CODING AND ANALYSIS SUBSYSTEMS OF DISTRIBUTED VIDEO SENSORS

Shao-Yi Chien (簡韶逸)
Media IC and System Lab

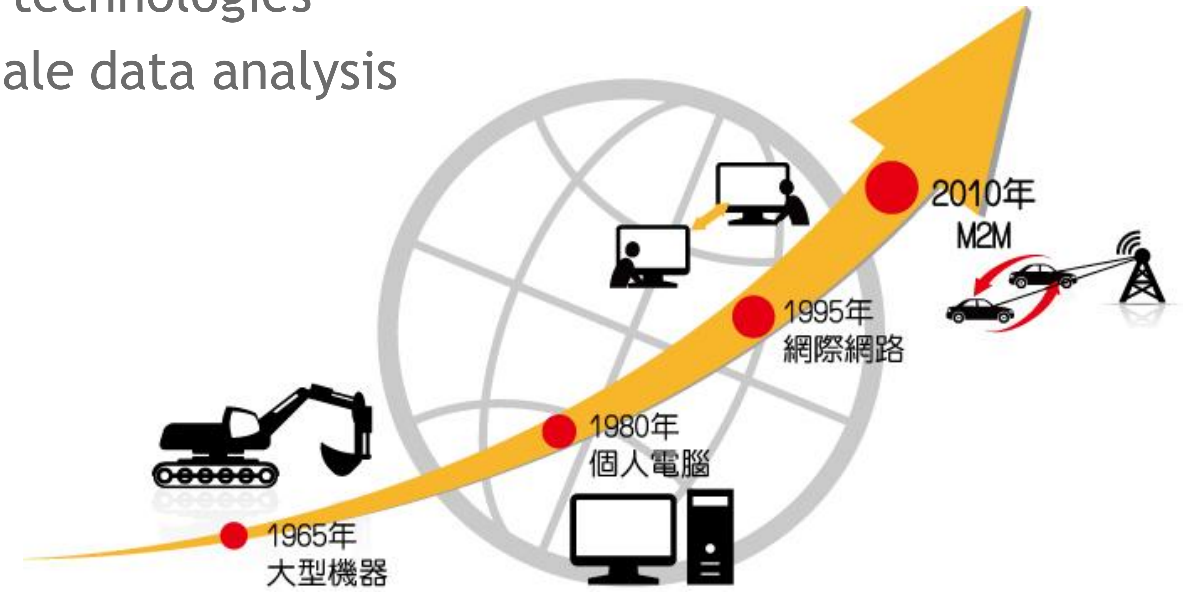
2011/12/07

OUTLINE

- Background
- Coding subsystem of distributed video sensors
- Analysis subsystem of distributed video sensors
- Discussion

BACKGROUND

- Newly introduced technologies
  - Cloud computing
  - M2M network
  - Internet-of-Things
  - Advanced computer vision/pattern recognition/machine learning technologies
  - Large-scale data analysis



BACKGROUND

- Billions of objects or machines are connected and interact with each other without human intervention

Intel: 15 billion connected and intelligent devices by 2015

BACKGROUND

- The future of wireless technologies from Berkeley Wireless Research Center (BWRC)

The Birth of *Societal IT Systems**:

Looking Beyond the Devices

Complex collections of sensors, controllers, compute and storage nodes, and actuators that work together to improve our daily lives

*Also known as SiS

The Emerging IT Platform

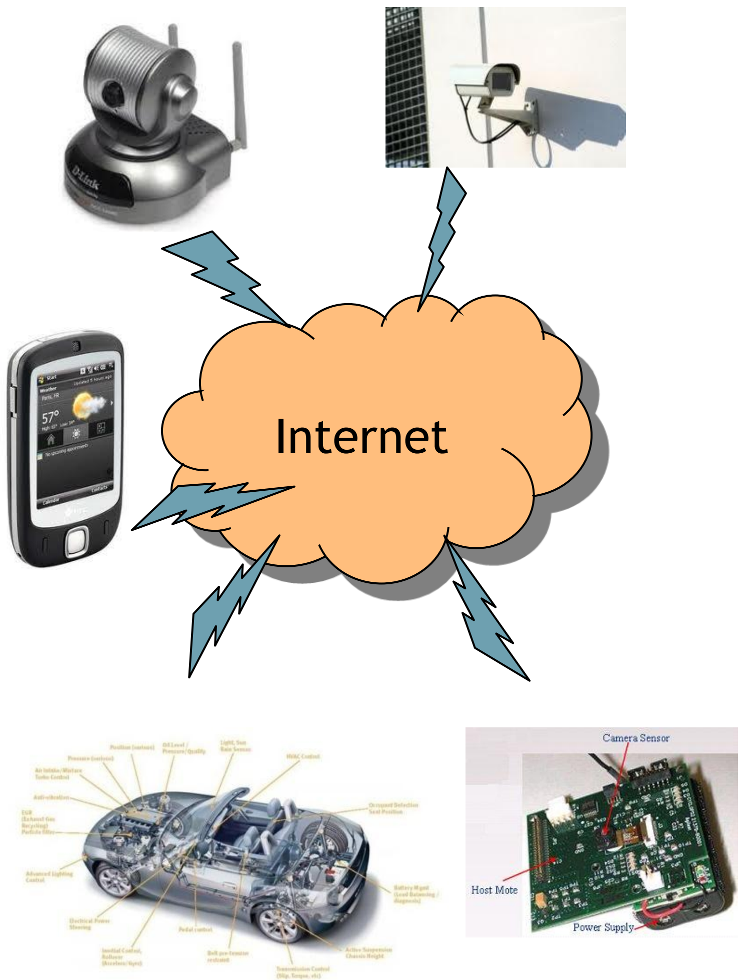
NTU'S VISION ON M2M: CAT

- Machines that collaboratively
  - Capture the data from surroundings
  - Analyze the collected information
  - Take appropriate action
  - before human reaction

Machines that talk to each other and collaborate with each other

DISTRIBUTED VIDEO SENSORS

- The growth of distributed video sensor deployment
  - Surveillance camera
  - Mobile phones
  - Video sensors on cars
  - Distributed sensors
- M2M network with video sensor nodes --- Eyes of M2M Networks
- How to store/access/analysis this large amount of content?



CODING AND ANALYSIS SUBSYSTEMS OF DISTRIBUTED VIDEO SENSORS

SIGGSP

S.-Y. Chien

C.-H. Lee

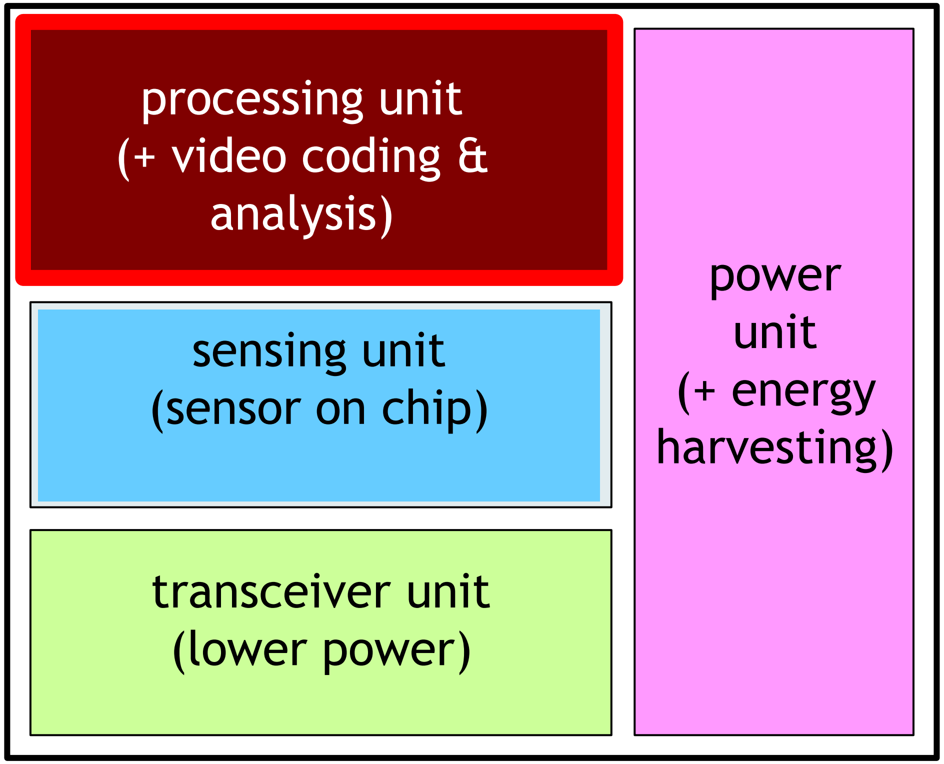
PI: Prof. Shao-Yi Chien
Co-PI: Dr. Chia-han Lee
Sponsor Technical Champions:
Dr. V Srinivasa Somayazulu
Dr. Yen-Kuang Chen

VIDEO SENSOR NODE FOREVER

An improvement of 3X power efficiency is expected to enable perpetual video sensor nodes

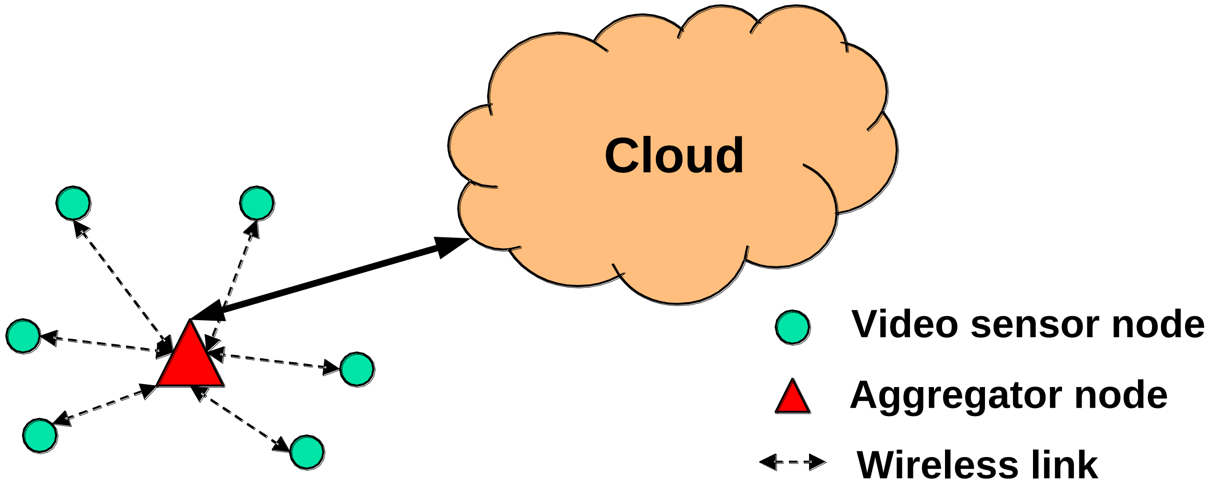
POSITION IN SIGGSP

- Intelligent Sensor Node (iSensor) Structure



EYES OF M2M NETWORKS

- M2M network with video sensor nodes



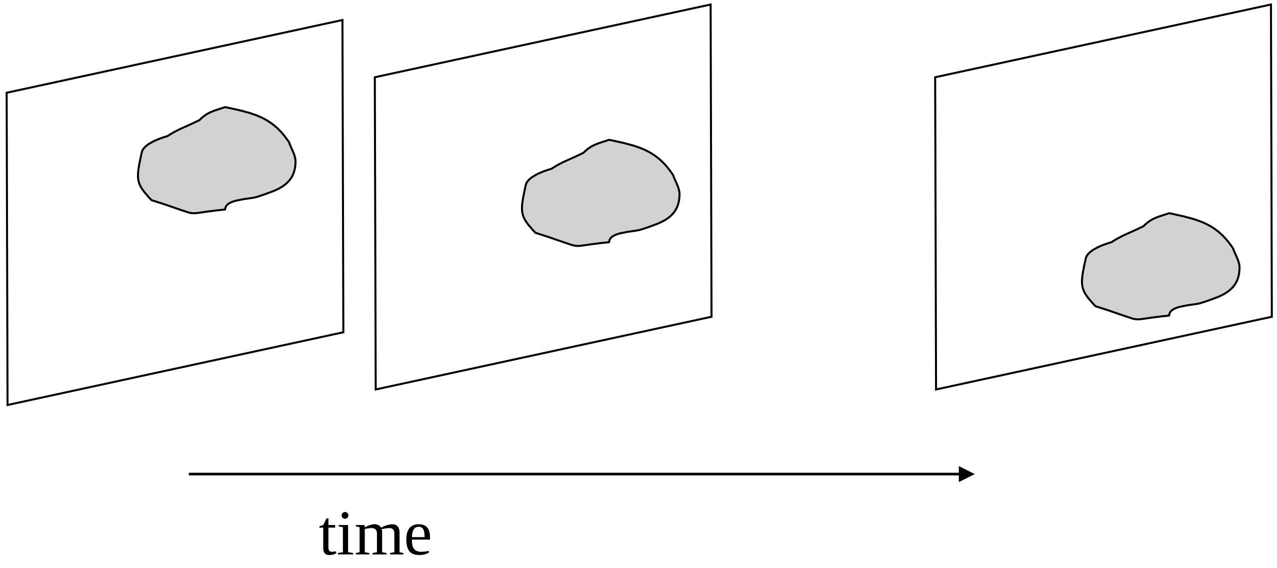
- Low power video coding and analysis techniques are the target of this project

