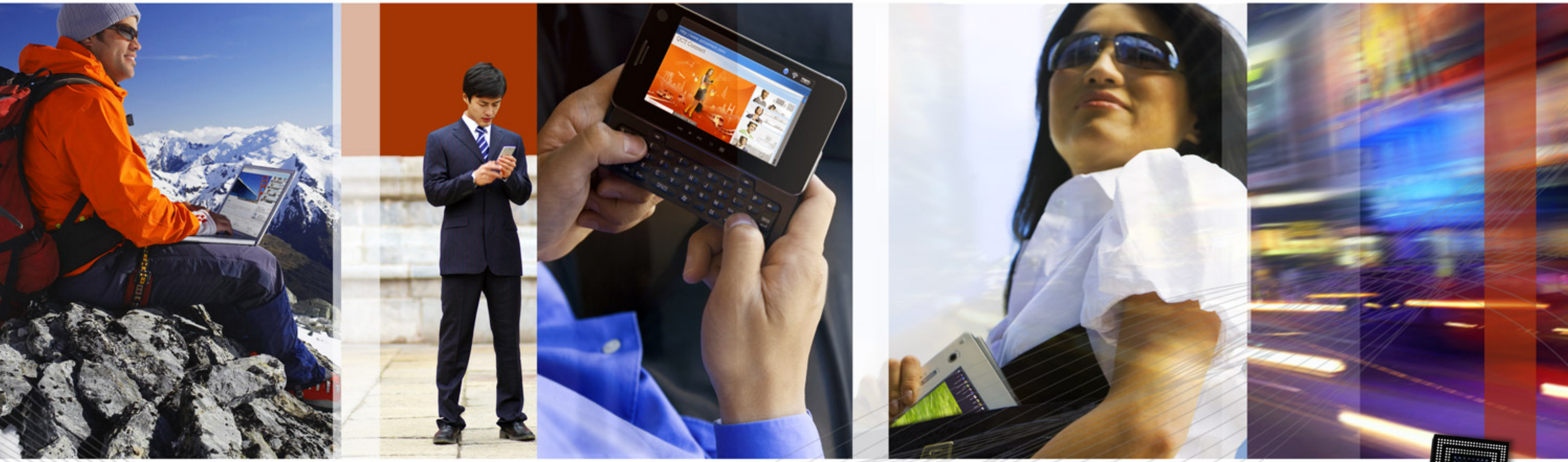


QUALCOMM CDMA Technologies

REDEFINING MOBILITY

Description of screen content coding technology proposal by Qualcomm

JCTVC-Q0031

Main aspects of the Qualcomm's response to the CfP

This response builds upon the HEVC Range Extensions Draft 6 specification and the corresponding reference software HM13.0-RExt6.0

- CU-based adaptive color transform is incorporated to further remove the redundancy among three color components
- Full frame intra BC shows large performance improvement
- Explicit RDPCM is applied to all the intra modes, thus unifying RDPCM
- A deblocking filter enhancement helps visual quality for screen content at the low bit-rates
- The palette mode in JCTVC-P0303 with some improvements is implemented

Main aspects of the Qualcomm’s response to the CfP

- A 1-D dictionary method related to the one in JCTVC-L0303 is implemented
  - Only for the lossless category, where it shows some potential to provide further gains on top of intra BC and palette

- A deflickering method is applied to alleviate the temporal flickering across frames occurring for the all-intra low bit-rate settings

- Additional encoder-only enhancements are implemented
  - Better motion estimation to deal with the specific characteristics of screen content
  - Scene change detection
  - Improved search for intra BC, quantization for RDPCM, etc.

Adaptive Color Transform is used to exploit cross-component correlations

- Each CU adaptively enables or disables the color-space transform (CST)
  - For intra BC and inter CUs, the CST is performed in the residual domain
  - For intra modes, the CST is applied to both the prediction and the original block, i.e., before the residual generation process

- Two different CSTs are applied depending on lossy or lossless configuration (SPS flag)
  - The forward and the inverse CST for lossy coding are modified YCoCg

Forward:

$$\begin{bmatrix} C'_0 \\ C'_1 \\ C'_2 \end{bmatrix} = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 0 & -2 \\ -1 & 2 & -1 \end{bmatrix} \begin{bmatrix} C_0 \\ C_1 \\ C_2 \end{bmatrix}$$

