Energy Optimization of Lower Layers in Wireless Sensor Networks

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INRIA/IRISA EPC CAIRN

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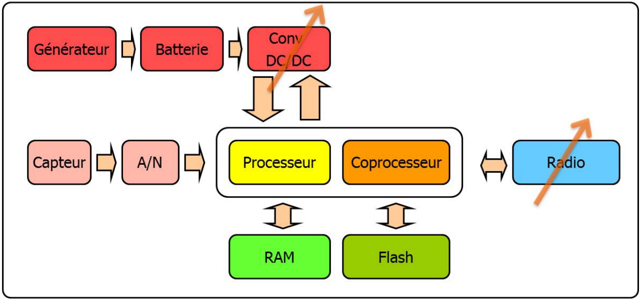
Wireless Sensor Networks

- Wide range of Wireless Sensor Network (WSN) applications
  - Health, buildings and agriculture monitoring, defense, etc
  - 2B€ per year market until 2022
- Set of smart radio nodes generating and relaying messages
- Ad Hoc, fault tolerant networks
- Low cost, low traffic and low power

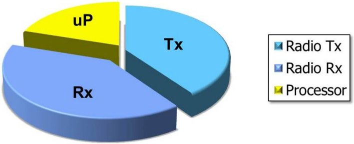
Which parts of a WSN node are energy consuming?

A WSN node is a typical embedded system



Classical power budget

- Radio: 30-70 mW
- Processor: 5-10 mW



How to design an energy efficient WSN platform?

1. Decrease Transmit Power

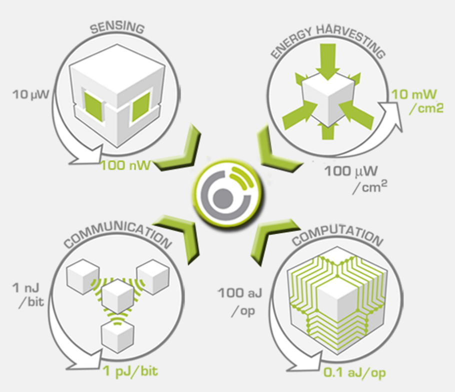
- Efficient signal processing
- Error detection and correction

2. Optimize radio activity

- MAC protocols
- Wake-up radio

3. Optimize hardware architecture

- Co-processing, DVFS, power-gating
- Energy harvesting



source: http://www.ga-project.eu/

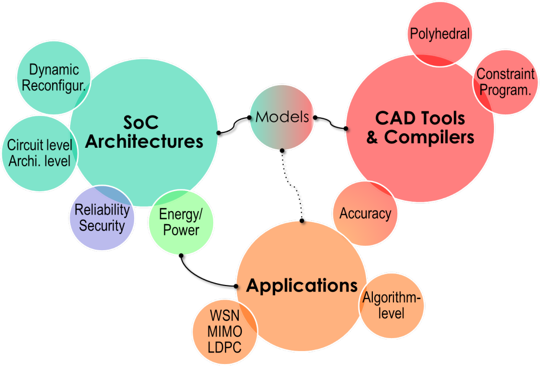
Goal of future WSNs: reach energy autonomy!

Outlines

CAIRN research topics

CAIRN Team at a glance

- Created in 2008, Rennes and Lannion campuses
- INRIA, CNRS, Univ. Rennes 1, ENS Rennes
- +50 people : 4PR, 8 MCF, 3 researchers, 25 PhD, 8 IGR

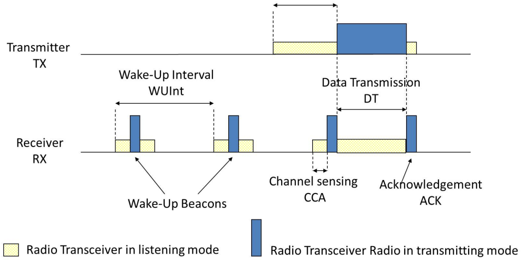


CAIRN Team WSN Platform : PowWow

Hardware components

- TI MSP430 Microprocessor
- TI CC2420 Radio transceiver
- Actel Igloo FPGA coprocessor
- Energy harvesting board

