EUSIPCO-2010 Aalborg, Denmark

Distributed Video Coding with Particle Filtering for Correlation Tracking

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Problem

Dynamic and unpredictable scene changes

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Wyner-Ziv coding of non-stationary sources with unknown statistics

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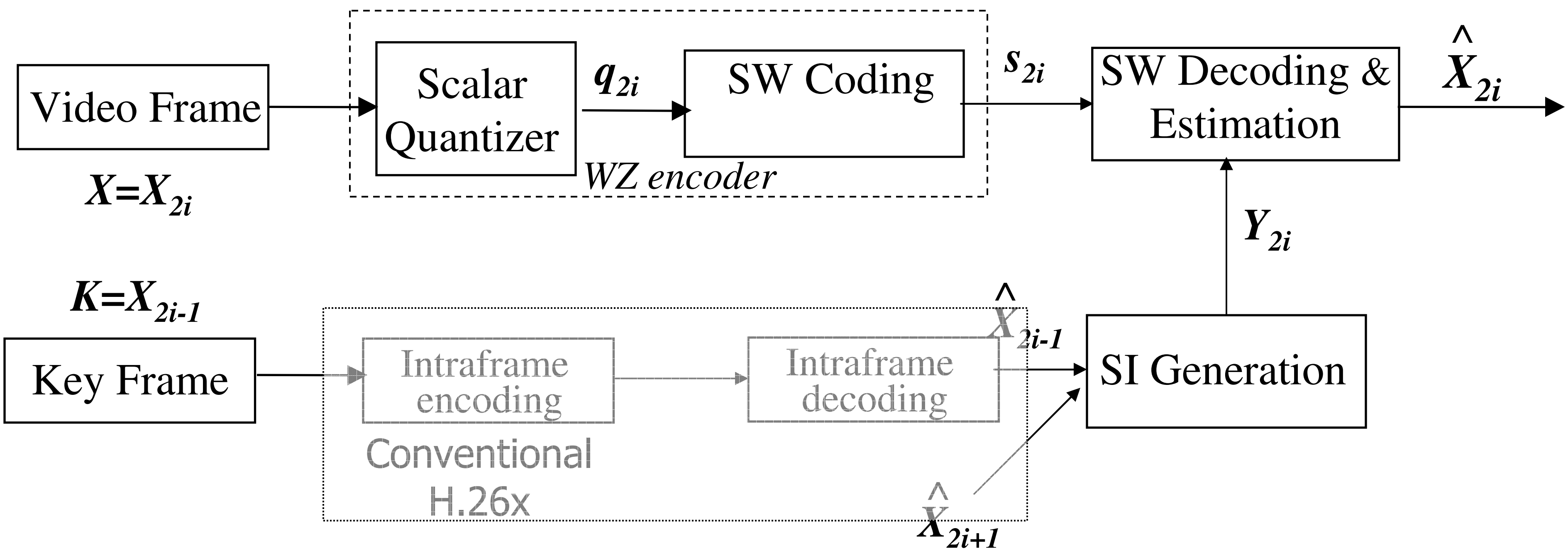
On-line estimation of varying correlation statistics at sequence/frame/block/pixel level at the decoder

Pixel-domain DVC



Related correlation modelling approaches

- Modelling correlation error as a Gaussian or Laplacian random variable with statistics estimated from previously decoded frames
- Vary the correlation noise statistics from pixel to pixel depending on the pixel difference between motion compensated blocks of 2 key frames providing side information
- Motion estimation with unsupervised learning where messages are iterated between the SW Decoder and the motion estimation block to generate better side-information/update probability model (Varodayan et al., 2008)

Contribution

- Current approaches adjust the correlation model online from previously decoded frames, providing updated statistics to the Slepian-Wolf decoder
  - However, once Slepian-Wolf (SW) decoding starts, correlation model is fixed
- We incorporate correlation estimation within our iterative SW decoder fitted with a particle filter (PF) to estimate correlation at bit level
  - Motivation: standard belief-propagation-based SW decoder cannot track varying correlation and cannot handle continuous variables like correlation

