SCCE3: Summary report of CE on palette mode

Presenter: Yu-Wen Huang

Rough Idea of Overall Coding Gain

- SCCE3 achieved good tradeoff between gain and complexity.
- A Test C palette versus palette-off

	FF-IBC Condition			2CTU-IBC Condition		
	All Intra			All Intra		
	G/Y	B/U	R/V	G/Y	B/U	R/V
RGB, text & graphics with motion, 1080p	-20.5%	-20.2%	-19.9%	-26.7%	-26.5%	-26.3%
RGB, text & graphics with motion, 720p	-13.4%	-11.9%	-12.2%	-18.1%	-16.6%	-16.8%
RGB, mixed content, 1440p	-4.5%	-3.8%	-3.9%	-6.1%	-5.1%	-5.1%
RGB, mixed content, 1080p	-5.8%	-5.8%	-5.6%	-8.5%	-8.6%	-8.3%
RGB, Animation, 720p	0.3%	-0.1%	-0.3%	0.3%	-0.1%	-0.3%
RGB, camera captured, 1080p	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
YUV, text & graphics with motion, 1080p	-21.3%	-24.3%	-22.8%	-27.1%	-30.5%	-29.3%
YUV, text & graphics with motion, 720p	-10.2%	-15.0%	-17.8%	-13.3%	-18.5%	-21.3%
YUV, mixed content, 1440p	-3.8%	-8.8%	-8.7%	-5.3%	-11.8%	-11.6%
YUV, mixed content, 1080p	-6.2%	-11.2%	-11.2%	-8.8%	-15.5%	-15.4%
YUV, Animation, 720p	0.2%	-0.9%	-0.9%	0.1%	-0.9%	-0.9%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	109%			114%		
Dec Time[%]	96%			96%		

Overview of SCCE3 Tests

- Category A – Palette table coding
  - 9 tests
- Category B – Color index coding
  - 15 tests
- Category C – Combinations of above tests
  - 4 tests
- Category D – Single color modes
  - 2 tests

List of SCCE3 Proposal Documents

Test	Document
A.1	Withdrawn
A.2	JCTVC-R0119
A.3	JCTVC-R0082
A.4	JCTVC-R0142
A.5	JCTVC-R0166
A.6	JCTVC-R0167
A.7	JCTVC-R0064
A.8	JCTVC-R0063
A.9	JCTVC-R0047
B.1	JCTVC-R0121
B.2	JCTVC-R0120
B.3	Withdrawn
B.4	JCTVC-R0057
B.5	JCTVC-R0083
B.6	JCTVC-R0084

Test	Document
B.7	JCTVC-R0085
B.8	JCTVC-R0143
B.9	JCTVC-R0168
B.10	JCTVC-R0169
B.11	JCTVC-R0170
B.12	JCTVC-R0065
B.13	JCTVC-R0066
B.14	JCTVC-R0045
B.15	JCTVC-R0048
C.1	JCTVC-R0122
C.2	JCTVC-R0086
C.3	JCTVC-R0144
C.4	JCTVC-R0067
D.1	JCTVC-R0058
D.2	JCTVC-R0200

JCTVC-Q0094 Palette

- Most SCCE3 tests are built on top of a bug-fixed palette from JCTVC-Q0094, so the Q0094BF palette is used as an anchor.
- Q0094BF palette versus palette-off as follows

	FF-IBC Condition All Intra			**2CTU-IBC Condition** All Intra		
	G/Y	B/U	R/V	G/Y	B/U	R/V
RGB, text & graphics with motion, 1080p	-10.4%	-10.4%	-10.3%	-13.2%	-13.3%	-13.3%
RGB, text & graphics with motion,720p	-5.6%	-5.0%	-5.3%	-7.0%	-6.4%	-6.7%
RGB, mixed content, 1440p	-1.2%	-1.1%	-1.0%	-1.4%	-1.2%	-1.2%
RGB, mixed content, 1080p	-2.2%	-2.3%	-2.1%	-2.9%	-3.2%	-2.7%
RGB, Animation, 720p	0.0%	-0.1%	0.0%	0.1%	-0.1%	-0.1%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-10.6%	-12.1%	-11.2%	-12.5%	-14.6%	-13.8%
YUV, text & graphics with motion,720p	-4.7%	-6.8%	-8.8%	-4.9%	-7.4%	-9.4%
YUV, mixed content, 1440p	-0.9%	-2.4%	-2.3%	-0.9%	-3.0%	-2.8%
YUV, mixed content, 1080p	-2.3%	-3.4%	-3.2%	-2.5%	-4.8%	-4.6%
YUV, Animation, 720p	0.1%	-0.1%	0.0%	0.1%	-0.1%	0.0%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	102%			107%		
Dec Time[%]	99%			101%		

Techniques in Category A Tests

- Palette table signaling
  - Palette sharing
  - Prediction flag versus reuse flag
- Palette propagation across CUs
  - Full palette propagation versus palette stuffing
- Palette generation, encoder-only
- Long-term palette prediction

Palette Sharing

- Tests A.2 (MediaTek), A.4 (Huawei), A.5 (InterDigital)

- Add a CU-level flag

- To indicate whether to fully use the previous CU's palette as the current CU's palette

Prediction Flag versus Reuse Flag

- Prediction flag, Test A.2 (MediaTek)
  - Scan the current palette entry by entry and signal if this color is predicted
- Reuse flag, Tests A.3 (Canon), A.5 (InterDigital), A.8 (Qualcomm)
  - Scan the reference palette entry by entry and signal if this color is reused

Reuse Flag
1
0
1
1
...
0

New Color
$Color_x$

Reference Palette	
0	$Color_0$
1	$Color_1$
2	$Color_2$
3	$Color_3$
...	...
63	$Color_{63}$

Current Palette	
0	$Color_0$
1	$Color_3$
2	$Color_2$
3	$Color_x$

Prediction Flag
1
0
1
0

New Color
$Color_3$
$Color_x$

Full Palette Propagation (FPP) versus Palette Stuffing (PS)

- To propagate colors that are unused for prediction across CUs
- Full palette propagation, Test A.2 (MediaTek)
  - Copy colors of larger indices, no redundancy check, less coding efficiency
- Palette stuffing, Tests A.3 (Canon), A.5 (InterDigital), A.8 (Qualcomm)
  - Copy unused colors, need redundancy check, better coding efficiency

Ref. Palette		Current Palette		Ref. Palette for Next Palette CU (FPP)		Ref. Palette for Next Palette CU (PS)	
0	$Color_0$	0	$Color_0$	0	$Color_0$	0	$Color_0$
1	$Color_1$	1	$Color_3$	1	$Color_3$	1	$Color_3$
2	$Color_2$	2	$Color_2$	2	$Color_2$	2	$Color_2$
3	$Color_3$			3	$Color_3$	3	$Color_1$
…	…			…	…	…	…
63	$Color_{63}$			63	$Color_{63}$	63	$Color_{63}$

Signaling Reuse Flags

- To reduce the number of reuse flags
- Tests A.3 (Canon) and A.5 (InterDigital) proposed to send stop bits.
  - Test A.3: positions 4, 8, 16, 24, 32, 40, 48, 56, 64
  - Test A.5: when a reuse flag == 1
- Test A.8 (Qualcomm) proposed group coding.
  - Four reuse flags as a group
  - Signal if this group is all zero.
  - If nonzero, signal if this group is the last group.

