JCTVC-E221:
On memory compression for motion vector prediction

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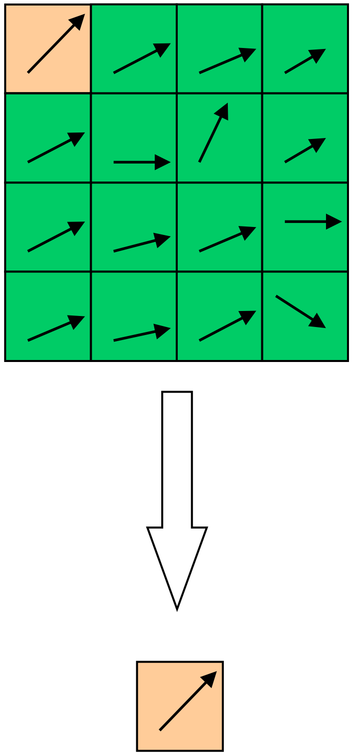
Introduction

- Current Motion Vectors Buffer in HM2.0
  - Proposed in JCTVC-D072 (Sharp) and adopted in HM2.0
  - Principle: Motion vectors summarizing:
    - Keep one 4x4 vector representative over 16
    - Top-Left candidate
  - Performance:
    - 0.8% loss on HM2.0 anchors due to MV buffer compression



- Proposal – 1 change / 3 improvements
  1. Fix an issue related to Motion data buffer compression
  2. Change the block used for the summarization process
  3. Adaptive MV components clipping
  4. Motion vectors scaling in one single list

Data related to the temporal motion vector predictor

- **Data needed:**
  - Collocated motion vector field
  - Reference frame Index of each motion vector
  - List index
  - Mode: Intra/Inter

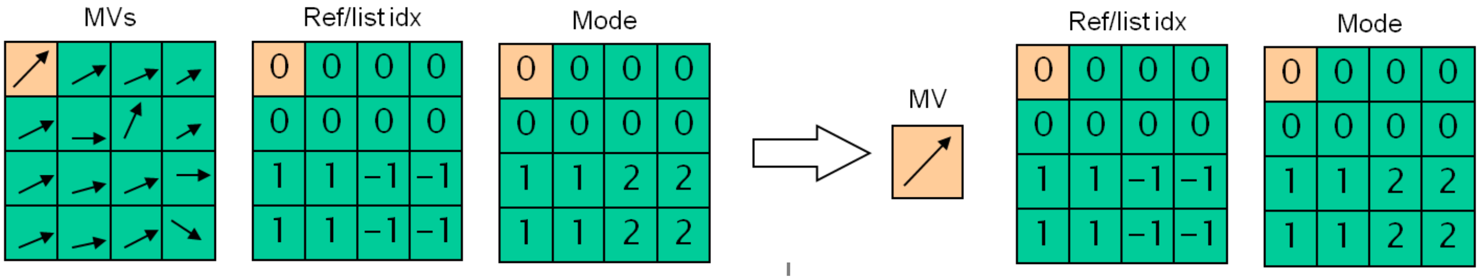
- **Total 55 bits per block need to be store**

L0		L1	
Mvx	12 bits	Mvx	12 bits
Mvy	12 bits	Mvy	12 bits
Ref idx	2 bits	Ref idx	2 bits
List idx	1 bit	List idx	1 bit
Inter/Intra mode			
1 bit			

Total
55 bits

1 - Issue related to ref/list indexes and mode storage

- Real compression rate in current HM2.0 implementation is 5.5
  - Considering 12 bits per MV component



