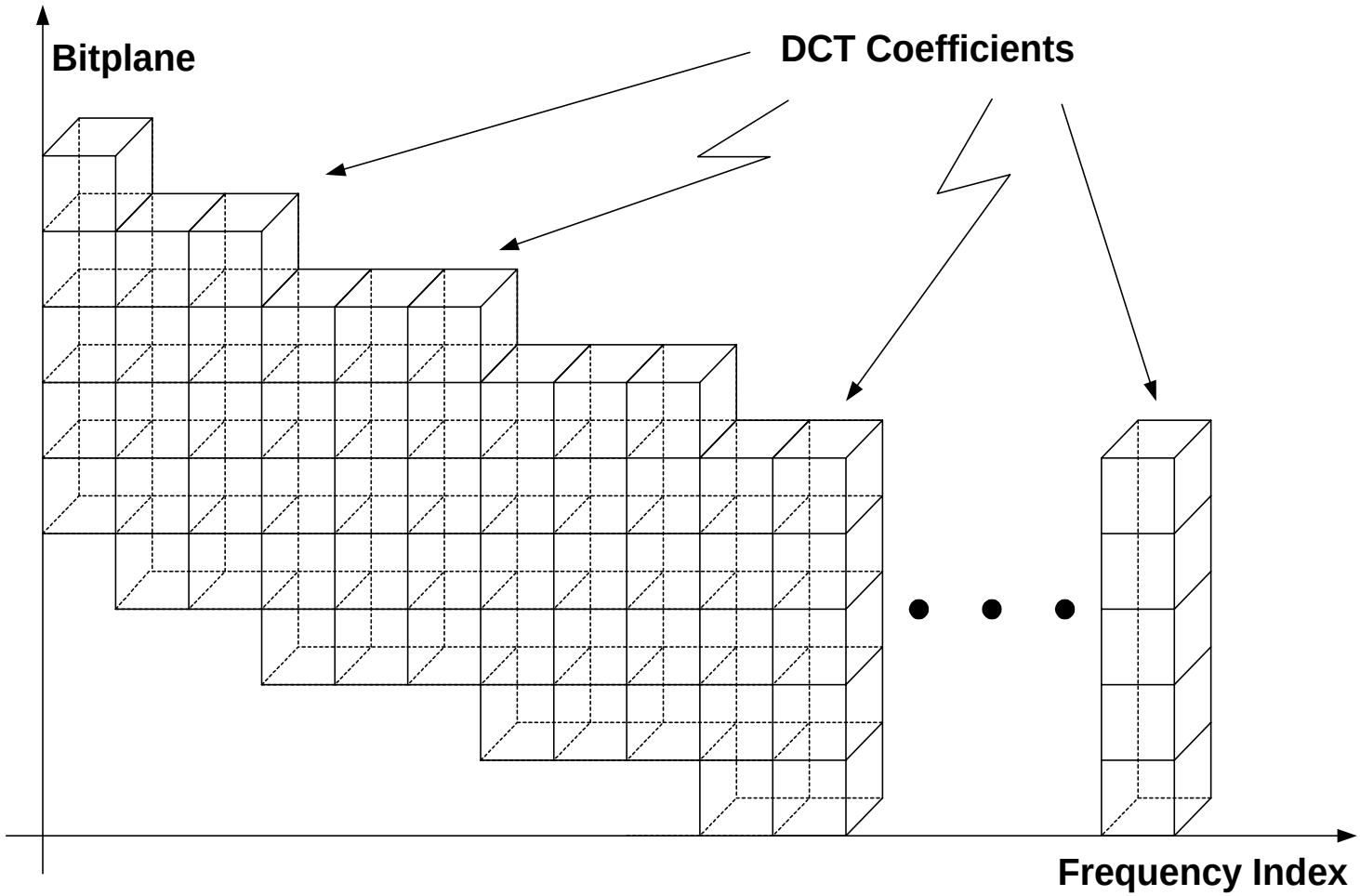
Code (RUN,EOP) Symbols & Signs

- Symbols
  - (All Zero)
  - (All Zero)
  - (0, 1)
  - (28, 1)
  - (6, 0), (2,0), (31, 1)
  - (0, 0), (0,0), (26, 1)
- Code
  - code(All Zero)
  - code(All Zero)
  - code(0, 1), 0
  - code(28, 1), 1
  - code(6, 0), 0, code(2,0), 0, code(31, 1), 0
  - code(0, 0), code(0,0), 1, code(26, 1)

