



# A Joint Trellis Coded Quantization (TCQ) Data Hiding Scheme in the JPEG2000 Part 2 Coding Framework

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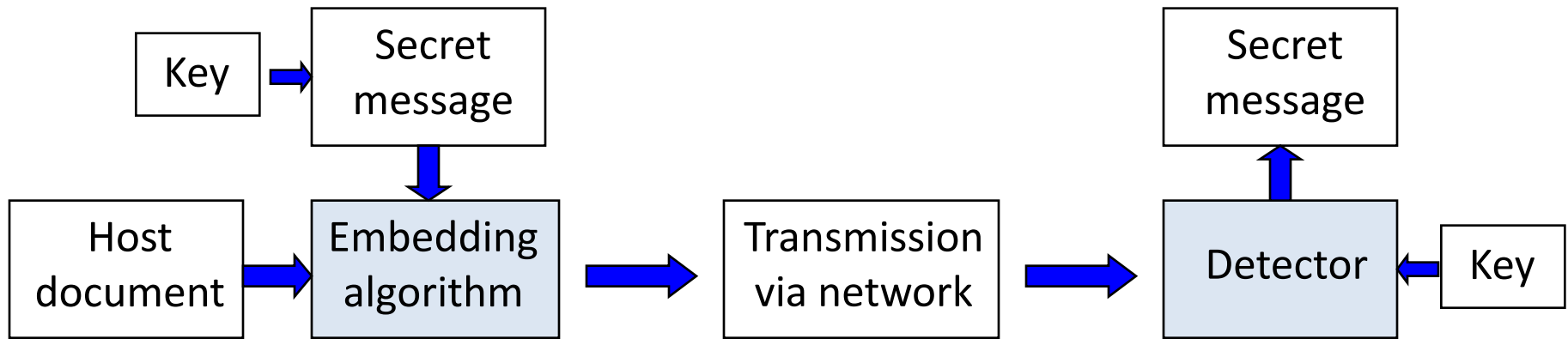
# Outline

- Generalities
  - Data hiding
  - Joint data hiding and compression approach
  - JPEG2000 standard
  - Trellis Coded Quantization (TCQ)
- Joint JPEG2000 compression & data hiding scheme
  - The TCQ-based data hiding strategy
  - The proposed joint scheme
  - The embedding and extraction algorithms
- Experimental evaluations
  - Protocol 1: data hiding performances
  - Protocol 2 : compression performances
- Conclusion

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# Data hiding



- Content description and meta data enrichment applications
- Embed the maximum amount of data (**payload**) in the host image without perceptually distorting it
- The information embedded must be recovered without error during the extraction stage

# Joint data hiding and compression approach

Joint data hiding and compression

Content description  
applications

Low  
complexity

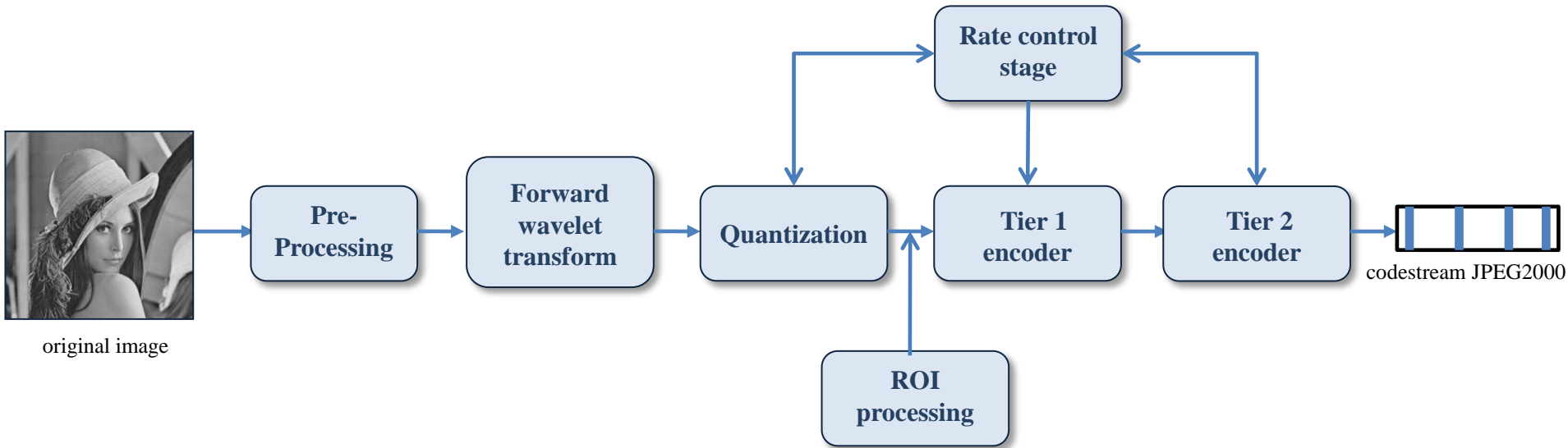
Compliant  
syntax  
bitstream

Good  
visual  
quality

High  
Payload

Robustness  
to  
compression

# JPEG2000 standard



ISO/IEC 15444-1, "Information Technology - JPEG2000 Image Coding System-Part 1: Core Coding System", 2000

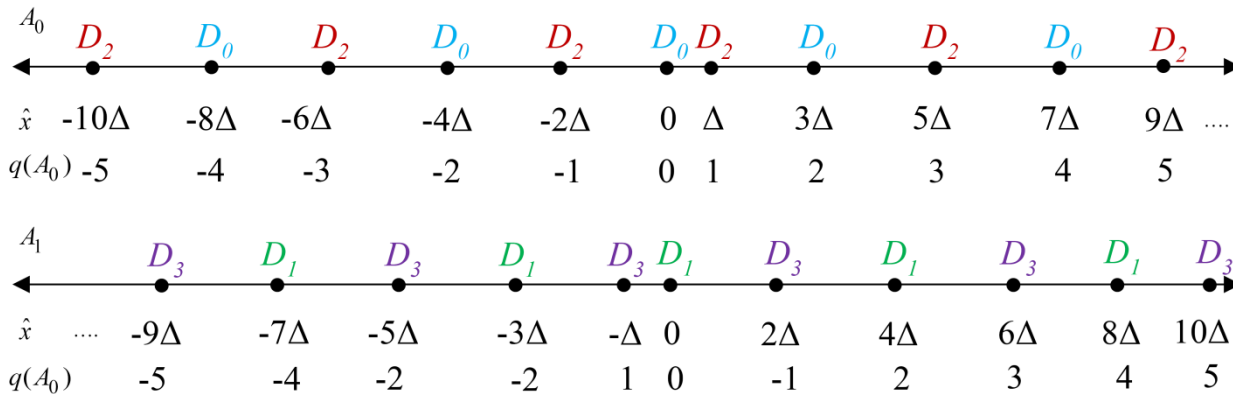
## JPEG2000 features

- Good compression performances, and smooth transmission from lossy to lossless
- Progressive transmission
- Regions of interest
- Flexible file format
- Error Resilience
- ...

# Trellis Coded Quantization (TCQ) in JPEG2000 part 2

Partitioning of a scalar quantizer into 4 subsets combined to form 2 union quantizers:

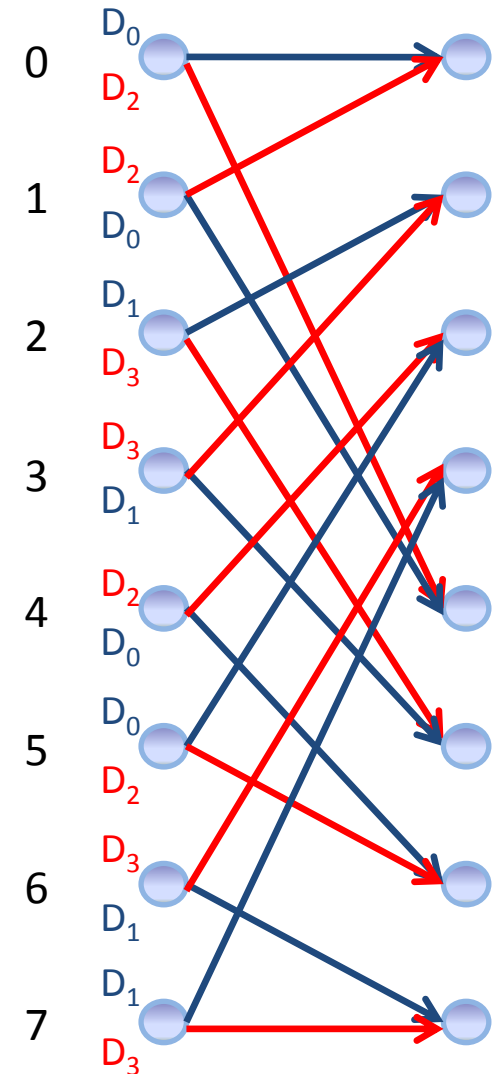
$$A_0 = D_0 \cup D_2 \quad \& \quad A_1 = D_1 \cup D_3$$



