

JVET-00429: Non-CE2: alternative solutions for chroma residual scaling factors derivation for dual tree

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Summary of proposal

- Enable chroma residual scaling (CRS) for separate luma/chroma tree
 - for dual tree only (using current VTM5.0 design for single tree)
 - for both dual tree and single tree
- Two options proposed

Luma and pipeline dependency for proposed CRS derivation options

Option	Description	Dependency	
		luma	pipeline
Option 1	signal CRS factor explicitly for each CTU	no	no
Option 2	derive CRS factor implicitly for each VDPU using neighbor VDPU	yes	no

- Fixed bug related to redundant rounding of chroma lambda adjustment in CRS

Summary of results (SDR)

BDRates (including bug fix) relative to VTM 5.0 anchor

	SDR								
	AI			RA			LDB		
	PSNR Y	PSNR U	PSNR V	PSNR Y	PSNR U	PSNR V	PSNR Y	PSNR U	PSNR V
Option 1: explicit signalling									
Dual tree only (single tree as in VTM5.0)	0.05%	-0.17%	-0.31%	0.05%	-0.71%	-0.78%	0.03%	-0.47%	-0.86%
Dual tree and single tree	0.03%	-0.23%	-0.33%	0.01%	-0.53%	-0.54%			
Option 2: implicit derivation									
Dual tree only (single tree as in VTM5.0)	0.03%	-0.37%	-0.49%	0.05%	-1.27%	-1.22%	0.03%	-0.26%	-0.72%
Dual tree and single tree	0.03%	-0.37%	-0.49%	0.08%	-1.24%	-1.22%	0.01%	-0.46%	-0.62%
Encoder Bug Fix only	0.00%	0.00%	0.00%	0.02%	-0.44%	-0.38%	0.02%	0.02%	-0.21%

Measured average EncT and DecT are within 99% to 101%

Summary of results (HDR PQ)

BDRates (including bug fix) relative to VTM 5.0 anchor

over HDR PQ Anchor (LQP1 LMCS0)	HDR PQ					
	AI			RA		
	DE100	L100	wPSNRY	DE100	L100	wPSNRY
VTM with LMCS1 (reference)	8.08%	-2.06%	-1.64%	6.26%	-1.79%	-1.59%
Option 1: explicit signalling						
Dual tree only (single tree as in VTM5.0)	2.22%	-1.71%	-1.26%	2.07%	-1.57%	-1.37%
Dual tree and single tree	2.22%	-1.71%	-1.26%	2.01%	-1.49%	-1.30%
Option 2: implicit derivation						
Dual tree only (single tree as in VTM5.0)	1.94%	-1.66%	-1.23%	2.08%	-1.47%	-1.30%
Dual tree and single tree	1.94%	-1.66%	-1.23%	2.14%	-1.48%	-1.30%

What problem are we trying to solve?

- In VTM5.0, chroma residual scaling (CRS) has pipeline latency
 - need to wait for co-located luma samples to be available before deriving CRS factor
- Current solution:
 - disable CRS in dual tree
- The problem with the current solution:
 - disabling CRS in dual tree causes LMCS chroma loss
- Proposed solution:
 - eliminate need to wait for co-located luma samples → eliminates pipeline latency
 - Option 1 eliminates pipeline latency and luma dependency by explicitly signalling
 - Option 2 eliminates pipeline latency by using neighbor samples instead of co-located samples



Description of Options 1 and 2

Option 1: explicit coding of CRS factor table and index

1. Construction of CRS factor table (CRS_factor[i]):

$$\text{CRS_factor}[i] = 64 * (1 \ll 11) / \text{fwdSlope}[i], \text{ for } i=0 \text{ to } 15$$

fwdSlope[i] is the slope of the i^{th} piece of the forward luma mapping table

2. Derivation of 1 CRS index per NxN CTUs (N=1 or 2)

- Step 1: compute the average value of the original luma samples in the CTU
- Step 2: identify CRS factor index from average luma (& avoid redundant indexes giving same factor)
- Step 3: predict CTU index from indexes of the two neighboring CTUs and derive a delta Index