Long-Term Palette Prediction

- Signal a long-term palette at slice header, Test A.9 (Nokia)

- At CU level, for each palette entry that is not predicted from a previous palette, one bit is signaled to indicate whether this entry is copied from the long term palette. If yes, then the index of the entry within the long term palette is signaled.

Summary of Category A Techniques

Test	Palette Propagation	Prediction Flag or Reuse Flag	Palette Share
A.2 (MediaTek)	Full	Prediction flags	Yes
A.3 (Canon)	Stuffing	Reuse flags, stop bits sent at fixed positions	No
A.4 (Huawei)	Last coded with maximum CU size, stuffing	Inter & intra palette prediction	Yes
A.5 (InterDigital)	Stuffing	Reuse flags, stop bits sent when reuse flag==1	Yes
A.6 (InterDigital), encoder-only	N/A	N/A	N/A
A.7 (Qualcomm), encoder-only	N/A	N/A	N/A
A.8 (Qualcomm)	Stuffing	Reuse flags, group coding	No
A.9 (Nokia)	Long-term	Reuse flags	No

Results of Category A Tests

- Anchor: Q0094BF palette
- B/U and R/V are averaged.

2CTU-IBC Condition

	A.2		A.2 share only		A.3		A.4		A.5		A.5 no share		A.6		A.7		A.8		A.9	
	All Intra		All Intra		All Intra		All Intra		All Intra		All Intra		All Intra		All Intra		All Intra		All Intra	
	G/Y	BR/UV	G/Y	BR/UV	G/Y	BR/UV	G/Y	BR/UV	G/Y	BR/UV	G/Y	BR/UV	G/Y	BR/UV	G/Y	BR/UV	G/Y	BR/UV	G/Y	BR/UV
RGB, text & graphics with motion, 1080p	-4.5%	-4.4%	-3.9%	-2.8%	-3.1%	-3.0%	0.5%	0.4%	-5.6%	-5.4%	-3.2%	-3.2%	-3.0%	-2.8%	-2.5%	-2.3%	-4.0%	-3.9%	-1.6%	-1.6%
RGB, text & graphics with motion,720p	-3.9%	-3.6%	-3.0%	-2.4%	-3.0%	-2.8%	0.7%	0.2%	-4.7%	-4.3%	-2.7%	-2.6%	-2.8%	-2.4%	-1.8%	-1.4%	-3.9%	-3.8%	-1.4%	-1.4%
RGB, mixed content, 1440p	-1.2%	-1.0%	-1.2%	-0.6%	-0.2%	-0.1%	1.0%	0.8%	-1.5%	-1.3%	-0.1%	-0.1%	-2.0%	-1.6%	-1.6%	-1.3%	-0.3%	-0.3%	-0.2%	-0.2%
RGB, mixed content, 1080p	-1.4%	-1.4%	-1.2%	-0.7%	-0.3%	-0.3%	1.5%	1.7%	-1.6%	-1.6%	-0.2%	-0.2%	-2.3%	-2.4%	-1.4%	-1.4%	-0.5%	-0.5%	-0.1%	-0.1%
RGB, Animation, 720p	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	-0.1%	0.0%	0.0%	-0.1%	-0.2%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-4.9%	-5.3%	-4.3%	-3.0%	-2.8%	-3.1%	0.0%	1.3%	-5.6%	-6.0%	-2.9%	-3.0%	-3.0%	-4.2%	-2.5%	-3.5%	-3.9%	-4.1%	-0.7%	-0.7%
YUV, text & graphics with motion,720p	-2.9%	-3.4%	-2.1%	-1.8%	-2.1%	-2.5%	1.8%	4.0%	-3.2%	-3.6%	-1.9%	-1.9%	-1.9%	-3.7%	-1.1%	-2.5%	-3.1%	-3.6%	-0.7%	-1.0%
YUV, mixed content, 1440p	-1.3%	-2.2%	-1.2%	-0.9%	0.0%	-0.4%	0.4%	2.6%	-1.6%	-2.5%	-0.1%	-0.2%	-1.4%	-4.0%	-1.1%	-2.8%	-0.3%	-0.5%	-0.1%	-0.2%
YUV, mixed content, 1080p	-1.5%	-2.8%	-1.4%	-1.1%	-0.3%	-0.7%	1.2%	4.0%	-1.8%	-3.0%	-0.3%	-0.3%	-2.4%	-5.3%	-1.4%	-2.8%	-0.6%	-0.8%	-0.2%	-0.2%
YUV, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	-0.1%	0.0%	0.0%	0.0%	-0.3%	0.1%	-0.3%	0.0%	0.0%	0.0%	0.0%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	98%		98%		98%		108%		95%		103%		101%		95%		104%		100%	
Dec Time[%]	96%		100%		85%		101%		93%		101%		97%		90%		105%		100%	

Comparison of Category A Tests

- BD-rate savings of the first four classes are averaged.

