<1st JCT-VC meeting @Dresden, DE, April 2010>

ETRI's Proposal for HVC

Hui Yong KIM

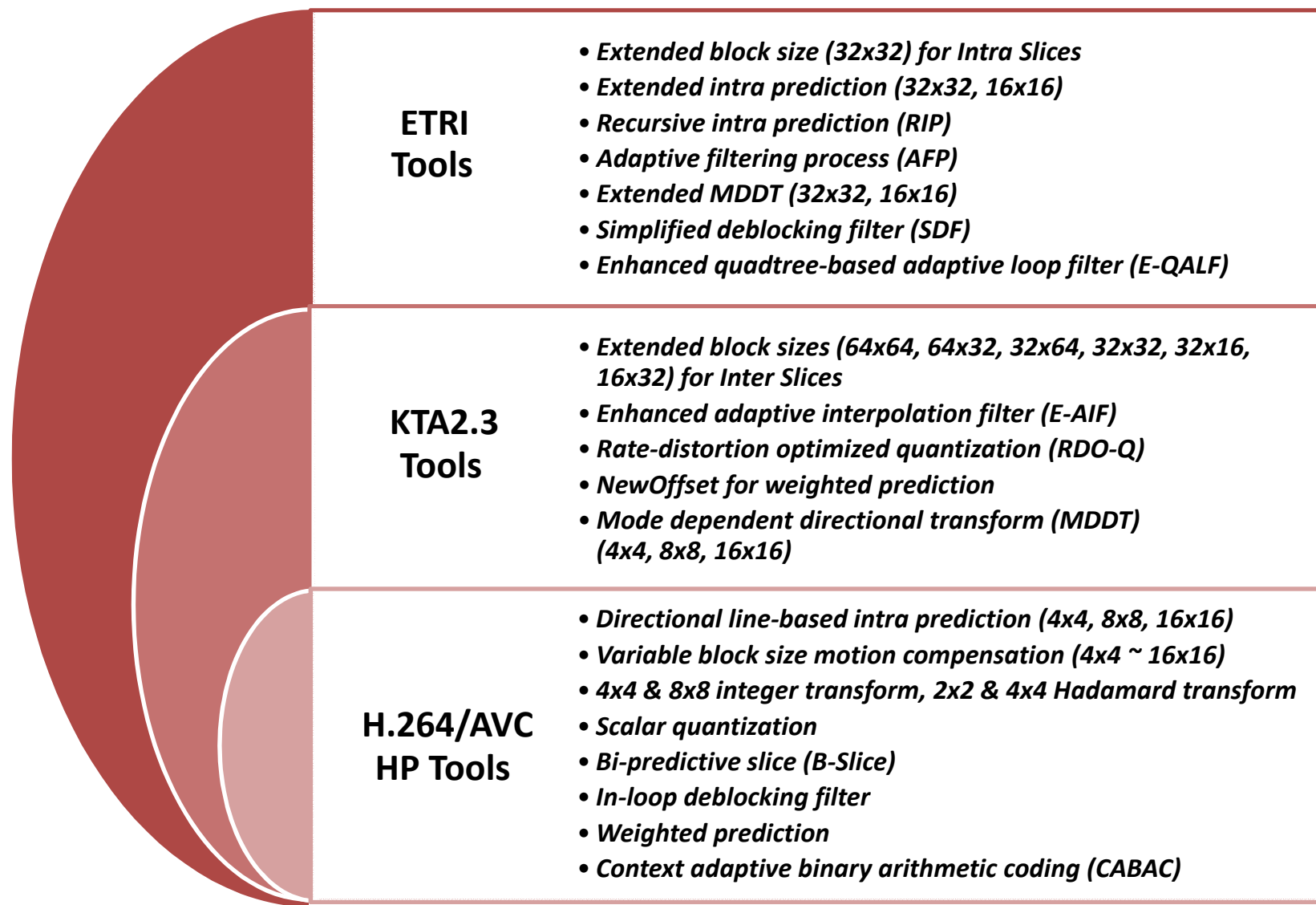hykim5@etri.re.kr

Realistic Media Research Team

2010-04-12

ETRI

Total: 25 pages

Contents

❑ **Tool Summary**

❑ **Prediction Structure**

❑ **Inter Coding Tools**

❑ **Intra Coding Tools**

❑ **Transforms & Quantization**

❑ **In-Loop Filters**

❑ **Entropy Coding**

❑ **RD Performance**

❑ **Subjective Quality Comparison**

❑ **Complexity**

❑ **Software Description**

Tool Summary

ETRI Tools
- *Extended block size (32x32) for Intra Slices*
- *Extended intra prediction (32x32, 16x16)*
- *Recursive intra prediction (RIP)*
- *Adaptive filtering process (AFP)*
- *Extended MDDT (32x32, 16x16)*
- *Simplified deblocking filter (SDF)*
- *Enhanced quadtree-based adaptive loop filter (E-QALF)*

KTA2.3 Tools
- *Extended block sizes (64x64, 64x32, 32x64, 32x32, 32x16, 16x32) for Inter Slices*
- *Enhanced adaptive interpolation filter (E-AIF)*
- *Rate-distortion optimized quantization (RDO-Q)*
- *NewOffset for weighted prediction*
- *Mode dependent directional transform (MDDT) (4x4, 8x8, 16x16)*

