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| *Title:* | **CE6: Intra Prediction Improvements Summary Report** | |
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| *Authors:* | Ali Tabatabai (Primary) | [ali.tabatabai@am.sony.com](mailto:ali.tabatabai@am.sony.com) |
|  | Keiichi Chono  Muhammed Coban  Marta Mrak  Akiyuki Tanizawa | [chono@ct.jp.nec.com](mailto:chono@ct.jp.nec.com)  [mcoban@qualcomm.com](mailto:mcoban@qualcomm.com)  marta.mrak@bbc.co.uk  [akiyuki.tanizawa@toshiba.co.jp](mailto:akiyuki.tanizawa@toshiba.co.jp) |
|  | Haoping Yu | [haopingyu@huawei.com](mailto:haopingyu@huawei.com) |
|  |  |  |
|  |  |  |
| *Source:* | BBC, Huawei Technologies, NEC, Qualcomm, Sony, Toshiba | |

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# Abstract

This contribution provides a summary of Core Experiment 6, Intra Prediction Improvements. From a total of 9 proposed CEs 8 had been cross-checked with full match by at least on organization. For cross checking, the recommended test conditions of intra-only were used for both high compression efficiency and low complexity as defined in the document JCTVC-D606.

# Introduction

Intra prediction improvement core experiments are divided into 7 categories

1. CE6.a: Block Based Intra Prediction
2. CE6.b: Short Distance Intra Prediction
3. CE6.c: Edge Based Intra Prediction
4. CE6.d: Parallel Intra Coding
5. CE6.e: Planar Intra Prediction
6. CE6.f: Intra Smoothing
7. CE6.g: Number of Intra Prediction Directions

# Experimental Summary

Table 1 summarizes the technologies tested together with the list of the proponents and cross-checkers:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Core Experiments** | **Technology** | **Proponent(s)** | | **Cross-checker(s)** |
| CE6.a.1 | Bidirectional Intra Prediction | Toshiba  JCTVC-D108 | | Withdrawn |
| CE6.a.2 | Bi-Intra Prediction Using Slope Information | Sejong University/SKT  JCTVC-D287  JCTVC-E170 | | Huawei JCTVC-E290  Sharp JCTVC-E161 |
| CE6.a.3 | Bidirectional Intra Prediction for Positive Directions in UDI | HiSilicon /Huawei  JCTVC-D300  JCTVC-E286 | | Microsoft JCTVC-E149 |
| CE6.a.4 | Chroma Intra prediction by Reconstructed Luma Samples | Samsung/LG Electronics  JCTVC-D350  JCTVC-E266 | | KDDI R&D Lab. JCTVC-E254  (results were not completed)  Microsoft JCTVC-E468 |
| CE6.b.1 | Short Distance Intra Prediction Method | Microsoft/HiSilicon/Huawei  JCTVC-D299 | | Qualcomm JCTVC-E406  Samsung JCTVC-E271  Mitsubishi JCTVC-E067 |
| CE.6.b.2 | Combined Intra Prediction | BBC  JCTVC-D191  JCTVC-E130 | | Toshiba JCTVC-E207  Ghent Univ. JCTVC-E263 |
| CE6.c | Differential coding of Intra Modes (DCIM) | Sharp ,Sony, Panasonic, Toshiba  JCTVC-C169, JCTVC-C176  JCTVC-D279, JCTVC-E318 | | Qualcomm JCTVC-E397  Sejong University JCTVC-E371  NHK JCTVC-E077 |
| CE6.d | Parallel Intra Coding | Sharp Labs. of America  JCTVC-B112, JCTVC-D074  JCTVC-E315 | | Toshiba JCTVC-E208 |
| CE6.e | Planar Intra Prediction | Nokia, LG, NTT Docomo, Santa Clara University  JCTVC-D326, JCTVC-D083, JCTVC-D235, JCTVC-D235, JCTVC-D026 | | NEC JCTVC-E185, JCTVC-E186  Toshiba JCTVC-E209  Qualcomm JCTVC-E406  Orange Labs JCTVC-E450  Sony Used for Combining Tool  Sharp JCTVC-E162  Samsung JCTVC-E124  Huawei JCTVC-E112 |
| CE6.f.1 | LUT-based Intra Prediction Filtering | Mitsubishi  JCTVC-D109 | | NEC JCTVC-E184  Qualcomm JCTVC-E369 |
| CE6.f.2 | Mode Dependent Multi Filter Intra Smoothing | Qualcomm  JCTVC-D282 | | Withdrawn |
| CE6.g | Number of Intra Prediction Directions | | Mitsubishi  JCTVC-C310?  JCTVC-E068 | Peking Univ. JCTVC-E439 |