Inverse:

$$\begin{bmatrix} C_0 \\ C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 & -1 \\ 1 & 0 & 1 \\ 1 & -1 & -1 \end{bmatrix} \begin{bmatrix} C'_0 \\ C'_1 \\ C'_2 \end{bmatrix} / 4$$

  - When CST is applied, the quantization parameter is set to QP+8 and the bit-depth is increased by 2

- Fast encoding methods are applied

Intra BC is extended and BV coding improved

- Intra BC is extended to search the entire current reconstructed frame
  - Encoder uses this larger area for 8×8 and 16×16 block sizes
    - Encoder search region is limited to the left CTU for the other block sizes
  - A hash-based algorithm speeds up the search
    - 16-bit hash entries for 8×8 blocks depending on the DC of each 4×4 and the gradient
    - Only blocks with the same hash value as the current block are examined using SAD
- Block vector coding in intra BC uses the left or above vector as predictor
  - Binarization for the block vector difference: non-zero flag + Exponential-Golomb of order 3 + sign flag (if necessary)

Deblocking filter is enhanced for SCC

- Observation
  - Blocking artifacts appear in large flat areas of screen content

- The following changes are applied to reduce these artifacts:
  - The luma filtering process is applied to the chroma components, since chroma content might be similar to the luma content
  - Definition of a new boundary strength equal to 3 for boundaries across large TUs with small gradient
  - If Bs = 3, eight pixels on each side of the boundary are filtered

$$p_i' = \text{Clip1}(\ p_i + (\ (\ (q_0 - p_0) * (\ 8 - i\ ) + 8\ ) >> 4\ )\ ) \quad \text{for } i = 0..7$$

$$q_i' = \text{Clip1}(\ q_i - (\ (\ (q_0 - p_0) * (\ 8 - i\ ) + 8\ ) >> 4\ )\ )$$

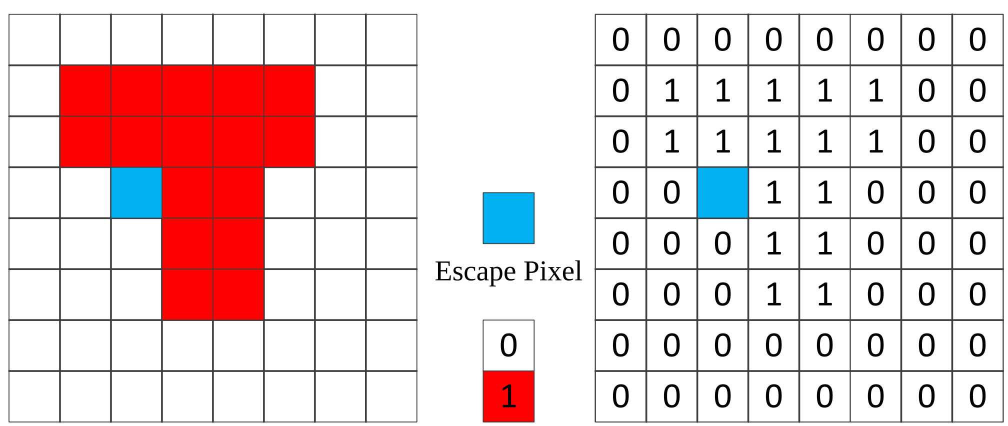
Palette Mode

The palette method is very similar to the AhG10 palette (JCTVC-P0303)

- Palette entries (pairs of index and pixel value) are derived using the histogram of the pixel values of the current CU
  - Up to 32 entries are used, predicted from the previous palette CU or explicitly signaled

- A CU is coded in a raster scan order using one of the three modes
  - Index mode: palette index is first signaled followed by the run length
  - Copy from top: run length of indices from the row above that are copied to the current row
  - Escape mode: the quantized pixel is directly coded - a flag signals if this mode is used