CODING SUBSYSTEM OF DISTRIBUTED VIDEO SENSORS

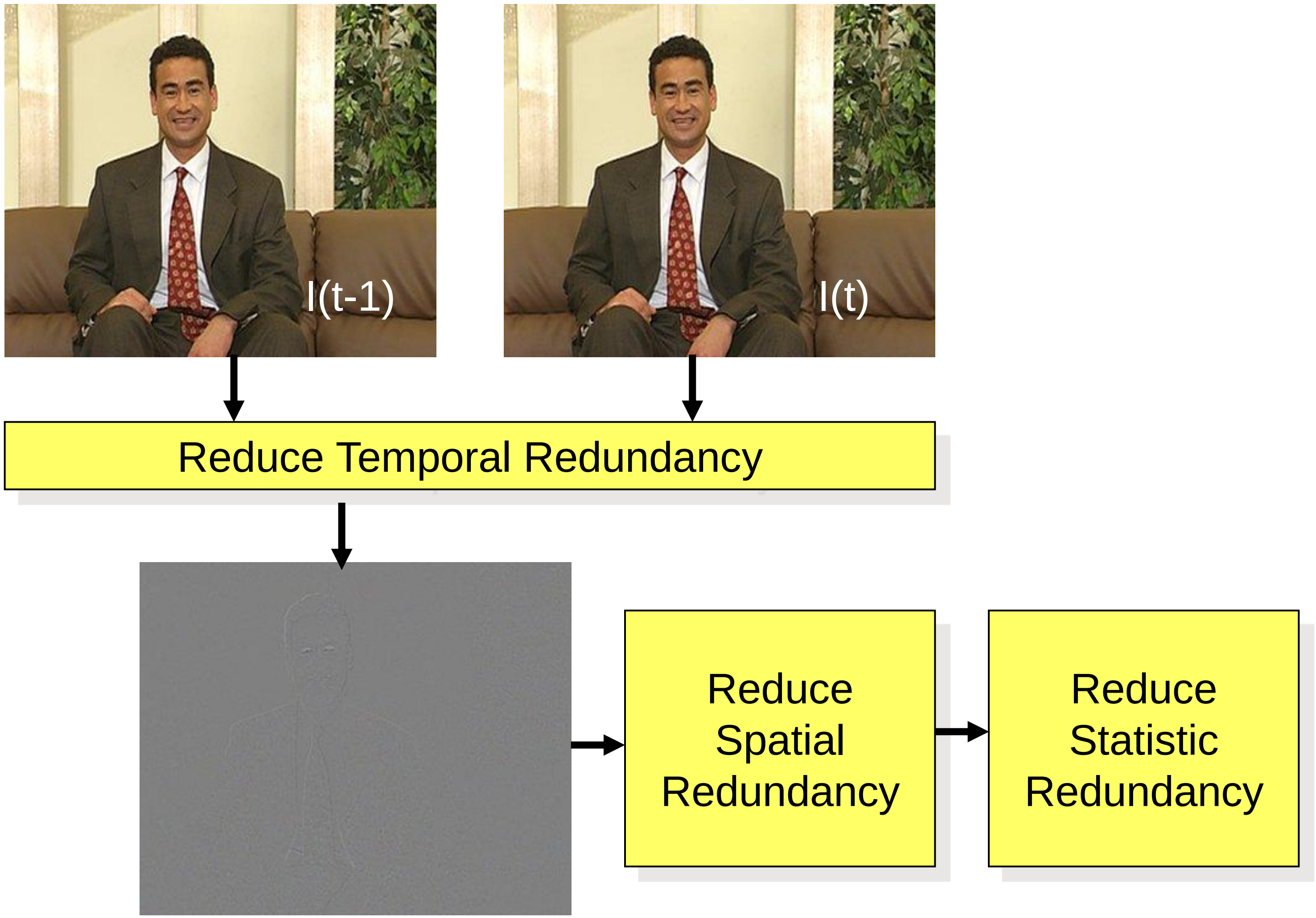
COMPRESSION IS NECESSARY!

- For 640x480 RGB 30fps video from 10 video sensors
  - 640x480x24x30x10=2.2Tbps!

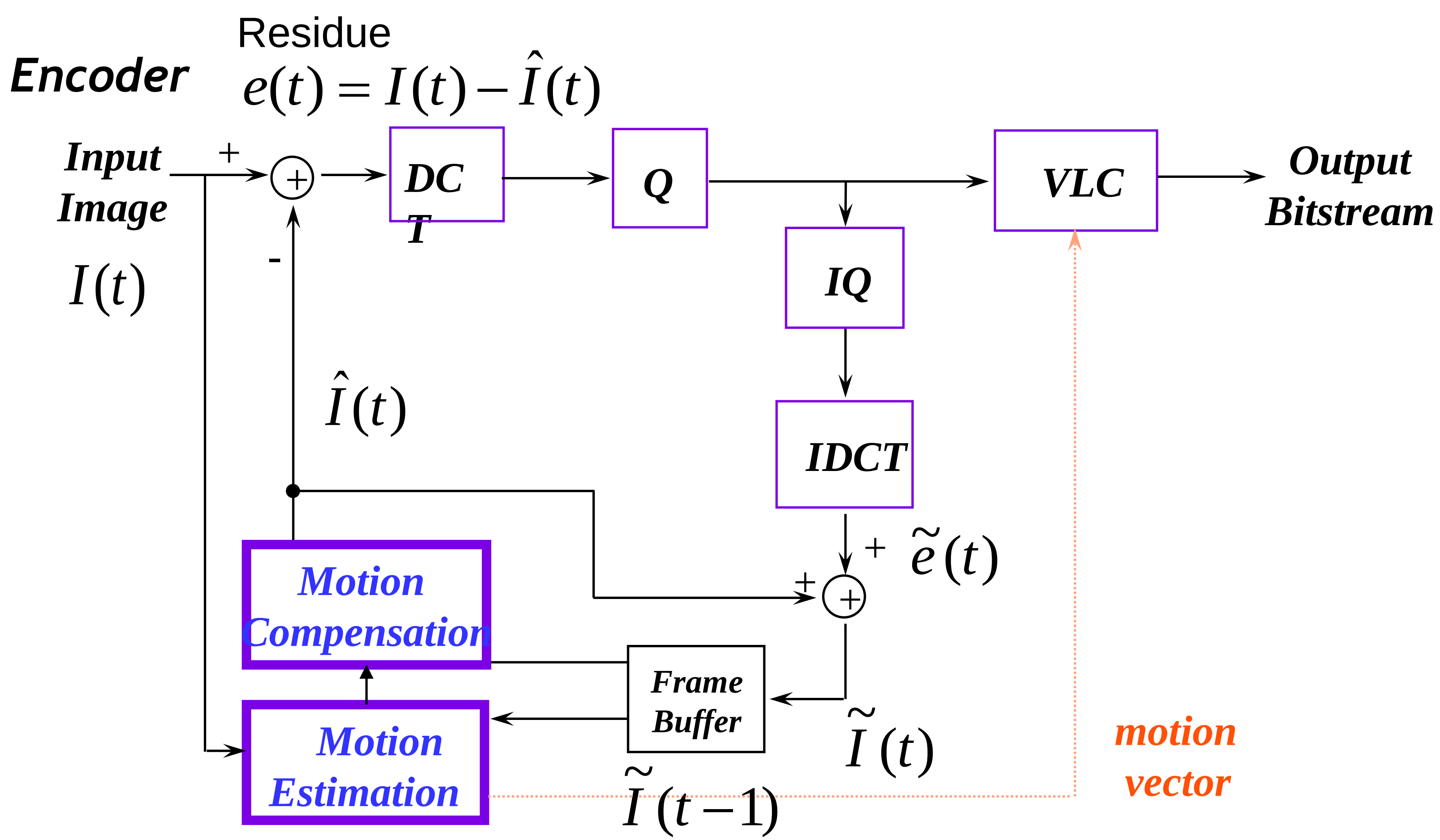
IMAGE SEQUENCE MODEL



CONVENTIONAL HYBRID VIDEO CODING PROCESS

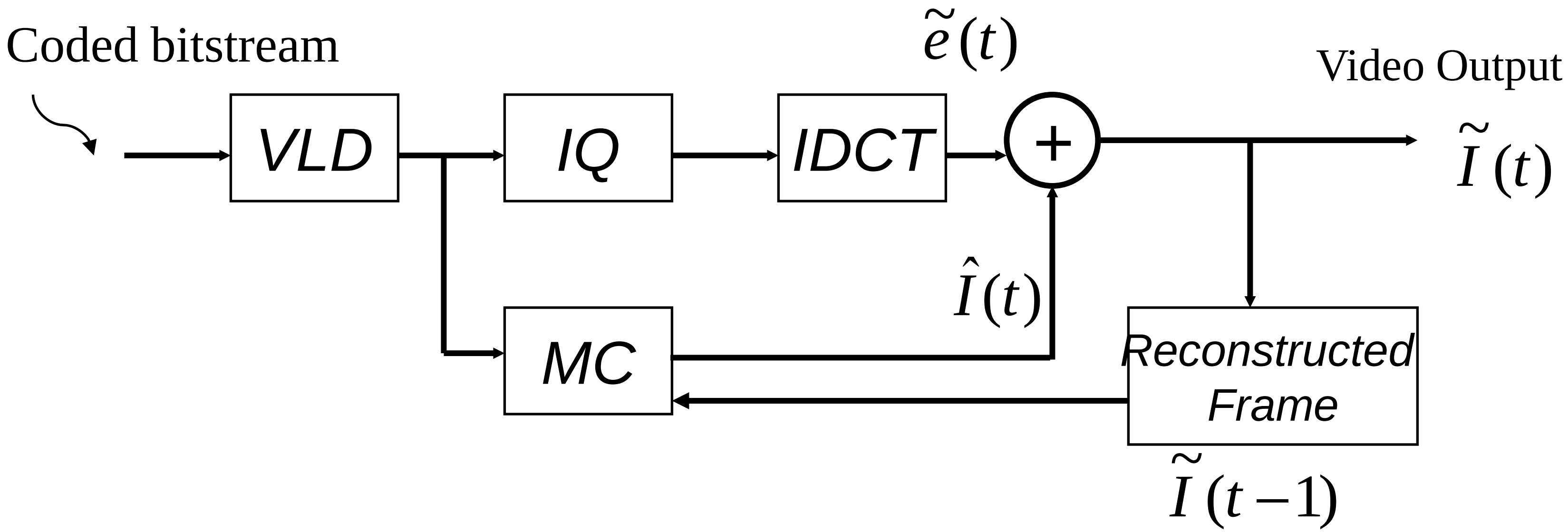


BASIC VIDEO CODING FLOW



DECODING BLOCK DIAGRAM

Decoder



Codec=Encoder+Decoder

STAGE 1 - REDUCING TEMPORAL REDUNDANCY

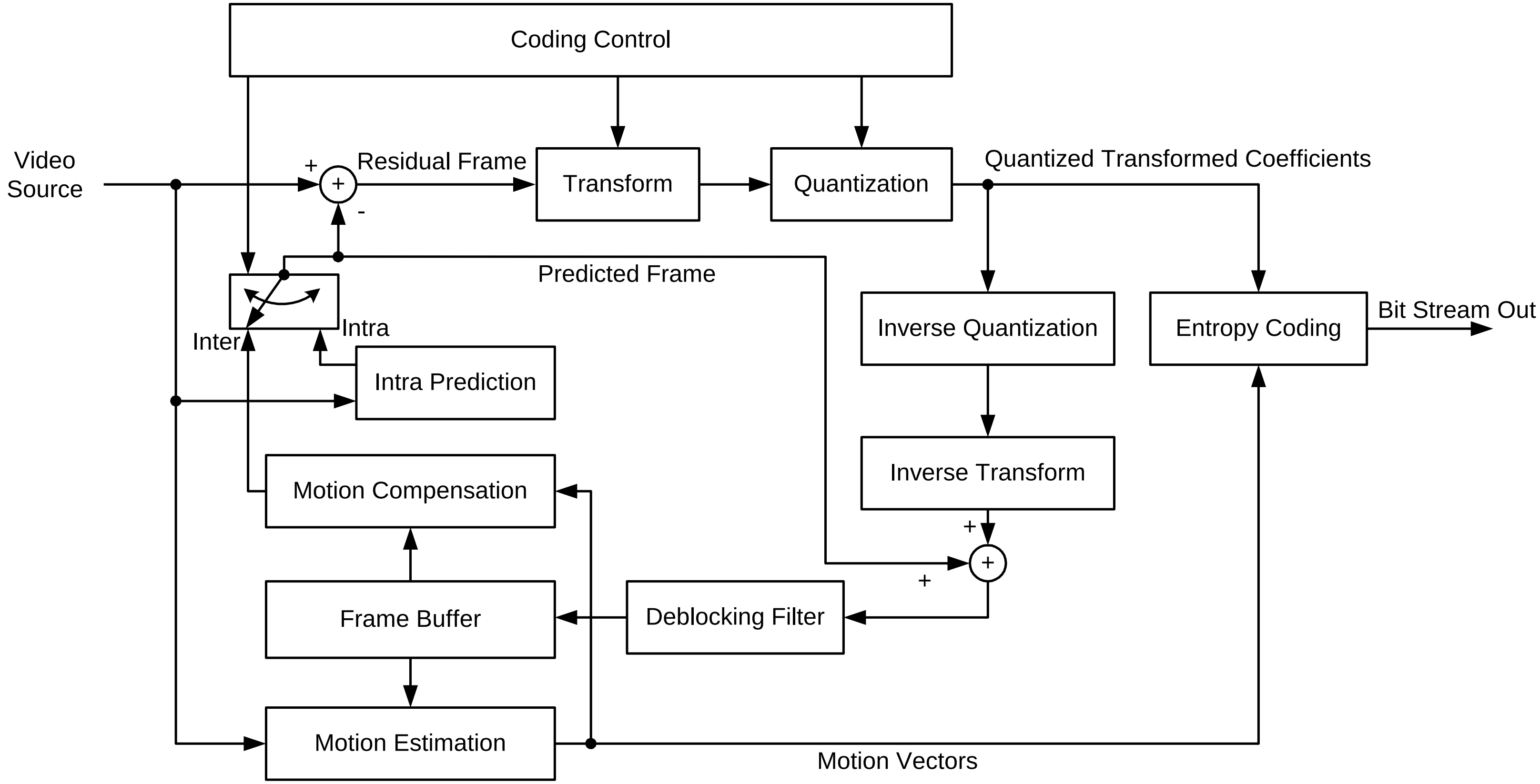
- Segment a frame into macroblocks
- Compensate motion and remove temporal redundancy
- Output energy is related to the degree of temporal redundancy
- This stage is Inter-frame coding

STAGE 2 - REDUCING SPATIAL REDUNDANCY

- Processing the difference frame (spatially correlated) from stage 1
- Usually using DCT coding
- This stage is Intra-frame coder
- The method by these two stages is Hybrid coding method

CONVENTIONAL VIDEO CODING

- MPEG-1/2/4, H.261/H.263/H.264



Ref: Shao-Yi Chien, Yu-Wen Huang, Ching-Yeh Chen, Homer H. Chen, and Liang-Gee Chen, "Hardware architecture design of video compression for multimedia communication systems," *IEEE Communications Magazine*, vol. 43, no. 8, pp. 122—131, Aug. 2005.