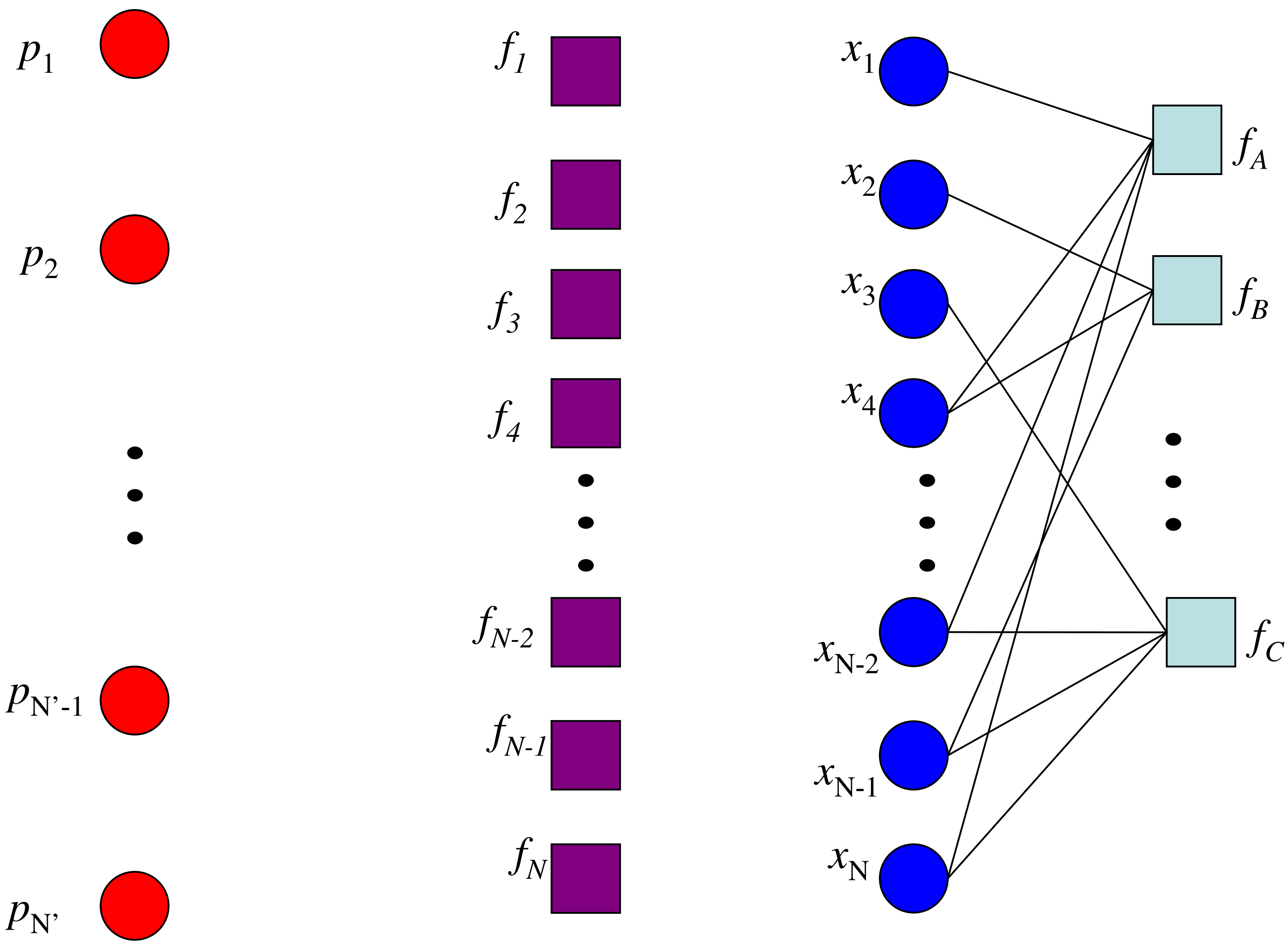
Adaptive SW decoding with PF

- SW decoder based on belief-propagation (BP) decoding of LDPC code factor graph

- Add to the LDPC factor graph with N source nodes x and M syndromes: N' correlation variable nodes p and N correlation factor nodes f_i, where

$$f_i(x_i) = \begin{cases} 1-p, & \text{if } x_i = y_i \\ p, & \text{otherwise} \end{cases}$$

