Improving Frame Interpolation With Spatial Motion Smoothing For Pixel Domain Distributed Video Coding

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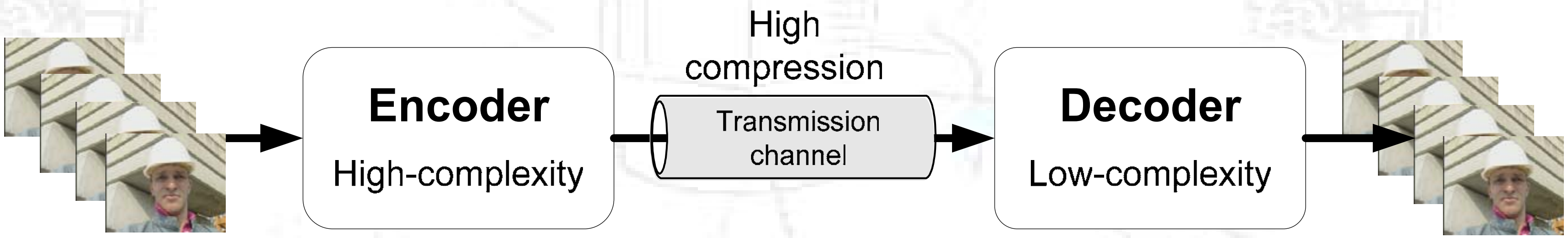
Summary

1. Context and Applications
2. Objectives
3. IST-PDWZ Video Codec
4. Frame Interpolation
5. Experimental Results
6. Conclusions and Future Work

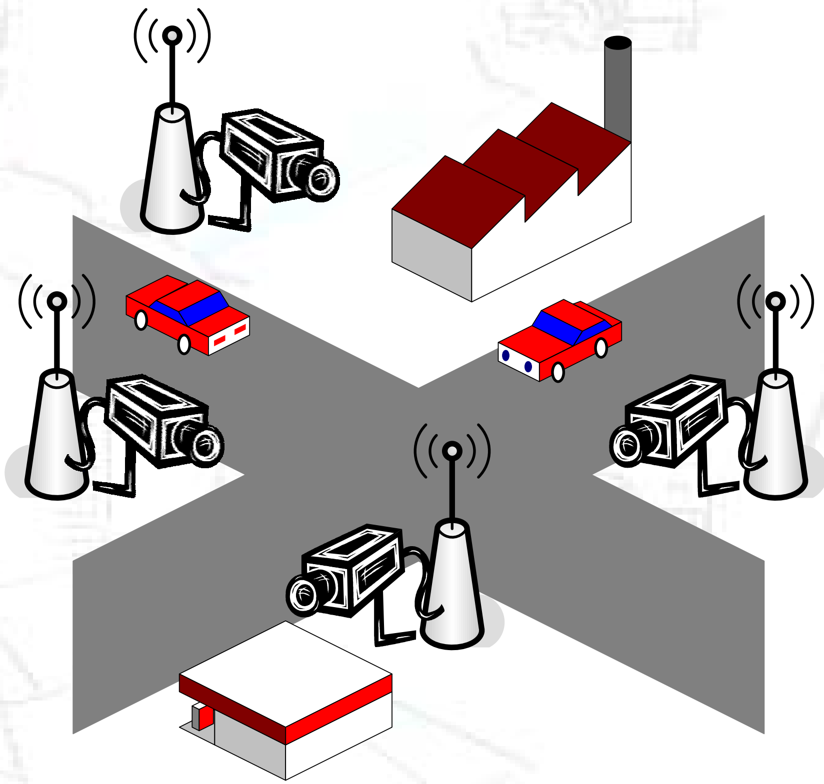
Traditional Video Coding

- Predictive coding framework:
  - Encoder is 5 to 10 times more complex than decoder mainly due to the motion estimation/compensation tools.
- Well-suited for "one-to-many" topologies:
  - Broadcasting or video-on-demand applications.