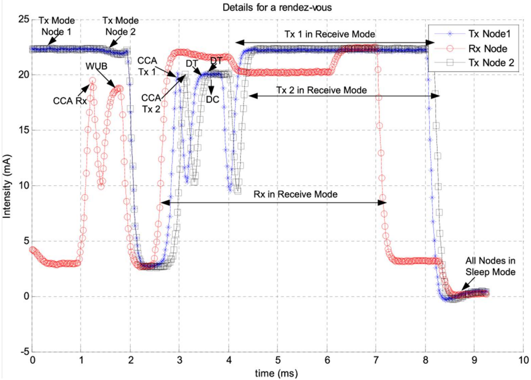
Asynchronous MAC protocol: well suited to low traffic applications



Hybrid energy model

Scenario-based hybrid model [M. Cartron and M.M. Alam PhDs]

- Real-Time measurements for scenarios
- Analytic expressions for traffic parameters
- Accurate energy consumption estimation [alam11eurasipjes]



Energy Optimization Methodology

Algorithm Library

- Channel coding
- Compression
- Modulation
- Cooperation
- Medium access
- Routing

Target

- Microrocessor
- FPGA
- Power-gating
- DVFS

Energy Optimization Methodology

Application constraints

Network topology

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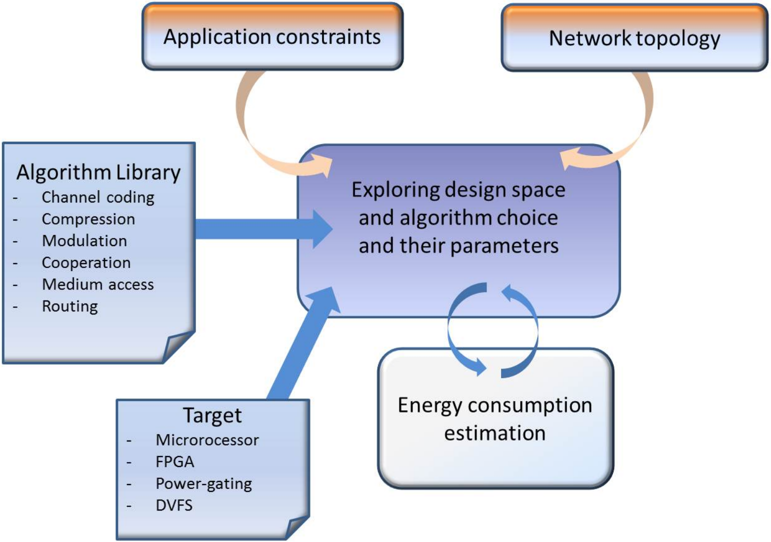
Energy Optimization Methodology



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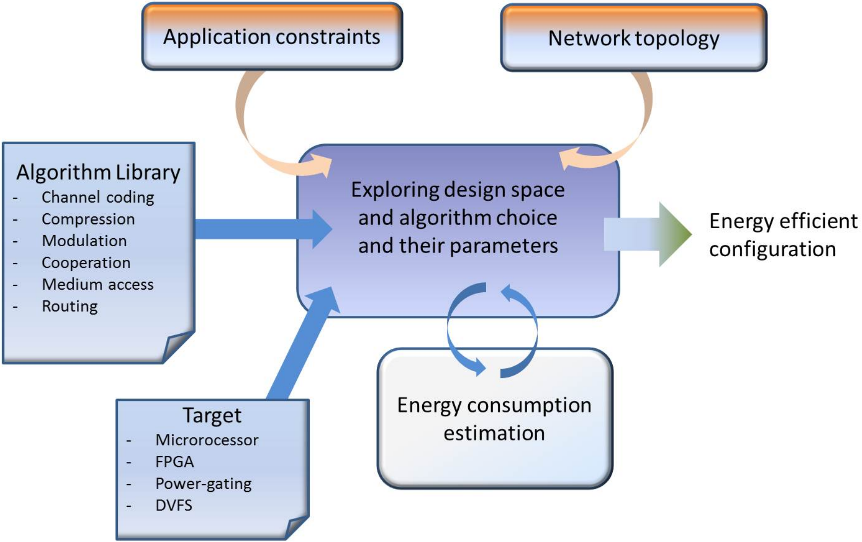
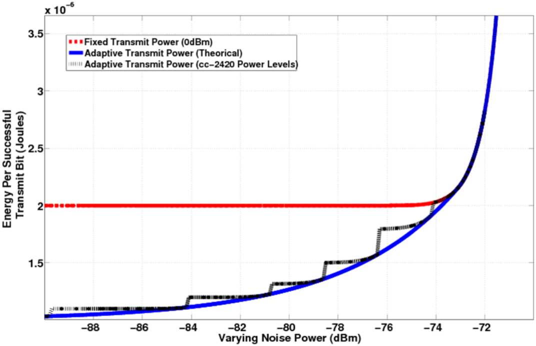


