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| **INTERNATIONAL ORGANIZATION FOR STANDARDIZATION ORGANISATION INTERNATIONALE DE NORMALISATION ISO/IEC JTC 1/SC 29/WG 5 MPEG JOINT VIDEO CODING TEAM(S) WITH ITU-T SG 16** |
| **ISO/IEC JTC 1 / SC 29 / WG 5 N 76** |
| **Online, 7–16 July 2021** |
| |  |  | | --- | --- | | **Title:** | **Exploration experiment on enhanced compression beyond VVC capability (EE2)** | | **Source:** | **Convenor (Jens-Rainer Ohm)** | | **Type:** | **General** | | **Subtype:** | **N/A** | | **Status:** | **Approved** | | **Date:** | **2021-09-23** | | **Expected Action:** | **Info** | | **Action due date:** | **N/A** | | **No. of pages** | 11 (without this cover page) | | **Email of convenor:** | **ohm @ ient . rwth-aachen . de** | | **Committee URL:** | **https://sd.iso.org/documents/ui/#!/browse/iso/iso-iec-jtc-1/iso-iec-jtc-1-sc-29/iso-iec-jtc-1-sc-29-wg-5** | |

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| **Joint Video Experts Team (JVET)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29**  23rd Meeting, by teleconference, 7–16 July 2021 | Document: JVET-W2024-v4 |

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| --- | --- | --- | --- |
| *Title:* | **Exploration Experiment on Enhanced Compression beyond VVC capability (EE2)** | | |
| *Status:* | Output document to JVET | | |
| *Purpose:* | EE description | | |
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| *Source:* | EE coordinators | | |

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# Abstract

This document describes Exploration Experiments (EEs) planned to be performed between 23rd and 24th JVET meetings to evaluate enhanced compression tools beyond VVC capability.

# Introduction

EE focus is to evaluate individual coding technologies and their combinations. Contributions improving compression efficiency further is highly encouraged.

EE related discussions shall happen on JVET and JVET-CE reflectors.

EE tests should be implemented on top the ECM software, ECM-2.0 is used as an anchor in the tests. For optional tool-on tests, VTM-11.0 with the improved MCTF from JVET-V0056 should be used as an anchor. ECM software can be found at <https://vcgit.hhi.fraunhofer.de/ecm/VVCSoftware_VTM>.

Tests shall be performed according to the CTC described in JVET-W2017 with an additional TGM 4:2:0 optional class. TGM tests are required for testing SCC tools.

AI and RA test configurations are required for intra tool testing, while RA and LB test configurations are required for inter tool testing. LP configuration is optional. In LB and LP configurations, the sequences length is reduced to 5 seconds for all classes.

