

# SensLAB: Very large scale open wireless sensor network testbed

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6th CAR, Grenoble, 24 Mai 2011

<http://www.senslab.info/>

# Outline

- « Sensor Networks » vanilla flavor
- Tools for development
- SensLAB : Very large scale open platform for deployment / experimentation
- SensLAB Applications
- Links with robotics ?

# Enabling Technology for Science

the complex

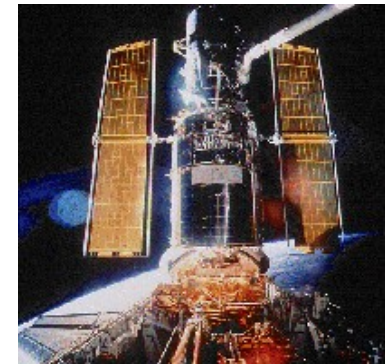
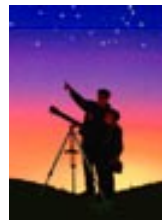
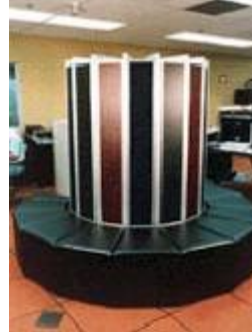
*Perceive ...*

the imperceptible

the atomic

the small

the far



# The (A) Promise of Sensor Networks

Dense monitoring & analysis of complex phenomena over large regions of space for long periods

- Many, small, inexpensive sensing devices
- Frequent sampling over long durations
- Non-perturbing
- Compute, communicate, and coordinate
- Many sensory modes and vantage points

Close to the physical phenomena of interest  
Observe complex interactions

# Embedded Networked Sensing

## Many critical issues facing science, government:

- Public call for high fidelity and real time observations of the physical world
- Networks of smart, wireless sensors can reveal the previously unobservable
- Designing physically-coupled, robust, scalable, distributed-systems is challenging

## The technology will also transform:

- business enterprise (from inventory to manufacturing),
- human interactions (from medical to social)



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# ENS: Embedded Networked Sensing

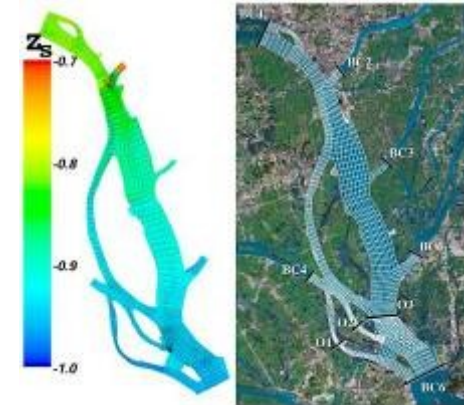
**Embed** numerous devices to monitor the physical world

**Network** to monitor, coordinate and perform higher-level identification

**Sense** and actuate adaptively to maximize information return

**In-network and multi-scale processing** algorithms to achieve:

- *Scalability* for densely deployed sensors
- *Low-latency* for interactivity, triggering, adaptation
- *Integrity* for challenging system deployments



# Wireless sensor networks

- A great recent technological success
- Many applications
  - Environmental
  - Security
  - Automotive
  - Health
  - And many more
- Still a hot topic in both the academic and industrial worlds

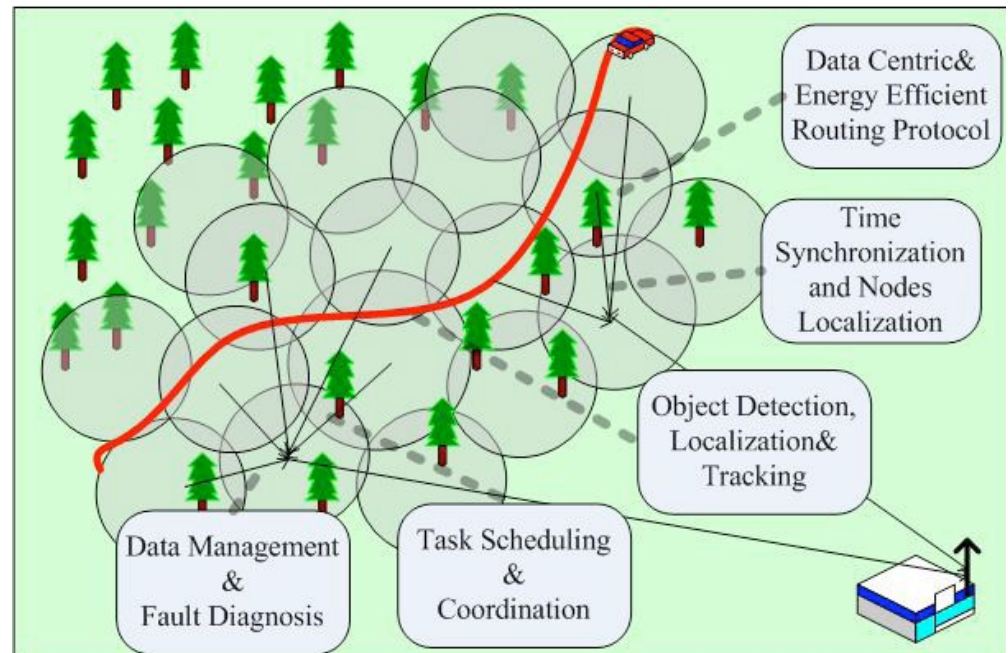
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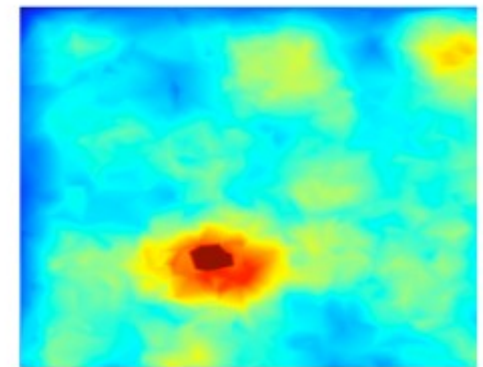
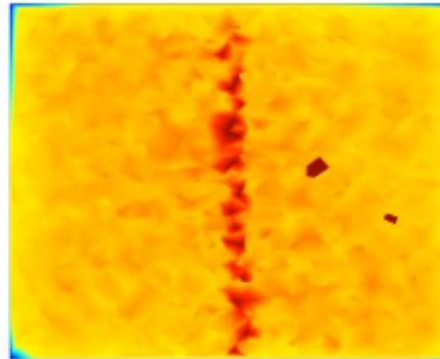
# Some classical topics

- MAC protocols
  - Neighbor discovery
  - 1-1, N-1, 1-N routing
  - Leader election protocols
  - clustering protocols
  - time synchronization protocols
  - activity scheduling
  - etc.
- Constraints:
    - energy efficiency
    - real-time
    - QoS
    - etc.



# Measures

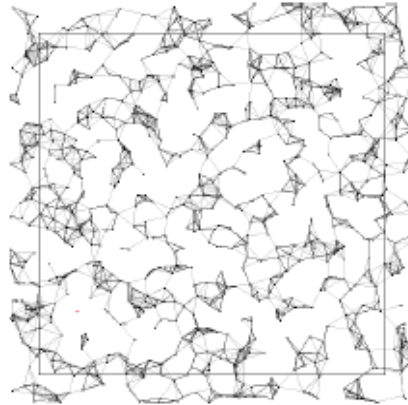
- Classical metrics:
  - Bandwidth
  - Latency
- Energy
  - Global energy consumption
  - Max energy consumption
  - Network lifetime
- Network lifetime
  - First node to die
  - x% of dead nodes
  - Based on coverage / connectivity properties
  - Given by the application operation



# Performance Evaluation

## ■ Analyse

- Stochastic geometry
- Percolation
- Process algebra
- Markov chains

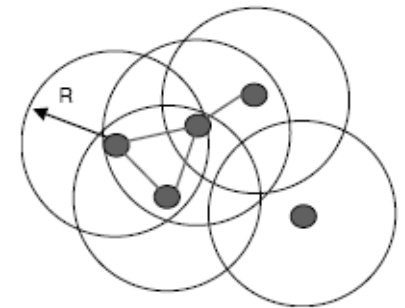


## ■ What to analyse

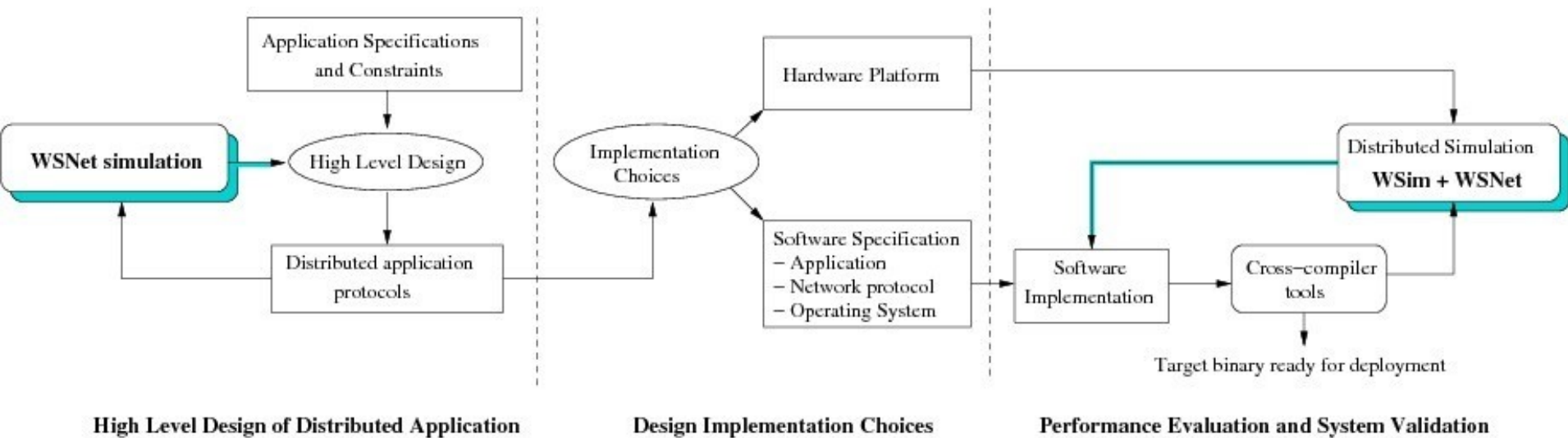
- Which radio model ?
- Which network models ?
- Which modeling precision ?
- Which protocol parameters ?