2CTU-IBC Condition
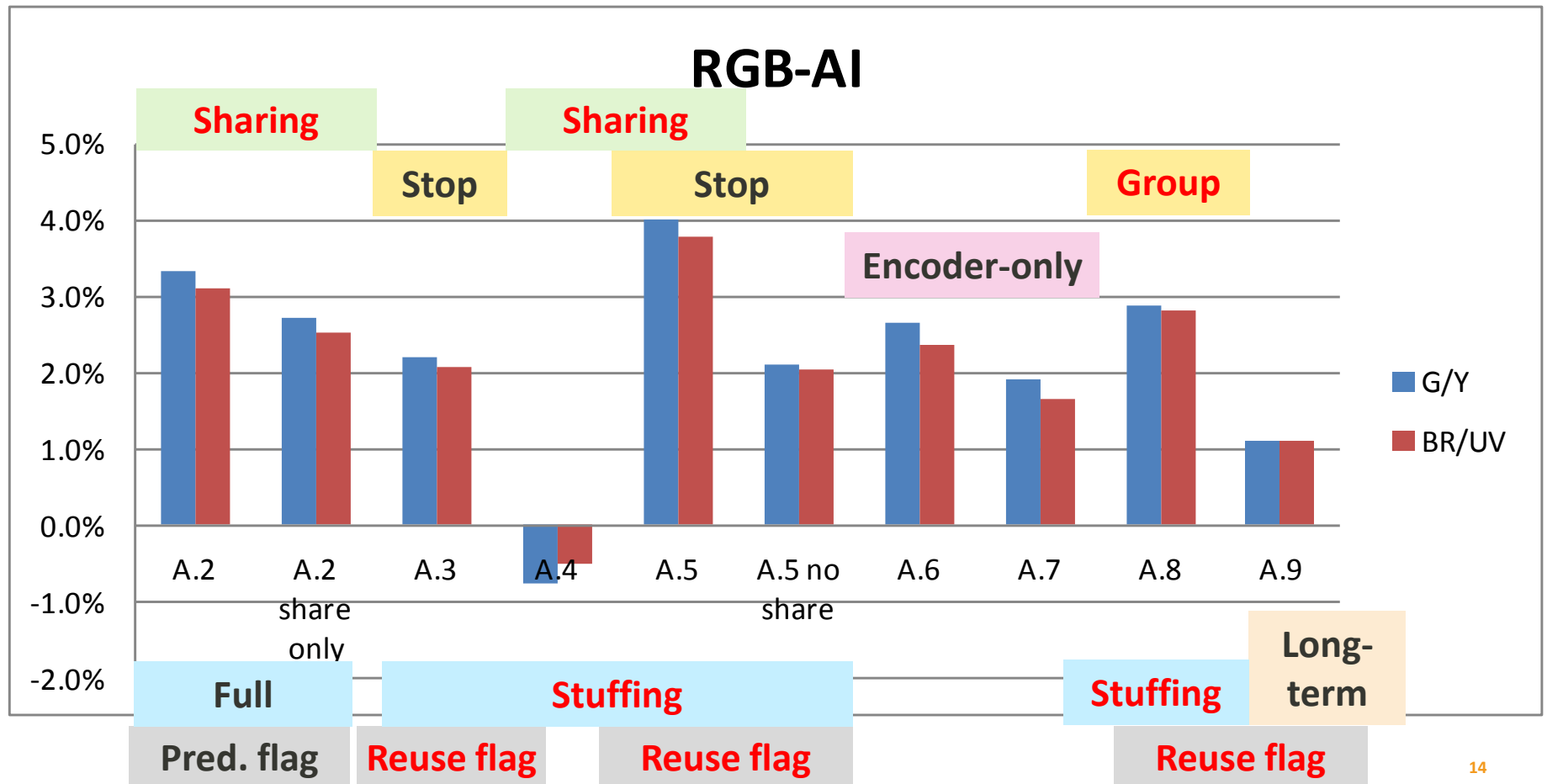
Category A Remarks

- Palette sharing is simple and effective (A.2, A.4, A.5).

- Palette stuffing with reuse flags (A.3, A.5, A.8) is beneficial and has higher coding gain than full palette propagation with prediction flags (A.2), where grouping reuse flags (A.8) has higher coding gain than sending stop bits (A.3, A.5).

- Encoder optimization improvements (A.6, A.7) are helpful; Test A.6 has higher coding gain than Test A.7.

- Long-term palette (A.9) is useful.

Techniques in Category B Tests

- All are built on top of the run-based color index map coding of Q0094BF palette mode, except Test B.1 and Test B.8.

- Color index map coding order
  - Adaptive scan, Burrows–Wheeler transform

- Color index prediction mode
  - Transition copy, restricted run signaling

- Color index value coding
  - Redundant index removal, truncated binary codes, truncated unary codes

- Escape color coding
  - Escape color representation, escape color flag, escape color prediction

Adaptive Scan

- Tests B.4 (MediaTek), B.8 (Huawei), B.9 (InterDigital), and B.15 (Nokia) proposed adaptive scan of color indices of samples.

- When horizontal or vertical scan is applied, 0.1-0.4% BD-rate savings are observed.

- Test B.4 supplemental shows the BD-rate savings of rotating the test sequences by 90 degrees.

  - To deal with automatic screen content rotation on phones or tablets
  - Characters may be column-wise written (Chinese, Japanese, …)

2CTU-IBC Condition

|	All Intra		
	Y	U	V
RGB, text & graphics with motion, 1080p	-3.4%	-3.4%	-3.4%
RGB, text & graphics with motion,720p	-3.0%	-2.8%	-2.9%
RGB, mixed content, 1440p	-0.7%	-0.6%	-0.6%
RGB, mixed content, 1080p	-0.8%	-0.8%	-0.8%
RGB, Animation, 720p	0.0%	0.0%	0.0%
RGB, camera captured, 1080p			
YUV, text & graphics with motion, 1080p	-3.5%	-4.0%	-3.9%
YUV, text & graphics with motion,720p	-2.5%	-3.1%	-3.4%
YUV, mixed content, 1440p	-0.6%	-1.6%	-1.6%
YUV, mixed content, 1080p	-0.7%	-1.5%	-1.8%
YUV, Animation, 720p	0.0%	0.0%	0.0%
YUV, camera captured, 1080p			

Burrows–Wheeler Transform (BWT)

- BWT can convert a 1-D string into another 1-D string that increases the correlation between neighbors
  - To favor run-based coding; needs sorting operations
- Test B.9 (InterDigital) proposed BWT with CU-level on/off and combined horizontal, vertical, and traverse scans in the software.

2CTU-IBC Condition

	All Intra		
	G/Y	B/U	R/V
RGB, text & graphics with motion, 1080p	-1.4%	-1.5%	-1.4%
RGB, text & graphics with motion,720p	-1.0%	-1.0%	-1.0%
RGB, mixed content, 1440p	-0.3%	-0.2%	-0.2%
RGB, mixed content, 1080p	-0.6%	-0.7%	-0.6%
RGB, Animation, 720p	0.0%	-0.1%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-1.2%	-1.4%	-1.3%
YUV, text & graphics with motion,720p	-0.6%	-1.0%	-1.1%
YUV, mixed content, 1440p	-0.2%	-0.5%	-0.5%
YUV, mixed content, 1080p	-0.4%	-1.4%	-1.2%
YUV, Animation, 720p	0.0%	-0.1%	-0.1%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%
Enc Time[%]	108%		
Dec Time[%]	101%		

Transition Copy (TC) Mode

- Store the "last transition sample value(s)" of each pilot sample (i.e., left sample of current sample)

  - Memory: 32*5bits = 20bytes

- Transition + run: repeat the stored samples for N times
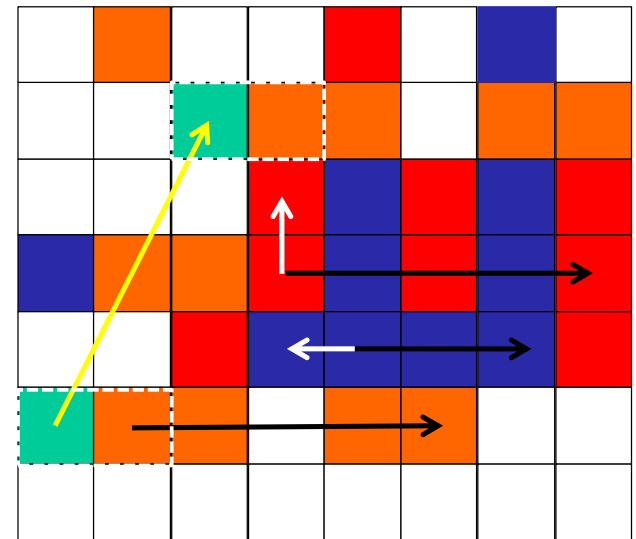
Comparison of Different TC Modes

- Test B.2 (MediaTek) codewords are copy above: 1, TC: 01, normal: 00, while Test B.6 (Canon) codewords are copy above: 10, TC: 11, normal: 0

- Test B.2 uses 2 TC candidates, while Test B.6 uses 1.

- Test B.2 has TC table propagation across CUs.