Subsets  $D_i$  of the 2 union quantizers  $A_0$  and  $A_1$  are used to label the branches of a trellis

Quantization is performed by running the Viterbi algorithm to find the optimal path (minimum distortion path) through the trellis

The least significant bit (LSB) of the TCQ indices determine the path through the trellis



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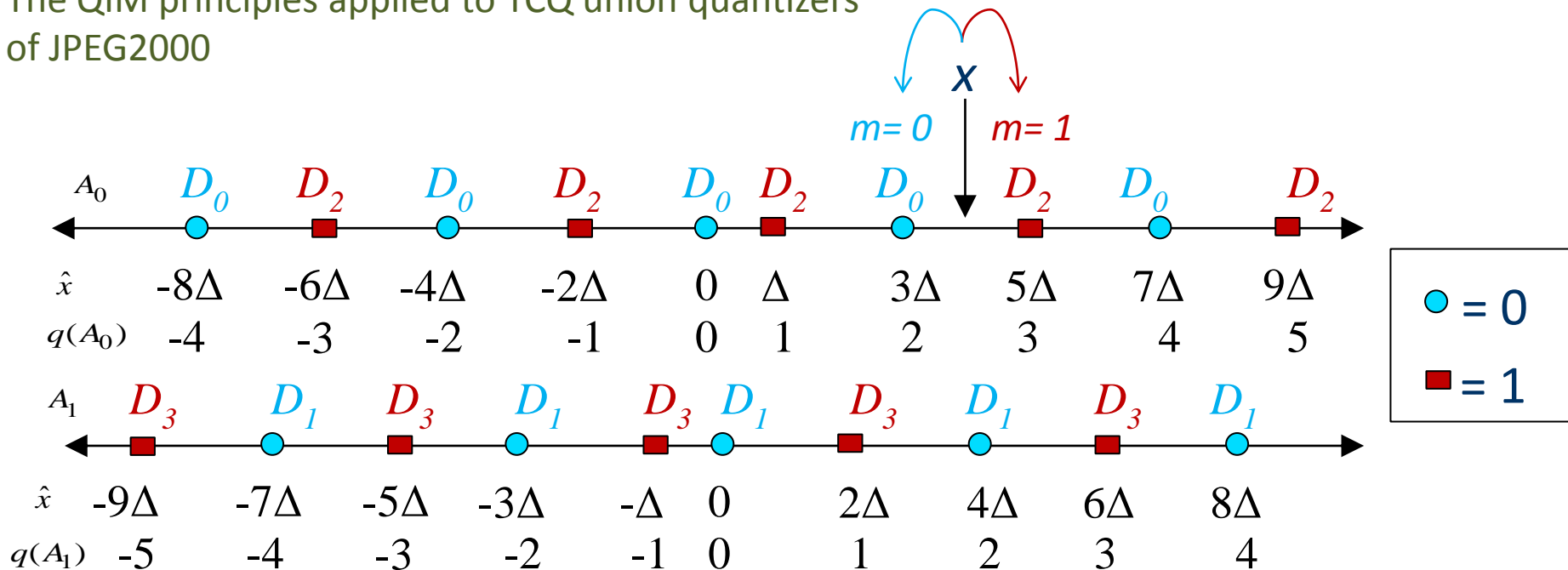


# The TCQ-based data hiding strategy

- The data is hidden during the quantization process without any additional stage for hiding data.
- Data hiding strategy derived from the QIM (Quantization Index Modulation) principles
- Integration into a TCQ approach (trellis)
- Quantizers are **modulated** according to the data to hide
- Data is embedded only in the **significant wavelet coefficients** which have a better chance of survival after JPEG2000 rate allocation stage.
- Selected coefficients are quantized with the associated quantizer

# The TCQ-based data hiding strategy

The QIM principles applied to TCQ union quantizers of JPEG2000



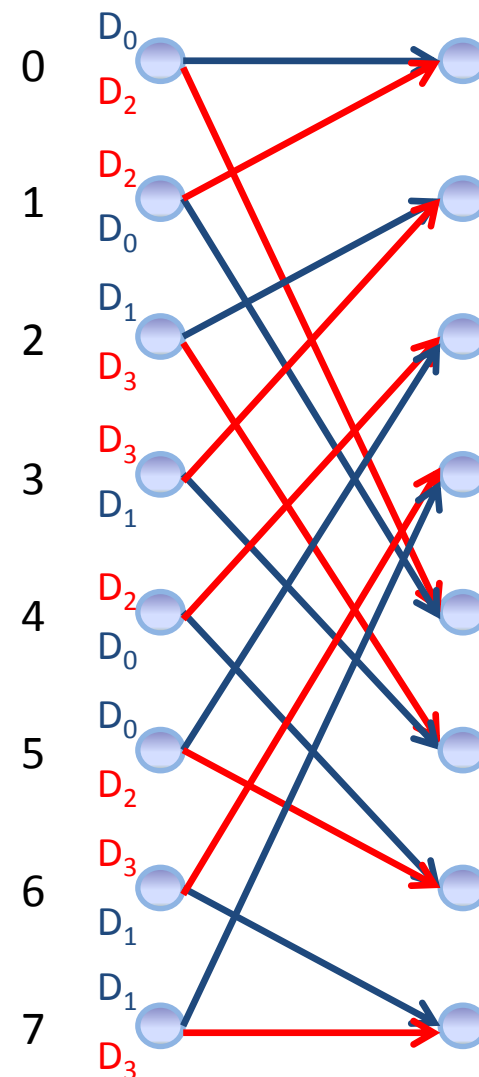
- Union quantizer  $A_0$ : if the bit to embed is the bit 0, then the quantizer  $D_0$  is used to quantize the wavelet coefficient. Otherwise the quantizer  $D_2$  is used.
- Union quantizer  $A_1$ : if the bit to embed is the bit 0, then the quantizer  $D_1$  is used to quantize the wavelet coefficient. Otherwise the quantizer  $D_3$  is used.

# The TCQ-based data hiding strategy

The choice of the branch to traverse is determined by the value of the bit to be embedded

The trellis is pruned only at the transitions which correspond to the **selected coefficients**

The trellis pruning is similar to Miller et al. scheme (DPTC)

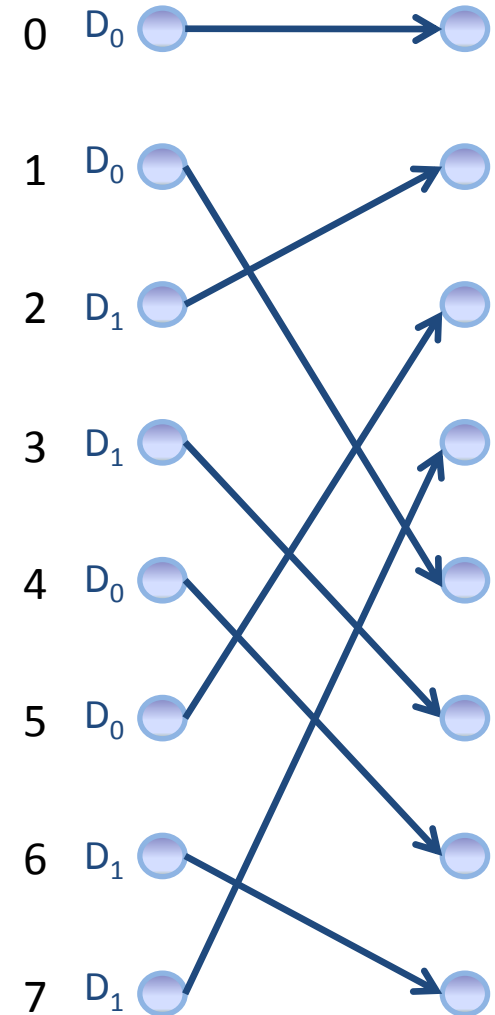


# The TCQ-based data hiding strategy

The trellis is pruned only at the transitions which correspond to the **selected coefficients**

- if the bit to embed is the bit 0 :  $D_0$  and  $D_1$  are used to quantize the wavelet coefficient.

