Fast Screen Content Coding

Fanyi Duanmu
Video Lab
Tandon School of Engineering
New York University
https://sites.google.com/site/duanmufanyi/

Agenda

Part 1: Fast Screen Content Encoding

- Background Review
- Fast Screen Content Encoder Design

Part 2: Fast Screen Content Transcoding

- Fast HEVC-SCC Transcoder Design
- Fast SCC-HEVC Transcoder Design
- Screen Content Adaptive Streaming Over Edge Cloud
- Summary

Part 1 – Fast Screen Content Encoding

Related Publications:

F. Duanmu, Z. Ma, and Y. Wang, “Fast Mode and Partition Decision Using Machine Learning for Intra-Frame Coding in HEVC Screen Content Coding Extension”, IEEE Journal on Emerging and Selected Topics in Circuits and Systems (JETCAS), Vol: 6, Issue: 4, Page:517-531, 2016.

F. Duanmu, Z. Ma, and Y. Wang, “Fast CU Partition Decision Using Machine Learning for Screen Content Compression”, in Proc. IEEE International Conference on Image Processing (ICIP), pp. 4972 - 4976, Quebec City, Canada, 2015.

Video LAB
NYU | TANDON SCHOOL OF ENGINEERING

Fanyi Duanmu
Video Lab
Tandon School of Engineering
New York University
https://sites.google.com/site/duanmufanyi/