- Small differences in updating TC table

2CTU-IBC Condition	Test B.2			Test B.6		
	All Intra			All Intra		
	G/Y	B/U	R/V	G/Y	B/U	R/V
RGB, text & graphics with motion, 1080p	-3.2%	-3.3%	-3.3%	-2.8%	-2.9%	-2.8%
RGB, text & graphics with motion,720p	-2.5%	-2.5%	-2.5%	-1.7%	-1.7%	-1.6%
RGB, mixed content, 1440p	-0.2%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
RGB, mixed content, 1080p	-0.3%	-0.4%	-0.3%	-0.4%	-0.4%	-0.3%
RGB, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-3.1%	-3.5%	-3.5%	-2.8%	-3.0%	-2.9%
YUV, text & graphics with motion,720p	-2.0%	-2.5%	-2.6%	-1.3%	-1.6%	-1.7%
YUV, mixed content, 1440p	-0.2%	-0.7%	-0.6%	-0.1%	-0.4%	-0.4%
YUV, mixed content, 1080p	-0.4%	-1.1%	-1.0%	-0.4%	-0.9%	-0.9%
YUV, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	99%			97%		
Dec Time[%]	100%			96%		

Restricted Run Signaling

▪ Test B.7 (Canon) and Test B.14 (Nokia) proposed to save run signaling and set the run to 0 when the color index is larger than a CU-level explicit threshold.
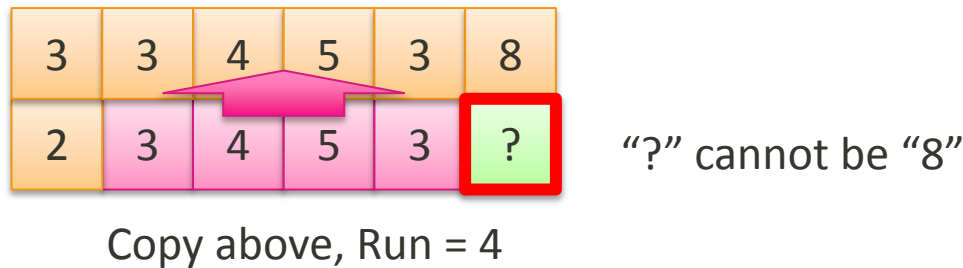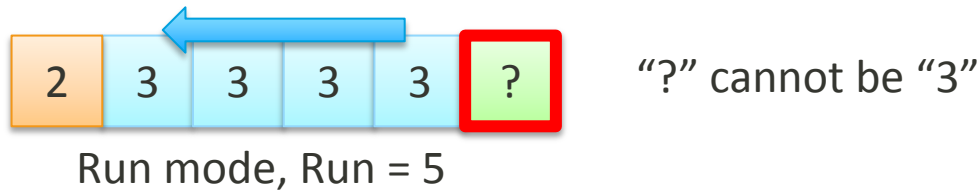
2CTU-IBC Condition	Test B.7			Test B.14		
	All Intra			**All Intra**		
	G/Y	B/U	R/V	G/Y	B/U	R/V
RGB, text & graphics with motion, 1080p	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%
RGB, text & graphics with motion,720p	-0.5%	-0.4%	-0.4%	-0.2%	-0.2%	-0.2%
RGB, mixed content, 1440p	-0.1%	-0.1%	-0.1%	0.0%	0.0%	0.0%
RGB, mixed content, 1080p	-0.2%	-0.2%	-0.2%	0.0%	0.0%	0.0%
RGB, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-0.2%	-0.5%	-0.5%	-0.2%	-0.3%	-0.3%
YUV, text & graphics with motion,720p	-0.3%	-0.4%	-0.5%	-0.2%	-0.2%	-0.2%
YUV, mixed content, 1440p	-0.1%	-0.2%	-0.2%	0.0%	0.0%	0.0%
YUV, mixed content, 1080p	-0.2%	-0.4%	-0.4%	0.0%	0.0%	0.0%
YUV, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	95%			100%		
Dec Time[%]	96%			100%		

Redundant Index Removal

- The signaled index cannot be the index of the left/above sample after a copy-left/copy-above mode

| 2 | 3 | 3 | 3 | 3 | ? |

Run mode, Run = 5

"?" cannot be "3"

| 3 | 3 | 4 | 5 | 3 | 8 |
| 2 | 3 | 4 | 5 | 3 | ? |

Copy above, Run = 4

"?" cannot be "8"

- Map current index Idx' = Idx − 1, if Idx > $Idx_{left/above}$

Truncated Binary Codes

- Fixed length codes (FLC) were used for color index values.

- Truncated binary codes (TBC) can remove unused index bins
  - Let N=$\lceil \log_2(P) \rceil$ be the FLC length, so that $P = 2^N - R$
  - If idx<R, use N-1 bits
  - Otherwise, use N bits

Size	5	6	7	8
0 (000)	00	00	00	000
1 (001)	01	01	010	001
2 (010)	10	100	011	010
3 (011)	110	101	100	011
4 (100)	111	110	101	100
5 (101)		111	110	101
6 (110)			111	110
7 (111)				111

Escape Color Representation

- 3 methods to indicate an escape color
  - Color index == palette size
  - Color index == 1
  - Signal an escape color flag
- Escape color constraint
  - No escape color if palette size is not full (i.e., <32)

Comparison of Test B.5, Test B.10 , and Test B.12

- Common parts:
  - Redundant index removal
- Test B.5 (Canon)
  - Truncated binary codes (TBC) for color indices
  - No escape color if palette size is not full
- Test B.10 (InterDigital)
  - Adaptive truncated Rice codes (TRC) for color indices
  - A CU-level explicit flag to switch between two escape color indication methods (index==palette size or index==1)
- Test B.12 (Qualcomm)
  - TBC for color indices and escape color values
  - No copy-above if above is escape
  - Save run mode signaling if the above sample is escape or left and above indices are equal
  - Only bypass bins are used.

Results of Test B.5, Test B.10, and Test B.12

- Test B.12 gain > Test B.10 gain = Test B.5 gain

2CTU-IBC Condition	Test B.5			Test B.10			Test B.12		
	All Intra			All Intra			All Intra		
	G/Y	B/U	R/V	G/Y	B/U	R/V	G/Y	B/U	R/V
RGB, text & graphics with motion, 1080p	-2.2%	-2.2%	-2.2%	-2.5%	-2.5%	-2.5%	-2.8%	-2.8%	-2.7%
RGB, text & graphics with motion, 720p	-1.5%	-1.4%	-1.4%	-1.2%	-1.2%	-1.1%	-1.6%	-1.5%	-1.5%
RGB, mixed content, 1440p	-0.2%	-0.1%	-0.2%	-0.2%	-0.1%	-0.2%	-0.2%	-0.2%	-0.2%
RGB, mixed content, 1080p	-0.4%	-0.4%	-0.4%	-0.4%	-0.3%	-0.3%	-0.5%	-0.5%	-0.4%
RGB, Animation, 720p	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-2.7%	-2.6%	-2.5%	-2.6%	-2.6%	-2.5%	-3.3%	-3.1%	-3.1%
YUV, text & graphics with motion, 720p	-1.2%	-1.6%	-2.0%	-0.9%	-1.3%	-1.5%	-1.3%	-1.8%	-2.1%
YUV, mixed content, 1440p	-0.2%	-0.5%	-0.5%	-0.2%	-0.3%	-0.4%	-0.2%	-0.5%	-0.6%
YUV, mixed content, 1080p	-0.6%	-0.9%	-0.9%	-0.4%	-0.6%	-0.7%	-0.7%	-1.0%	-1.0%
YUV, Animation, 720p	0.0%	-0.1%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	97%			99%			103%		
Dec Time[%]	97%			100%			105%		

Escape Color Flag

- CU-level explicit escape color flag
- Sample-level explicit escape color flag
- Test B.13 (Qualcomm) default setting: apply CU-level flag
- Test B.13 alternative setting: apply sample-level flag