Trellis structure : remove the red branches at the considered transition

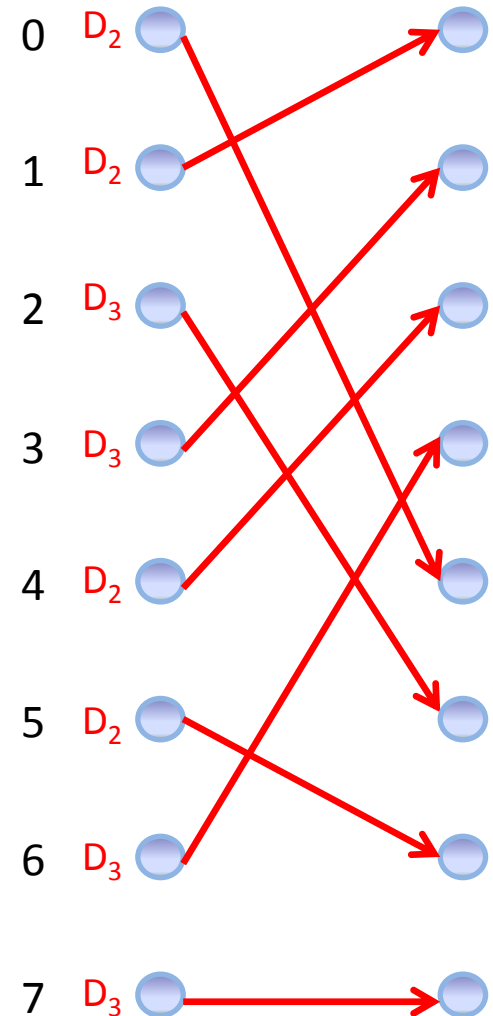


# The TCQ-based data hiding strategy

The trellis is pruned only at the transitions which correspond to the **selected coefficients**

- if the bit to embed is the bit 1 :  $D_2$  and  $D_3$  are used to quantize the wavelet coefficient.

Trellis structure : remove the blue branches at the considered transition

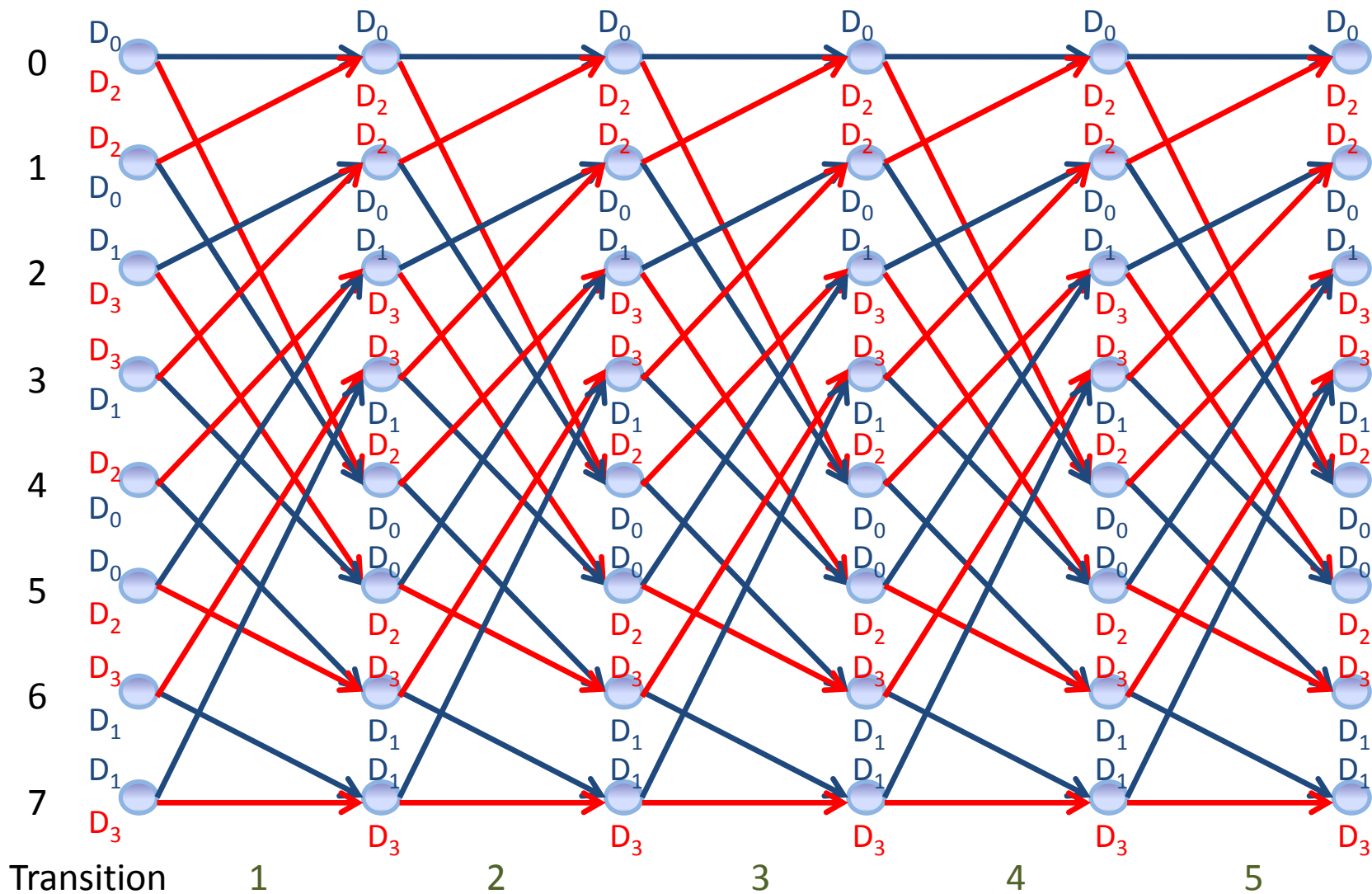


# Selection of the wavelet coefficients included in the data hiding process

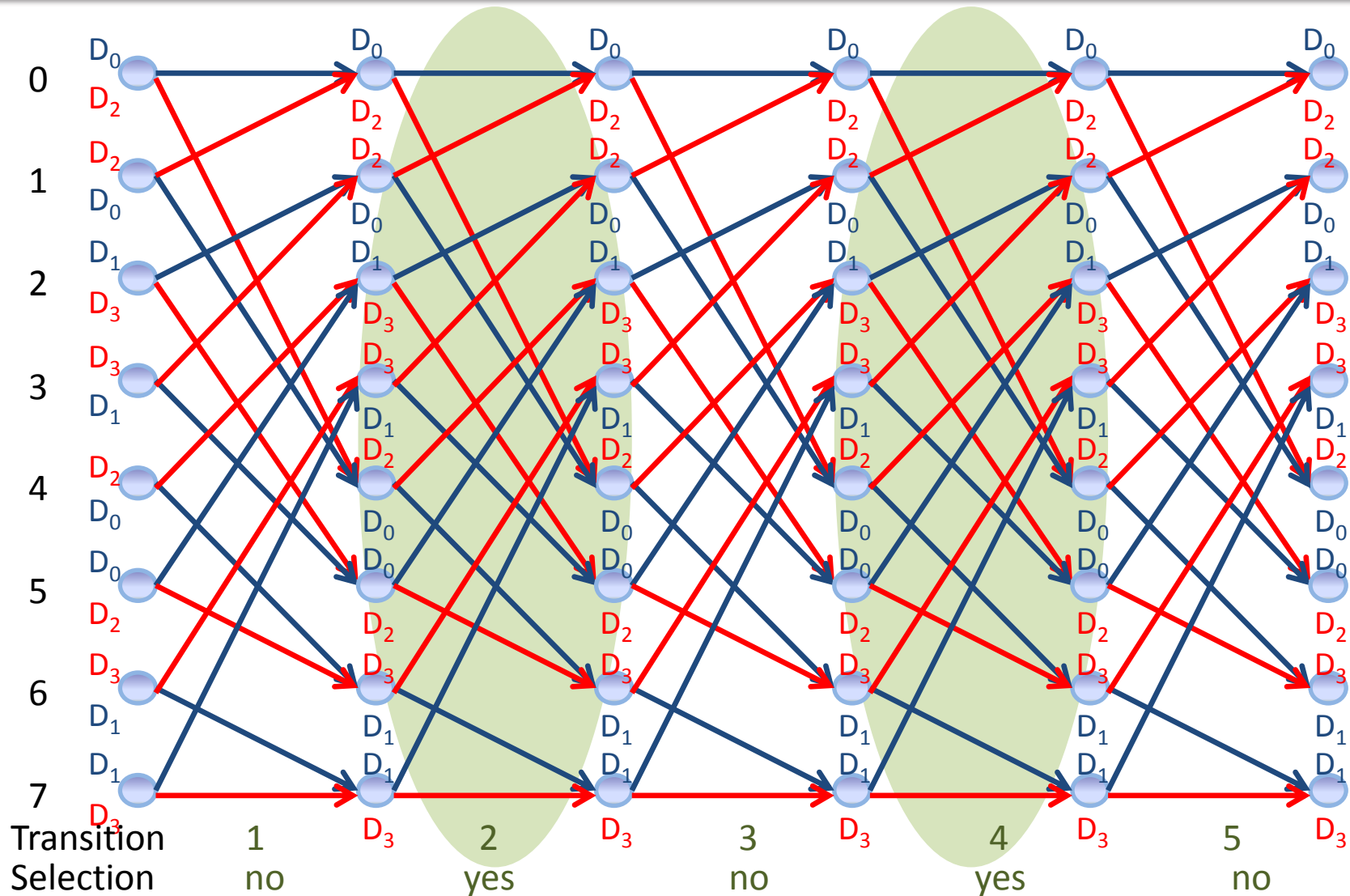
- Computation of selection threshold  $\tau_{IBP}$  for each code-block
- Coefficients are selected if their TCQ indices have their absolute magnitude bits greater than  $\tau_{IBP}$
- Data is hidden in the least significant bits (LSB) of the TCQ indices of the selected coefficients

