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# JVET-K0195

## CE4-5-RELATED:

### INTER/INTRA BOUNDARY PADDING

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# Inter-prediction based boundary padding

- **Padding per picture (CE4-5.2 and CE4-5.3):**
  - Devide boundary padding area into  $4 \times M$  or  $M \times 4$  blocks
  - Use motion info of adjacent blocks
  - Perpendicular intra-prediction based padding fall back



# Inter-prediction based boundary padding

## ■ Variations of the two related CE proposals:

- **CE4-5.2:** Addition of average residual of adjacent block
- **CE4-5.3:** Bi-predictive motion compensation
- Performance varies depending coding configuration (RA/LD) or TL



# Inter-prediction based boundary padding

- **CE4-5.2 modifications** (measured on 49 pictures VTM RA)
  - MC block size adjustment: decoder runtime reduction 129% to 105%
  - Luma/Chroma cost calculation mix-up:  
UV-PSNR performance increases from +0,34% to -0,12%
  - Max sample value clipping to avoid enc/dec mismatches

- **Effectiveness (measured on CE4-5.2\_mod)**

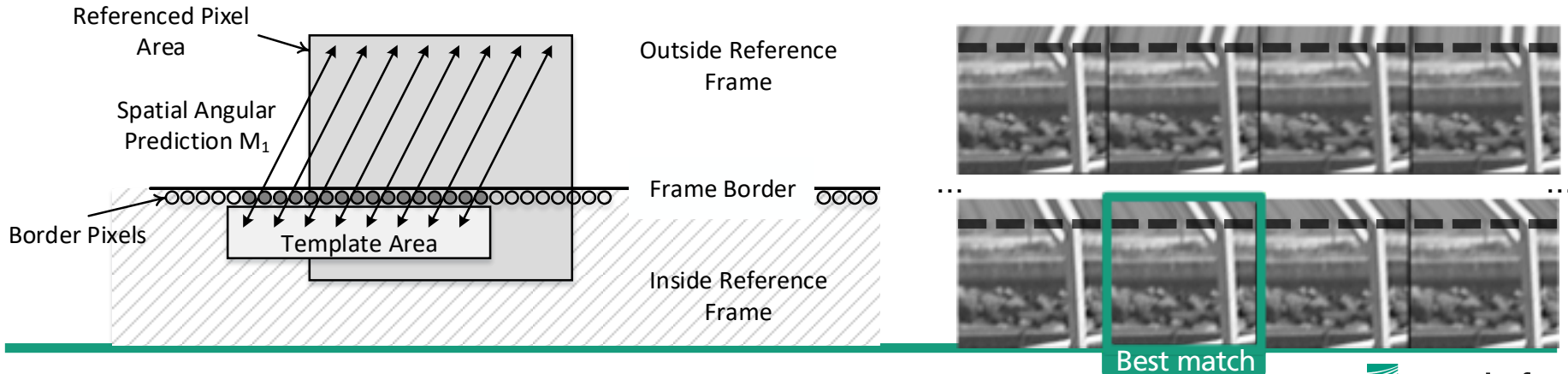
- Ratio of samples stemming from inter-prediction in boundary padding (64 samples wide)
- Inter-prediction based padding relatively seldom

|                    | RA           | LB           |
|--------------------|--------------|--------------|
| Class A1           | 11,41%       |              |
| Class A2           | 18,08%       |              |
| Class B            | 8,86%        | 4,72%        |
| Class C            | 4,49%        | 3,15%        |
| Class E            |              | 0,22%        |
| <b>Overall</b>     | <b>8,37%</b> | <b>2,05%</b> |
| Class D            | 2,95%        | 1,64%        |
| Class F (optional) | 1,37%        | 1,30%        |