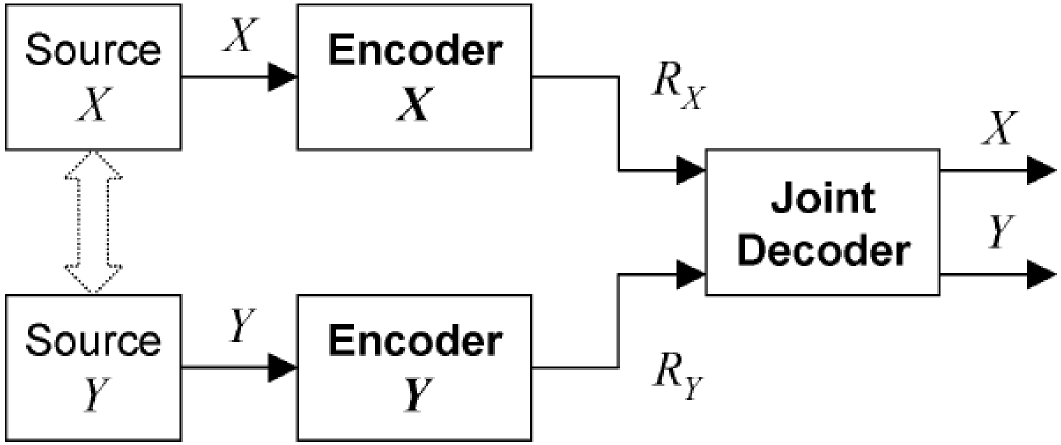
CHARACTERISTICS OF CONVENTIONAL VIDEO CODING SYSTEMS

- Good coding performance
- Complex encoder and simple decoder
- Close-loop coding system
- Not robust over noisy channel

- Suitable for M2M networks?

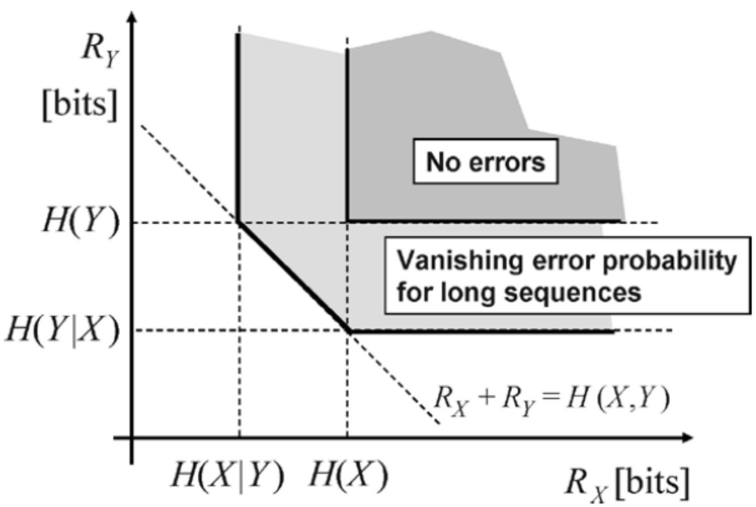
NEW PARADIGM --- DISTRIBUTED VIDEO CODING (DVC)

- Distributed compression refers to the coding of two (or more) dependent random sequences.
- Special case of distributed video coding
  - Compression with the side information



FUNDAMENTAL OF DISTRIBUTED SOURCE CODING

- Slepian-Wolf Theorem
  - Separate convention encoder
    - Rx ≧ H(X) , Ry ≧ H(Y)
  - With jointly decoder
    - Rx + Ry ≧ H(X,Y)
    - Rx ≧ H(X|Y) , Ry ≧ H(Y|X)

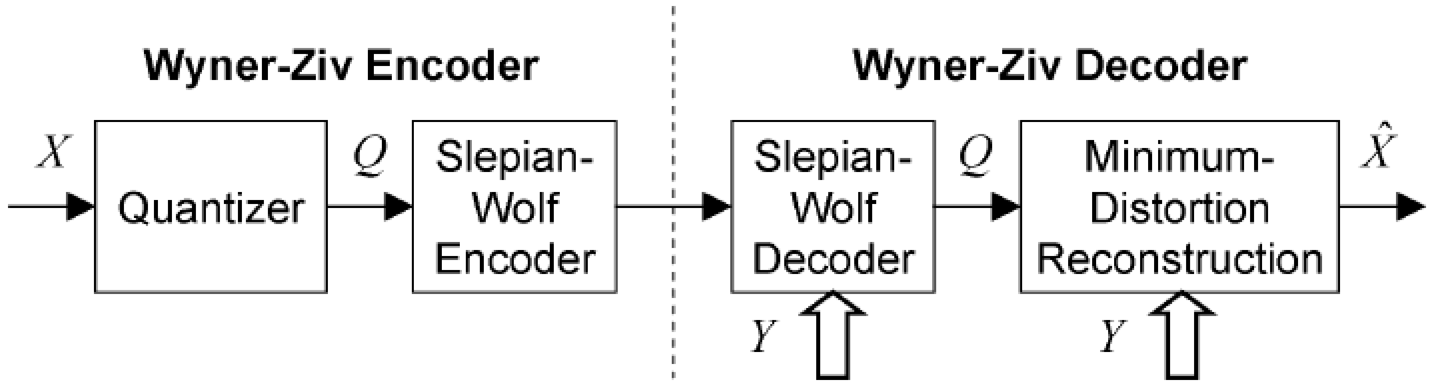


SOURCE CODING METHOD

- Channel Coding
  - LDPC , Turbo Code
- Considering two similar binary sources (X , Y)
  - X: source, Y: side information
  - We use systematic channel code to generate parity bit to protect X
  - Treat Y as the received signal with noise
  - Perform error-correction decoding
- The compression is achieved because only the parity bits of the error correction codes are sent to the decoder

DISTRIBUTED VIDEO CODING

- Wyner-Ziv & Slepian-Wolf Coding
  - Slepian-Wolf Coding
    - Channel coding (turbo code , LDPC)
    - Encoder only transmits the parity bits to decoder

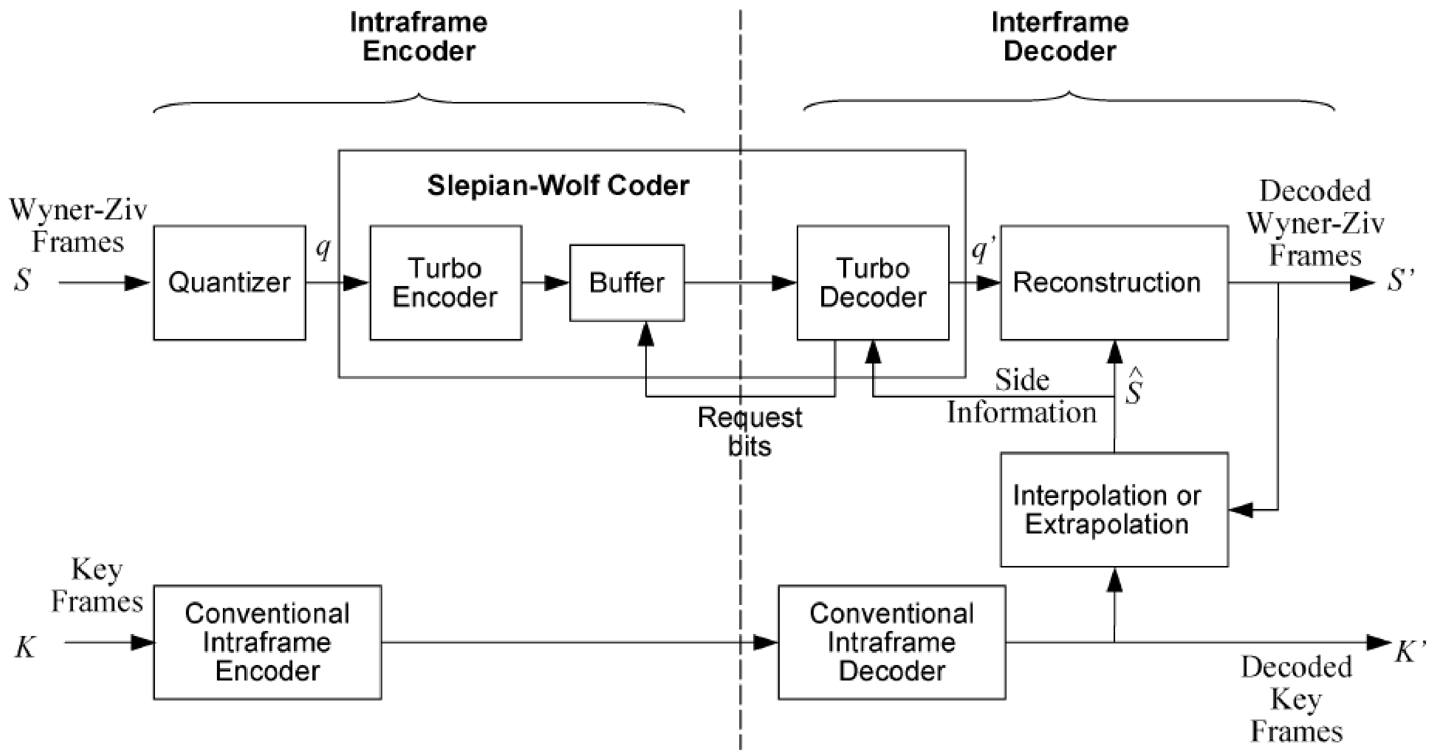


DISTRIBUTED VIDEO CODING

- Pixel-Domain Encoding
  - Key frame
    - Coded using conventional intra frame
  - Wyner-Ziv frame
    - Each pixel is uniform quantized with 2^M intervals
    - Intra frame coded but Inter frame decoded
  - Splepian-Wolf coder
    - Rate-Compatible Punctured Turbo code (RCPT)
    - Request-and-decode process

DISTRIBUTED VIDEO CODING

- Pixel-Domain Encoding – Block diagram



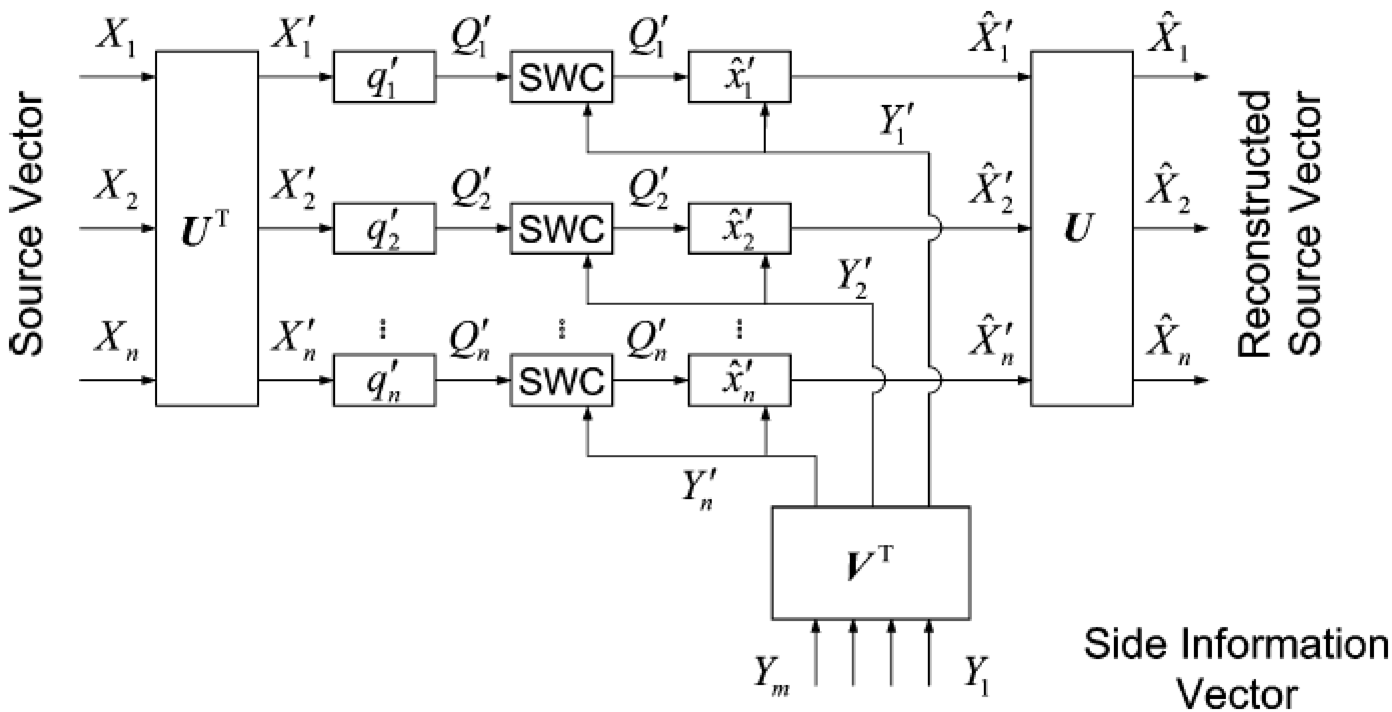
Ref: B. Girod, A.M. Aaron, S. Rane, D. Rebollo-Monedero,
"Distributed Video Coding," *Proceedings of the IEEE* , vol.93, no.1, pp.71-83, Jan. 2005