## ■ Simulation

- Network simulator
- SHAWN
- SENSE
- QualNet
- COOJA
- Bonnmotion
- OMNeT++
- **WSNet / WSim**
- TOSSIM
- OPNET

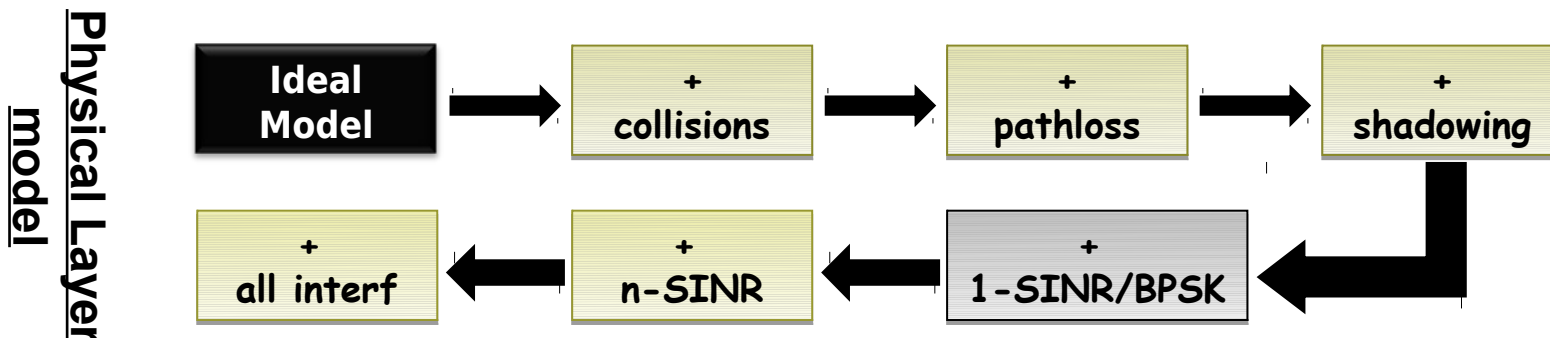
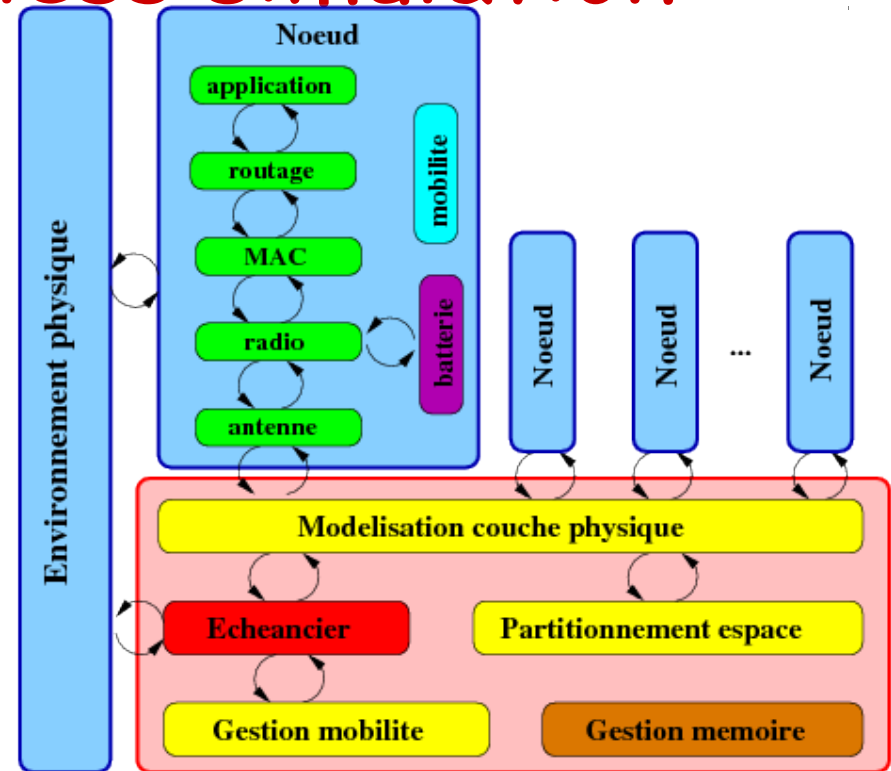
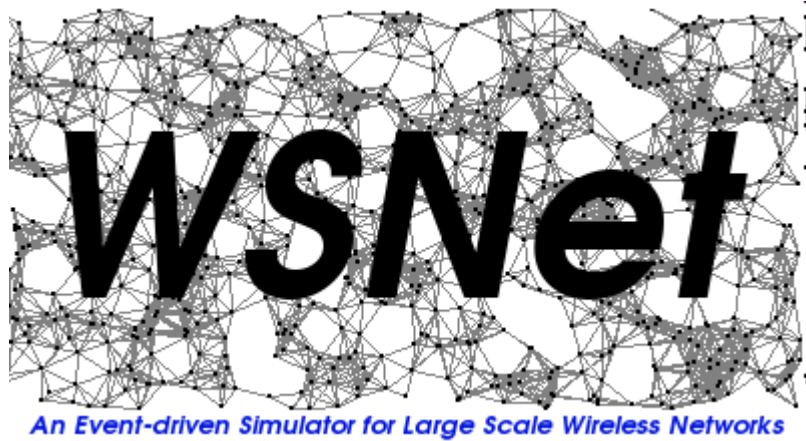