H.264/AVC HP Tools
- *Directional line-based intra prediction (4x4, 8x8, 16x16)*
- *Variable block size motion compensation (4x4 ~ 16x16)*
- *4x4 & 8x8 integer transform, 2x2 & 4x4 Hadamard transform*
- *Scalar quantization*
- *Bi-predictive slice (B-Slice)*
- *In-loop deblocking filter*
- *Weighted prediction*
- *Context adaptive binary arithmetic coding (CABAC)*
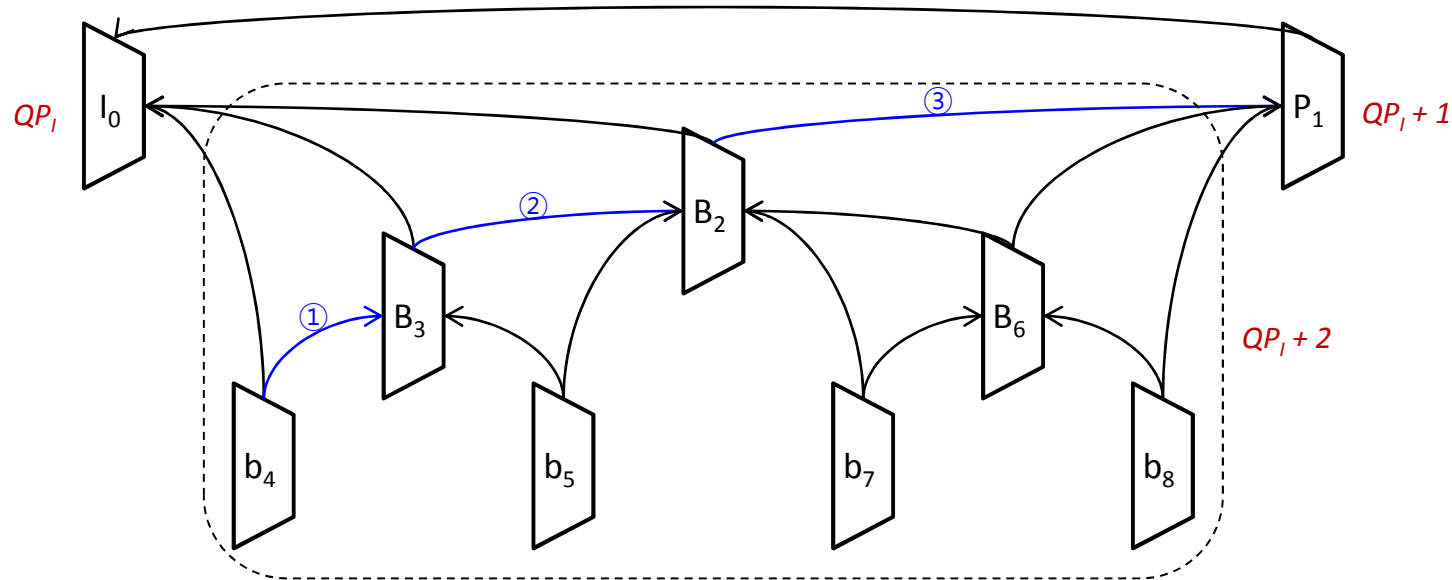
Prediction Structure

❑ **Constraint Set 1**

   ❖ Hierarchical B with 4 levels (similar to Alpha anchor)
- ➢ open GOP with length=<u>8</u>
- ➢ max <u>4</u> reference frames (B: max 2 per list, P: max 4) not from the lower levels
- ➢ max <u>3</u> frames reordering

   ❖ Structural delay less than <u>8</u> pictures

   ❖ Static QPs with possible 1-time change for each seq.

   ❖ Random access intervals less than <u>1.1</u> seconds
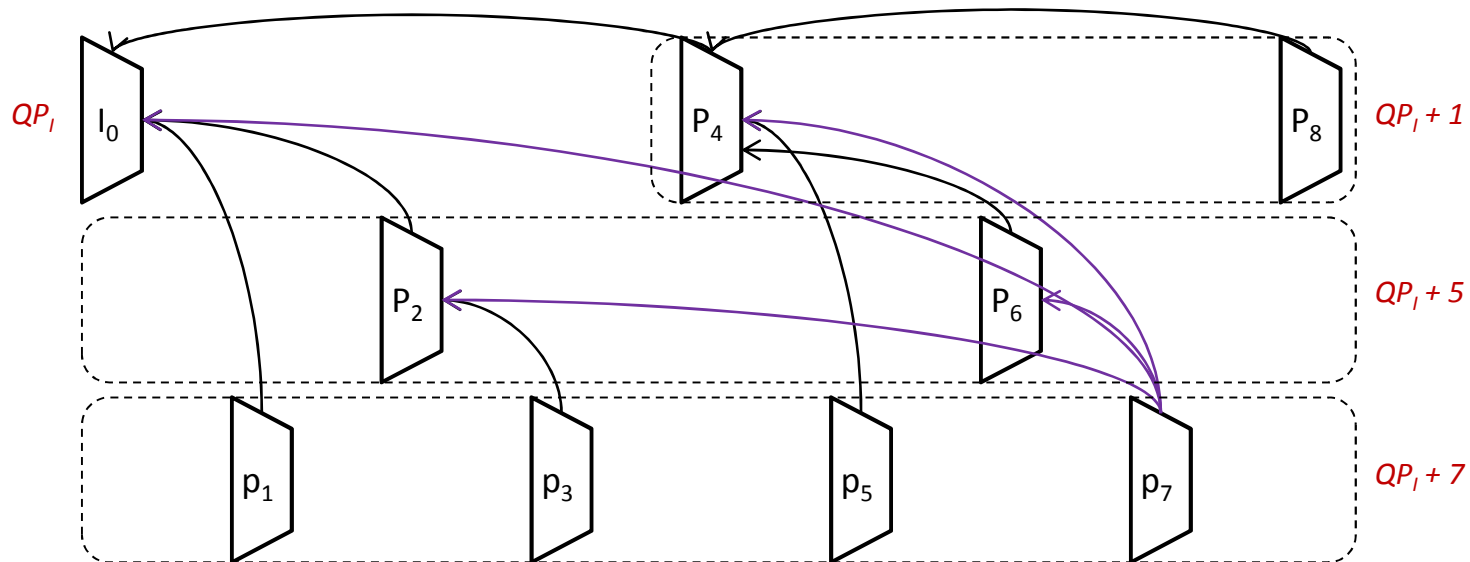- ➢ I-picture every 24/32/48/64 pictures (for 24/30/50/60 fps seq. respectively)

QP_I I_0 ③ P_1 $QP_I + 1$

② B_2

① B_3 B_6 $QP_I + 2$

b_4 b_5 b_7 b_8

• *Upper case: reference, lower case: non reference*
• *Subscripted numbers: decoding order*

(cont'd)

❏ Constraint Set 2

❖ Hierarchical P with 3 levels (similar to Beta anchor)

➤ open GOP with length=<u>4</u>

➤ max <u>4</u> reference frames (not from the lower levels)

➤ no picture reordering

❖ Static QPs with possible 1-time change for each seq.

