Communicating Objects & Sensor Networks Bring New Intelligence to Society

CNRIA'2013
Univ. Ziguinchor
April 24th, 2013, Senegal

Prof. Congduc Pham
http://www.univ-pau.fr/~cpham
Université de Pau, France

Objets Communicants et Réseaux de capteurs pour une Intelligence Ambiante au Service de la Société

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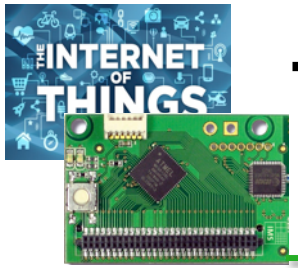
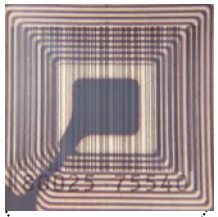
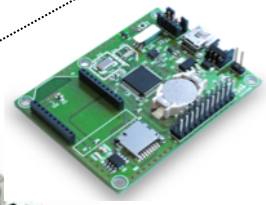


Towards small, smart devices!

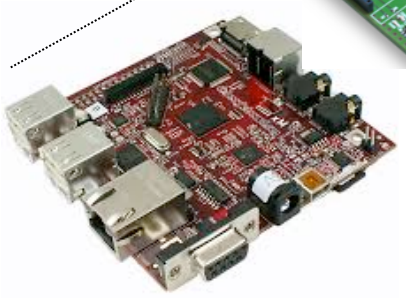






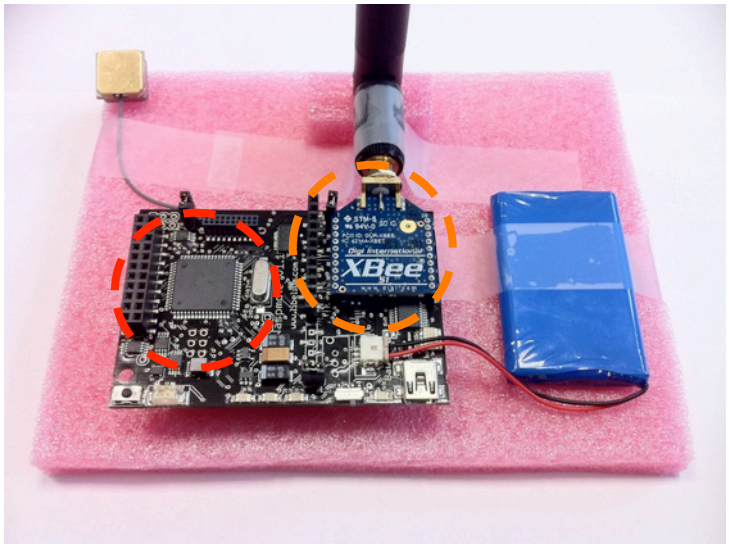


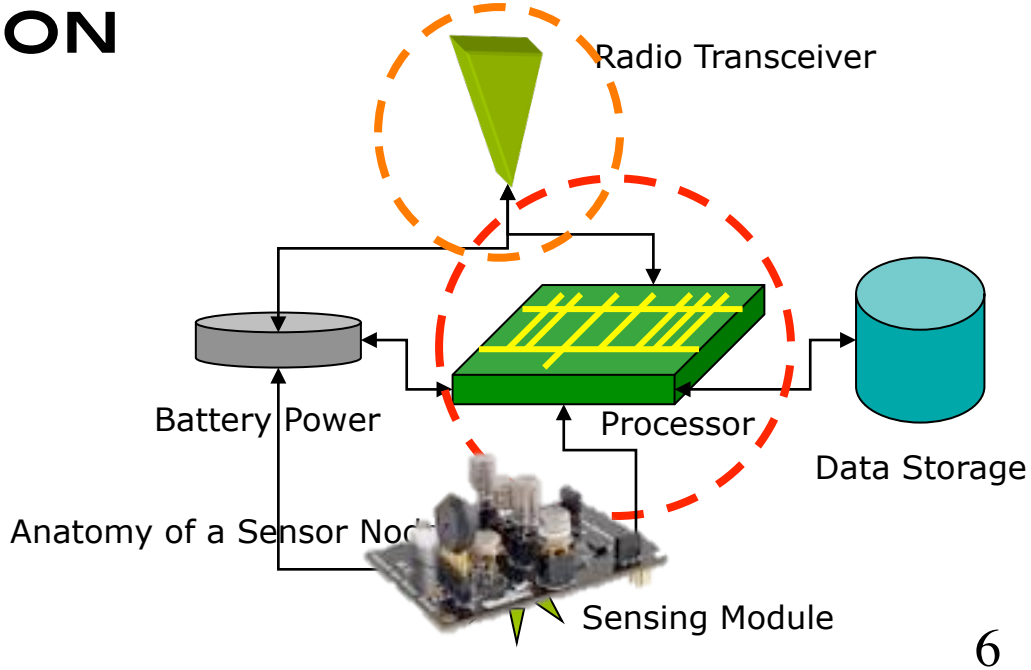


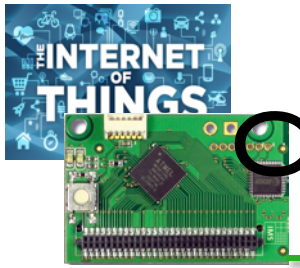


Wireless autonomous sensor

- In general: low cost, low power (the battery may not be replaceable), small size, prone to failure, possibly disposable
- Role: sensing, **data processing**, communication







Communicating Objects

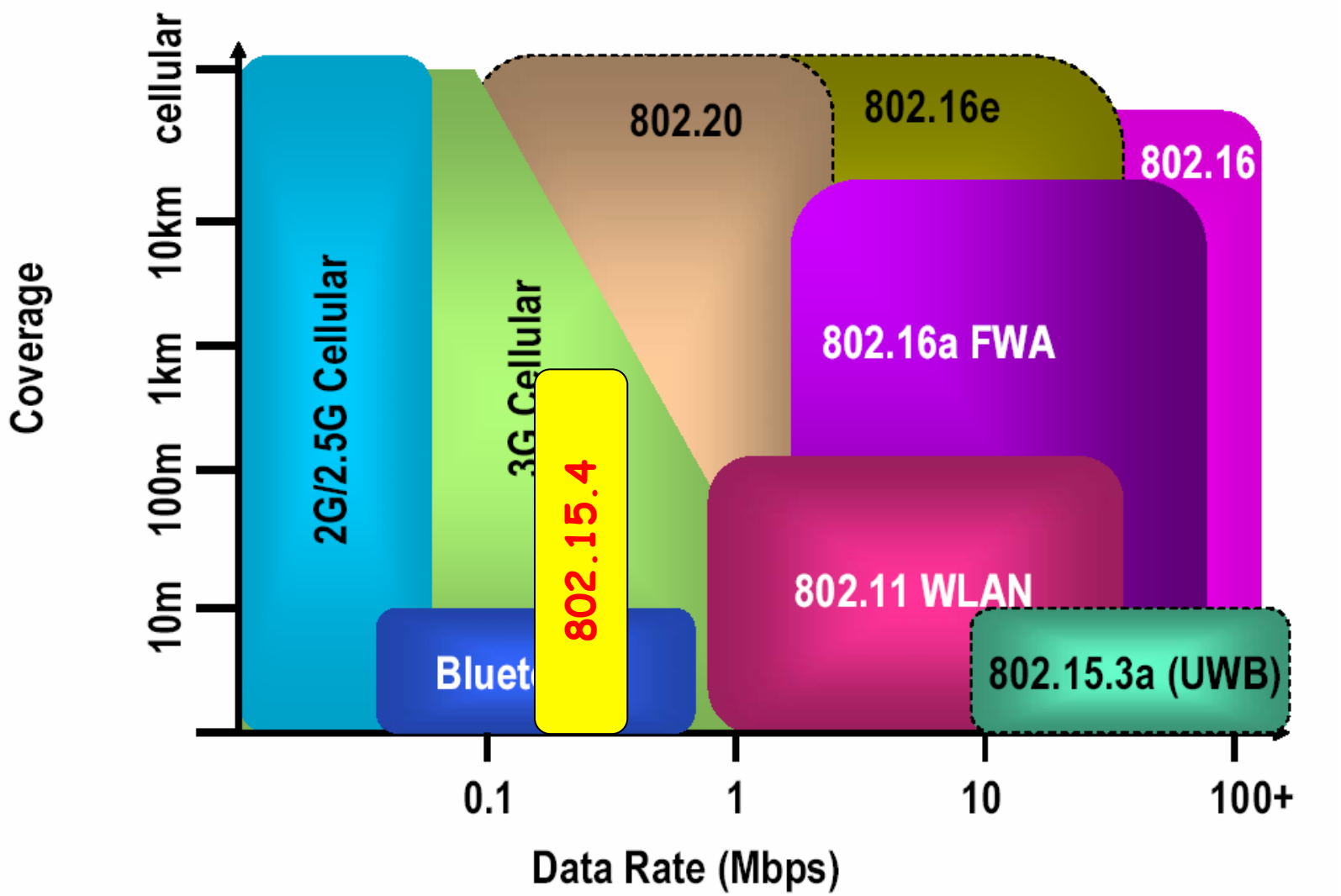
- Native communication:

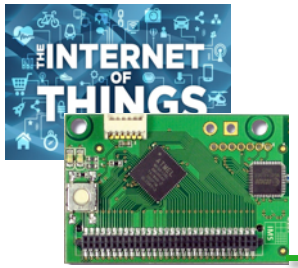
- Added communication
  - Active communication

  - Passive communication

Wireless Communication made easy

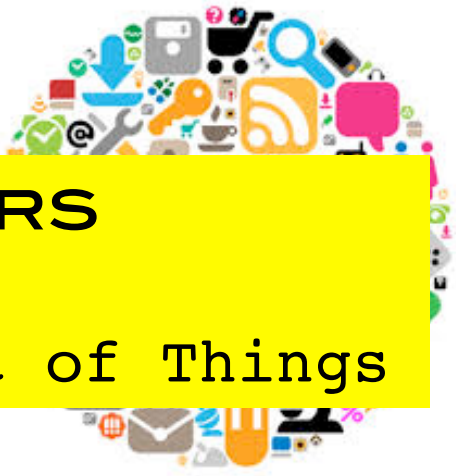
Wireless technologies





Internet of Things

- Many new terms for quite old concepts!
  - Internet 0
  - Internet of Things



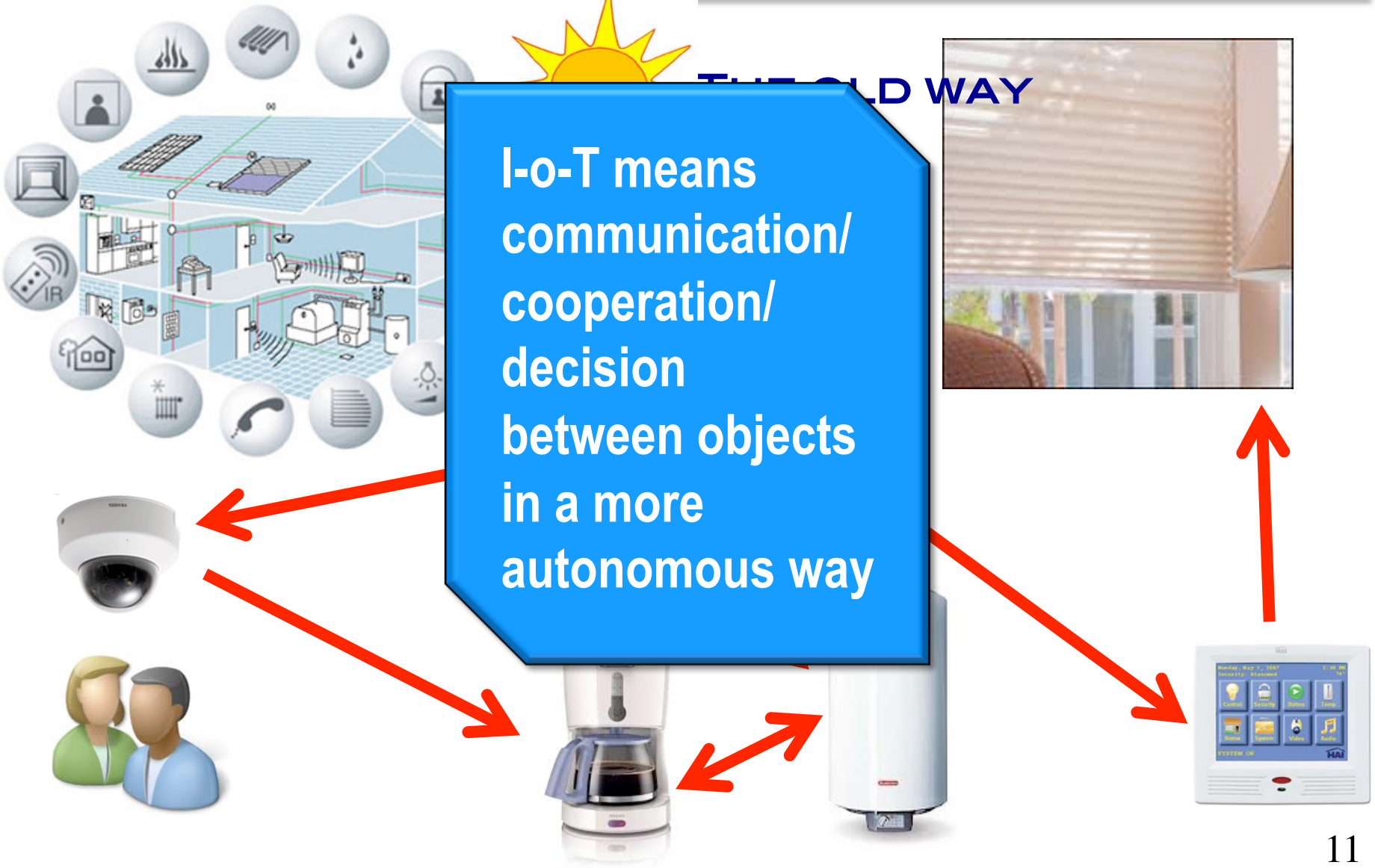
The I-o-T for beginners

http://readwrite.com/tag/Internet of Things