2CTU-IBC Condition	Default			Alternative		
	All Intra			**All Intra**		
	G/Y	B/U	R/V	G/Y	B/U	R/V
RGB, text & graphics with motion, 1080p	-0.6%	-0.6%	-0.6%	-0.8%	-0.8%	-0.7%
RGB, text & graphics with motion,720p	-0.2%	-0.2%	-0.2%	-0.1%	-0.1%	-0.1%
RGB, mixed content, 1440p	0.0%	0.0%	0.0%	-0.2%	-0.1%	-0.1%
RGB, mixed content, 1080p	-0.1%	-0.1%	-0.1%	-0.1%	-0.2%	-0.1%
RGB, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-0.8%	-0.6%	-0.6%	-0.8%	-0.6%	-0.6%
YUV, text & graphics with motion,720p	-0.2%	-0.2%	-0.2%	-0.1%	-0.1%	-0.2%
YUV, mixed content, 1440p	0.0%	-0.1%	0.0%	0.0%	-0.1%	0.0%
YUV, mixed content, 1080p	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
YUV, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	98%			97%		
Dec Time[%]	98%			103%		

Escape Color Prediction

- Test B.11 (InterDigital) proposed predictive coding of escape color values

  - One flag to indicate if the current escape color is equal to the last escape color.

  - If not, signal a color index of and prediction error

- Only for lossless coding

2CTU-IBC Condition

	All Intra	Random Access	Low Delay B
	Bit-rate saving (Total)	Bit-rate saving (Total)	Bit-rate saving (Total)
RGB, text & graphics with motion, 1080p	0.9%	0.9%	0.8%
RGB, text & graphics with motion,720p	0.7%	0.1%	0.1%
RGB, mixed content, 1440p	0.8%	0.1%	0.0%
RGB, mixed content, 1080p	0.3%	0.0%	0.0%
RGB, Animation, 720p	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	2.4%	1.5%	1.2%
YUV, text & graphics with motion,720p	1.4%	0.2%	0.1%
YUV, mixed content, 1440p	0.5%	0.1%	0.0%
YUV, mixed content, 1080p	0.4%	0.1%	0.0%
YUV, Animation, 720p	0.0%	0.0%	0.0%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%

Other Color Index Map Coding Methods

- Test B.1 (MediaTek) proposed a line-based method.

  - Horizontal or vertical scan

  - Line mode #1: copy previous line

  - Line mode #2: send first sample, reuse it for the entire line

  - Line mode #3: normal line, sample by sample coding
    - Including transition copy, candidate-based color index coding

- Test B.8 (Huawei) proposed a string-based method.

  - Horizontal or vertical scan

  - Search 1-D string match, signal match distance and length

Summary of Category B Techniques

	Run/Line-based	Scan	Color index predictor	Restricted run signaling	Redund. index removal	Color index value	Escape color	Escape quant.
MediaTek	Line Test B.1	H & V Test B.1 Test B.4	Spatial Test B.1 TC Test B.1 Test B.2		Remove 1 idx Test B.1	Skip infer Test B.1	Idx==max	Simple shift
Qualcomm	Run				Remove 1 index Test B.12	TBC Test B.12	Explicit flag Test B.13	HEVC Q
Canon	Run		TC Test B.2	Yes Test B.7	Remove 1 index Test B.5	TBC Test B.5	Idx==max	HEVC Q
InterDigital	Run	BWT, H, V, snake Test B.9			Remove 1 index Test B.10	TRC Test B.10	Idx==1 Test B.10	HEVC Q Pred. Test B.10
Nokia	Run	H, V Test B.15		Yes Test B.14			Idx==max	HEVC Q
Huawei	Run	H, V Test B.8	String matching Test B.8					

Results of Category B Tests

- Anchor: Q0094BF palette

2CTU-IBC Condition

	B.1	B.4	B.15	B.9	B.2	B.6	B.7	B.14	B.5	B.10	B.12	B.13	B.8
	AI	**AI**	**AI**	**AI**	**AI**	**AI**	**AI**	**AI**	**AI**	**AI**	**AI**	**AI**	**AI**
	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y
RGB, text & graphics with motion, 1080p	-6.7%	-0.4%	-0.4%	-1.4%	-3.2%	-2.8%	-0.3%	-0.3%	-2.2%	-2.5%	-2.8%	-0.6%	-2.4%
RGB, text & graphics with motion,720p	-3.6%	-0.2%	-0.2%	-1.0%	-2.5%	-1.7%	-0.5%	-0.2%	-1.5%	-1.2%	-1.6%	-0.2%	-1.9%
RGB, mixed content, 1440p	-0.6%	-0.1%	-0.1%	-0.3%	-0.2%	-0.1%	-0.1%	0.0%	-0.2%	-0.2%	-0.2%	0.0%	0.2%
RGB, mixed content, 1080p	-1.1%	-0.2%	-0.2%	-0.6%	-0.3%	-0.4%	-0.2%	0.0%	-0.4%	-0.4%	-0.5%	-0.1%	-0.1%
RGB, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-7.0%	-0.4%	-0.4%	-1.2%	-3.1%	-2.8%	-0.2%	-0.2%	-2.7%	-2.6%	-3.3%	-0.8%	-3.1%
YUV, text & graphics with motion,720p	-2.9%	0.0%	-0.1%	-0.6%	-2.0%	-1.3%	-0.3%	-0.2%	-1.2%	-0.9%	-1.3%	-0.2%	-2.0%
YUV, mixed content, 1440p	-0.5%	-0.1%	-0.1%	-0.2%	-0.2%	-0.1%	-0.1%	0.0%	-0.2%	-0.2%	-0.2%	0.0%	-0.1%
YUV, mixed content, 1080p	-1.4%	-0.2%	-0.2%	-0.4%	-0.4%	-0.4%	-0.2%	0.0%	-0.6%	-0.4%	-0.7%	-0.1%	0.0%
YUV, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	100%	99%	103%	108%	99%	97%	95%	103%	97%	99%	103%	98%	113%
Dec Time[%]	96%	105%	101%	101%	100%	96%	96%	101%	97%	100%	105%	98%	102%

Comparison of Category B Tests

- BD-rate savings of the first four classes are averaged.