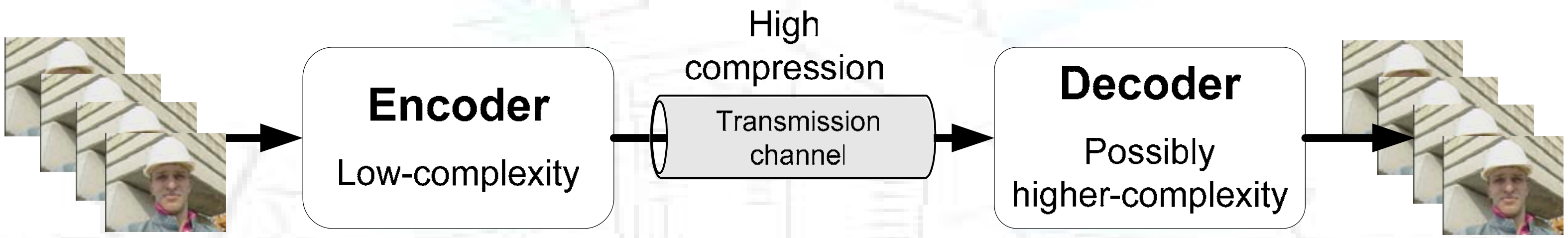
Emerging Applications, New Requirements

- Applications:
  - Mobile video.
  - Multimedia sensor networks.
  - Wireless video surveillance.
  - Multi-view acquisition.
  - …
- Encoding requirements:
  - Low complexity.
  - Low power-consumption.
  - Low cost.
  - …



Need for a New Coding Paradigm

- Coding configuration with low-complexity and low-power encoder at the expense of a high-complexity decoder
  - Without compromising coding efficiency.



New video coding paradigm:

Distributed Video Coding (DVC)

Exploits video statistics, partially or totally, at the decoder.

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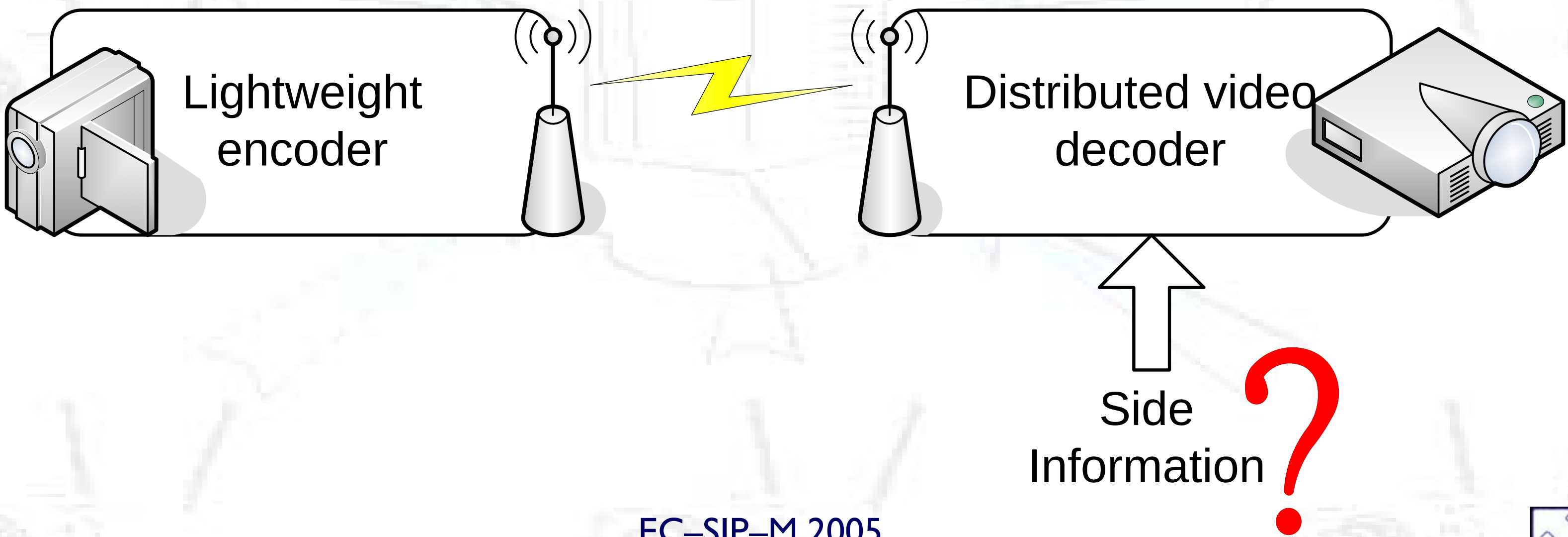
Main Goal

The rate-distortion (RD) performance of a distributed video coding scheme is highly dependent on the quality of the side information.