Background


Remote Desktop Interfacing

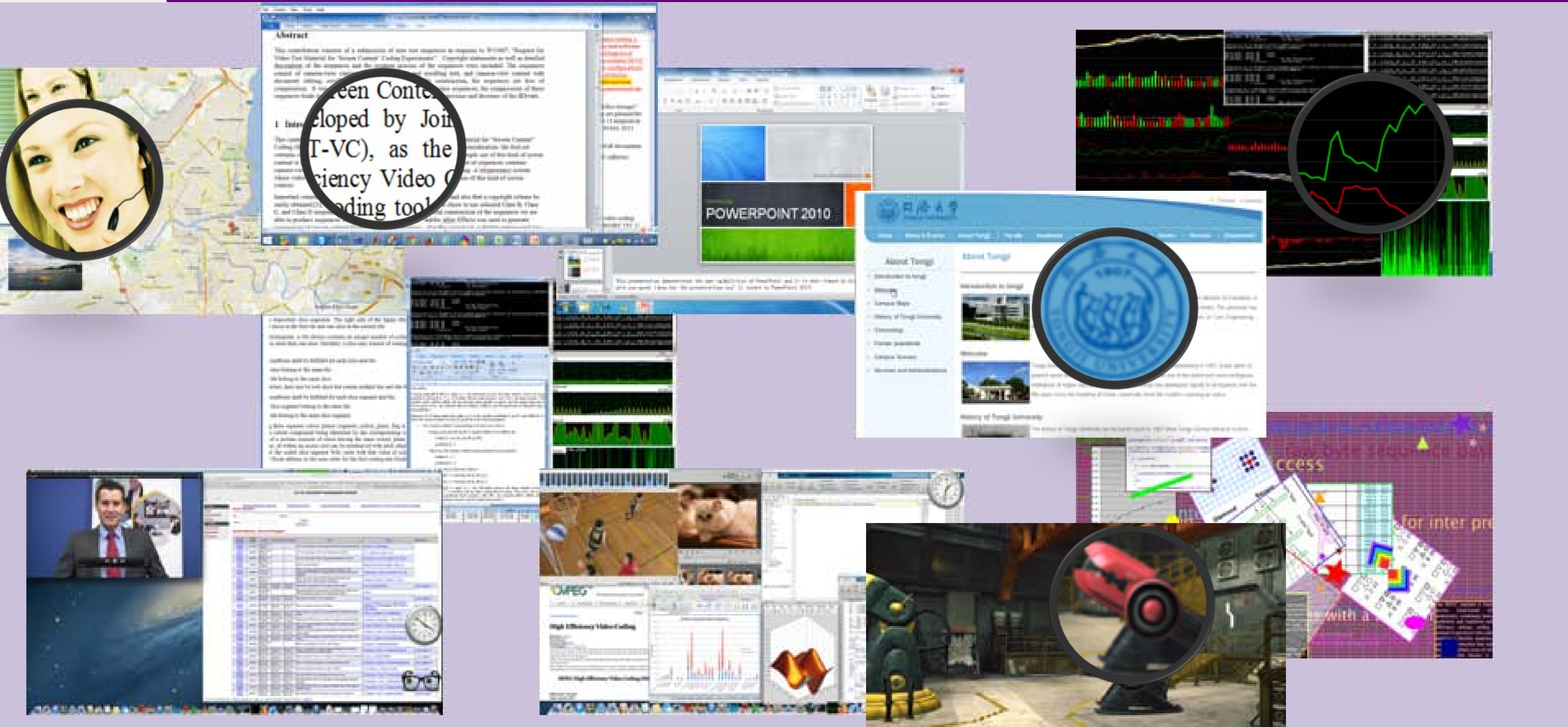

Animation Streaming

Wireless Display

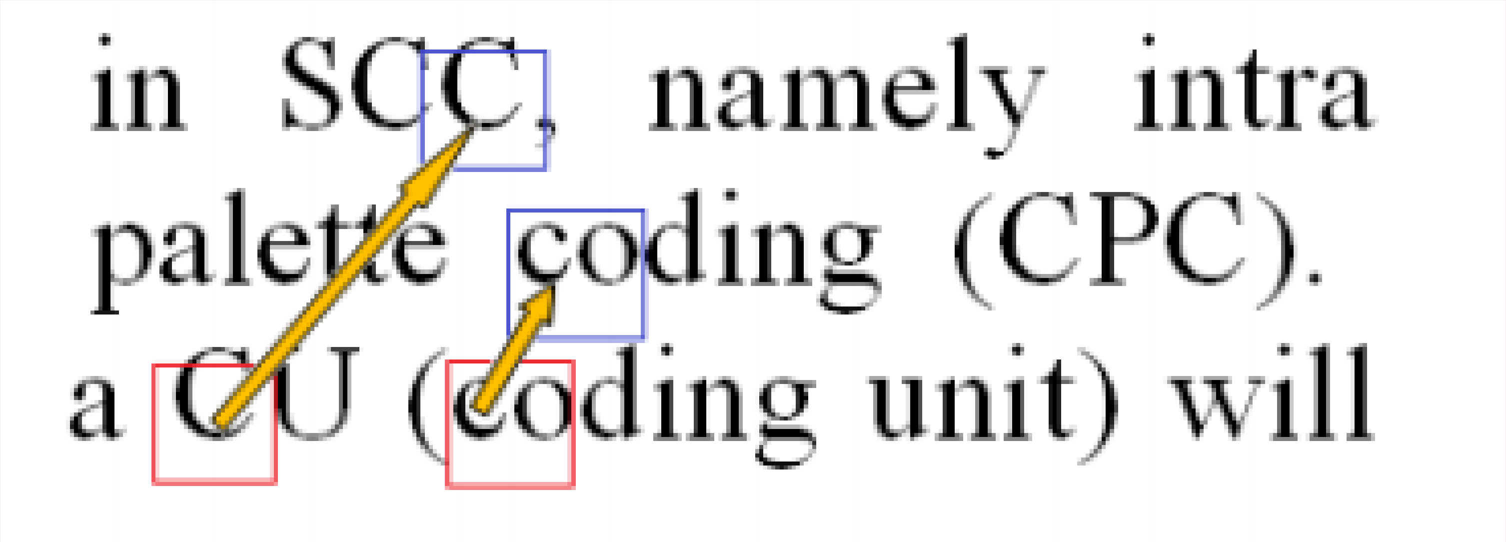

Cloud Gamming

- Screen Content Videos (SCV) have become popular due to the recent advances in mobile technologies and cloud applications.
- Real-time transport of SCV becomes critical in many applications.
- “Joint Collaborative Team on Video Coding” (JCTVC) started the screen content coding (SCC) extension standardization over the latest High Efficiency Video Coding (HEVC) in 2014 and finalized this extension in 2016.

Background


Abstract
POWERPOINT 2010
About Tongji
High Efficiency Video Coding

- New SCC Mode – Intra Block Copy (IBC)



- An Intra-frame block search and motion compensation scheme.
- Leveraging on screen content repetitive pattern property to reduce signaling.
- Screen content encoder only signals the block vector (BV) to indicate location offset and residual signal (if exists).

- New SCC Mode – Palette Coding Mode (PLT)

=

Color Table

Index	R	G	B
1	255	255	255
2	0	170	238
3	0	167	237
4	120	210	246
5	255	245	253
⋮	⋮	⋮	⋮

\+

Index Map

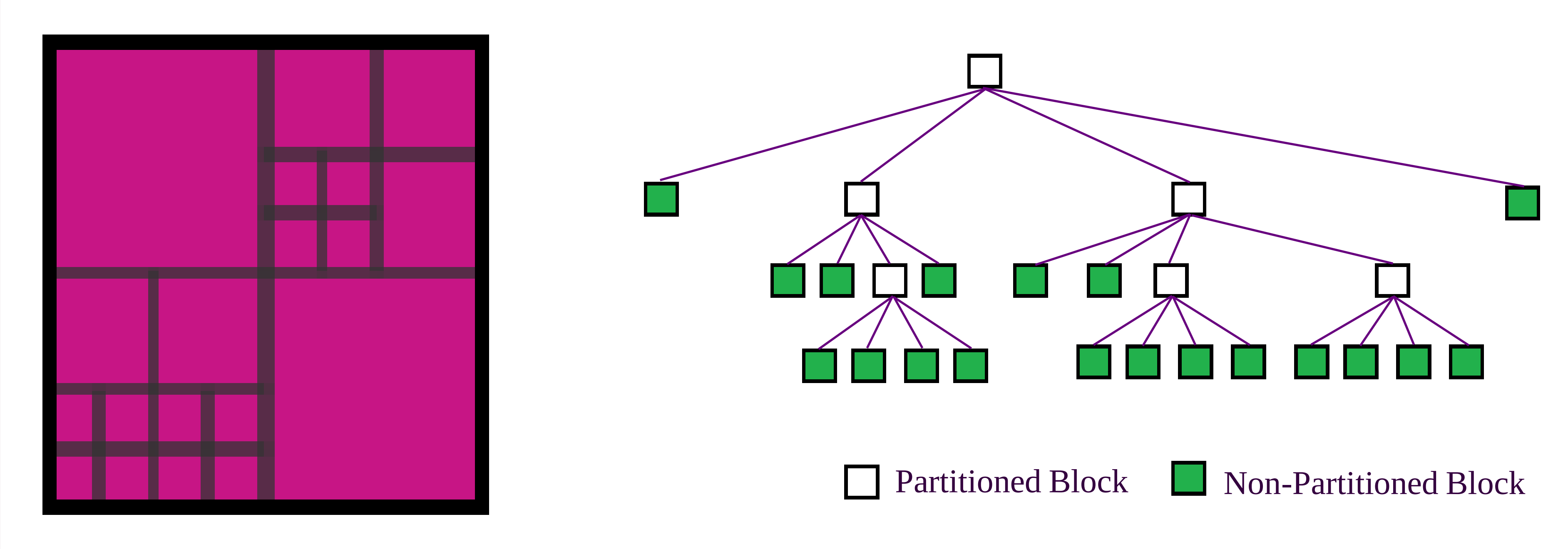
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	2
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
18	15	12	12	19	16	-1	12	12	1	2	11	4	16	5	11
11	10	9	10	17	13	14	16	9	9	5	11	4	16	5	11
15	12	12	12	14	19	15	17	16	3	5	11	4	16	5	11
15	19	16	3	3	3	5	6	12	6	2	11	4	16	5	11
11	17	16	16	3	3	3	3	6	17	9	14	1	16	8	12
18	15	12	12	14	13	15	12	12	19	3	10	15	12	14	7
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- Representing screen content block as a combination of a color lookup table and the corresponding index map.
- Leveraging on screen content low color quantity property to reduce signaling.
- Screen content encoder signals color table triplet (e.g., RGB) and index map scan.

Challenges with Mode and Partition Decisions

- Novel screen content coding (SCC) technologies achieve 50% bitrate saving over HEVC and is so far the most efficient screen content compression solution.
- However… Significant computational complexity limits the application potential, caused by two fundamental decisions: (a) How to partition? (b) Which mode to use?

Default Approach for Mode and Partition Decisions



Encoder:

- Examines and compares the costs for every coding mode over the coding unit (CU).
- Compares the best cost of current CU against the sum of costs for all its recursive sub-CUs, each coded with the optimal mode and partition recursively.

