MPEG-4 Video: Opportunities and Challenges Ahead

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What do these products have in common?

- DVD players
- Digital cameras
- High definition television sets
- Personal Video Recorders

- They use image/video compression as the core technology (MPEG/JPEG)
- They are 4 of top 5 fastest growing consumer electronics products of last year

Purpose of the talk

- To present current status of MPEG-4 digital video codec efforts
- To highlight market applications in which next-generation compression will likely be deployed

Digital video application areas

- Broadcast, cable, satellite
- DVD, VCD
- Personal Video Recorders (PVR)
- Wireless video
- Internet video
- Private networks (e.g. surveillance)

Primary areas of focus of Marc's presentation

Primary areas of focus of Vinay's presentation

MPEG-4 AVC
Market Opportunities

MPEG-4 AVC (H.264): Next Generation Media Technology

- Satellite television
- Cable VOD
- Telco DSL video
- Broadcast television
- DVD
- HDTV
- PVR
- Wireless video
- Internet video

Basic Market Premise

- MPEG-2
  - 10 years old
  - Several useful years left for digital television (satellite/cable/terrestrial) and DVD
  - Interim for low-volume VOD
- MPEG-4 (AVC)
  - Satellite DBS operators are bandwidth constrained
  - Will enable wide scale VOD for cable operators and is the telco's ticket into the video market
  - Will be a foundational element for the next-generation broadband home (PVRs, DVDs, HDTV and wireless devices)

Satellite Television

- In TV world, satellite operators are traditionally first to embrace new technologies
  - Encryption (VideoCipher®)
  - Digital television (DigiCipher®, DirecTV)
  - HDTV
- Growing demand for HDTV and local broadcast signals highlights need for more bandwidth-efficient technologies
  - 8PSK modulation
  - MPEG-4 AVC

Cable Video On Demand (VOD): Revolution in the Home

- Next step in home entertainment, giving consumers “what they want, when they want”
- Cable’s best opportunity to stem further subscriber losses to DBS operators (DirecTV and EchoStar)
  - 20 million going to ?

VOD Market Finally Poised to Take Off

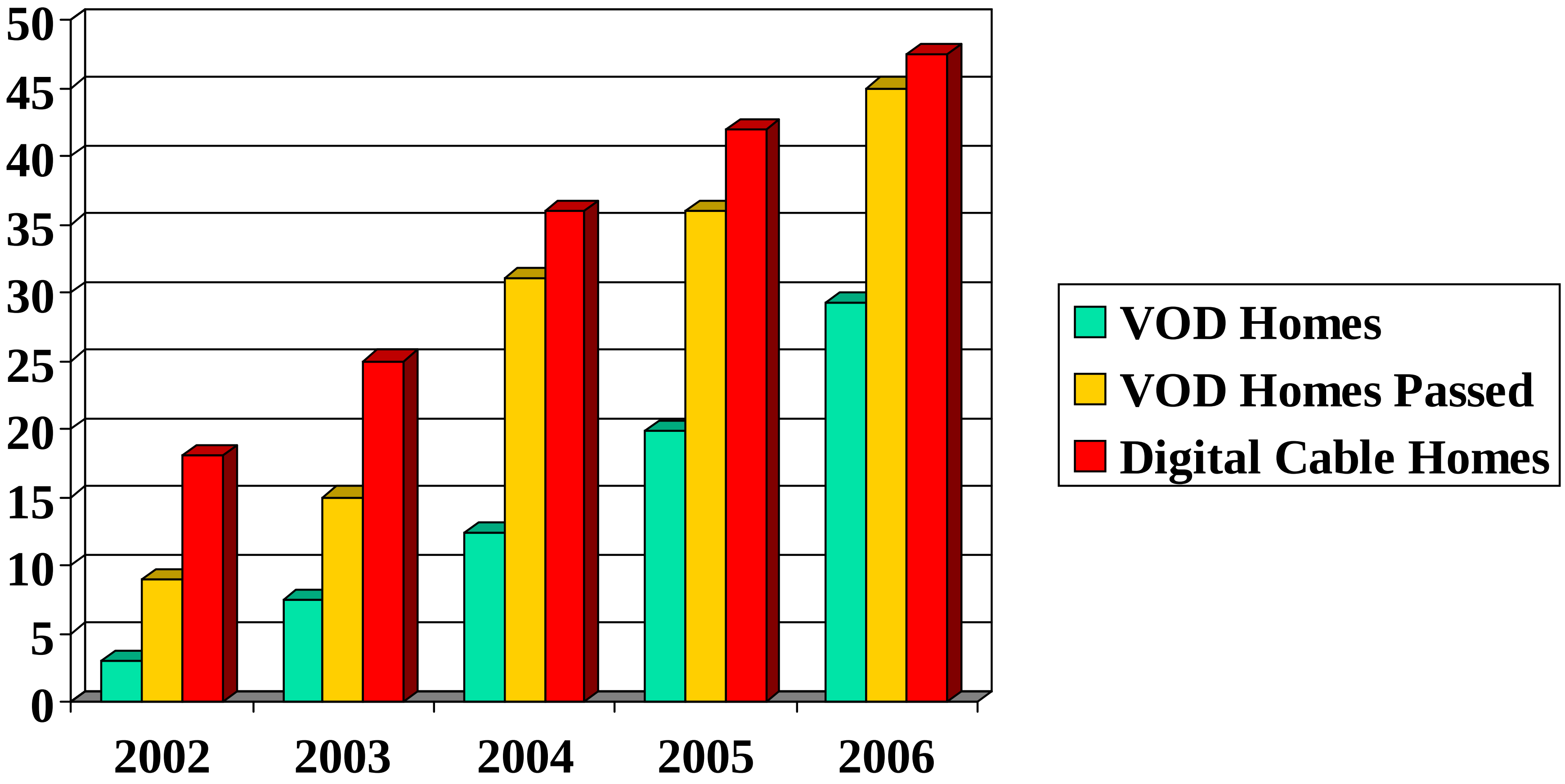
- VOD has been talked about for over 10 years: Why is it only now starting to take off?
  - Critical mass of digital cable set-top penetration
  - Content availability
  - Two-way plant capability and last mile bandwidth
  - More effective marketing
- Remaining hurdles
  - Persistently high cost per stream
  - MPEG-2 technology inertia

