Wireless Sensor Networks for Precision Agriculture: Methods and Experiences

Novel Sensor Technologies for Plant Phenotyping
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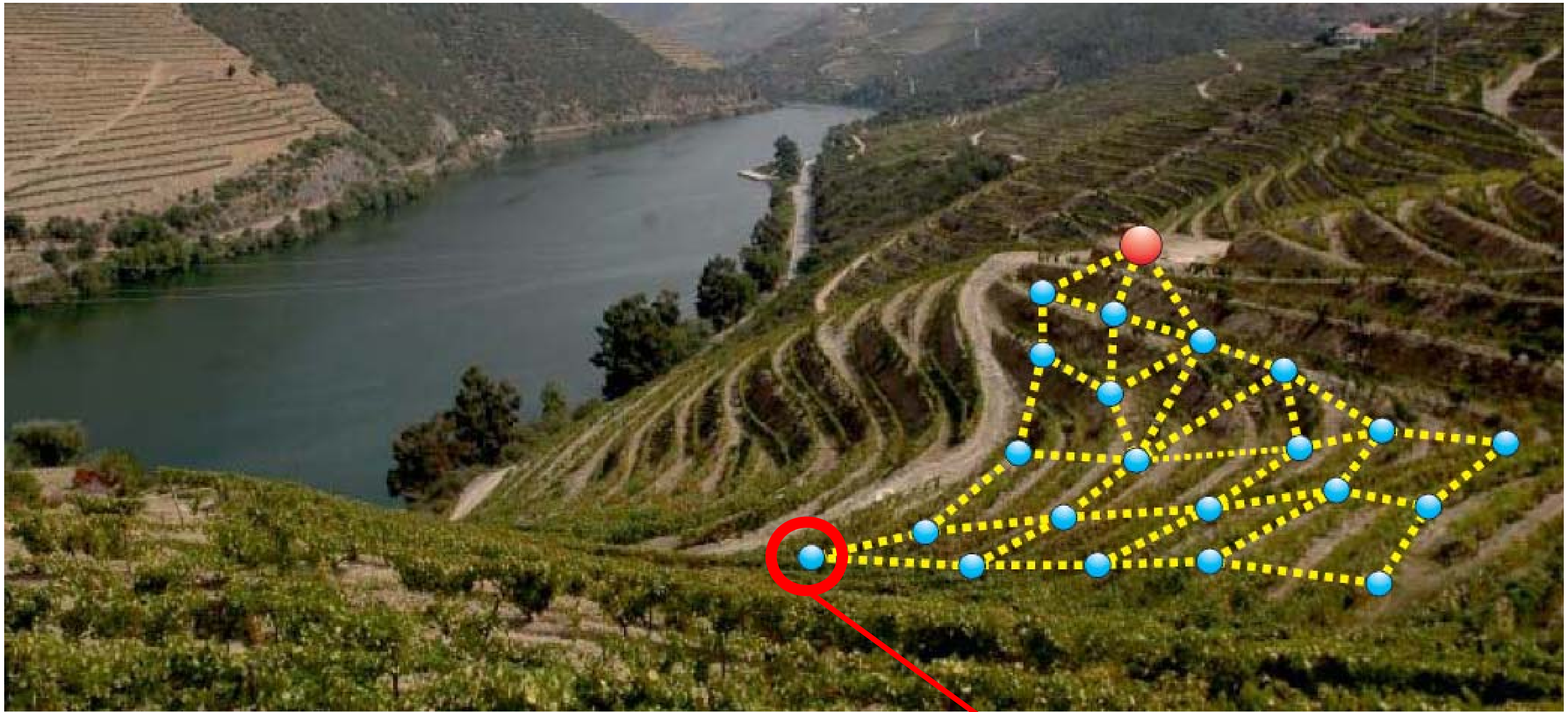
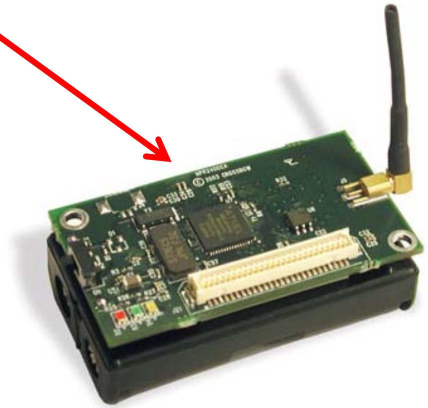
What is a WSN?



Wireless Sensor Networks (WSNs) consist of multiple unassisted embedded devices (nodes) which process and transmit data collected from different on-board physical sensors (temperature, humidity, pressure, etc.)

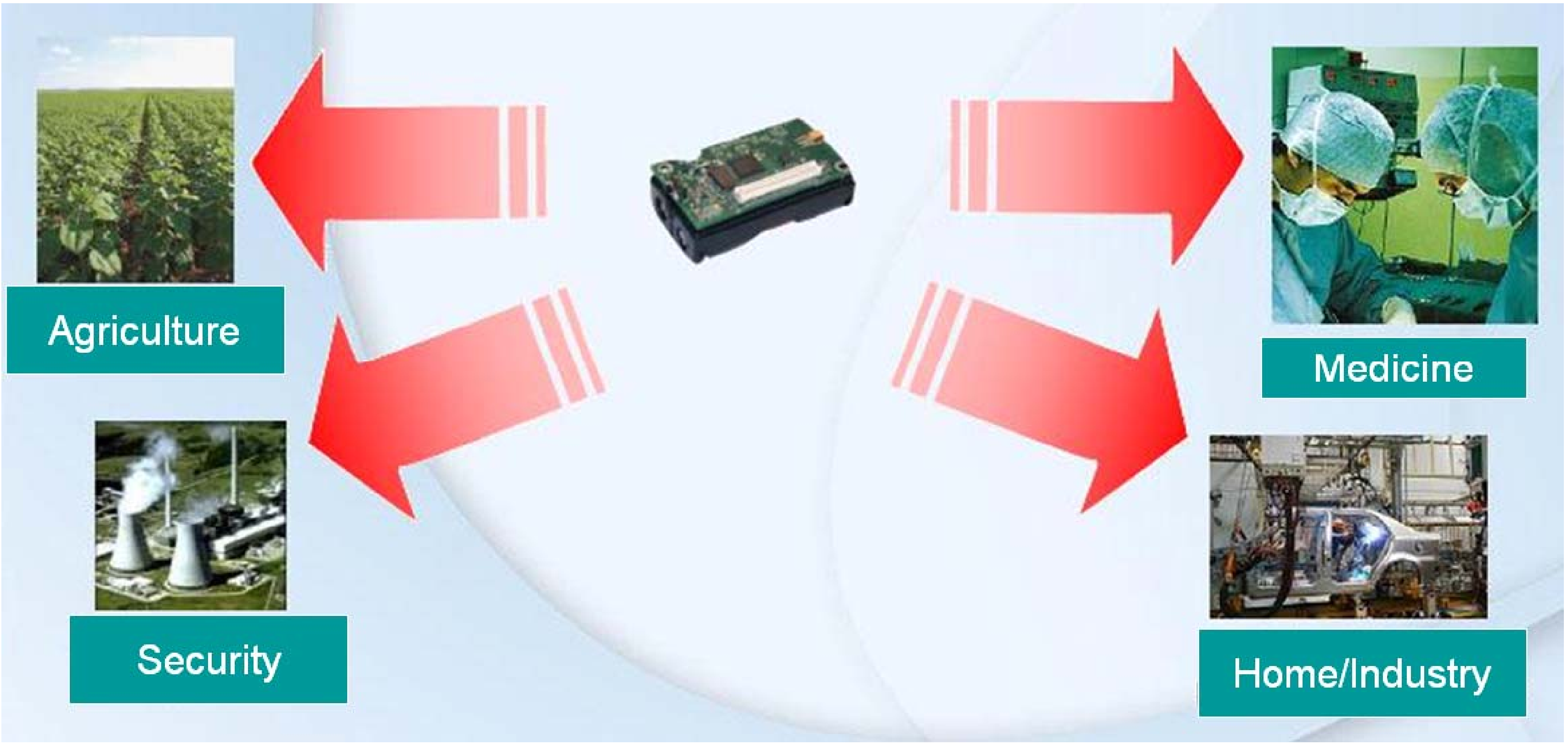


What are the WSNs?

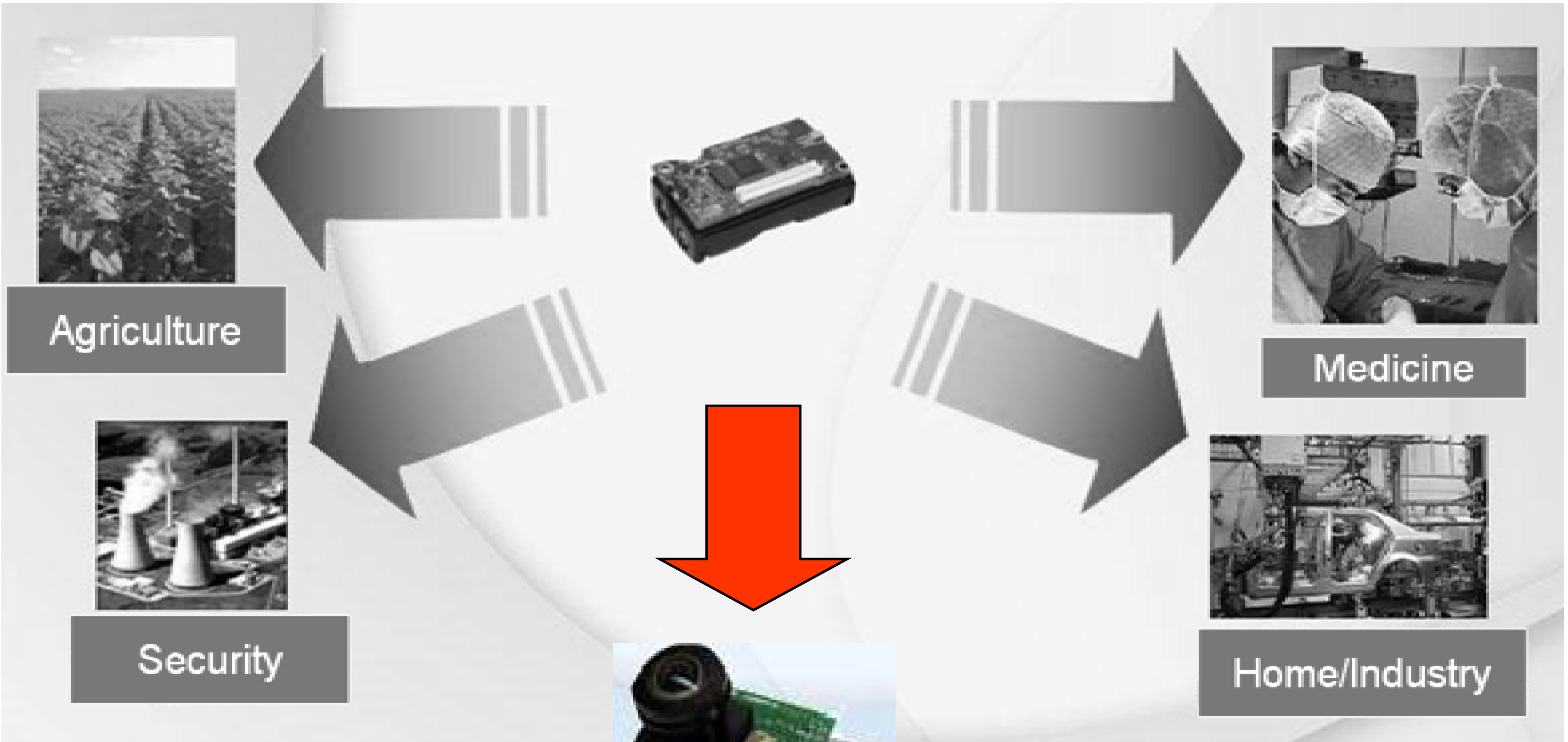
Main WSN Features:

- ❑ Low Cost
- ❑ Low Power Consumption
- ❑ Small Size
- ❑ Wireless comunications ranging 100 meters
- ❑ Resource-constrained nodes (memory and processing)
- ❑ Energy constrained!!

WSN Applications



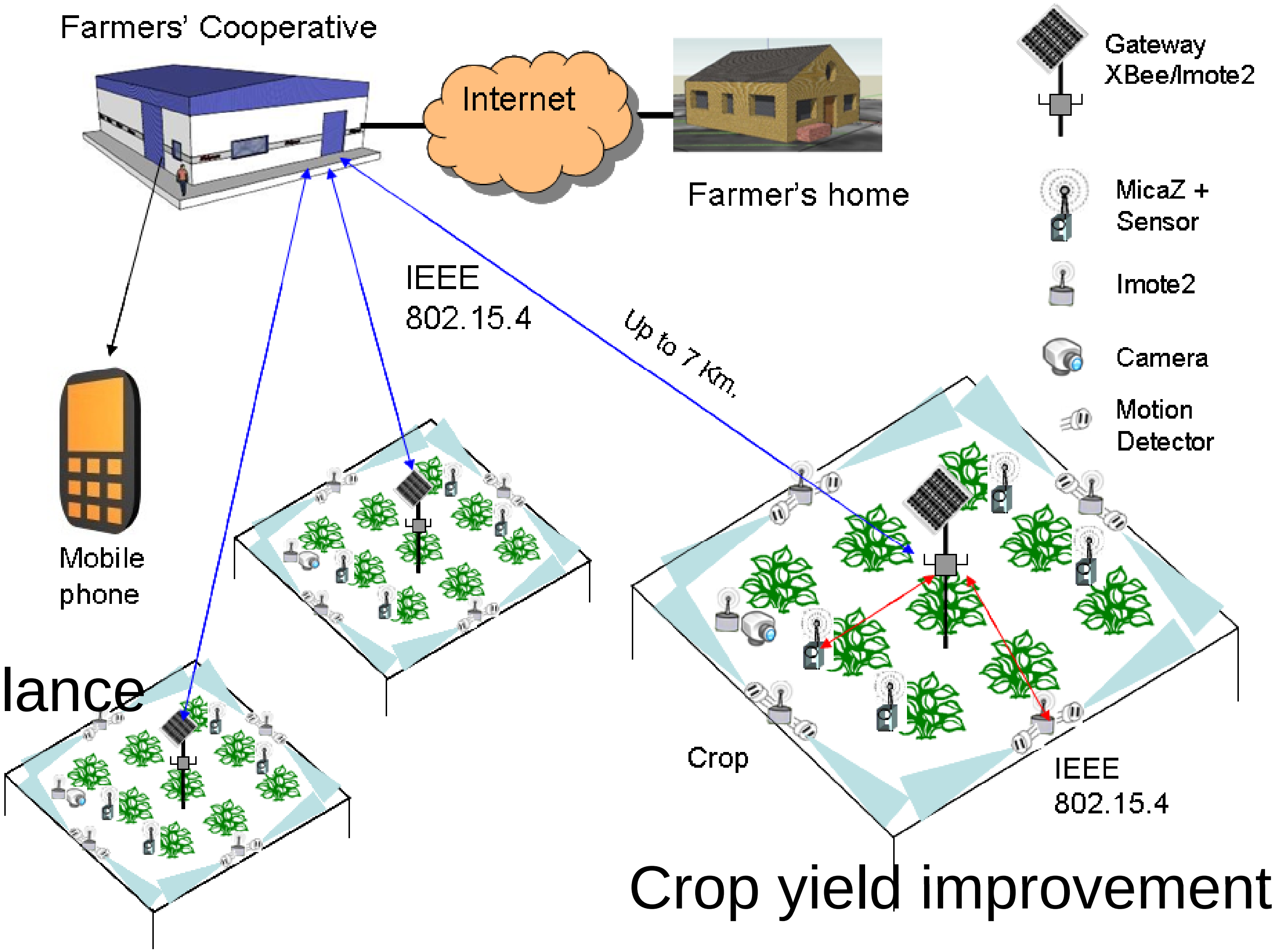
WSN Applications



Video
Services

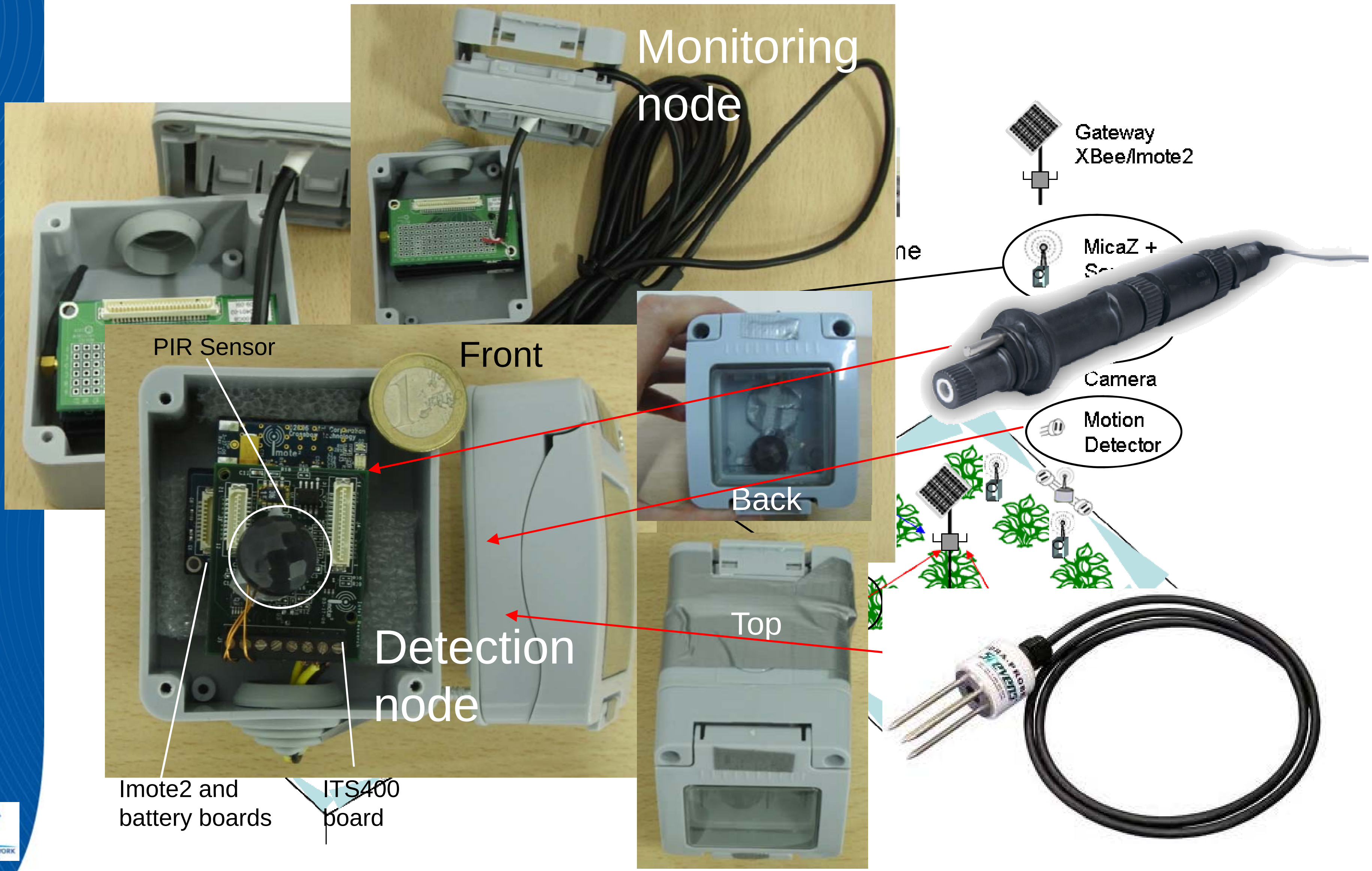
WSN Applications:Precision Agriculture

To monitor small-size and scattered crops

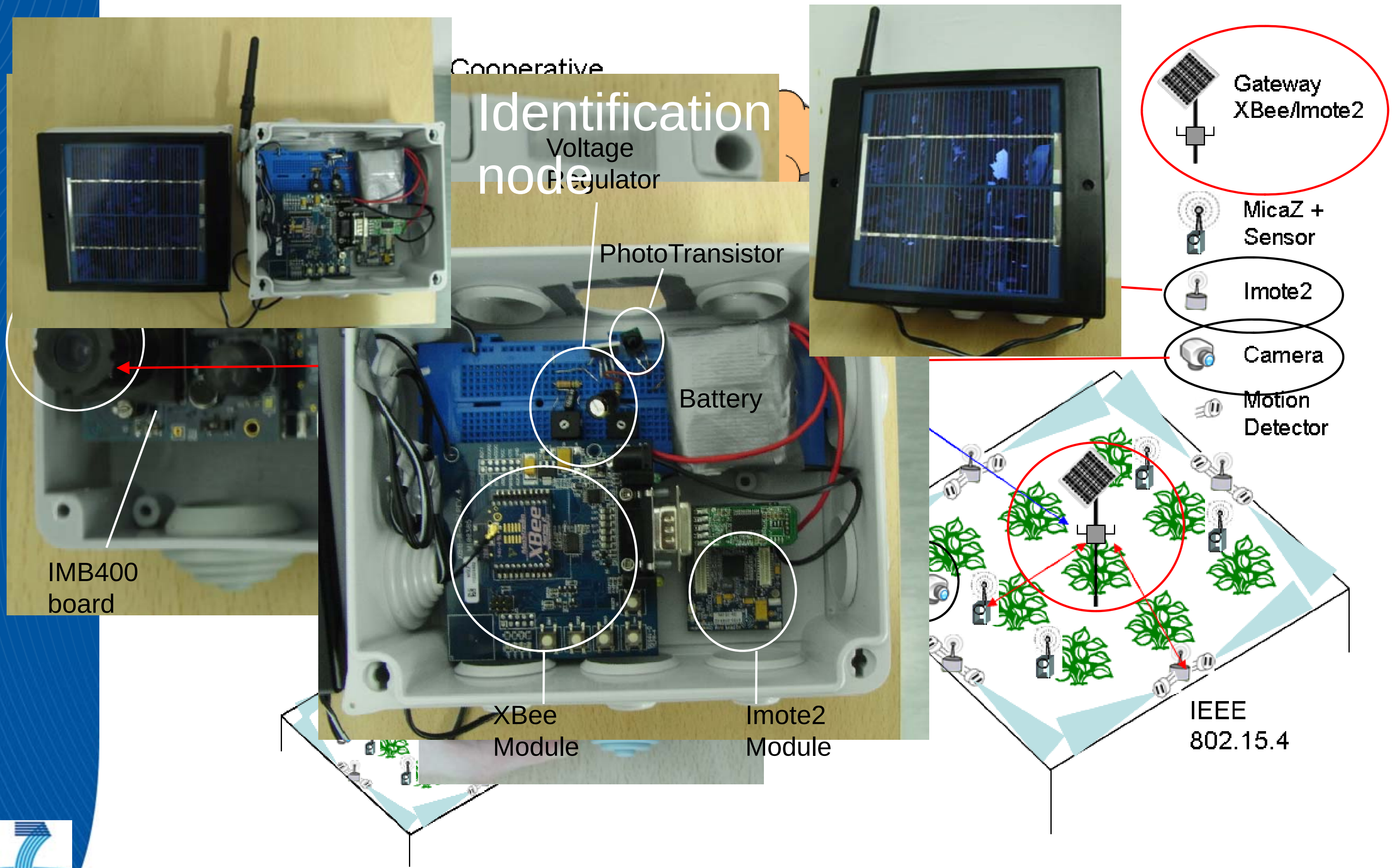


"Wireless Sensor Network deployment for integrating video-surveillance and data-monitoring in precision agriculture over distributed crops", in Computers and Electronics in Agriculture, Vol. 75, pp. 288-303. 2011