Factor graph construction

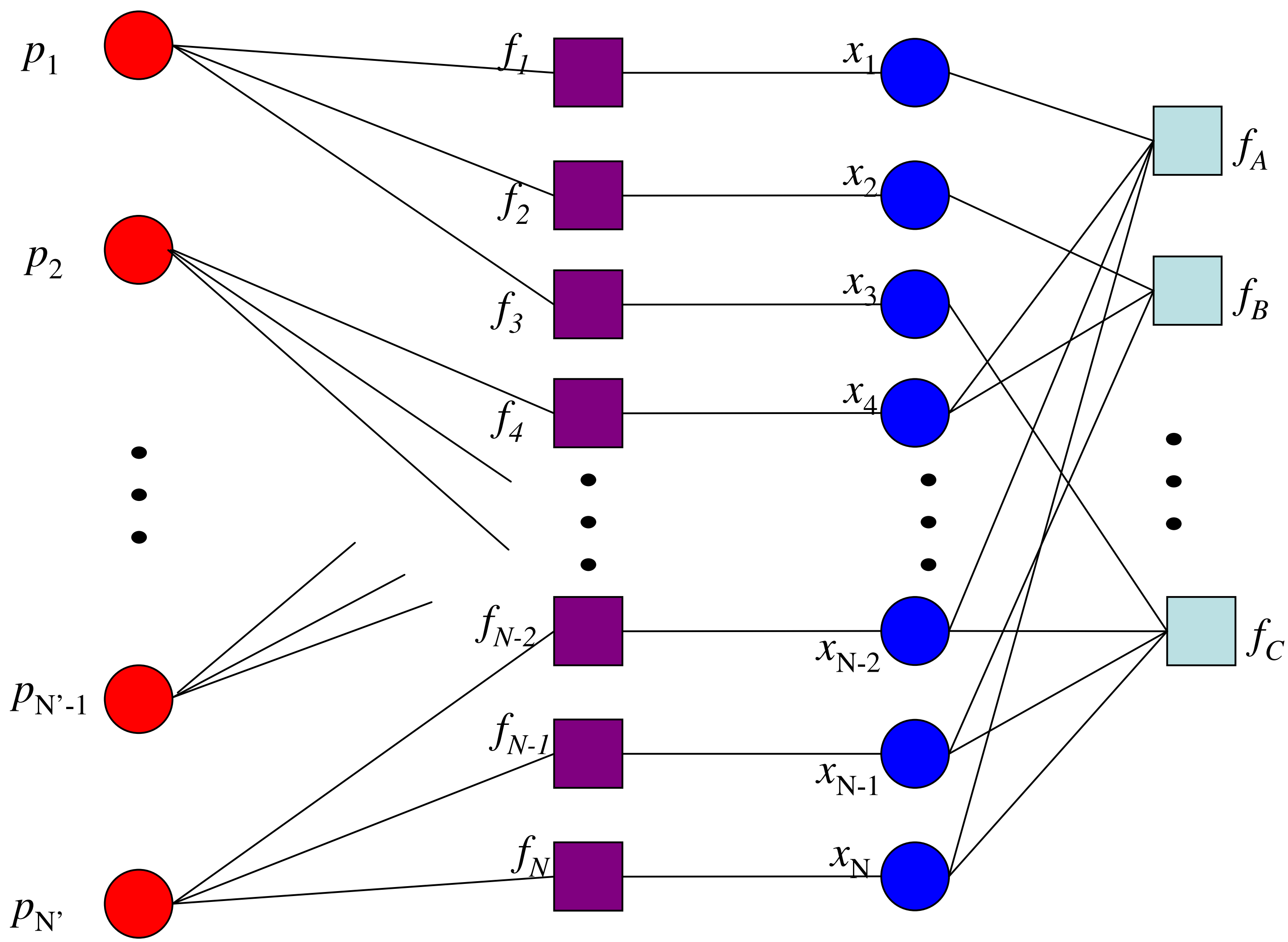


Non-stationarity of p over time

- Connect p nodes to correlation factor nodes, which in turn are connected to source variable nodes x to check if $x=y$

- Number of correlation factor nodes connected to each variable node p is termed connection ratio

