Using 10-bit AVC/H.264 Encoding with 4:2:2 for Broadcast Contribution

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Based on a paper by Pierre Larbier, ATEME CTO

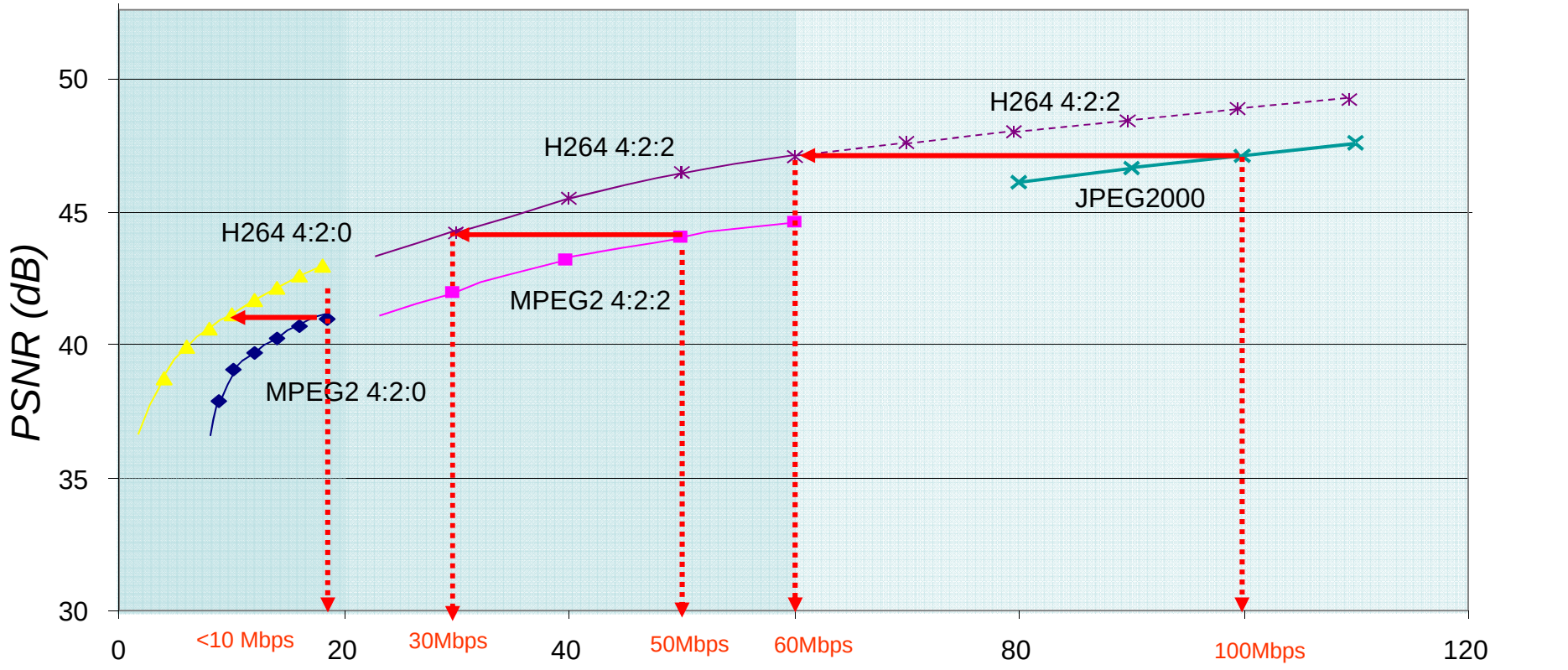
Contribution Requirements

- Contribution Feeds Require the Highest Possible Quality to Support Multiple Generations:
  - Must Maintain Pixel Depth and Chroma Information
- The Entire Production Chain is 10 bits
  - Starting form the SDI/HDSDI
  - Film scanning, cameras, AVC-Intra, video editing, tape decks, playout servers, etc
- Bit Rates Ranging form 15Mbps to 3G
- Latencies from 300msec to 1 sec
- Transport over Satellite
  - Up to 60Mbps with DVB-S2
  - Maximize the number & quality programs
- Transport over Fiber Optics
  - Very high bandwidth available… at some operations cost

Contribution Today – Tomorrow?