Transmit power optimization

Adaptation to the channel quality

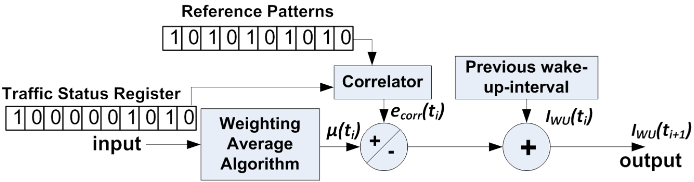
- Lifetime increase through static TX power tuning [M. Cartron PhD]
- Different coding schemes (implementation on low-power FPGA)
- Dynamic TX power adaptation



Wake-up interval optimization

Decrease radio activity [M.M. Alam PhD]

- Static adaptation to application constraints [sentieys07dasip]
- Traffic-Aware Dynamic MAC protocol [alam12ieeejetcas, alam11bsn]
    - Definition of Traffic Status Registers
    - Self-adaptive algorithm
    - Significant reduction of idle listening



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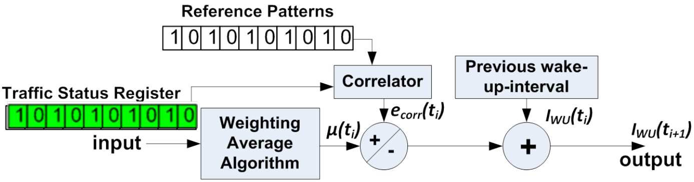

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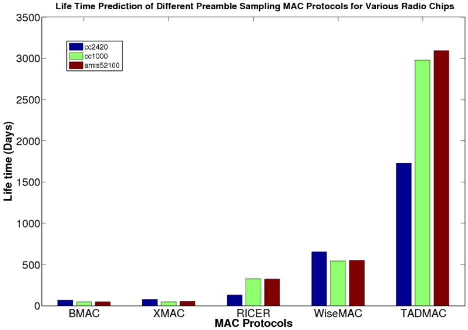
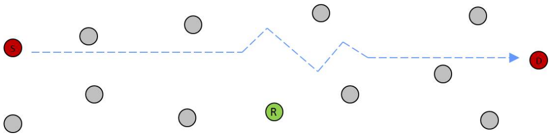


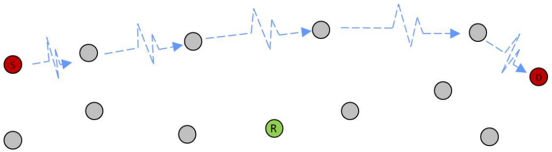
Cooperative strategies



Which one to choose between

- Direct transmission: fast but energy consuming (when possible)

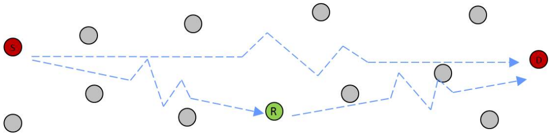
Cooperative strategies



Which one to choose between

- Direct transmission: fast but energy consuming (when possible)
- Multi-hop: variable latency

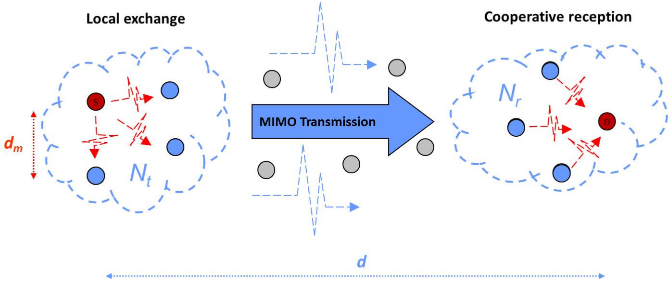
Cooperative strategies



Which one to choose between

- Direct transmission: fast but energy consuming (when possible)
- Multi-hop: variable latency
- Cooperative relay: simple, reliable [tran11wcc, tran11ccc, tran13eurasipjwcn]