The challenge is:

How to generate the best side information (a frame) as close as possible to the current frame to be decoded ?



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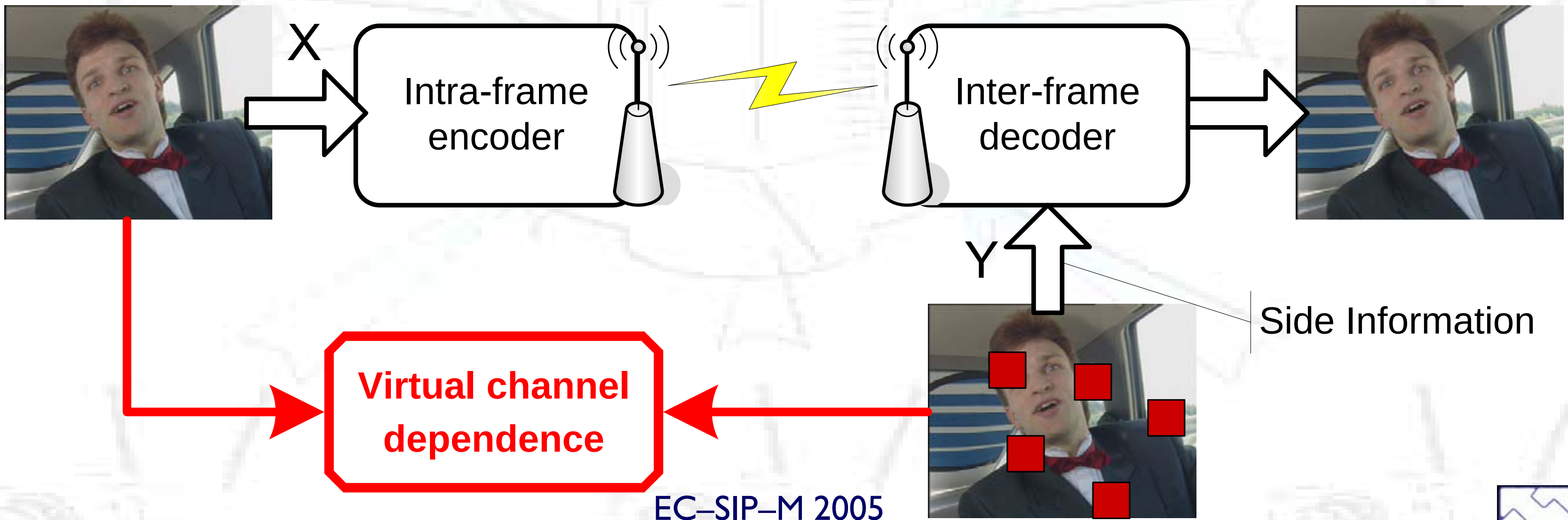
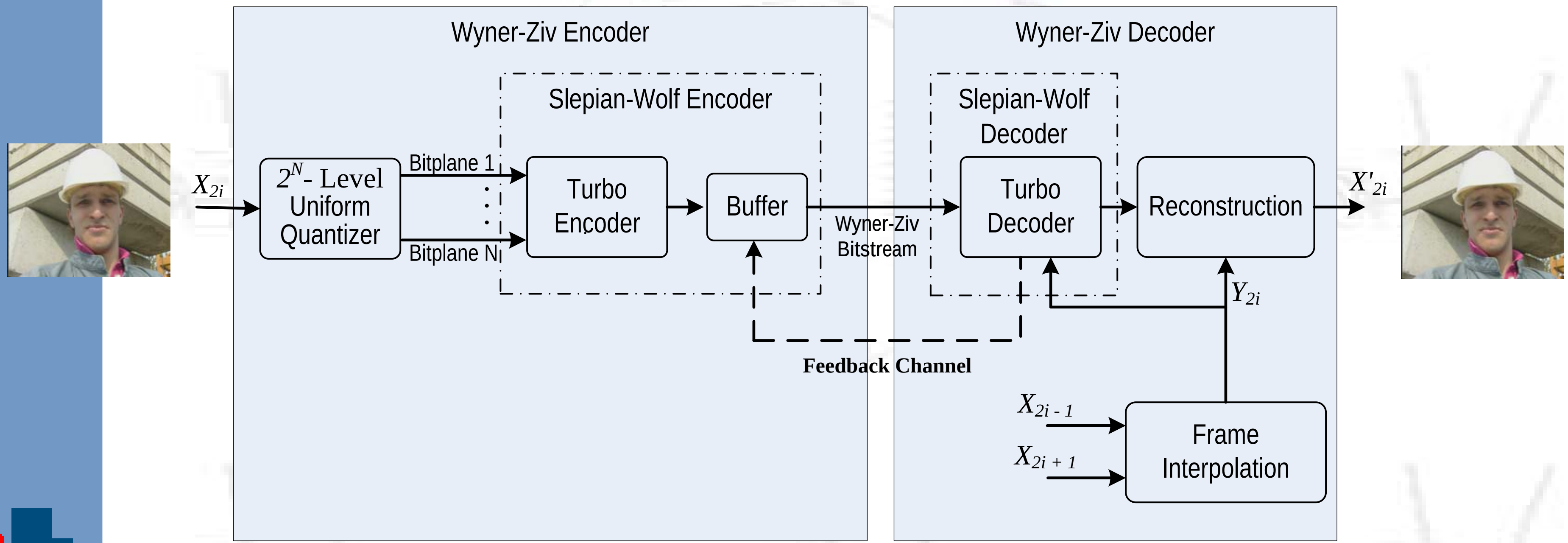
IST Pixel-Domain Wyner-Ziv Video Codec