- Large amount of content ingested at less than 60Mbps
- MPEG-2 [4:2:2 Profile] is most widely used – 19Mbps, 55Mbps
  - JPEG-2000 (above 100Mbps) - Fiber
  - AVC/H.264 in 4:2:2 8-bit (up to 60Mbps) – intermediate step (skipped)
    - Limited gain over MPEG-2 at high bitrates
- H.264 Encoders & Decoders Supporting All **High 4:2:2 Profile** tools are being released
  - 4:2:2 Chrominance
  - 10 bit Depth
  - Better Bit Rate Efficiency
  - 1080p60 a must for new deployments

A Full Range of MPEG-4 Contribution Applications



IP contribution:
Decrease Bandwidth

Satellite contribution:
Increase Service Density

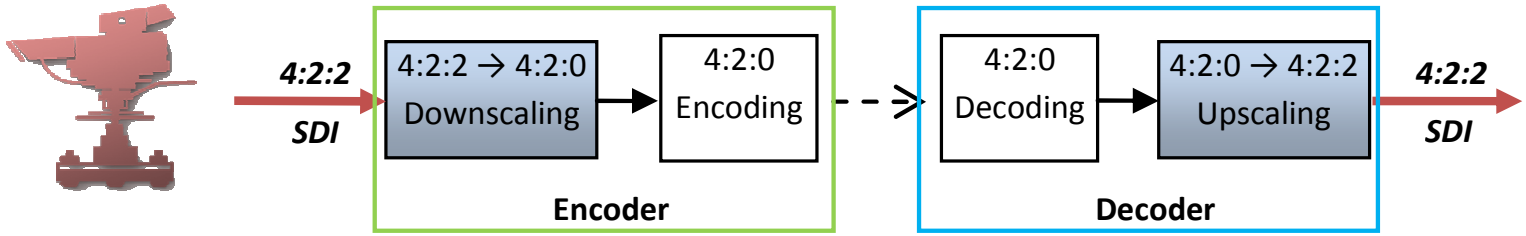
High Video quality Contribution:
Increase Video Quality

AVC/H.264 Broadcast Profiles

Coding Tools	Main Profile	High Profile	High 4:2:2 Profile
I,P,B slices	X	X	X
Multiple Reference Pictures	X	X	X
CAVLC, CABAC Entropy Coding	X	X	X
Interlaced Coding	X	X	X
Weighted Prediction	X	X	X
In-loop Filtering	X	X	X
4:2:0 Chroma Format	X	X	X
8-bit Sample Depth	X	X	X
8x8 Transform		X	X
8x8 Intra Prediction		X	X
Quantization Scaling Matrices		X	X
Separate Chroma Quantizers		X	X
Monochrome Video Format		X	X
9 and 10-bit Sample Depth			X
4:2:2 Chroma Format			X

4:2:0 Compression

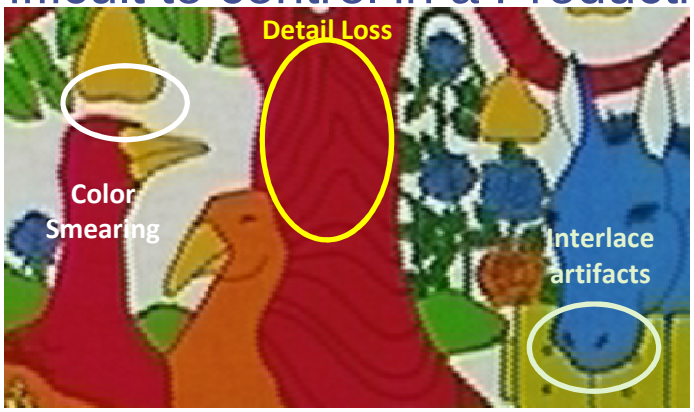
- Professional video sources are 4:2:2
- 4:2:0 compression requires resampling filters