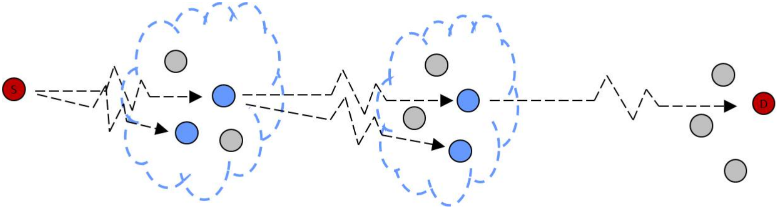
Cooperative strategies



Which one to choose between

- Direct transmission: fast but energy consuming (when possible)
- Multi-hop: variable latency
- Cooperative relay: simple, reliable
- Cooperative MIMO: efficient but synchronization requirement and complex reception [nguyen07vtc, nguyen08icc, nguyen11ieeetits]

Cooperative strategies

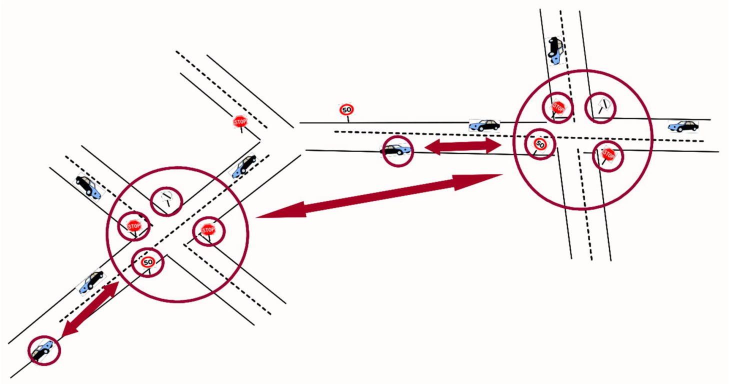


Which one to choose between

- Direct transmission: fast but energy consuming (when possible)
- Multi-hop: variable latency
- Cooperative relay: simple, reliable
- Cooperative MIMO: efficient but synchronization requirement and complex reception
- Opportunistic relaying: reliable but variable latency [zhang12ahn]

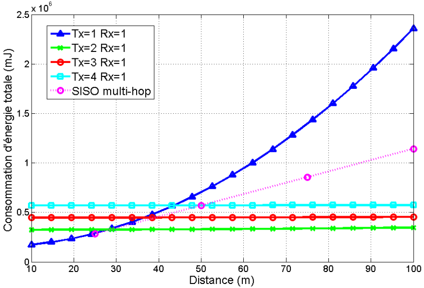
ITS Application Context

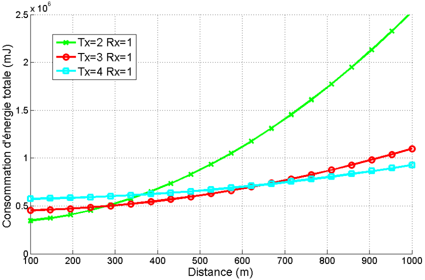
- Application constraints and network topology can drive cooperative scheme choice
- Infrastructure to Vehicle (I2V) Communications in CAPTIV[1]
- Cooperative MIMO well suited to crossroads configuration



[1] Cooperative strAtegies for low Power wireless Transmissions between Infrastructure and Vehicles

Energy efficiency of cooperative MIMO [T.D. Nguyen PhD]



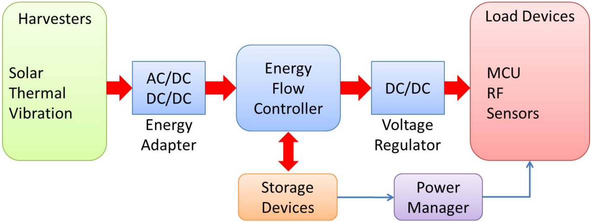


- Energy models (literature, transceiver characteristics)
- Cooperative MISO more energy efficient from 30 meters
- Cooperation at the receiver not really energy efficient