Factor graph construction

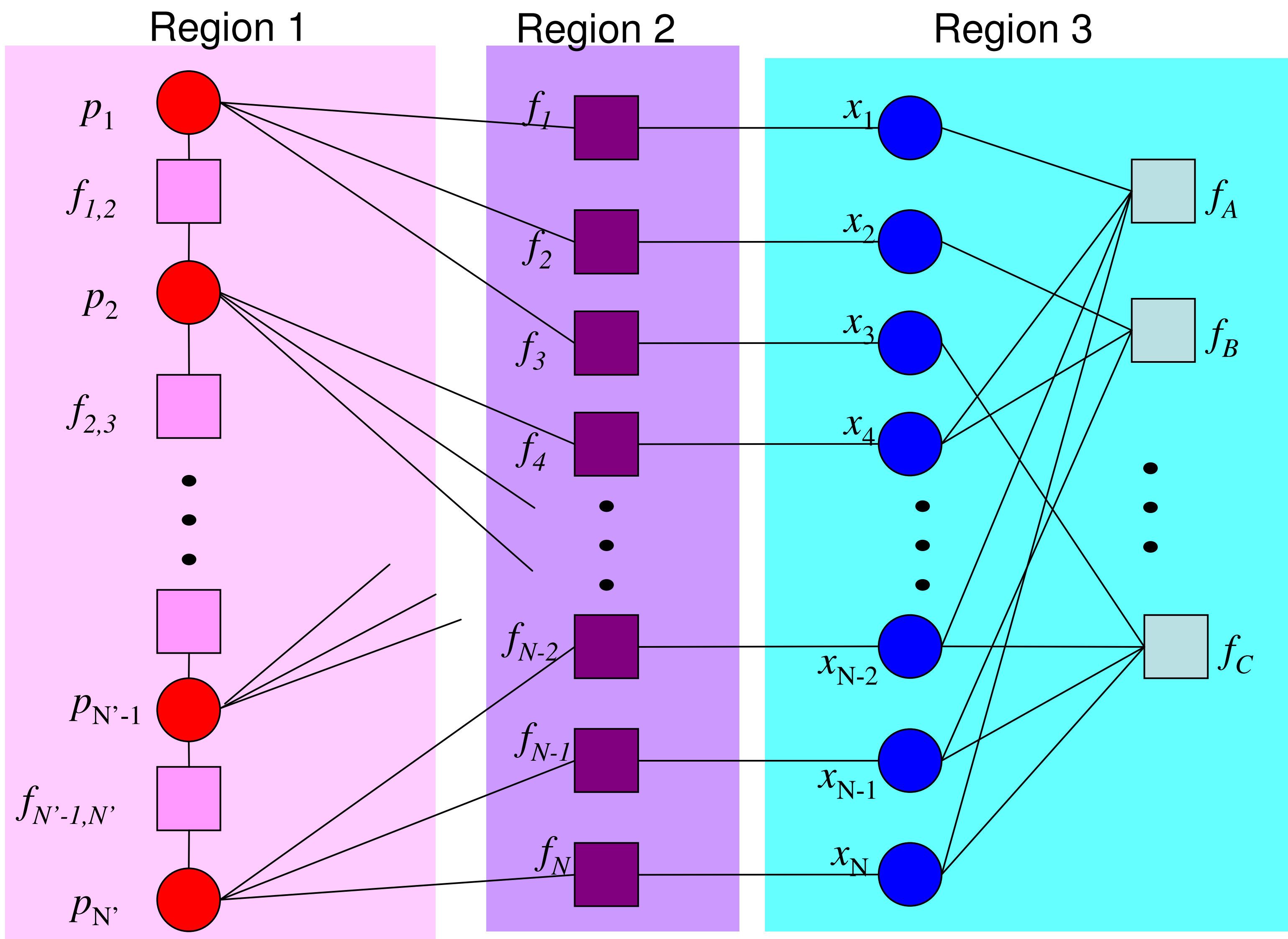


Non-stationarity of p over time

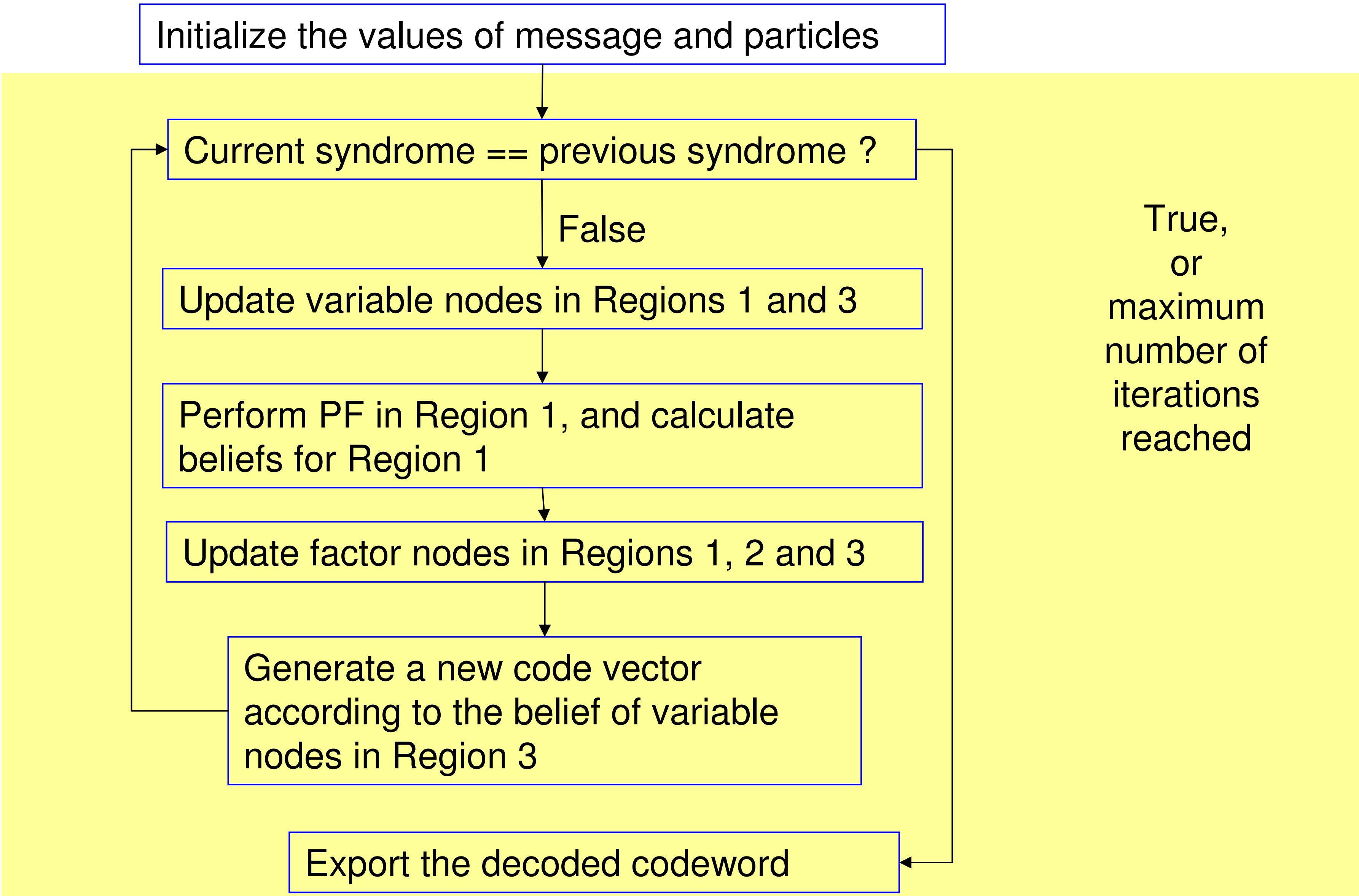
- Insert additional factor nodes $f_{i,j}$ connecting adjacent p nodes

$$f_{i,j}(p_i, p_j) = \frac{1}{\sqrt{2\pi\lambda}} \exp\left(-\frac{(p_j - p_i)^2}{2\lambda} \right)$$