- Based on the **Wyner-Ziv** coding scenario.
- **Intra-frame** encoder and **inter-frame** decoder.
- X source: even frames of the video sequence.
- Y source corresponds to the Side Information:
  - Generated using the odd frames at the decoder
  - Y is an estimate of the current frame X and is available at the decoder.
- Channel coding of X allows to improve the quality of Y.



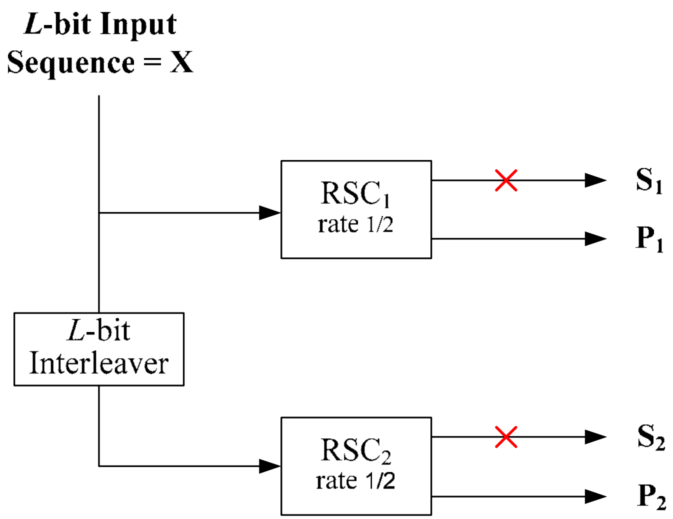
IST Pixel-Domain Wyner-Ziv Video Codec

- Turbo code based Slepian-Wolf codec.
- Each bitplane is independently turbo coded.
- Two frame types:
  - Key-frames (odd frames) and Wyner-Ziv frames (even frames).
- Side information (Y2i) is obtained by frame interpolation.



Slepian-Wolf Codec

- Turbo encoder:
  - Two identical recursive systematic convolutional (RSC) encoders.
  - Pseudo-random interleaver.
- Each RSC encoder outputs the systematic and the parity streams:
  - Systematic stream is discarded.
  - Parity stream is stored in the buffer and punctured.
  - Decoder request parity bits until successful decoding.



- Iterative turbo decoder:
  - Two SISO decoders.
  - Maximum A Posteriori (MAP) algorithm.
  - Laplacian distribution to model the correlation between X and Y.