# Timeline

**T1** = 2 weeks (July 30, 2021) after JVET meeting: ECM is released

**T2** = T1 + 1 week (August 6, 2021): EE description is finalized

**T3** = T2 + 2 weeks (August 20, 2021): Initial software release for EE tests

**T4** = JVET meeting start – 3 weeks (September 17, 2021): Software in EE branches is frozen

# List of tools

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Tests** | **Tester** | **Cross-checker** |
| **1 Partitioning** | | | |
| 1.1 | Encoder optimization for ECM | ByteDance  [Kai Zhang](mailto:zhangkai.video@bytedance.com)  InterDigital  [Fabrice Le Léannec](mailto:fabrice.leleannec@interdigital.com) |  |
| 1.2 | ABT | ByteDance  [Kai Zhang](mailto:zhangkai.video@bytedance.com)  InterDigital  [Fabrice Le Léannec](mailto:fabrice.leleannec@interdigital.com) |  |
| 1.3 | UQT | ByteDance  [Kai Zhang](mailto:zhangkai.video@bytedance.com)  InterDigital  [Fabrice Le Léannec](mailto:fabrice.leleannec@interdigital.com) |  |
| 1.4 | ABT + UQT | ByteDance  [Kai Zhang](mailto:zhangkai.video@bytedance.com)  InterDigital  [Fabrice Le Léannec](mailto:fabrice.leleannec@interdigital.com) |  |
| **2 Intra prediction** | | | |
| ~~2.1~~ | ~~MPM sorting based on TIMD cost~~ | ~~Qualcomm~~  [~~Keming Cao~~](mailto:kemicao@qti.qualcomm.com) | withdrawn |
| **3 Inter prediction** | | | |
| 3.1a | Combination of CIIP and DIMD | Alibaba  [Xinwei Li](mailto:sid.lxw@alibaba-inc.com) |  |
| 3.1b | Combination of CIIP and TIMD | Alibaba  [Xinwei Li](mailto:sid.lxw@alibaba-inc.com) |  |
| 3.2a | GPM with inter and intra prediction – method A | KDDI  [Yoshitaka Kidani](mailto:yo-kidani@kddi.com) |  |
| 3.2b | GPM with inter and intra prediction – method B | KDDI  [Yoshitaka Kidani](mailto:yo-kidani@kddi.com) |  |
| 3.3a | Bilateral matching AMVP-merge mode | Qualcomm  [Zhi Zhang](mailto:zhizhang@qti.qualcomm.com) |  |
| 3.3b | Bilateral matching AMVP-merge mode with TM disabled | Qualcomm  [Zhi Zhang](mailto:zhizhang@qti.qualcomm.com) |  |
| 3.3c | Template matching AMVP-merge mode | Qualcomm  [Zhi Zhang](mailto:zhizhang@qti.qualcomm.com) |  |
| 3.4a | Adaptive decoder side motion vector refinement | Qualcomm  [Han Huang](mailto:hanhuang@qti.qualcomm.com) |  |
| 3.4b | Adaptive decoder side motion vector refinement with TM disabled | Qualcomm  [Han Huang](mailto:hanhuang@qti.qualcomm.com) |  |
| **4 In-loop filtering** | | | |
| 4.1 | Chroma bilateral filter | Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com) |  |
| 4.2a | CTB level filter shape selection of CCALF | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) | Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.2b | CTB level filter shape selection of CCALF with removal of power of 2 constraint of filter coefficients | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) | Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.3a | CCALF with larger filter size | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) | Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.3b | CCALF with larger filter size with removal of power of 2 constraint of filter coefficients | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) | Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.4 | Alternative 2x2 classifiers for ALF | Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) |
| 4.5 | Alternative sample-based classifier for ALF | Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) |
| 4.6a | Combination of 4.2a and 4.4 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |  |
| 4.6b | Combination of 4.2a and 4.5 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |  |
| 4.6c | Combination of 4.3a and 4.4 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |  |
| 4.6d | Combination of 4.3a and 4.5 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |  |
| 4.7a | Combination of 4.2a and 4.1 (CTB level filter shape selection of CCALF and Chroma Bilateral) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com) |  |
| 4.7b | Combination of 4.3a and 4.1 (CCALF with larger filter size and Chroma Bilateral) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com) |  |
| 4.8a | Combination of 4.6a and 4.1 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |  |
| 4.8b | Combination of 4.6b and 4.1 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |  |
| 4.8c | Combination of 4.6c and 4.1 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |  |
| 4.8d | Combination of 4.6d and 4.1 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |  |
| 4.9a | Combination of 4.1 and 4.4 (Chroma Bilateral Filter and alternative 2x2 classifiers for ALF) | Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  Nan Hu |  |
| 4.9b | Combination of 4.1 and 4.5 (Chroma Bilateral Filter and alternative sample-based classifiers for ALF) | Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  Nan Hu |  |

# Tools description

## Partitioning

### Asymmetric Binary Tree (ABT) partitioning (JVET-W0087)

Four new asymmetric binary tree splitting modes are added to the multi-type tree structure of VVC, to allow new splitting configurations. These added split modes are shown on Figure 1.

According to the added split modes, a coding unit with size S is divided into 2 sub-CU with sizes S/4 and 3.S/4, either in the horizontal or in the vertical direction. In practice the added available CU sizes are 6, 12, 24 and 48.