# Simulation and prototyping tools

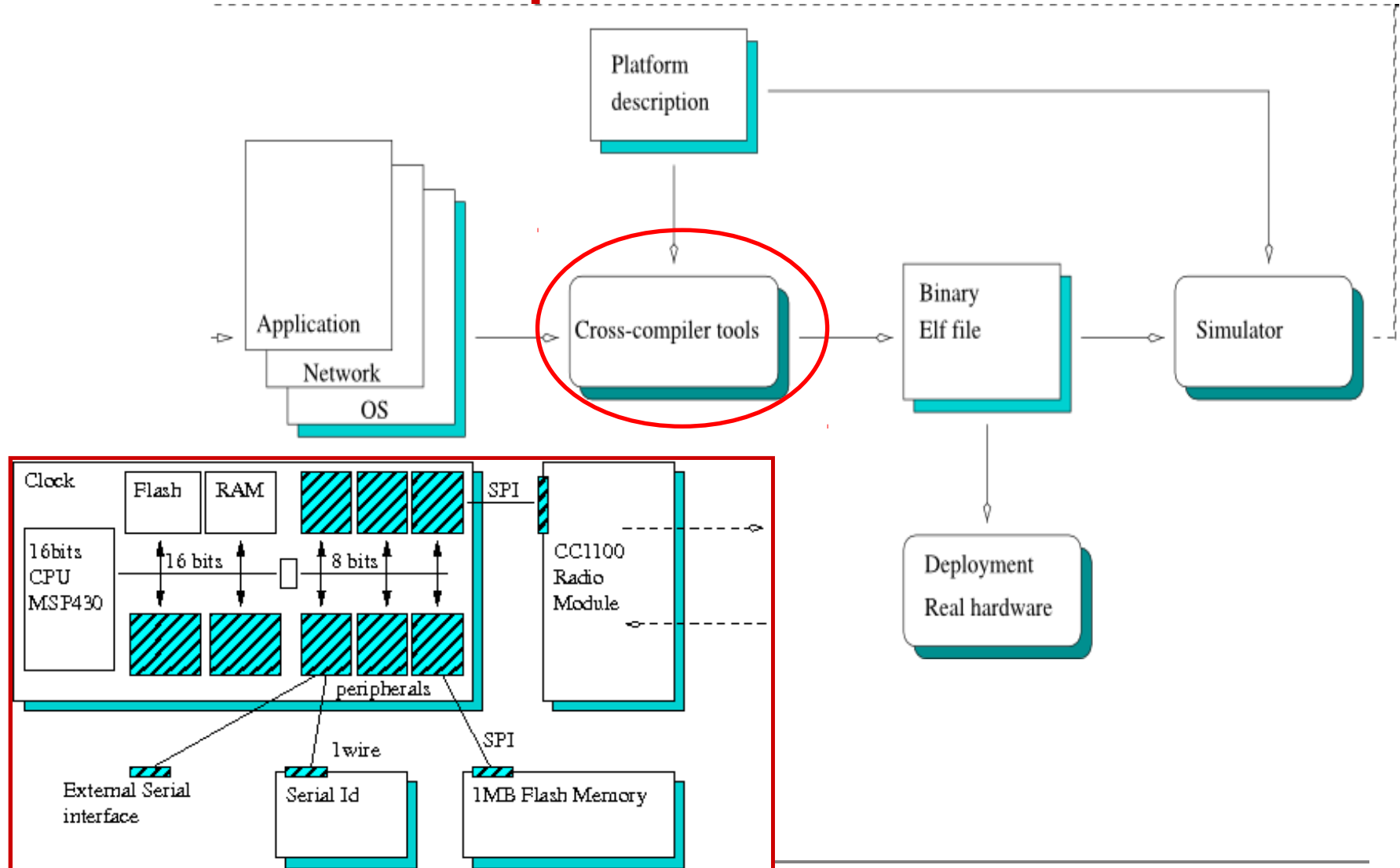


High-level design to implementation, test and performance evaluation

# Network and wireless simulation



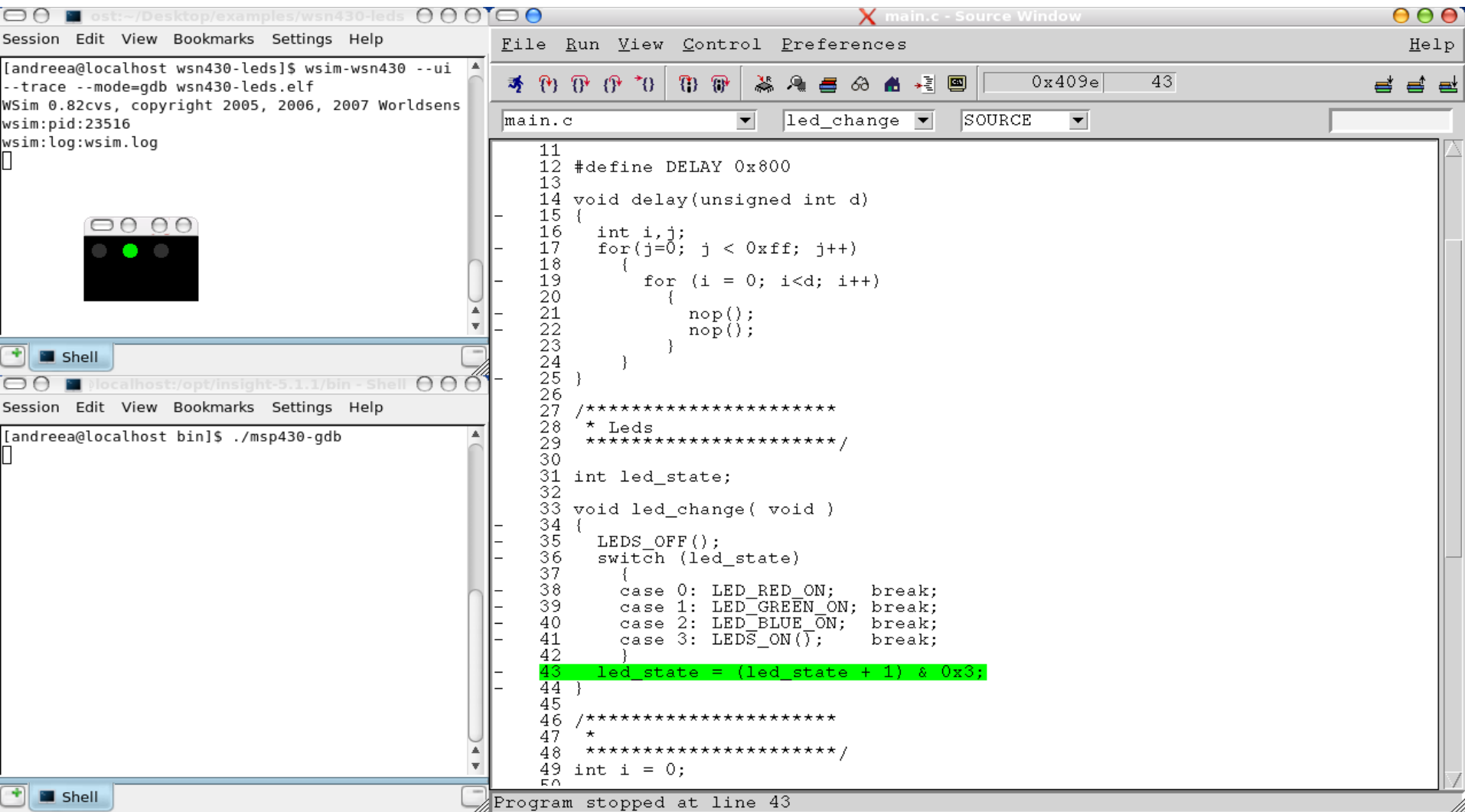
# WSim : Full platform simulator



# WSim

- Full instruction set support for the target microcontroller
- Cycle-accurate simulation
- Accurate simulation of peripherals
  - timers
  - interrupts
  - cycle-accurate simulation of communications (e.g. UART)
- External peripherals (radio modules, display ...)
- A full system debug and performance analysis framework

# WSim : debug



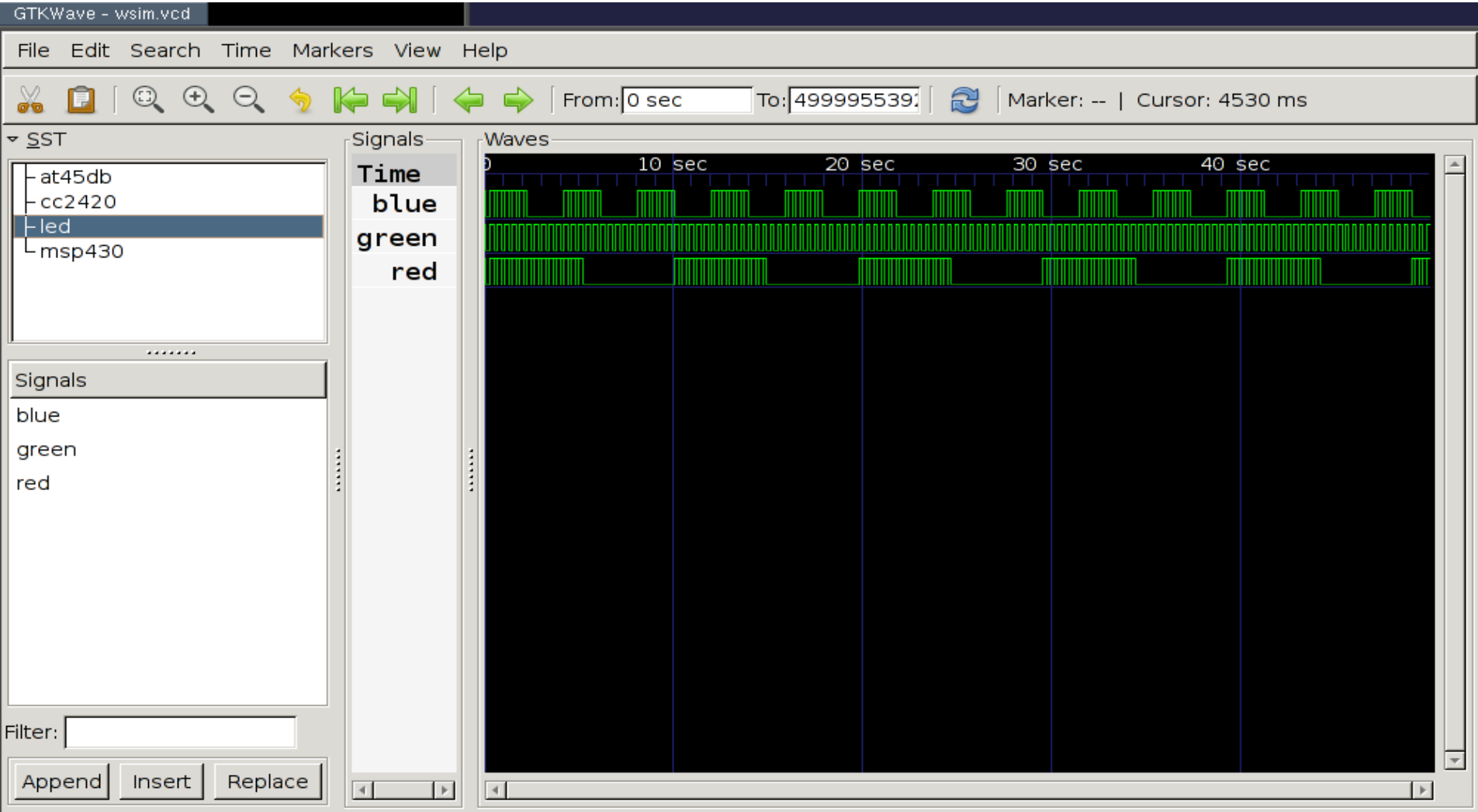
The screenshot displays a development environment with three main windows:

- WSim Window:** Shows the execution of `wsim-wsn430 --ui --trace --mode=gdb wsn430-leds.elf`. The output includes `WSim 0.82cvs, copyright 2005, 2006, 2007 Worldsens`, `wsim:pid:23516`, and `wsim:log:wsim.log`. A small window below it shows three LEDs, with the middle one (green) illuminated.
- Shell Window:** Shows the command `./msp430-gdb` being executed in the `bin` directory.
- main.c - Source Window:** Displays the source code for `main.c`. The current line of execution is highlighted in green: `43 led_state = (led_state + 1) & 0x3;`. The code includes a `delay` function and a `led_change` function that cycles through LED states (0, 1, 2, 3).

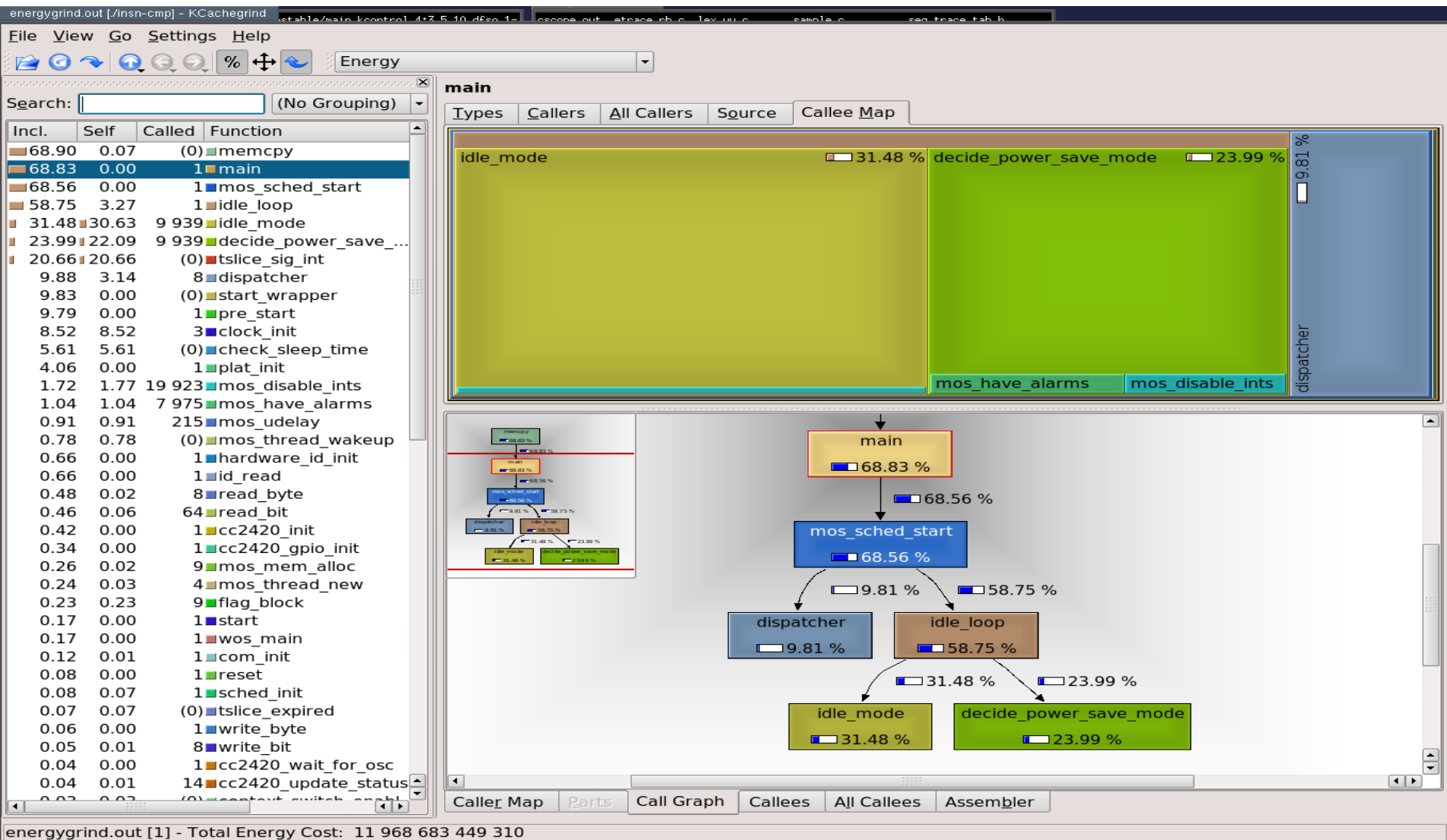
At the bottom of the source window, a status bar indicates: `Program stopped at line 43`.