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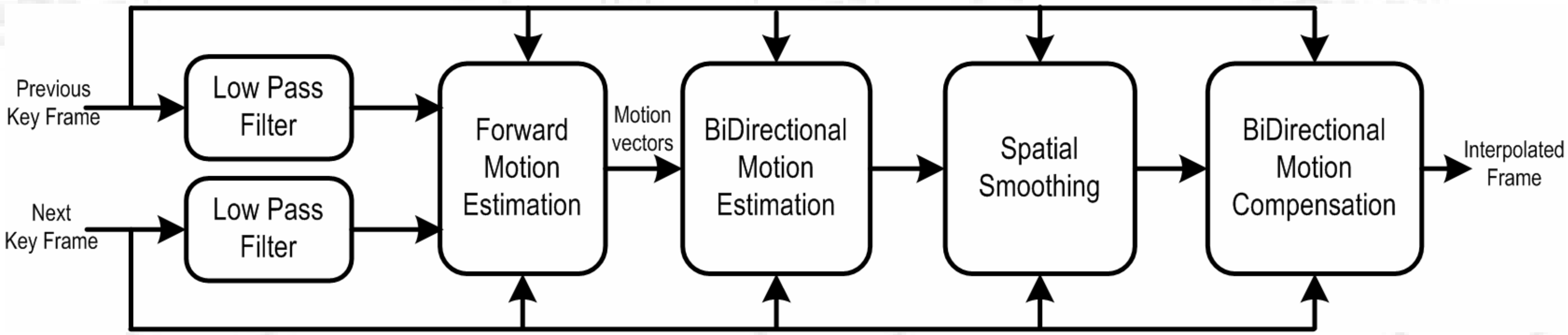
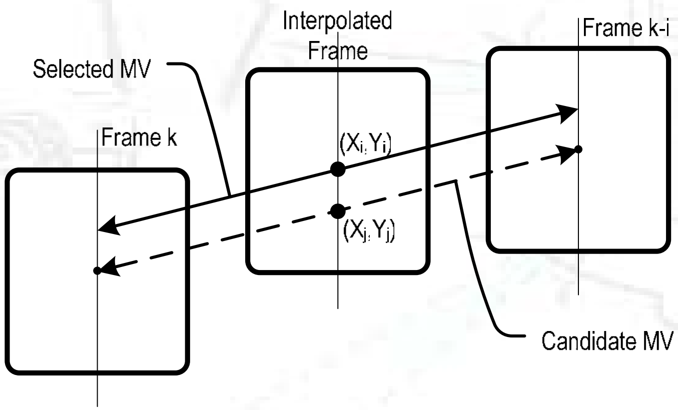
Frame Interpolation: Architecture

- Block-based motion compensated interpolation (5 steps):
  - 1) Low pass filter to improve the motion vectors reliability.
  - 2) Forward motion estimation.
  - 3) Bi-directional motion refines initial motion vector estimate.
  - 4) Spatial smoothing of motion vectors.
  - 5) Bi-directional MC to fill the interpolated frame.

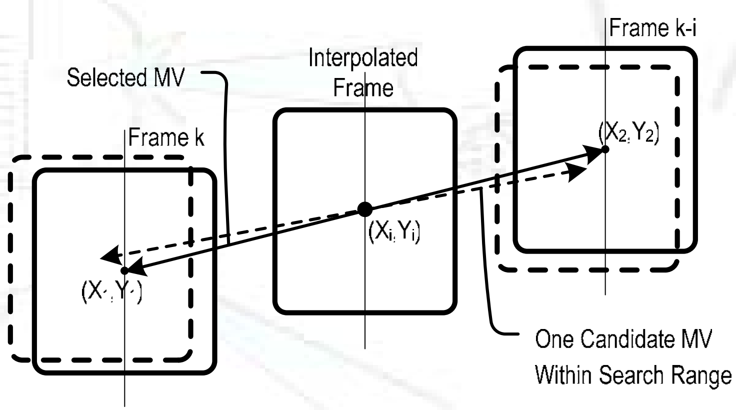


Initial MV & Bi-directional ME

- Motion vectors obtained by FME are candidates for each non-overlapped block in the interpolation frame:
  - Selected the MV that intercepts the interpolated frame closest to the center of block.
- Find linear trajectory (symmetric MVs) between key frames passing at the center of the block in the interpolated frame:
  - Small displacement around the initial block position.