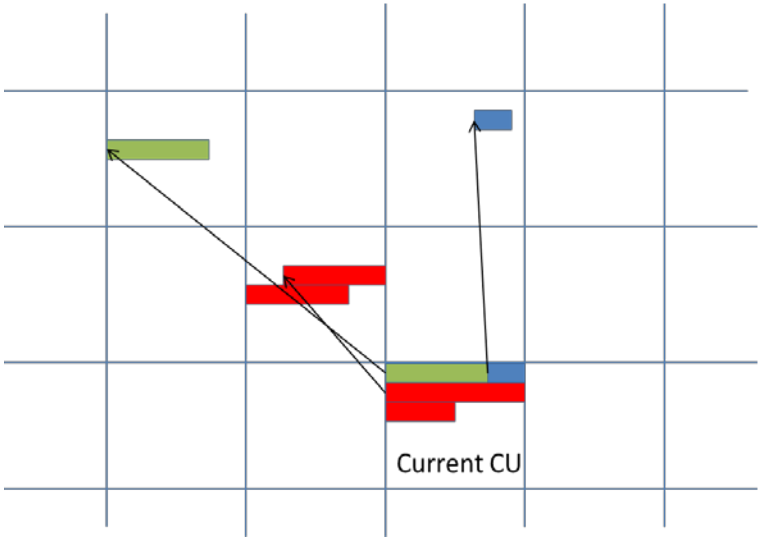
CU with 3 colors:



Input CU Palette Index Block

A 1-D dictionary is applied for lossless

The 1-D dictionary provides an arbitrary shape matching scheme



- ‘Dictionary’ is the reconstructed area in the current frame
- CTU-based raster scan processing of the pixels
  - The position and length of the matches are signaled
  - An escape value is signaled if no match is found
- To enable fast matching at the encoder, a hash table is used with 21-bit entries calculated by a simple concatenation of the pixel MSBs

Deflickering to handle all-intra at low bit-rates

- Observation
  - Temporal flickering is the main artifact observed in all-intra configuration at low bit-rates (high QPs)

- Proposed deflickering method

  - CU level flicker decision depends on the luma gradient, the number of major colors, and the SAD between the original and collocated block

  - If flicker flag is on, then spatially neighboring blocks of the CU are marked as unavailable for spatial intra prediction

Encoder-only methods have been applied

- Motion estimation is improved for screen content coding (JCTVC-Q0147)
  - These sequences exhibit non-monotonic error surface and high spatial frequency characteristics contrary to the assumptions of conventional fast motion estimation
- Uniform quantization (rounding) of RDPCM samples (JCTVC-Q0148)
- Chroma in the R-D decision of Intra BC (JCTVC-Q0175)
  - Best 4 block vectors with lowest luma SAD used in a second step of ME with chroma SAD included
- Scene change detection for low delay configuration
  - The picture that starts a new scene is coded as a CRA picture
- Maximum RQT depth is set to 2 (instead of 3), transform skip 8×8 is enabled, intra BC 2N×N disabled, etc.

Large BD-rate gains for lossy

	All Intra		
	Y	U	V
RGB, text & graphics with motion, 1080p	-52.7%	-51.9%	-51.6%
RGB, text & graphics with motion,720p	-39.9%	-33.4%	-36.0%
RGB, mixed content, 1440p	-35.4%	-29.4%	-29.4%
RGB, mixed content, 1080p	-31.1%	-26.3%	-25.6%
RGB, Animation, 720p	-23.4%	-20.4%	-17.1%
YUV, text & graphics with motion, 1080p	-47.5%	-49.3%	-48.9%
YUV, text & graphics with motion,720p	-27.7%	-31.3%	-33.8%
YUV, mixed content, 1440p	-21.8%	-25.1%	-25.0%
YUV, mixed content, 1080p	-20.2%	-22.5%	-22.1%
YUV, Animation, 720p	-0.6%	-6.7%	-3.5%

	Random Access		
	Y	U	V
RGB, text & graphics with motion, 1080p	-45.4%	-43.1%	-42.6%
RGB, text & graphics with motion,720p	-42.2%	-34.7%	-38.9%
RGB, mixed content, 1440p	-42.3%	-34.4%	-34.6%
RGB, mixed content, 1080p	-36.6%	-28.3%	-26.6%
RGB, Animation, 720p	-26.5%	-23.2%	-17.1%
YUV, text & graphics with motion, 1080p	-36.9%	-40.2%	-39.9%
YUV, text & graphics with motion,720p	-29.5%	-33.4%	-38.2%
YUV, mixed content, 1440p	-22.8%	-29.3%	-29.1%
YUV, mixed content, 1080p	-20.6%	-26.8%	-25.9%
YUV, Animation, 720p	-3.8%	-15.1%	-13.1%