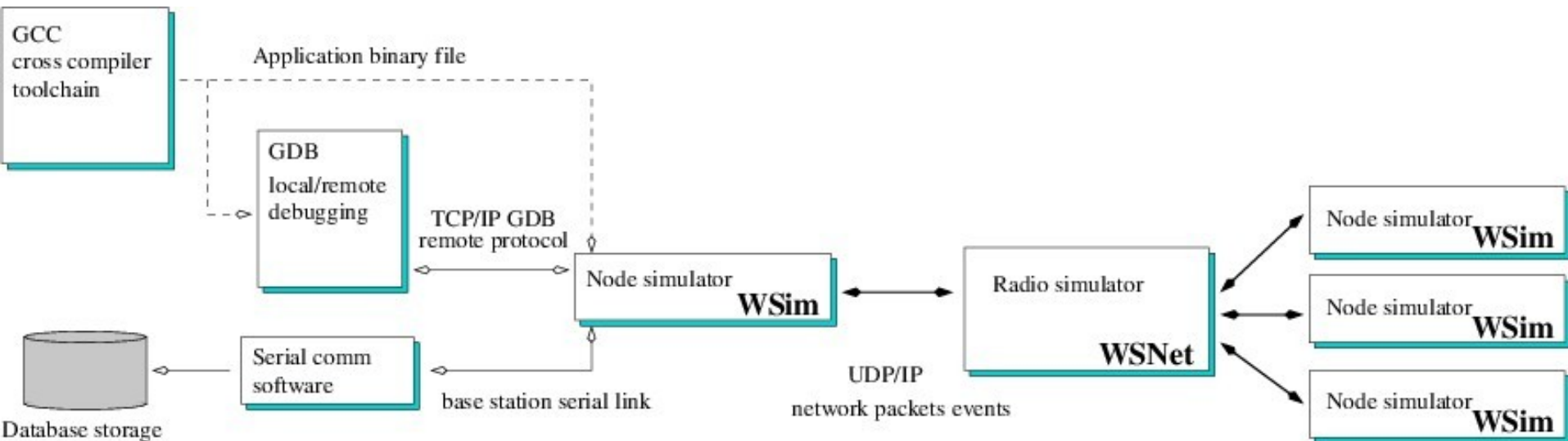
# WSim : chronograms



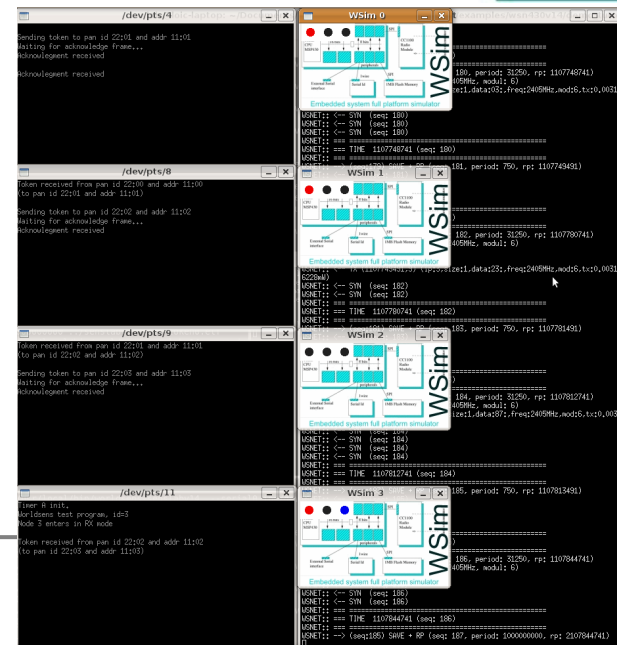
# WSim : source code evaluation



# Coupling WSim + WSNNet



- Distributed simulation
  - Wireless simulation
  - Cycle accurate code simulation
  - Distributed debug with step by step mode

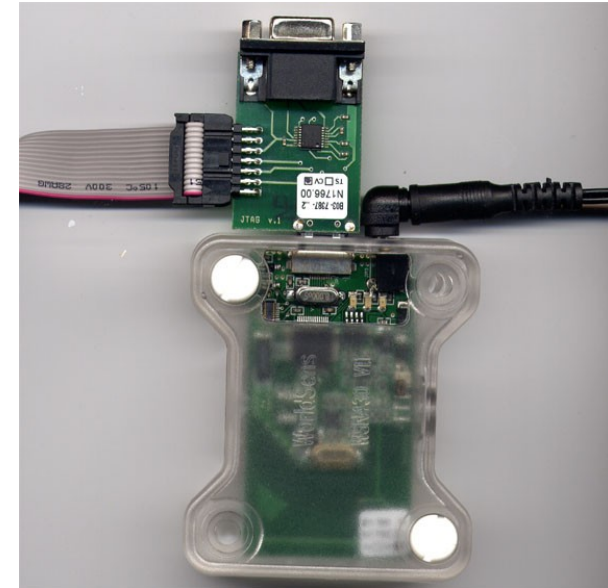


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# Deploying real application

- Build new protocols / application
    - Specification / Design
    - simulation
    - **Experimentation**
  - Large scale experimentation is a nightmare
    - Fastidious for a dozen of nodes
    - **Manual handling / time consuming / boring**
- Needs to have a specific scientific tool
- **Reproducibility is a key factor**
  - **Scientific experiment**



# An expérimental Platform

- ◉ SensLAB Goals

- Wireless Sensor Network Platform
- Large scale open to the community
- Projet ANR
  - Kickoff 2008

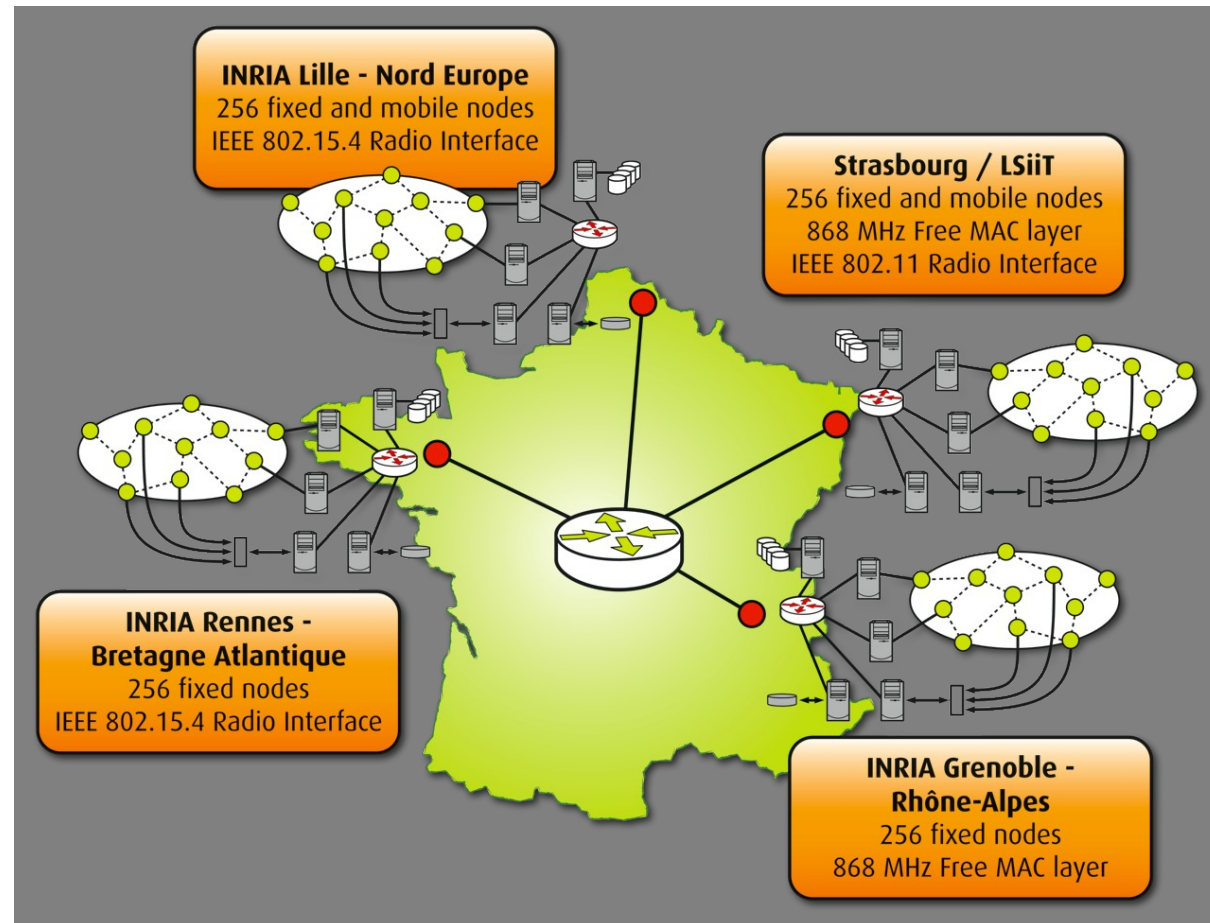
- ◉ Key points

- Distributed on 4 remote sites
- Large scale 256 nodes / site
- Automated / **Open**
- Remote access

SUPPORTED BY  
ANR

# Experimental platform

- ◉ Academia
  - INRIA
    - ASAP
    - D-NET
    - POPS
    - UPMC / LIP6
    - LSIIT
- Industrial
  - Thalès



# Main goals

- ◉ Scientific tool
  - Large scale → 1000 nodes
  - Generic / Open
  - Automation
  - Heterogeneous
  - Remote access
- ◉ Functionality
  - Non intrusive Monitoring
    - Energy consumption,
    - Radio
    - Activity
- ◉ Validation tools
  - Post experiments
  - Prototyping, debugging,
  - Performance Evaluation
- ◉ Reproducibility
  - *Experiments Versioning*
  - *Log / stimuli replay*



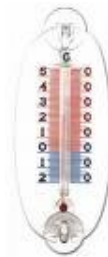
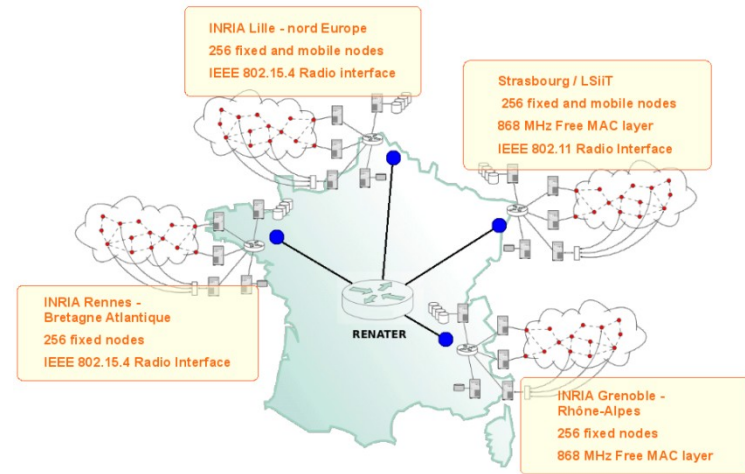
# Main goals

- ◉ Hardware
  - Real time access
  - Robust
  - Reliable access to all remote site
  - Reliable (wired) feedback channel
- ◉ Software
  - Multi applications handling in parallel
  - Security / integrity
  - Real time data access during experiments