QP_I I_0 P_4 P_8 $QP_I + 1$

P_2 P_6 $QP_I + 5$

p_1 p_3 p_5 p_7 $QP_I + 7$

- *Upper case: reference, lower case: non reference*
- *Subscripted numbers: decoding order*

Inter Coding

❑ **Some KTA 2.3 Tools are employed**

❖ <u>64x64 SMB</u> (Super-Macroblock)

➢ Ref.) "COM16-C123," Jan. 2009, Qualcomm

❖ <u>E-AIF</u> (Enhanced Adaptive Interpolation Filter)

➢ Ref.) "VCEG-AJ30," Oct. 2008, Qualcomm

❖ Weighted Prediction with <u>NewOffset</u>

➢ Ref.) "COM16-C463," Apr. 2008, Qualcomm

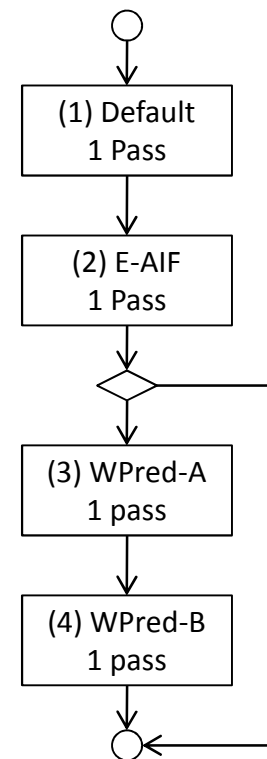❑ **Others are based on AVC HP (High Profile)**

❖ EPZS fast motion estimation (search range: 128x128) from JM11.0

❖ etc…

(cont'd)

❑ **Frame-Level Multi-Pass**
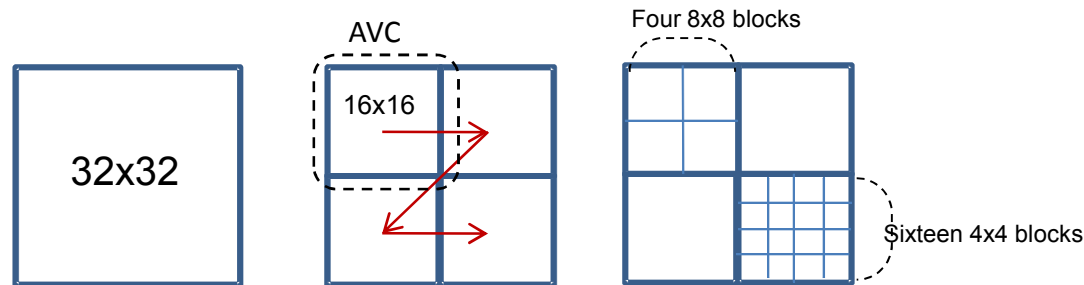
❖ Max 4 passes for P/B Slices (the same as KTA 2.3)

➢ *RDPictureDecision* = 1 (on)

➢ *GenerateMultiplePPS* = 1 (on)

➢ *WeightedPrediction* = 1 (on)

➢ *WeightedBiprediction* = 1 (on)

➢ *UseNewOffset* = 1 (on)

➢ *UseAdaptiveFilter* = 5 (E-AIF)

```
      ○
      │
      ▼
┌─────────────┐
│ (1) Default │
│   1 Pass    │
└─────────────┘
      │
      ▼
┌─────────────┐
│  (2) E-AIF  │
│   1 Pass    │
└─────────────┘
      │
      ▼
      ◇─────────────┐
      │             │
      ▼             │
┌─────────────┐     │
│ (3) WPred-A │     │
│   1 pass    │     │
└─────────────┘     │
      │             │
      ▼             │
┌─────────────┐     │
│ (4) WPred-B │     │
│   1 pass    │     │
└─────────────┘     │
      │             │
      ▼             │
      ○◄────────────┘
```

Intra Coding - SMB

❑ **32x32 SMB (Super-Macroblock)**
  ❖ Based on "VCEG-AL28", July 2009, ETRI
  ❖ <u>32x32 SMB</u> structure as an extension of 16x16 MB structure of AVC

  ❖ <u>*I_32x32* prediction</u>
    ➢ 4 modes similar to AVC *I_16x16* prediction
      (vertical, horizontal, DC, and plane mode)
    ➢ Applied to both Luma (32x32) and Chroma (16x16)

  ❖ <u>*I_16x16* Prediction</u>
    ➢ Luma: 9 modes similar to AVC *I_8x8* (or *I_4x4*) prediction
    ➢ *mb_type* and *cbp* are coded separately. MPM syntax is adopted for pred_mode.

  ❖ Applied only to I-Slices
    Cf.) In *P/B-Slices*, 64x64 SMB structure of KTA 2.3 is used.

ETRI IT R&D Global Leader

Intra Coding - RIP

❑ **Recursive Intra Prediction (RIP)**

❖ Recursive predictions along the directional lines

(1) the first pixels are predicted from the reconstructed reference pixels (AVC)

(2) the nth pixels are predicted from the $(n-1)^{th}$ predicted pixels

❖ Applied only to

➢ 6 directional modes (excluding vertical, horizontal and DC)

➢ *I_8x8* and *I_16x16* Luma in *I-Slices*

E.g.) *I_8x8* Vertical-Left

<1st stage>
- d1 = (D+E+2)>>2
- e1 = (E+F+2)>>2
- ......