VOD Content Evolution

- PPV VOD (movie studios via In Demand and TVN)
- Subscription VOD (HBO, Showtime, StarzEncore)
- Free VOD (HGTV, DIY, Comedy Central, A&E)
- Everything On Demand ("XOD") via Network PVR
  - Includes network TV viewing (still 50% of viewers)
  - Unprecedented and massive scalability
  - Network architecture paradigm shift vs. today's solutions

U.S. Cable VOD Subscriber Forecast

Source: Kagan World Media (2002), millions



The Paradox of Success

- Parallel successes of cable VOD and HDTV will create a new bandwidth crunch
- Cable operators will realize they need to move to next generation of technology
- FCC and Congress need to stop imposing regulations which impede new technologies
- Local system nature enables cable operators to transition to MPEG-4 AVC
  - Move bandwidth-intensive services (VOD, HDTV) to MPEG-4
  - Provide premium subs with dual mode (MPEG-4/MPEG-2) set-top boxes

MPEG-2 VOD Bandwidth

- Assume:
  - 500 home node
  - 150 VOD capable homes (@30% digital penetration)
  - MPEG-2 stream at 3.75 Mbps
- 7 simultaneous users will consumer an entire 6 MHz channel (10 users @ 256 QAM)
- MPEG-2 video only supports 2 simultaneous HDTV VOD users per 6 MHz channel

- With MPEG-4 AVC, instant gain of 2-3X !!!

Telcos

- Local phone monopolies under siege by wireless carriers and some cable operators
  - 2^{nd} lines being disconnected by new broadband subs and wireless users
- DSL speeds and subscriber penetration will increase over the next few years
- Desperately need video product for long-term revenue and profit growth
- MPEG-4 (AVC) allows entertainment-quality at 1 Mbps and lower rates

HD-DVD

- DVD technology is currently MPEG-2
- DVD Forum evaluating new technologies for HD-DVD
- Red laser vs. blue laser
- Leading candidates are MPEG-4 AVC and Windows Media 9

Personal Video Recorder (PVR)

- With MPEG-2, PVR with 80 GB hard drive can store:
  - 23 MPEG-2 SDTV movies (3.5 Mbps) or
  - 7 HDTV movies (12 Mbps)
- With MPEG-4 AVC, same PVR can store:
  - 57 SDTV movies (1.5 Mbps) or
  - 14 HDTV movies (6 Mbps)

MPEG-4/AVC Technology Overview

MPEG-4 Overview

- Very broad standard, with many “tools” and “profiles”
- Early video profiles were much more focused on interactivity than video coding performance
  - In parallel, ITU focused on coding efficiency with “H.26L”
- In early 2002, ITU and ISO/MPEG got together (“JVT”) to develop the best possible next-generation video codec
- The result is MPEG-4 Advanced Video Coding (AVC)
  - ITU calls it H.264
- Goal of more than 2X coding efficiency over MPEG-2
- Final spec was frozen in Q2 2003
- AVC can be used with MPEG-4 system and audio specs