Ref/list idx

0	0	0	0
0	0	0	0
1	1	-1	-1
1	1	-1	-1

Mode

0	0	0	0
0	0	0	0
1	1	2	2
1	1	2	2

Ref/list idx

0	0	0	0
0	0	0	0
1	1	-1	-1
1	1	-1	-1

Mode

0	0	0	0
0	0	0	0
1	1	2	2
1	1	2	2

Without Compression

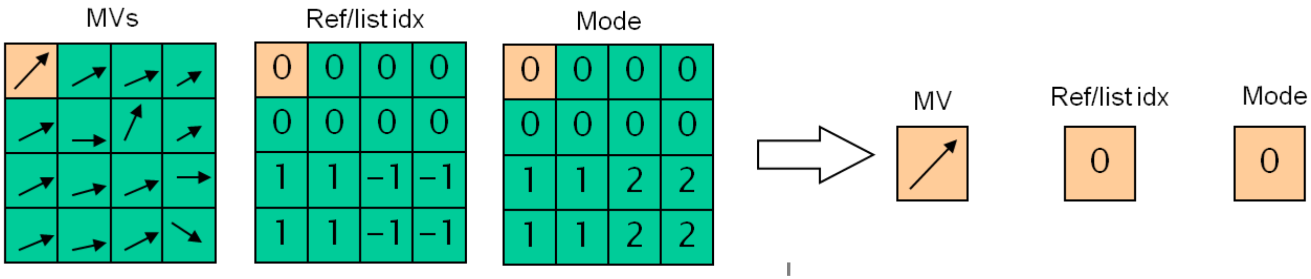
16 4x4 blocks		
MVs	Ref/list idx	Mode
48x16=**768** bits	6x16=**96** bits	1x16=16 bits
Total		**880** bits
Compression ratio		**1x**

Current MV Buffer Compression

16 4x4 blocks		
MVs	Ref/list idx	Mode
48 bits	96 bits	16 bits
Total		**160** bits
Compression ratio		**5.5x**

1 - Issue related to ref/list indexes and mode storage

- Proposal
  - Also summarize ref indexes and modes with same ratio as MVs



Ref/list idx

0	0	0	0
0	0	0	0
1	1	-1	-1
1	1	-1	-1

Mode

0	0	0	0
0	0	0	0
1	1	2	2
1	1	2	2

Without Compression

Bits / 16 4x4 blocks		
MVs	Ref/list idx	Mode
768	96	16
Total		**880**
Compression ratio		**1x**

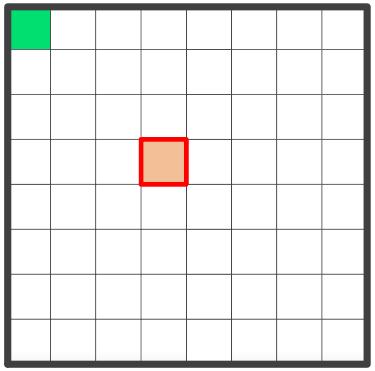
MV Buffer (ref/list included) Compression

Bits / 16 4x4 blocks		
MVs	Ref/list idx	Mode
48	6	1
Total		**55**
Compression ratio		**16x**

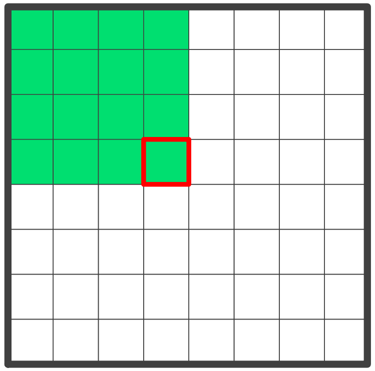
2 – Modify the Block summarization candidate

- Use Bottom-Right instead of Top-Left
  - For small CUs, gives more diversity compared to spatial predictors
  - For large CUs, Bottom Right vector is closer to the 'real' collocated centered blocks

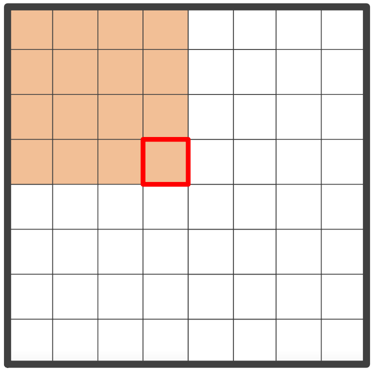
No MV memory compression
Temporal MV is the central MV
(red bold lines)