Note : in order to avoid destruction of those LSBs (path in the trellis) by the JPEG2000 R-D optimisation stage, they are moved to a higher bit plane position.

# The TCQ-based data hiding strategy



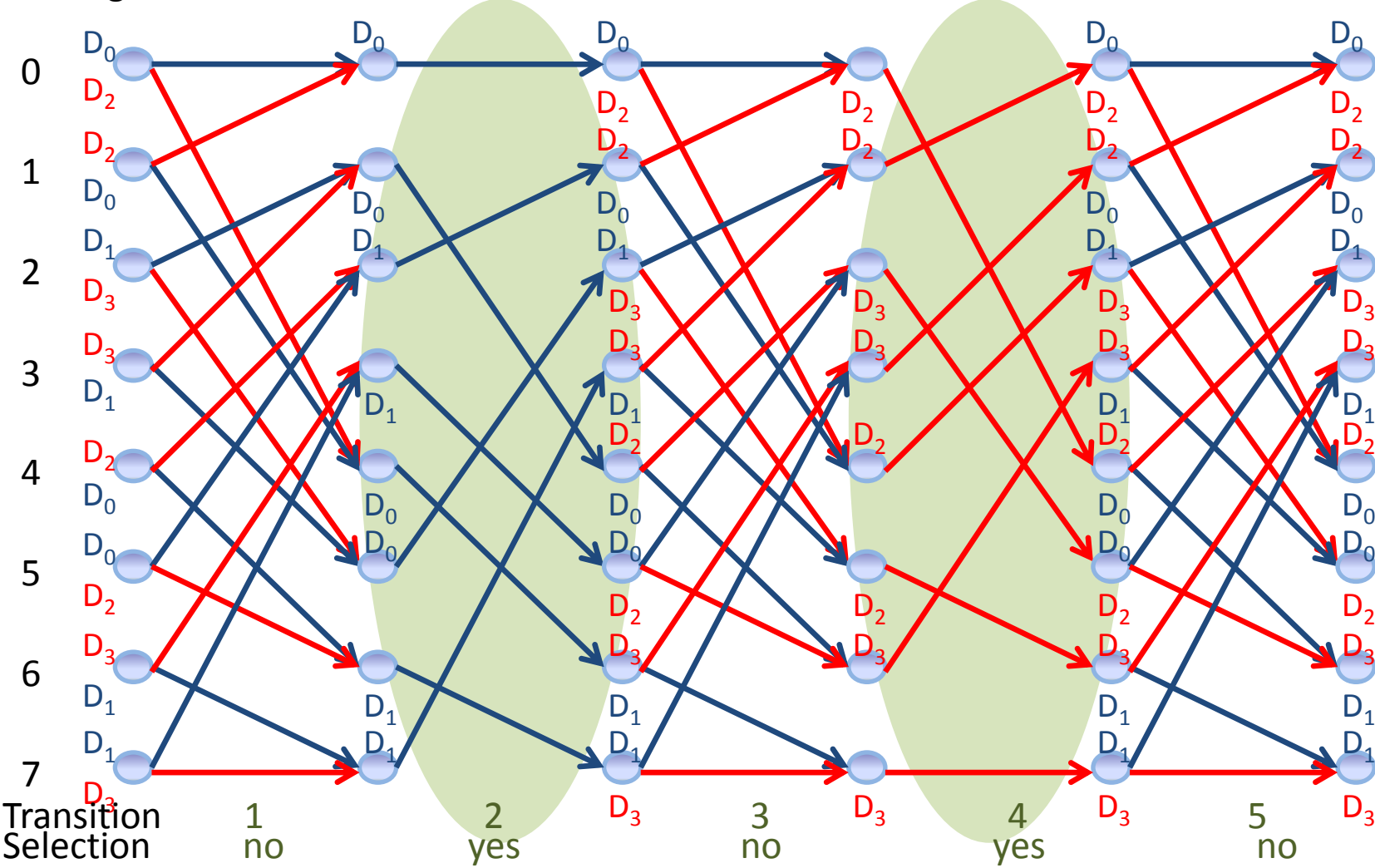
# The TCQ-based data hiding strategy



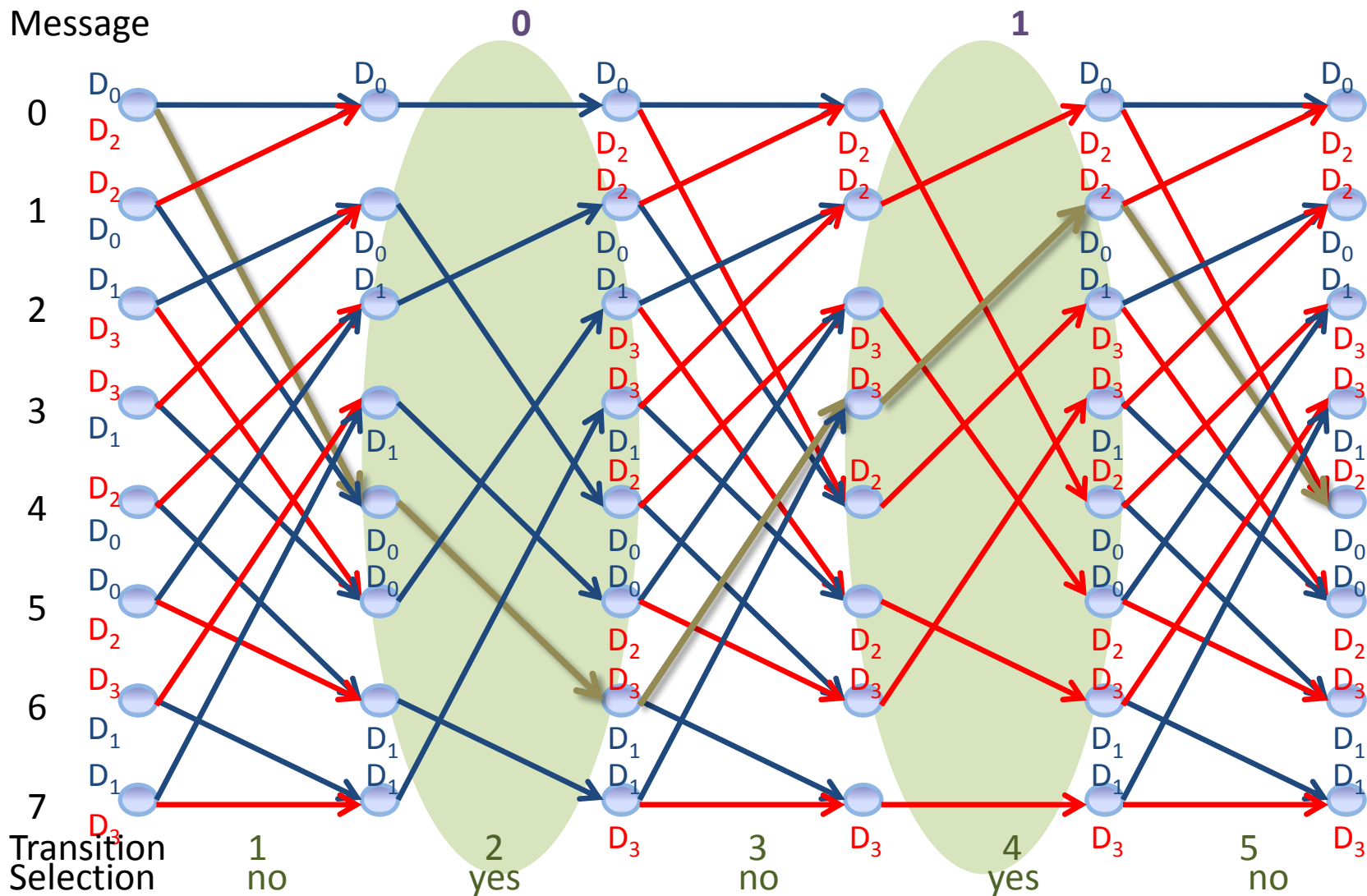


# The TCQ-based data hiding strategy

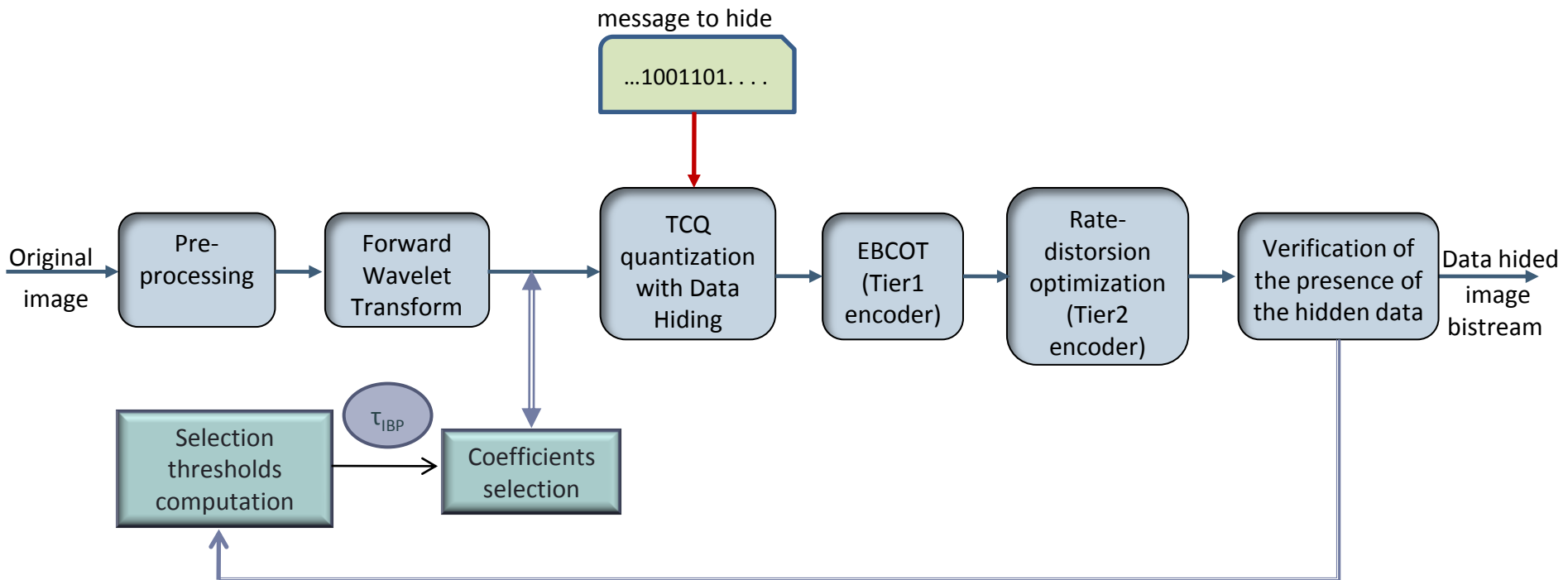