MPEG-4 AVC: Superior Performance

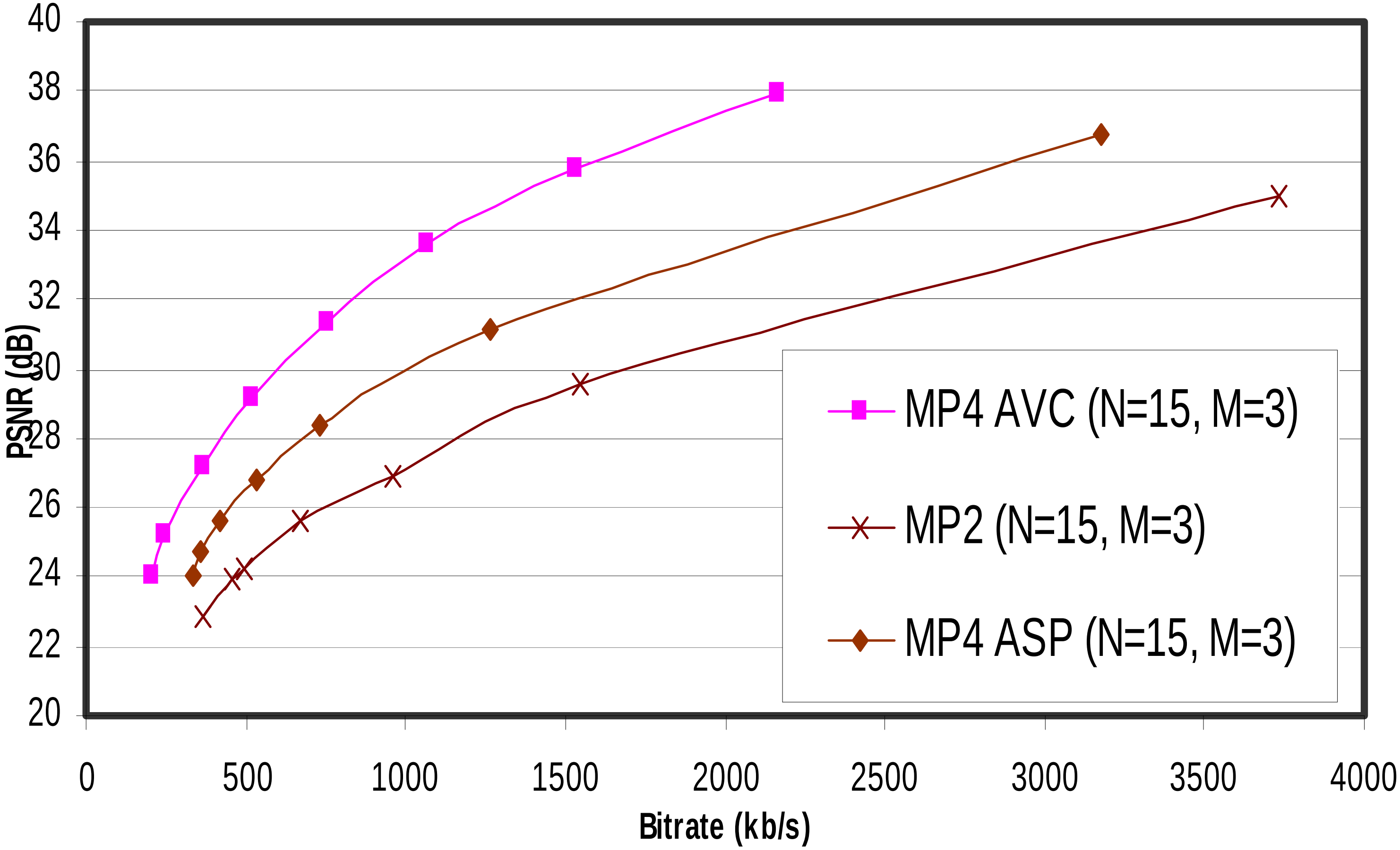
Video Codec	Approximate Bit Rate Equivalence
MPEG-4 AVC	1.0 Mbps
MPEG-4 ASP	1.5 Mbps
MPEG-2	2.0 Mbps
MPEG-1	3.0 Mbps
MPEG-4 SP	3.5 Mbps

MPEG-4 AVC/H.264 Highlights of New Coding Tools

- Multiple reference frames for prediction
- Variable block size for prediction
  - 16x16, 16x8, 8x16, 8x8, 8x4, 4x8, 4x4
- Special prediction mode to do motion compensation across fade (fading in and out of a video)
- ¼ pixel motion estimation
- Multiple directions of prediction for I-Macroblocks
- Loop filter (controls the propagation of compression noise from one frame to another)
- Arithmetic coder (for better lossless coding than Huffman coder)