Selective Enhancement

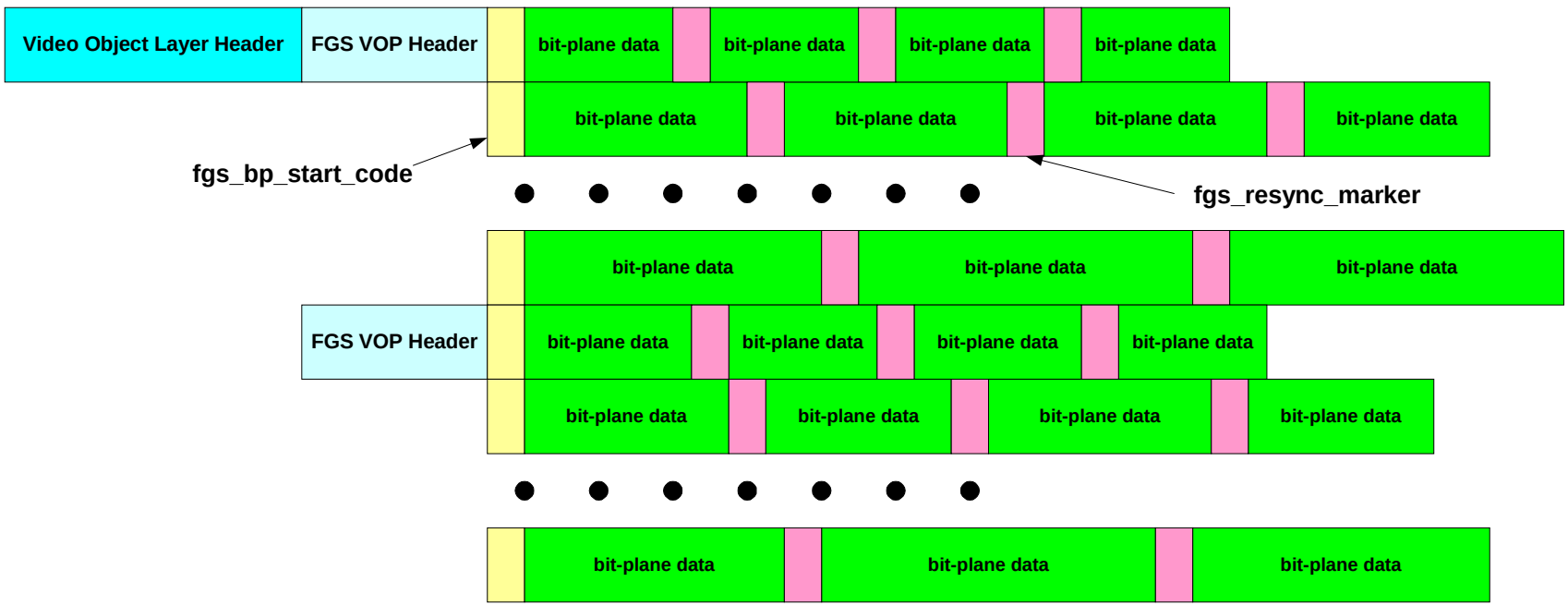


Frequency Weighting

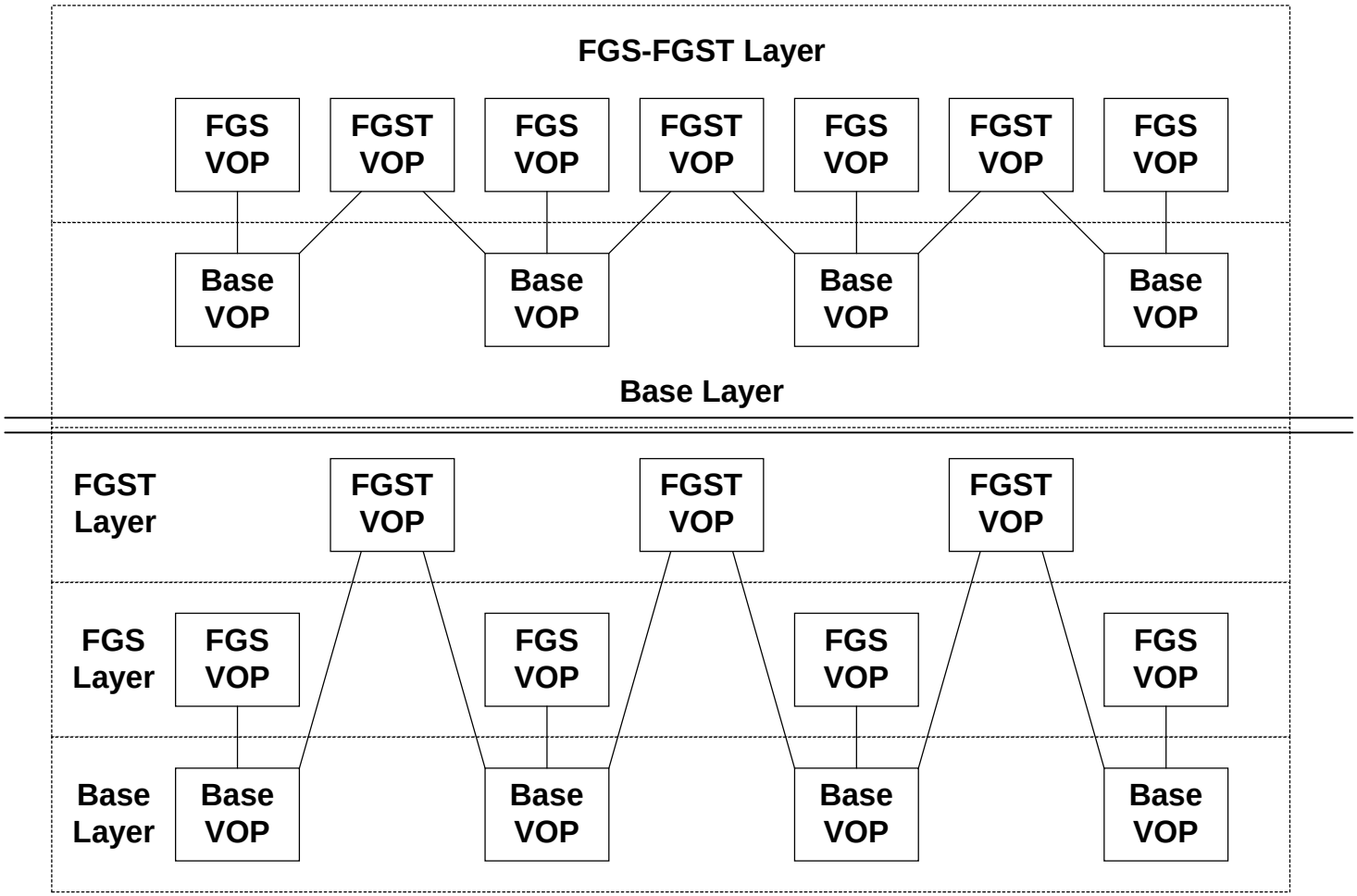


Error Resilience