# Summary of Experimental Results

## CE6.a Block Based Intra Prediction

### CE6.a.1 Bidirectional Intra Prediction

This proposal has been withdrawn.

### CE6.a.2 Bi-Intra Prediction Using Slope Information

This contribution includes bi-intra prediction scheme which is used with offset and reference smoothing. The results are presented in Table a.2.

**Table a.2 – Results for Bi-Intra Prediction Using Slope Information**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -0.3 | -0.5 | -0.5 | -0.6 | -0.8 | -0.8 |
| Class B | -0.3 | -0.6 | -0.6 | -0.7 | -1.0 | -0.9 |
| Class C | -0.4 | -0.9 | -0.9 | -0.6 | -1.1 | -1.0 |
| Class D | -0.5 | -1.0 | -0.9 | -0.8 | -1.0 | -1.1 |
| Class E | -0.4 | -1.0 | -0.8 | -0.7 | -1.2 | -1.2 |
| All | -0.4 | -0.8 | -0.7 | -0.7 | -1.0 | -1.0 |
| Enc Time[%] | 139% | | | 122% | | |
| Dec Time[%] | 101% | | | 104% | | |

### CE6.a.3 Bidirectional Intra Prediction for Positive Directions in UDI

BUDI was originally proposed to replace mode 6 (i.e. ver+8). In this contribution BUDI has been extended to other positive directions, including ver+8, ver+5 and hor+6. Results for three tests have been reported:

1. Table a.3.1 shows the performance of the BUDI approach with the replacement of the existing mode ver+8 (which is denoted as “BUDI”).
2. “BUDI\_EXT” denotes the BUDI approach which has been extended to other positive directions. Besides mode ver+8, other mode ver+5 and hor+6 are also replaced in this “BUDI\_EXT” approach. The results are shown in Table a.3.2.
3. “BUDI\_EXT\_FAST” denotes the division-free “BUDI\_EXT” approach, where division operation in linear interpolation process can be removed by using a kind of approximate weighting algorithm. Test results are summarized in Table a.3.3.

**Table a.3.1 – Results for Test 1: BUDI with replacement of mode ver+8 (“BUDI”)**



**Table a.3.2 – Results for Test 2: BUDI with replacement of mode ver+8, ver+5 and hor+6 (“BUDI\_EXT”)**



**Table a.3.3 – Results for Test 3:   
Division-free BUDI with replacement of mode ver+8, ver+5 and hor+6 (“BUDI\_EXT\_FAST”)**



### CE6.a.4 Chroma Intra prediction by Reconstructed Luma Samples

The results for the core experiment on Chroma Intra prediction by Reconstructed Luma Samples have been evaluated for all 6 coding configurations (intra, random access, low delay). The intra coding results are summarized in Tables a.4.1.

**Table a.4.1 – Results for intra coding configurations**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.3 | -16.2 | -8.3 | -1.1 | -14.6 | -9.4 |
| Class B | -0.8 | -7.2 | -3.7 | -0.8 | -7.3 | -4.2 |
| Class C | -1.1 | -6.7 | -7.4 | -1.2 | -6.4 | -7.1 |
| Class D | -0.7 | -4.7 | -4.6 | -0.8 | -4.8 | -4.6 |
| Class E | -0.1 | -3.3 | -3.7 | -0.2 | -4.8 | -5.2 |
| All | -0.8 | -7.8 | -5.6 | -0.8 | -7.7 | -6.1 |
| Enc Time[%] | 102% | | | 104% | | |
| Dec Time[%] | 104% | | | 108% | | |

## CE6.b

### CE6.b.1

There are 3 versions of the software:

|  |  |  |
| --- | --- | --- |
| **Version** | **Cross Checkers** | **Report** |
| Normal | Samsung, TI | Yes (match) |
| 1x4\_OFF | Qualcomm | Yes (match) |
| 1x4\_OFF\_BUDI\_OFF | Mitsubishi | Yes (match) |

The software only runs under Intra configuration. Version that supports RA and LD modes was released on 3/10/2011.