Message



# The TCQ-based data hiding strategy

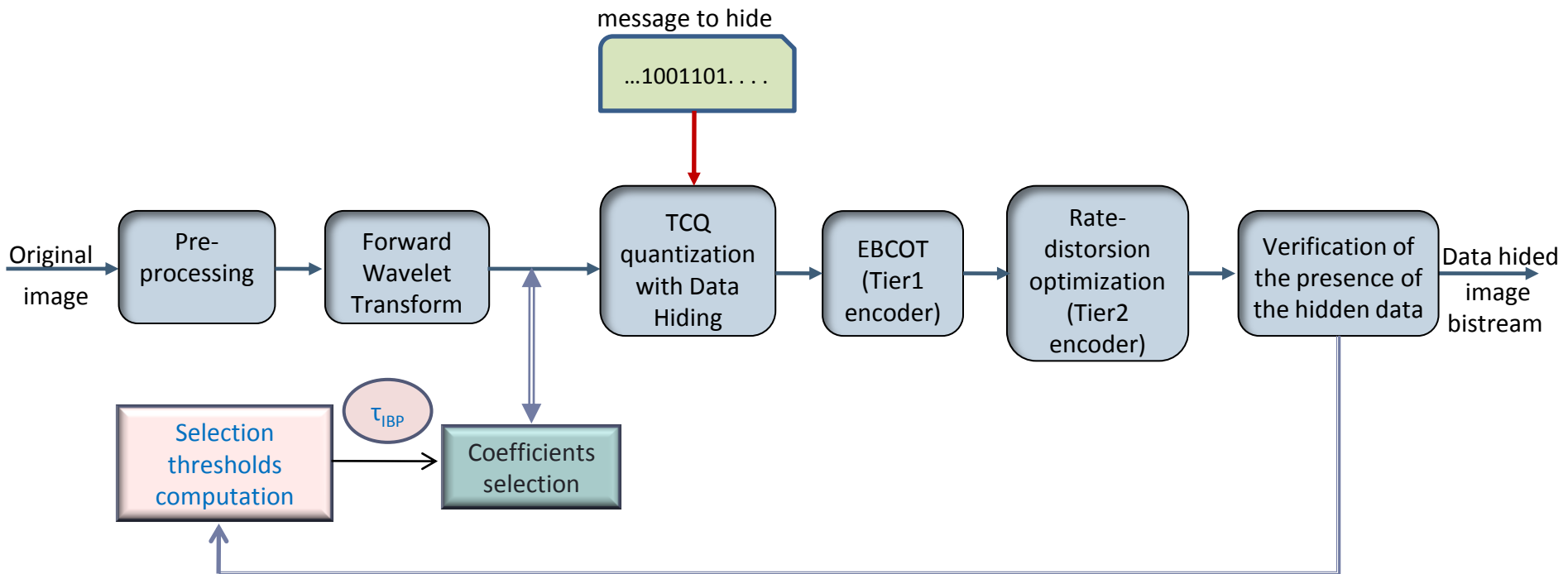


# The proposed joint JPEG2000 compression and data hiding scheme



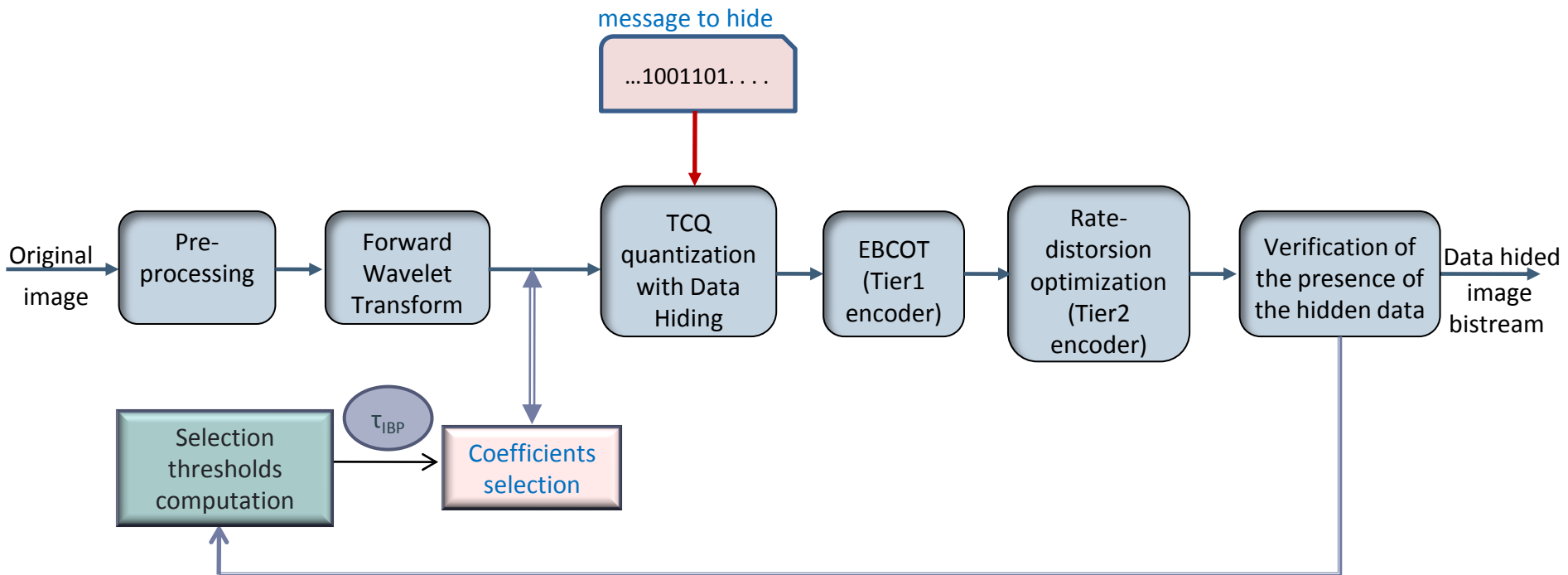
The joint JPEG2000 encoder/data hiding embedding scheme.

# Iterative embedding algorithm



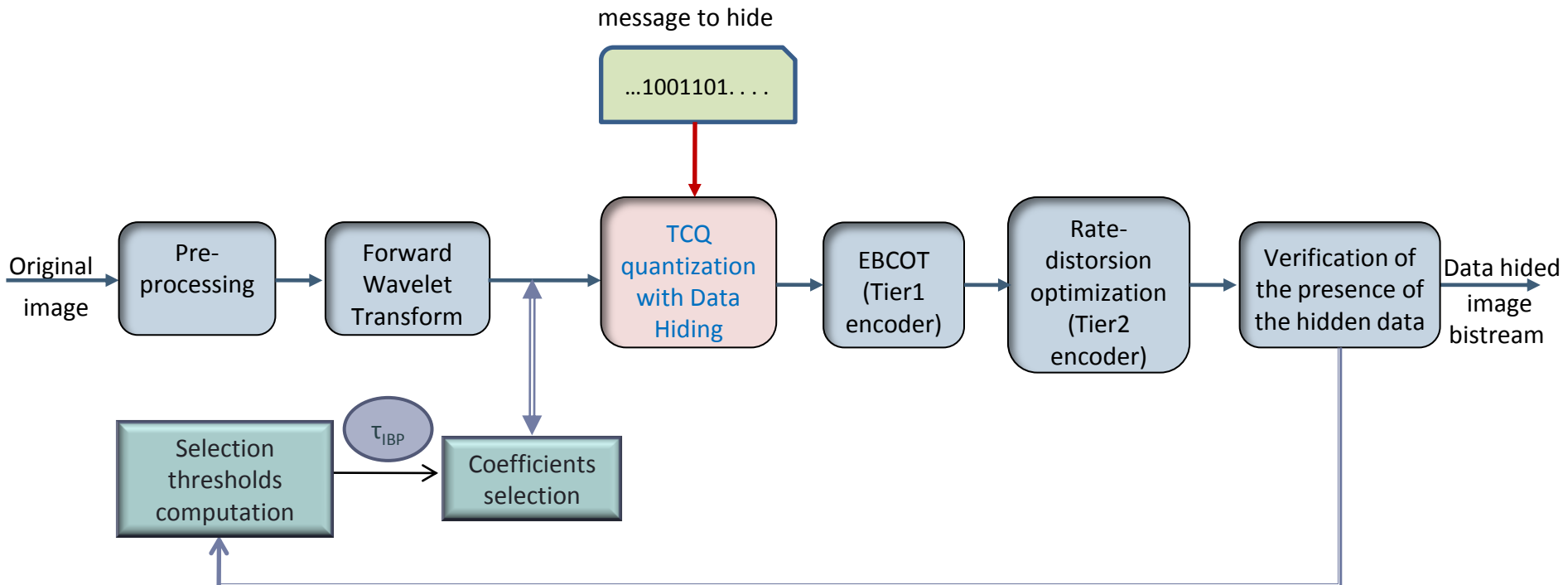
## 1. Computation of the selection thresholds $\tau_{IBP}$

# Iterative