Previous Work

Fast CU Partition Decision Using Machine Learning for Screen Content Compression

Fanyi Duanmu*, Zhan Ma+ and Yao Wang*
*New York University, Brooklyn, NY 11201, USA
+ Nanjing University, 22 Hankou Road, Nanjing 210093, P.R. China
(fanyi.duanmu@nyu.edu, mazhan@nju.edu.cn, yw523@nyu.edu)

2015 – ICIP[1]

- Fast CU Partition Decision Algorithm based on a pre-trained Neural Network.
- Input features include distinct color number, CU Variance, Gradient Kurtosis, Sub-CU Difference, etc.
- For the target CU, encoder chooses to either fast-partition or fast-termination.
- Achieved **37%** complexity reductions with 3.0% coding efficiency loss for Intra-frame encoding.

IEEE JOURNAL ON EMERGING AND SELECTED TOPICS IN CIRCUITS AND SYSTEMS, VOL. 6, NO. 4, DECEMBER 2016 517

Fast Mode and Partition Decision Using Machine Learning for Intra-Frame Coding in HEVC Screen Content Coding Extension

Fanyi Duanmu, Zhan Ma, and Yao Wang, *Fellow, IEEE*

2016 – JETCAS[2]

Fast CU Mode and Partition Decision Framework based on pre-trained Decision Trees.

- Input features include distinct color number, CU Variance, Gradient Kurtosis, Zero Gradient percentage, etc.
- Classifier 1: Block Decision: Natural Image Block (NIB) or Screen Content Block (SCB).
- Classifier 2: Partition Decision: Split or Un-split?
- Classifier 3: Direction Decision: Directional Intra-block or Non-Directional intra-block.
- Achieved **40%** and **52%** complexity reductions with 1.5% and 3.6% coding efficiency losses for Intra-frame encoding.

[1]F. Duanmu, Z. Ma, and Y. Wang, "*Fast CU Partition Decision Using Machine Learning for Screen Content Compression*", in Proc. IEEE International Conference on Image Processing (ICIP), pp. 4972 - 4976, Quebec City, Canada, 2015.

[2]F. Duanmu, Z. Ma, and Y. Wang, "Fast Mode and Partition Decision Using Machine Learning for Intra-Frame Coding in HEVC Screen Content Coding Extension", IEEE Journal on Emerging and Selected Topics in Circuits and Systems (JETCAS), Vol: 6, Issue: 4, Page:517-531, 2016.

Part 2 – Fast Screen Content Transcoding

Related Publications:

F. Duanmu, Z. Ma, M. Xu, and Y. Wang, "An HEVC-Compliant Fast Screen Content Transcoding Framework Based on Mode Mapping," IEEE Transactions on Circuits and Systems for Video Technology (TCSVT), 2018 (Under Review).

F. Duanmu, M. Xu, Y. Wang, and Z. Ma, "HEVC-Compliant Screen Content Transcoding Based on Mode Mapping and Fast Termination," in Proc. of IEEE Visual Communications and Image Processing (VCIP), Petersburg, FL, USA, 2017.

F. Duanmu, Z. Ma, and Y. Wang "A Novel Screen Content Fast Transcoding Framework Based on Statistical Study and Machine Learning", in Proc. IEEE International Conference of Image Processing (ICIP), Phoenix, AZ, USA, 2016.

Fanyi Duanmu
Video Lab
Tandon School of Engineering
New York University
https://sites.google.com/site/duanmufanyi/

Previous Work

A NOVEL SCREEN CONTENT FAST TRANSCODING FRAMEWORK BASED ON STATISTICAL STUDY AND MACHINE LEARNING

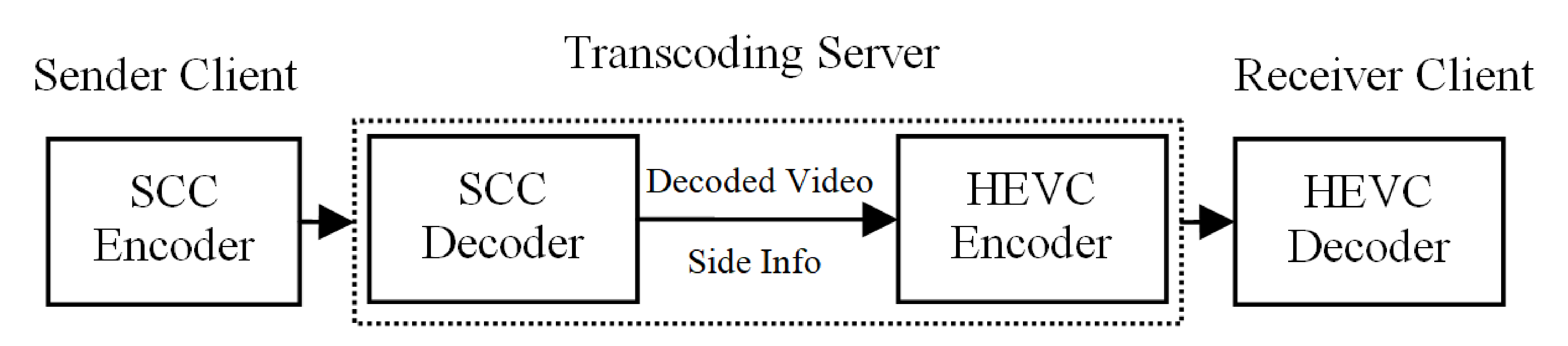
Fanyi Duanmu[1], Zhan Ma[2], Wei Wang[3], Meng Xu[4] and Yao Wang[1]

2016 – ICIP

- Fast HEVC-SCC transcoding for bandwidth reduction applications.
- Use CU features (color#, variance, gradient) and HEVC decoded side information (i.e., residual sparsity) to train a block type classifier, i.e., NIB or SCB.
- NIB bypasses the SCC modes at the current CU depth.
- Reuse HEVC coding depth to infer SCC coding depth.
- Achieved **48%** transcoding complexity reduction with only 2.1% BD-Rate loss for Intra-frame transcoding.

F. Duanmu, Z. Ma, and Y. Wang "*A Novel Screen Content Fast Transcoding Framework Based on Statistical Study and Machine Learning*", in Proc. IEEE International Conference of Image Processing (ICIP), pp. 4205-4209, Phoenix, Arizona, USA, 2016.