Precision Agriculture: Devices



Precision Agriculture:Devices

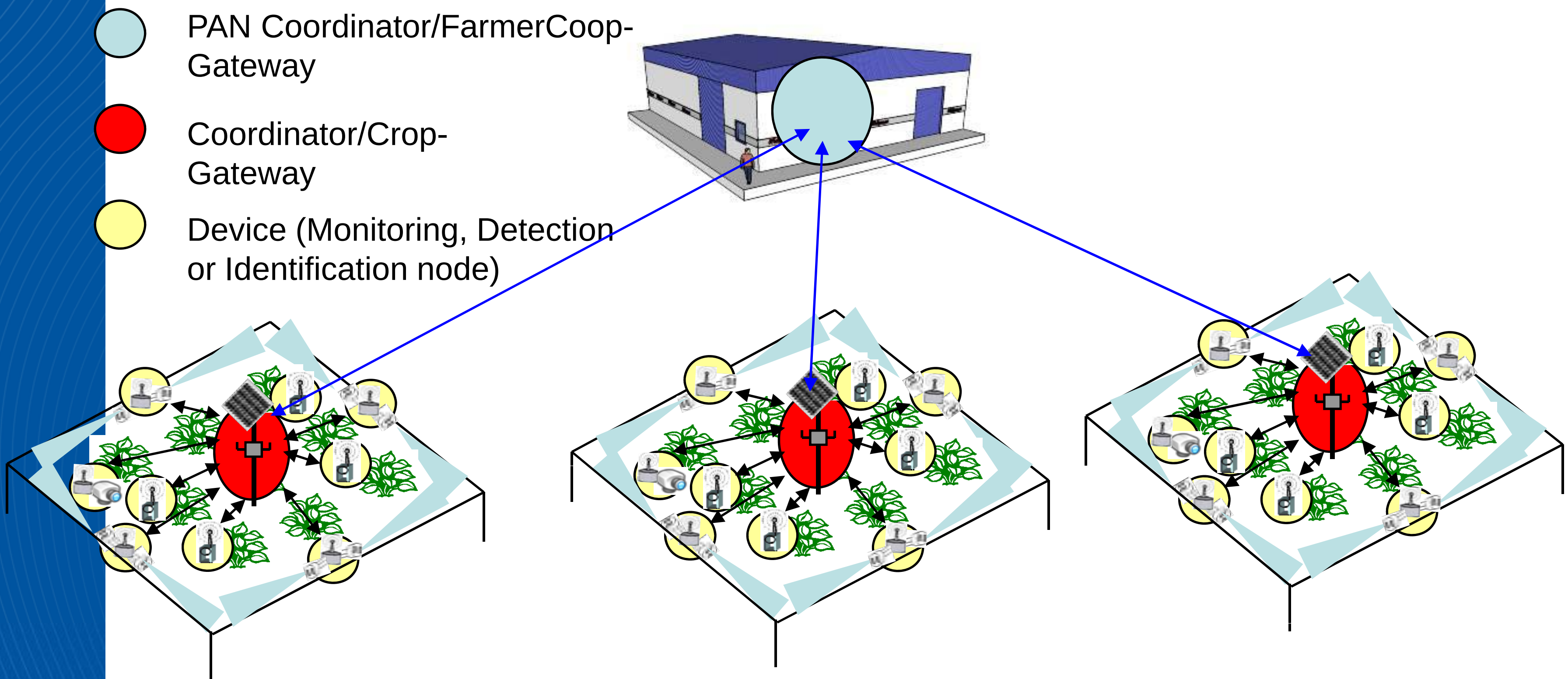


Design: Integrated WSN Solution for Precision Agriculture (ISSPA)

Features to remark:

- ❑ Topology
- ❑Communications
- ❑ Efficient Energy design at devices
- ❑ Crop parameters monitoring
- ❑ Detection functionality
- ❑ Video Surveillance
- ❑ Network operation

Design: Cluster-Tree Topology



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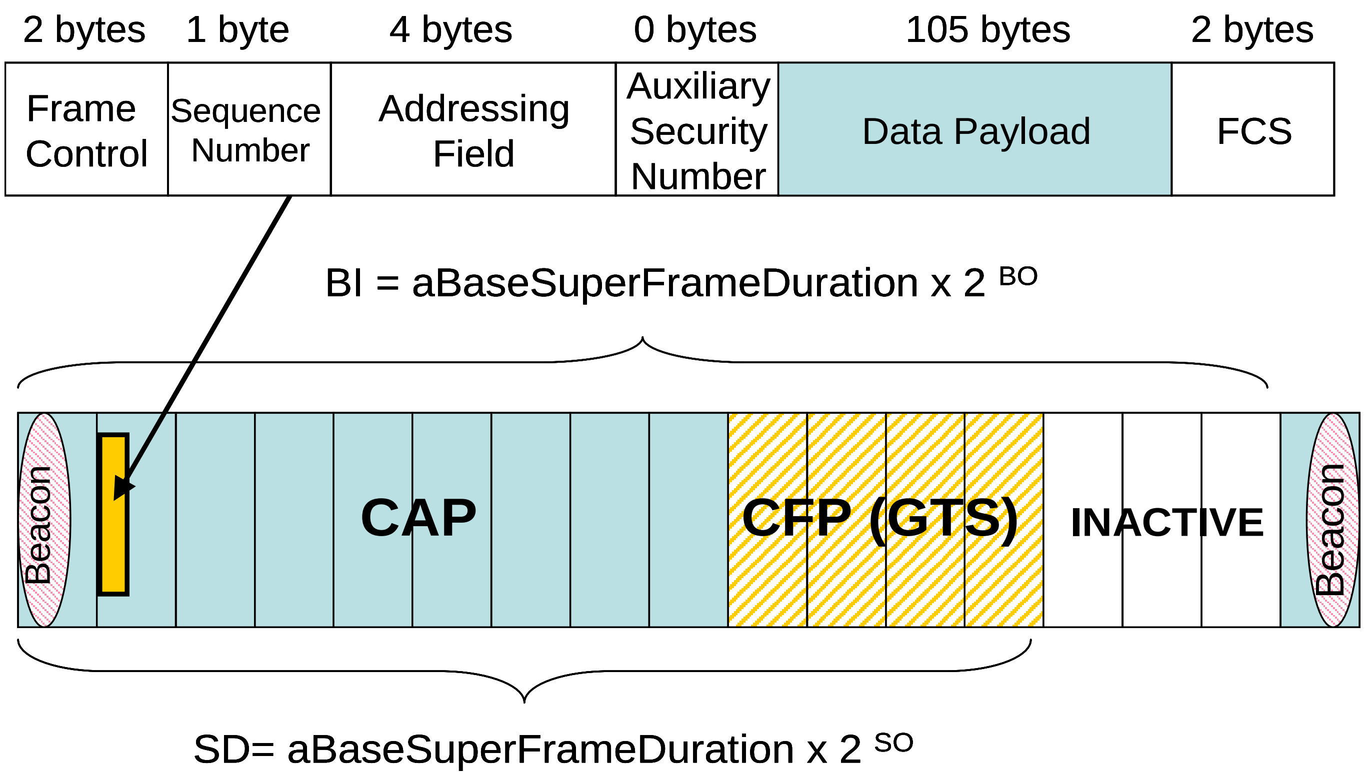
Design: Communications under IEEE 802.15.4 standard