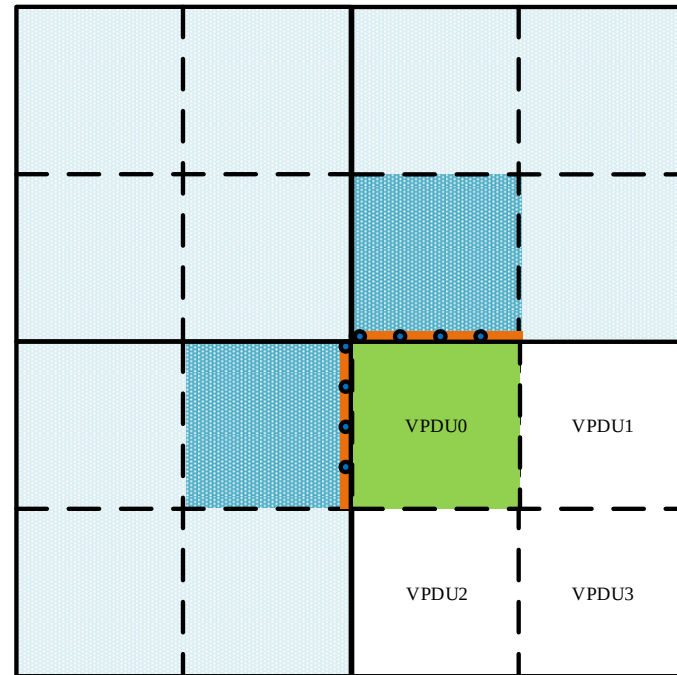
3. Signalling of CRS index

- CRS delta Index: similar to delta coding of QP

Option 2: derive CRS factor implicitly for each VPDU

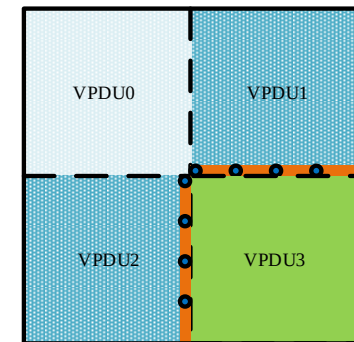
- One chroma scaling factor is derived for each VPDU, used by all chroma TUs inside
- Derivation using luma reconstructed samples in previously coded neighbor VPDU

1. Find available nearest row and column luma reconstructed samples in neighbor VPDU
2. Compute average of these neighboring luma samples
 - use power of 2 samples to replace division by shift
 - subsampling can be used, 4 samples at each direction
3. Compute CRS scale with the luma average



Neighbor VPDU in neighbor CTU

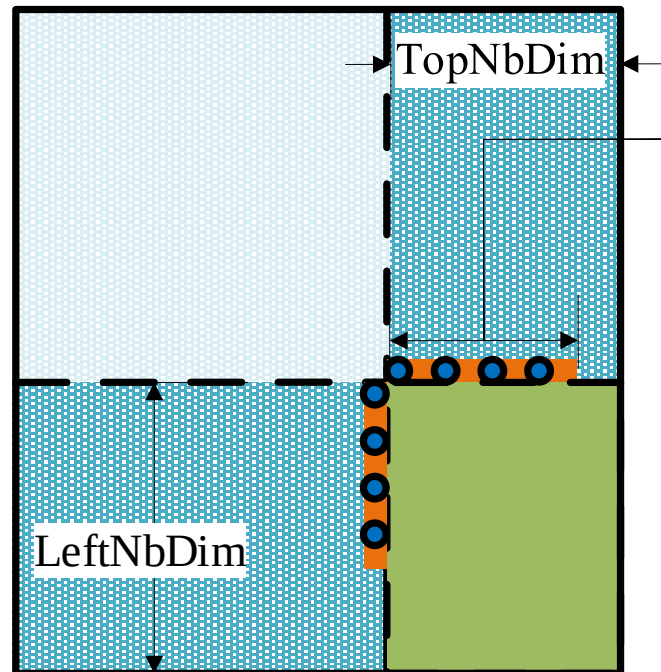
- CTU boundary □ VPDU boundary
- current VPDU ■ neighbor VPDU
- coded VPDU (recon luma available)
- luma samples used for scale derivation
- samples selected when subsampling is enabled