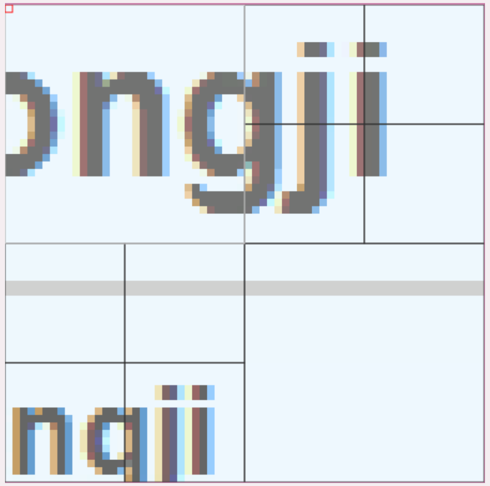
SCC-HEVC Transcoding



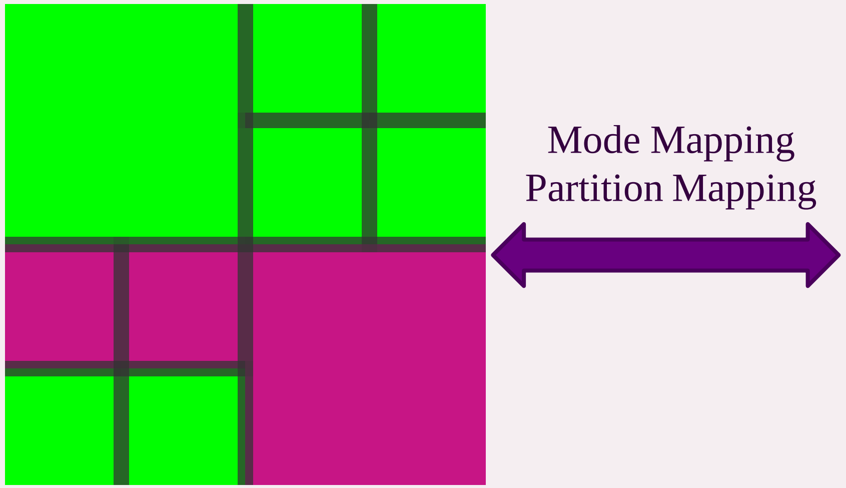
Motivation:

- SCC bitstream is efficient but not decodable over legacy devices.
- SCC chipsets are not available. Software-decision is desirable.
- Efficient transcoding algorithms are needed to reduce the processing complexity while preserving the coding efficiency to to support emerging screen content applications, such as cloud gaming, remote desktop interfacing, etc.

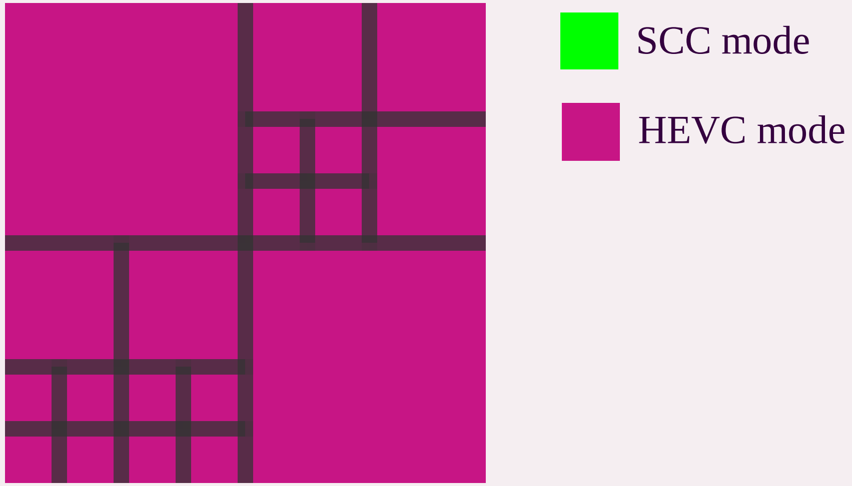
SCC-HEVC Transcoding



Screen Content Image Block



SCC Mode & Partition



HEVC Mode & Partition

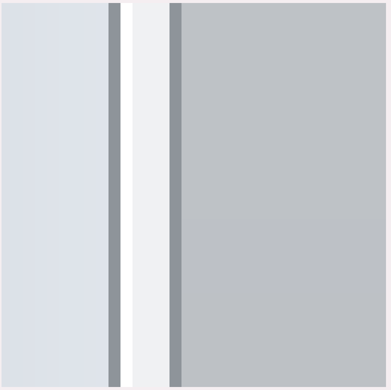
Challenges:

- How to accurately map novel SCC mode and Partition into conventional HEVC mode and partition without sacrificing much coding performance?
- How to best utilize decoded SCC bitstream side information (e.g., block mode, partition, residual, color, motion vector, etc) to accelerate HEVC re-encoding?

Intra-mode Transcoding

Flat Block

Smooth Block



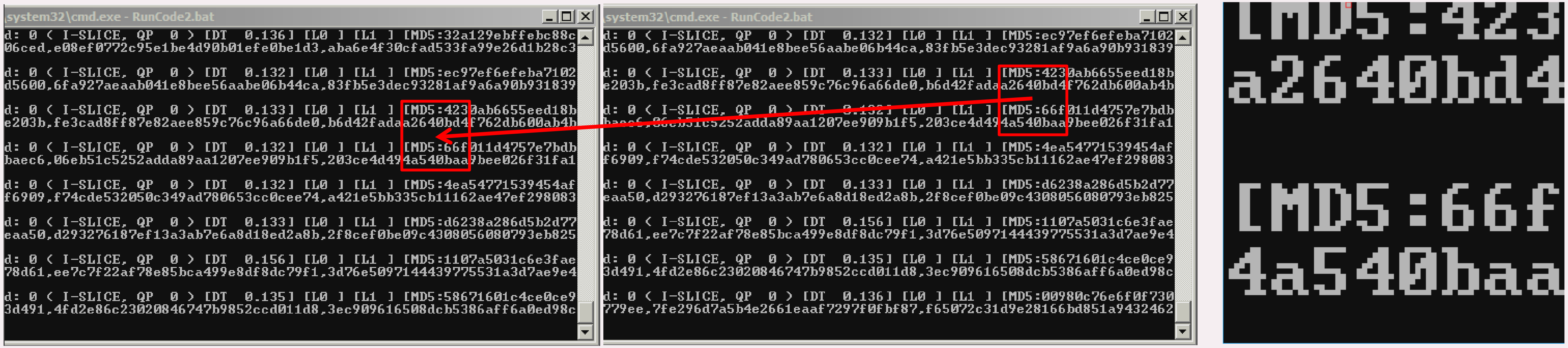
Vertical Block

Horizontal Block

Intra Block:

- Both SCC and HEVC use Intra mode to code blocks with “Flat”, “Smooth” and “Directional” block patterns.
- Our transcoding system directly copies these Intra mode from SCC bitstream and apply to HEVC.