DISTRIBUTED VIDEO CODING

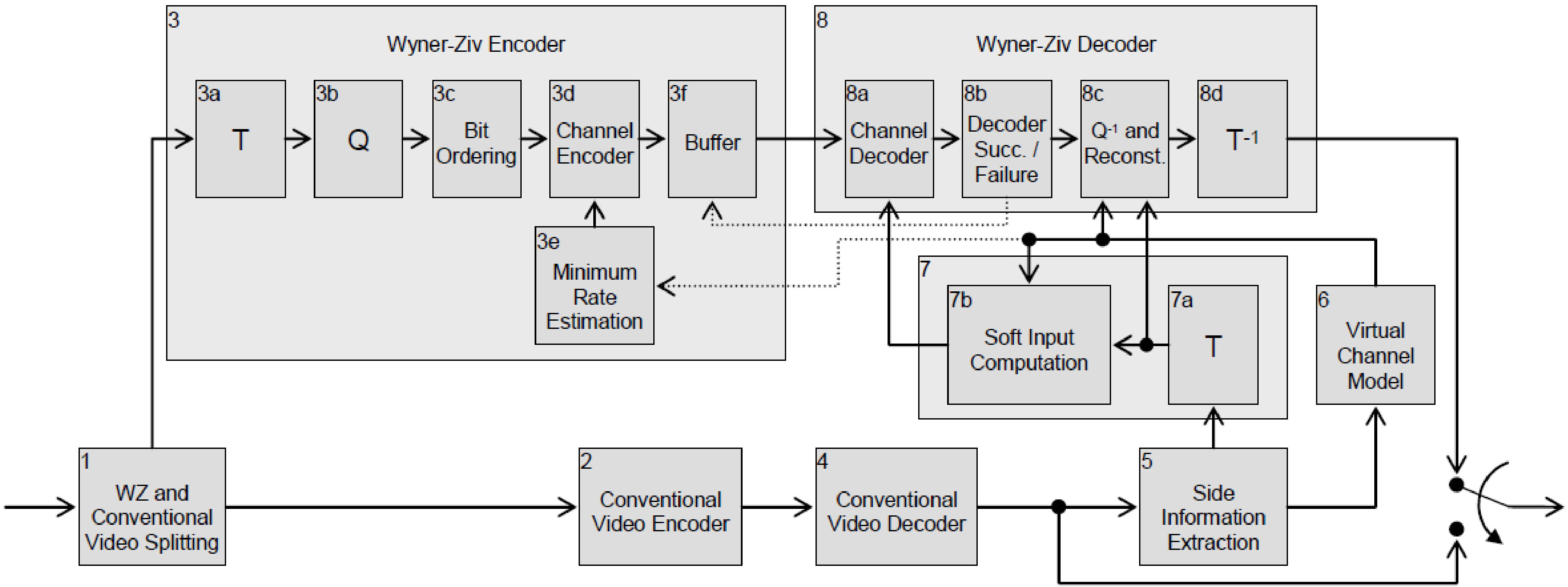
- Transform-Domain Encoding
  - Conventional coding
    - Transform spatial data into spectral data
      - Ex: DCT , KLT , Wavelet ,etc
  - Perform blockwise DCT to Wyner-Ziv frame
    - Decoder would get side information (spectral) from previous frames
    - A bank of turbo decoders reconstructed the qauntized coefficient bands
    - Each coefficient band is reconstructed with the side information

DISTRIBUTED VIDEO CODING

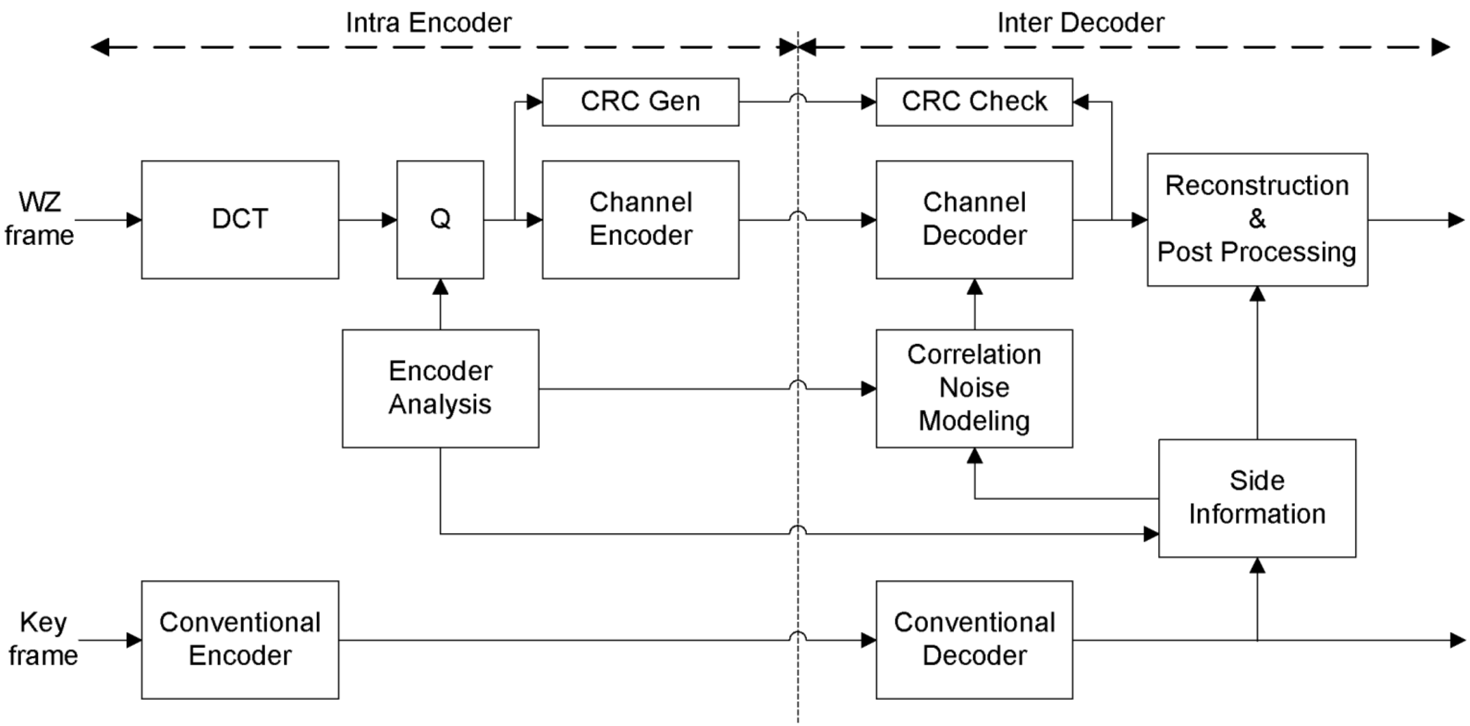
- Transform-Domain Encoding



STATE-OF-THE-ART DVC: DISCOVER CODEC



UNIFIED DVC



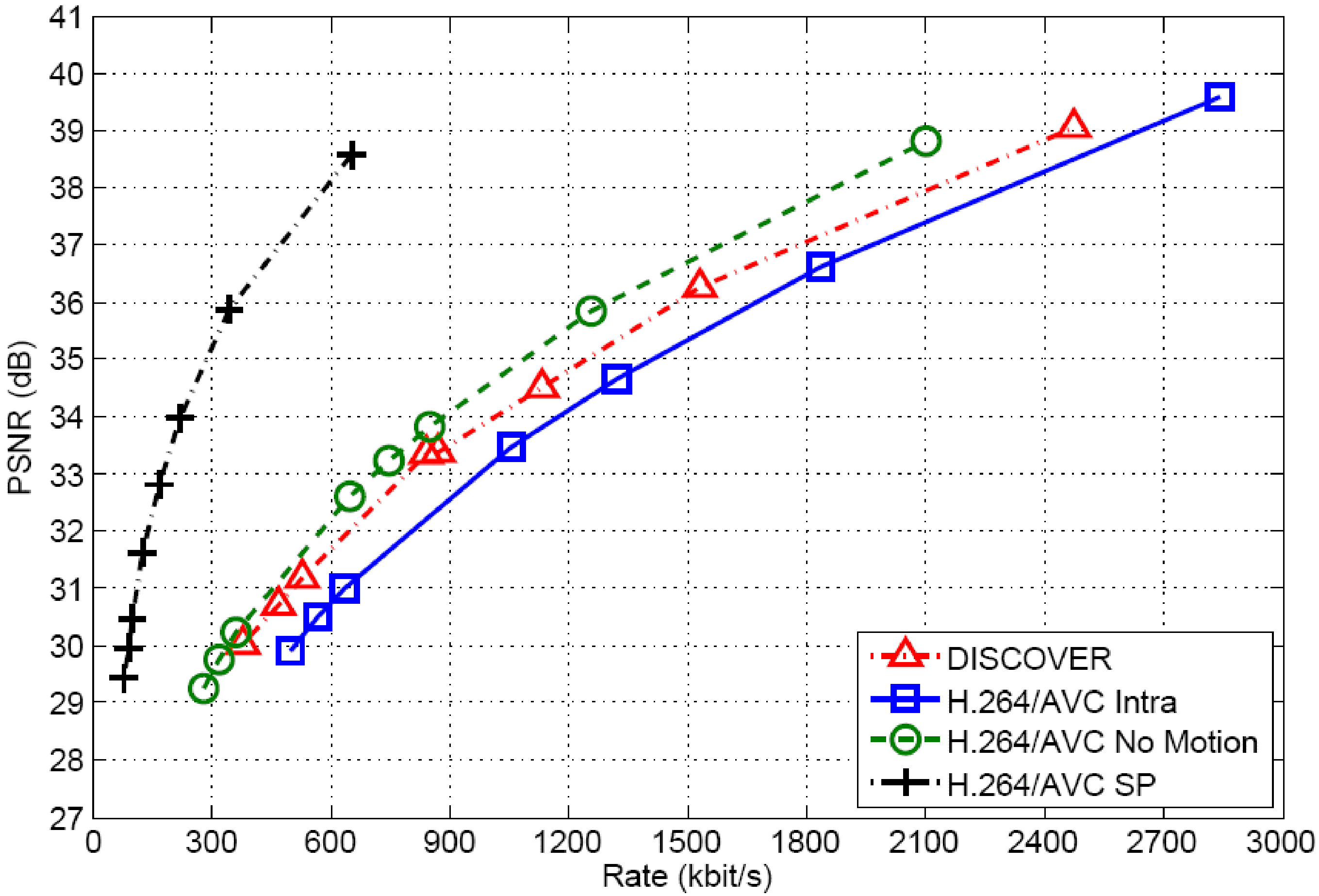
Ref: Chieh-Chuan Chiu, Shao-Yi Chien, Chia-han Lee, V. Srinivasa Somayazulu, and Yen-Kuang Chen, "Distributed video coding: a promising solution for distributed wireless video sensors or not?" in *Proc. Visual Communications and Image Processing 2011*, Nov. 2011.

Analysis of Existing DVC Systems

- Analysis environment
  - DISCOVER codec
    - Improved frame interpolation with spatial motion smoothing
    - Online correlation noise modeling
    - LDPCA for syndrome coding
  - Conditions
    - Sequences: Foreman, Coastguard, and Hall Monitor
    - Resolution: CIF at 30Hz
    - Q tables from DISCOVER
    - GOP is 2 for DVC, and GOP is 30 for H.264/AVC SP