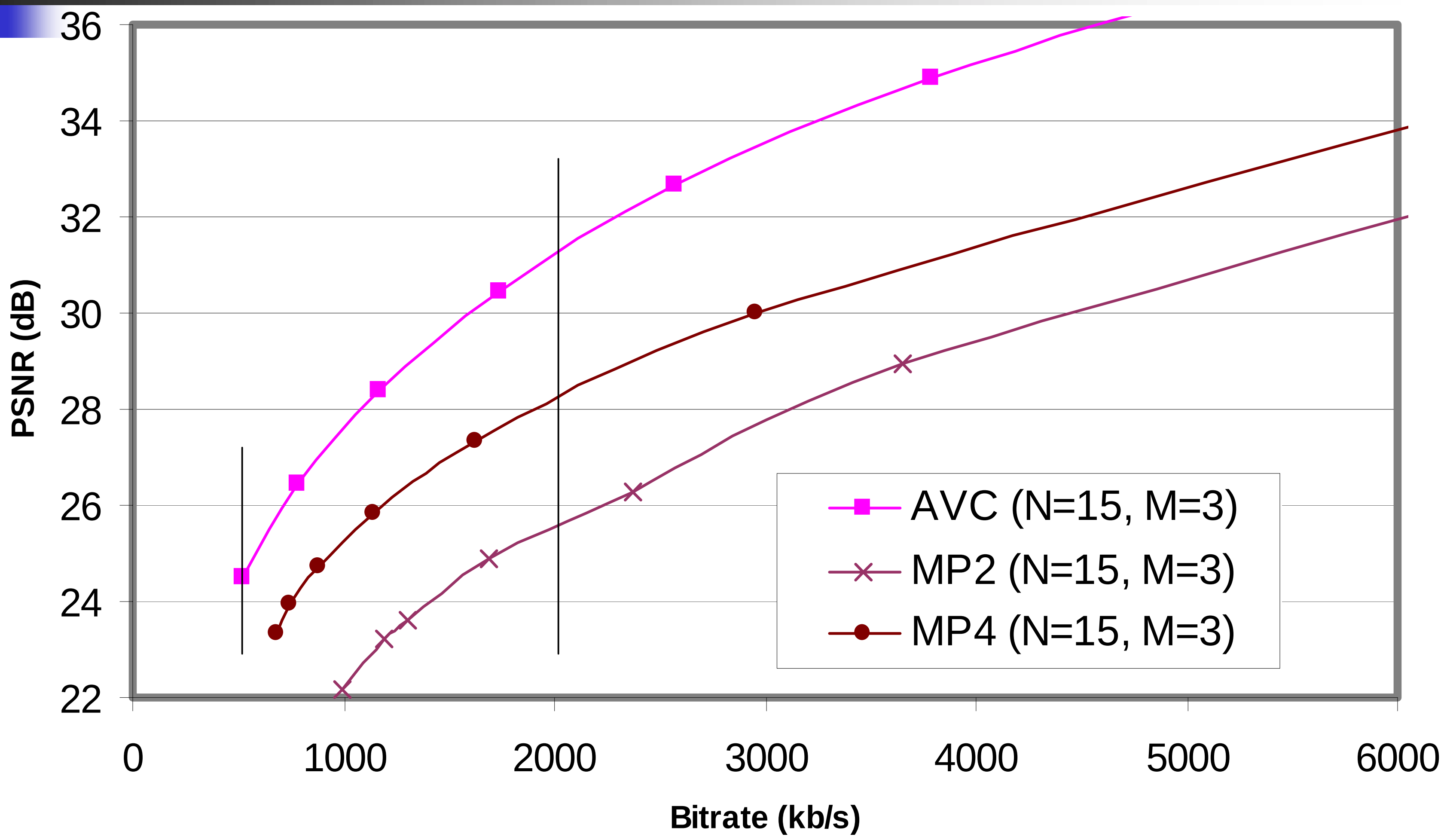
MPEG-2 vs. MPEG-4 ASP vs. MPEG-4 AVC

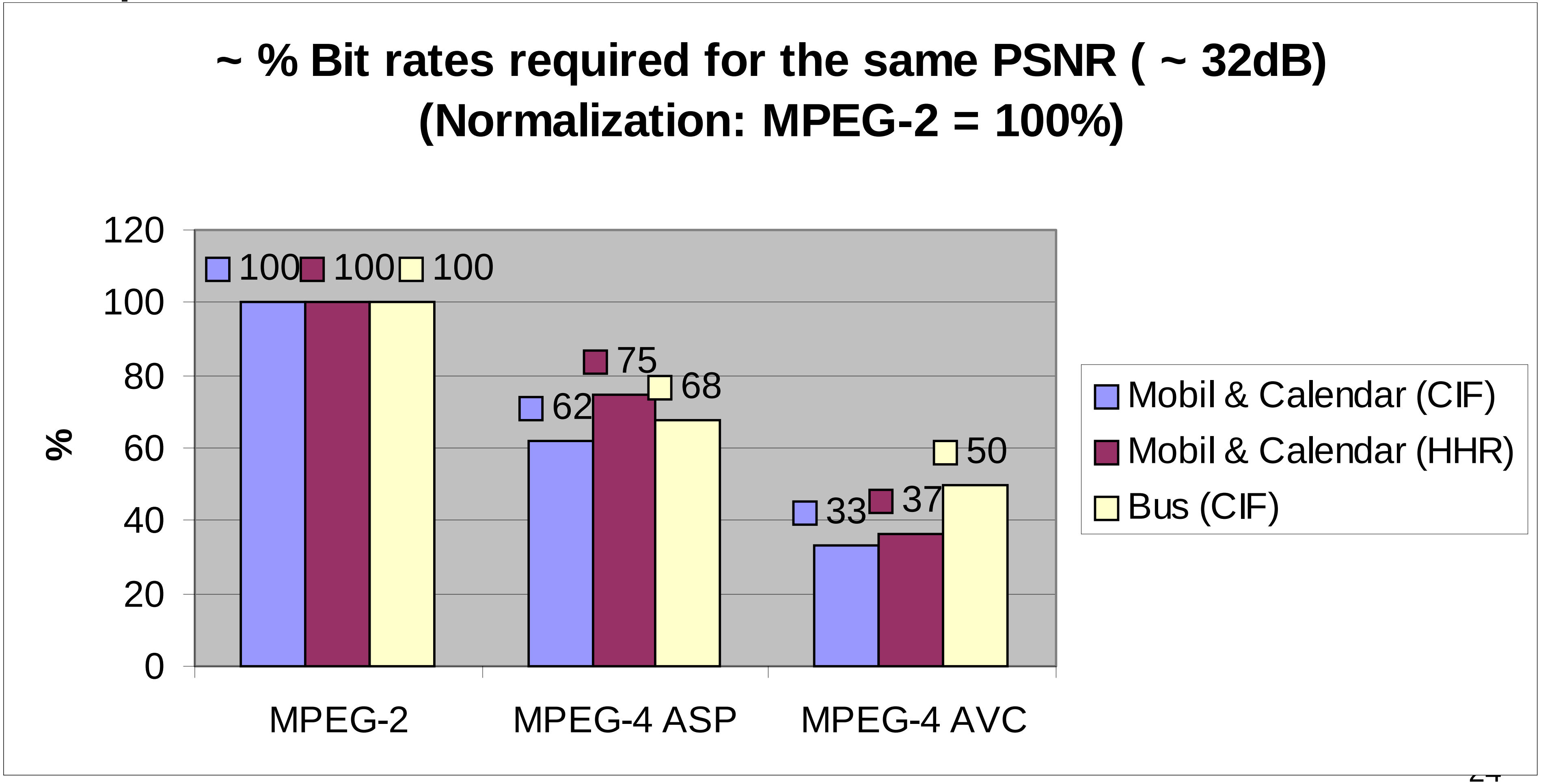
Mobile & Calendar (CIF)



MPEG-2 vs. MPEG-4 ASP vs. MPEG-4 AVC

Mobile & Calendar (HHR)




~ % Bit rates required for the same PSNR (~ 32dB)
(Normalization: MPEG-2 = 100%)
%
120
100
80
60
40
20
0
100
100
100
62
75
68
33
37
50
MPEG-2
MPEG-4 ASP
MPEG-4 AVC
Mobil & Calendar (CIF)
Mobil & Calendar (HHR)
Bus (CIF)

End of Part I

Why scalable video compression?