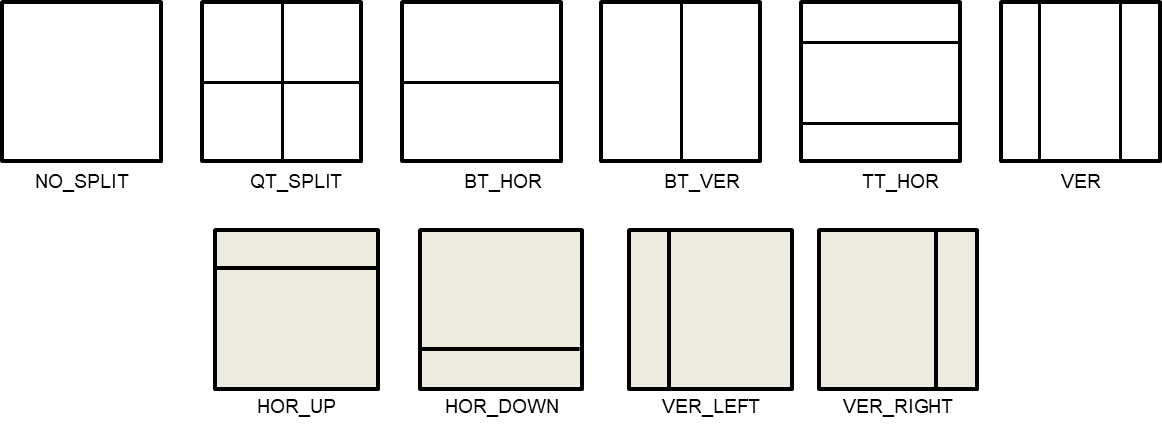


Figure 1. Split modes supported in the proposed QTBT+TT+ABT framework

### Unsymmetric Quad-Tree (UQT) partitioning (JVET-W0087)

Four types of UQT are proposed. UQT-H1 and UQT-H2 split a CU with dimension W×H into four child-CUs with dimensions {W×H/8, W×H/2, W×H/4, W×H/8} and {W×H/8, W×H/4, W×H/2, W×H/8}, respectively. UQT-V1 and UQT-V2 split a CU with dimension W×H into four child-CUs with dimensions {W/8×H, W/2×H, W/4×H, W/8×H} and {W/8×H, W/4×H, W/2×H, W/8×H}, respectively.

In those partitioning tests, additional encoder optimization is applied. During EE2 discussion, it was requested to test such encoder optimizations applied to ECM anchor.

It was also requested to provide similar complexity points (encoder runtime) for comparison purpose among different partitioning tests.

***List of tests to be performed***

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 1.1 | Encoder optimization for ECM | ByteDance  [Kai Zhang](mailto:zhangkai.video@bytedance.com)  InterDigital  [Fabrice Le Léannec](mailto:fabrice.leleannec@interdigital.com) |
| 1.2 | ABT | ByteDance  [Kai Zhang](mailto:zhangkai.video@bytedance.com)  InterDigital  [Fabrice Le Léannec](mailto:fabrice.leleannec@interdigital.com) |
| 1.3 | UQT | ByteDance  [Kai Zhang](mailto:zhangkai.video@bytedance.com)  InterDigital  [Fabrice Le Léannec](mailto:fabrice.leleannec@interdigital.com) |
| 1.4 | ABT + UQT | ByteDance  [Kai Zhang](mailto:zhangkai.video@bytedance.com)  InterDigital  [Fabrice Le Léannec](mailto:fabrice.leleannec@interdigital.com) |

## Intra prediction

### MPM sorting based on TIMD cost (JVET-W0124)

Sorting method on intra most probable modes (MPMs) list based on TIMD cost is tested. For each intra mode in the list, the sum of absolute transformed differences between prediction and reconstruction samples of a template is computed, based on which MPMs are sorted.