# Intra-prediction based boundary padding

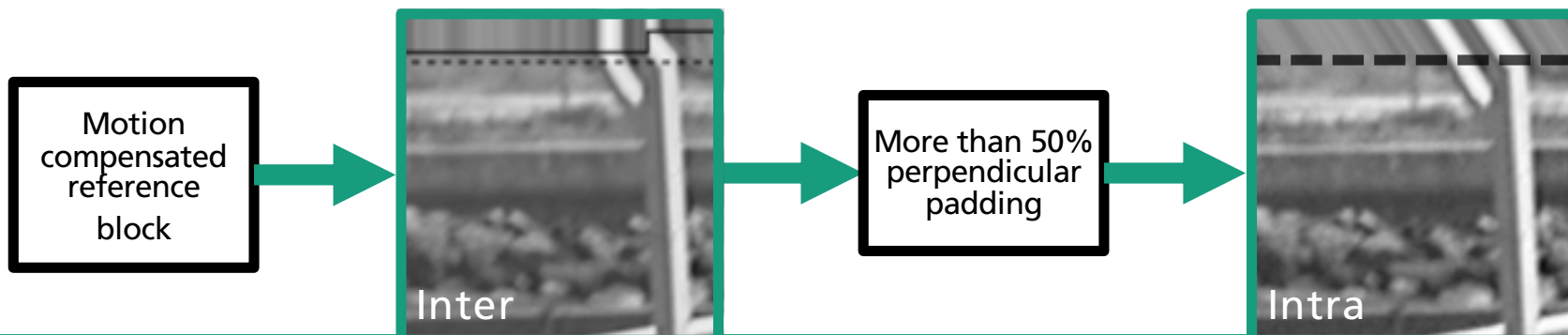
## ■ **Padding per reference (CE4-5.1):**

- Fill boundary padding area with directional intra prediction (33 modes)
- Determine intra mode based on decoded samples (2 samples x block height/width)
- Performs steady independent of codec configuration (RA/LD) or TL

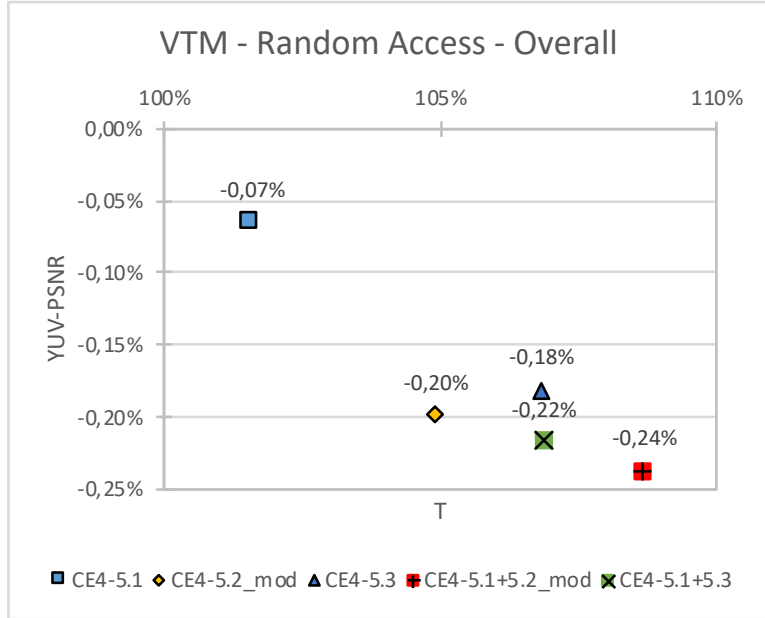


# Inter/Intra-prediction based boundary padding

- **Inter-prediction** (CE4-5.2 or CE4-5.3) based padding per picture
- If reference block contains boundary padding samples
  - If above threshold for perpendicular padding sample ratio (50% of padding)
    - **Intra-prediction** (CE4-5.1) based padding as fall back