Inter-mode Transcoding



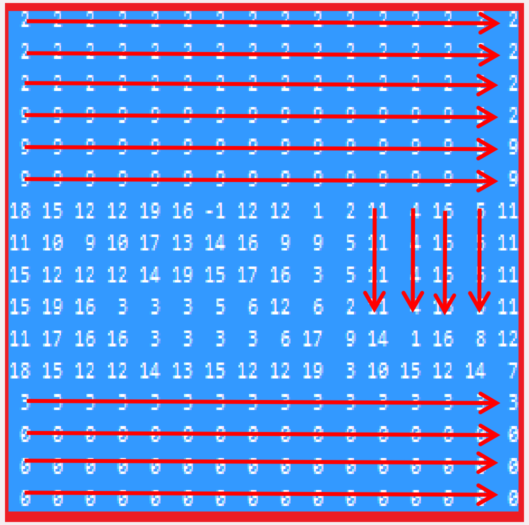
Frame N

Frame N+1

Inter Block:

- For temporally-predictable blocks, both SCC and HEVC uses Inter mode.
- Our transcoding system directly reuses the motion from SCC bitstream and apply to HEVC. Motion information includes motion vector, reference picture list, reference frame index.

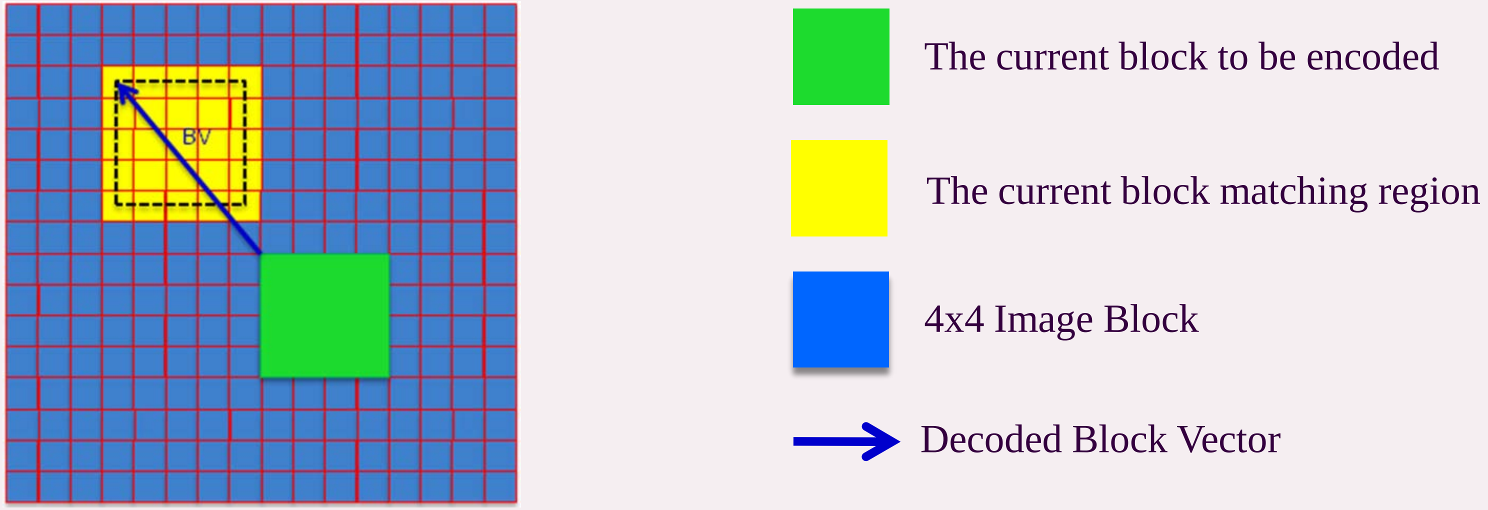
PLT-mode Transcoding



PLT Block:

- Infer the block structure and directionality from decoded index map.
- Trigger fast Intra mode selection for flat, horizontal and vertical block.

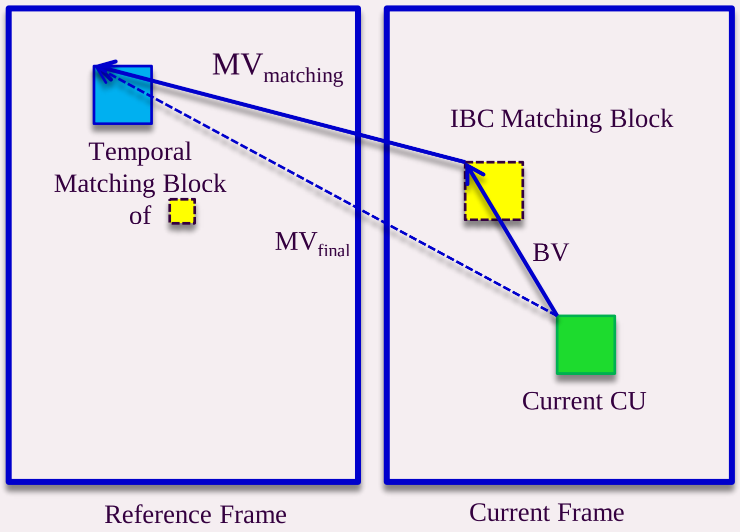
IBC-mode Transcoding in Intra-frame



IBC Block:

- The decoded IBC mode block vector (BV) is used to determine the matching region in the previously-coded area.
- "***BV-based Mode Lookup***": If the matching region is coded in the same intra mode, directly copies this mode. Otherwise, direct partition at the current CU depth.