embedding algorithm



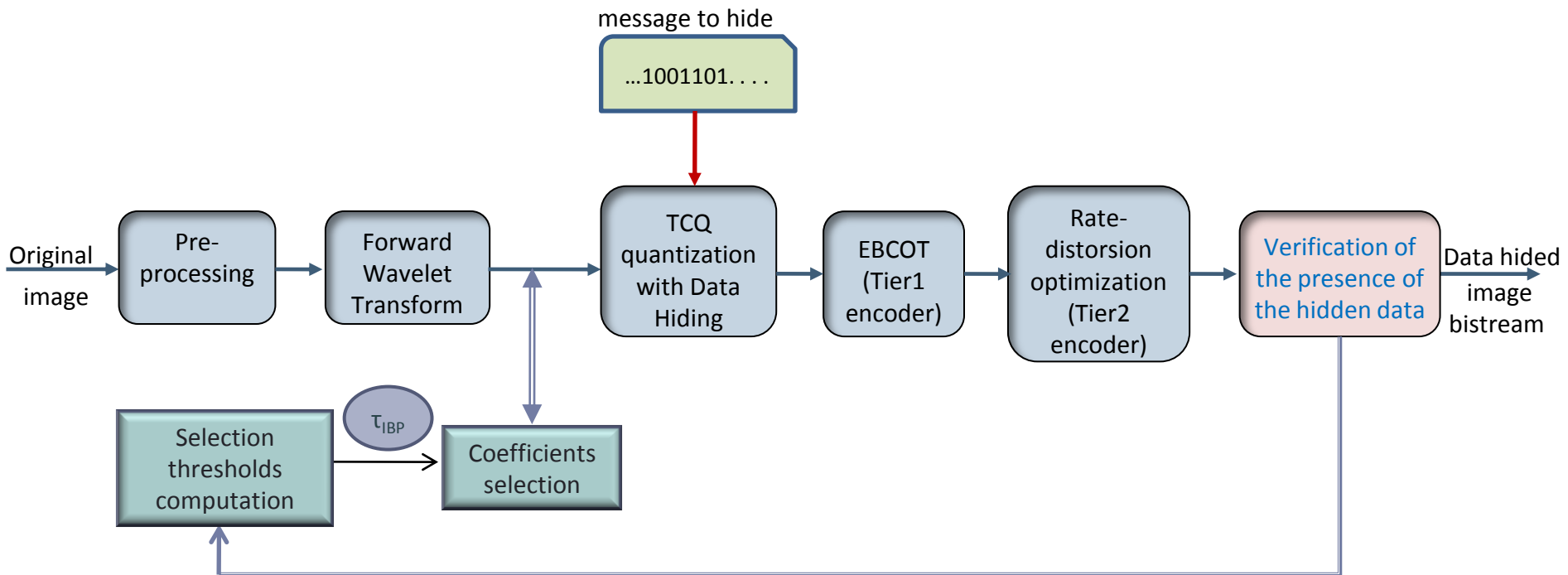
1. Computation of the selection thresholds  $\tau_{IBP}$
2. Selection of the wavelet coefficients included in the data hiding process
  - Determination of the hiding payload
  - Generation of the message to hide  $\mathbf{m}$
  - Pseudo random shuffling of the message  $\mathbf{m}$  with a secret key to obtain the message  $\mathbf{b}$