Note that BO and SO delimited the Superframe size and the active duration interval (CAP+CFP), respectively

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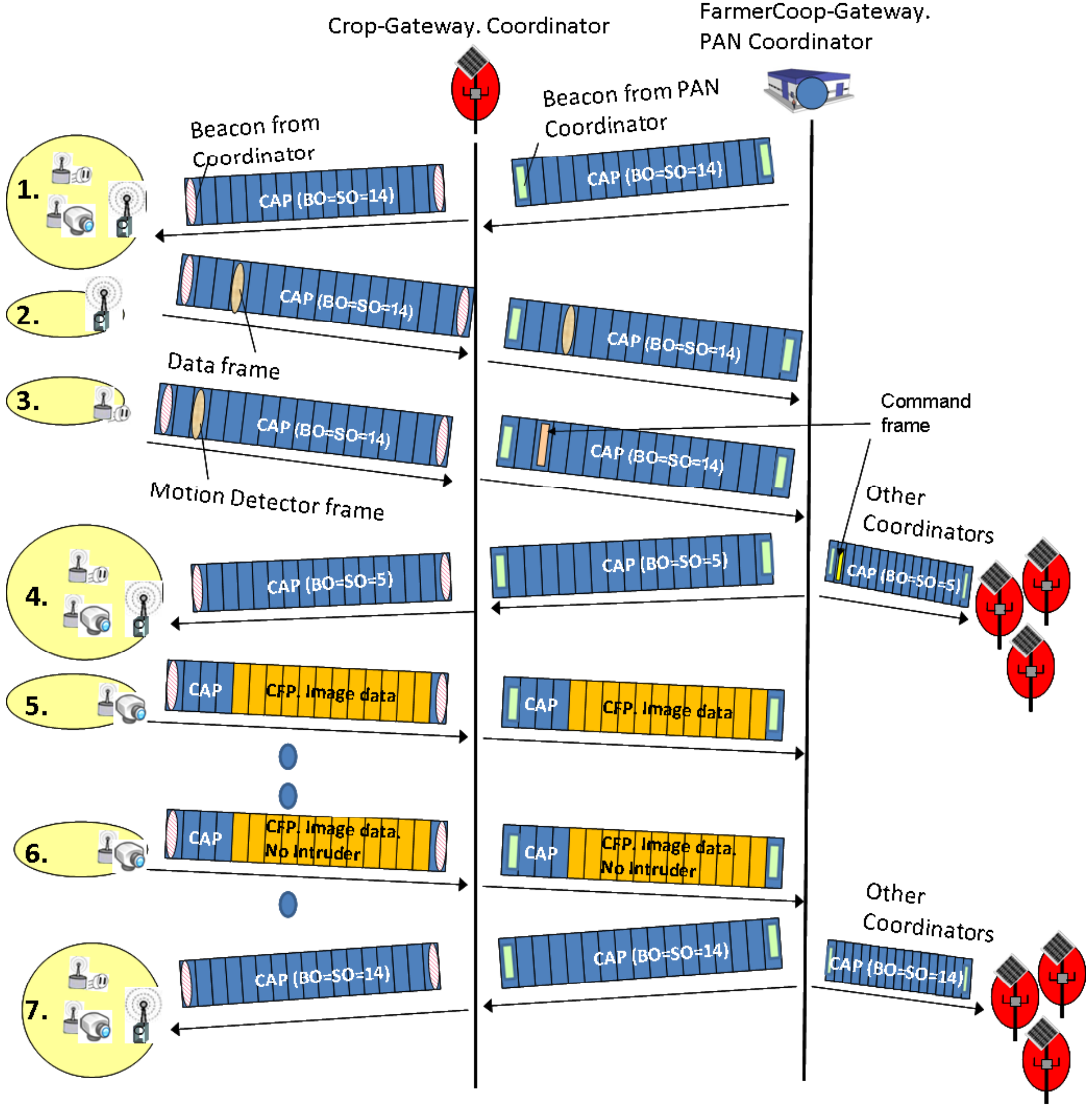
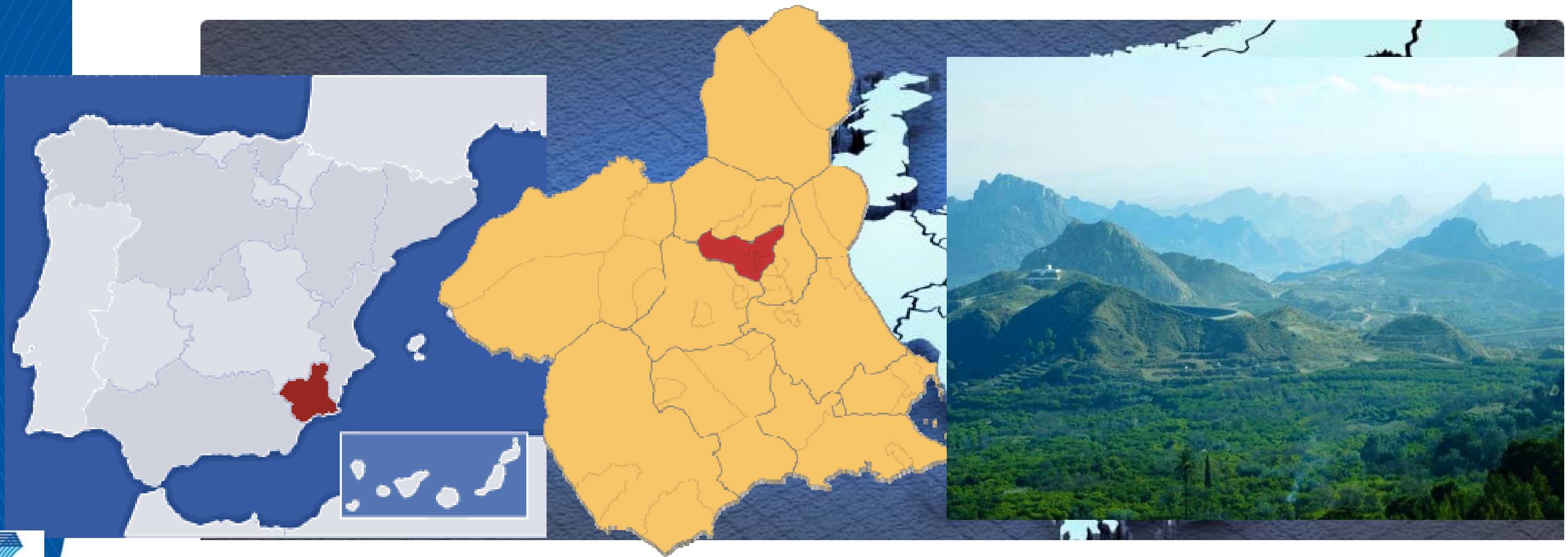
ISSPA Functionality