- Progressive and Interlace chroma location schemes are different
- Challenges for existing chroma re-sampling architecture:
  - Possible mismatch between the 2 re-sampling filters
  - Re-sampling filters quality not guaranteed
  - Choosing between Progressive and Interlace filters is not obvious

4:2:0 Chroma Artifacts

- Mainly caused by a mismatch between downscale/upscale filters
  - Color bleeding
  - Chroma detail loss
  - Interlace/Progressive artifacts
- Worsen with each generation
- Difficult to control in a Production chain

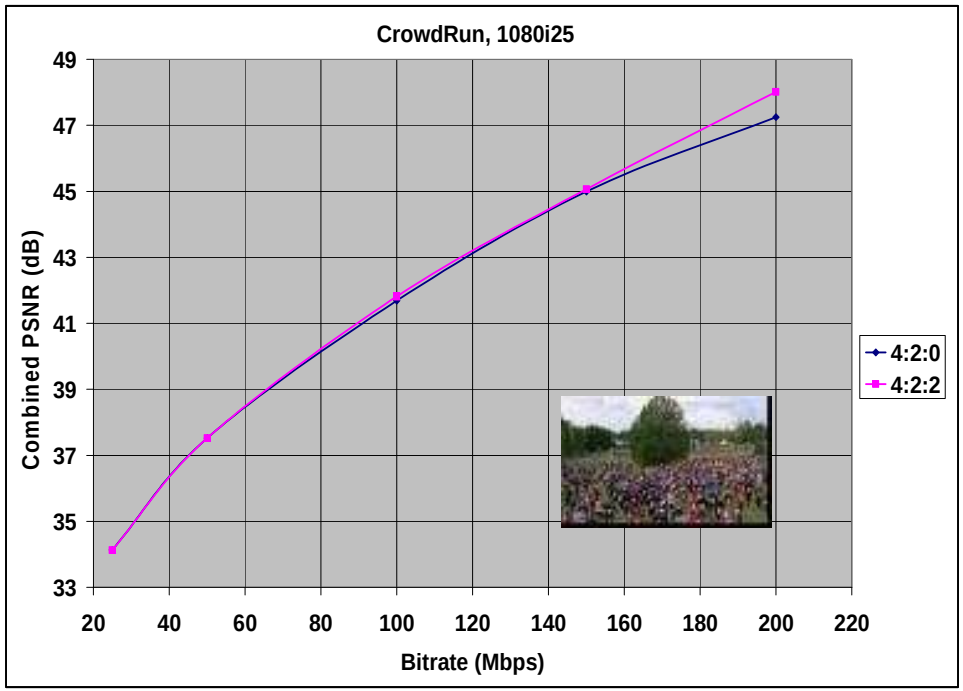


After 5x 4:2:2 ↔ 4:2:0 conversions

Source picture

4:2:2 Compression - Concatenation

- At the 1st generation, with perfect re-sampling filters, 4:2:2 and 4:2:0 overall quality is roughly the same:

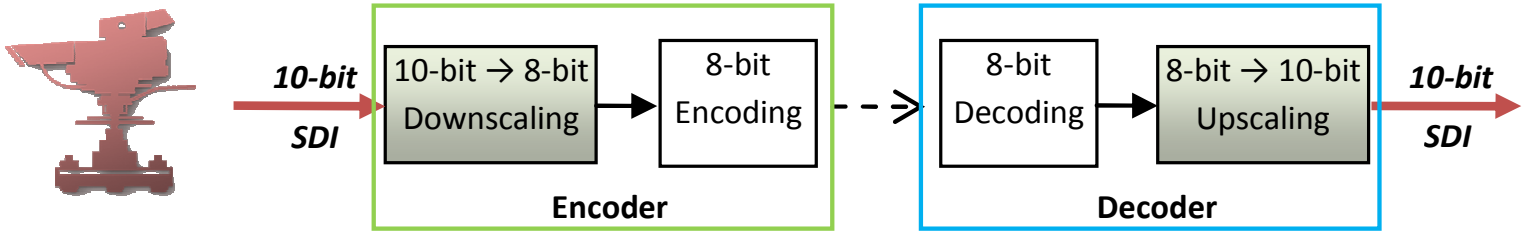


4:2:2 vs. 4:2:0 with perfect re-sampling filters

- But in multi-generation and/or with mismatched sampling filters, 4:2:2 quality is much better than 4:2:0

8-bit versus 10-bit Compression: Precision

- Professional video sources are 10-bit
- 8-bit compression requires rounding before compression



- Motion compensation and loop-filtering are performed using 8-bit samples
- Challenges for 8-bit architecture:
  - Scalers match and quality not guaranteed
  - Reduced accuracy in the encoding process reduces coding efficiency
  - Luma shift caused by lack of rounding control

10-bit Compression: Banding Removal

- Processing video with 8-bit sample depth may create banding artifacts in shallow changing light scenes:
  - Blue skies
  - Underwater scenes
  - Sunsets
- These defects are not visible at 10-bit or more

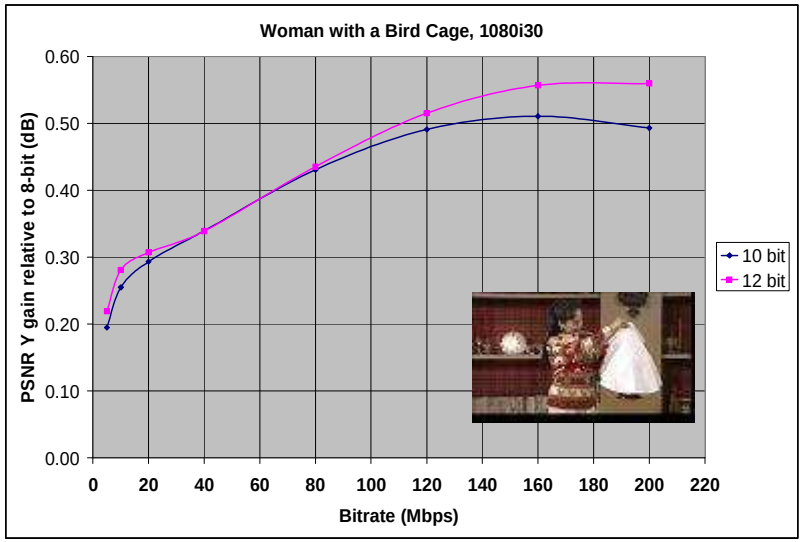
8-bit compression

10-bit compression

10-bit Compression: Increased Coding Efficiency

- Coding efficiency is increased: less bit-rate for the same quality
- Rate saving between 5% and 20% on most sources
- Most of the gain is provided with 10-bit coding. 12-bit and 14-bit coding efficiency gain is much smaller

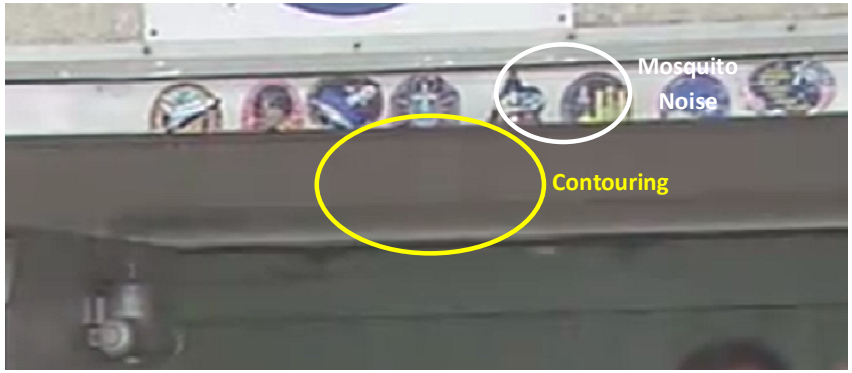
RD curve at 8,10 and 12-bit



Distortion gain vs 8-bit compression

10-bit Compression: Artifacts Reduction

- 10-bit compression reduces 3 kind of artifacts:
  - Contouring
  - Smearing
  - Mosquito noise
- As a side-effect, 10-bit compression also reduces random distortion of shallow textured objects (clouds for instance)