	Low delay B		
	Y	U	V
RGB, text & graphics with motion, 1080p	-41.7%	-38.9%	-38.4%
RGB, text & graphics with motion,720p	-39.7%	-30.2%	-34.4%
RGB, mixed content, 1440p	-48.3%	-38.5%	-38.3%
RGB, mixed content, 1080p	-38.1%	-28.2%	-26.0%
RGB, Animation, 720p	-28.4%	-19.8%	-12.8%
YUV, text & graphics with motion, 1080p	-30.7%	-33.7%	-33.6%
YUV, text & graphics with motion,720p	-26.0%	-29.4%	-34.6%
YUV, mixed content, 1440p	-29.5%	-38.7%	-38.2%
YUV, mixed content, 1080p	-20.9%	-28.7%	-27.8%
YUV, Animation, 720p	-6.1%	-18.2%	-17.5%

Large bit-rate savings for lossless

Bit-rate savings	AI Total	AI Average	AI Min	AI Max
RGB, text & graphics with motion, 1080p	51.4%	51.8%	44.7%	65.6%
RGB, text & graphics with motion,720p	23.9%	25.4%	5.2%	46.9%
RGB, mixed content, 1440p	18.5%	18.1%	16.6%	19.7%
RGB, mixed content, 1080p	22.0%	21.3%	19.7%	22.9%
RGB, Animation, 720p	5.2%	5.2%	5.2%	5.2%
YUV, text & graphics with motion, 1080p	49.9%	50.3%	40.7%	66.6%
YUV, text & graphics with motion,720p	21.7%	24.5%	3.6%	52.7%
YUV, mixed content, 1440p	16.2%	16.0%	15.0%	17.0%
YUV, mixed content, 1080p	15.9%	16.6%	14.9%	18.2%
YUV, Animation, 720p	2.2%	2.2%	2.2%	2.2%

Bit-rate savings	RA Total	RA Average	RA Min	RA Max
RGB, text & graphics with motion, 1080p	41.4%	49.4%	40.7%	65.7%
RGB, text & graphics with motion,720p	10.6%	21.0%	7.7%	48.1%
RGB, mixed content, 1440p	13.0%	13.0%	12.8%	13.2%
RGB, mixed content, 1080p	19.3%	16.5%	13.2%	19.8%
RGB, Animation, 720p	9.5%	9.5%	9.5%	9.5%
YUV, text & graphics with motion, 1080p	34.4%	43.5%	33.4%	61.5%
YUV, text & graphics with motion,720p	7.3%	17.9%	2.9%	52.9%
YUV, mixed content, 1440p	5.6%	5.7%	4.6%	6.7%
YUV, mixed content, 1080p	10.9%	8.7%	6.1%	11.2%
YUV, Animation, 720p	2.7%	2.7%	2.7%	2.7%

Bit-rate savings	LB Total	LB Average	LB Min	LB Max
RGB, text & graphics with motion, 1080p	41.5%	49.0%	40.6%	65.3%
RGB, text & graphics with motion,720p	10.3%	20.8%	7.7%	46.7%
RGB, mixed content, 1440p	12.7%	12.7%	12.6%	12.8%
RGB, mixed content, 1080p	19.0%	15.9%	12.5%	19.4%
RGB, Animation, 720p	10.2%	10.2%	10.2%	10.2%
YUV, text & graphics with motion, 1080p	33.3%	41.0%	32.9%	56.3%
YUV, text & graphics with motion,720p	6.1%	16.3%	2.4%	51.1%
YUV, mixed content, 1440p	4.1%	4.2%	3.3%	5.1%
YUV, mixed content, 1080p	10.6%	7.5%	4.0%	11.0%
YUV, Animation, 720p	2.7%	2.7%	2.7%	2.7%