- Improved QoS for Internet streaming
- Suitable for wireless video
- Tiered subscription services
- Storage capacity trade-offs
- Etc.

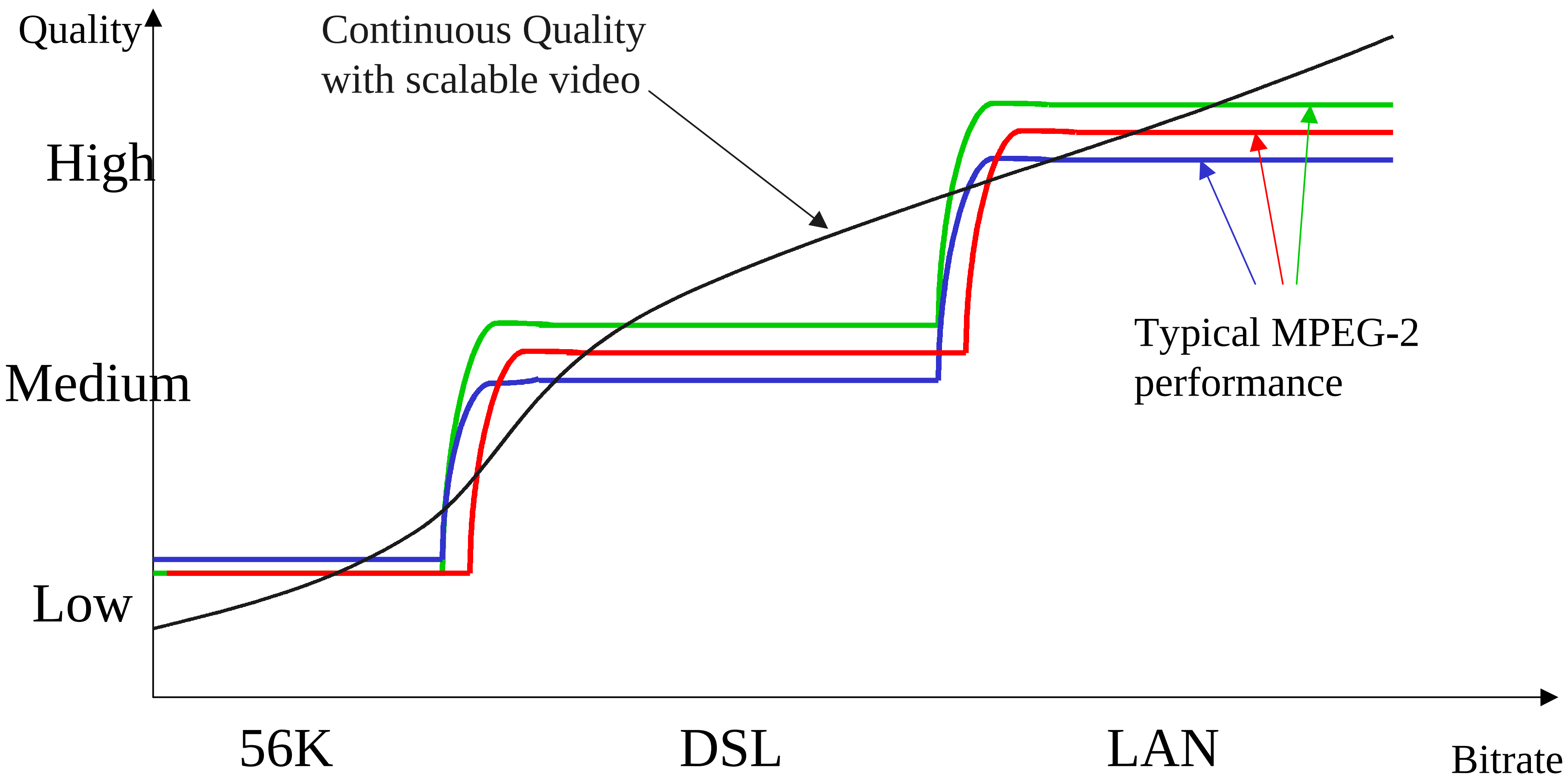
Video streaming over the Internet

- Link quality:
  - Unicast sessions based on bandwidth profile (“56K” “cable modem” “LAN” etc.)
  - Multicast session quality < individual unicast links

Video streaming over the Internet

- Servers store multiple quality copies of a program for each link profile.
- These copies are typically not interchangeable (backward/forward direction).
- Switch between copies to manage BW variations

Continuous quality trade-off



Video streaming over the Internet

- Packet loss
  - Researchers have reported packet loss numbers in the 0.2% to 5% range
  - These packet loss estimates have stayed fairly constant over the last 5 years
    - Reasons: Transmission errors/ congestion loss/ congestion delay increase)
- Leads to unpredictable quality loss

Streaming video over wireless networks

- Link quality and packet loss problems mentioned before, to a greater extent
- For mobile environments, link quality variation could be fast
- (Future application): In hybrid networks, (Wi-Fi/3G), hand-off of streaming sessions may result in abrupt change in available bandwidth.