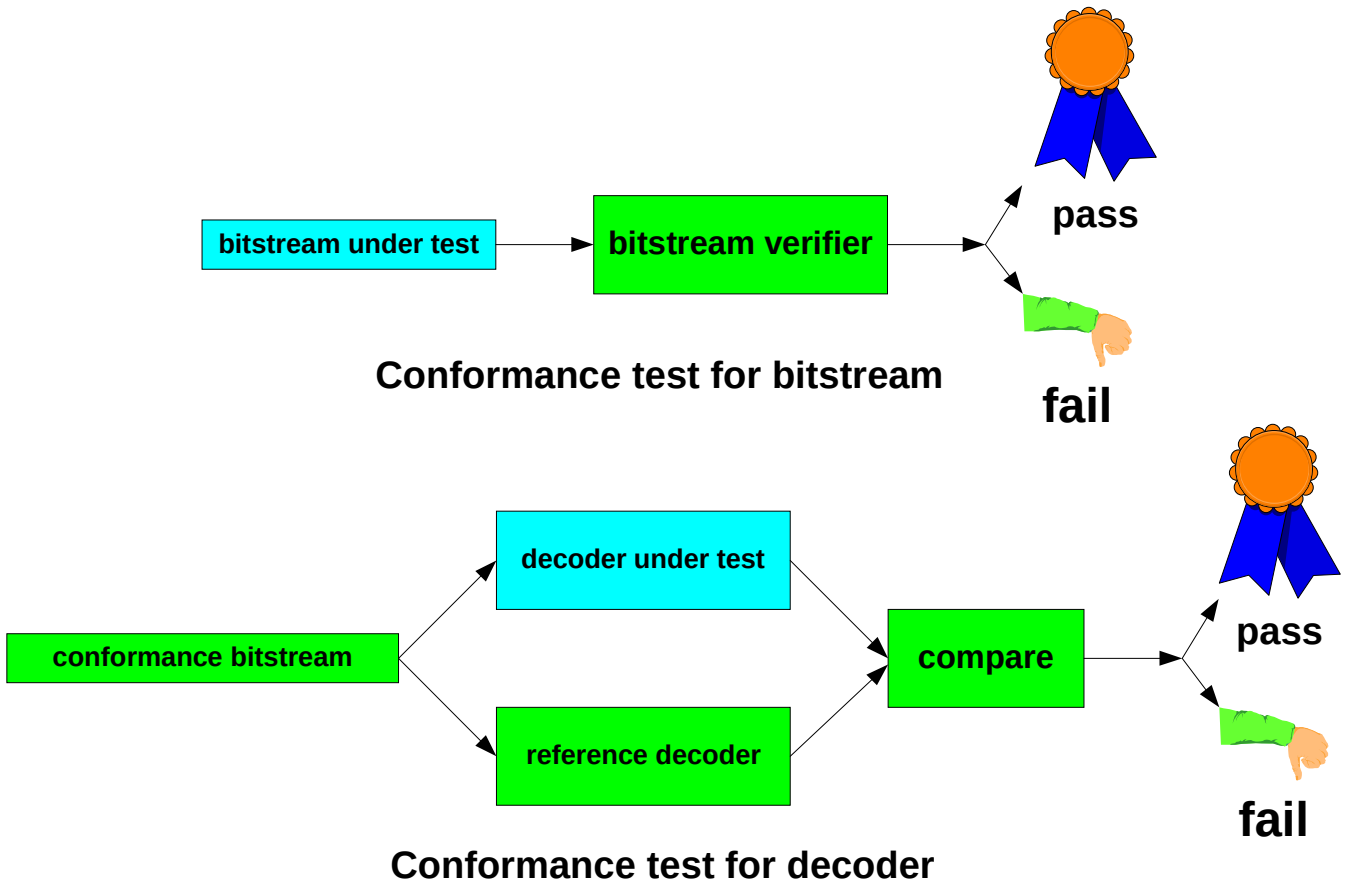
- Wireless channel
- Random burst error
- Use resync marker in enhancement layer
- Isolate error and recover useful bits