# Iterative embedding algorithm



1. Computation of the selection thresholds  $\tau_{IBP}$
2. Selection of the wavelet coefficients
3. TCQ quantization with data hiding

# Iterative embedding algorithm



1. Computation of the selection thresholds  $\tau_{IBP}$
2. Selection of the wavelet coefficients included in the data hiding process
3. TCQ quantization with data hiding
4. Verification process after R-D optimization stage of JPEG2000
  - Extraction of the embedded message  $\mathbf{b}'$
  - if  $\mathbf{b}' = \mathbf{b}$  then Stop
  - else Modify the selection threshold value for the considered code-blocks where erroneous bits were found and Go to 2

# Extraction algorithm

1. Decoding of the image bitstream
2. Inverse TCQ quantization
  - For each reconstructed TCQ index :
    - If the absolute magnitude bits of the TCQ index is **greater** than  $\tau_{IBP}$  then extract the LSB bit
3. Invert the shuffle to retrieve the hidden message **m**



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# Experimental results

## Evaluation protocol 1 : Data hiding performances

- 200 test images of 8 bits/pixels and size 512 x 512 (BOWS2 data base : <http://bows2.gipsa-lab.inpg.fr>)
- 5 levels of wavelet decomposition, one tile, no ROI coding
- Variation of the bitrate from 2.5 bpp to 0.2 bpp
- Selection of the coefficients included in the data hiding process within the wavelet coefficients of the HL, LH and HH detail sub-bands of all resolution levels except the first one
- Payload and imperceptibility constraints

# Experimental results

## Protocol 1 : Data hiding performances

Bitrate (bpp)	2.5 bpp	2 bpp	1.6 bpp	1 bpp	0.5 bpp	0.2 bpp
Average payload (bits)	11.257	11.203	11.143	7459	3683	1659
Minimum payload (bits)	1261	1261	1261	1261	1090	410
Maximum payload (bits)	37.313	26.180	21.809	12.732	5946	3129

Table 1 : Hiding payload obtained on 200 images for different bitrates

- High hiding payloads
- At higher bitrates, more bits are hidden
- The payload decreases as the bitrate decreases
- The hiding payload is dependent on the content of the original image

# Experimental results

## Protocol 1 : Data hiding performances

Bitrate (bpp)	2.5 bpp	2 bpp	1.6 bpp	1 bpp	0.5 bpp	0.2 bpp
Average PSNR (dB)	48.34	47.10	46.31	45.00	43.24	41.23
Average SSIM	0.9890	0.9851	0.9817	0.9713	0.9469	0.8944
Minimum PSNR (dB)	40.11	38.86	36.70	34.18	29.75	25.95
Minimum SSIM	0.9773	0.9655	0.9482	0.8871	0.7857	0.6279
Maximum PSNR (dB)	53.82	52.97	51.83	51.77	52.30	52.23
Maximum SSIM	0.9951	0.9951	0.9933	0.9889	0.9852	0.9821

Table 2 : PSNR and SSIM values on 200 images for different bitrates

- Average PSNR > 40 dB for all bitrates
- Average SSIM remains above 0.9 up to 0.2 bpp
- Good perceptual quality of the data hidden images
- The proposed joint scheme exhibits good quality performances in terms of PSNR and SSIM

# Experimental results

## Evaluation protocol 2 : Compression performances

- 7 well known test images of size 512 x 512 : Lena, Gold, Girl, Barbara, Bike, Peppers and Clown
- 5 levels of wavelet decomposition , one tile, no ROI coding
- Variation of the bitrate from 2.5 bpp to 0.2 bpp
- Visual quality (PSNR & SSIM) and comparison with JPEG2000