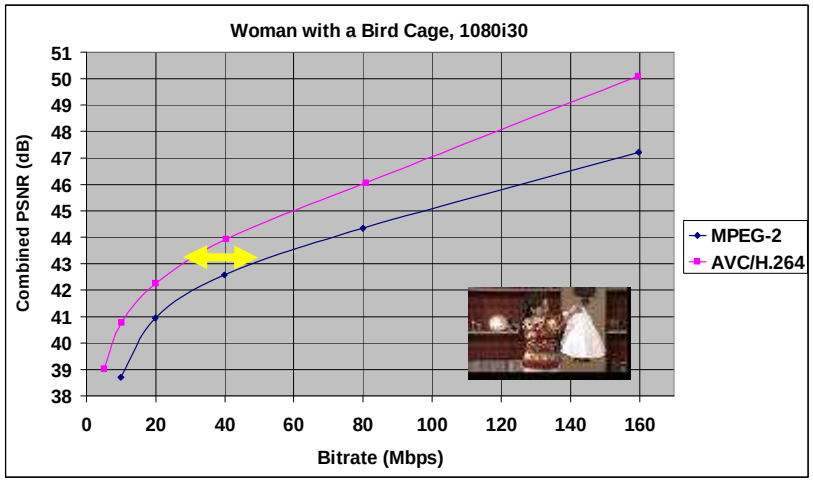


8-bit compression

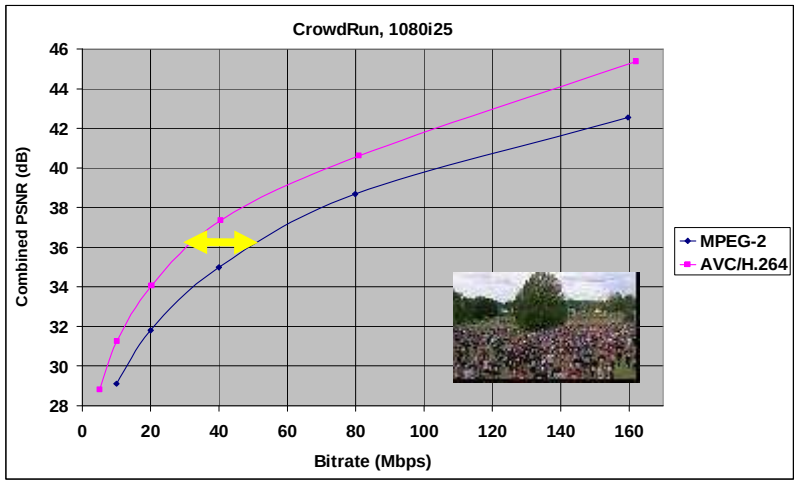
10-bit compression

MPEG-4/AVC *H422P* vs. MPEG-2 *422P*

- H.264 *H422P* outperforms MPEG-2 *422P* in Contribution applications:
  - 10-bit support
  - More than 20Mbps saved at Contribution rates



Example 1



Example 2

Summary

- Supporting the native video format, H.264 *High422P* was designed for high quality professional applications:

  ⇒ 4:2:2 sampling format reduces chroma artifacts

  ⇒ 10-bit compression increases coding efficiency over 8-bit

  ⇒ 10-bit compression helps removing artifacts difficult to mask

  ⇒ H.264 *High422P* outperforms legacy MPEG-2 *422P*, at all bitrates

H.264 4:2:2 10-bit compression is the ideal encoding format for Contribution applications

Thank You !

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