Combination with Temporal Scalability



Conformance for Enhancement Layer



- Definition of conformance for FGS enhancement layer
- Decoder complexity scalability

WebCast Tech

MPEG-4 Industry Forum

- To further the adoption of the MPEG-4 Standard, by establishing MPEG-4 as an accepted and widely used standard among application developers, service providers, content creators and end users.

3D Pipeline Corporation
Adherent
America Online
Anystream, Inc.
Apple Computer, Inc.
ARM Ltd
AT&T Ltd
Blaxxun
Canon Inc.
Celvibe
Cirrus Logic, Inc.
Cisco Systems
ClearBand, LLC
Comlink Group, Inc.
Comverse network systems
CSELT S.p.A.
DiamondBack Vision, Inc.
DIRECTV
DivXNetworks, Inc.
Dolby Laboratories Inc.
Edge Networks Corporation
Enformatica Limited
Enquad
Envivio
ETRI
France Telecom
Fraunhofer Institute IIS-A
Fujitsu Limited
Geocast
GMV Network
Gordon & Glickson LLC
Hantro Products Oy
Hitachi, Ltd
Hyundai Electronics
Hypnotizer
IBM Ltd
Indigo Vision Ltd
Intel Corp.
InterTrust Technologies Intl.
iVAST Inc.
JiGami Corporation
LightSurf Technologies, Inc.
Lumic Electronics Inc.
Luxxon Corp.
Matsushita Electric
MedioStream, Inc.
Microsoft Corporation
Mitsubishi Electric Corp.
Motorola
mp4cast
MPEG LA, LLC
NEC Corporation
Neomagic Corporation
NTT Corp.
Nogatech Ltd.
Nokia
Oki Electric Ind. Co., Ltd.
Optibase
Optivision, Inc.
Packetvideo
ParallelGraphics
Philips Electronics
Philips Semiconductors
PixStream Incorporated
Samsung Electronics
Scientific-Atlanta, Inc.
Serome Technology, Inc.
Sharp Corporation
Siemens AG
SolidStreaming, Inc.
Sony Corporation
SPaSE BV
Sun Microsystems
TANDBERG Television ASA
TDK Corporation
THOMSON multimedia
Toshiba
Tvia, Inc.
Vianet Technologies
VideoSpheres Inc.
WebCast Technologies, Inc.
Wiral
Xilinx Inc.
Zapex Research Limited
Zoran

Conclusions

- MPEG-4 provides an open standard platform for many new products, new services, and new opportunities
- MPEG-4 provides higher coding efficiency than previous video coding standards
- MPEG-4 enables innovations for visual content creation and visual object interaction
- MPEG-4 is good for a wide range of new transmission channels such as Internet and wireless
- Video coding becomes an optimization problem over an interval of bitrates instead of against a point of bitrate
- There are still many new research problems in video coding