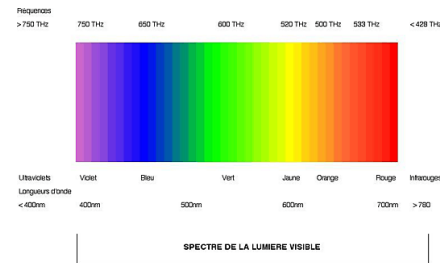
# General characteristics

## 4 complementary sites:

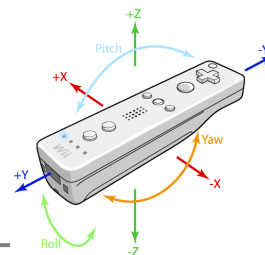
- Radio technology
  - IEEE 802.15.4 2,4GHz (TI CC2420)
  - Open MAC 868MHz (TI CC1101)
  - Wi-Fi IEEE 802.11b
- Standard sensor
  - temperature
  - luminosity
  - sound
- Optional sensors
  - Accelerometer / gyroscope
  - accelerometer + GPS



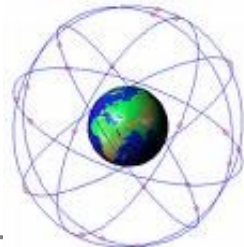
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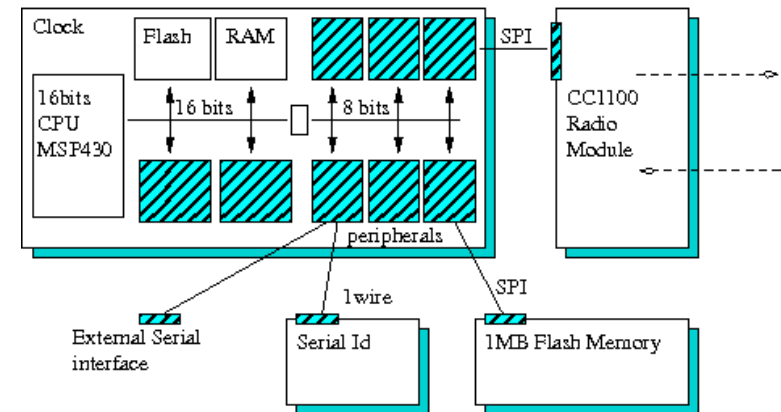
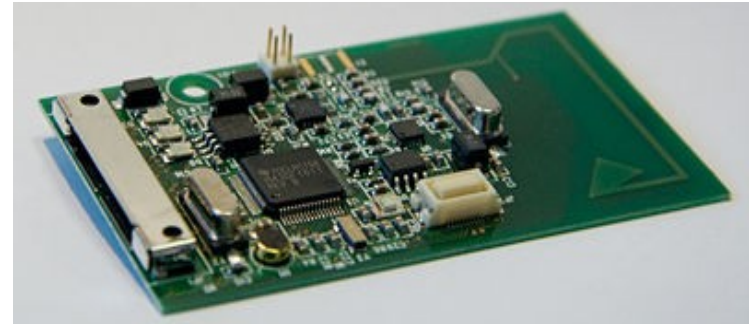


And / or

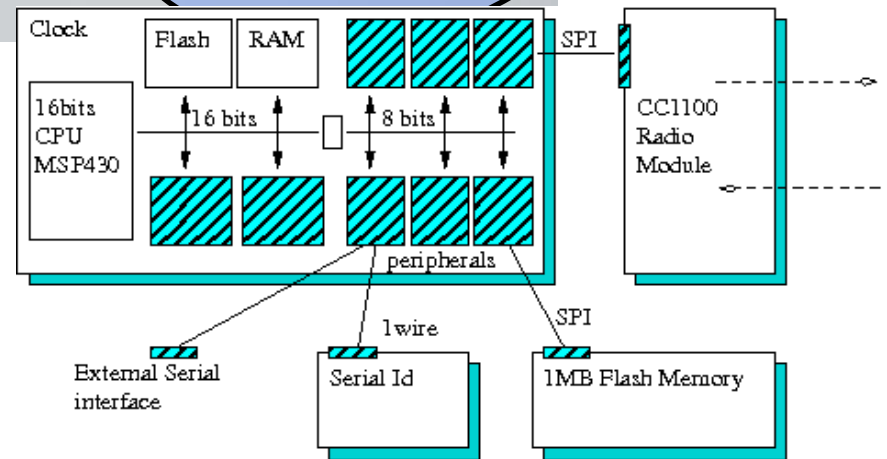
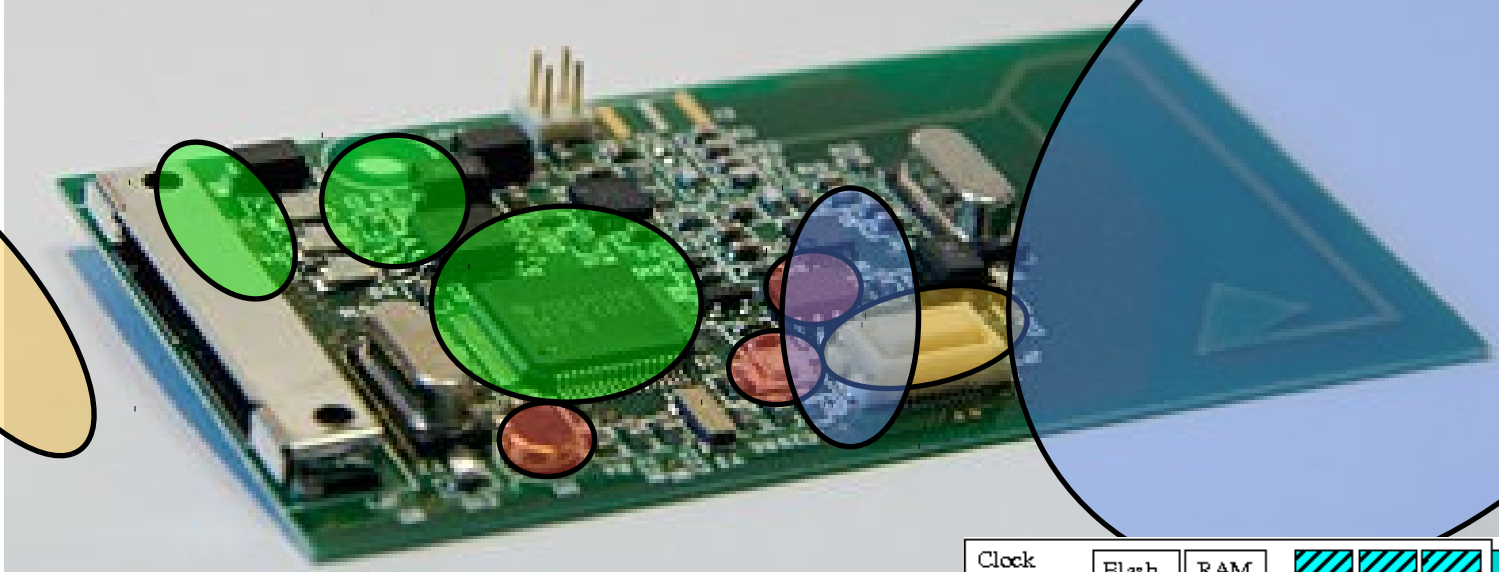


# Sensor Architecture

- ◉ Developed by INRIA (creative common)
- ◉ Characteristic
  - Micro-controller TI MSP430-1611
    - 8Mhz@16bit
    - 48Ko ROM
    - 10Ko RAM
  - Interface Radio TI CC1101/CC2420
    - frequency 868Mhz/2.4Ghz
    - Power from -30dBm to +10 dBm
  - Serial unique DS2411 (6 bytes)
  - External 1MB Flash Mem STM25P80
  - Varta battery with controller MCP73861

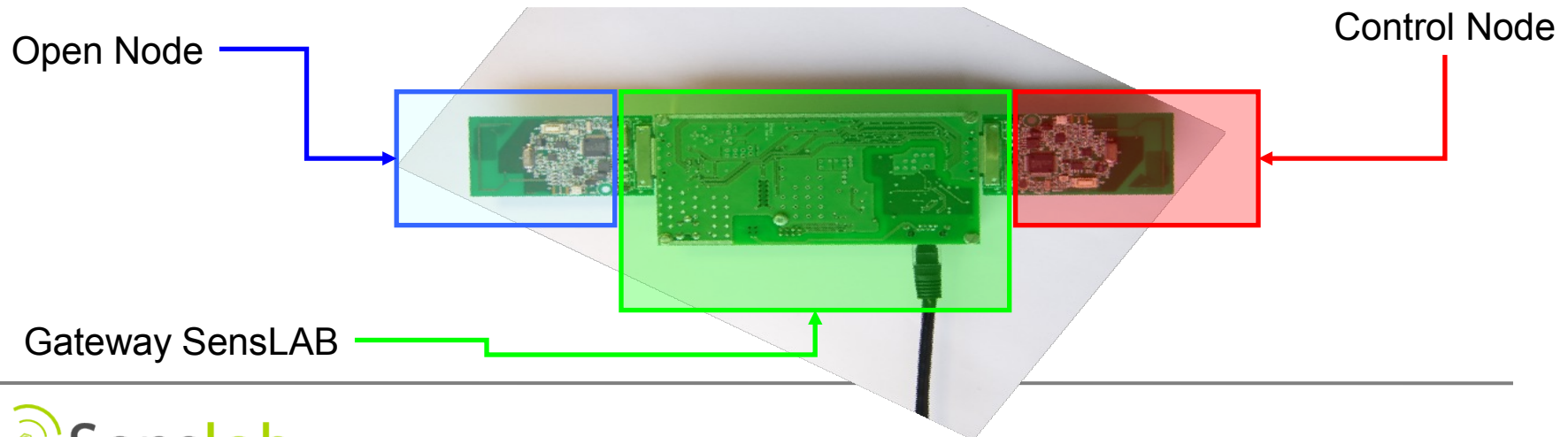


# SensLAB sensors



# SensLAB Node

- ◉ What is a SensLAB node ?
    - **OPEN, i.e., no apriori on the software**
    - **Reliable feedback channel**
    - An open node dedicated to the user
    - A control node
    - A gateway SensLAB
- = **Open Noeud** + **Gateway SensLAB** + **Control Node**