IBC-mode Transcoding in Inter-frame



$$MV_{final} = BV + MV_{matching}$$

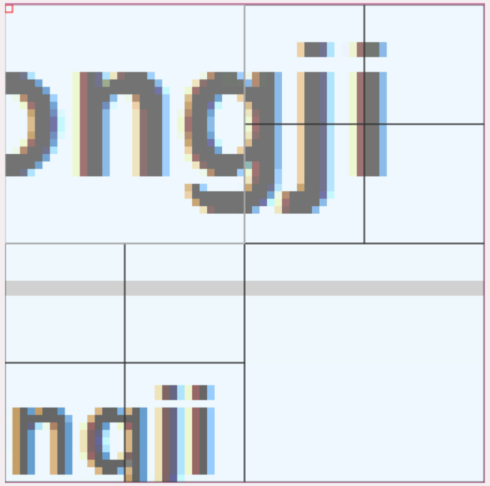
IBC Block:

- The decoded IBC mode block vector (BV) is used to determine the matching region in the current frame.
- "***Motion Vector Relay***": If the matching region is coded using the same inter mode, relay the block vector with temporal motion vector to derive final temporal MV.

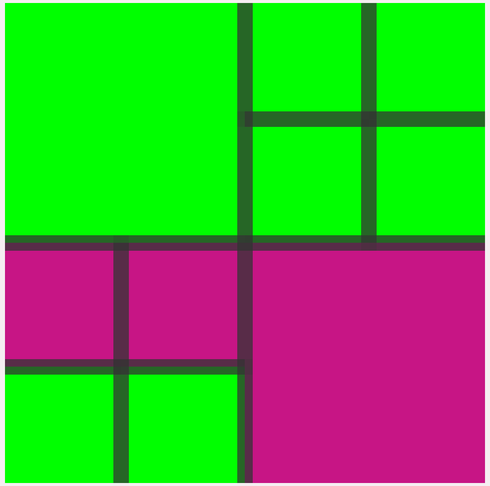
SCC Partition Decision Transfer

SCC mode

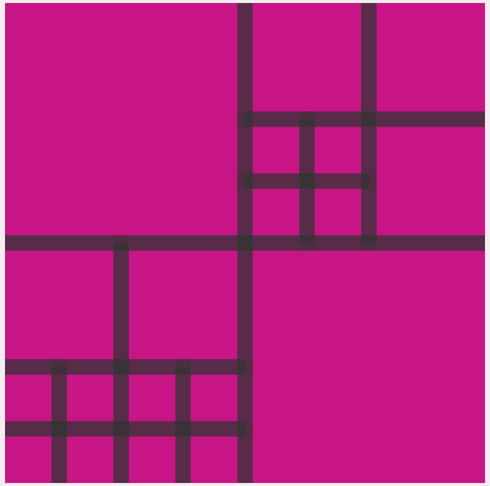
HEVC mode



Screen Content Image Block



SCC Mode & Partition



HEVC Mode & Partition

Partition Decision Heuristic:

- SCC modes (PLT and IBC) enable “inhomogeneous” blocks to be encoded at a larger CU size.
- Intuitive yet safe heuristic: For screen content blocks, coding depth in HEVC should be greater than or at least equal to the coding depth of SCC.