MV memory compression x16
with Top Left
central MV=top left MV

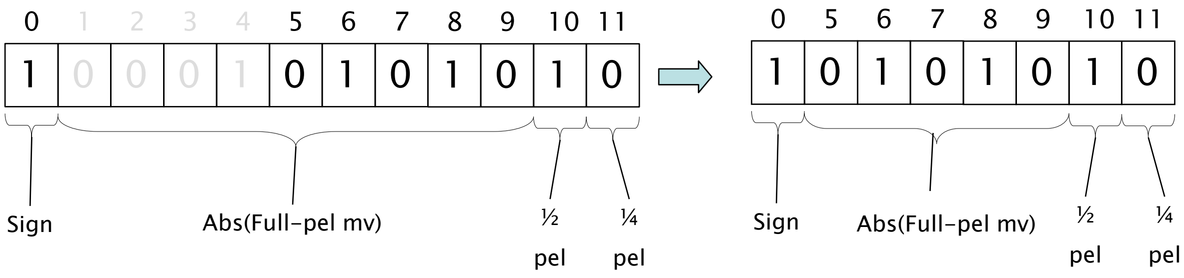


MV memory compression x16
with Bottom right
central MV is the right one



3 – Adaptive MV components Clipping

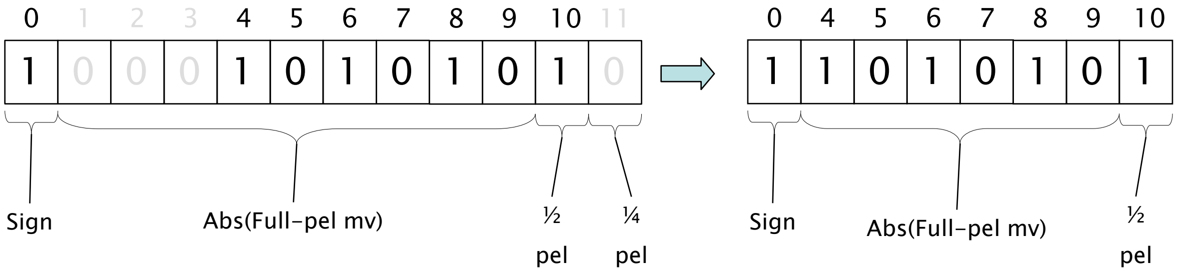
- **Each collocated motion vector component is clipped from 12 to 8 bits**
  - «Clip3» process as specified in H.264/AVC
  - Case 1: current frame is close to its nearest reference frame
    → only reduce the range of each Motion Vector



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

0	5	6	7	8	9	10	11
1	0	1	0	1	0	1	0

  - Case 2: larger distance between current frame and its nearest reference frame
    → reduce the range and accuracy of each Motion Vector



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

0	4	5	6	7	8	9	10
1	1	0	1	0	1	0	1

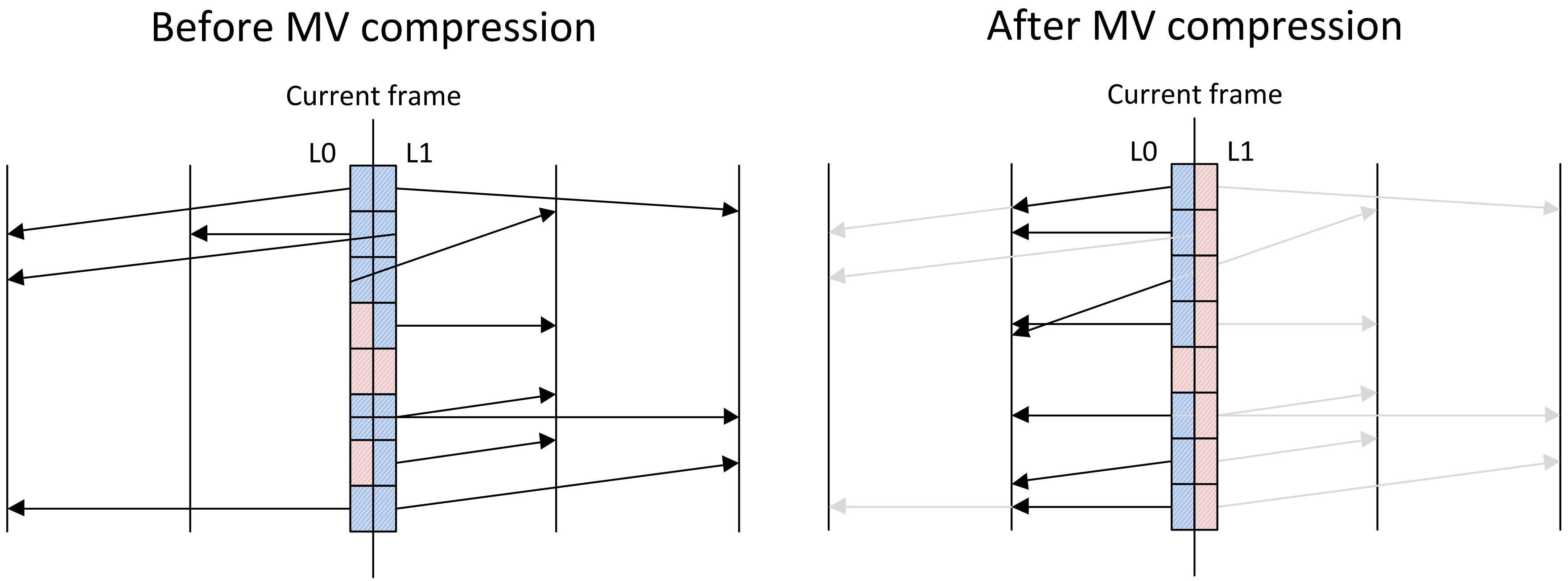
4 – Motion vectors scaling in one single list