AVC

<2nd stage>
- d2 = (d1+e1+2)>>2
- e2 = (e1+f1+2)>>2
- ......

<3rd stage>
- d3 = (d2+e2+2)>>2
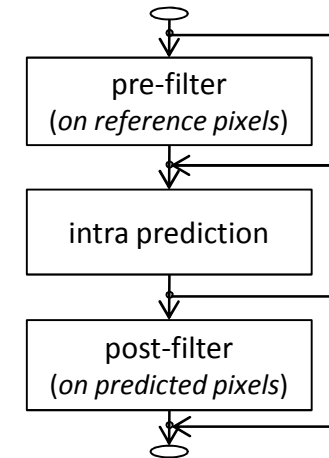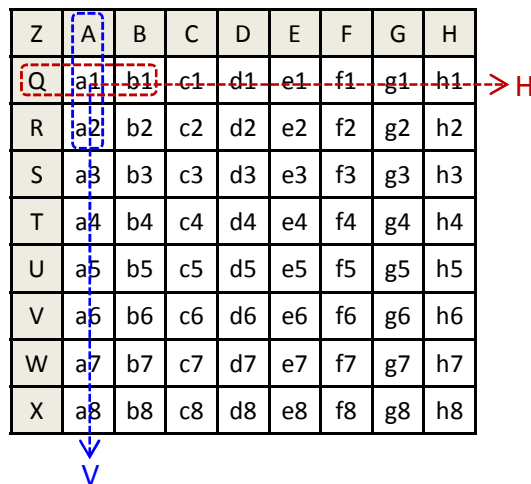- e3 = (e2+f2+2)>>2
- ......

⋮

<8th stage>
- ......

Intra Coding - AFP

❑ **Adaptive Filtering Process (AFP)**

(1) <u>Pre-filter</u> before prediction (similar to AVC HP *I_8x8*)
  ➢ 3-tap (¼, ½, ¼) filtering on the reconstructed <u>reference</u>

(2) <u>Post-filter</u> after prediction
  ➢ recursive 3-tap (¼, ½, ¼) filtering on the <u>predicted</u> pixels
  ➢ vertical filtering followed by horizontal filtering

❖ RDO-based filter on/off decision
❖ Applied only to *I_8x8* and *I_16x16* Luma in *I-Slices*

E.g.) *I_8x8* Post-filter

Z	A	B	C	D	E	F	G	H
Q	a1	b1	c1	d1	e1	f1	g1	h1	→ H
R	a2	b2	c2	d2	e2	f2	g2	h2
S	a3	b3	c3	d3	e3	f3	g3	h3
T	a4	b4	c4	d4	e4	f4	g4	h4
U	a5	b5	c5	d5	e5	f5	g5	h5
V	a6	b6	c6	d6	e6	f6	g6	h6
W	a7	b7	c7	d7	e7	f7	g7	h7
X	a8	b8	c8	d8	e8	f8	g8	h8

↓ V

\<Vertical\>
$V[a1] = (A + 2 \cdot a1 + a2 + 2) >> 2$
$V[a2] = (V[a1] + 2 \cdot a2 + a3 + 2) >> 2$
. . .
$V[a8] = (V[a7] + 3 \cdot a8 + 2) >> 2$
$V[b1] = (B + 2 \cdot b1 + b2 + 2) >> 2$
$V[b2] = (V[b1] + 2 \cdot b2 + b3 + 2) >> 2$
:
:

\<Horizontal\>
$H[a1] = (Q + 2 \cdot V[a1] + V[b1] + 2) >> 2$
$H[b1] = (H[a1] + 2 \cdot V[b1] + V[c1] + 2) >> 2$
. . .
$H[h1] = (H[g1] + 3 \cdot V[h1] + 2) >> 2$
$H[a2] = (R + 2 \cdot V[a2] + V[b2] + 2) >> 2$
:
:

pre-filter
(*on reference pixels*)

↓

intra prediction

↓

post-filter
(*on predicted pixels*)

\<AFP modes\>

MB type	AFP modes	Pre-filter	Post-filter	
I_8x8	1	*on*	*on*	
	2	*on*	*off*	: AVC HP
	3	*off*	*on*	
	4	*off*	*off*	
I_16x16	1	*off*	*on*	
	2	*off*	*off*	

Transforms & Quantization

❑ **Transforms in I-Slices**
  ❖ Based on KTA 2.3 MDDT("VCEG-AJ24", Oct. 2008, Qualcomm)
  ❖ New MDDT kernels for I_32x32(4-modes) & I_16x16(9-modes)

❑ **Transforms in P/B-Slices**
  ❖ KTA 2.3 is used without modification.

Slice type	Luma		Chroma	
	Block size	Transform	Block size	Transform
I	32x32	MDDT: 32x32	16x16	8x8 ICT + 2x2 HT
	16x16	MDDT: 16x16	8x8	4x4 ICT + 2x2 HT
	8x8	MDDT: 8x8		
	4x4	MDDT: 4x4		
P or B	64x64, 64x32, 32x64, 32x32, 32x16, 16x32	ICT: 16x16, 8x8, 4x4	8x8	4x4 ICT + 2x2 HT
	16x16	ICT: 16x16, 8x8, 4x4 (MDDT: 16x16 for I)		
	16x8	ICT: 16x8, 8x8, 4x4		
	8x16	ICT: 8x16, 8x8, 4x4		
	8x8	ICT: 8x8, 4x4 (MDDT: 8x8 for I)		
	8x4, 4x8, 4x4	ICT: 4x4 (MDDT: 4x4 for I)		