2CTU-IBC Condition
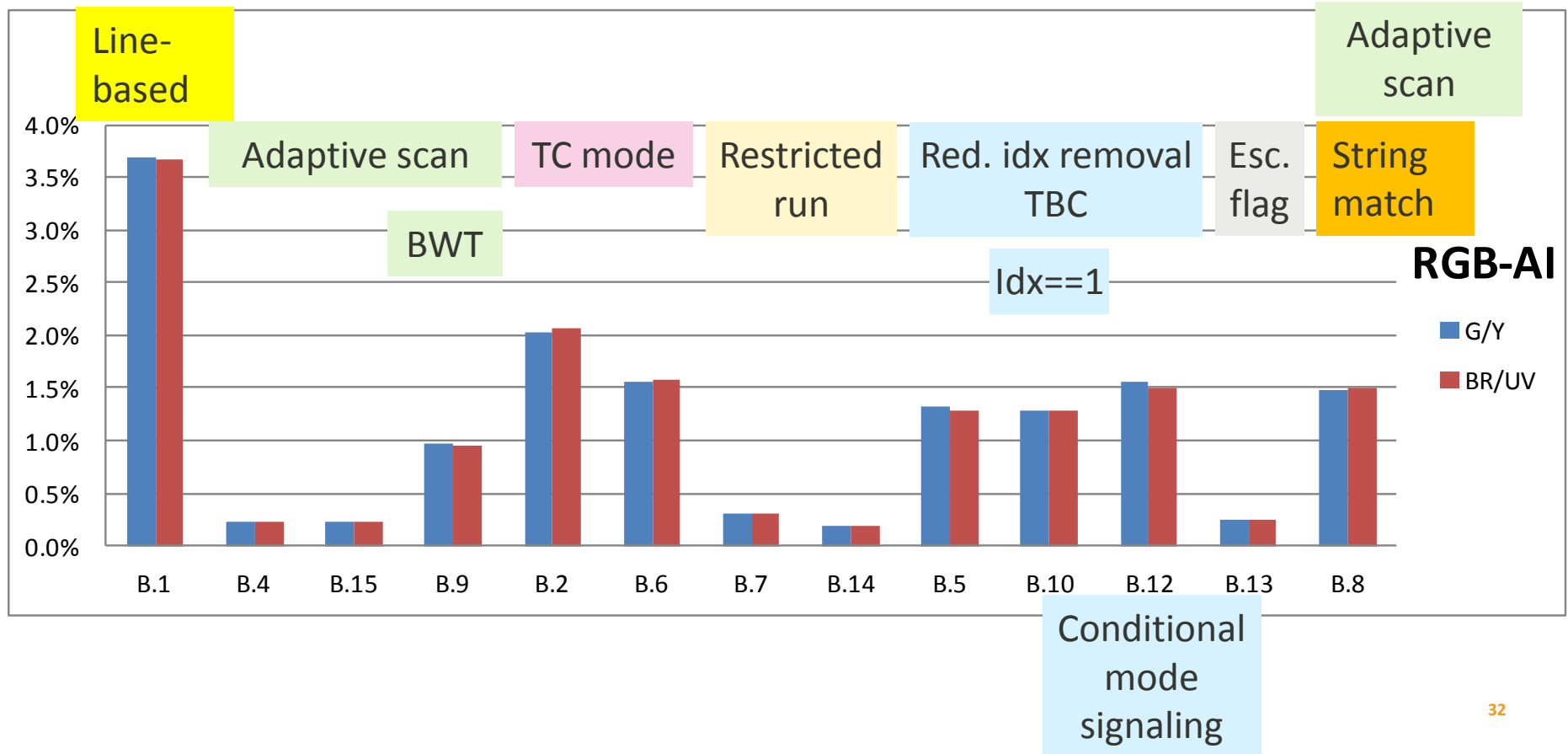
Category B Remarks

- Adaptive scan (B.1, B.4, B.8, B.9, B.15) is somewhat helpful in common test conditions and shows much higher gain when sequences are rotated by 90 degrees.

- Burrows–Wheeler transform (B.9): gain-complexity analysis?

- Transition copy (B.1, B.2, B.6) is beneficial.

- Restricted run signaling (B.7, B.14), redundant index removal (B.5, B.10, B.12), and truncated binary codes (B.5, B.12) / truncated Rice codes (B.10) are useful; suggest to study the interactions of these techniques.

- Escape color flag (B.13) is useful.

- Escape color prediction (B.11) is useful for lossless coding.

- Line-based method (B.1) and string-based method (B.8) are very different from run-based method.

Summary of Category C Techniques

Test	RDO	Note
C.1 (MediaTek)	N/A	A.2 + B.1, line-based coding
C.1 supplemental	A.6	A.2 + A.6 + B.1
C.2 (Canon)	C.2	Canon's category A + category B techniques
C.3 (Huawei)	C.3	A.4 + B.8, string-based + 2D block match, apply 3CTU search Maximum palette size is changed from 32 to 128.
C.4 (Qualcomm)	A.7	A.3 + A.7 + A.8 + B.12 + B.13
C.4 supplemental	C.2+…	A.3 + A.7 + A.8 + B.12 + B.13 + RDO in C.2

Results of Category C Tests (1/2)

- Anchor: Q0094BF palette

2CTU-IBC Condition

	C.1	C.1 sup	C.2	C.3	C.4	C.4 sup
	AI	**AI**	**AI**	**AI**	**AI**	**AI**
	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y
RGB, text & graphics with motion, 1080p	-12.4%	-14.9%	-11.4%	-18.6%	-11.2%	-13.4%
RGB, text & graphics with motion,720p	-9.2%	-11.8%	-10.6%	-13.3%	-8.8%	-11.6%
RGB, mixed content, 1440p	-2.5%	-4.8%	-5.2%	-4.6%	-3.5%	-6.9%
RGB, mixed content, 1080p	-3.4%	-5.7%	-5.9%	-6.0%	-3.9%	-7.6%
RGB, Animation, 720p	0.0%	0.2%	0.0%	0.0%	0.0%	-0.3%
RGB, camera captured, 1080p	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%
YUV, text & graphics with motion, 1080p	-13.8%	-16.4%	-11.5%	-19.0%	-11.3%	-13.7%
YUV, text & graphics with motion,720p	-7.6%	-9.2%	-7.4%	-11.6%	-6.5%	-8.4%
YUV, mixed content, 1440p	-2.7%	-4.3%	-4.4%	-5.4%	-2.5%	-5.8%
YUV, mixed content, 1080p	-3.9%	-6.4%	-6.0%	-6.7%	-3.5%	-7.3%
YUV, Animation, 720p	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	106%	106%	91%	114%	101%	111%
Dec Time[%]	96%	95%	80%	109%	100%	112%

Results of Category C Tests (2/2)

- Anchor: Q0094BF palette

FF-IBC Condition

	C.1	C.1 sup	C.2	C.3	C.4	C.4 sup
	AI	**AI**	**AI**	**AI**	**AI**	**AI**
	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y
RGB, text & graphics with motion, 1080p	-8.3%	-10.8%	-8.8%	-9.7%	-9.3%	-11.4%
RGB, text & graphics with motion,720p	-5.8%	-8.2%	-7.6%	-6.3%	-7.2%	-9.6%
RGB, mixed content, 1440p	-1.6%	-3.4%	-3.6%	-1.5%	-2.7%	-5.3%
RGB, mixed content, 1080p	-1.9%	-3.7%	-3.9%	-3.1%	-3.0%	-5.2%
RGB, Animation, 720p	0.0%	0.2%	0.0%	0.0%	0.0%	-0.2%
RGB, camera captured, 1080p	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%
YUV, text & graphics with motion, 1080p	-9.3%	-12.0%	-9.0%	-10.2%	-9.4%	-11.5%
YUV, text & graphics with motion,720p	-4.2%	-5.9%	-4.7%	-4.3%	-4.9%	-6.4%
YUV, mixed content, 1440p	-1.5%	-2.9%	-2.7%	-2.0%	-1.9%	-4.1%
YUV, mixed content, 1080p	-2.4%	-4.0%	-3.6%	-3.6%	-2.7%	-4.8%
YUV, Animation, 720p	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	107%	107%	95%	113%	102%	113%
Dec Time[%]	98%	97%	83%	118%	97%	116%