**Test-Result 1: Normal**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.0 | -0.5 | -0.8 | -2.1 | -2.0 | -2.6 |
| Class B | -1.9 | -1.0 | -1.4 | -3.7 | -3.7 | -4.8 |
| Class C | -3.5 | -2.4 | -2.6 | -4.8 | -5.0 | -5.7 |
| Class D | -3.6 | -2.1 | -2.2 | -5.1 | -4.8 | -5.2 |
| Class E | -2.9 | -2.2 | -2.1 | -4.9 | -7.5 | -6.0 |
| All | -2.5 | -1.6 | -1.8 | -4.0 | -4.4 | -4.8 |
| Enc Time[%] | 124% | | | 147% | | |
| Dec Time[%] | 103% | | | 104% | | |

**Test-Result 2: 1x4\_OFF**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.1 | -0.6 | -0.9 | -2.0 | -2.0 | -2.6 |
| Class B | -1.9 | -1.1 | -1.5 | -3.6 | -3.8 | -4.9 |
| Class C | -3.2 | -2.4 | -2.6 | -4.1 | -5.0 | -5.7 |
| Class D | -3.2 | -2.1 | -2.2 | -4.2 | -4.7 | -5.0 |
| Class E | -3.0 | -2.4 | -2.2 | -4.8 | -7.5 | -6.1 |
| All | -2.4 | -1.6 | -1.8 | -3.7 | -4.4 | -4.8 |
| Enc Time[%] | 116% | | | 133% | | |
| Dec Time[%] | 101% | | | 101% | | |

**Test-Result 3: 1x4\_OFF\_BUDI\_OFF**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -0.7 | -0.5 | -0.8 | -1.4 | -1.7 | -2.4 |
| Class B | -1.5 | -0.9 | -1.4 | -3.2 | -3.4 | -4.5 |
| Class C | -2.8 | -2.3 | -2.5 | -3.7 | -4.6 | -5.3 |
| Class D | -2.9 | -2.0 | -2.1 | -3.8 | -4.4 | -4.7 |
| Class E | -2.6 | -2.3 | -2.3 | -4.4 | -7.4 | -5.9 |
| All | -2.0 | -1.5 | -1.8 | -3.2 | -4.1 | -4.5 |
| Enc Time[%] | 116% | | | 133% | | |
| Dec Time[%] | 101% | | | 99% | | |