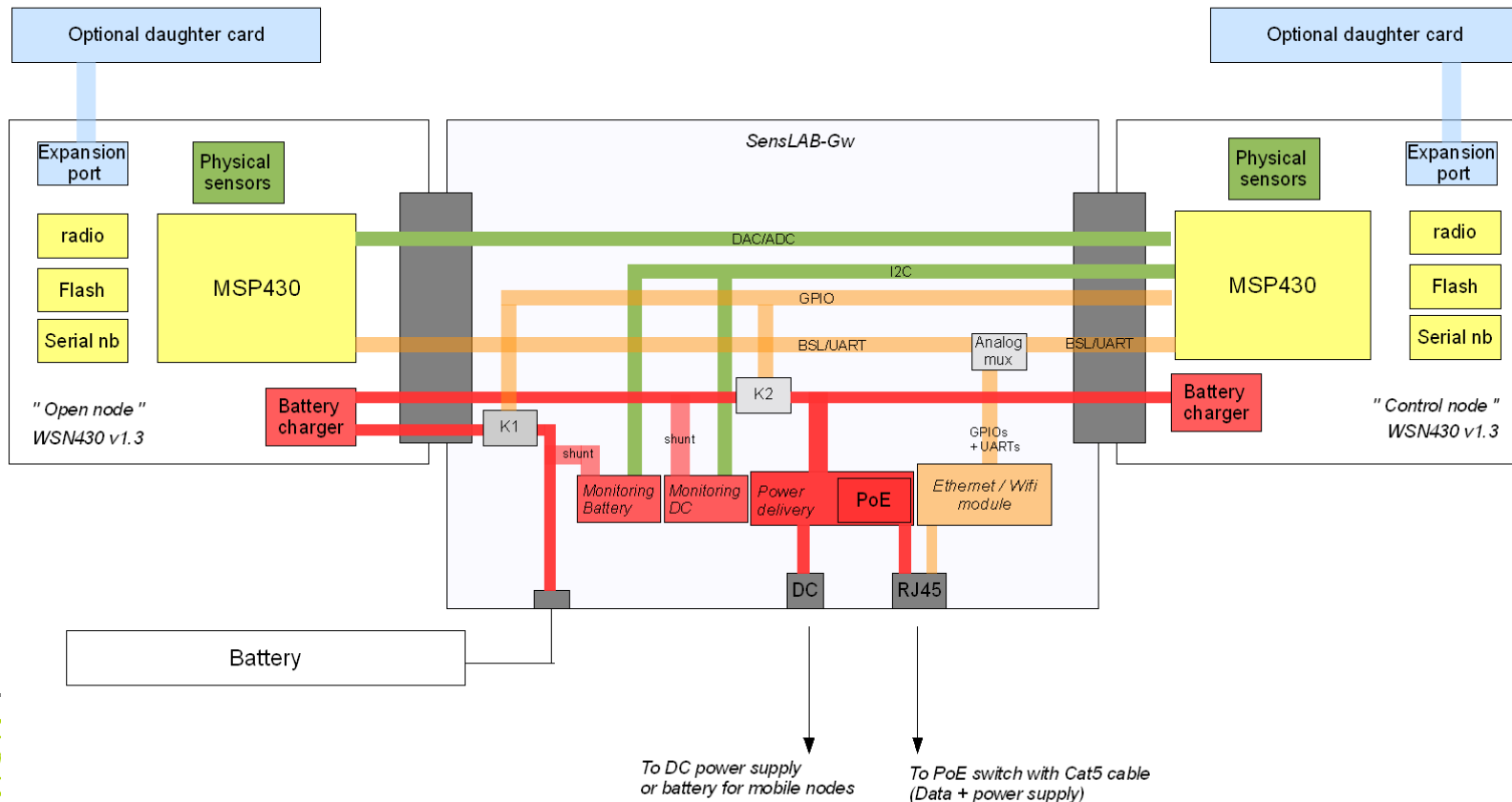


# SensLAB Node

- ◉ Open Node and Control Node
  - Same technology → Simplicity / Open license
  - Different roles
- ◉ Open Node
  - Totally programmable
- ◉ Control Node
  - Not accessible by the user
  - Monitor the open node
  - Handle all interfaces

# SensLAB Gateway Node

- Gather measures + SINK
- Offer a communication interface
- Deploy code
- Control the nodes
- Monitor energy consumption
- Trigger faults



# Deploy code on SensLAB

- Using the Gateway / IPv4
  - Ethernet (fixed node)
  - WiFi (mobile nodes / outdoor nodes)





# Plate-forme expérimentale

- Résumé des fonctionnalités par site :

	Grenoble	Lille	Rennes	Strasbourg
802.15.4		x	x	
OpenMAC	x			x
802.11b				x

Intérieur	x	x	x	x
Mobilité		x		x
Extérieur				x

Accéléromètre		x		x
GPS				x

# Strasbourg - LSIIT

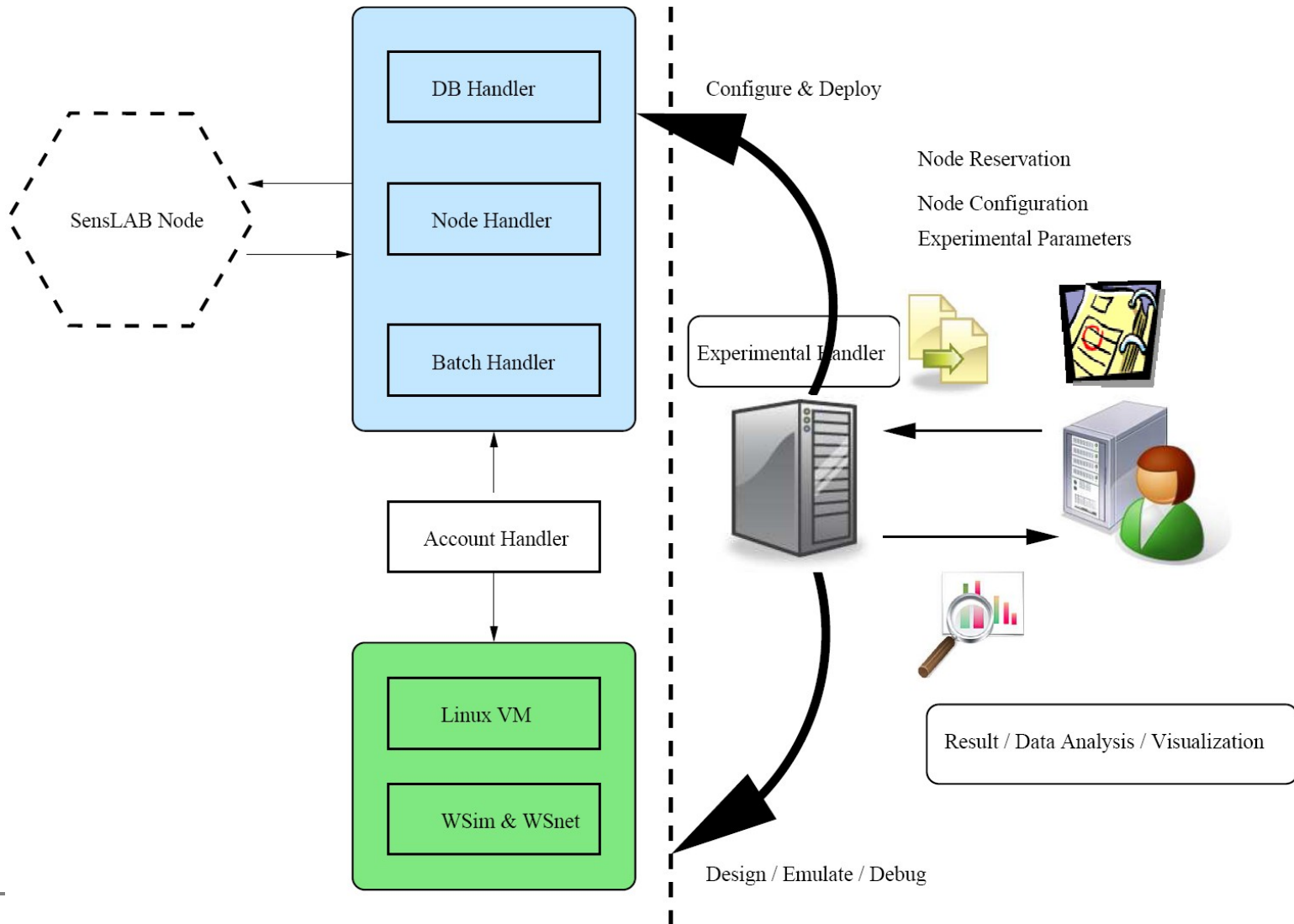


# INRIA Grenoble - Rhône Alpes



© INRIA / Photo Keksonen

# Global picture

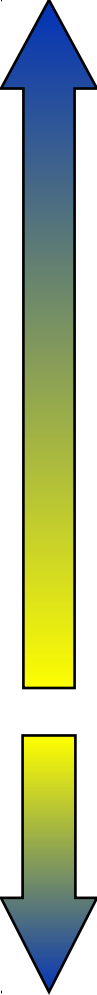


# Open tools / community

- Tutorials (creative common)
- Daughter cards (creative common)
- WSN430 Drivers (msp gcc-430 tool chain)
- OS
  - Contiki / TinyOS / FreeRTOS
- Communication Lib
  - MAC Layers / Simplicity® / Routing



# Small Technology, Broad Agenda

- 
- **Social factors**
    - security, privacy, information sharing
  - **Applications**
    - long lived, self-maintaining, dense instrumentation of previously unobservable phenomena
    - interacting with a computational environment
  - **Programming the Ensemble**
    - describe global behavior, synthesis local rules that have correct, predictable global behavior
  - **Distributed services**
    - localization, time synchronization, resilient aggregation
  - **Networking**
    - self-organizing multihop, resilient, energy efficient routing
    - despite limited storage and tremendous noise
  - **Operating system**
    - extensive resource-constrained concurrency, modularity
    - framework for defining boundaries
  - **Architecture**
    - rich interfaces and simple primitives allowing cross-layer optimization
  - **Components**
    - low-power processor, ADC, radio, communication, encryption, sensors, batteries

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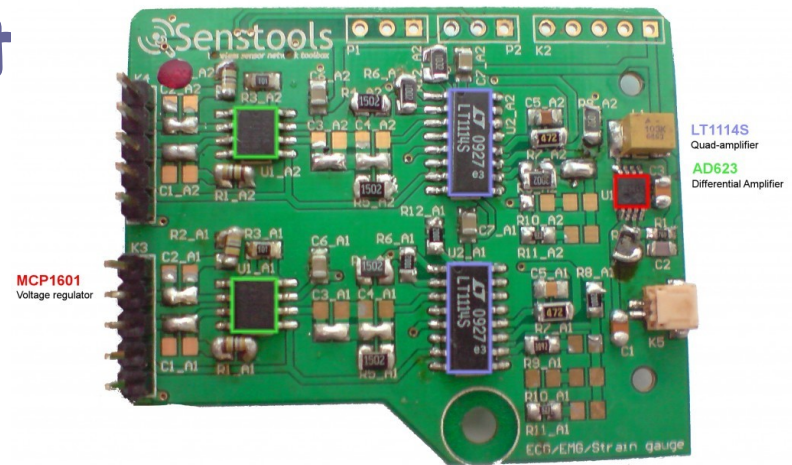
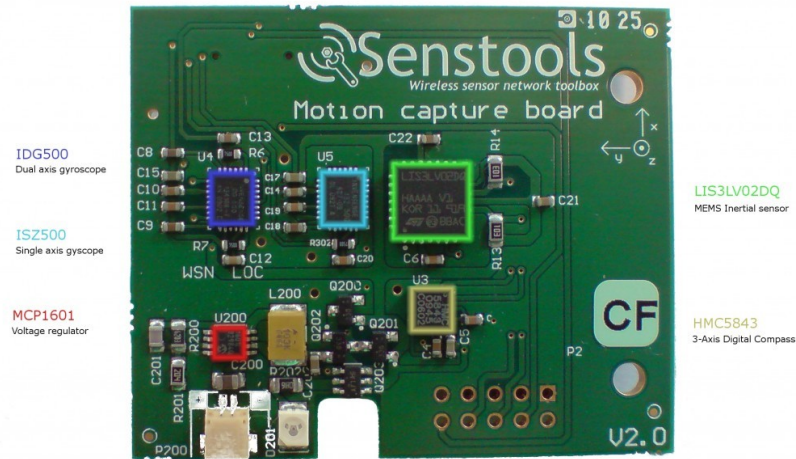
# Examples of Applications