***List of tests to be performed***

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 2.1 | MPM sorting based on TIMD cost | Qualcomm  [Keming Cao](mailto:kemicao@qti.qualcomm.com) |

## Inter prediction

### Combination of CIIP and DIMD/TIMD (JVET-W0068)

In CIIP mode, the prediction samples are generated by weighting an inter prediction signal predicted using regular merge mode and an intra prediction signal predicted using planar mode. In this test, replacing planar mode in CIIP with other intra prediction mode which is implicitly derived by DIMD or TIMD method.

***List of tests to be performed***

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 3.1a | Combination of CIIP and DIMD | Alibaba  [Xinwei Li](mailto:sid.lxw@alibaba-inc.com) |
| 3.1b | Combination of CIIP and TIMD | Alibaba  [Xinwei Li](mailto:sid.lxw@alibaba-inc.com) |

### GPM with inter and intra prediction (JVET-W0110)

Geometric partitioning mode (GPM) with inter and intra prediction is tested. With the method, pre-defined intra prediction modes against geometric partitioning line can be selected in addition to motion vectors from a merge candidate list for each non-rectangular split region in the GPM-applied coding unit.

For the variation of possible intra prediction mode, the following two options are tested.

Method A: Pre-defined intra prediction modes are restricted to the parallel and perpendicular angular mode against GPM-splitting line.

Method B: Pre-defined intra prediction modes are restricted to the parallel and perpendicular angular mode against GPM-splitting line, and planar mode.

Tests for AI and LDP configurations will be provided. Intra only (AI) tests were withdrawn.

***List of tests to be performed***

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 3.2a | GPM with inter and intra prediction – method A | KDDI  [Yoshitaka Kidani](mailto:yo-kidani@kddi.com) |
| 3.2b | GPM with inter and intra prediction – method B | KDDI  [Yoshitaka Kidani](mailto:yo-kidani@kddi.com) |

### Bilateral matching AMVP-merge mode (JVET-W0106)

In these tests, bilateral matching and template matching AMVP-merge mode is investigated, where AMVP and merge inter predictors are combined. The merge candidate list is reordered based on the minimum bilateral matching error between a reference block that is generated by AMVP candidate and a reference block that is generated by the merge candidate or merge list is reordered based on the template matching cost. The motion vector of the merge inter predictor is selected from the reordered merge list.

Additionally, this method is tested with the template matching methods disabled in the anchor and the test: TM AMVP, TM MERGE, TM GPM, ARMC.

***List of tests to be performed***

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 3.3a | Bilateral matching AMVP-merge mode | Qualcomm  [Zhi Zhang](mailto:zhizhang@qti.qualcomm.com) |
| 3.3b | Bilateral matching AMVP-merge mode with TM disabled | Qualcomm  [Zhi Zhang](mailto:zhizhang@qti.qualcomm.com) |
| 3.3c | Template matching AMVP-merge mode | Qualcomm  [Zhi Zhang](mailto:zhizhang@qti.qualcomm.com) |

### Adaptive decoder side motion vector refinement (JVET-W0107)

In this test, adaptive decoder side motion vector refinement method is investigated. In the method, two new merge modes are designed, in which each of the merge candidate satisfies the DMVR conditions. The multi-pass DMVR process is applied to the selected merge candidate to refine the motion vectors. However, in the first pass of BM process, instead of imposing the symmetric MVD constrain (MVD0 = -MVD1), MVD0 is set equal to zero vector in one of the new merge modes and MVD1 is set equal to zero vector in the other new merge mode.

The merge candidates for the new merge mode are derived from spatial neighboring coded blocks, TMVPs, non-adjacent blocks, HMVPs, pair-wise candidate, similar as in the regular merge mode. The difference is that only those satisfy DMVR conditions are added into the candidate list. The same merge candidate list is used by the two new merge modes. Merge index is coded as in regular merge mode.

Additionally, this method is tested with the template matching methods disabled in the anchor and the test: TM AMVP, TM MERGE, TM GPM, ARMC.