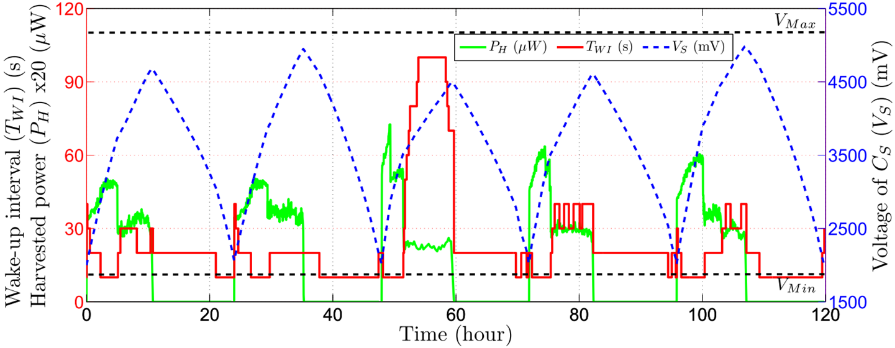
Towards a complete autonomy of wireless nodes

Power manager design [GRECO, N.L. Trong PhD]

- Multi-source harvesting hardware
  - Light, Heat, Moves, RF, Bio …
- Prediction algorithms
- Energy neutral operations
- Efficient implementation

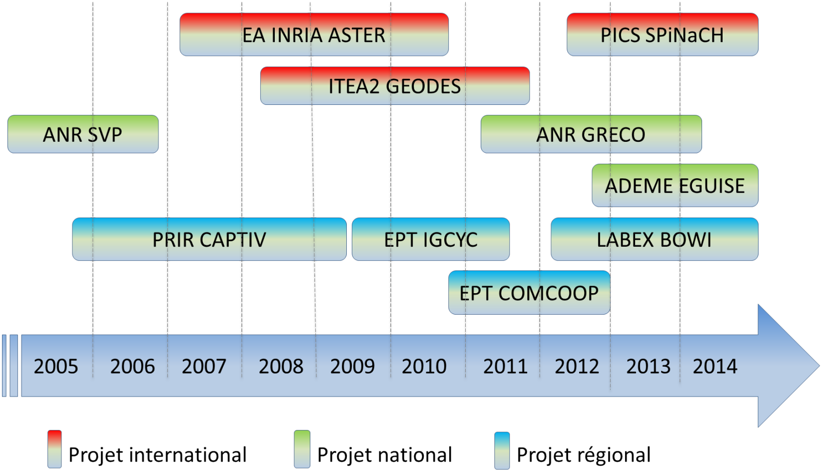


Wake-up period adaptation

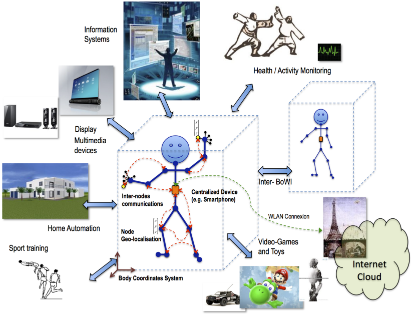


- Daily energy neutral operation
- No battery failure
- Data rate increase

Collaborative projects in energy-efficient WSN



Wireless Body Area Networks



BOdy World Interaction

- CominLabs Labex project
- 4 linked PhD subjects
  - Cooperative communications
  - Channel models
  - Hardware architecture
  - Algorithms for gesture recognition

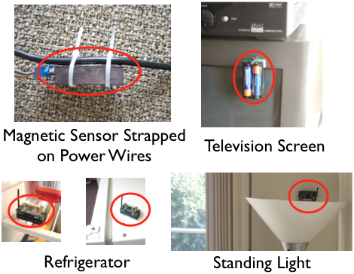
I3 Toys

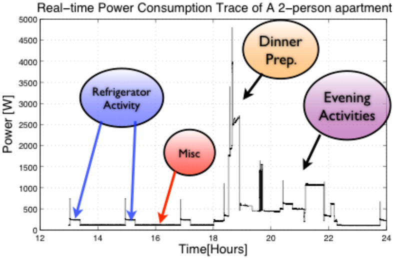
- Intelligent Interfaces for Improved Access to Toys for children with physical disabilities
- Gesture recognition

Energy consumption modeling

New approach

- Less intrusive and cooperative sensors





http://nesl.ee.ucla.edu (viridiscope)

PhD Thesis (2013-2015)

- Algorithms with data fusion
- Best trade-off radio/computation

Thanks for listening !