*MDDT: Mode-Dependent Directional Transform
*ICT: Integer Cosine Transform
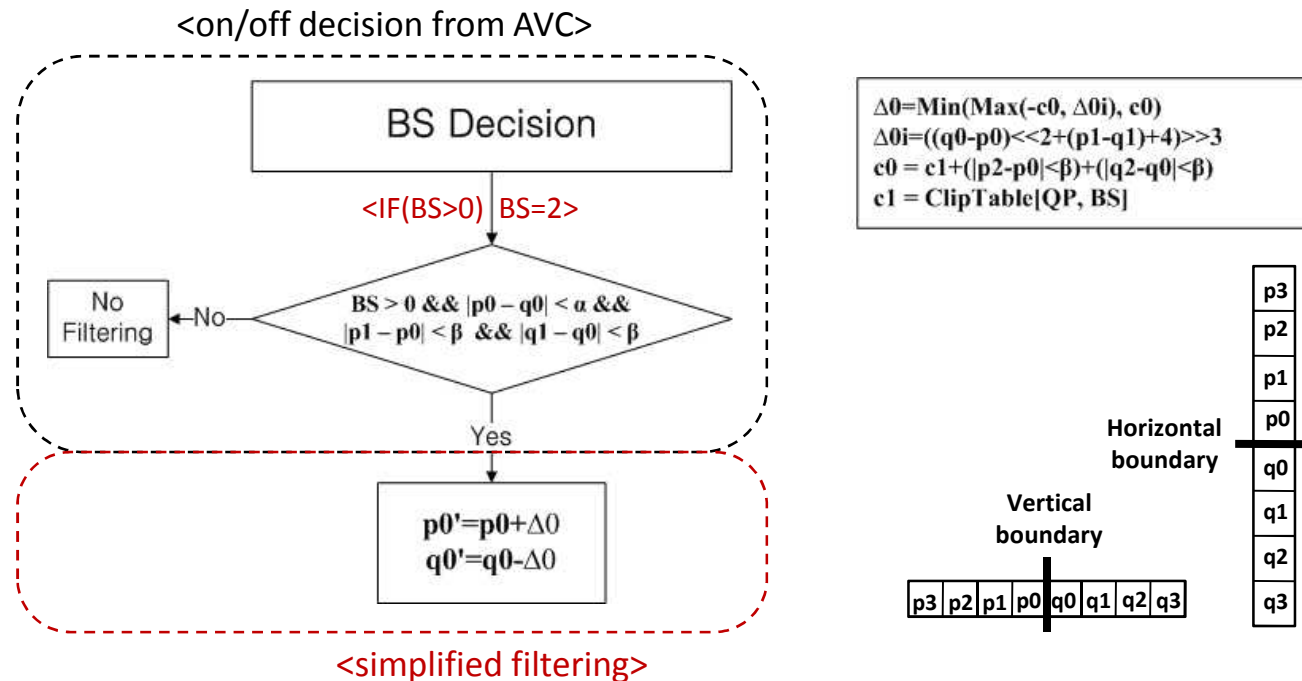*HT: Hadamard Transform

❑ **Quantization**
  ❖ <u>RDO-Q</u> from KTA 2.3 is employed for all the transform types.
  ❖ Ref.) "VCEG-AI36," Jul. 2008, Qualcomm

In-Loop Filters

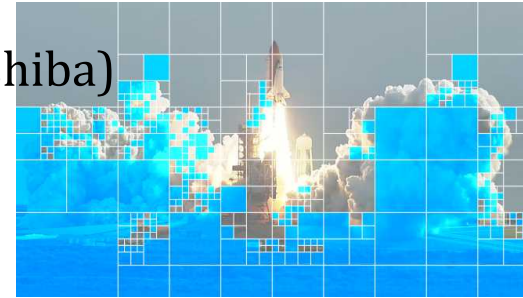❑ **Simplified Deblocking Filter (SDF)**

❖ Simplified version of AVC deblocking filter

➢ only the boundary pixels are filtered (p0 & q0)

➢ reduced # of BS types: if BS>0, then BS is set to 2

❖ Ref.) "VCEG-AJ17" Oct. 2008, Kwangwoon Univ.

<on/off decision from AVC>

BS Decision

<IF(BS>0) BS=2>

No Filtering ←No— BS > 0 && |p0 − q0| < α && |p1 − p0| < β && |q1 − q0| < β

$\Delta 0 = Min(Max(-c0, \Delta 0i), c0)$
$\Delta 0i = ((q0-p0)<<2+(p1-q1)+4)>>3$
$c0 = c1+(|p2-p0|<\beta)+(|q2-q0|<\beta)$
$c1 = ClipTable[QP, BS]$

Yes

$p0' = p0 + \Delta 0$
$q0' = q0 - \Delta 0$

<simplified filtering>

Horizontal boundary

Vertical boundary

| p3 | p2 | p1 | p0 | q0 | q1 | q2 | q3 |

p3
p2
p1
p0
q0
q1
q2
q3

(cont'd)

□ **Enhanced QALF (E-QALF)**

❖ QALF from KTA 2.3 ("VCEG-AK22", Apr. 2009, Toshiba)

➢ loop filter based on Wiener filter

➢ quadtree-based filter on/off

❖ E-QALF adds 3-more symmetries to QALF

➢ Competition based on RDO at the last stage

➢ improved RD performance without increasing decoder complexity

QALF

0	1	2	3	4
5	6	7	8	9
10	11	12	11	10
9	8	7	6	5
4	3	2	1	0

Centro

E-QALF

0	1	2	3	4
5	6	7	8	9
10	11	12	11	10
5	6	7	8	9
0	1	2	3	4

Vertical

0	5	10	5	0
1	6	11	6	1
2	7	12	7	2
3	8	11	8	3
4	9	10	9	4

Horizontal

0	1	2	3	4
5	6	7	8	3
9	10	12	7	2
11	8	10	6	1
4	11	9	5	0

Diagonal

Centro Symmetry (5x5)	→	Block Filtering On/Off (Quad-tree)	→	TAP Size Decision	QALF
Vertical Symmetry (5x5)	→	Block Filtering On/Off (Quad-tree)	→	TAP Size Decision	
Horizontal Symmetry (5x5)	→	Block Filtering On/Off (Quad-tree)	→	TAP Size Decision	RDO
Diagonal Symmetry (5x5)	→	Block Filtering On/Off (Quad-tree)	→	TAP Size Decision	