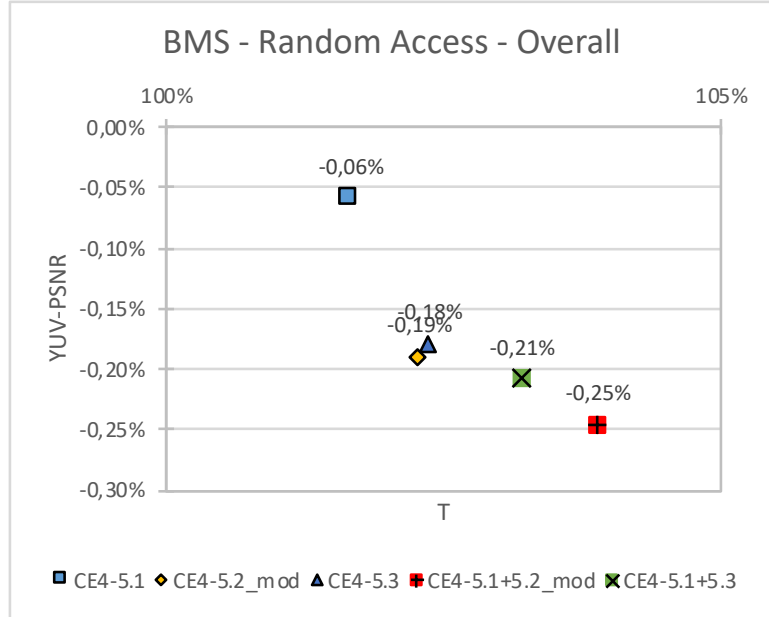
# Results – RA VTM



| VTM - RA - Overall     |               |               |               |             |             |
|------------------------|---------------|---------------|---------------|-------------|-------------|
| Test                   | Y             | U             | V             | Tenc        | Tdec        |
| CE4-5.1                | -0,07%        | -0,05%        | -0,07%        | 102%        | 101%        |
| CE4-5.2_mod            | -0,21%        | -0,20%        | -0,16%        | 101%        | 106%        |
| CE4-5.3                | -0,18%        | -0,19%        | -0,16%        | 100%        | 108%        |
| <b>CE4-5.1+5.2_mod</b> | <b>-0,25%</b> | <b>-0,24%</b> | <b>-0,20%</b> | <b>102%</b> | <b>110%</b> |
| CE4-5.1+5.3            | -0,22%        | -0,21%        | -0,20%        | 101%        | 108%        |

| VTM - RA - Class D     |               |               |               |             |             |
|------------------------|---------------|---------------|---------------|-------------|-------------|
| Test                   | Y             | U             | V             | Tenc        | Tdec        |
| CE4-5.1                | -0,14%        | 0,03%         | -0,29%        | 109%        | 108%        |
| CE4-5.2_mod            | -0,51%        | -0,38%        | -0,34%        | 103%        | 114%        |
| CE4-5.3                | -0,44%        | -0,28%        | -0,36%        | 101%        | 121%        |
| <b>CE4-5.1+5.2_mod</b> | <b>-0,61%</b> | <b>-0,47%</b> | <b>-0,72%</b> | <b>109%</b> | <b>129%</b> |
| CE4-5.1+5.3            | -0,54%        | -0,36%        | -0,59%        | 106%        | 121%        |