### CE6.b.2

Two sets of experiments, each including two tests, have been performed  
  
**1st set: CIP integrated to HM2.0**CIP as reported in JCTVC-D191 is integrated into HM2.0. As in JCTVC-D191, two test show that this flexible implementation of CIP can provide a trade-off between encoder’s complexity and the performance in terms of the BD-rate.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | | Intra LoCo | | | |
| Y BD-rate | U BD-rate | V BD-rate | YUV BD-rate | Y BD-rate | U BD-rate | V BD-rate | YUV BD-rate |
| Class A | -0.4 | -0.7 | -0.6 | -0.5 | -0.8 | -0.8 | -0.7 | -0.8 |
| Class B | -0.3 | -0.6 | -0.6 | -0.4 | -0.4 | -0.9 | -0.9 | -0.6 |
| Class C | -0.1 | -0.6 | -0.6 | -0.2 | 0.0 | -0.7 | -0.7 | -0.2 |
| Class D | -0.1 | -0.6 | -0.6 | -0.2 | 0.0 | -0.6 | -0.6 | -0.2 |
| Class E | -0.4 | -0.8 | -0.8 | -0.5 | -0.7 | -1.0 | -1.0 | -0.8 |
| All | -0.2 | -0.6 | -0.6 | -0.3 | -0.4 | -0.8 | -0.8 | -0.5 |
| Enc Time[%] | 98% | | |  | 101% | | |  |
| Dec Time[%] | 99% | | |  | 97% | | |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | | Intra LoCo | | | |
| Y BD-rate | U BD-rate | V BD-rate | YUV BD-rate | Y BD-rate | U BD-rate | V BD-rate | YUV BD-rate |
| Class A | -0.8 | -2.7 | -2.6 | -1.2 | -2.2 | -3.6 | -3.5 | -2.5 |
| Class B | -0.3 | -1.5 | -1.6 | -0.7 | -0.8 | -2.0 | -2.1 | -1.1 |
| Class C | 0.1 | -1.1 | -1.1 | -0.2 | -0.1 | -1.3 | -1.3 | -0.4 |
| Class D | 0.0 | -1.1 | -1.1 | -0.3 | -0.3 | -1.1 | -1.2 | -0.5 |
| Class E | -0.2 | -2.1 | -1.9 | -0.7 | -1.2 | -2.6 | -2.6 | -1.5 |
| All | -0.3 | -1.6 | -1.7 | -0.6 | -0.9 | -2.1 | -2.1 | -1.2 |
| Enc Time[%] | 114% | | |  | 127% | | |  |
| Dec Time[%] | 102% | | |  | 102% | | |  |

**2nd set: integrated CIP (BBC) and Parallel Intra Prediction (Sharp)**BBC and Sharp have integrated two intra tools. These tests show that without increase of complexity, the performance of Parallel Intra prediction can be improved using CIP. In addition with more complex setting CIP is capable to further improve the results of HM2.0 that uses parallel intra prediction.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | | Intra LoCo | | | |
| Y BD-rate | U BD-rate | V BD-rate | YUV BD-rate | Y BD-rate | U BD-rate | V BD-rate | YUV BD-rate |
| Class A | 0.1 | -0.4 | -0.4 | 0.0 | -0.1 | -0.3 | -0.4 | -0.1 |
| Class B | 0.3 | -0.4 | -0.4 | 0.2 | 0.4 | -0.5 | -0.5 | 0.1 |
| Class C | 0.1 | -0.5 | -0.5 | -0.1 | 0.2 | -0.6 | -0.6 | 0.0 |
| Class D | 0.1 | -0.5 | -0.5 | 0.0 | 0.2 | -0.5 | -0.5 | 0.0 |
| Class E | 0.6 | -0.4 | -0.5 | 0.3 | 0.6 | -0.4 | -0.5 | 0.3 |
| All | 0.2 | -0.4 | -0.4 | 0.1 | 0.2 | -0.5 | -0.5 | 0.1 |
| Enc Time[%] | 102% | | |  | 105% | | |  |
| Dec Time[%] | 100% | | |  | 101% | | |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | | Intra LoCo | | | |
| Y BD-rate | U BD-rate | V BD-rate | YUV BD-rate | Y BD-rate | U BD-rate | V BD-rate | YUV BD-rate |
| Class A | -0.3 | -2.4 | -2.3 | -0.8 | -1.6 | -3.2 | -3.2 | -1.9 |
| Class B | 0.2 | -1.3 | -1.4 | -0.2 | -0.1 | -1.7 | -1.9 | -0.5 |
| Class C | 0.3 | -1.0 | -1.1 | -0.1 | 0.1 | -1.2 | -1.2 | -0.3 |
| Class D | 0.3 | -1.0 | -0.9 | 0.0 | 0.0 | -1.0 | -1.0 | -0.3 |
| Class E | 0.7 | -1.8 | -1.7 | 0.1 | -0.1 | -2.3 | -2.1 | -0.6 |
| All | 0.2 | -1.5 | -1.5 | -0.2 | -0.3 | -1.9 | -1.9 | -0.7 |
| Enc Time[%] | 113% | | |  | 128% | | |  |
| Dec Time[%] | 100% | | |  | 102% | | |  |

## CE6.c

The results of two set of tests are shown below. In the first test DCIM is used and in the second test a combination of DCIM and planar coding is shown.