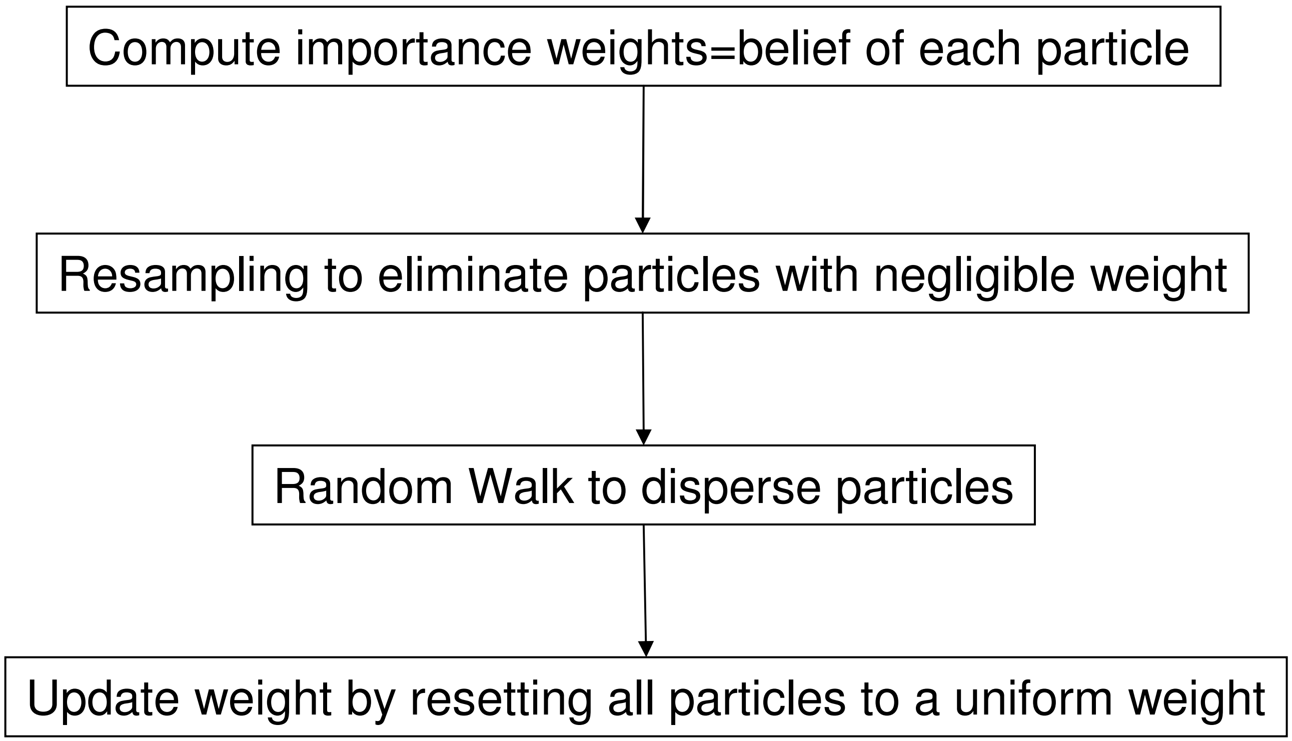
SW decoder graph with PF

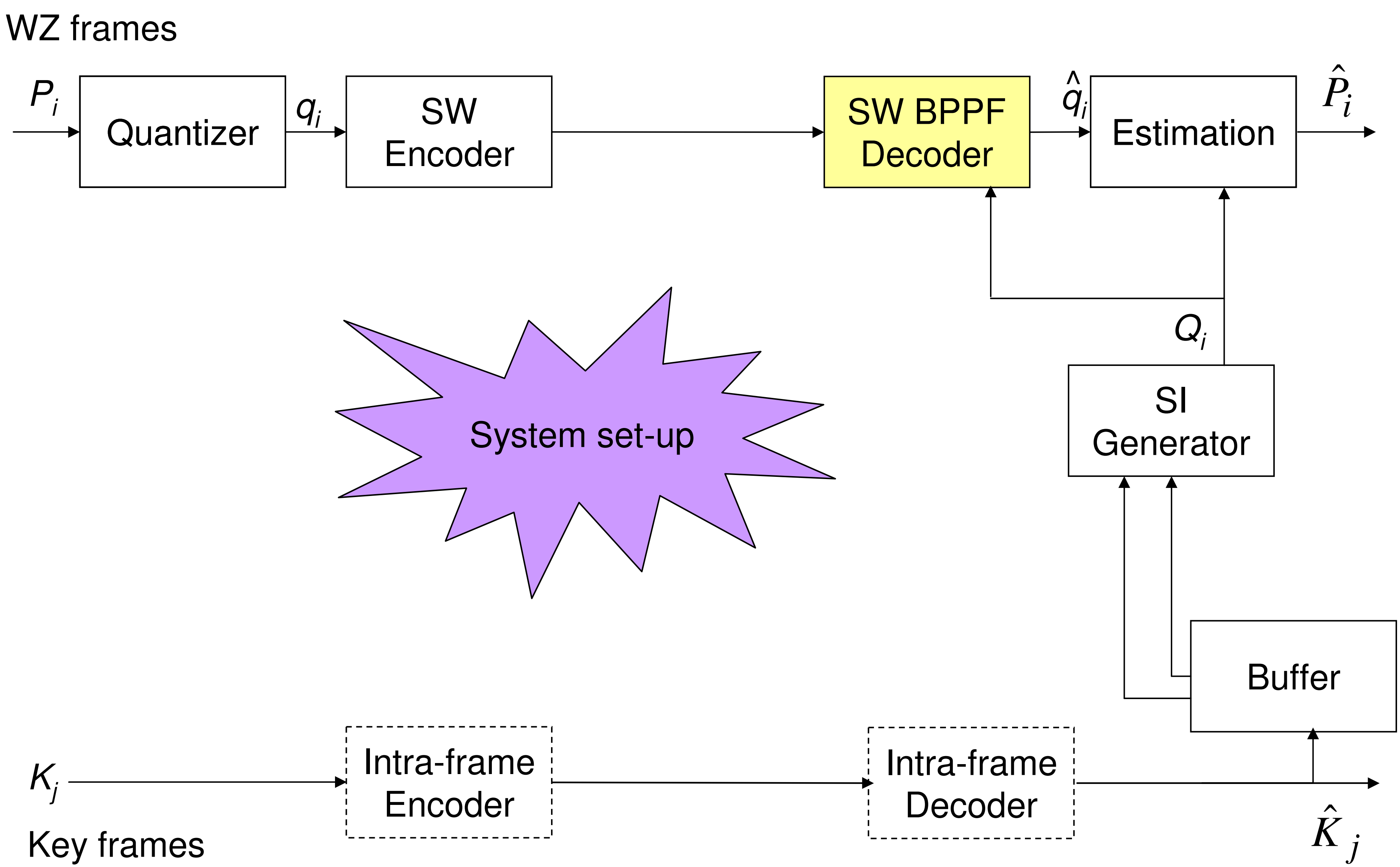


Message passing algorithm



Particle filtering in Region 1



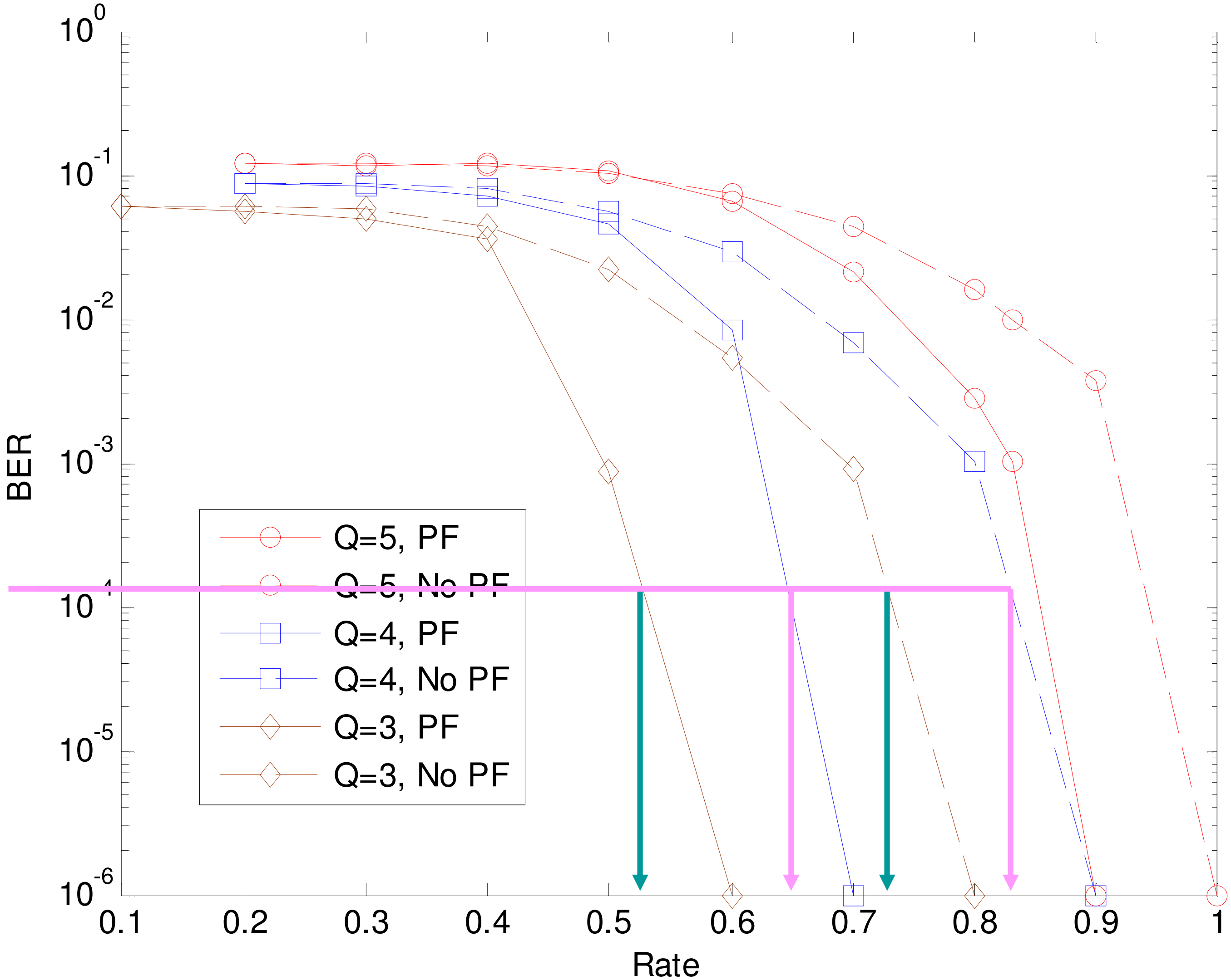


WZ frames
P_i
Quantizer
q_i
SW Encoder
SW BPPF Decoder
$\hat{q}_i$
Estimation
$\hat{P}_i$
Q_i
System set-up
SI Generator
Buffer
K_j
Intra-frame Encoder
Intra-frame Decoder
$\hat{K}_j$
Key frames