- « Motion-capture » and more...
  - Sport
  - Rehabilitation
  - Bio-logging
- « Smart-home »
  - Sensitive tiles
- Mosar

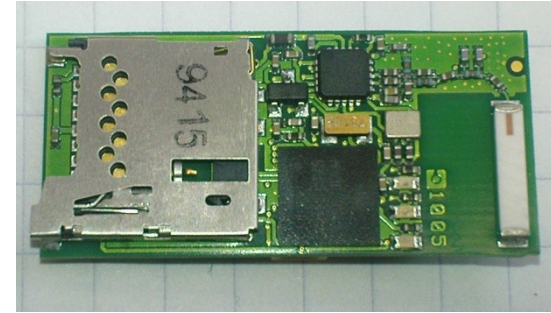
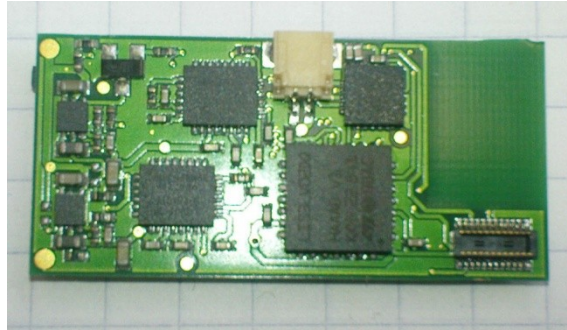


# Sensors extension

- Inertial sensors
  - Accelerometer, gyroscope, magnet
- GPS / accelerometers
- Analogic sensors (force, pressure, EMG ...)
- Cardiometer (Polar belt)
- Prototype board ...



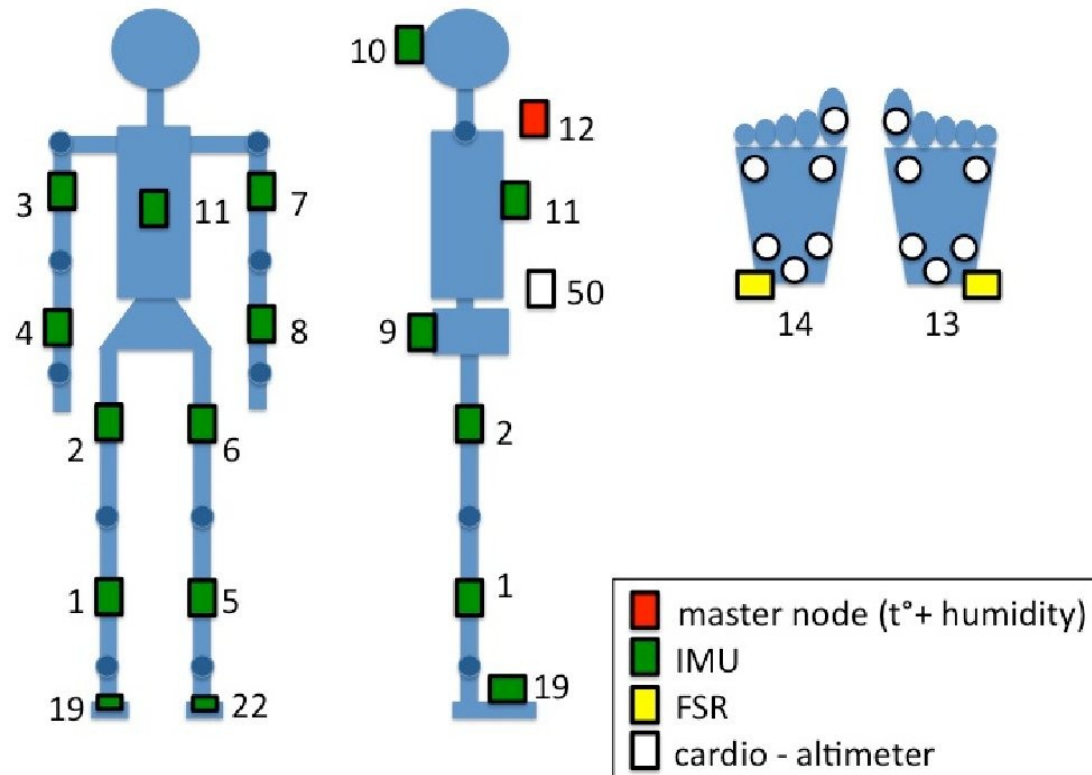
# « Marathon des Sables » Sensors



- Like WSN but with more integration:
  - Tri-axis inertial sensor : accéléro., gyro, magnéto
  - 6 analogic input: sole pressure sensor (FSR)
- micro-SD card to log data (FAT32)
- Radio 2.4 Ghz, CC2500

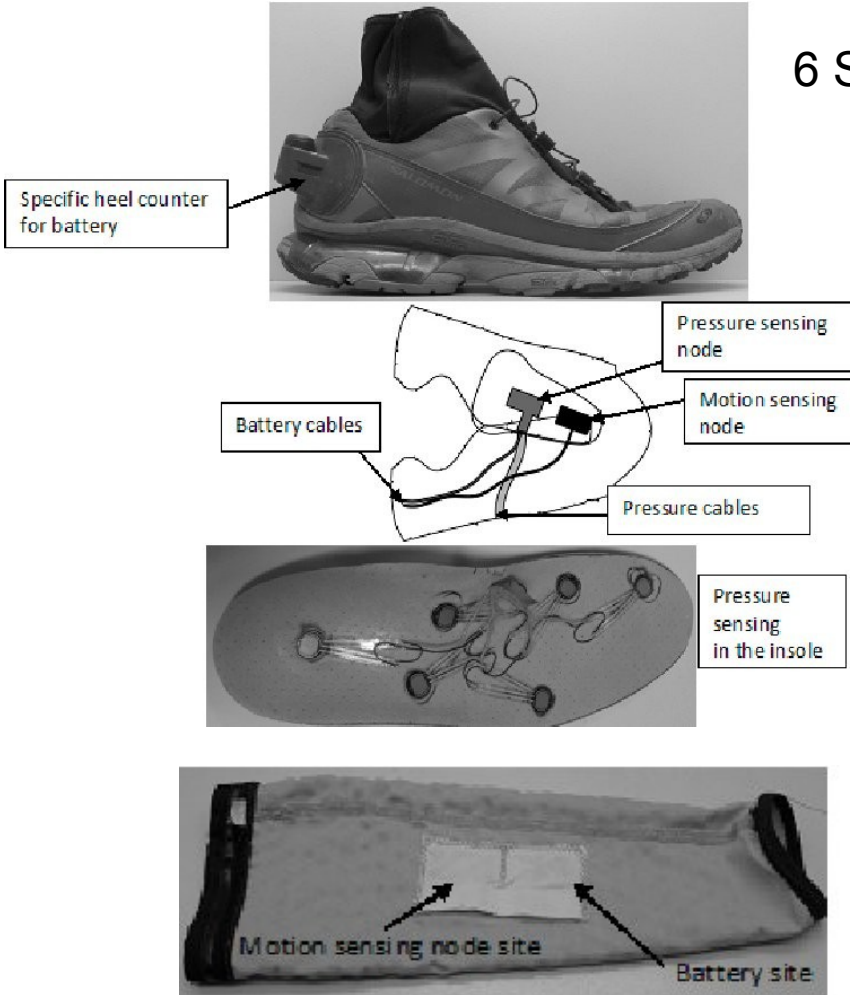
# Marathon des Sables - 1

- GPS, humidity, altitude
- accelero, gyro, magneto
- force resistive sensors
- cardio
- frequencemeter