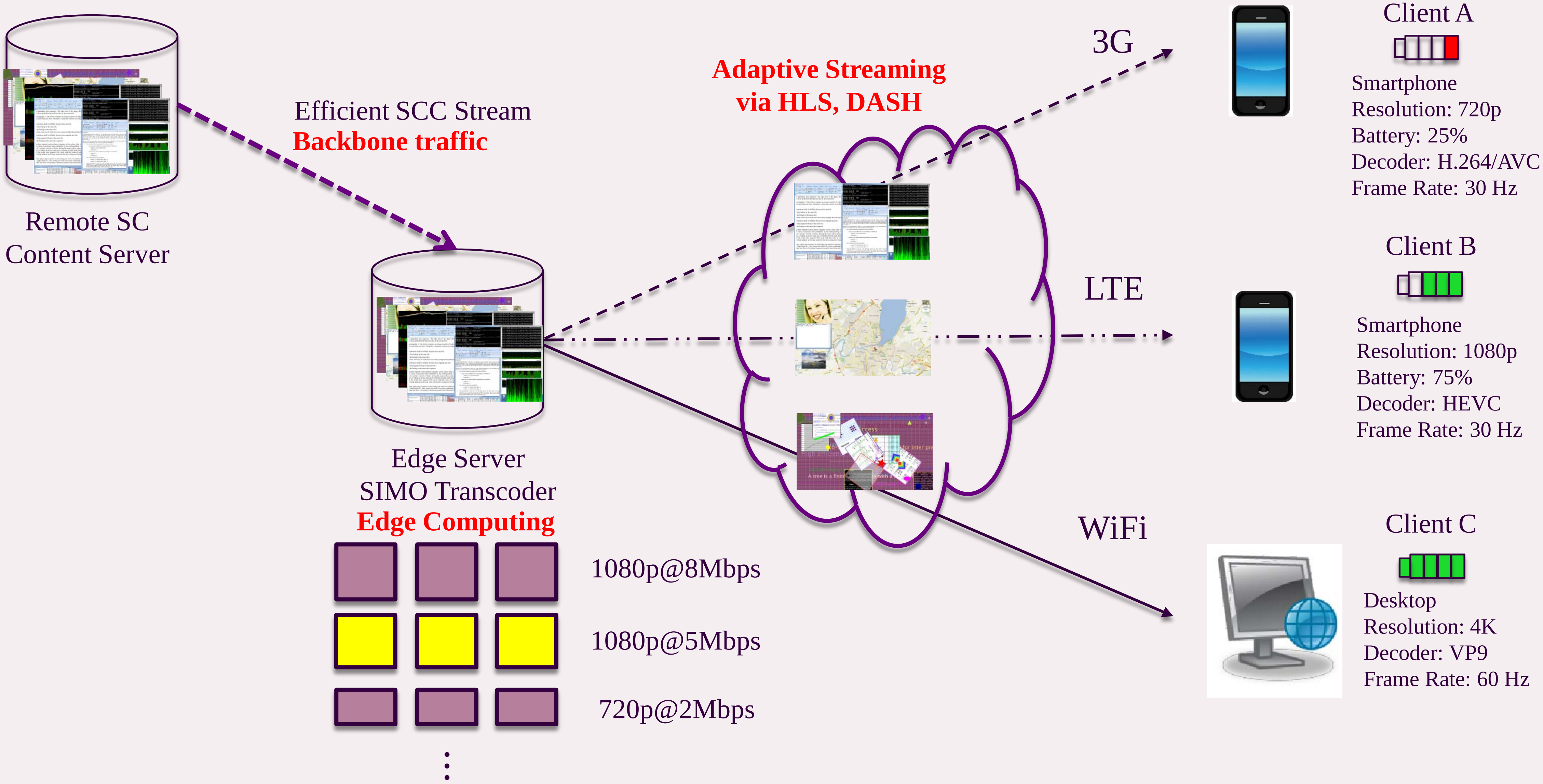
Experimental Results

Transcoding Performance Evaluation against HM-16.4			
Sequence	Resolution	Re-encoding Complexity (AI / LD)	BD-Rate (AI / LD)
Desktop	1920x1080	-44% / -81%	+0.66% / -12.03%
Console	1920x1080	-49% / -80%	+1.00% / -9.33%
WebBrowsing	1280x720	-43% / -79%	+0.34% / -2.92%
Map	1280x720	-51% / -84%	+0.84% / -45.80%
Programming	1280x720	-45% / -83%	+0.14% / -0.30%
SlideShow	1280x720	-51% / -84%	+0.93% / -0.97%
BasketballScreen	2560x1440	-71% / -86%	+1.63% / -1.11%
MissionControlClip2	2560x1440	-53% / -82%	+0.41% / +0.66%
MissionControlClip3	1920x1080	-53% / -81%	+0.42% / +0.89%
ChineseEditing	1920x1080	-48% / -81%	+0.21% / -15.89%
	Average	**-51% / -82%**	**+0.57% / -9.74%**

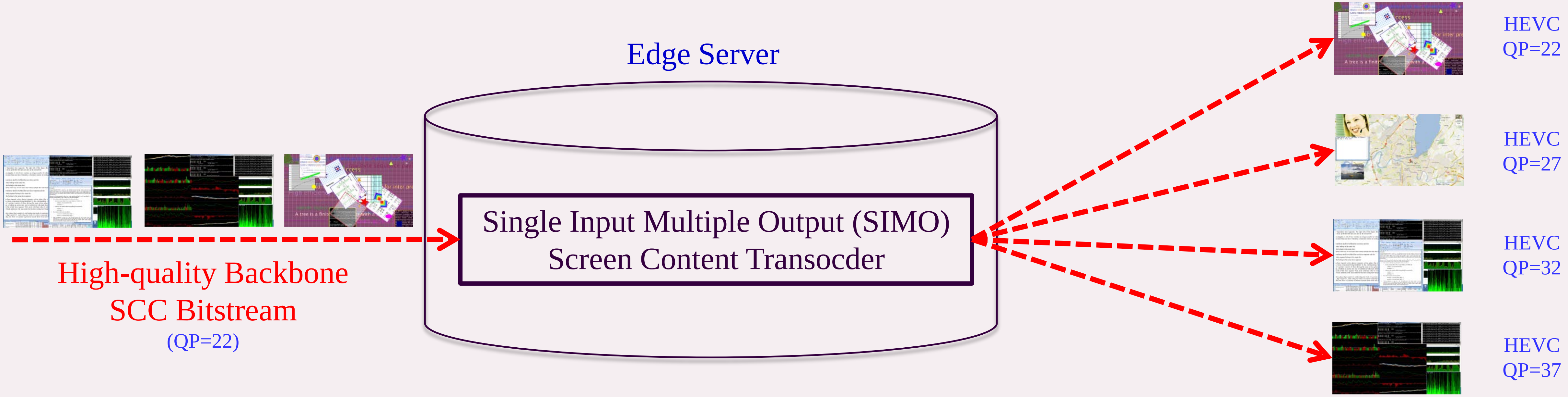
2x and 5x transcoding speedups are achieved under All-Intra and Low-Delay configurations.

[1]***F. Duanmu***, Z. Ma, M. Xu, and Y. Wang, "An HEVC-Compliant Fast Screen Content Transcoding Framework Based on Mode Mapping," IEEE Transactions on Circuits and Systems for Video Technology.

Edge-Cloud SIMO Transcoding



SIMO Quality Transcoding



- A novel Single-Input-Multiple-Output (SIMO) SC Transcoding Framework.
- Quality transcoding: From a single high bitrate SCC stream to multiple HEVC streams in reduced qualities (by adjusting QP configurations).
- Supporting Parallel SC Transcoding with quality multi-streaming.
- Minimal backbone bandwidth and edge buffer storage.
- Low edge computing complexity and system processing delay.

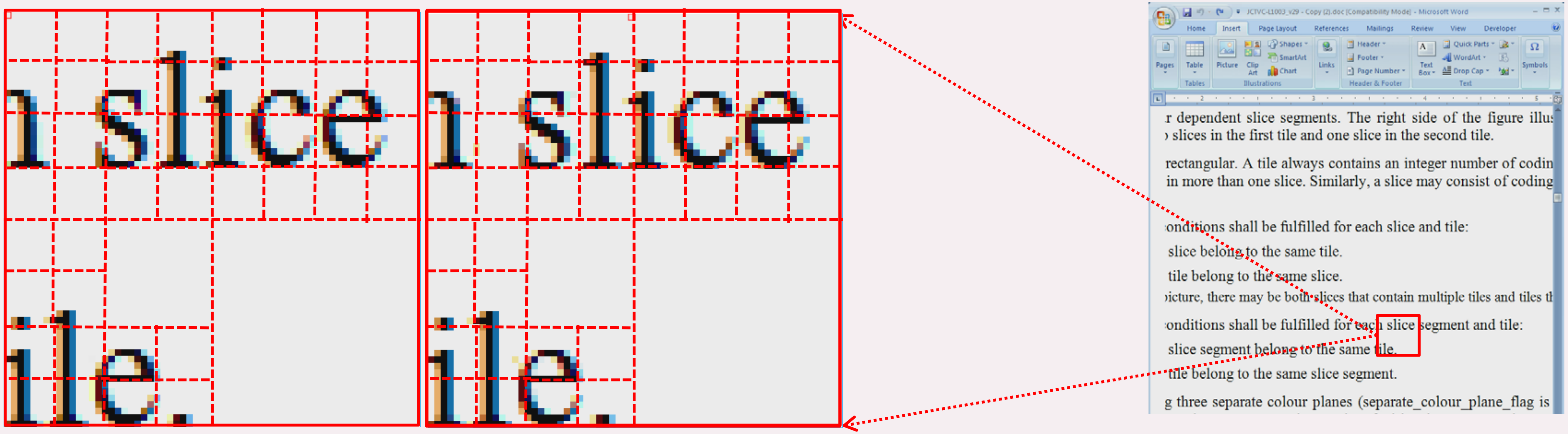
QP = 22
High Bitrate

QP = 37
Low Bitrate

Mixed Content Sequence “BasketballScreen”

- In Video Coding, the block partition is jointly determined by content and quantization parameter (QP).
- Natural Image Block (NIB) is VERY sensitive to QP configurations and the coding depth is hard to predict.