Neighbor VPDU in same CTU

Option 2: Derive CRS factor implicitly for each VPDU

- No division process for average computation: handling of non-square VPDU
 - use only a power-of-two subset of available samples
 - subsampling also within the NbSamplesOneDir samples to guarantee power to 2



number of samples is power of 2:

$$\text{NbSamplesOneDir} = 1 \ll (\text{floorLog2}(\min(\text{TopNbDim}, \text{LeftNbDim})))$$



Results

Experiments

- Two test cases:
 - SDR CTC
 - HDR PQ
 - Anchor: Luma-based QP adaptation on (LPQ=1); LMCS is off (LMCS=0); dual tree CRS off
 - HDR1.a: Luma-based QP adaptation off (LPQ=0); LMCS is on (LMCS=1) ; dual tree CRS off
- Two main configurations:
 - Dual tree CRS only (current VTM5.0 CRS design used in single tree)
 - Option1: SDR1.a, HDR1.b
 - Option2: SDR2.a, HDR2.b
 - Dual tree and single tree
 - Option1: SDR1.b, HDR1.c
 - Option2: SDR2.b, HDR2.c

Option 1 (explicit signalling) results: Dual tree CRS only

Test SDR1.a: CRS index coded in DualTree

	All Intra Main10					Random access Main10					Low delay B Main10				
	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT
Class A1	-0.08%	0.82%	0.61%	98%	99%	0.03%	-0.34%	-0.25%	101%	98%	0.01%	-0.04%	-0.38%	98%	99%
Class A2	-0.10%	1.32%	1.44%	100%	100%	0.02%	0.02%	-0.05%	102%	102%					
Class B	0.03%	0.02%	-0.07%	97%	100%	0.03%	-0.33%	-0.42%	100%	99%					
Class C	0.21%	-1.55%	-1.71%	100%	102%	0.10%	-2.02%	-2.17%	101%	100%					
Class E	0.17%	-1.14%	-1.54%	98%	97%										
Overall	0.05%	-0.17%	-0.31%	99%	99%	0.05%	-0.71%	-0.78%	101%	100%	0.03%	-0.47%	-0.86%	99%	99%
Class D	0.14%	-0.61%	-0.84%	99%	99%	0.04%	-1.06%	-1.26%	98%	101%	0.05%	-1.34%	0.02%	101%	100%
Class F	0.32%	-1.43%	-1.56%	99%	100%	0.23%	-1.79%	-1.77%	101%	99%	0.05%	-0.75%	-0.80%	103%	99%

Option 1 (explicit signalling) results: Dual and single tree CRS

Test SDR1.b: CRS index coded in DualTree and SingleTree

	All Intra Main10					Random access Main10					Low delay B Main10				
	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT
Class A1	-0.13%	0.67%	0.52%	97%	99%	-0.07%	0.24%	0.25%	99%	101%					
Class A2	-0.13%	1.21%	1.35%	102%	102%	-0.01%	0.03%	0.00%	100%	101%					
Class B	0.03%	-0.05%	-0.10%	98%	102%	0.01%	-0.20%	-0.26%	99%	99%					
Class C	0.20%	-1.62%	-1.75%	101%	99%	0.08%	-1.96%	-1.88%	101%	101%	-0.06%	0.64%	0.60%	99%	100%
Class E	0.12%	-1.00%	-1.34%	100%	99%						-0.02%	-1.57%	-0.40%	101%	99%
Overall	0.03%	-0.23%	-0.33%	99%	100%	0.01%	-0.53%	-0.54%	100%	100%					
Class D	0.13%	-0.84%	-1.04%	99%	99%	0.02%	-0.84%	-0.68%	99%	100%	-0.04%	0.50%	1.76%	102%	100%
Class F	0.30%	-1.40%	-1.56%	99%	101%	0.23%	-1.74%	-1.64%	100%	99%	-0.03%	-0.13%	-0.14%	86%	87%