Entropy Coding

❑ **CABAC in AVC HP is employed.**

  ❖ For the newly added Syntax Elements (SEs), the binarization procedure and the context models were designed similarly to AVC.
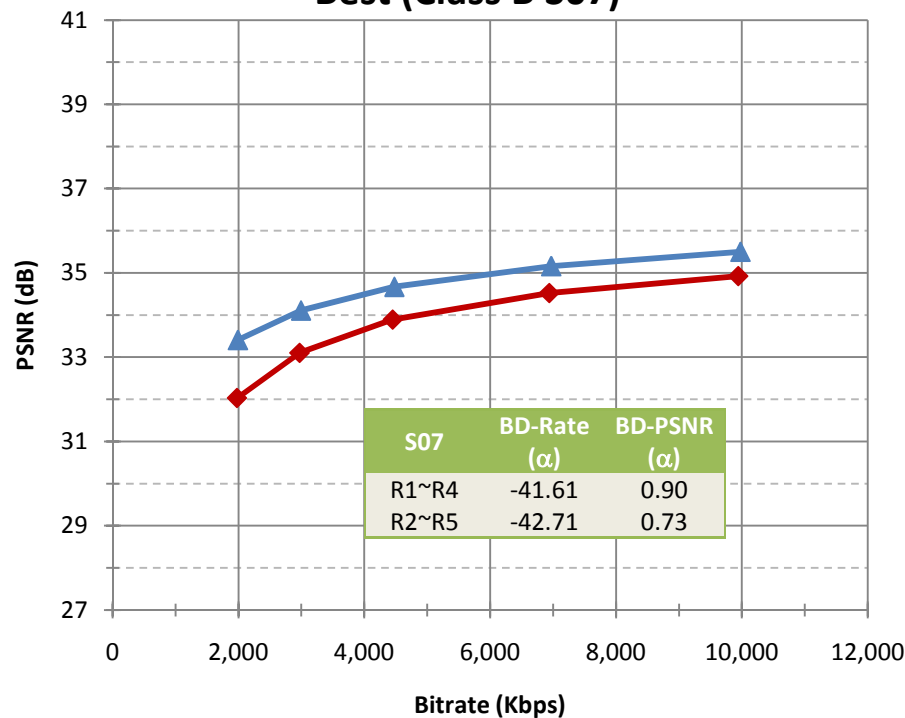
RD Performance

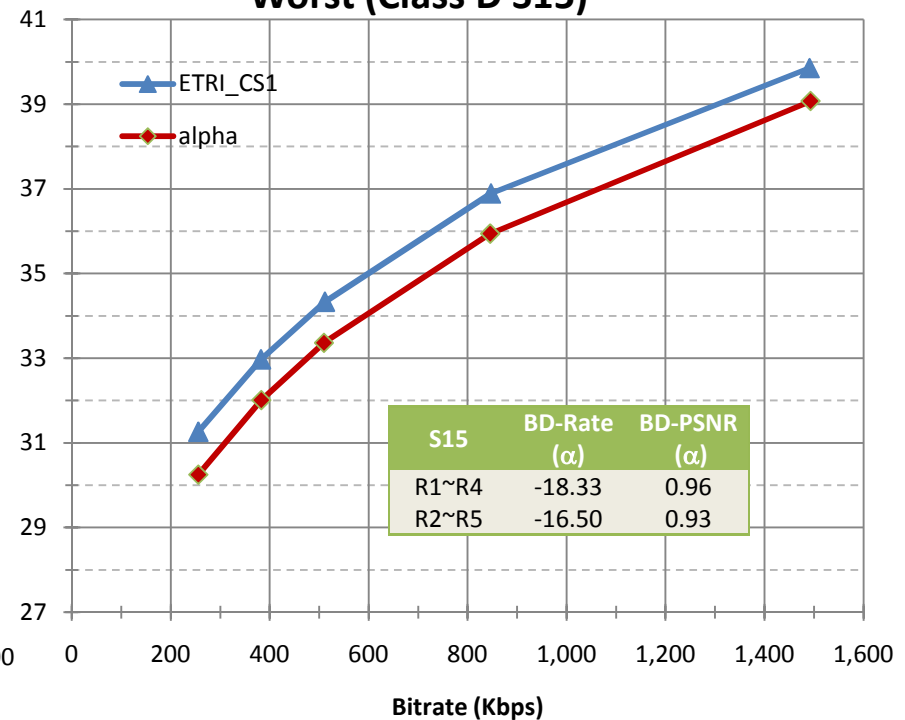## ❑ Constraint Set 1 (relative to Alpha)

Class	BD-Rate (α)	BD-PSNR (α)
A	-24.89	1.17
B	-33.74	1.11
C	-28.68	1.36
D	-23.45	1.12
Avg.	-27.69	1.19

(Only Luma results are shown here.)

Best (Class B S07)

S07	BD-Rate (α)	BD-PSNR (α)
R1~R4	-41.61	0.90
R2~R5	-42.71	0.73

Worst (Class D S15)

S15	BD-Rate (α)	BD-PSNR (α)
R1~R4	-18.33	0.96
R2~R5	-16.50	0.93

(cont'd)

❑ Constraint Set 2 (relative to Beta & Gamma)

Class	BD-Rate (β)	BD-PSNR (β)	BD-Rate(γ)	BD-PSNR (γ)
B	-30.58	0.77	-48.94	2.02
C	-20.36	0.89	-38.72	1.90
D	-10.85	0.47	-33.23	1.62
E	-34.96	1.60	-51.80	2.78
Avg.	-24.19	0.93	-41.17	2.08

(Only Luma results are shown here.)