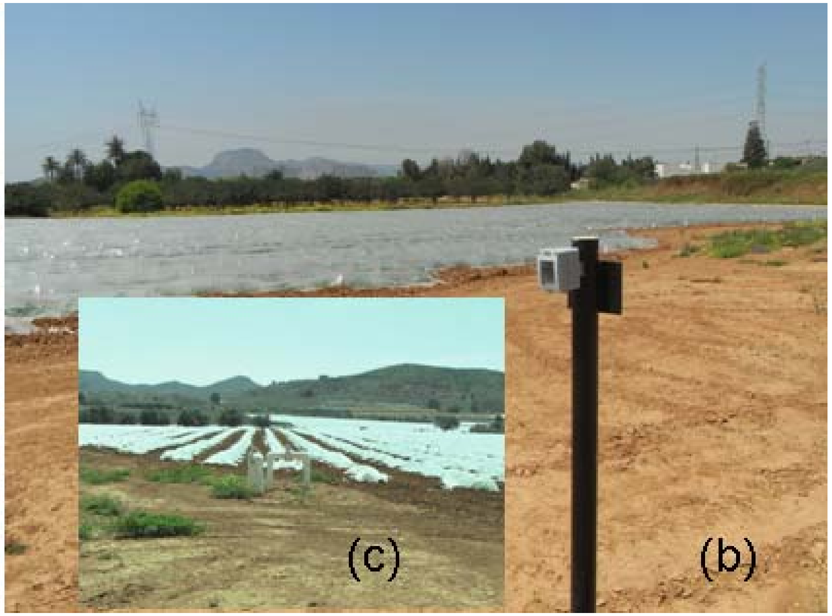
Implementation and deployment

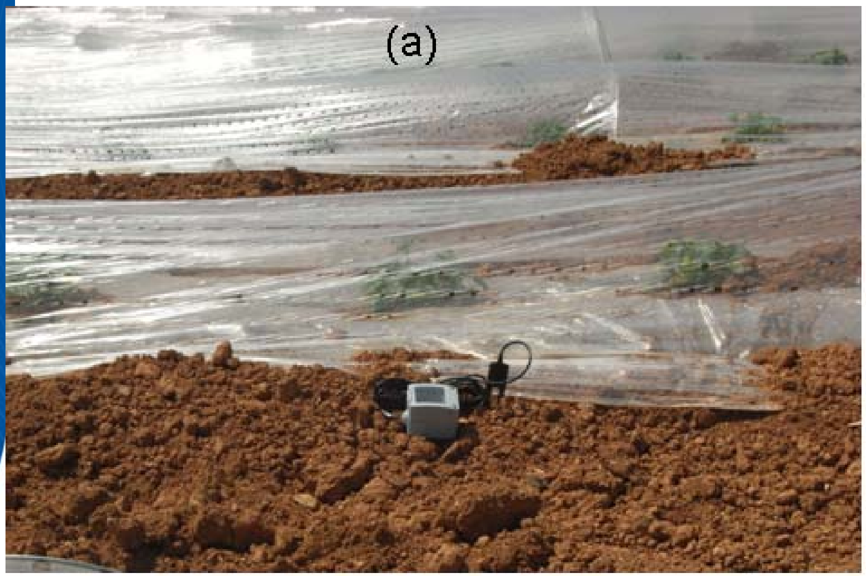
SOFTWARE: TinyOS and Open-Zigbee

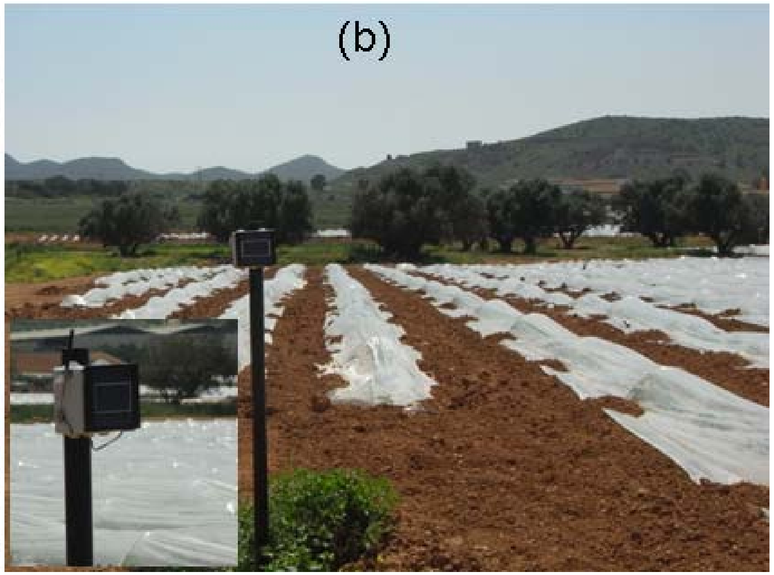
DEPLOYMENT: Broccoli crop placed in the Valle de Ricote, Southern Spain.



Deployment- Trial Scenario

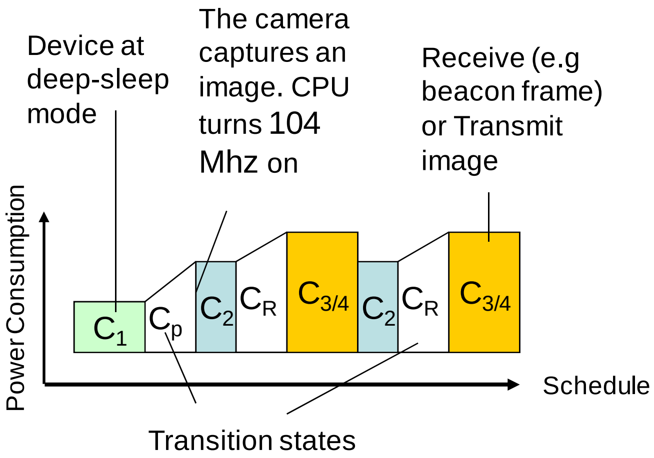




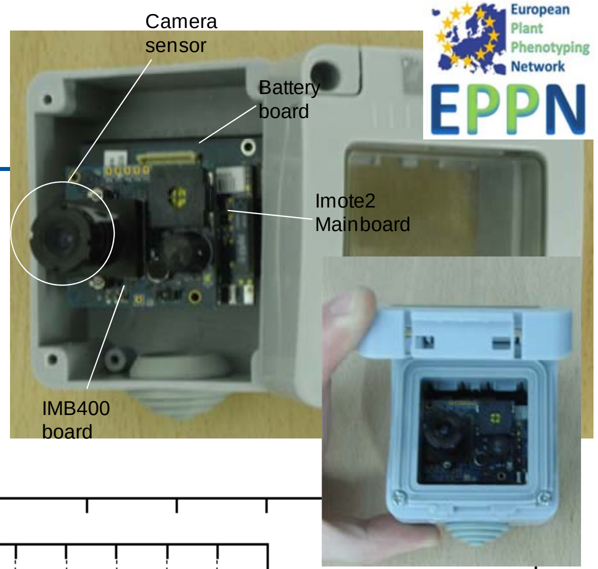


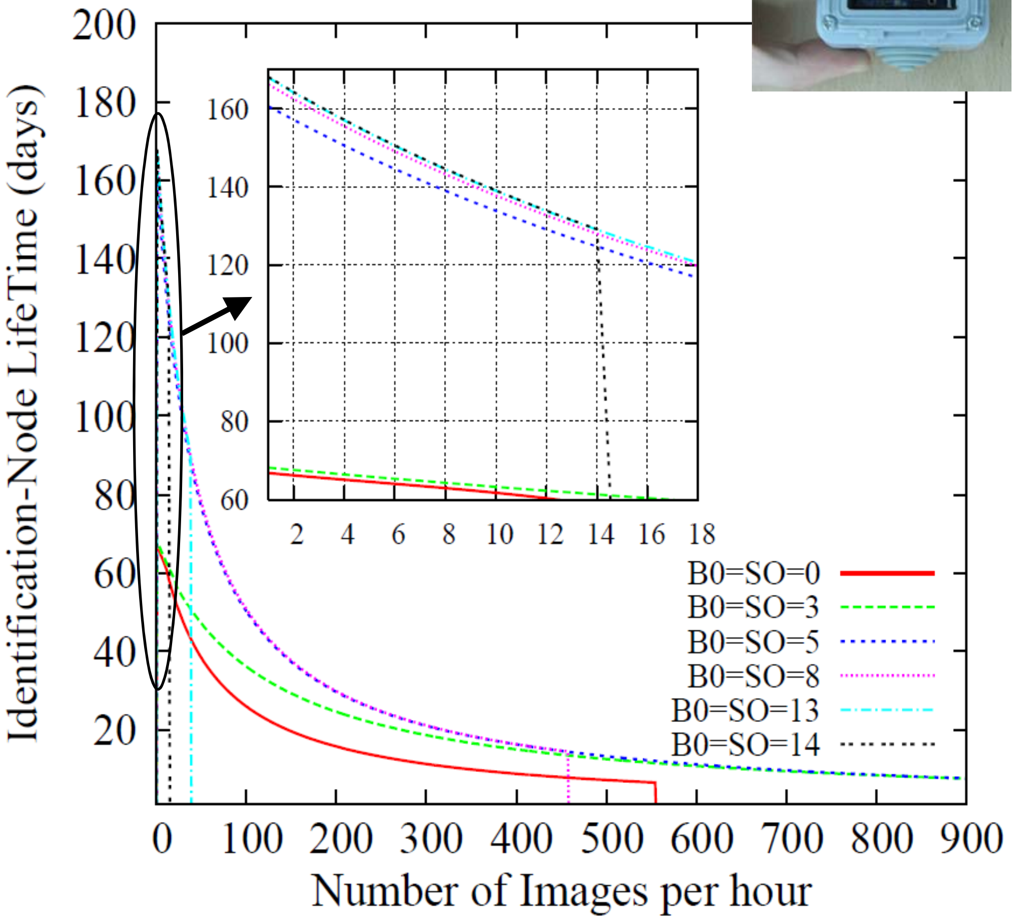
Results. Energy Simulation

State	Consumption
C_1	1.86 mW
Cp	48.63 mJ/ 253 msec.
C_2	253.71 mW
C_R	6.63 uJ/194 usec.
$C_{3/4}$	331 mW