Option 2 (implicit derivation) results: Dual tree CRS only

Test SDR2.a: CRS scale calculated using VPDU neighbor in DualTree

	All Intra Main10					Random access Main10					Low delay B Main10				
	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT
Class A1	-0.20%	1.09%	0.84%	98%	100%	0.09%	-1.04%	-0.34%	101%	101%					
Class A2	-0.21%	1.85%	2.19%	98%	98%	0.01%	-0.11%	-0.15%	100%	97%					
Class B	0.03%	-0.11%	-0.26%	105%	103%	0.02%	-0.72%	-0.92%	99%	99%	0.03%	0.39%	-0.30%	100%	102%
Class C	0.27%	-2.25%	-2.34%	100%	99%	0.10%	-2.99%	-3.05%	99%	101%	0.04%	-0.19%	-0.62%	99%	99%
Class E	0.18%	-1.94%	-2.42%	104%	100%						0.02%	-1.44%	-1.54%	95%	98%
Overall	0.03%	-0.37%	-0.49%	101%	101%	0.05%	-1.27%	-1.22%	100%	100%	0.03%	-0.26%	-0.72%	99%	100%
Class D	0.18%	-1.18%	-1.48%	100%	103%	0.10%	-1.76%	-2.01%	102%	103%	0.06%	-0.23%	0.34%	97%	101%
Class F	0.44%	-2.05%	-2.24%	100%	101%	0.38%	-2.34%	-2.36%	102%	98%	0.14%	-1.15%	-0.86%	95%	99%

Option 2 (implicit derivation) results: Dual and single tree

Test SDR2.b: CRS scale calculated using VPDU neighbor in DualTree and SingleTree

	All Intra Main10					Random access Main10					Low delay B Main10				
	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT
Class A1	-0.20%	1.09%	0.84%	100%	95%	0.10%	-1.04%	-0.51%	106%	99%					
Class A2	-0.21%	1.85%	2.19%	98%	95%	0.02%	-0.02%	-0.09%	103%	92%					
Class B	0.03%	-0.11%	-0.26%	103%	103%	0.03%	-0.76%	-0.86%	97%	99%	0.02%	0.13%	-0.13%	98%	99%
Class C	0.27%	-2.25%	-2.34%	100%	105%	0.17%	-2.93%	-3.06%	100%	107%	0.06%	-0.40%	-0.47%	103%	99%
Class E	0.18%	-1.94%	-2.42%	102%	102%						-0.04%	-1.53%	-1.65%	99%	98%
Overall	0.03%	-0.37%	-0.49%	101%	101%	0.08%	-1.24%	-1.22%	101%	100%	0.01%	-0.46%	-0.62%	100%	99%
Class D	0.18%	-1.18%	-1.48%	99%	108%	0.12%	-1.87%	-1.96%	103%	101%	0.08%	-0.58%	0.34%	102%	94%
Class F	0.44%	-2.05%	-2.24%	102%	107%	0.36%	-2.46%	-2.37%	100%	103%	0.09%	-0.94%	-0.78%	100%	99%

Summary of results

BDRates (including bug fix) relative to VTM 5.0 anchor

	SDR								
	AI			RA			LDB		
	PSNR Y	PSNR U	PSNR V	PSNR Y	PSNR U	PSNR V	PSNR Y	PSNR U	PSNR V
Option 1: explicit signalling									
Dual tree only (single tree as in VTM5.0)	0.05%	-0.17%	-0.31%	0.05%	-0.71%	-0.78%	0.03%	-0.47%	-0.86%
Dual tree and single tree	0.03%	-0.23%	-0.33%	0.01%	-0.53%	-0.54%			
Option 2: implicit derivation									
Dual tree only (single tree as in VTM5.0)	0.03%	-0.37%	-0.49%	0.05%	-1.27%	-1.22%	0.03%	-0.26%	-0.72%
Dual tree and single tree	0.03%	-0.37%	-0.49%	0.08%	-1.24%	-1.22%	0.01%	-0.46%	-0.62%
Encoder Bug Fix only	0.00%	0.00%	0.00%	0.02%	-0.44%	-0.38%	0.02%	0.02%	-0.21%