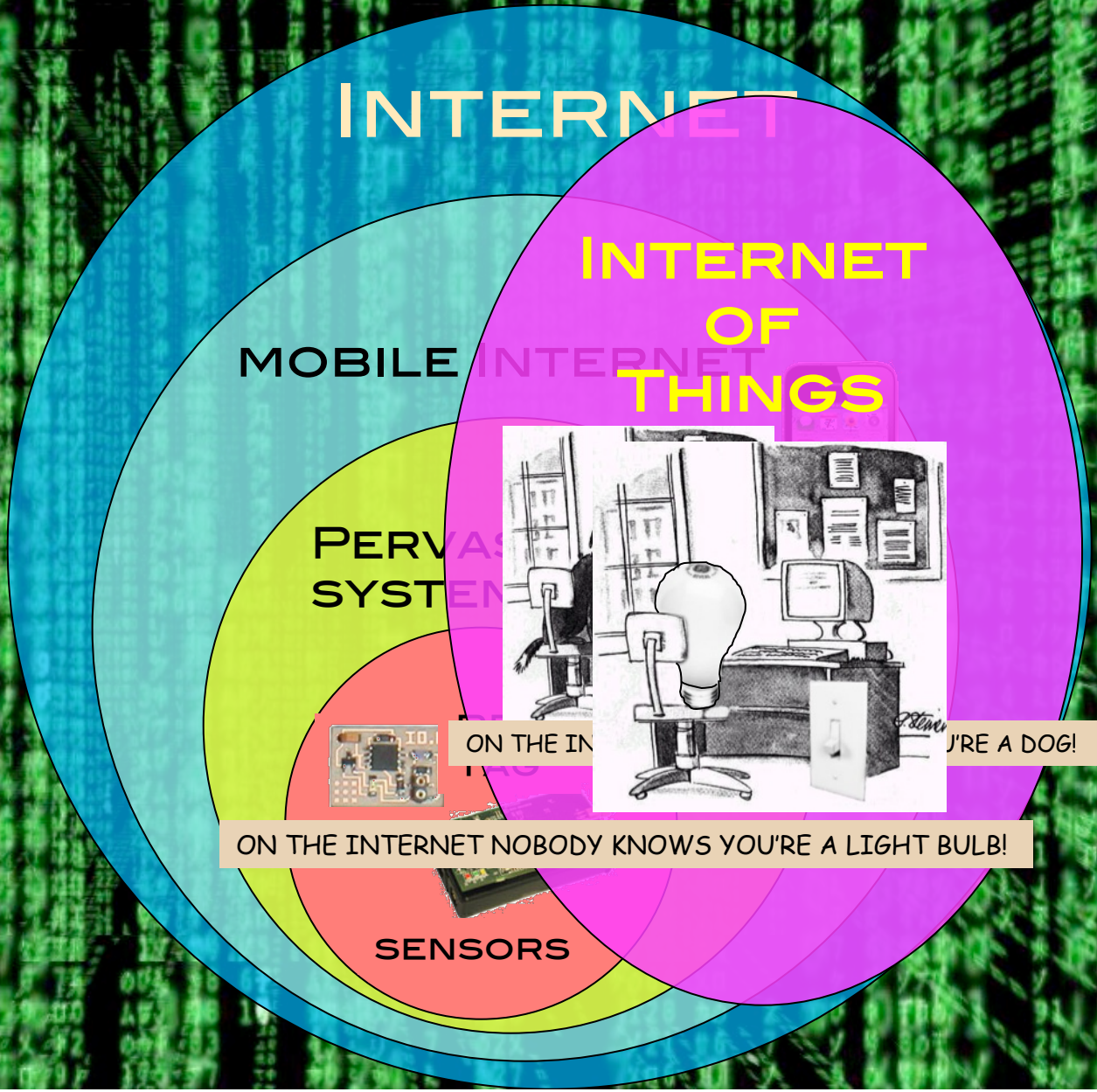
  - D2D: Device-to-Device

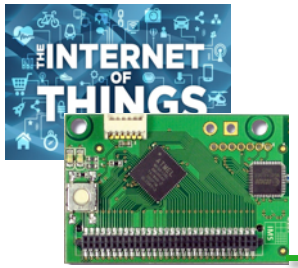
- Motivations are
  - Situation/Context awareness
  - Ubiquitous sensing/computing
  - More « intelligence » into machines

WHAT'S NEW?


THE OLD WAY
I-o-T means communication/ cooperation/ decision between objects in a more autonomous way

Digital Wireless World