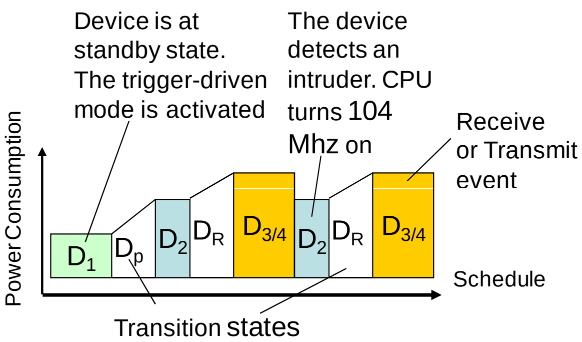
IDENTIFICATION-NODE



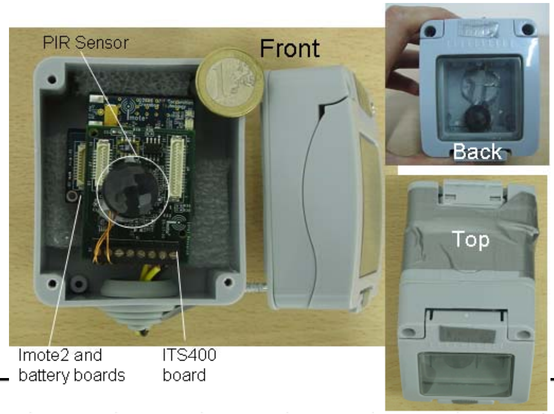


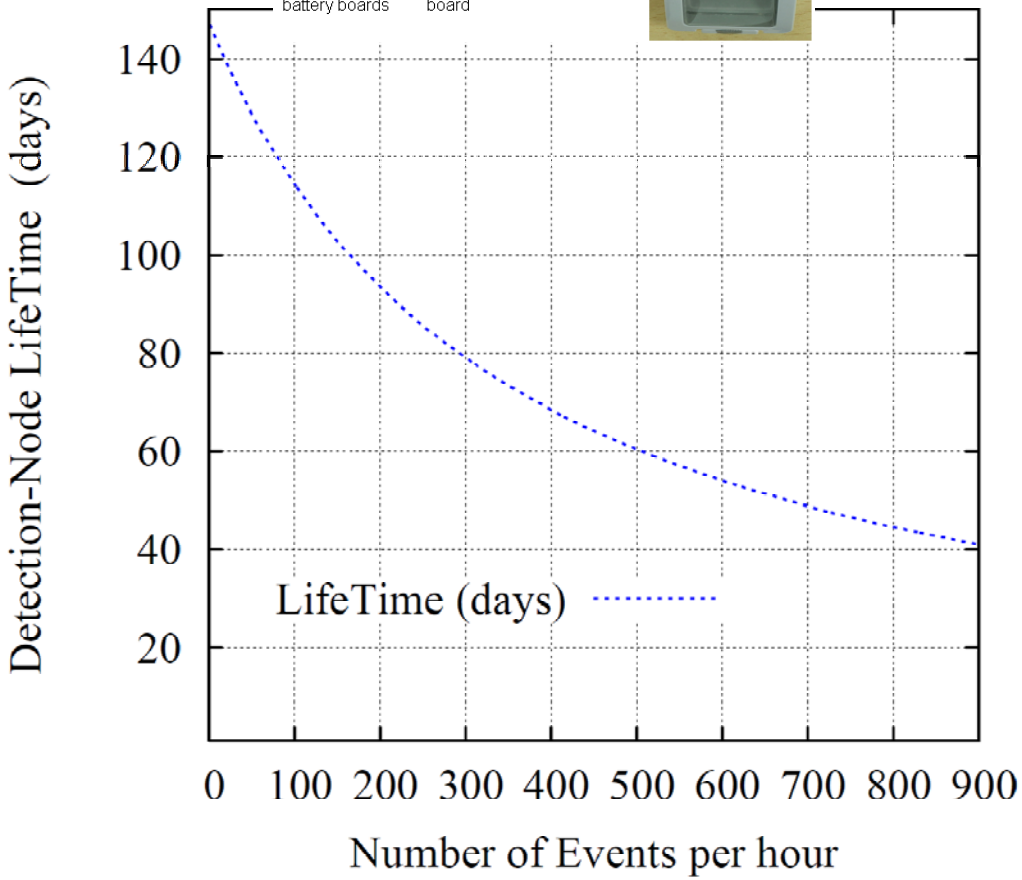
Results. Energy Simulation

State	Consumption
D_1	17.34 mW
Dp	2.2 uJ/ 12.4 msec.
D_2	194.52 mW
D_R	6.63 uJ/194 usec.
$D_{3/4}$	271.34 mW



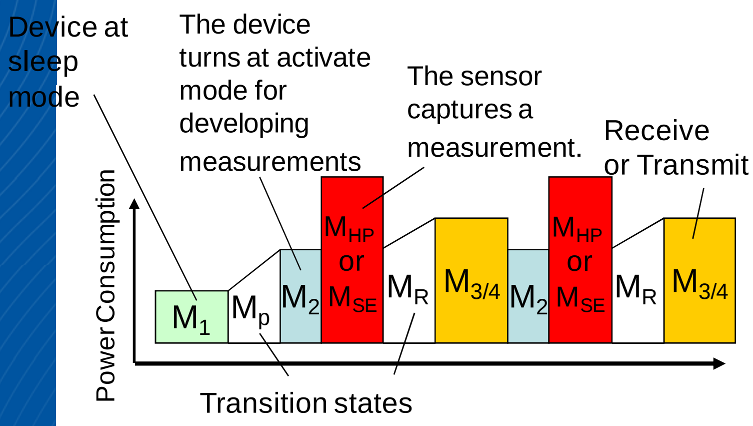
DETECTION- NODE

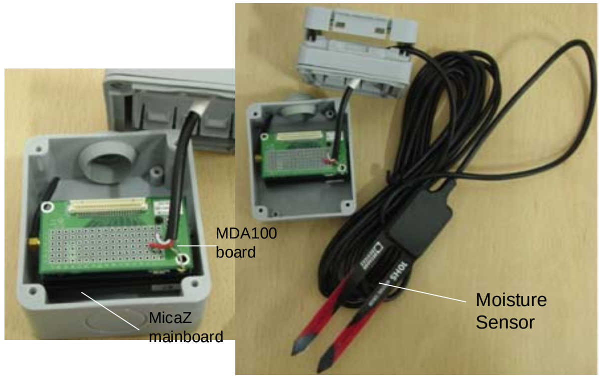




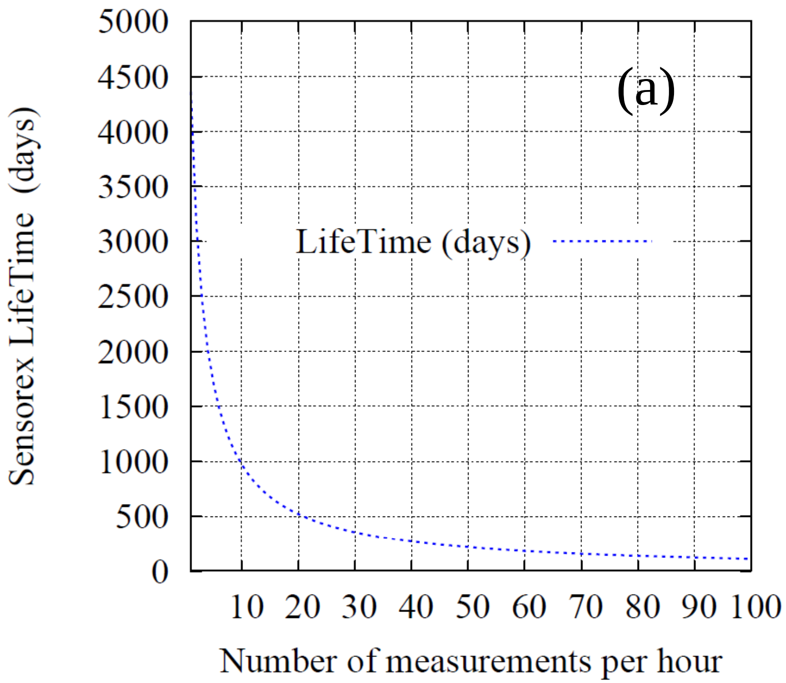
Results. Energy Simulation

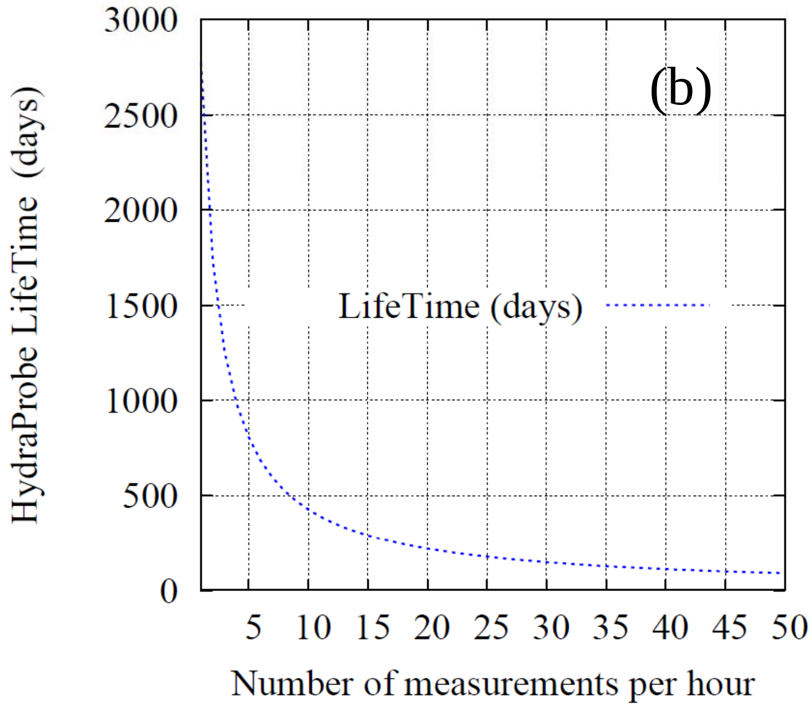
MONITORING- NODE





State	Consun
M_1	0.7125 mW
Mp	10.3 uJ/ 22 msec
M_2	8 mA
M_{HP} HidraProbe	110 mA/1.8 sec
M_{SE} Sensorex	40 mA/2 sec
C_R	6.63 uJ/194 usec.
M_3	71.28 (Rx) mW
M_4	66.67 (Tx) mW