Scalability in Wireless streaming

- Active research, but no commercial deployments
- 3GPP uses MPEG-4 Simple Profile for video
- Proposals have been made to push scalability in wireless networks
- 3G/Wi-Fi type hybrid networks can benefit from scalable profile

MPEG-2 Scalability Work

- Temporal, spatial and SNR scalability have been a part of the MPEG standard since MPEG-2.
- The enhancement layers can only be decoded as “all or none”.

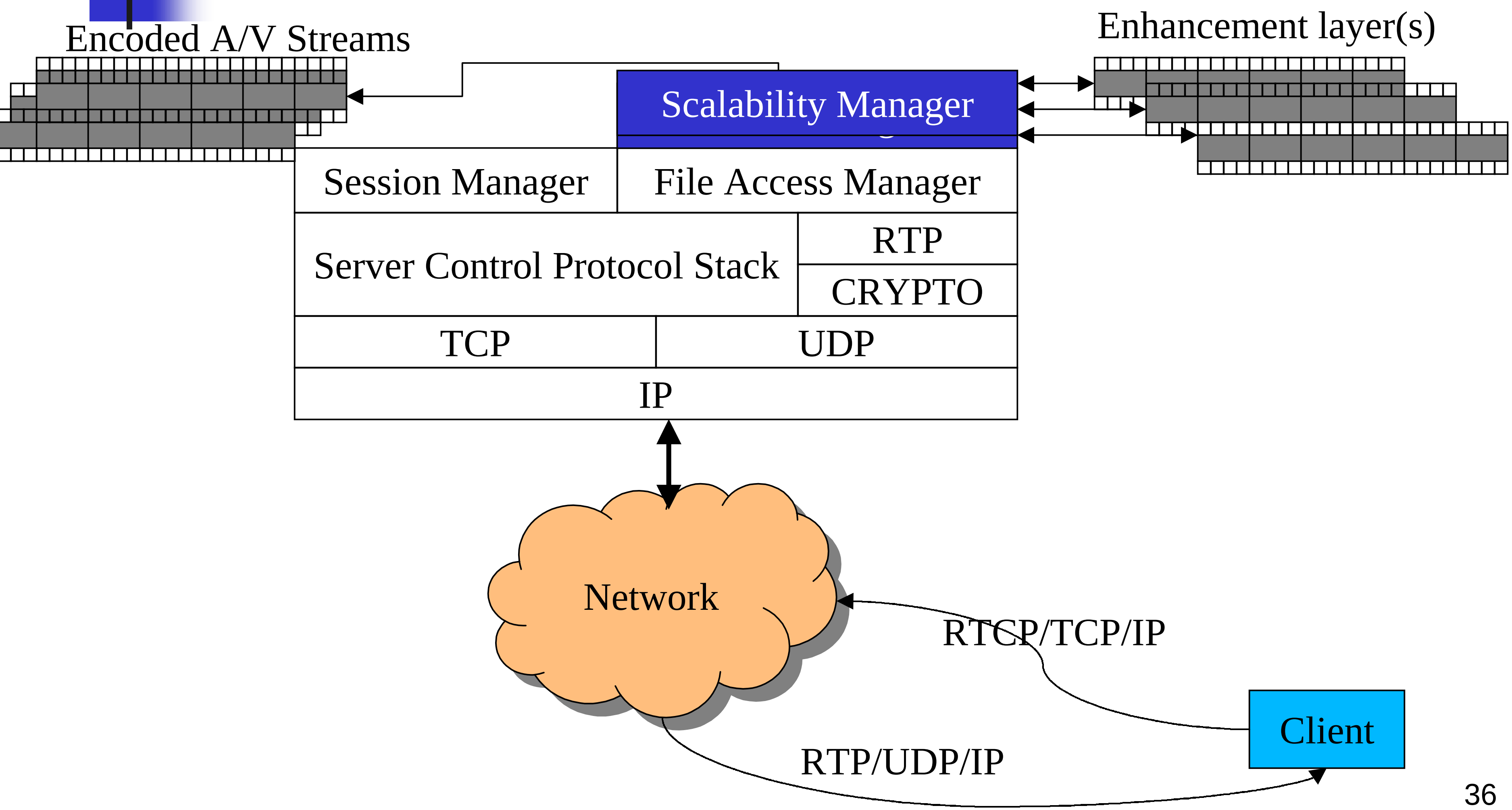
Rate adaptation to available bandwidth

- Non-scalability solutions exist
  - VBR
  - Real time compression
- Potential problems
  - Sub-optimal coding gains
  - CPU-intensive real-time encoder
- MPEG-2 scalability inadequate

JPEG 2000 can do it

- Scalable image compression coding
- High quality, all- Intra coded compression
- IETF proposal for streaming M-JPEG 2000 over RTP (Sony) has been well received.

