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
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\textsuperscript{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

<table>
<thead>
<tr>
<th>Video Codec</th>
<th>Approximate Bit Rate Equivalence</th>
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<tbody>
<tr>
<td>MPEG-4 AVC</td>
<td>1.0 Mbps</td>
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<tr>
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<td>1.5 Mbps</td>
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<tr>
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<td>MPEG-4 SP</td>
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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%)
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

Quality

High

Medium

Low

Continuous Quality with scalable video

Typical MPEG-2 performance

Bitrate
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.
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

STORAGE

BL

Object 1
Object 2
Object 3

Transmission

Bandwidth
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.

64 entries

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(MSB)

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(MSB-1)

(MSB-2)

(MSB-3)
Bit Plane Coding (Contd..)

- 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

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

(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??