**Test I: DCIM**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -0.7 | -0.5 | -0.3 | -1.0 | -0.2 | -0.3 |
| Class B | -1.3 | -0.9 | -1.0 | -1.2 | -1.3 | -1.5 |
| Class C | -1.8 | -1.5 | -1.8 | -2.2 | -1.9 | -2.1 |
| Class D | -1.3 | -0.9 | -1.0 | -1.7 | -1.3 | -1.4 |
| Class E | -1.8 | -1.7 | -1.6 | -2.3 | -0.5 | -0.9 |
| All | -1.4 | -1.1 | -1.1 | -1.6 | -1.1 | -1.3 |
| Enc Time[%] | 107% | | | 112% | | |
| Dec Time[%] | 103% | | | 108% | | |

**Test II: DCIM + Planar**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.1 | 1.1 | 1.4 | -1.4 | 0.4 | 0.8 |
| Class B | -2.1 | -0.3 | -0.2 | -1.7 | -1.2 | -1.0 |
| Class C | -2.2 | -0.6 | -0.6 | -2.6 | -1.8 | -1.9 |
| Class D | -1.9 | -0.1 | 0.1 | -2.1 | -1.3 | -1.3 |
| Class E | -2.8 | -0.9 | -0.3 | -2.9 | -0.4 | -0.9 |
| All | -2.0 | -0.1 | 0.1 | -2.1 | -0.9 | -0.9 |
| Enc Time[%] | 109% | | | 113% | | |
| Dec Time[%] | 105% | | | 111% | | |

## CE6.d

**Parallel Intra prediction for 2X parallelism**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | 0.4 | 0.3 | 0.3 | 0.5 | 0.4 | 0.3 |
| Class B | 0.4 | 0.2 | 0.3 | 0.6 | 0.3 | 0.3 |
| Class C | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Class D | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Class E | 0.7 | 0.4 | 0.4 | 1.0 | 0.5 | 0.5 |
| All | 0.3 | 0.2 | 0.2 | 0.4 | 0.2 | 0.2 |
| Enc Time[%] | 103% | | | 106% | | |
| Dec Time[%] | 101% | | | 104% | | |

**Parallel Intra prediction for 8X parallelism**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | 0.4 | 0.3 | 0.3 | 0.5 | 0.4 | 0.3 |
| Class B | 0.5 | 0.3 | 0.3 | 0.7 | 0.4 | 0.4 |
| Class C | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Class D | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Class E | 0.8 | 0.5 | 0.4 | 1.0 | 0.5 | 0.5 |
| All | 0.3 | 0.2 | 0.2 | 0.4 | 0.2 | 0.2 |
| Enc Time[%] | 103% | | | 106% | | |
| Dec Time[%] | 101% | | | 104% | | |

## CE6.e

Performance evaluation of different configurations and combinations of proposed planar intra prediction methods (JCTVC-D026, JCTVC-D083, JCTVC-D235, JCTVC-D326) has been successfully completed. The following conclusions were derived from the three subtests of CE6.e:

- (Subtest1) Performance and complexity of different planar intra prediction methods except JCTVC-D026 prediction method are close to each other, and a combination of different approaches seem to provide the best objective performance  
- (Subtest1) Refinement process of 1.f. provides additional gains on top of different planar intra prediction approaches  
- (Subtest2) DST provides additional gains on top of different planar prediction approaches, and its potential in enhancing coding performance of HM is verified  
- (Subtest3) Introducing planar mode as an additional prediction mode in PU level provides additional gains on top of different planar intra prediction and transform approaches

**Subtest1**

Six different planar intra prediction schemes below were tested by replacing DC mode with planar intra prediction mode. SCU’s software was used for 1.d, and NTT DOCOMO’s software was used for the others. Proposal and cross-verification documents of each of planar intra prediction schemes are as follows:

1.a. JCTVC-D326 Planar prediction, disabling the adjustment for corner sample (bilinear prediction of samples)

Proposal document: JCTVC-E317 (Nokia)

Cross-check document: JCTVC-E185(NEC), JCTVC-E321 (NTT DOCOMO)

1.b. JCTVC-D326 Planar prediction with the JCTVC-D083 refinement step

Proposal document: JCTVC-E166:

Cross-check document: JCTVC-E112, JCTVC-E185, JCTVC-EX321 (NTT DOCOMO)

1.c. JCTVC-D235 Planar prediction (averaging two linear interpolations)

Proposal document: JCTVC-E321 (NTT DOCOMO)

Cross-check document: JCTVC-E185

1.d. Plane prediction as defined in JCTVC-D026 (TMuC plane mode)

Proposal document: JCTVC-E110

Cross-check document: JCTVC-E165

1.e. JCTVC-D326 Planar prediction (Multiplication-free version of 1.a)

Proposal document: JCTVC-E317 (Nokia)

Cross-check document: JCTVC-E185

1.f. JCTVC-D235 Planar prediction with a modified version of the JCTVC-D083 refinement step

Proposal document: JCTVC-E166

Cross-check document: JCTVC-E112, JCTVC-E185, JCTVC-E321 (NTT DOCOMO)

From the summary results of subtest1 results tabulated in Table 1 and 2, the following are confirmed:

* Performance and complexity of different planar intra prediction methods except 1.d JCTVC-D026 method are close to each other;
* Different planar intra prediction methods except 1.d JCTVC-D026 provides about 0.5% BD-rate improvements;
* JCTVC-D083 refinement process provides additional BD-rate improvements (about 0.1%) on top of different planar intra prediction methods

Table 1 Results of 1.a-c



Table 2 Results of 1.d-f



**Subtest2**

Three planar intra predictions (1.c, 1.e, and 1.f) were further tested by replacing DCT with DST in NTT DOCOMO software. Proposal and cross-verification documents of each of DST results are as follows:

1.c+2.b JCTVC-D235 Planar prediction (averaging two linear interpolations) + DST

Proposal document: JCTVC-E321 (NTT DOCOMO)

Cross-check document: JCTVC-E185

1.e+2.b JCTVC-D326 Planar prediction (Multiplication-free version) + DST

Proposal document: JCTVC-E317 (Nokia)

Cross-check document: JCTVC-E209

1.f+2.b JCTVC-D235 Planar prediction with a modified version of the JCTVC-D083 refinement step + DST

Proposal document: JCTVC-E166

Cross-check document: JCTVC-E112 and JCTVC-E321 (NTT DOCOMO)

From the summary results of 1.c, 1.e, and 1.f results tabulated in Tables 3-5, it is confirmed that DST provides additional gains (about 0.3% in HE case and 0.5% in LC case) on top of different planar prediction approaches.

Table 3 Results of 1.c+2.a and 1.c+2.b



Table 4 Results of 1.e+2.a and 1.e+2.b



Table 5 Results of 1.f+2.a and 1.f+2.b



**Subtest3**

PU level planar mode signaling as an additional prediction mode using DCT/DST was tested by using the NTT DOCOMO software, and CU level planar mode indication jointly for all color components was tested by using NOKIA’s software. Proposal and cross-verification documents of those results are as follows:

1.c+2.a/b+3.b JCTVC-D235 Planar prediction + DCT/DST + PU level signaling

Proposal document: JCTVC-E321 (NTT DOCOMO)

Cross-check document: JCTVC-E185

1.e+2.a/b+3.b JCTVC-D326 Planar prediction (Multiplication-free version) + DCT/DST + PU level signaling

Proposal document: JCTVC-E317 (Nokia)

Cross-check document: JCTVC-E209 and JCTVC-E321 (NTT DOCOMO)

1.f+2.a/b+3.b JCTVC-D235 Planar prediction with a modified version of the JCTVC-D083 refinement step + DCT/DST + PU level signaling

Proposal document: JCTVC-E166

Cross-check document: JCTVC-E112, JCTVC-E161, JCTVC-E450 (Orange labs.) and JCTVC-E321 (NTT DOCOMO)

1.e+3.c JCTVC-D326 Planar prediction (Multiplication-free version) + CU level planar mode indication

Proposal document: JCTVC-E317 ( (Nokia)

Cross-check document t: JCTVC-E185

Tables 6-8 show the summary results comparing the PU-level additional prediction mode signaling with the DC mode replacement on the top of DCT-based transform coding. Tables 9-11 show the summary results comparing the PU-level additional prediction mode signaling with the DC mode replacement on the top of DST-based transform coding. Table 12 shows the summary results comparing PU-level additional prediction mode with CU level planar mode indication.