Selection of the motion vector



Bi-directional motion estimation

Spatial Motion Smoothing

- Spatial smoothing algorithms target:
  - Reduction on the number of false motion vectors when compared to the true motion field.
  - Better spatial homogeneity of the resulting motion field.
- Weighted vector median filters are proposed:
  - Filter smoothing strength depends on the prediction MSE.
  - Low value weights when MSE for the candidate vector is high.
  - High value weights when MSE for the candidate vector is low.

$$\sum_{j=1}^{N} w_j \left\| x_{wvmf} - x_j \right\|_L \leq \sum_{j=1}^{N} w_j \left\| x_i - x_j \right\|_L \qquad w_j = \frac{MSE\left(x_c, B\right)}{MSE\left(x_j, B\right)}$$

Spatial Motion Smoothing

– <u>Without</u> motion vector smoothing filter

Spatial Motion Smoothing

– <u>With</u> motion vector smoothing filter

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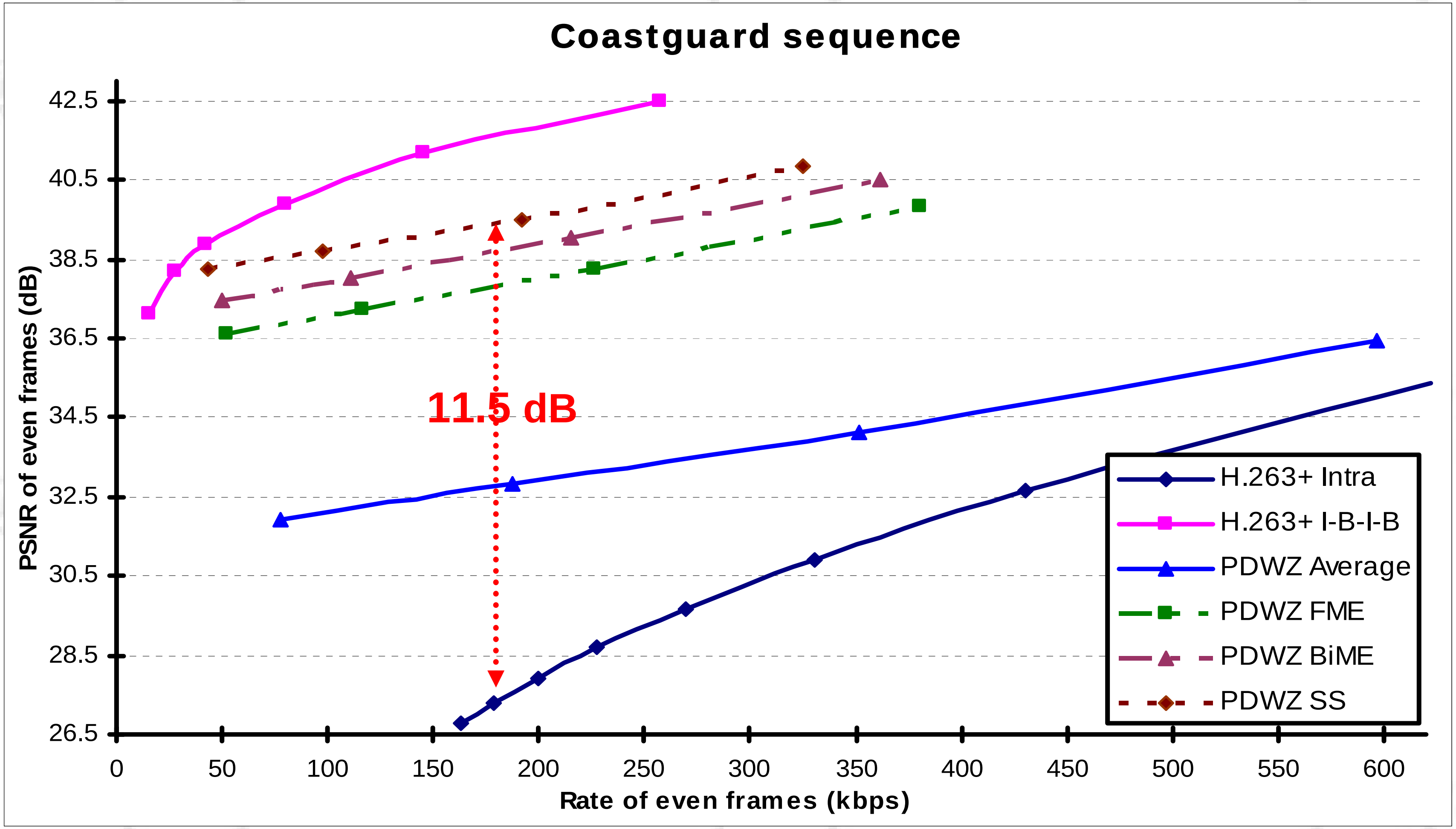
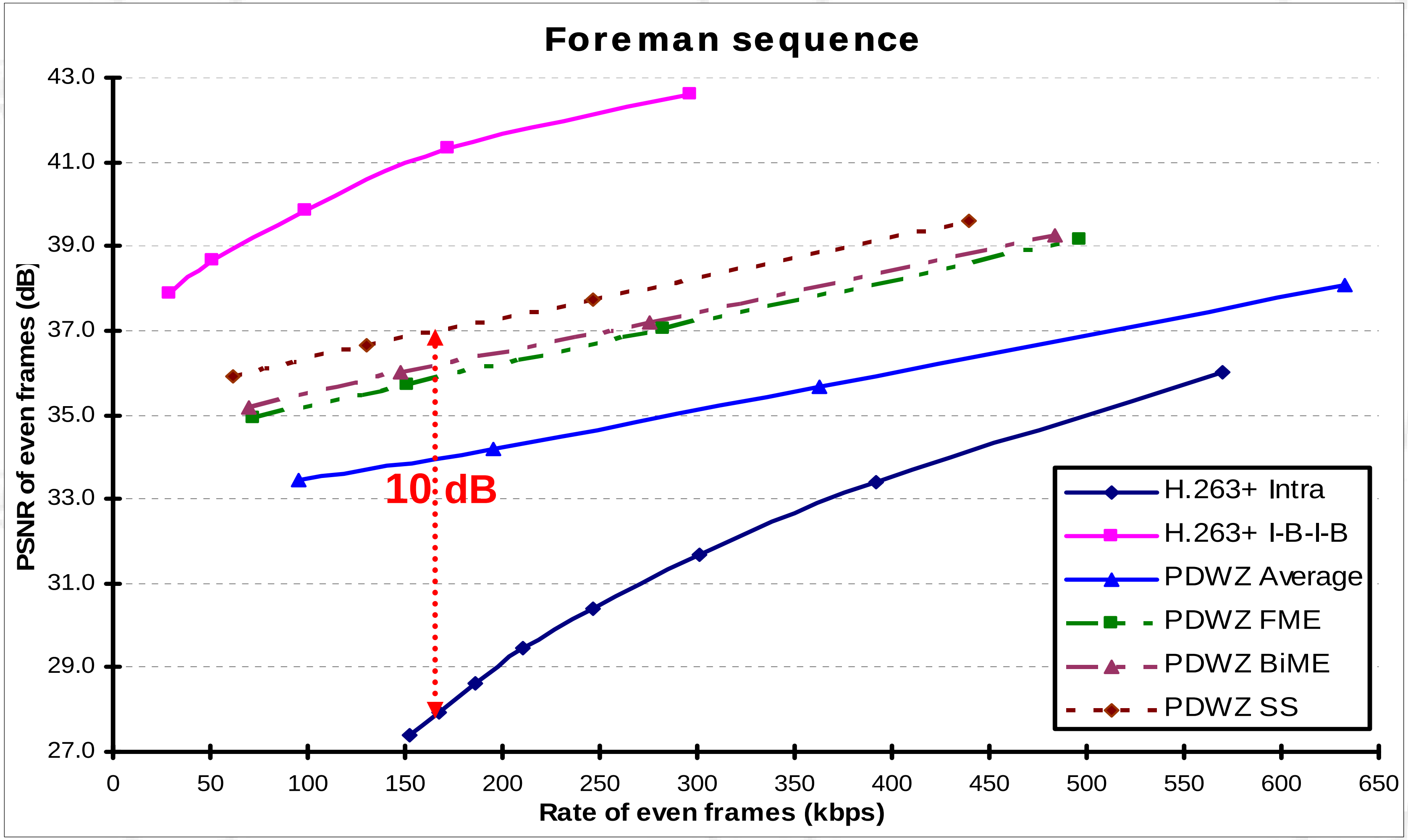
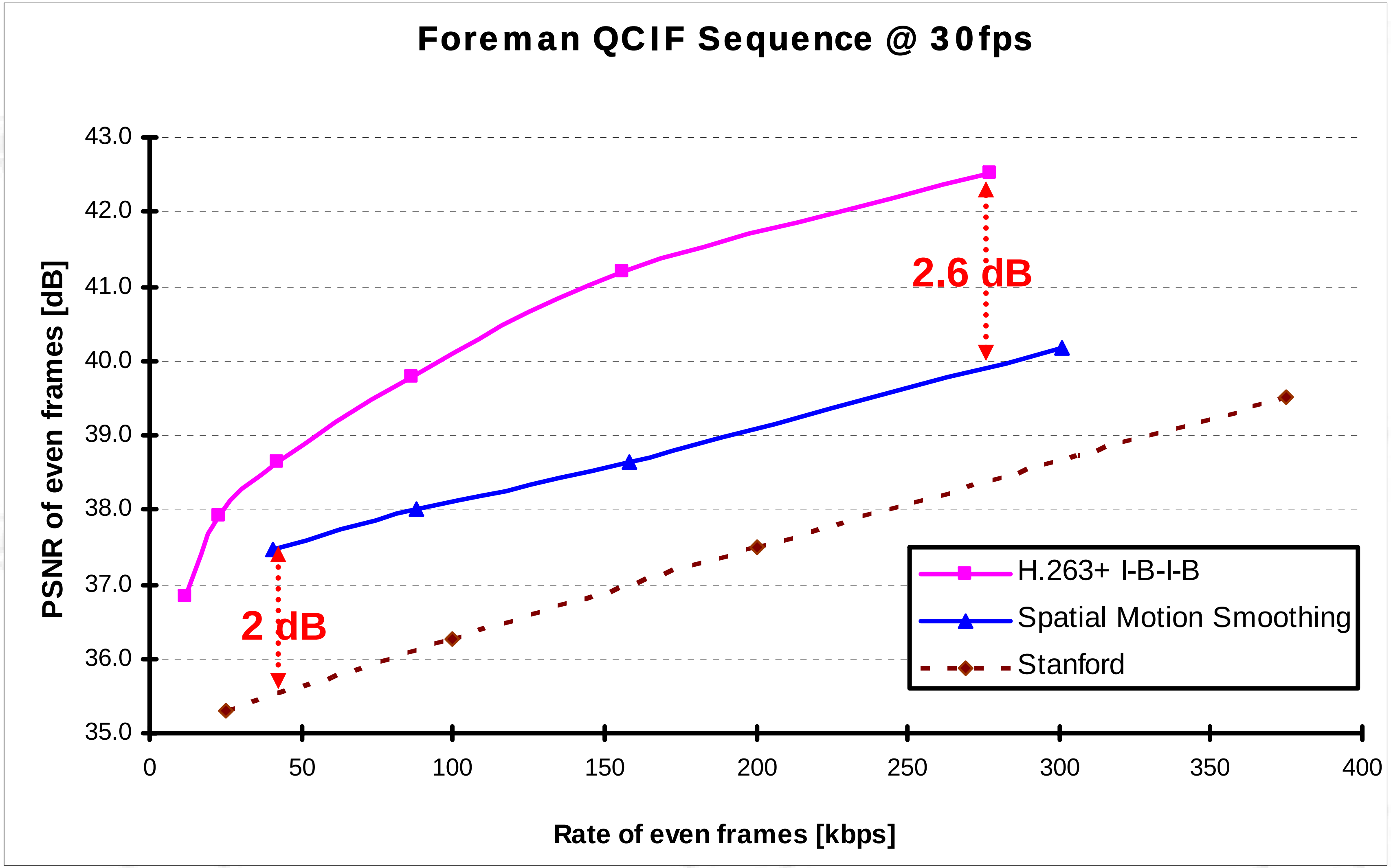
Coastguard Sequence



Foreman Sequence



Rate-Distortion Comparison



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Conclusions & Future Work

- New motion compensated frame interpolation tools are proposed and compared in a DVC framework.
- Major gains in RD performance:
  - Essentially due to spatial motion smoothing.
- Future Work:
  - Adaptation to longer GOPs.
  - Improve performance when large camera movements occur.
  - Iterative motion refinement approach using decoded image and keyframes.

Thanks for your attention !