# Experimental results

## Protocol 2 : Compression performances

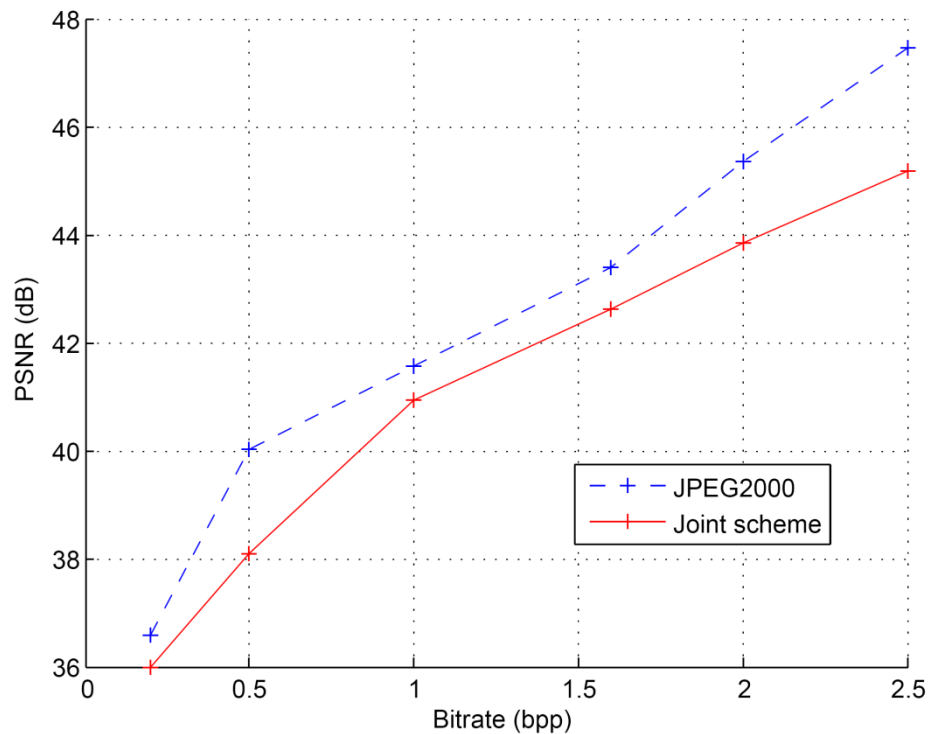


Image Lena

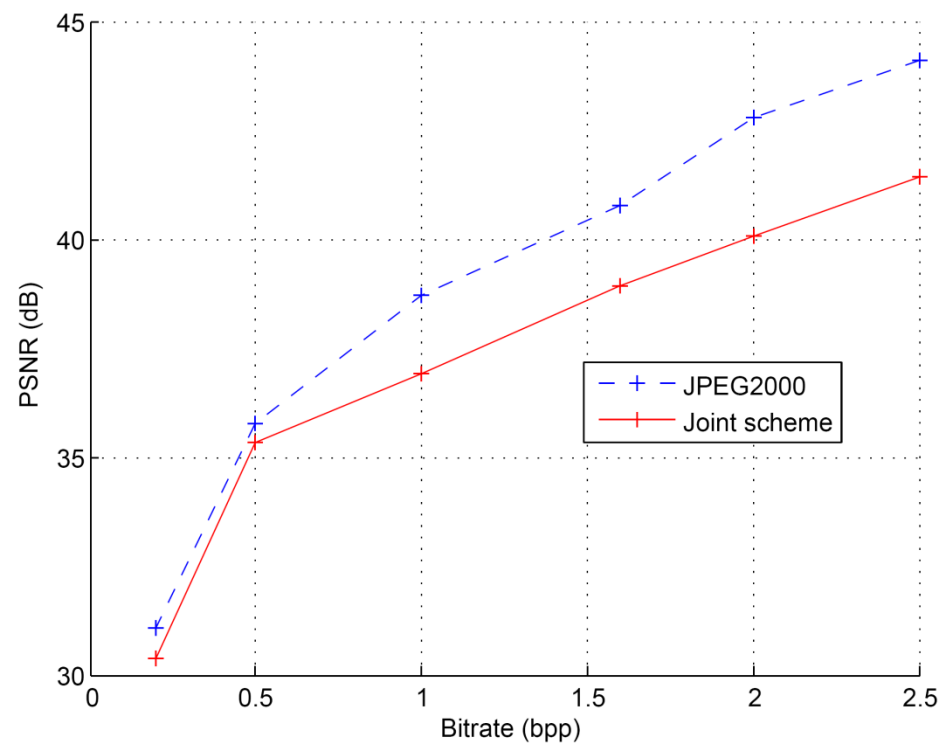


Image Clown

Visual quality comparison in terms of PSNR with JPEG2000

# Experimental results

## Protocol 2 : Compression performances

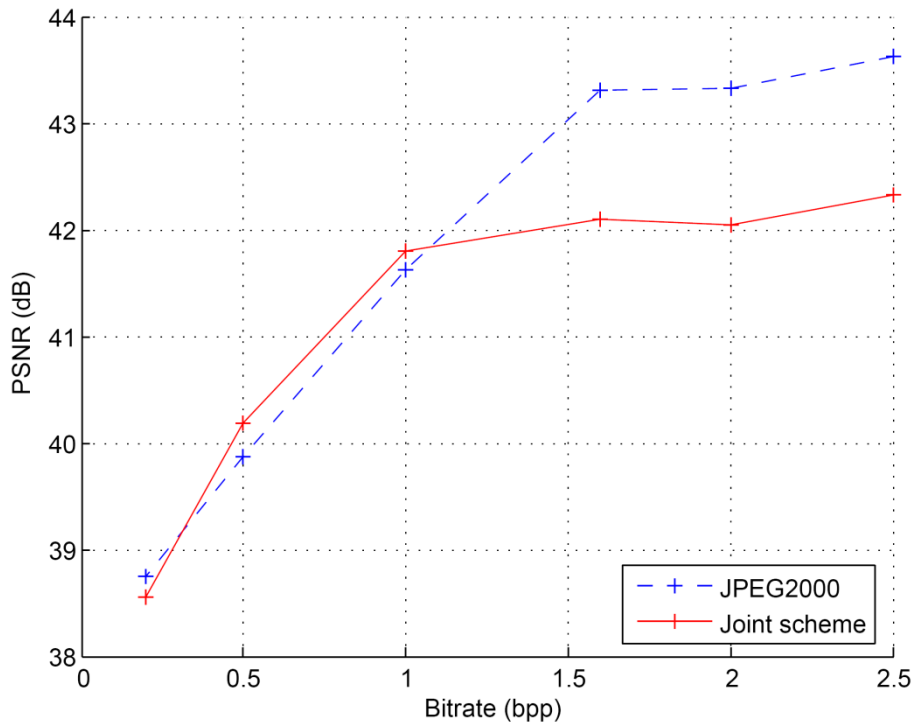


Image Gold

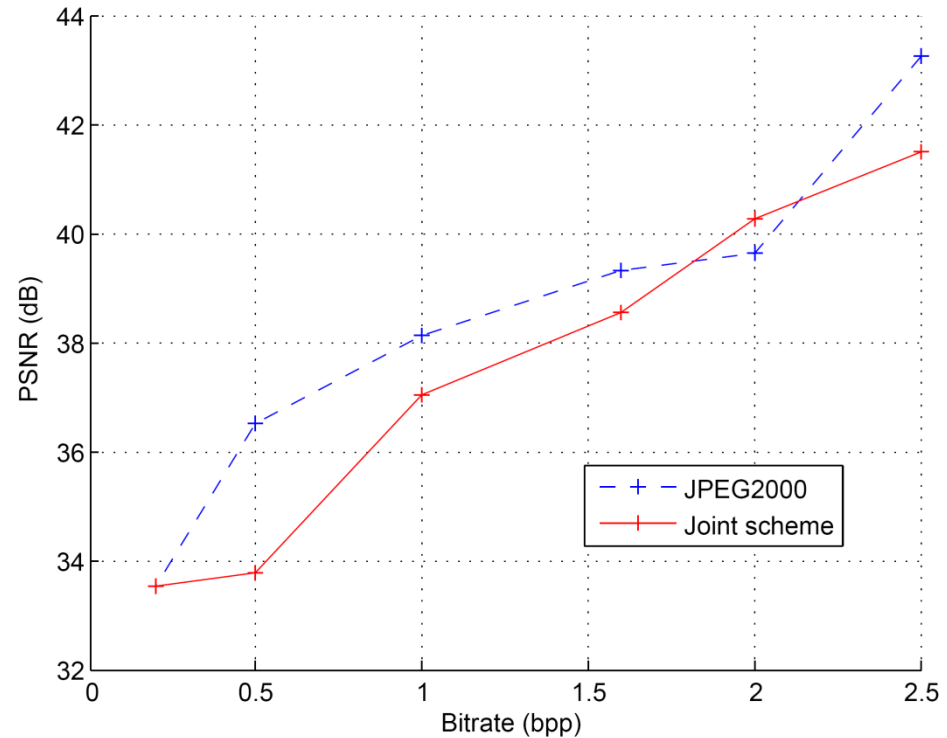


Image Bike

Visual quality comparison in terms of PSNR with JPEG2000

# Experimental results

Visual quality of the image obtained with the proposed joint scheme



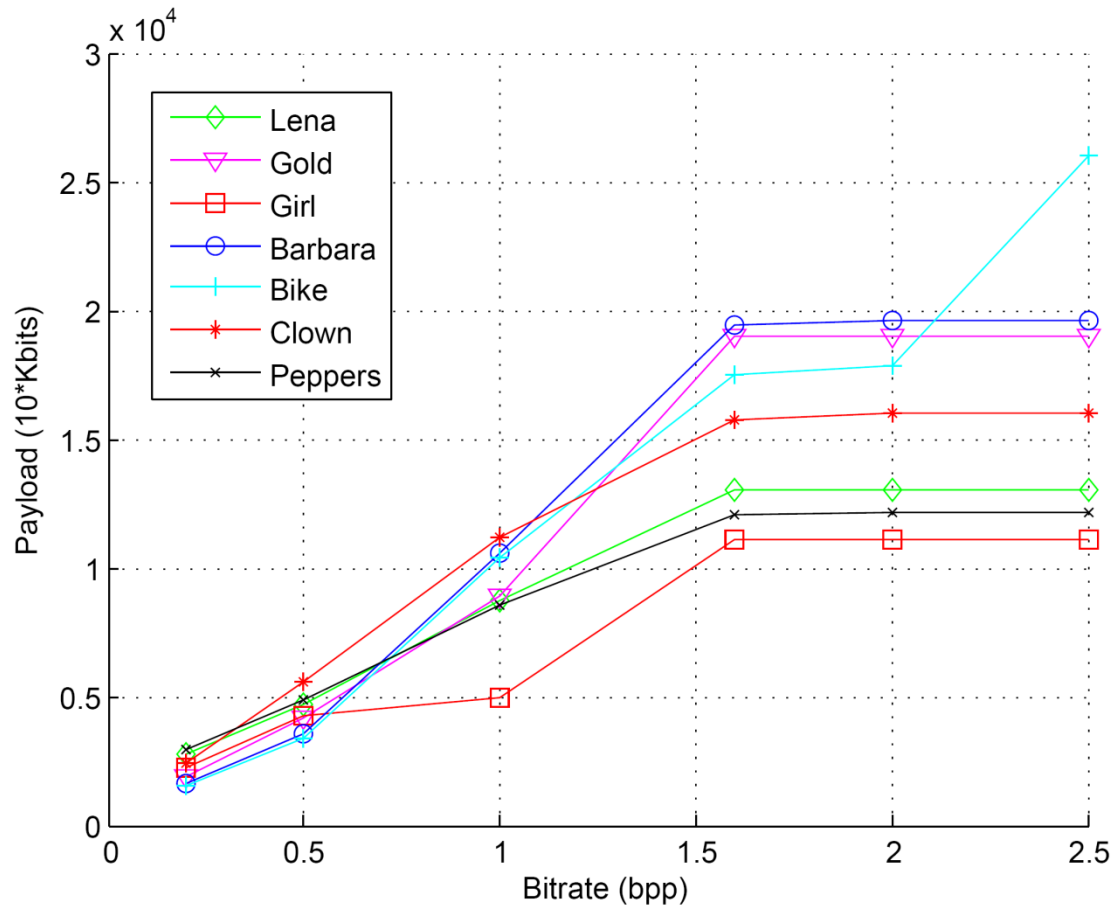
Original Lena image



Reconstructed image at 0.5 bpp :  
PSNR = 38.10 dB, SSIM = 0.9164 and  
hiding payload = 4710 bits



# Experimental results



Hiding payload vs bitrate.

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# Conclusion

- New TCQ-based data hiding strategy in the framework of JPEG2000 part 2 for content description applications
- Data is hidden in the TCQ indices of the selected coefficients
- The proposed data hiding technique successfully survives JPEG2000 compression
- The proposed joint scheme can achieve high payloads and gives good visual quality performances



# Thank You!

**Any questions ?**