Measured average EncT and DecT are within 98% to 102%

Additional Results: HDR PQ

Summary of additional HDR PQ testing results

over HDR PQ Anchor (LQP1 LMCS0)	HDR PQ					
	AI			RA		
	DE100	L100	wPSNRY	DE100	L100	wPSNRY
VTM with LMCS1 (reference)	8.08%	-2.06%	-1.64%	6.26%	-1.79%	-1.59%
Option 1: explicit signalling						
Dual tree only (single tree as in VTM5.0)	2.22%	-1.71%	-1.26%	2.07%	-1.57%	-1.37%
Dual tree and single tree	2.22%	-1.71%	-1.26%	2.01%	-1.49%	-1.30%
Option 2: implicit derivation						
Dual tree only (single tree as in VTM5.0)	1.94%	-1.66%	-1.23%	2.08%	-1.47%	-1.30%
Dual tree and single tree	1.94%	-1.66%	-1.23%	2.14%	-1.48%	-1.30%

Both options significantly improve the chroma performance (in DE)
compared to current VTM CRS design
while keeping good luma gain (in L100/wPSNR) over the HDR Anchors (LQP1)

Conclusion

- Option 1 eliminates both pipeline latency and luma-chroma dependence by explicitly signalling CRS index values
- Option 2 eliminates pipeline latency by using reconstructed luma values from neighboring VPDUs to derive the chroma scaling factor value
- Each option can be applied to both single and dual tree CRS
- Recommend to adopt either option

Acknowledgement

- We would like to thank ByteDance (JVET-00744) and Qualcomm for crosschecking the test results.

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Bug fix in VTM5.0 encoder

Encoder CRS lambda bugfix

- An encoder bug related to CRS was found in VTM encoder implementation
 - A redundant rounding process was applied for chroma lambda adjustment in CRS
 - The errant rounding operation results in a loss of precision for floating point lambda values
- Bug fix slightly improves chroma coding performance for RA and LDB
 - CRS is disabled in AI so bugfix has no impact

	All Intra Main10					Random access Main10					Low delay B Main10				
	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT
Class A1	0.00%	0.00%	0.00%	100%	100%	0.09%	-1.04%	-0.34%	100%	100%					
Class A2	0.00%	0.00%	0.00%	100%	100%	0.01%	-0.11%	-0.15%	100%	100%					
Class B	0.00%	0.00%	0.00%	100%	100%	0.01%	-0.31%	-0.34%	100%	100%					
Class C	0.00%	0.00%	0.00%	100%	100%	0.00%	-0.38%	-0.63%	100%	100%	0.01%	0.13%	-0.15%	100%	100%
Class E	0.00%	0.00%	0.00%	100%	100%						0.04%	-0.28%	-0.16%	100%	100%
Overall	0.00%	0.00%	0.00%	100%	100%						-0.01%	0.22%	-0.37%	100%	100%
Class D	0.00%	0.00%	0.00%	100%	100%						0.02%	0.02%	-0.21%	100%	100%
Class F	0.00%	0.00%	0.00%	100%	100%	0.01%	-0.27%	-0.28%	100%	100%	0.04%	-0.04%	-0.08%	100%	100%

Encoder CRS lambda bugfix (HDR PQ)

Remove round fix Over vtm5 HDR reshape0 lqp1										
All Intra: BD-rate						Random Access: BD-rate				
	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV
Average HDR-B	8.08%	-2.06%	-1.63%	14.15%	8.35%	6.64%	-1.79%	-1.61%	15.03%	8.44%

Remove round fix Over vtm5 HDR reshaper1 lqp0										
All Intra: BD-rate						Random Access: BD-rate				
	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV
Average HDR-B	0.00%	0.00%	0.00%	0.00%	0.00%	0.38%	-0.01%	-0.02%	0.87%	1.71%