- Motion Vector field is scaled to the nearest reference frame
- Only the list L0 is stored
  - When only MV_L1 available, apply a scaling to convert into MV_L0

▨ MV available

▨ MV not available

▨▨ Intra mode



Before MV compression

After MV compression

4 – Motion vectors scaling in one single list

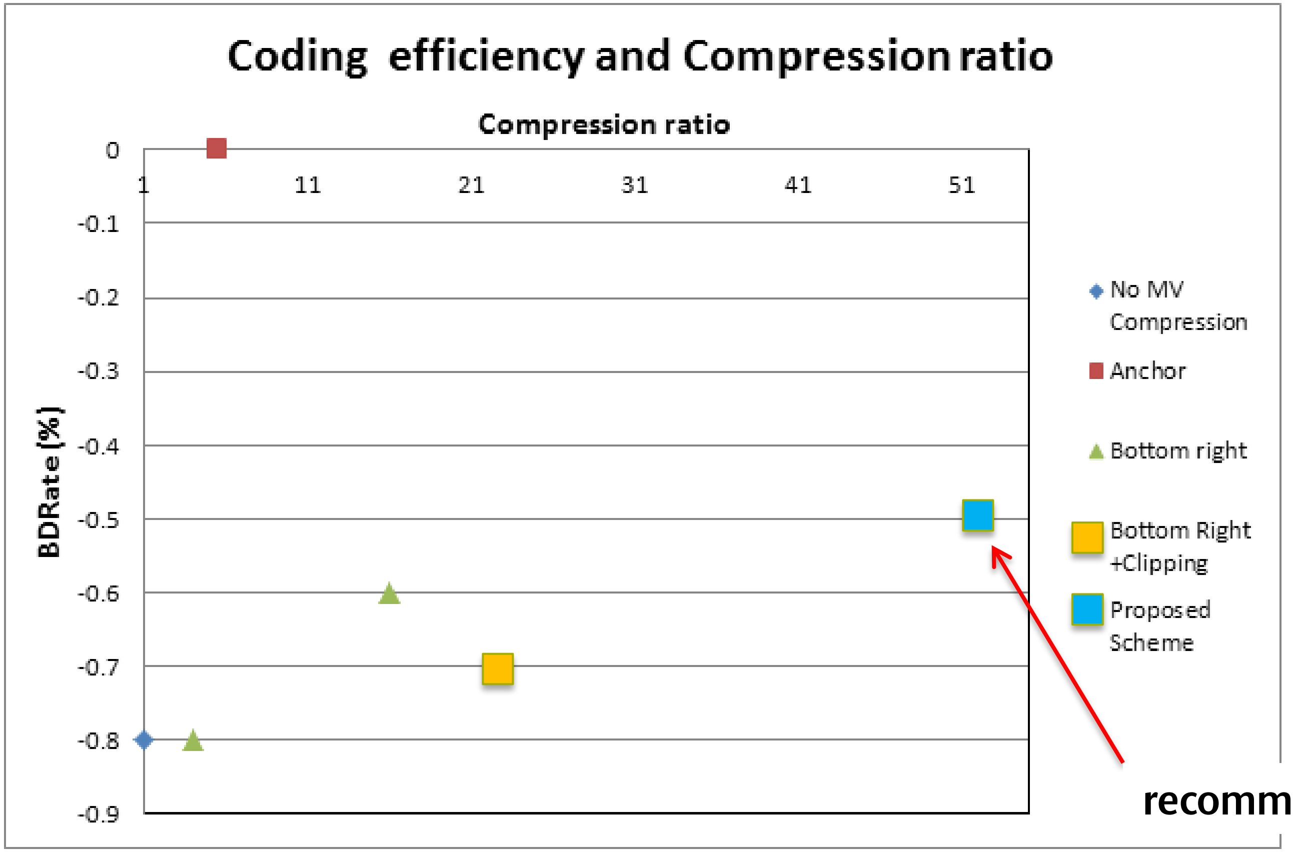
- Resulting compression ratio:
  - 17 bits needed instead of 55 = 3.2
  - With block summarization: compression ratio 52x