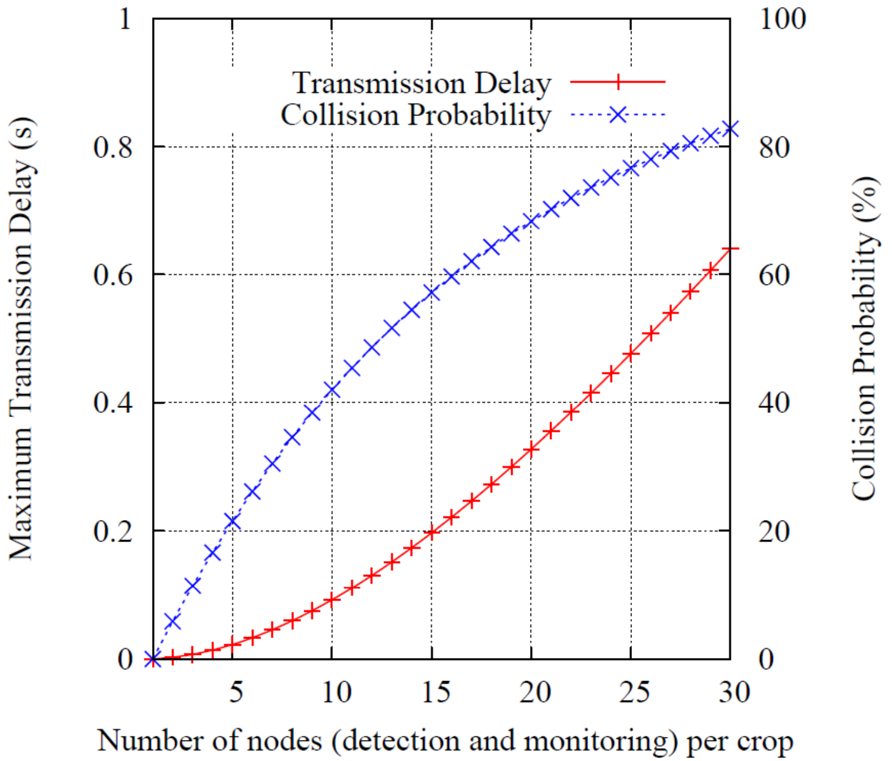
Results. Analysis

$$P_{ca} = 1 - \left(1 - \frac{1}{1 + \frac{CW}{2*(1-p_a)}}\right)^{n-1}$$

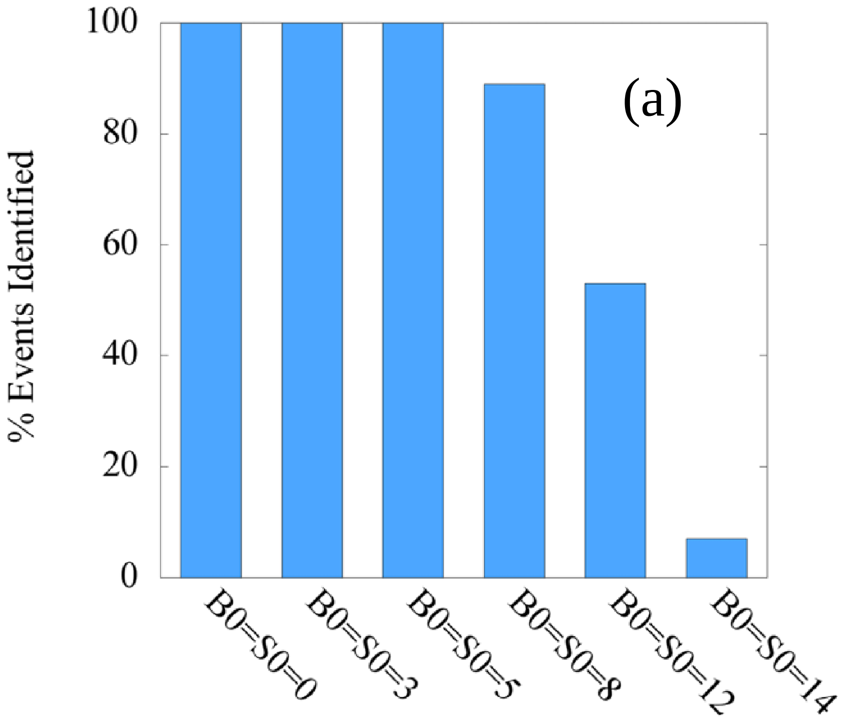
$$\Delta_{\max} = 2 * P_{ca} * (2^{BE} - 1) * \Delta_{backoff} \qquad BE_{\max} = 5$$

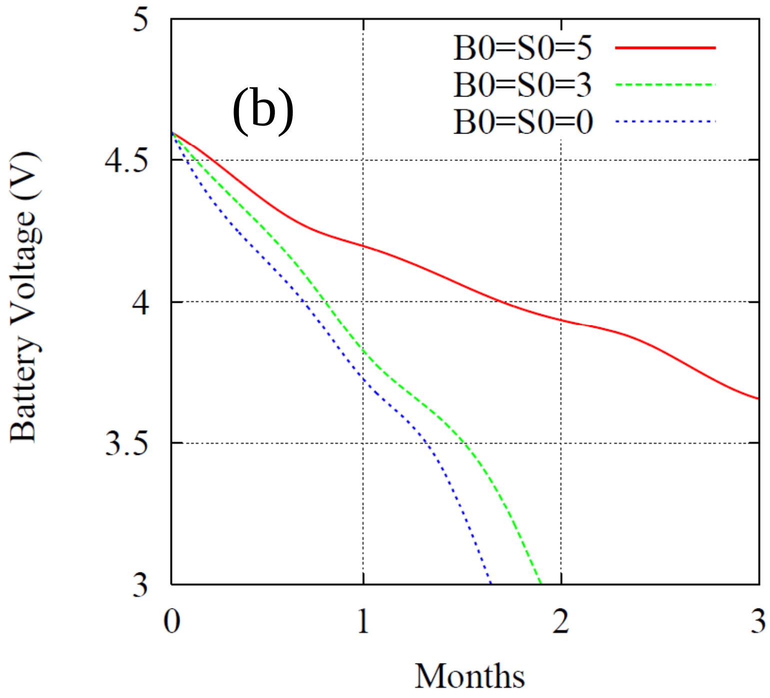
$$p_a = \frac{1}{m+1} * \frac{a}{numberCAPslot * (2^{BO} - 2)}$$

$$for\ a = 1,2,\ldots,m+1$$



Experimental Results





Experimental Results

$$\Delta_{max} = 2 * P_{ca} * (2^{BE} - 1) * \Delta_{backoff}$$

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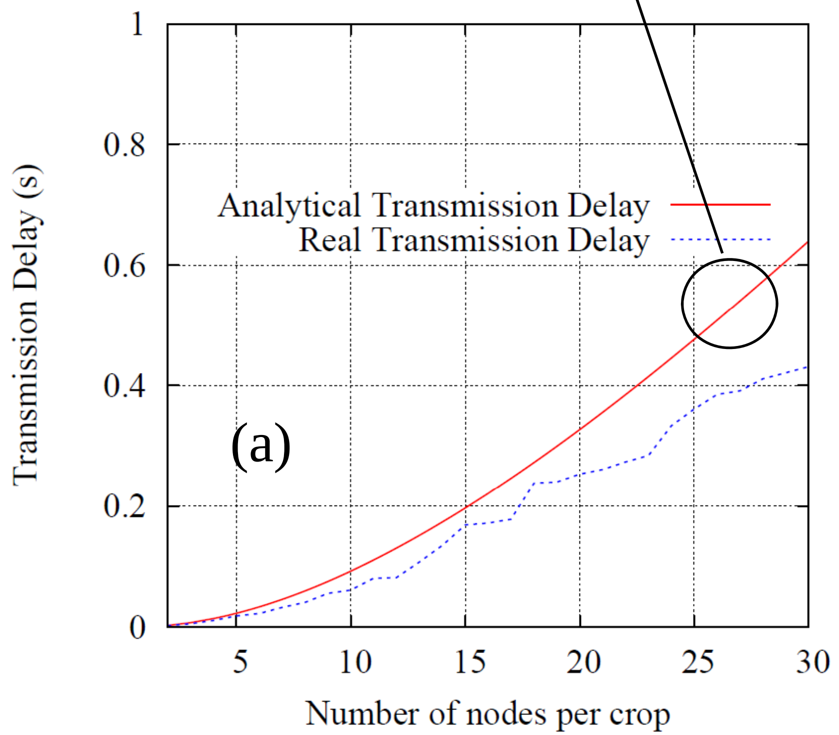
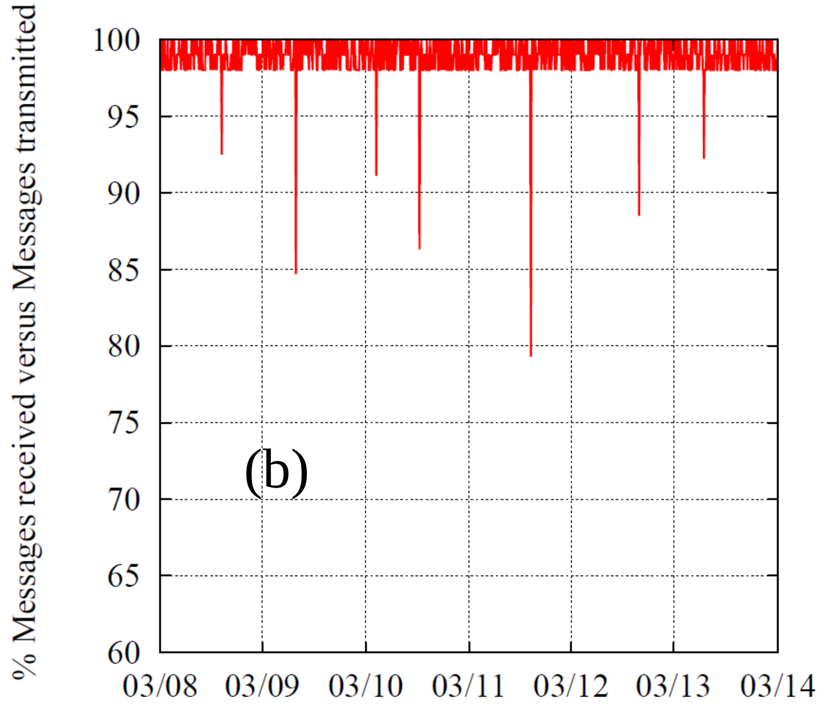




Recent works: Large crop area or forest monitoring

Forest Fire prevention Biomass study Tracking animals

Recent works

Requirements

Physical sensors to monitor diverse parameters (temperature, humidity, pressure, gases, soil moisture, etc.)

Available multimedia services, in particular, video.