Scalable video streaming server



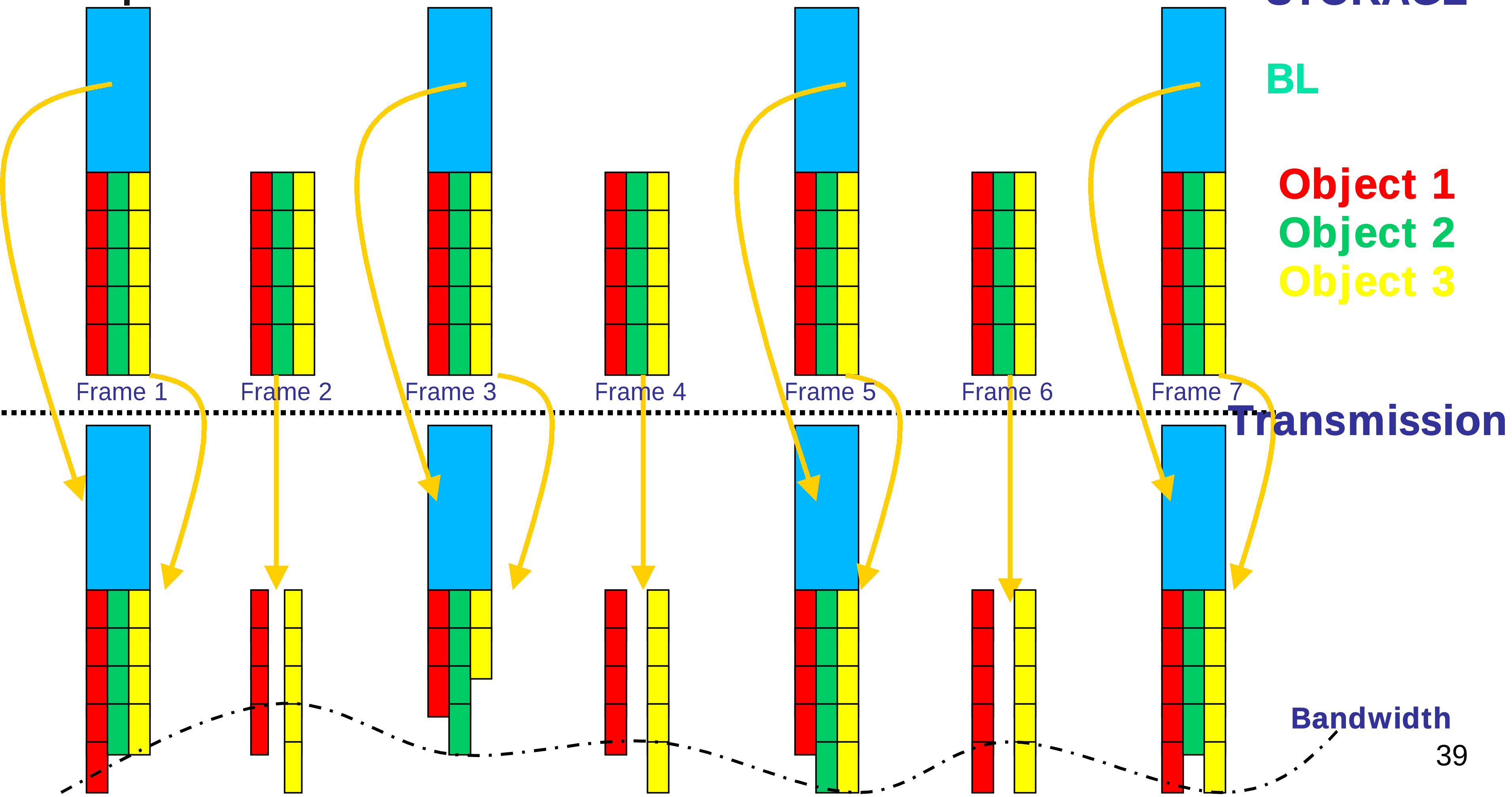
MPEG-4 Version 3 (March 2001)

- “Fine Granularity Scalability Streaming Video Profile”, a new form of scalable video coding
  - Uses a scalable enhancement layer
  - Temporal prediction in enhancement layer is stopped to prevent temporal error propagation
  - Enhancement layer coded by bit-planes to form a “progressive-transmission” bitstream