# Marathon des Sables - 2

6 Stages Desert Race

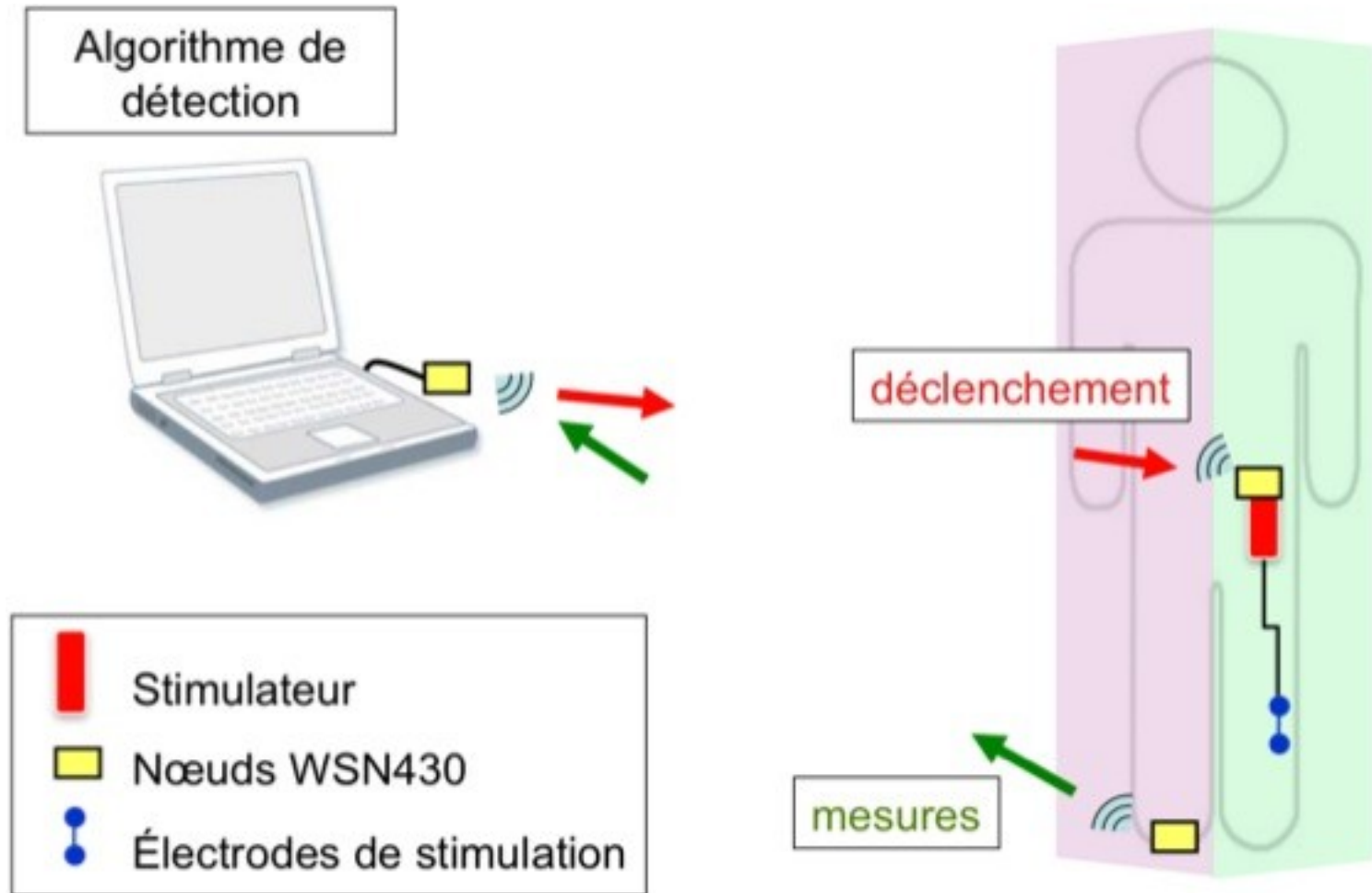


# Releveur de pied - 1

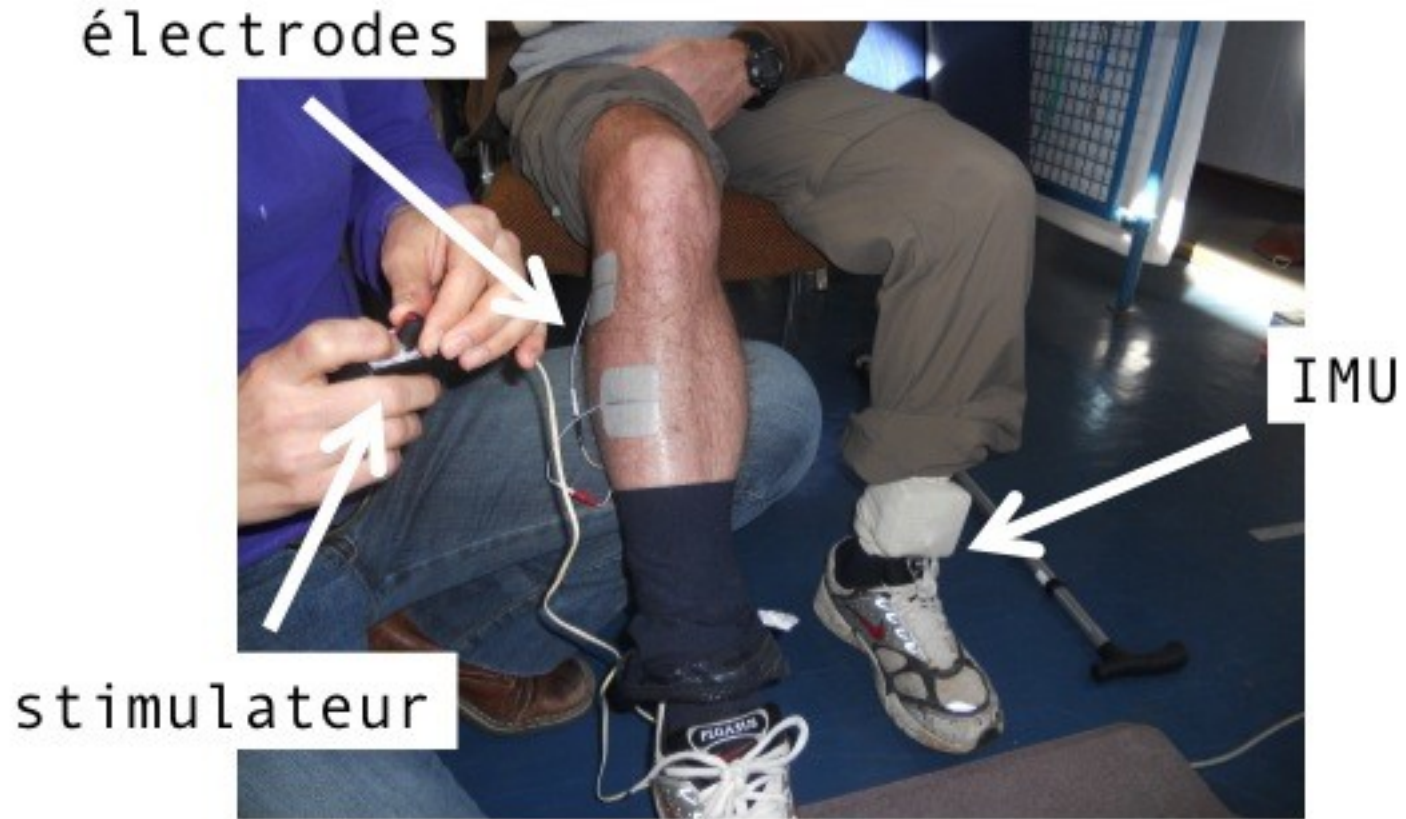
## Demar

- Marche Hémiplégique après un AVC récupération neurologique dans les mois qui suivent, mais dans 10 à 20% des cas le syndrome de pied tombant (**drop foot**) persiste.
- Drop foot : incapacité plus ou moins importante à relever le pied en phase oscillante de la marche (jambier antérieur)
- Rééducation/suppléance fonctionnelles

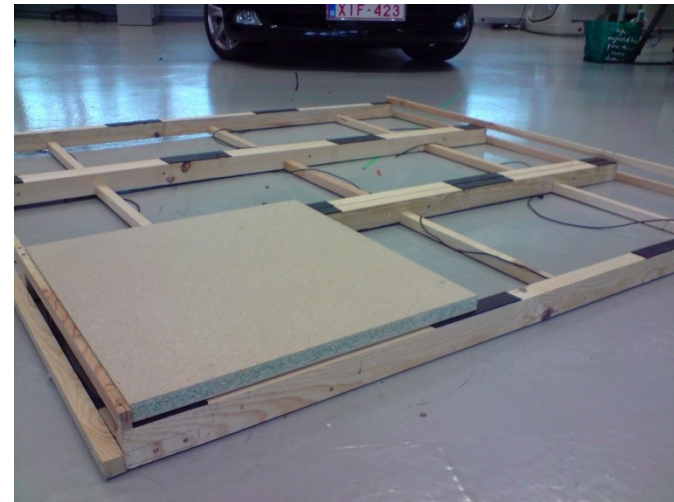
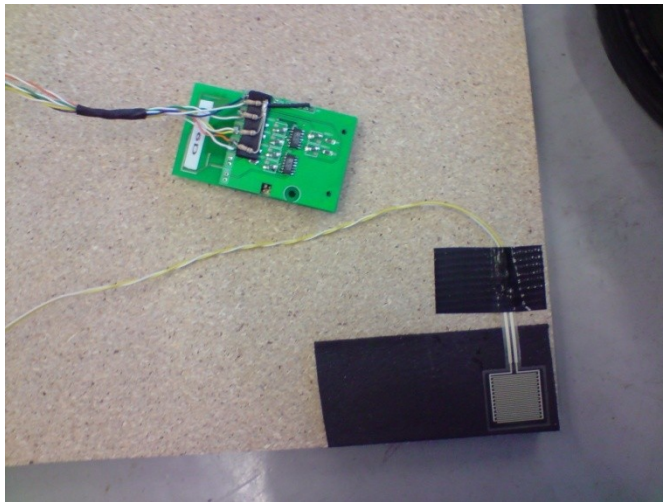
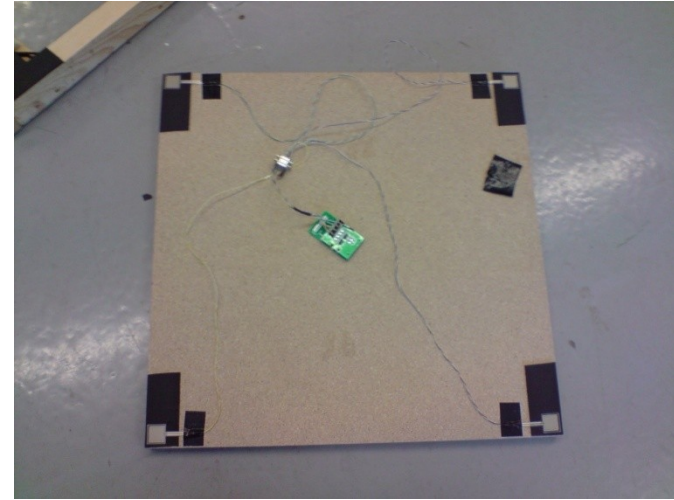
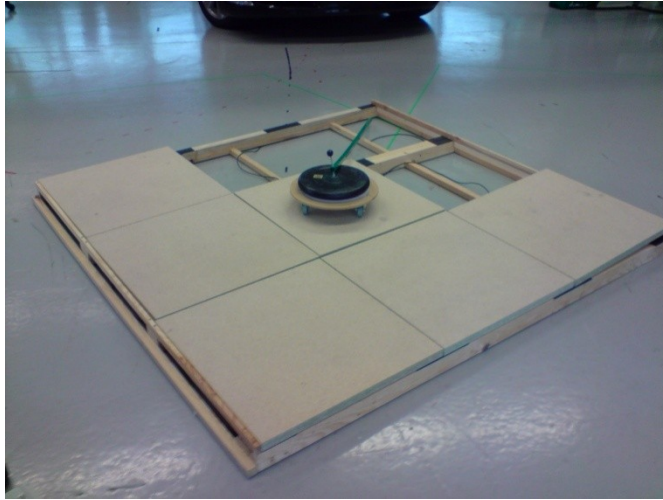
# Releveur de pied -2



# Releveur de pied -3



# Perceptive Floor tiles - Maia





# Mosar

- Mastering hOSpital Antimicrobial Resistance in Europe sensor network
- Individual-based Investigation of Resistance Dissemination



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# Wireless sensors and Actuators

- Nodes collaborate to accomplish distributed sensing and actuation tasks.
- Robotics & WSN synergies
  - Robots are used as actor nodes
  - WSNs as an extension of the sensorial capabilities of the robots
- IEEE Workshop on Wireless Sensor, Actuator and Robot Networks (WiSARN)

# Robots -> Mobile Nodes

INRIA Lille - Nord Europe



# Human interaction with robots

- Synchronous Motion Imitation by Humans equipped with a BANET - (BIPOP)
  - A robot imitates a human achieving stepping motions on horizontal plane
  - New device of motion capture
- Humans localisation using MOSAR technologies

# Node localization

- WSN can be used as a new device for robot localization
- Principles
  - Receive Signal Strength
  - Time Of flight

# Sharing Methods & Tools ?

- Communication protocols
- Localization and time synchronization
- Embedded Development Tools
- Simulation tools
- Applications and Prototypes

# Conclusions

- A mobile robot act as a gateway into a wireless sensor network
- Sensor networks take advantage of robot's mobility and intelligence.
- Tools can be shared ?
- Benefits are limited only by imagination



# More information

- [www.senslab.info](http://www.senslab.info)
  - SensLAB portal

- [esimu.gforge.inria.fr](http://esimu.gforge.inria.fr) :

- Trace analysis, source code annotation for performance & consumption.

- [wsim.gforge.inria.fr](http://wsim.gforge.inria.fr)

- Sensor platform emulator

- [wsnet.gforge.inria.fr](http://wsnet.gforge.inria.fr)

- Wireless network simulator