SIMO Transcoding



QP = 22
High-Bitrate

QP = 37
Low-Bitrate

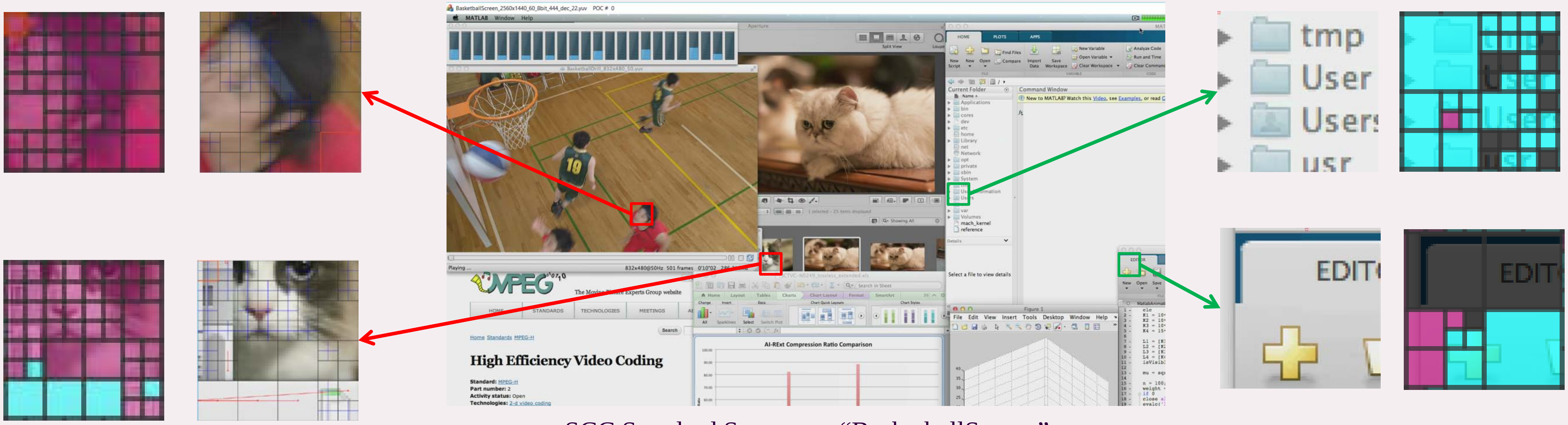
Text & Graphics Sequence “Desktop”

- In contrast, Screen Content Block (SCB) is Not sensitive to QP configurations and the coding depth is very close.
- Besides, simulation results reveal that coding depth mismatch in SCB mostly does not introduce visible coding efficiency loss, particularly for Inter-frames.

SIMO Transcoding

Intra-frame Coding

- Use Intra-coded sub-block percentage to determine quantization sensitivity.
- High Intra sub-block percentage triggers additional mode examination at larger CU sizes.
- Low Intra sub-block percentage triggers direct CU bypass at the current CU depth.



SCC Standard Sequence: “BasketballScreen”

HEVC mode   IBC mode   PLT mode

- Inter-frame Coding
  - High Intra sub-block percentage:
    1. Execute Intra-mode Rate-Distortion Optimization at the current CU.
    2. Bypass Inter-mode Rate-Distortion Optimization at the current CU.
  - High Merge/Skip or SCC sub-block percentage (dominant):

    Bypass Intra and Inter mode Rate-Distortion Optimization at the current CU.

Experimental Results

Transcoding Performance Evaluation against HM-16.4			
Sequence	Resolution	Re-encoding Complexity	BD-Rate
Desktop	1920x1080	-43% / -78%	+0.64% / -18.13%
Console	1920x1080	-50% / -72%	+1.08% / -10.23%
WebBrowsing	1280x720	-51% / -83%	+0.55% / -47.90%
Map	1280x720	-44% / -74%	+1.03% / +1.99%
Programming	1280x720	-48% / -72%	+1.00% / +2.69%
SlideShow	1280x720	-67% / -73%	+1.26% / +3.07%
BasketballScreen	2560x1440	-47%/ -76%	+0.68% / +3.34%
MissionControlClip2	2560x1440	-48% / -81%	+0.60 / +1.93%
MissionControlClip3	1920x1080	-45% / -78%	+0.43% / -7.09%
ChineseEditing	1920x1080	-43% / -78%	+0.53% / -3.66%
	Average	**-49%** / **-76%**	**+0.78%** / **-7.40%**

[1] ***F. Duanmu***, Z. Ma, M. Xu, and Y. Wang, "An HEVC-Compliant Fast Screen Content Transcoding Framework Based on Mode Mapping," IEEE Transactions on Circuits and Systems for Video Technology.

Summary

- In my thesis, several fast screen content encoding and transcoding solutions are proposed.
- The fast encoding solution[1] achieves up to **52%** complexity reduction with marginal coding efficiency loss.
- The fast HEVC-SCC transcoding solution[2] introduces **48%** complexity reduction with negligible coding efficiency loss.
- The fast SCC-HEVC transcoding solution[3] achieves **2x** and **5x** speedup, under All-intra and Low-delay configurations, respectively.

[1] F. Duanmu, Z. Ma, and Y. Wang, "Fast Mode and Partition Decision Using Machine Learning for Intra-Frame Coding in HEVC Screen Content Coding Extension", IEEE Journal on Emerging and Selected Topics in Circuits and Systems (JETCAS), Vol: 6, Issue: 4, Page:517-531, 2016.

[2] F. Duanmu, Z. Ma, and Y. Wang "A Novel Screen Content Fast Transcoding Framework Based on Statistical Study and Machine Learning", in Proc. IEEE International Conference of Image Processing (ICIP), pp. 4205-4209, Phoenix, Arizona, USA, 2016.

[3] F. Duanmu, Z. Ma, M. Xu, and Y. Wang, "An HEVC-Compliant Fast Screen Content Transcoding Framework Based on Mode Mapping," IEEE Transactions on Circuits and Systems for Video Technology, 2018.