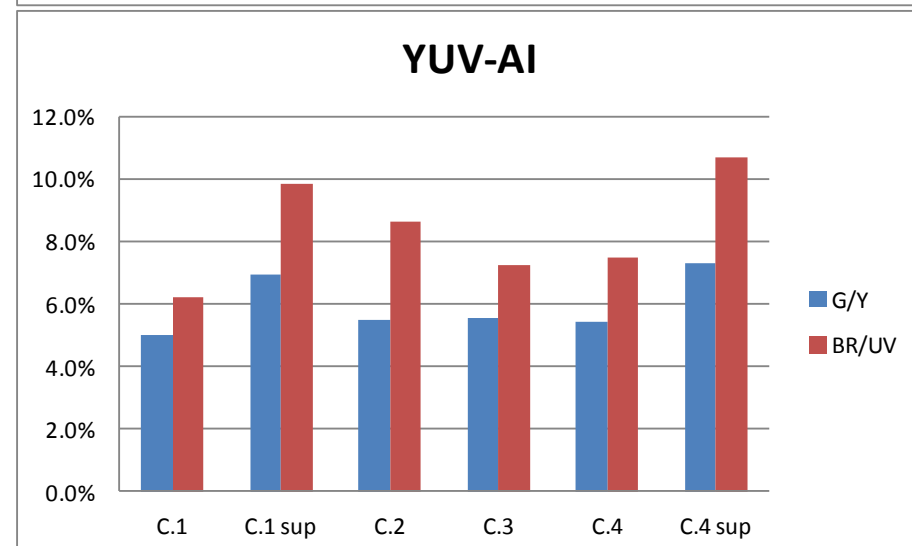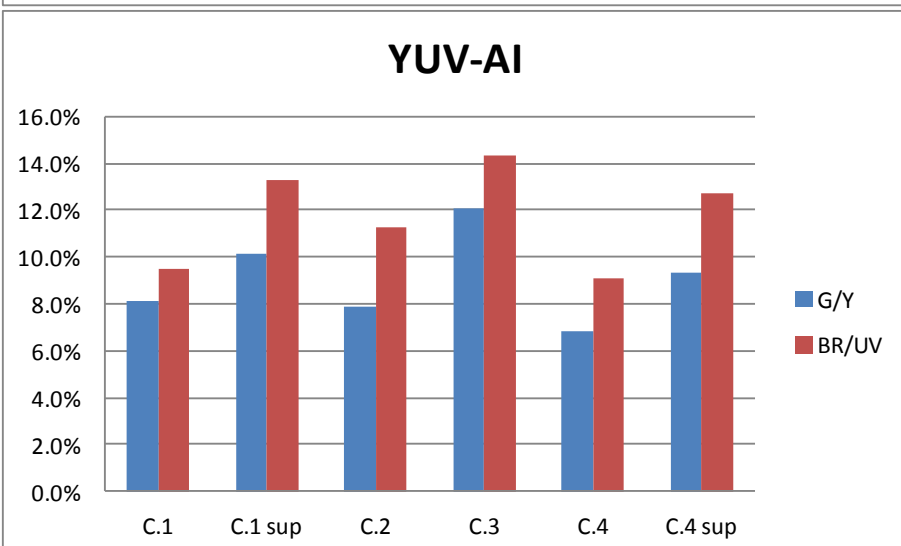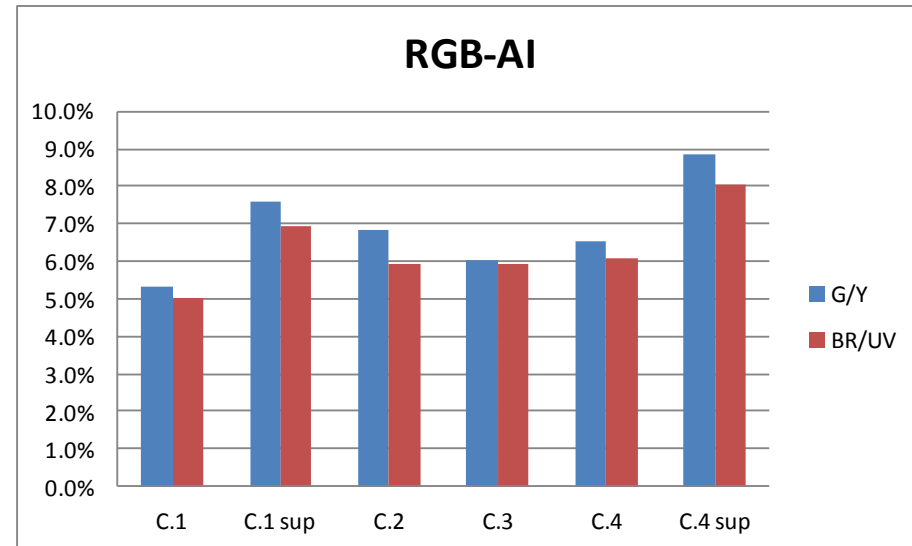# Comparison of Category C Tests

- BD-rate savings of the first four classes are averaged.
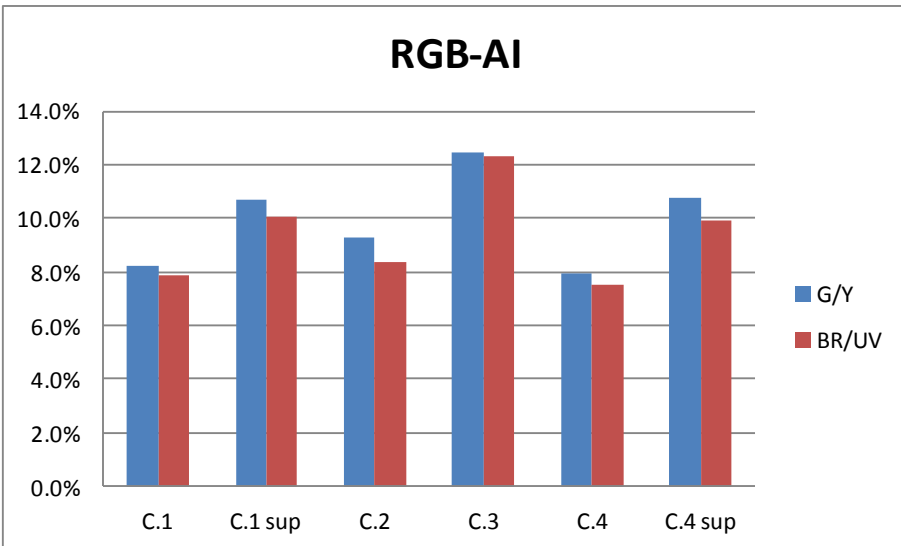
Category C Remarks

- Provided strong evidence of good coding efficiency achieved by palette mode

- Line-based and run-based color index map coding have much smaller gain overlap with FF-IBC than string-based color index map coding.