***List of tests to be performed***

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 3.4a | Adaptive decoder side motion vector refinement | Qualcomm  [Han Huang](mailto:hanhuang@qti.qualcomm.com) |
| 3.4b | Adaptive decoder side motion vector refinement with TM disabled | Qualcomm  [Han Huang](mailto:hanhuang@qti.qualcomm.com) |

## In-loop filtering

### Chroma bilateral filter (JVET-W0098)

This method extends Bilateral Inloop Filter (BIF) in ECM to chroma components. The BIF-chroma keeps the same design as BIF-luma in ECM. A diamond 5×5 filtering kernel and a CTU level on/off control mechanism are used. The filtering coefficients are retrained for chroma components and the filtering strength for chroma is decided based on the chroma block size as well as the corresponding luma block size.

***List of tests to be performed***

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 4.1 | Chroma bilateral filter | Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com) |

### CTB level filter shape selection of CCALF (JVET-W0079)

CTB level filter shape selection of CCALF process is tested. Two filter shapes are used. In the test, in each APS, up-to 16 filters and their associated shapes and coefficients are signalled. For each CTB, an index is signalled to the decoder to specify which filter shape and coefficients are used for that CTB.

In addition to multiple filter shapes, this tests also includes the removal the power of 2 constraint of filter coefficient values.

During JVET-W0079 review, it was asked the impact of the removed power of 2 constraint of filter coefficient values and whether similar gain can be achieved by only increasing the filter size in CCALF.

***List of tests to be performed***

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 4.2a | CTB level filter shape selection of CCALF | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) |
| 4.2b | CTB level filter shape selection of CCALF with removal of power of 2 constraint of filter coefficients | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) |
| 4.3a | CCALF with larger filter size | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) |
| 4.3b | CCALF with larger filter size with removal of power of 2 constraint of filter coefficients | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com) |

### Alternative classifiers for ALF (JVET-W0128)

In adaptive loop filter process of ECM, when a signalled filter set is applied to a luma coding tree block, a classifier is applied to each 2x2 luma block. For each class, a specific filter is applied among the signalled filter set. Based on the classification, a geometric transformation can also be applied. In this test, a two-classifier method is applied, and two options of the second classifier is tested: band classification based on 2x2 blocks and sample-based band classification. For a luma filter set, a flag is signalled to indicate whether the classifier in ECM-1.0 or the proposed alternative classifier is applied.

***List of tests to be performed***

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 4.4 | Alternative 2x2 classifiers for ALF | Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.5 | Alternative sample-based classifier for ALF | Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |

### Combination of in-loop filtering tests

This section defines the combination tests for in-loop filtering methods.

|  |  |  |
| --- | --- | --- |
| # | Test | Tester |
| 4.6a | Combination of 4.2a and 4.4 (CTB level filter shape selection of CCALF and alternative 2x2 classifiers for ALF) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.6b | Combination of 4.2a and 4.5 (CTB level filter shape selection of CCALF and alternative sample-based classifiers for ALF) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.6c | Combination of 4.3a and 4.4 (CCALF with larger filter size and alternative 2x2 classifiers for ALF) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.6d | Combination of 4.3a and 4.5 (CCALF with larger filter size and alternative sample-based classifiers for ALF) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.7a | Combination of 4.2a and 4.1 (CTB level filter shape selection of CCALF and Chroma Bilateral) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com) |
| 4.7b | Combination of 4.3a and 4.1 (CCALF with larger filter size and Chroma Bilateral) | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com) |
| 4.8a | Combination of 4.6a and 4.1 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.8b | Combination of 4.6b and 4.1 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.8c | Combination of 4.6c and 4.1 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.8d | Combination of 4.6d and 4.1 | Alibaba  [Mohammed Golam Sarwer](mailto:m.sarwer@alibaba-inc.com)  Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  [Nan Hu](mailto:nanh@qti.qualcomm.com) |
| 4.9a | Combination of 4.1 and 4.4 (Chroma Bilateral Filter and alternative 2x2 classifiers for ALF) | Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  Nan Hu |
| 4.9b | Combination of 4.1 and 4.5 (Chroma Bilateral Filter and alternative sample-based classifiers for ALF) | Bytedance  [Wenbin Yin](mailto:yinwenbin.hit@bytedance.com)  Qualcomm  Nan Hu |