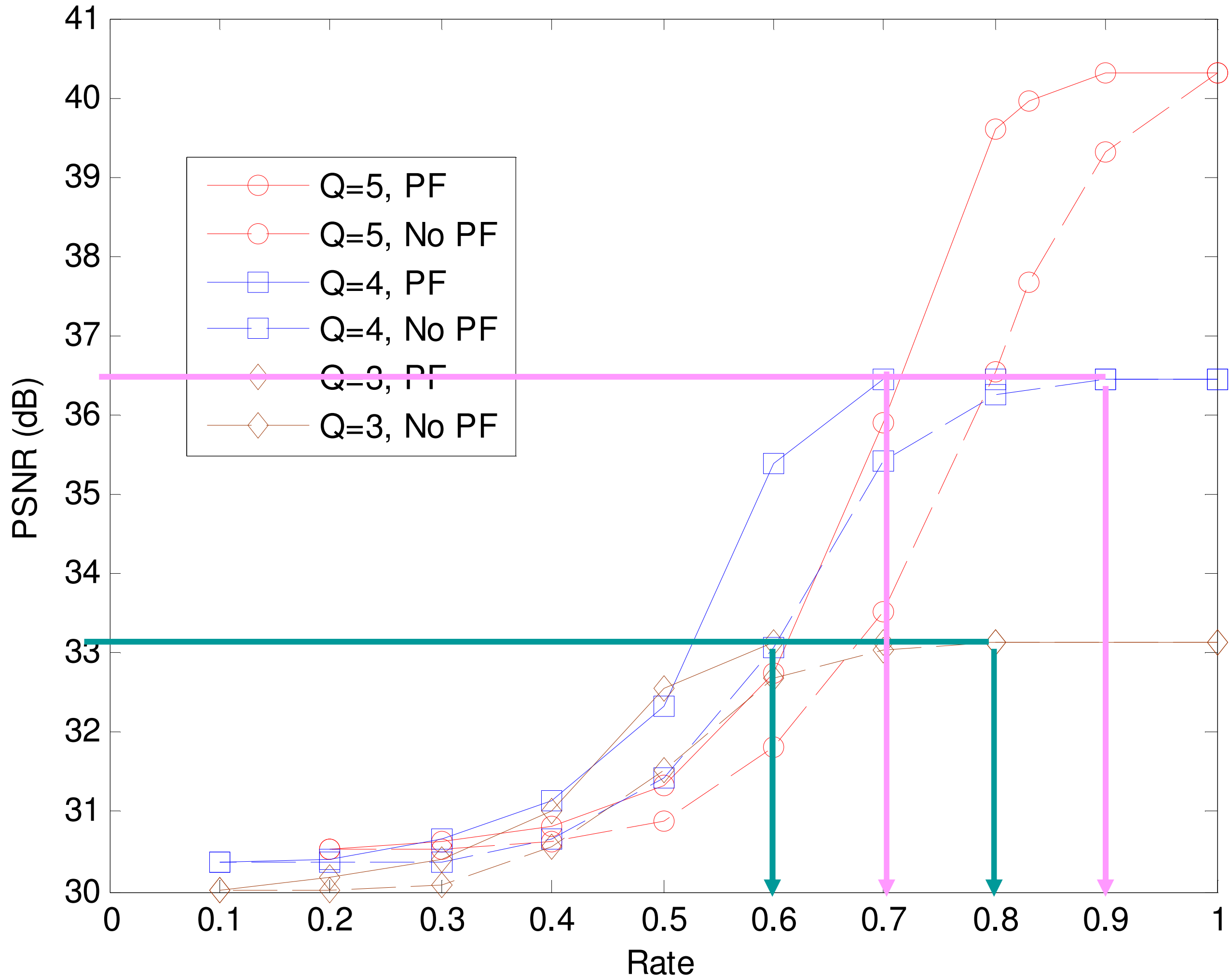
Parameters

- Tuneable parameters:
  - X and Y quantization ratio → Q=3, 4, 5 bits/pixel
  - hyper-prior λ → 0.1
  - connection ratio between regions 1 and 2 → 16
  - Metropolis-Hastings random walk → enabled
  - maximum number of iterations → 100
  - number of particles → 10
  - initial estimate of correlation p → 0.13
- 16 frames of Coast and Car sequences
- Assume that key frames available at the decoder are perfectly reconstructed
- Rate=number of syndrome bits/number of quantized bits