Test C.4 Related Data
(Provided by Qualcomm)

full-frame IBC	A.7	A.8	B.12	B.13	A.7 + A.8 + B.12 + B.13	C4
RGB, text & graphics with motion, 1080p	-2.4%	-3.3%	-1.6%	-0.5%	-7.8%	-9.3%
RGB, text & graphics with motion,720p	-1.6%	-3.1%	-1.1%	-0.1%	-6.0%	-7.2%
RGB, mixed content, 1440p	-1.3%	-0.2%	-0.2%	-0.1%	-1.8%	-2.7%
RGB, mixed content, 1080p	-1.3%	-0.3%	-0.3%	-0.1%	-2.0%	-3.0%
RGB, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-2.4%	-3.4%	-2.1%	-0.5%	-8.5%	-9.4%
YUV, text & graphics with motion,720p	-0.8%	-2.3%	-0.8%	0.0%	-3.9%	-4.9%
YUV, mixed content, 1440p	-0.9%	-0.2%	-0.2%	0.0%	-1.3%	-1.9%
YUV, mixed content, 1080p	-1.1%	-0.5%	-0.5%	-0.1%	-2.3%	-2.7%
YUV, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Two CTU IBC	A.7	A.8	B.12	B.13	A.7 + A.8 + B.12 + B.13	C4
RGB, text & graphics with motion, 1080p	-2.5%	-4.0%	-2.8%	-0.8%	-10.0%	-11.2%
RGB, text & graphics with motion,720p	-1.8%	-3.9%	-1.6%	-0.1%	-7.4%	-8.8%
RGB, mixed content, 1440p	-1.6%	-0.3%	-0.2%	-0.2%	-2.3%	-3.5%
RGB, mixed content, 1080p	-1.4%	-0.5%	-0.5%	-0.1%	-2.6%	-3.9%
RGB, Animation, 720p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-2.5%	-3.9%	-3.3%	-0.8%	-10.5%	-11.3%
YUV, text & graphics with motion,720p	-1.1%	-3.1%	-1.3%	-0.1%	-5.7%	-6.5%
YUV, mixed content, 1440p	-1.1%	-0.3%	-0.2%	0.0%	-1.7%	-2.5%
YUV, mixed content, 1080p	-1.4%	-0.6%	-0.7%	-0.1%	-2.8%	-3.5%
YUV, Animation, 720p	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%
YUV, camera captured, 1080p	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Summary of Category D Techniques

Note: Single color mode is NOT a modification of palette mode.

	D.1: Single Color (MediaTek)	D.2: IUP = Independent Uniform Prediction (MERL)
Concept	Reconstruct the current CU as a smooth area with a single color value	Predict the current CU as a smooth area with a single color value
Sample Candidate derivation	The candidate samples are derived for each CU locally.	The candidate samples are signaled for whole slice globally.
Residual coding	No	Yes
Slice-level on/off control	On/off flag is signaled in slice header	The size of the global candidate list is signaled (0, 1, 2); 0 indicates off
Encoding algorithm	Slice-level on/off is determined according to the coding information of the previously decoded slice	Global candidate list is determined according to the statistic of the original samples of current slice

Results of Category D Tests

- Anchor: Q0094BF palette
- If palette is off, the BD-rate savings increase 0.3-1.0%.

2CTU-IBC Condition	Test D.1			Test D.2		
	All Intra			**All Intra**		
	G/Y	B/U	R/V	G/Y	B/U	R/V
RGB, text & graphics with motion, 1080p	-0.5%	-0.5%	-0.5%	-0.6%	-0.5%	-0.6%
RGB, text & graphics with motion,720p	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%
RGB, mixed content, 1440p	-0.6%	-0.5%	-0.6%	-0.7%	-0.7%	-0.7%
RGB, mixed content, 1080p	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%
RGB, Animation, 720p	-0.1%	-0.1%	-0.1%	0.0%	0.0%	0.0%
RGB, camera captured, 1080p	-0.1%	0.0%	-0.1%	0.0%	0.0%	0.0%
YUV, text & graphics with motion, 1080p	-0.5%	-0.5%	-0.6%	-0.5%	-0.5%	-0.5%
YUV, text & graphics with motion,720p	-1.0%	-1.1%	-1.0%	-0.9%	-1.2%	-1.2%
YUV, mixed content, 1440p	-0.6%	-0.6%	-0.5%	-0.6%	-0.6%	-0.5%
YUV, mixed content, 1080p	-0.5%	-0.5%	-0.5%	-0.4%	-0.5%	-0.4%
YUV, Animation, 720p	0.0%	-0.2%	-0.2%	0.0%	0.0%	0.0%
YUV, camera captured, 1080p	0.0%	-0.1%	-0.2%	0.0%	0.0%	0.0%
Enc Time[%]	102%			99%		
Dec Time[%]	99%			97%		

Comparison of Category D Tests

- BD-rate savings of the first four classes are averaged.

2CTU-IBC Condition
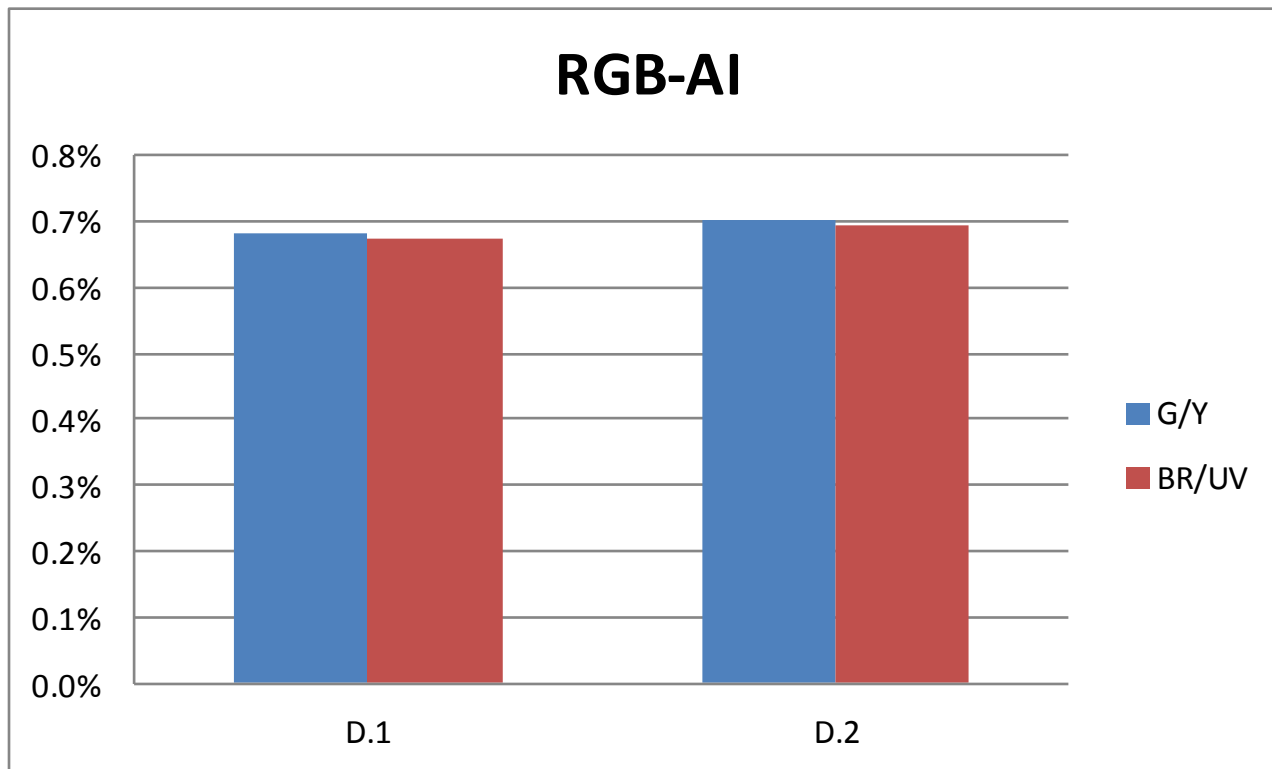
Category D Remarks

- Single color mode is helpful.

THANK YOU