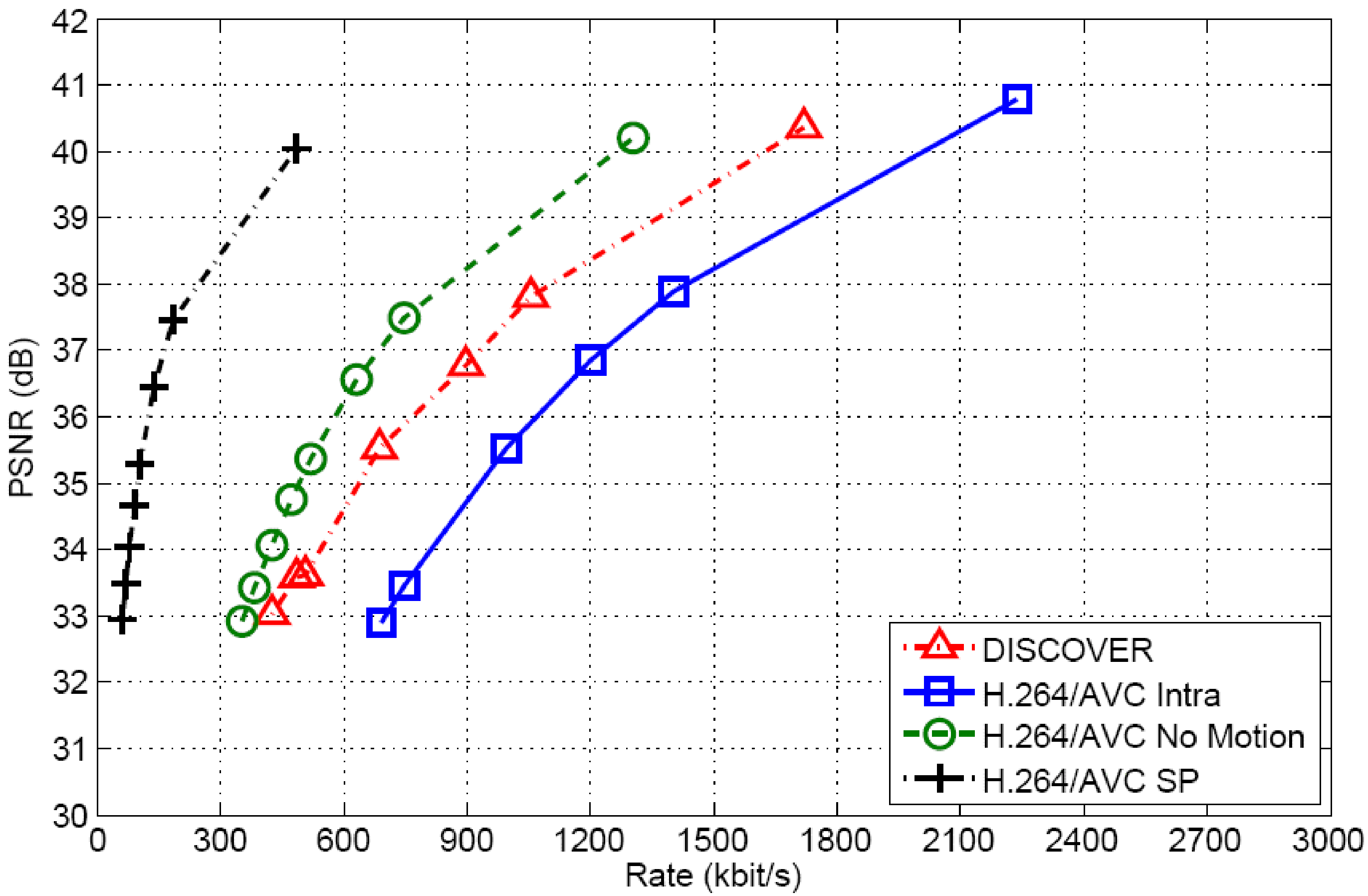
RATE-DISTORTION PERFORMANCE

- Foreman



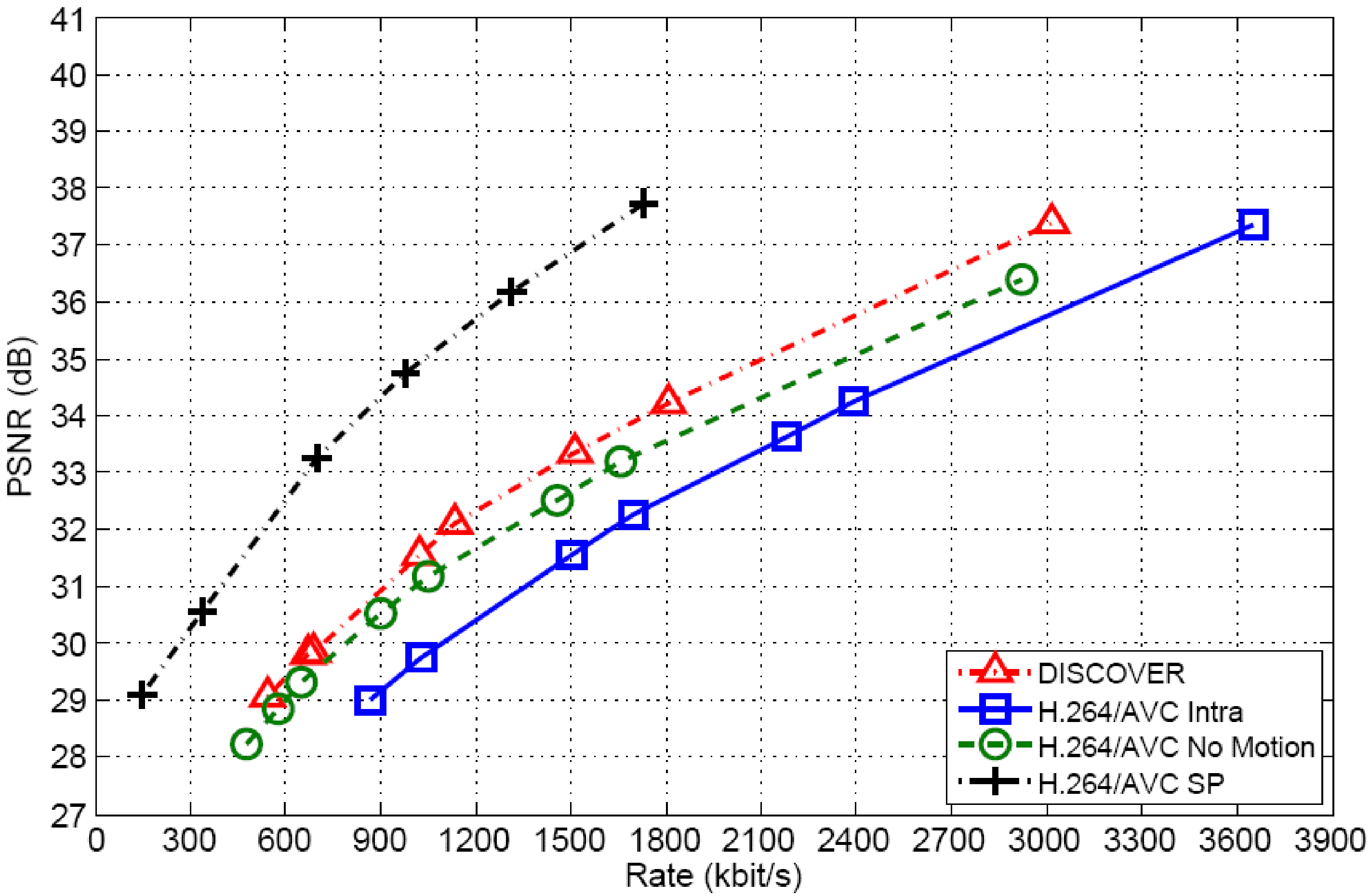
RATE-DISTORTION PERFORMANCE

- Hall Monitor



RATE-DISTORTION PERFORMANCE

- Coastguard

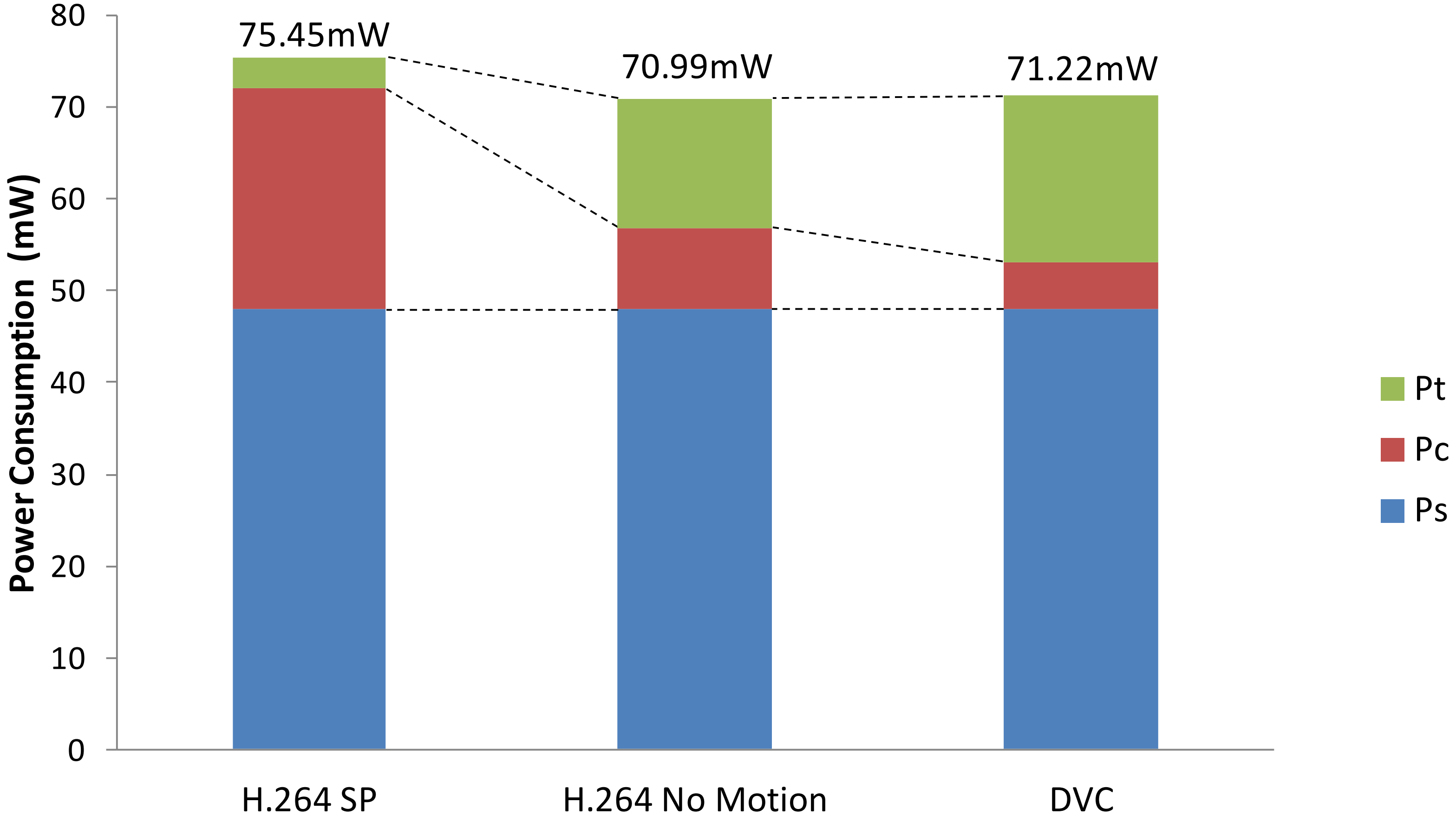


POWER CONSUMPTION ANASLYSIS

- System power consumption is modeled as
  - $P_{total}=P_t+P_c+P_s$,
    where P_t: transmission power, P_c: coding power, and P_s: sensor power
- Two test platforms:
  - ASIC-based solution in 65nm technology
  - Processor-based solution with Intel ATOM Z530 processor