Limited encoding/decoding time increases

Encoding Time / Lossy	**AI**	**RA**	**LB**
RGB, text & graphics with motion, 1080p	145%	136%	143%
RGB, text & graphics with motion,720p	164%	104%	116%
RGB, mixed content, 1440p	179%	98%	112%
RGB, mixed content, 1080p	239%	136%	165%
RGB, Animation, 720p	210%	136%	170%
YUV, text & graphics with motion, 1080p	169%	137%	145%
YUV, text & graphics with motion,720p	152%	97%	111%
YUV, mixed content, 1440p	178%	98%	102%
YUV, mixed content, 1080p	221%	125%	136%
YUV, Animation, 720p	206%	118%	137%
All	**175%**	**115%**	**128%**

Decoding Time / Lossy	**AI**	**RA**	**LB**
RGB, text & graphics with motion, 1080p	64%	117%	113%
RGB, text & graphics with motion,720p	87%	114%	109%
RGB, mixed content, 1440p	99%	122%	120%
RGB, mixed content, 1080p	101%	125%	115%
RGB, Animation, 720p	109%	123%	115%
YUV, text & graphics with motion, 1080p	59%	110%	110%
YUV, text & graphics with motion,720p	71%	111%	105%
YUV, mixed content, 1440p	76%	119%	109%
YUV, mixed content, 1080p	83%	116%	113%
YUV, Animation, 720p	92%	120%	113%
All	**79%**	**116%**	**111%**

Lossless	**AI**	**RA**	**LB**
Encoding Time / All	**238%**	**178%**	**172%**
Deocding Time / All	**78%**	**104%**	**97%**

Closing Remarks

- High performing solution based on HM13.0-RExt6.0 with
  - extensions of current tools (intra BC, deblocking filter and explicit RDPCM)
  - new tools, like palette and adaptive color transform
  - and encoder modifications and subjective enhancements for screen content

- Suggestion to move forward the work on Screen Content Coding:
  1) Use HEVC Range Extensions software with encoder improvements and intra bock copying with full frame search
  2) New tools such as palette, 1-D dictionary, etc. should be developed on top of and compared against this benchmark

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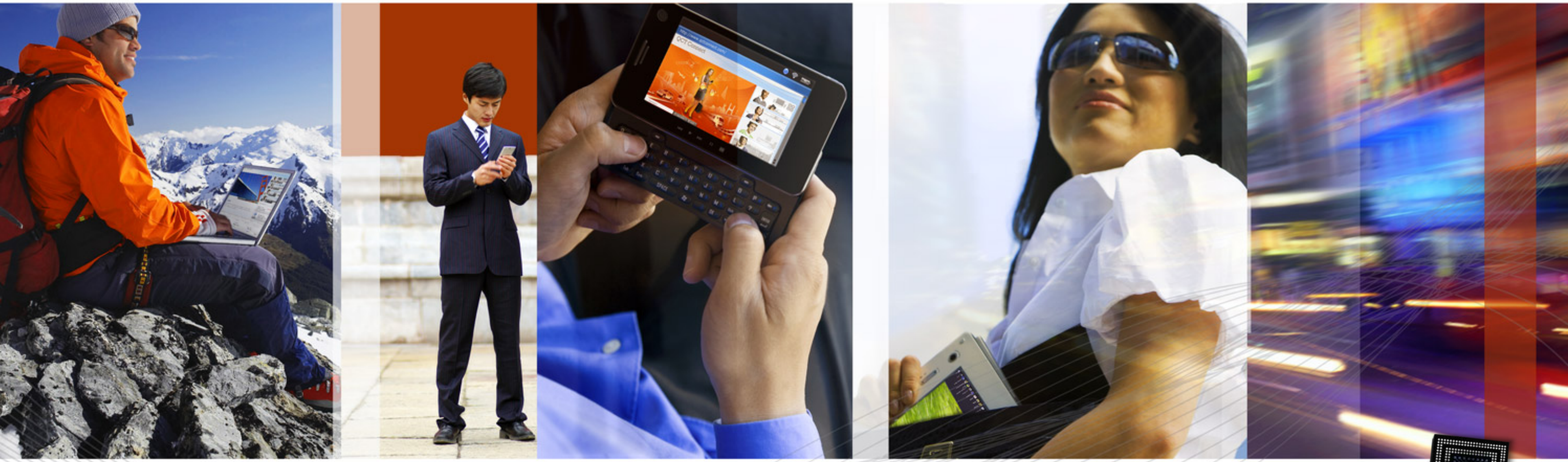

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