To guarantee different paths between source and sink

End-user must access multimedia/data information with the best performance

… and , of course, the requirements of WSNs

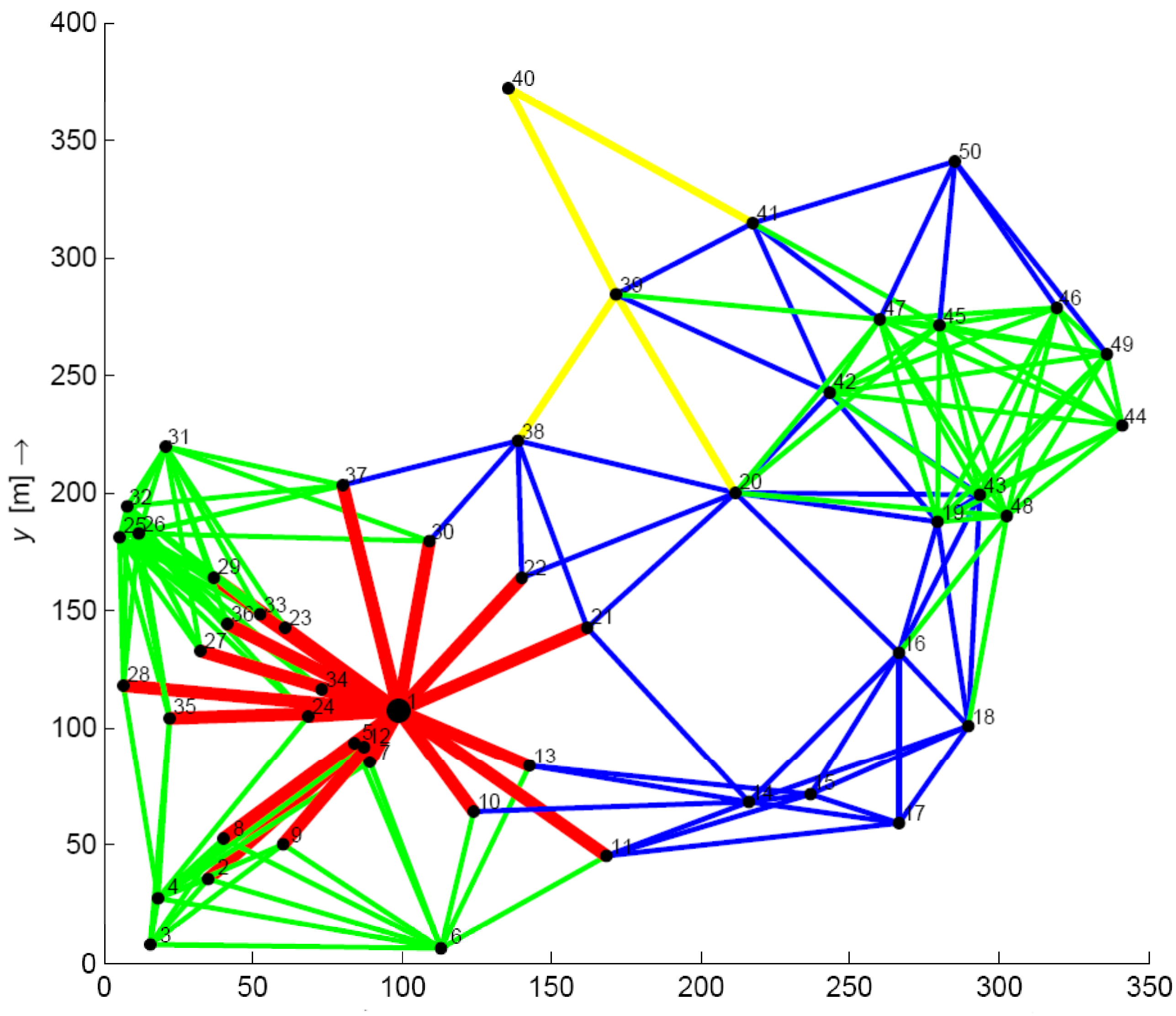
Mesh Topology

IEEE 802.15.5

Optimization techniques

SOLUTIONS

Recent works. Mesh Topology



Recent Researches. IEEE 802.15.5

- ❑ IEEE 802.15.5 provides, in a single recommendation, all the distinctive features for transmitting data efficiently in a mesh topology, including an effective energy saving procedure.

- ❑ Synchronous Energy Saving (SES) is part of the IEEE 802.15.5 standard planned to provide energy saving to scheduled communications with strict temporal requirements that, a priori, facilitate the development of delay-sensitive applications (video).

- ❑ The problem of SES and, therefore, IEEE 802.15.5 is that the synchronization scheme introduces variable delays in the dissemination of information that reduce lifetime of the nodes and the entire network.

- ❑ Solution: A new synchronization approach is designed. This issue is dealt with the research “On the synchronization of IEEE 802.15.5 wireless mesh sensor networks: shortcomings and improvements”, EURASIP Journal on Wireless Communications and Networking, 2012:198

Recent Researches. Optimization

STEP 1. Theoretical Study

- ❑ In a mesh network where video and monitoring nodes dispatch data, Optimization techniques to achieve the best network performance.

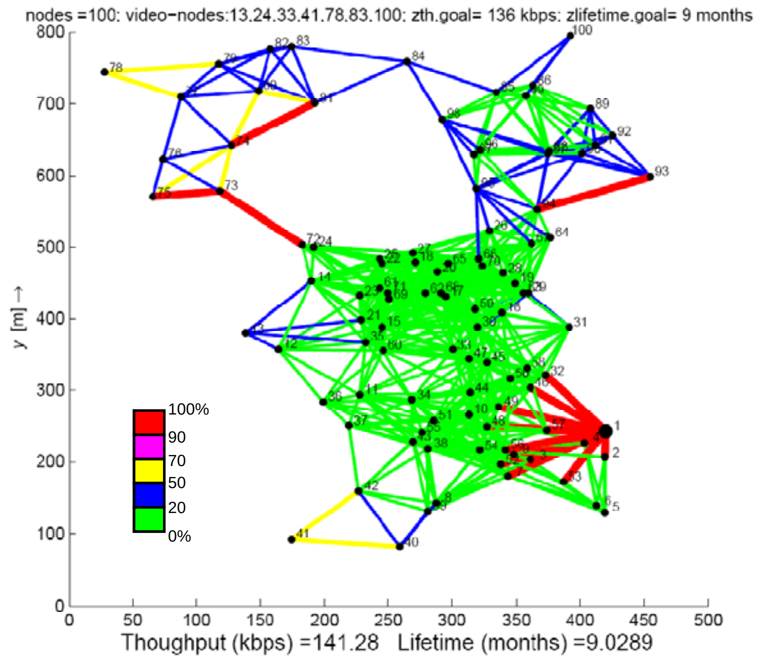
- ❑In particular, our group has carried out investigations that lead to maximize the set throughput and lifetime metrics of the network together.

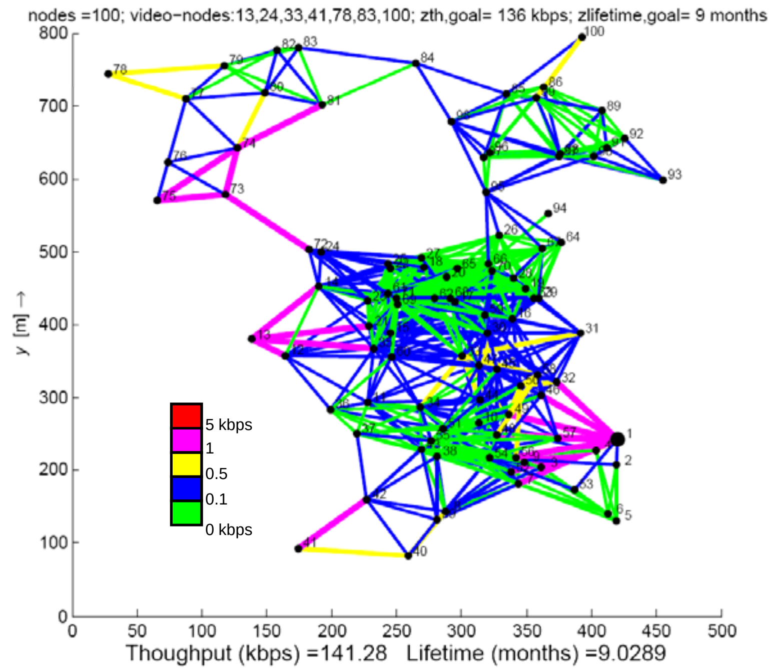
STEP 2. Real Deployment

To design and implement a **new load-balancing algorithm** which obtains results that are close to the optimization study, validating this theoretical work.

Recent Researches. Optimization

STEP 1

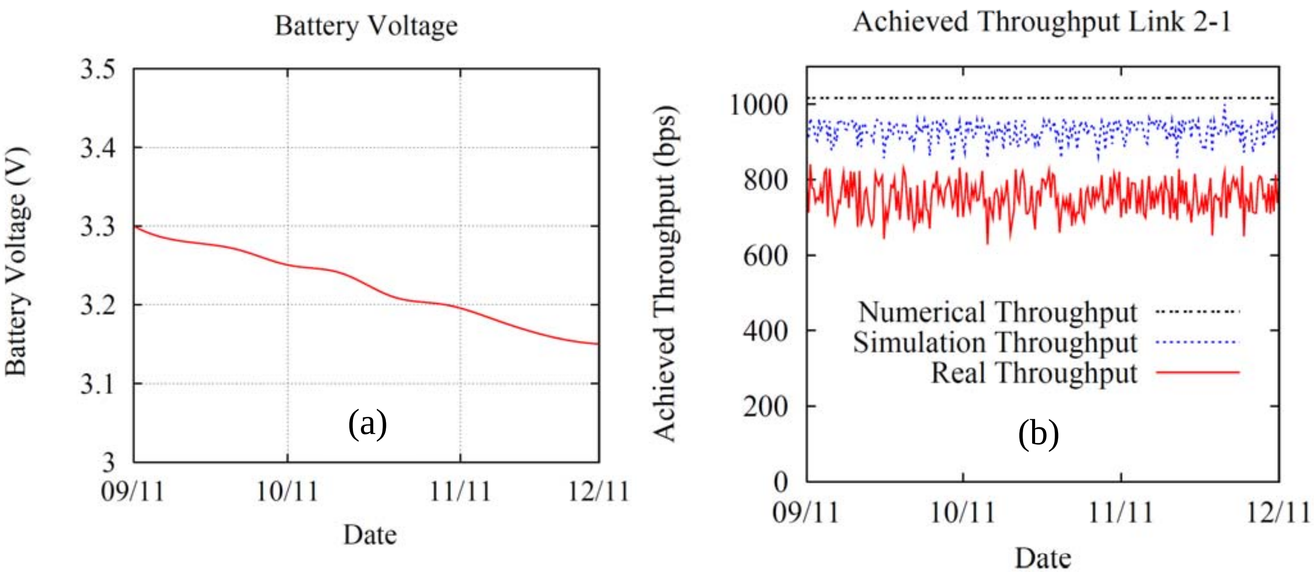




Recent Researches. Optimization

STEP 2

Recent Researches. Optimization



Antonio-Javier Garcia-Sanchez, Felipe Garcia-Sanchez, David Rodenas-Herraiz, Joan Garcia-Haro, "On the Optimization of Wireless Multimedia Sensor Networks: A Goal Programming approach", accepted in Sensors, vol.12, no. 09, 2012, ISSN 1424-8220.

Conclusions

- We presented an integrated WSN-based system for small-size and scattered crops monitoring, video-surveillance and process of cultivations control. This network implies an innovative deployment of precision agriculture using the IEEE 802.15.4 cost-effective technology.
- We also showed our recent works addressed to monitor large crops including value-added services as video.
- Our works are conducted from a twofold perspective: (i) theoretical studies (analysis and simulation) and (ii) real experiments including novel devices, sensor integration, trial scenarios, test-beds, etc.
- Plant Phenotyping is an emerging technology that, in our humble opinion, would profit from WSN advances in precision agriculture.

Thanks!

Questions?