MPEG-4 scalability features

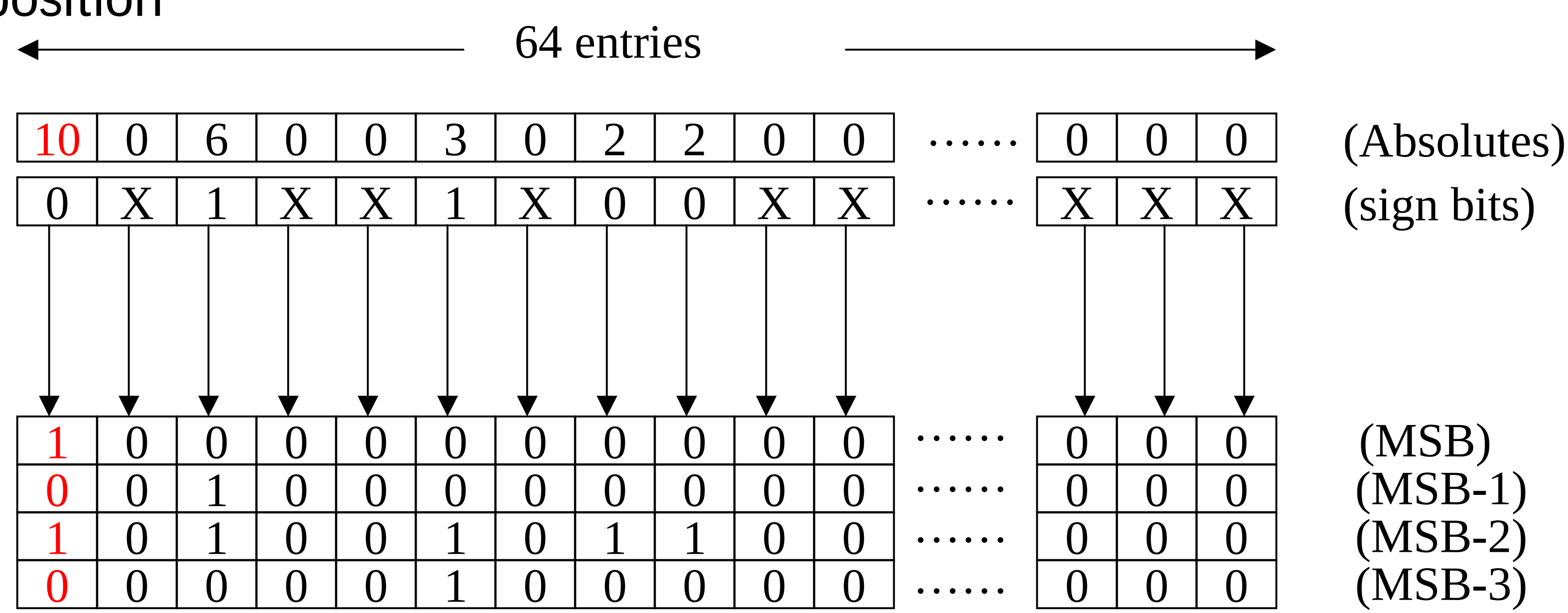
- Eliminates picture drift in a decoder that can reconstruct base layer only
- Higher layers are transmitted on a bit-wise improvement
- Hardware implementation will be important for the target markets

Fine Granular Scalability



FGS tool: Bit Plane Encoding

- 64 absolute values for each **residual** 8 by 8 DCT block are zigzag ordered into an array
- DCT coefficients are represented losslessly in binary digits
- Bit plane of a block is an array of 64 bits, taken one from each absolute value of the DCT coefficients at the same significant position



Bit Plane Coding (Contd..)

1	0	0	0	0	0	0	0	0	0	0	……	0	0	0	(MSB)
0	0	1	0	0	0	0	0	0	0	0	……	0	0	0	(MSB-1)
1	0	1	0	0	1	0	1	1	0	0	……	0	0	0	(MSB-2)
0	0	0	0	0	1	0	0	0	0	0	……	0	0	0	(MSB-3)

- Bit plane within each block is coded using run-length coding
  - Bit-planes are converted into (RUN,EOP) symbols
    - Run ~ # of zeros before a "1"
    - EOP flag ~ end-of-plane

(0,1) (MSB)

(2,1) (MSB-1)

(0,0),(1,0),(2,0),(1,0),(0,0),(2,1) (MSB-2)

(5,0),(8,1) (MSB-3)

Bit Plane Coding (Contd..)

- Encode sign right after the VLC code of (Run, EOP) symbol containing MSB of the associated non-zero coefficient value

VLC (0,1), 0 (MSB)

VLC (2,1), 1 (MSB-1)

VLC (0,0),VLC (1,0),VLC (2,0), 1,VLC (1,0), 0,

VLC (0,0), 0, VLC (2,1), 1 (MSB-2)

VLC (5,0), VLC (8,1) (MSB-3)

More Scalability work underway

- Combined Spatio-temporal-SNR granular scalability codec proposals due in July 2003

- Standardization is key to promote wide-scale implementation

- Hardware implementation will be important for the target markets

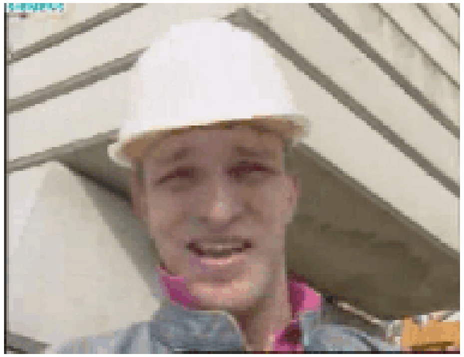
Storage of digital video

- Fixed HD capacity
- More storage time => lower video quality
- High definition storage – All or none storage in big chunks
- Optimal multimedia file systems for personal storage is still a relatively new field

Scalability in personal video storage

- PVRs fuelled growth in archived digital video
- Scalability provides a method to keep up with file-size hungry video formats.
- Analogous to JPEG 2000 application to digital photo memory cards

FGS example

Error robustness for Internet packet loss using Unequal Packet Protection with a non-scalable MPEG coder (left) and an FGS MPEG-4 coder at 330 kbit/s (right) where the enhancement layer is completely lost.

[Source: http://www.eesi.tue.nl/VCA/projects/fine_granular_scalability/]

Multirate Systems has more examples available

Scalable video: concluding remarks -1

- Streaming video
  - MSFT, REAL domination (rate switched video)
  - Apple QuickTime is a distant third
- Apple has embraced MPEG-4 (Simple Profile)
- PC-centric/software nature of Internet video, combined with Microsoft's market power, makes success of streaming MPEG-4 less certain
- Wireless scalable video more likely
- But, wireless video is rolling out very slowly…

Scalable video: concluding remarks -2

- Closed systems applications such as PVR file systems and surveillance video are evaluating FGS-type video

- Availability of design/test tools and IP blocks important

Thank you!
Any questions??