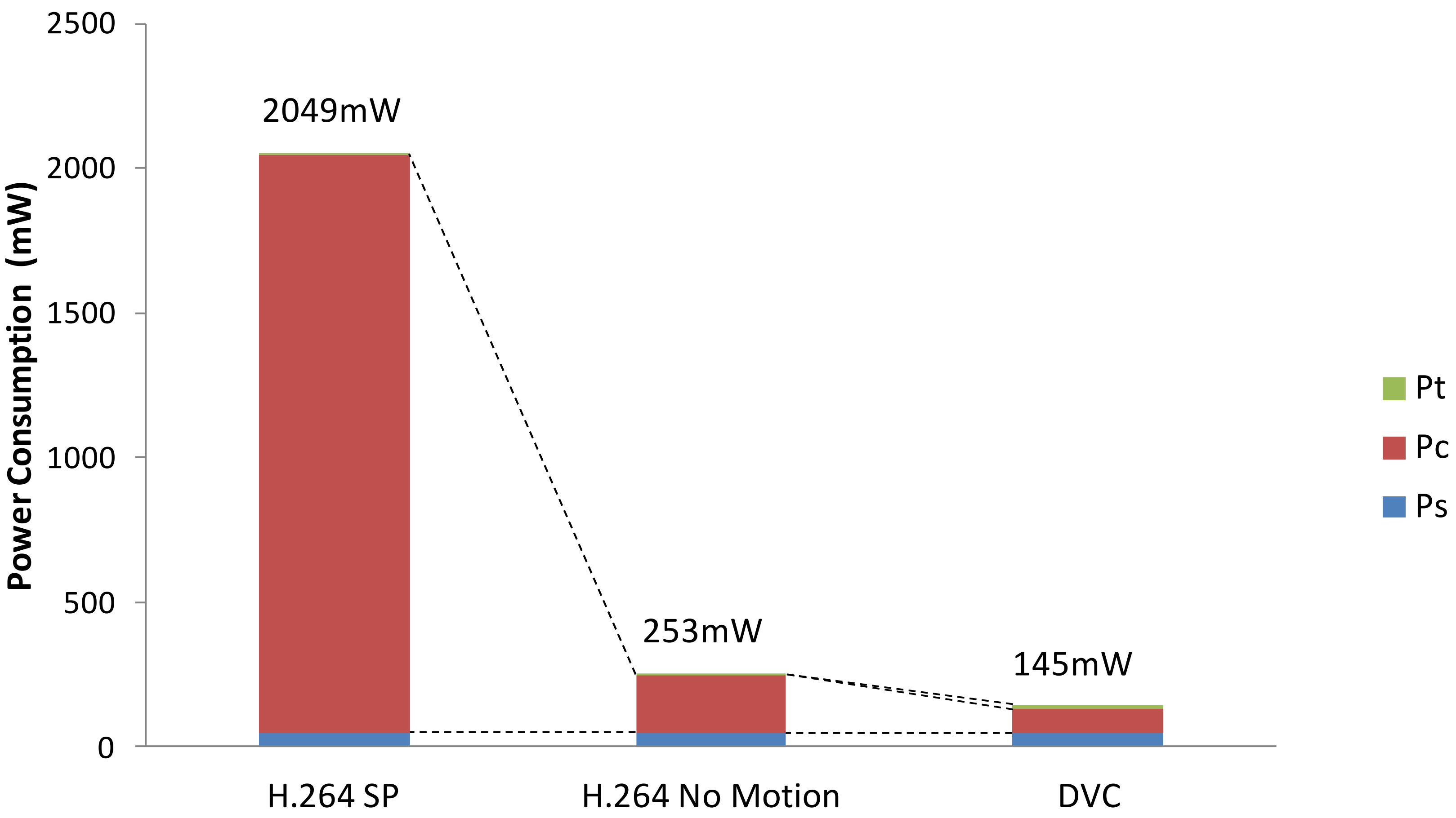
PRELIMINARY POWER ANALYSIS RESULTS

- ASIC-based sensor node

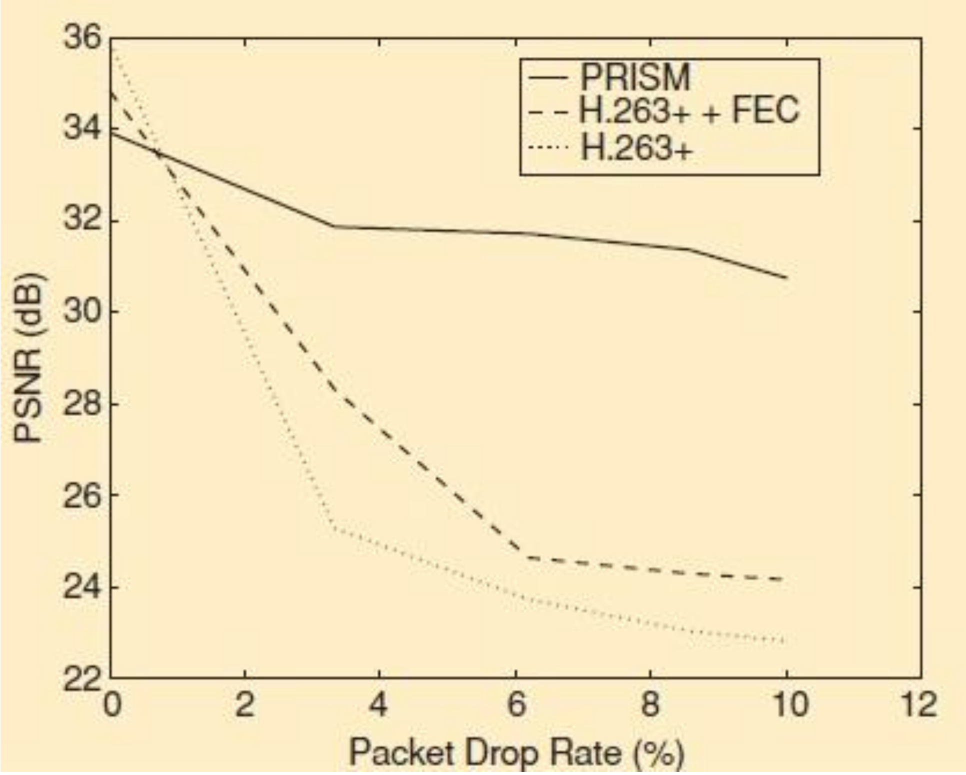


PRELIMINARY POWER ANALYSIS RESULTS

- Processor-based sensor node



MUCH BETTER ERROR ROBUSTNESS

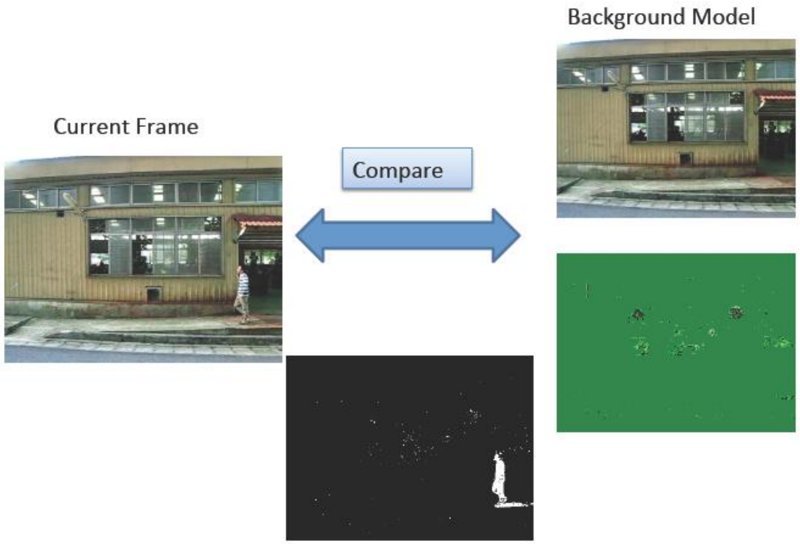


Ref: R. Puri, A. Majumdar, P.Ishwar, and K. Ramchandran, "Distributed Video Coding in Wireless Sensor Networks," *IEEE Signal Processing Magazine*, July, 2006