Best (Class E S16)

S16	BD-Rate (β)	BD-PSNR (β)	BD-Rate (γ)	BD-PSNR (γ)
R1~R4	-38.41	1.99	-53.02	3.17
R2~R5	-36.98	1.54	-53.00	2.59

Worst (Class D S15)

S15	BD-Rate (β)	BD-PSNR (β)	BD-Rate (γ)	BD-PSNR (γ)
R1~R4	-7.23	0.35	-16.34	0.82
R2~R5	-6.61	0.35	-14.46	0.81

ETRI IT R&D Global Leader

Subjective Quality Comparison

❑ **C1 - Class A S01 & S02 @R1(2.5Mbps)**

(cont'd)

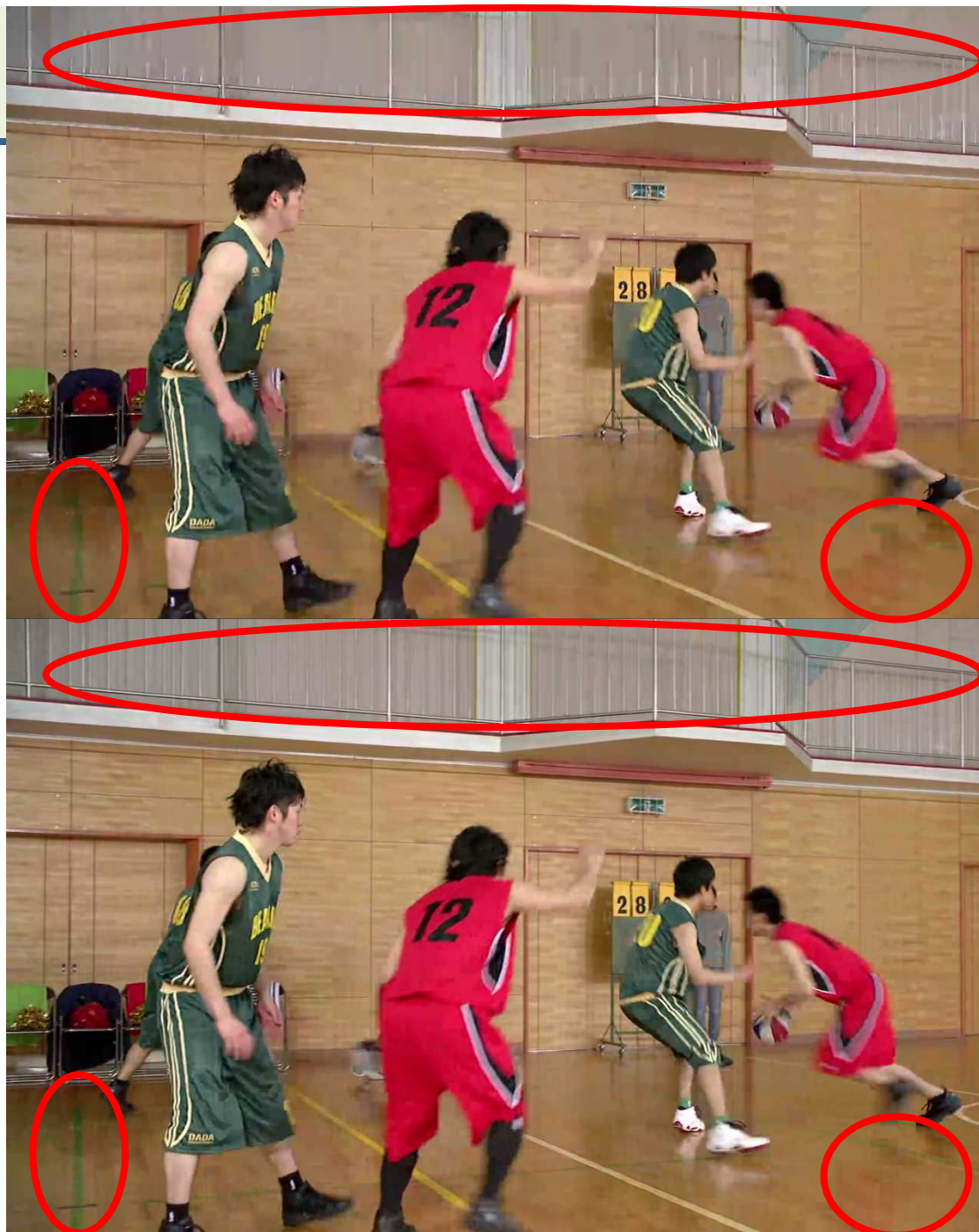❑ **C1 – Class C S08**
  @R1(384Kbps)

(co

❑ **C2 - Class B S03 @R1(1Mbps)**

❑ C2 - Class B S06 @R1(2Mbps)