L0		L1	
Mvx	8 bits	Mvx	8 bits
Mvy	8 bits	Mvy	8 bits
Ref idx	2 bits	Ref idx	2 bits
List idx	1 bit	List idx	1 bit
mode			
1 bit			
Total			
17 bits			

Results

Configuration			MV Block summarization	Compression ratio	Mbits/frame 4kx2k	Average BDRate
Bottom Right	Clipping	Scaling				
✓			4	4x	7.6	-0.8
✓	✓	✓	4	13x	2.4	-0.7
✓			16	16x	1.9	-0.6
✓	✓		16	22.6x	1.3	-0.7
✓	✓	✓	16	52x	0.6	-0.5
No MV compression			-	1x	30.4	-0.8
Anchor			16	5.5x	5.5	0.0

Results



recommended

Conclusion

- Proposal – 1 change and 3 improvements
  1. Fix an issue related to Motion data buffer compression

  2. Change the block used for the summarization process
  3. Adaptive MV components clipping
  4. Motion vectors scaling in one single list

- All combined
  - **0.5%** gain v.s HM2.0 anchors with a compression ratio of **52 instead of 5.5**
  - 0.3% loss compared to HM2.0 anchors without MV buffer compression

- Cross-check performed by Sharp
  - JCTVC-E410
- We recommend to adopt these modifications in the HM design

ANNEX: more detailed results

1 - Issue related to ref/list indexes and mode storage

- **Results 1**

	Compression ratio	RAHE	RALC	LDHE	LDLC
H2.0 anchors	5.5x	0.0	0.0	0.0	0.0
Full summarization	16x	0.0	0.0	-0.1	-0.1

2 – Modify the Block summarization candidate

- Results 1+2

Compression ratio	4x					16x				
	RAHE	RALC	LDHE	LDLC	AVG	RAHE	RALC	LDHE	LDLC	AVG
Top Left	-0.6	-0.5	-0.8	-0.8	**-0.7**	0.0	0.0	-0.1	-0.1	**0.0**
Bottom Right	-0.6	-0.7	-0.9	-0.9	**-0.8**	-0.5	-0.5	-0.6	-0.6	**-0.6**

3 – Reduce the number of bits to store the MV components

- **Results 1+2+3**

Compression ratio	22.6x				
	RAHE	RALC	LDHE	LDLC	AVG
Bottom right + MV clipping	-0.7%	-0.6%	-0.7%	-0.6%	**-0.7%**

4 – Motion vectors scaling in one single list

- **Results 1+2+3+4**

Compression ratio	13x					52x				
	RAHE	RALC	LDHE	LDLC	AVG	RAHE	RALC	LDHE	LDLC	AVG
Bottom Right + MV Clipping +MV scaling	-0.6	-0.5	-0.8	-0.8	**-0.7**	-0.5	-0.4	-0.5	-0.6	**-0.5**

Combination Bottom-Right + MV shift + MV Scaling

	Random access			Random access LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	-0.1	-0.2	-0.3	-0.1	0.0	0.1
Class B	-0.4	-0.3	-0.3	-0.3	-0.1	-0.1
Class C	-0.7	-0.6	-0.7	-0.6	-0.4	-0.4
Class D	-0.8	-0.8	-0.8	-0.6	-0.6	-0.7
Class E						
All	-0.5	-0.5	-0.5	-0.4	-0.3	-0.2
Enc Time[%]	100%			100%		
Dec Time[%]	99%			98%		

	Low delay			Low delay LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A						
Class B	-0.4	-0.2	-0.4	-0.3	-0.2	-0.2
Class C	-0.6	-0.6	-0.5	-0.7	-0.7	-0.8
Class D	-0.7	-1.1	-0.9	-0.6	-0.4	-0.3
Class E	-0.6	-0.7	-0.3	-0.7	-0.9	-0.8
All	-0.5	-0.6	-0.5	-0.6	-0.5	-0.5
Enc Time[%]	100%			100%		
Dec Time[%]	99%			99%		