ANALYSIS SUBSYSTEM OF DISTRIBUTED VIDEO SENSORS

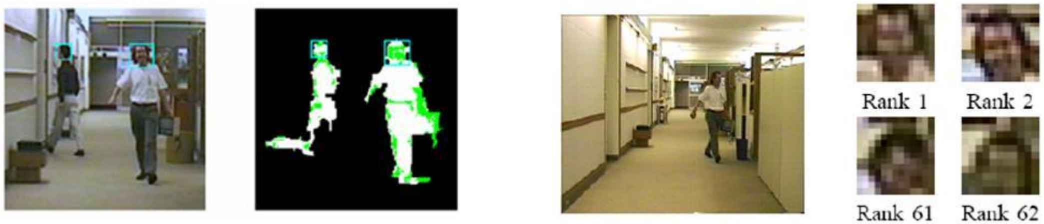
VIDEO ANALYSIS ALGORITHMS

- Segmentation



- Tracking

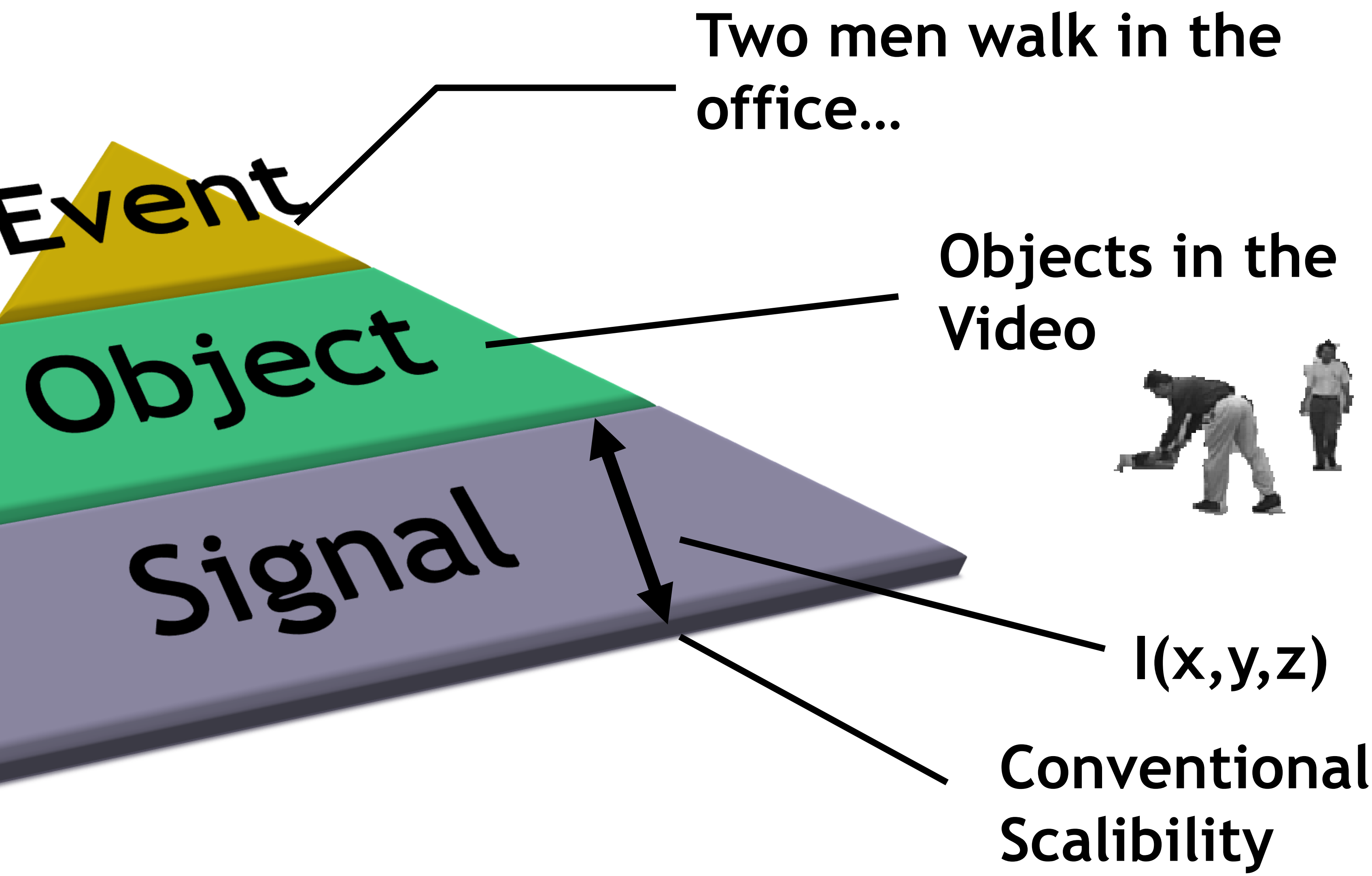
- Face detection/scoring



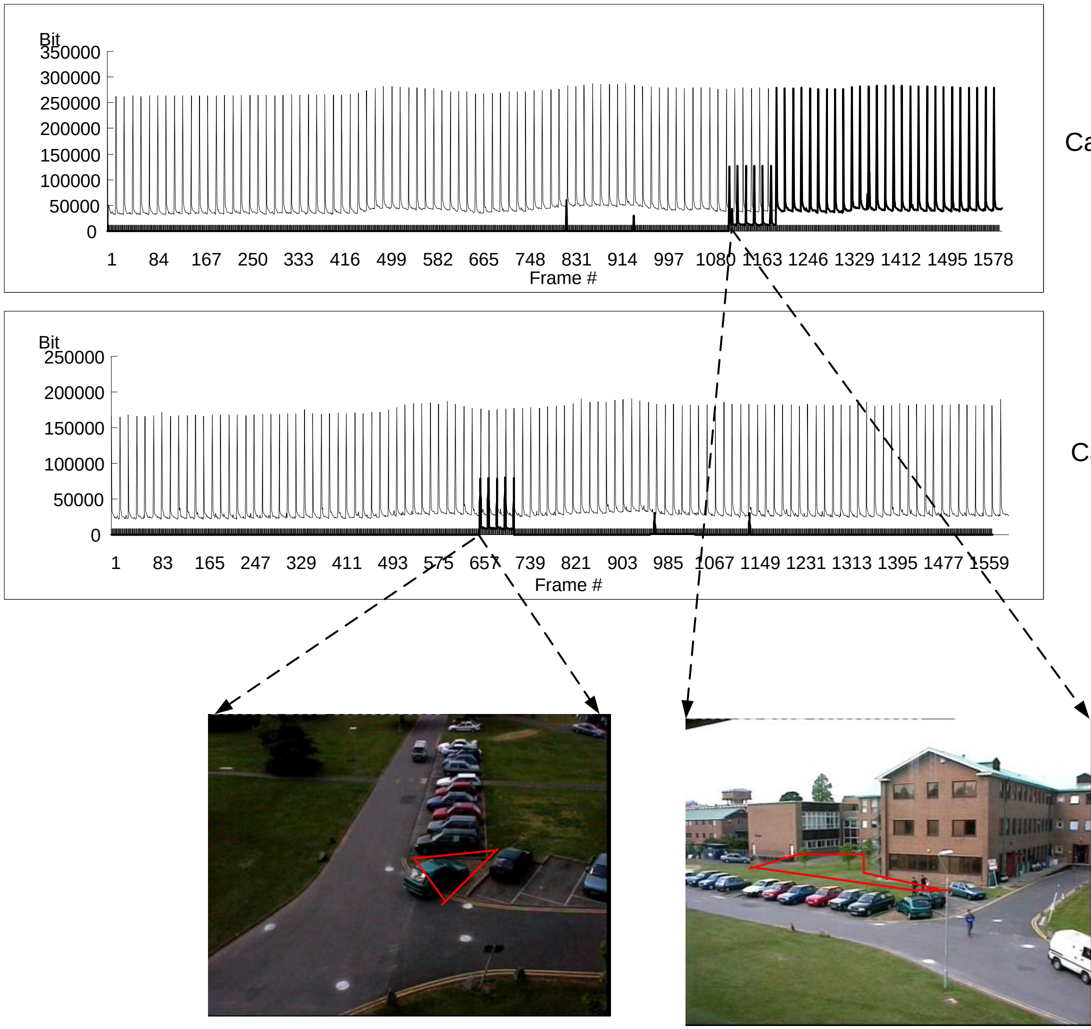
VIDEO ANALYSIS ALGORITHMS

2006年旺宏金矽獎優等

SEMANTIC LEVELS



REDUCE THE TRAFFIC LOAD WITH SEMANTIC LEVELS



Camera 1

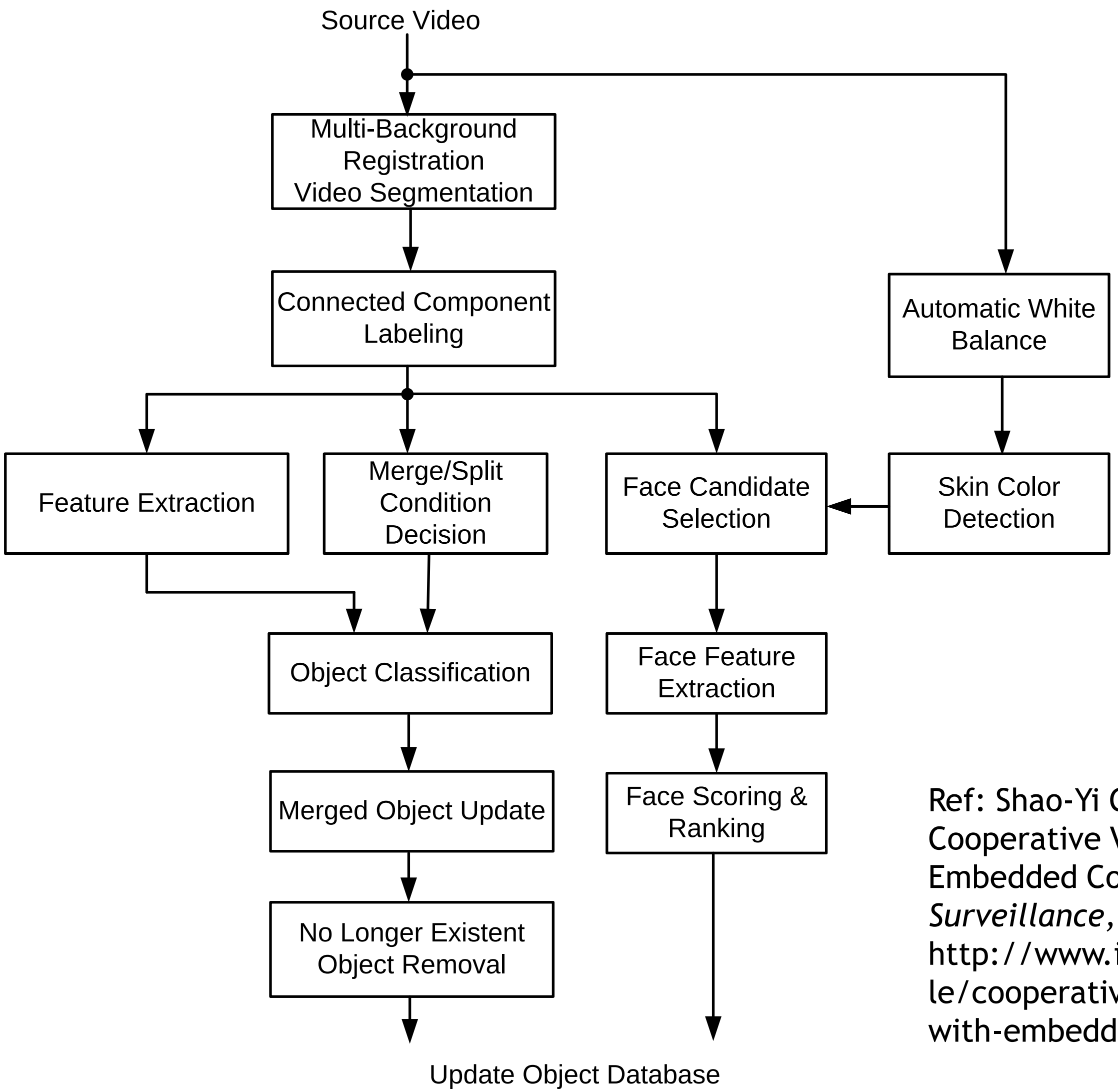
Camera 2

PETS2001 Cemera2
Frame # 660

PETS2001 Cemera1
Frame # 1116

Ref: Shao-Yi Chien and Wei-Kai Chan (2011). Cooperative Visual Surveillance Network with Embedded Content Analysis Engine, *Video Surveillance*, Available from: http://www.intechopen.com/articles/show/title/cooperative-visual-surveillance-network-with-embedded-content-analysis-engine

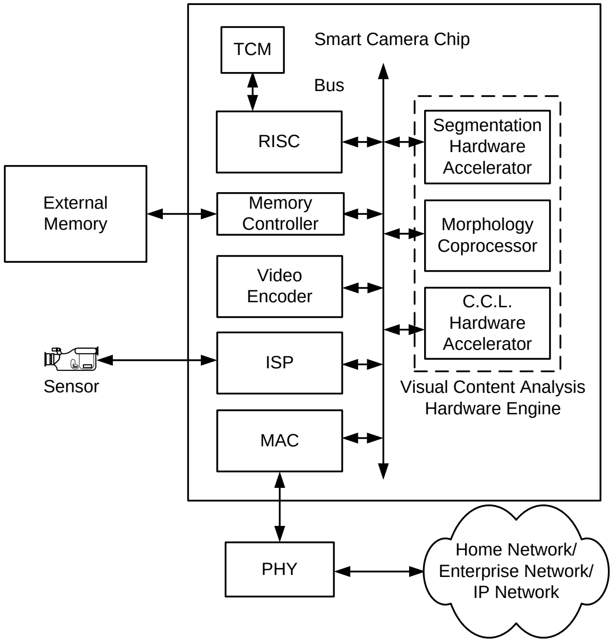
VIDEO ANALYSIS ALGORITHM FOR SINGLE CAMERA



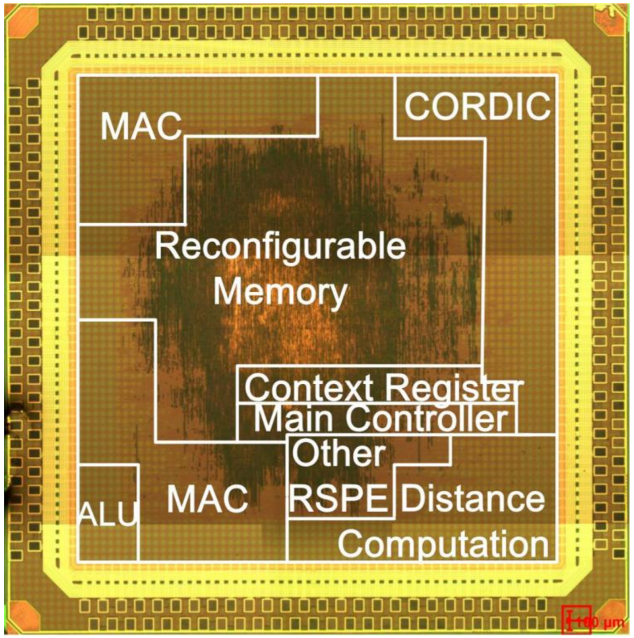
Ref: Shao-Yi Chien and Wei-Kai Chan (2011). Cooperative Visual Surveillance Network with Embedded Content Analysis Engine, *Video Surveillance*, Available from: http://www.intechopen.com/articles/show/title/cooperative-visual-surveillance-network-with-embedded-content-analysis-engine

WHAT WE HAVE DONE

- Algorithm/hardware architecture design for single smart camera

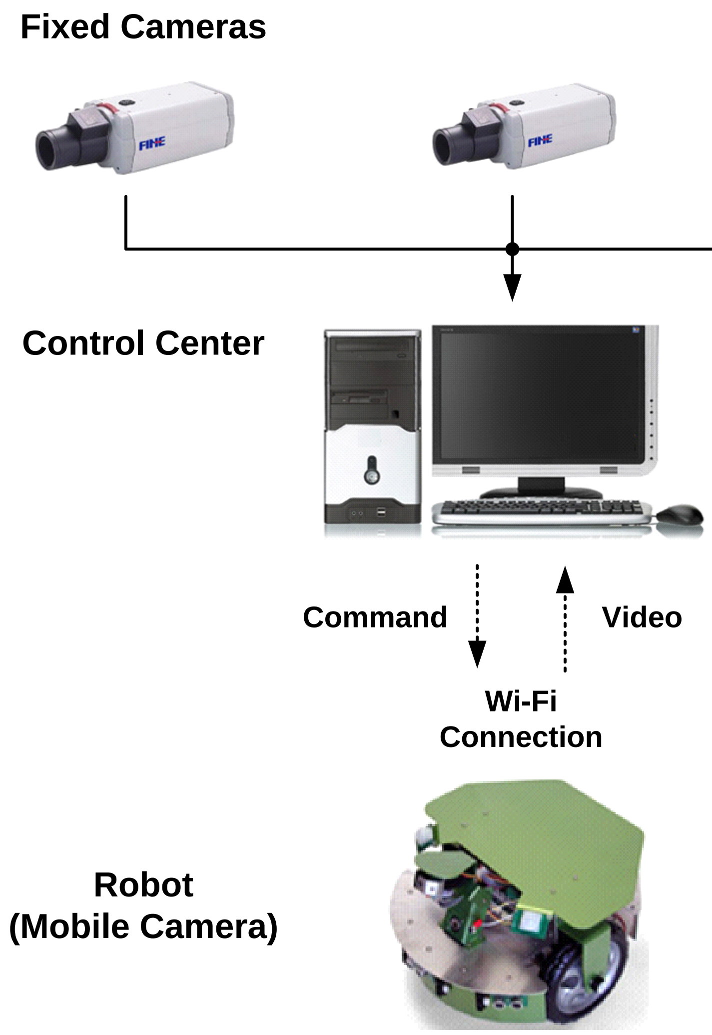


[TCSVT2009]



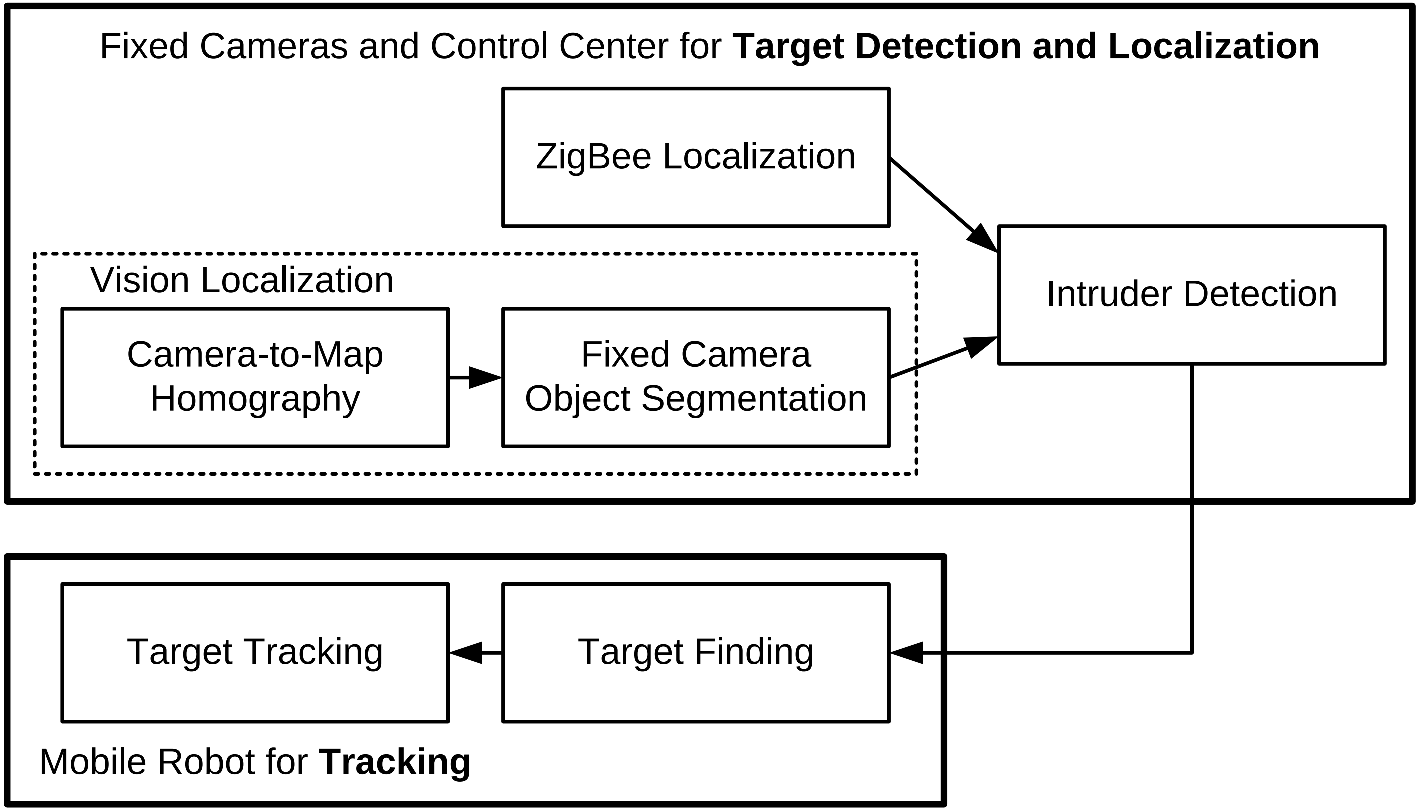
[CICC2011]
(1157.82 GOPS,197 mW
@90nm process)