Complexity

❑ **Time Measurement**

❖ '*ntimer*' for Windows systems were used

❖ All the measurements were performed on the same platform

➢ Microsoft Windows Vista Business K 64bit

➢ Intel Xeon CPU X5482 (3.2GHz 2-CPUs, 8 Core) with 8GB RAM

❖ Both anchors and proposed are compiled into 64-bit binary executables

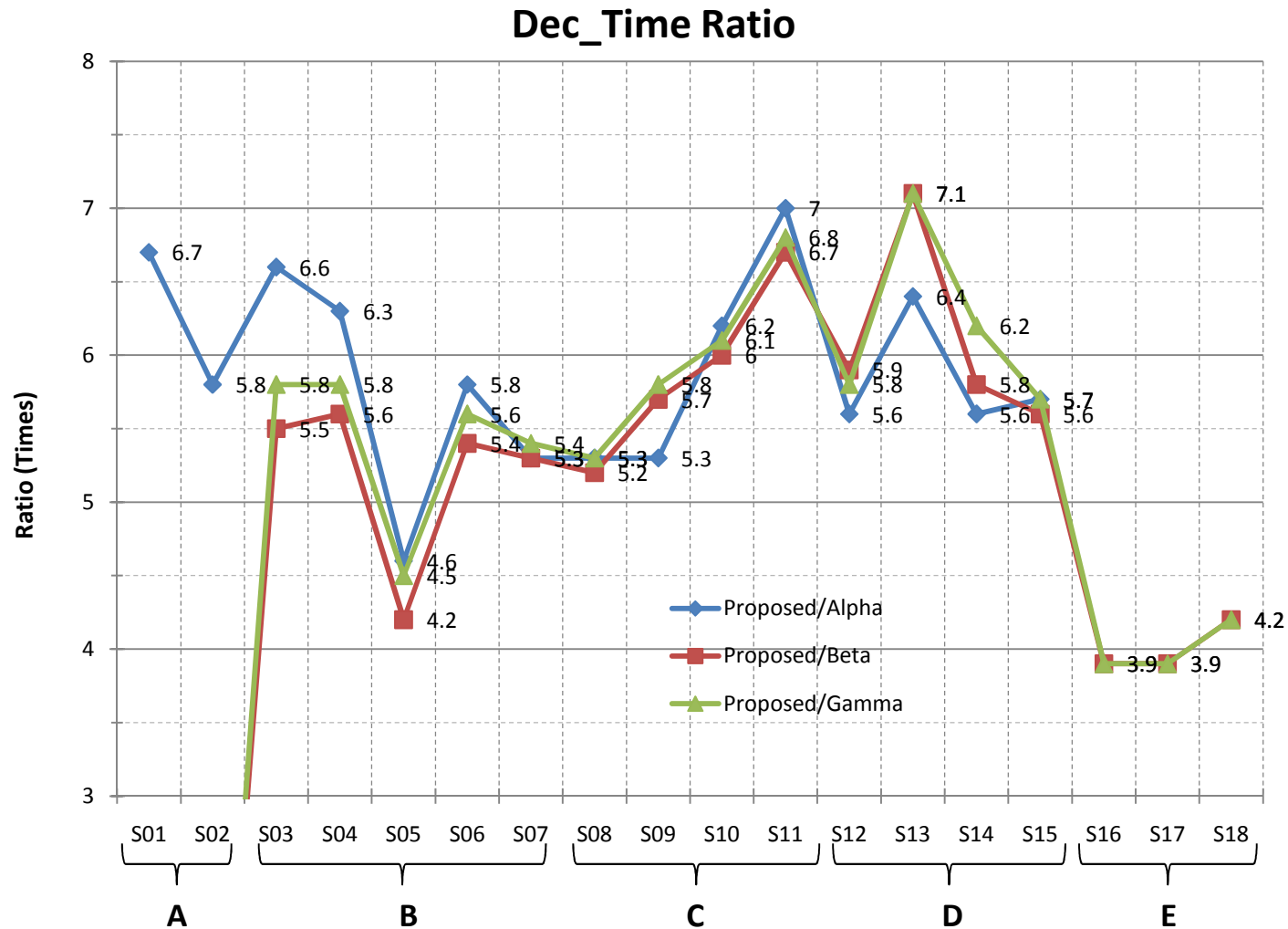❑ **Encoding Time**

Constraint Set 1

Class	Seq.	Ave.	fps	EncTime/DecTime
A	S01	113,256	0.0013	427
	S02	132,799	0.0011	578
B	S03	117,636	0.0020	487
	S04	107,421	0.0022	484
	S05	242,098	0.0021	736
	S06	245,059	0.0020	548
	S07	265,227	0.0023	542
C	S08	49,832	0.0100	944
	S09	67,189	0.0089	985
	S10	53,531	0.0093	817
	S11	34,277	0.0088	797
D	S12	16,761	0.0298	1133
	S13	15,854	0.0378	734
	S14	16,633	0.0301	1139
	S15	10,937	0.0274	968

Constraint Set 2

Class	Seq.	Ave. (sec)	fps	EncTime/DecTime
B	S03	94,373	0.0025	510
	S04	88,644	0.0027	492
	S05	195,300	0.0026	703
	S06	194,591	0.0026	531
	S07	203,439	0.0029	491
C	S08	40,305	0.0124	841
	S09	53,004	0.0113	822
	S10	41,442	0.0121	735
	S11	32,702	0.0092	884
D	S12	13,621	0.0367	1032
	S13	11,073	0.0542	589
	S14	12,780	0.0391	968
	S15	9,917	0.0302	992
E	S16	81,678	0.0073	716
	S17	81,773	0.0073	711
	S18	81,981	0.0073	669

(cont'd)

❏ Decoding Time (relative to Anchors)

Dec_Time Ratio

Software Implementation

❑ **Based on JM11.0KTA2.3.**

❑ **Program Language**
  ❖ C

❑ **Compilation**
  ❖ Platform: Microsoft Windows 7 x64 edition
  ❖ Compiler: Microsoft Visual Studio 2008
    ➢ both 64- and 32-bit compiled versions are submitted

❑ **Low-level programming optimization**
  ❖ No.

❑ **Usage of external video libraries**
  ❖ No.

Summary

❑ **ETRI's CODEC is based on the KTA 2.3**
   ❖ 64x64 SMB for Inter-Slices
   ❖ MDDT
   ❖ E-AIF
   ❖ RDO-Q
   ❖ NewOffset

❑ **Proposed tools are:**
   ❖ 32x32 SMB for I-Slices
   ❖ 4-modes I_32x32 & 9-modes I_16x16 prediction
   ❖ 32x32 and 16x16 MDDT kernels
   ❖ Recursive Intra prediction for the 6 directional modes (RIP)
   ❖ Adaptive pre-/post-filtering for Intra prediction (AFP)
   ❖ Simplified deblocking filter (SDF)
   ❖ Enhanced QALF (E-QALF)

❑ **RD Performance**
   ❖ Under CS1 (against Alpha)
      ➢ min -23.45% (Class D) and max -33.74% (Class B) average BD-Rate are achieved.
   ❖ Under CS2
      ➢ min -10.85% (Class D) and max -34.96% (Class E) average BD-Rate are achieved.
      ➢ min - 33.23% (Class D) and max -51.80% (Class E) average BD-Rate are achieved.

Thank You Very Much !

www.etri.re.kr

ETRI | IT R&D Global Leader