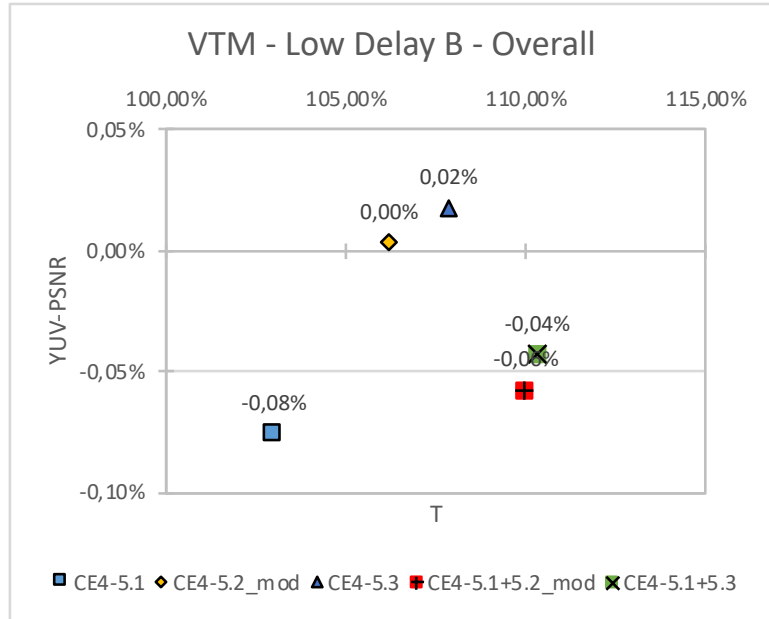
# Results – RA BMS



| BMS - RA - Overall     |               |               |               |             |             |
|------------------------|---------------|---------------|---------------|-------------|-------------|
| Test                   | Y             | U             | V             | Tenc        | Tdec        |
| CE4-5.1                | -0,04%        | -0,10%        | -0,08%        | 102%        | 102%        |
| CE4-5.2_mod            | -0,20%        | -0,19%        | -0,14%        | 101%        | 103%        |
| CE4-5.3                | -0,18%        | -0,17%        | -0,17%        | 101%        | 103%        |
| <b>CE4-5.1+5.2_mod</b> | <b>-0,25%</b> | <b>-0,24%</b> | <b>-0,23%</b> | <b>102%</b> | <b>104%</b> |
| CE4-5.1+5.3            | -0,20%        | -0,23%        | -0,21%        | 101%        | 104%        |

| BMS - RA - Class D     |               |               |               |             |             |
|------------------------|---------------|---------------|---------------|-------------|-------------|
| Test                   | Y             | U             | V             | Tenc        | Tdec        |
| CE4-5.1                | -0,11%        | -0,24%        | -0,27%        | 105%        | 108%        |
| CE4-5.2_mod            | -0,44%        | -0,47%        | -0,44%        | 102%        | 108%        |
| CE4-5.3                | -0,39%        | -0,30%        | -0,23%        | 101%        | 111%        |
| <b>CE4-5.1+5.2_mod</b> | <b>-0,58%</b> | <b>-0,56%</b> | <b>-0,57%</b> | <b>104%</b> | <b>116%</b> |
| CE4-5.1+5.3            | -0,51%        | -0,56%        | -0,61%        | 104%        | 113%        |