COOPERATIVE SURVEILLANCE SYSTEM

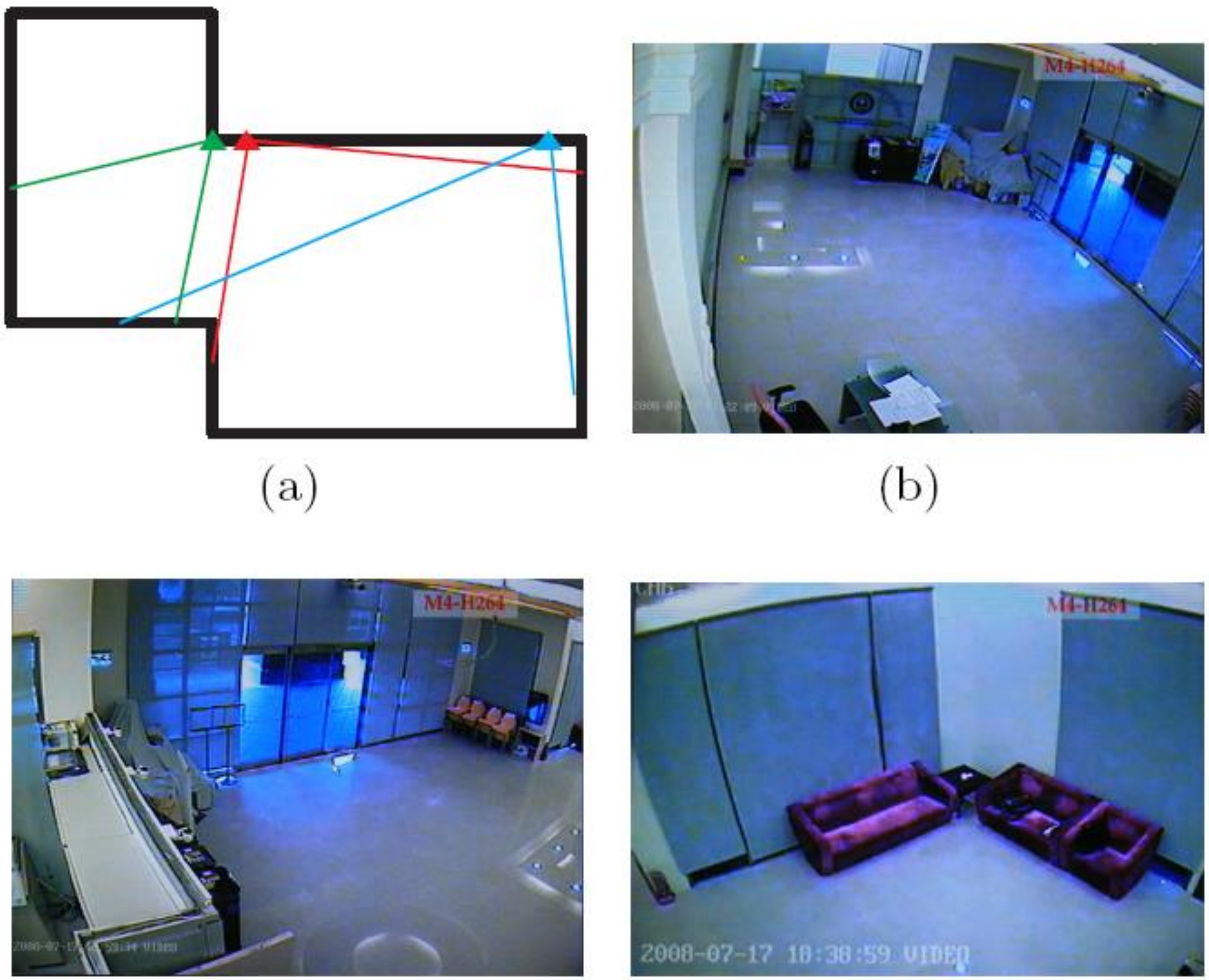


Ref: Chih-Chun Chia, Wei-Kai Chan, and Shao-Yi Chien, "Cooperative surveillance system with fixed camera object localization and mobile robot target tracking," in *Proc. Pacific Rim Symposium on Advances in Image and Video Technology (PSIVT 2009)*, pp. 886 - 897, Tokyo, Japan, Jan. 2009.

COOPERATIVE SURVEILLANCE SYSTEM



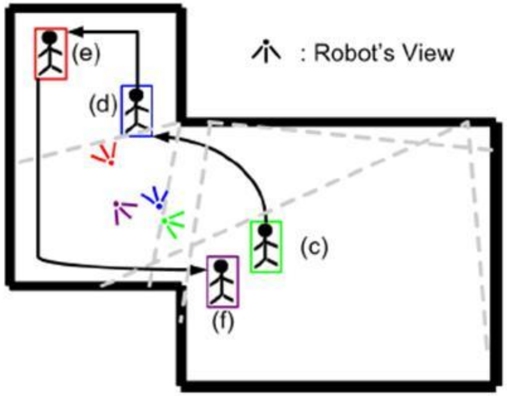
COOPERATIVE SURVEILLANCE SYSTEM



(a) (b)

(c) (d)

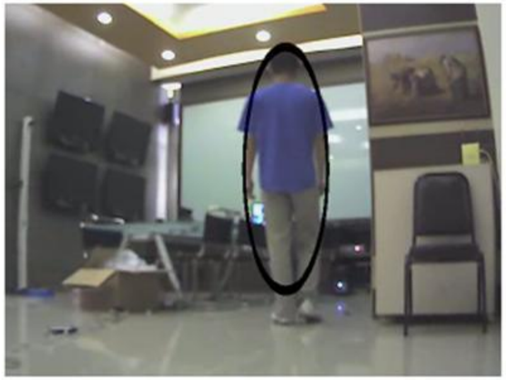
COOPERATIVE SURVEILLANCE SYSTEM



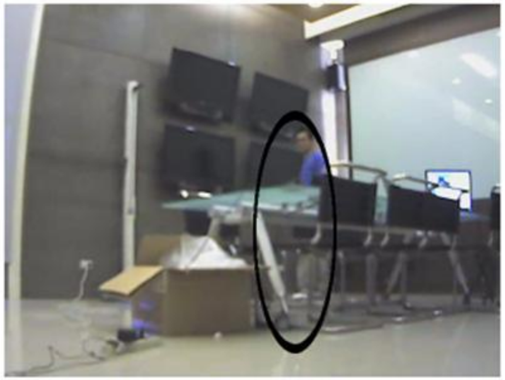
(a)

(b)

(c)



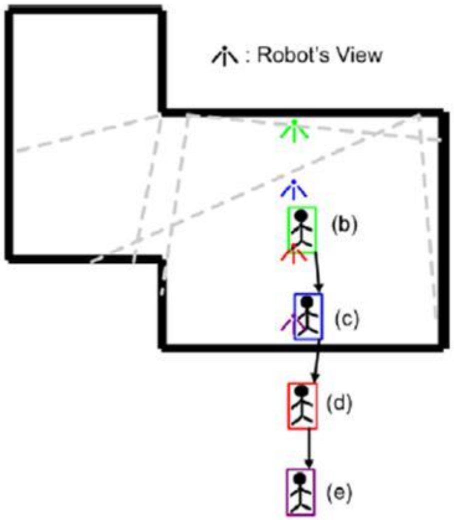
(d)



(e)

(f)

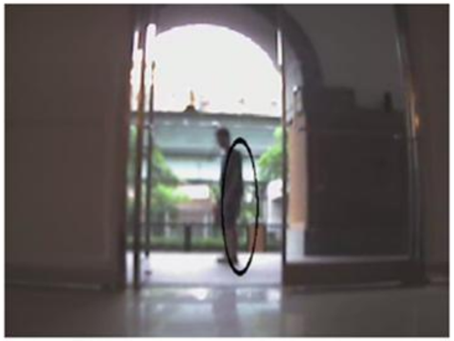
COOPERATIVE SURVEILLANCE SYSTEM



(a)

(b)

(c)



(d)

(e)

SUMMARY

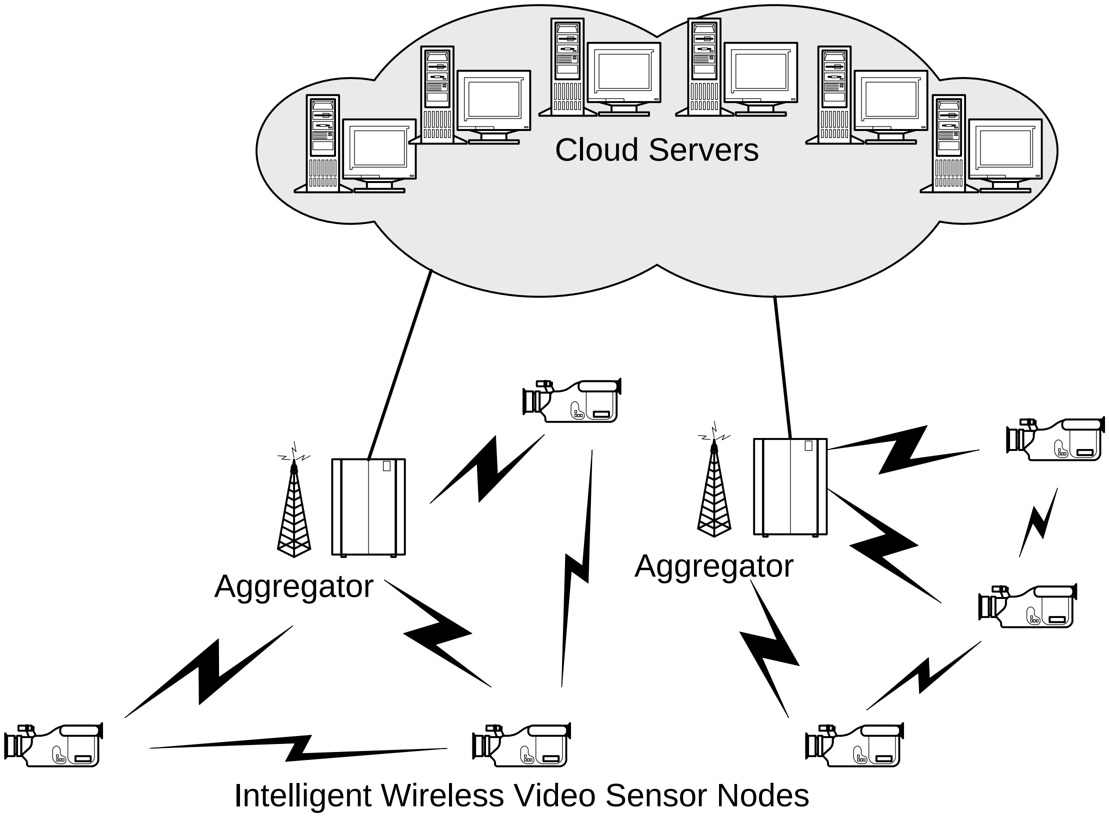
SUMMARY

- Our target: distributed video sensor nodes with low power consumption
- DVC seems a promising solution for the coding subsystems of distributed video sensors
  - It surprisingly shows that the power consumption of DVC-based systems is not as low as people usually thought
  - The R-D performance of DVC should be further improved
- Better system efficiency can be achieved with integrated video analysis engine
  - How to distribute the workload of video analysis?
- Trade-off analysis plays an important role for this project

DISCUSSIONS

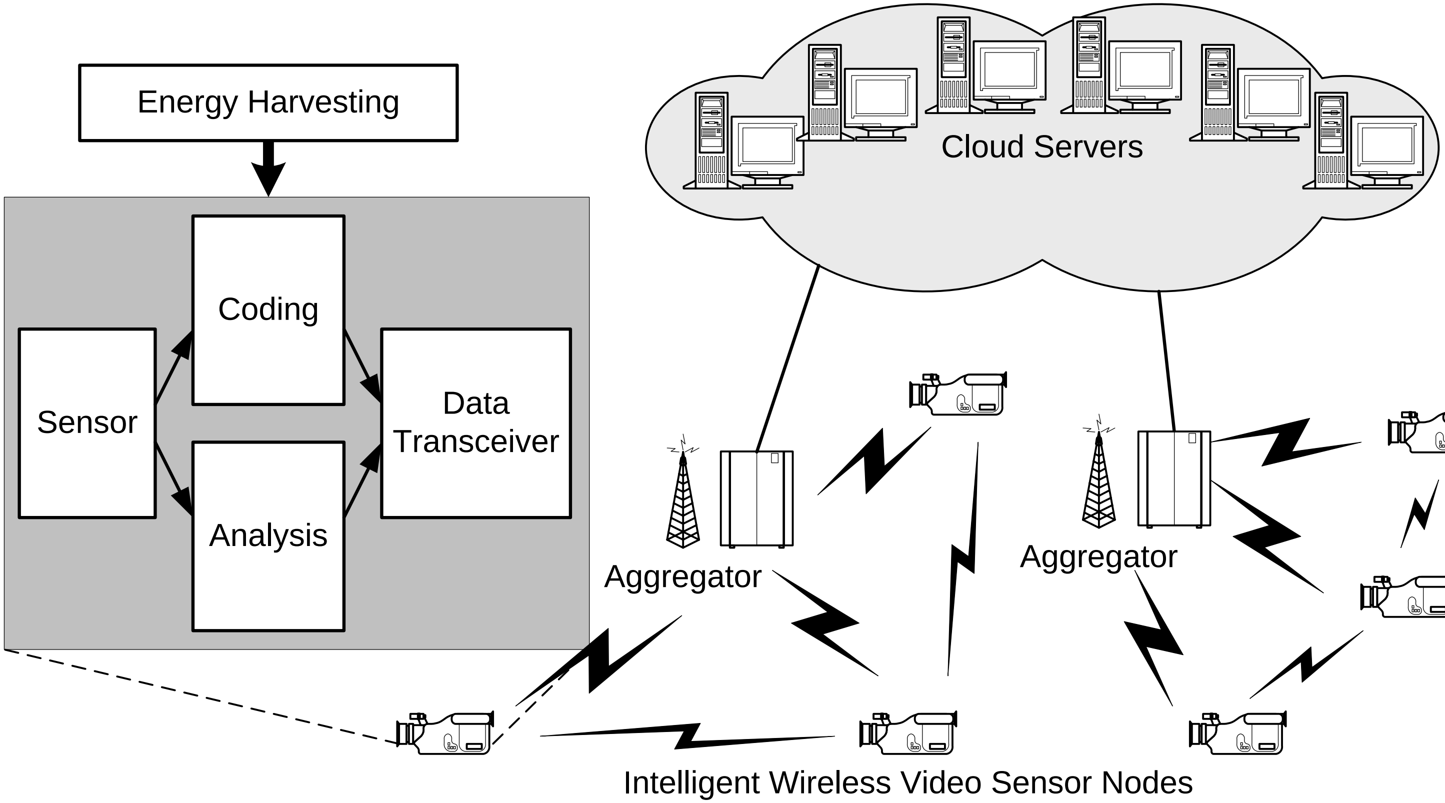
QUESTION 1

- Possible applications with distributed video sensors?



QUESTION 2

- Possible applications with perpetual distributed video sensors?



QUESTION 3

- Any other solutions to reduce the power consumption?