Results: Car video sequence



Results: Car video sequence

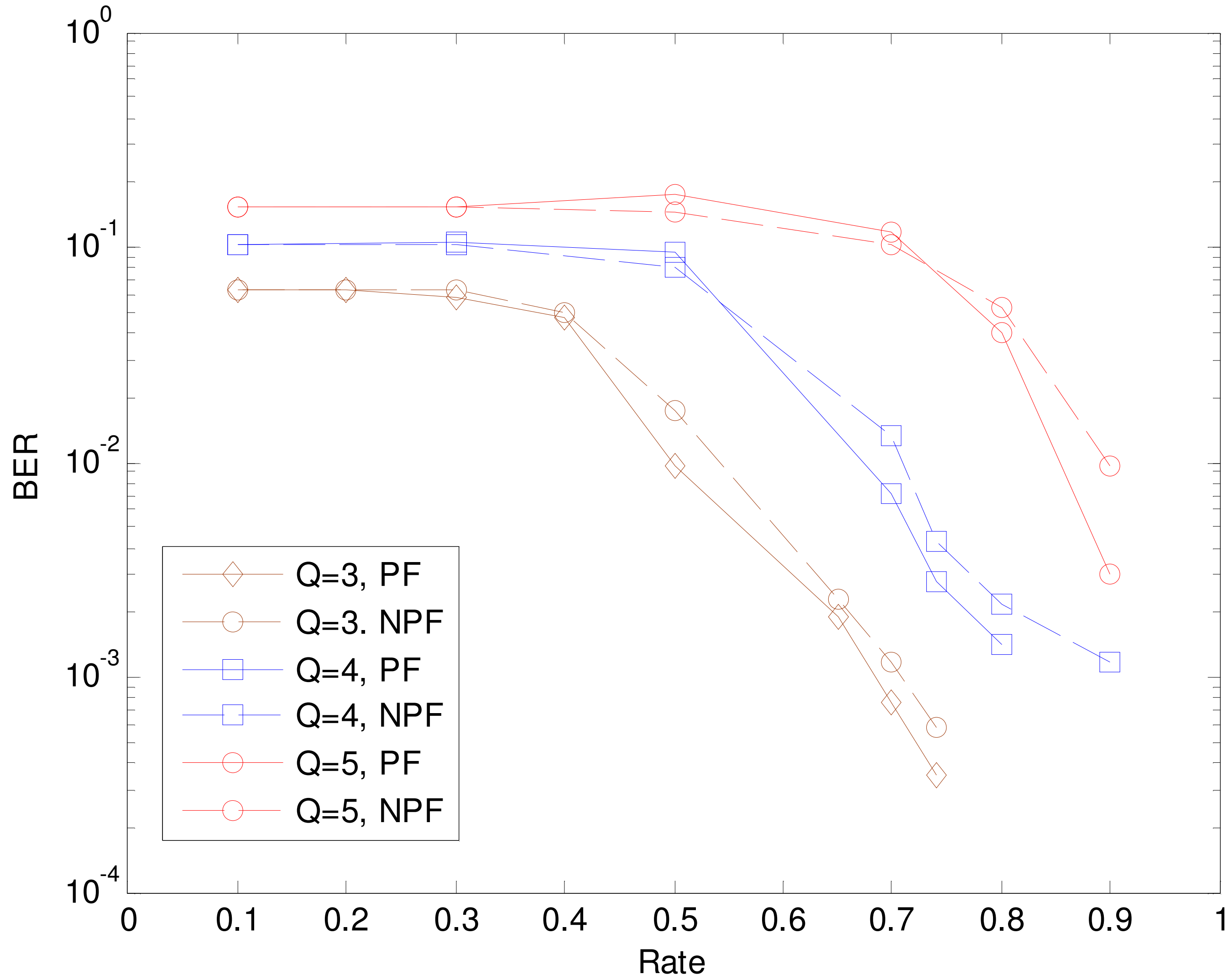


Results: Reconstruction of Frame 7 with Q=3

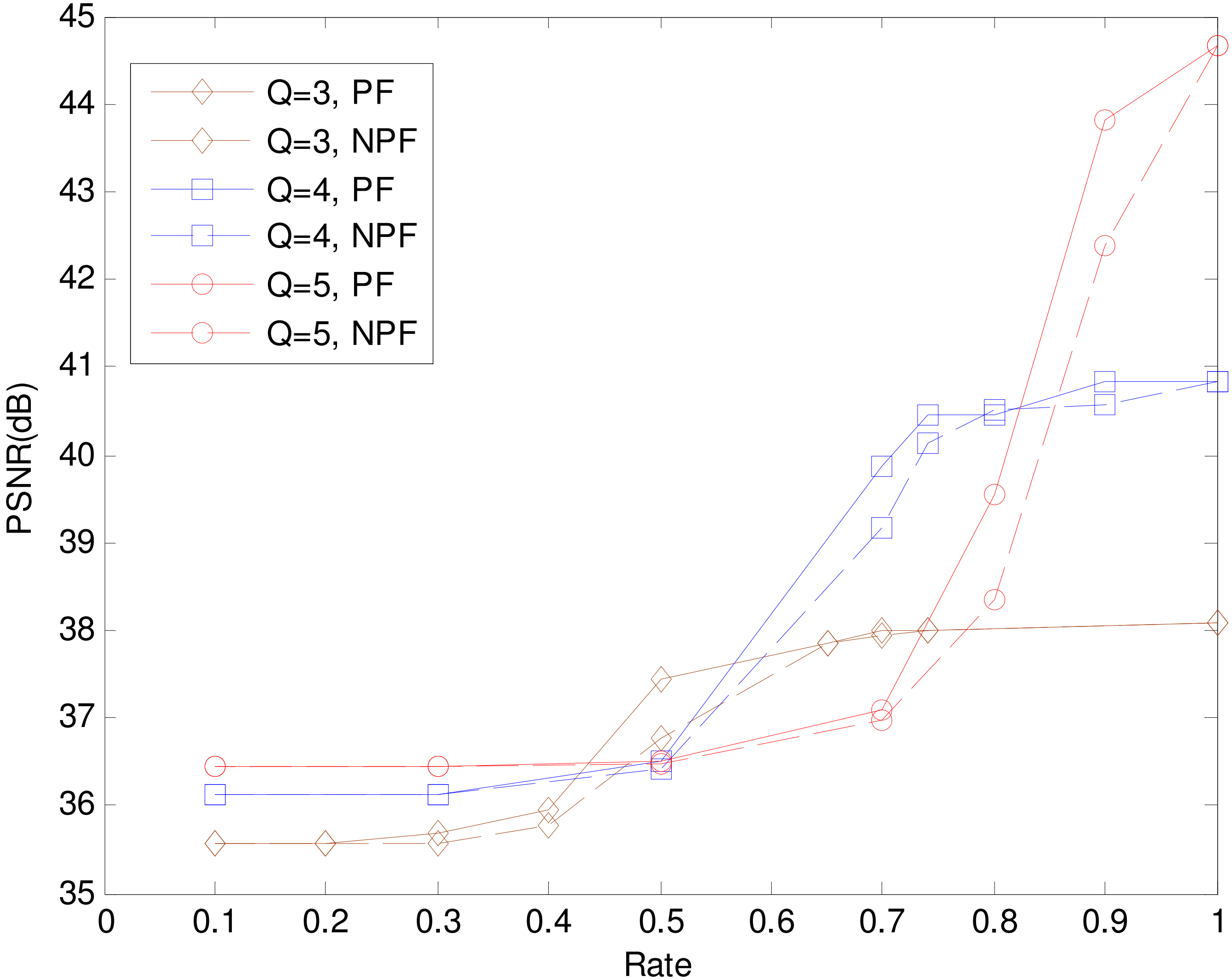
Without BPPF correlation tracking

With proposed system

Results: Coast video sequence



Results: Coast video sequence



Conclusions

- ✓ Performance improvement of DVC by incorporating correlation estimation via PF within the SW BP decoder
- ✓ Our PF-based BP helps estimate correlation evolving over time, improving SW decoder performance
- ✓ Developed a tool with a number of tuneable parameters, which can be optimised
- ✓ Our set-up can be used with DCT-based DVC, with/without feedback, and even with correlation noise modelling outside SW decoder

Further work

- SW BPPF decoding with bit-plane splitting
- Modelling correlation noise as AWGN or Laplacian
- Optimise tunable parameters
- Use correlation estimation approaches prior to SW decoding to initialise parameters