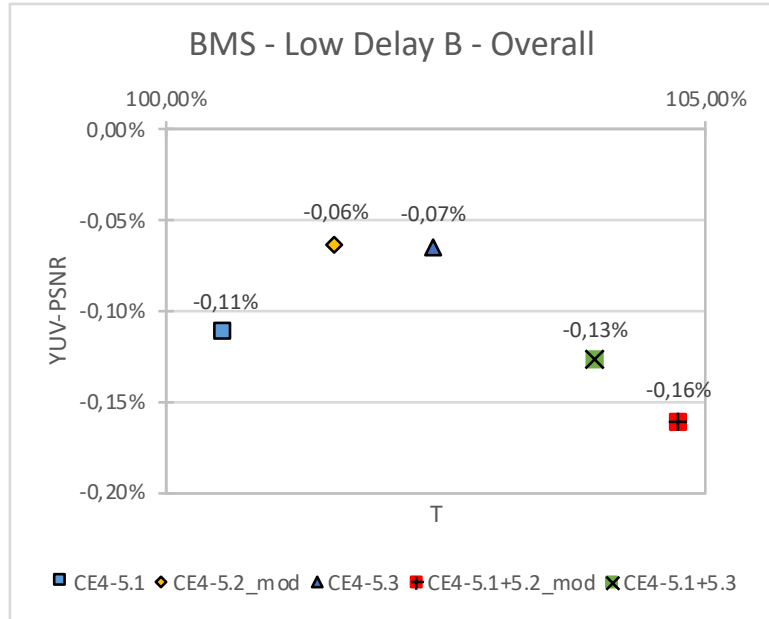
# Results – LD VTM



| VTM - LD - Overall     |               |               |              |             |             |
|------------------------|---------------|---------------|--------------|-------------|-------------|
| Test                   | Y             | U             | V            | Tenc        | Tdec        |
| CE4-5.1                | -0,07%        | -0,07%        | -0,11%       | 104%        | 103%        |
| CE4-5.2_mod            | -0,01%        | 0,05%         | 0,01%        | 100%        | 107%        |
| CE4-5.3                | -0,01%        | 0,12%         | 0,01%        | 100%        | 109%        |
| <b>CE4-5.1+5.2_mod</b> | <b>-0,08%</b> | <b>-0,13%</b> | <b>0,11%</b> | <b>104%</b> | <b>111%</b> |
| CE4-5.1+5.3            | -0,07%        | -0,06%        | 0,06%        | 104%        | 112%        |

| VTM - LD - Class D     |               |               |               |             |             |
|------------------------|---------------|---------------|---------------|-------------|-------------|
| Test                   | Y             | U             | V             | Tenc        | Tdec        |
| CE4-5.1                | -0,44%        | -1,08%        | -0,85%        | 117%        | 111%        |
| CE4-5.2_mod            | -0,03%        | -0,19%        | 0,16%         | 101%        | 111%        |
| CE4-5.3                | -0,09%        | -0,55%        | -0,20%        | 100%        | 117%        |
| <b>CE4-5.1+5.2_mod</b> | <b>-0,51%</b> | <b>-0,63%</b> | <b>-0,89%</b> | <b>117%</b> | <b>125%</b> |
| CE4-5.1+5.3            | -0,49%        | -1,06%        | -0,89%        | 118%        | 128%        |

# Results – LD BMS



| BMS - LD - Overall     |               |               |               |             |             |
|------------------------|---------------|---------------|---------------|-------------|-------------|
| Test                   | Y             | U             | V             | Tenc        | Tdec        |
| CE4-5.1                | -0,13%        | -0,08%        | -0,07%        | 103%        | 100%        |
| CE4-5.2_mod            | -0,09%        | -0,16%        | 0,15%         | 101%        | 102%        |
| CE4-5.3                | -0,07%        | -0,15%        | 0,03%         | 101%        | 103%        |
| <b>CE4-5.1+5.2_mod</b> | <b>-0,15%</b> | <b>-0,20%</b> | <b>-0,18%</b> | <b>104%</b> | <b>105%</b> |
| CE4-5.1+5.3            | -0,13%        | -0,26%        | 0,00%         | 103%        | 104%        |

| BMS - LD - Class D     |               |               |               |             |             |
|------------------------|---------------|---------------|---------------|-------------|-------------|
| Test                   | Y             | U             | V             | Tenc        | Tdec        |
| CE4-5.1                | -0,42%        | -0,77%        | -1,14%        | 110%        | 106%        |
| CE4-5.2_mod            | -0,06%        | 0,19%         | -0,54%        | 99%         | 102%        |
| CE4-5.3                | -0,05%        | 0,03%         | -0,35%        | 100%        | 108%        |
| <b>CE4-5.1+5.2_mod</b> | <b>-0,51%</b> | <b>-0,79%</b> | <b>-1,44%</b> | <b>110%</b> | <b>113%</b> |
| CE4-5.1+5.3            | -0,44%        | -0,83%        | -0,71%        | 109%        | 111%        |

# Summary

- Harmonized Inter/Intra-prediction based boundary padding
- Per-picture inter padding with conditional per-reference intra padding
- Overall: -0,24% BD-rate gain at 109% combined VTM Enc/Dec runtime
- Class D: -0.61% BD-rate gain at 125% combined VTM Enc/Dec runtime
- RA gains similar in VTM&BMS, LD gains higher in BMS
- BMS complexity fairly low, e.g. 104% combined Enc/Dec runtime in RA overall
- Complexity outside coding loop
- **Proposal:** Adopt best performing combination (CE4-5.1 + CE4-5.2\_mod)