Tables 6-8 show that the PU-level additional prediction mode signaling provides additional gains (about 0.2% in HE case and 0.1% in LC case) on top of different planar prediction approaches using DCT.

Tables 9-11 show that the PU-level additional prediction mode signaling provides additional gains (about 0.3% in HE case and 0.2% in LC case) on top of different planar prediction approaches using DST.

Tables 12 shows that the CU level join indication without residual transmission causes coding losses (about 0.5% in HE case and 0.7% in LC case).

It is verified that introducing planar mode as an additional prediction mode in PU level provides additional gains on top of different planar intra prediction and transform approaches

Table 6 Results of 1.c+2.a+3.a and 1.c+2.a+3.b



Table 7 Results of 1.e+2.a+3.a and 1.e+2.a+3.b



Table 8 Results of 1.f+2.a+3.a and 1.f+2.a+3.b



Table 9 Results of 1.c+2.b+3.a and 1.c+2.b+3.b



Table 10 Results of 1.e+2.b+3.a and 1.e+2.b+3.b



Table 11 Results of 1.f+2.b+3.a and 1.f+2.b+3.b



Table 12 Results of 1.e+3.c



## CE6.f

Performance of JCTVC-E069 intra smoothing has been tested by Qualcomm and NEC. It was confirmed that the JCTVC-E069 intra smoothing improves BD-rates by 0.2% and 0.4% in High Efficiency (HE) and Low Complexity (LC) all intra coding conditions defined in JCTVC-D600 while reducing encoder/decoder runtime by using an MDIS with less number of filterings. In addition, it was also confirmed that the JCTVC-E069 intra smoothing provides additional coding gains (0.2% in HE and LC intra coding conditions) on the top of one of the best performing planar intra prediction schemes in CE6.e, 1.c+2.b+3.b of JCTVC-E321.

Table 1. BD Bitrate saving of JCTVC-E069 against HM2.0



Table 2. BD Bitrate saving of JCTVC-E321 against HM2.0



Table 3. BD Bitrate saving of JCTVC-E321＋JCTVC-E069 against HM2.0



## CE6.g

(Test #1) using only 17 instead of 34 modes for 8x8

0.424% and 0.848% for high efficiency and low complexity conditions respectively.

(Test #2) using only 17 instead of 34 modes for 16x16

0.239% and 0.394% for high efficiency and low complexity conditions respectively.

(Test #3) using only 17 instead of 34 modes for 32x32

0.152% and 0.091% for high efficiency and low complexity conditions respectively.

(Test #4) using only 9 instead of 34 modes for 32x32

0.235% and 0.115% for high efficiency and low complexity conditions respectively.

(Test #5) using only DC prediction mode instead of 3 modes for 64x64

0.012% and 0.015% for high efficiency and low complexity conditions respectively.

It is proposed by the contributor that only DC prediction mode instead of 3 modes for intra 64x64 should be supported in the next version of the HEVC test model.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  | HE | | LC | |
|  | 4x4 | 8x8 | 16x16 | 32x32 | 64x64 | BDrate | Enc Time | Bdrate | Enc Time |
| Reference | 17 | 34 | 34 | 34 | 3 | 0.000 | 100.00% | 0.000 | 100.00% |
| Test#1 | 17 | 17 | 34 | 34 | 3 | 0.424 | 98.46% | 0.848 | 96.41% |
| Test#2 | 17 | 34 | 17 | 34 | 3 | 0.239 | 99.01% | 0.394 | 97.33% |
| Test#3 | 17 | 34 | 34 | 17 | 3 | 0.152 | 99.29% | 0.091 | 97.71% |
| Test#4 | 17 | 34 | 34 | 9 | 3 | 0.235 | 98.68% | 0.115 | 96.45% |
| Test#5 | 17 | 34 | 34 | 34 | 1 | 0.012 | 98.32% | 0.015 | 99.03% |