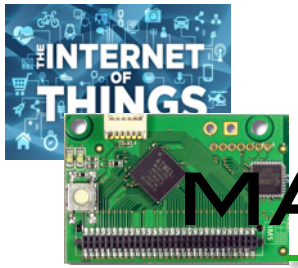




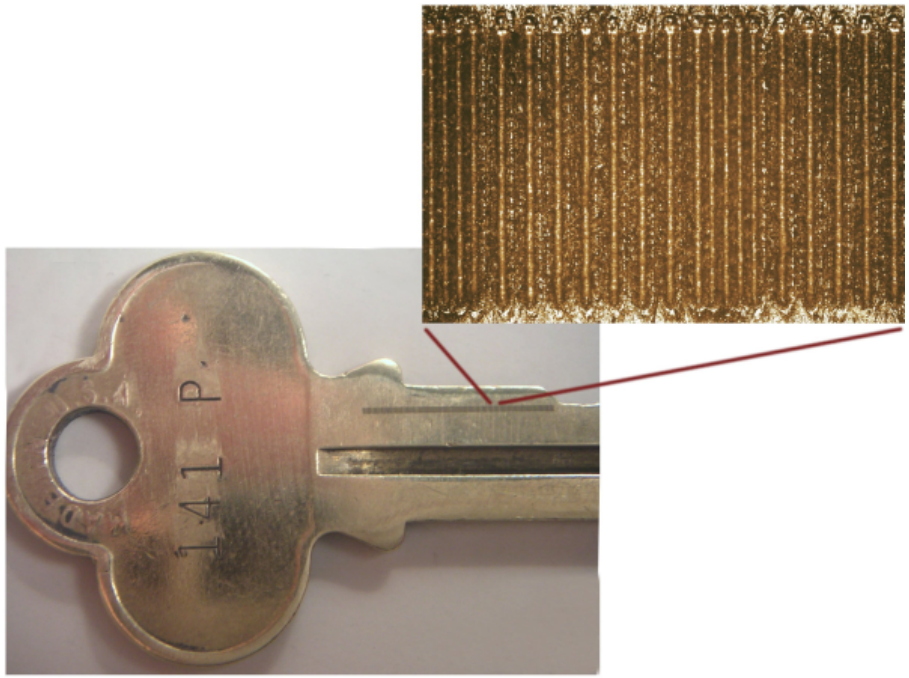
Are you I-o-T or WSN?

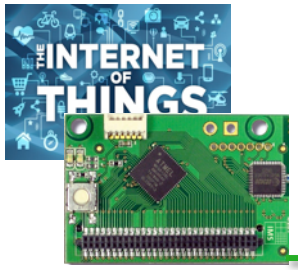
- IP integration, WWW
- IPv6
- Inter-operability
- Interactions (all kind)
- Semantic, Ontology
- Data representation
- Data logging
- WebServices

- Organization
- Programmability
- Energy saving
- Scheduling
- Efficient MAC, routing
- Congestion control
- Data transmission

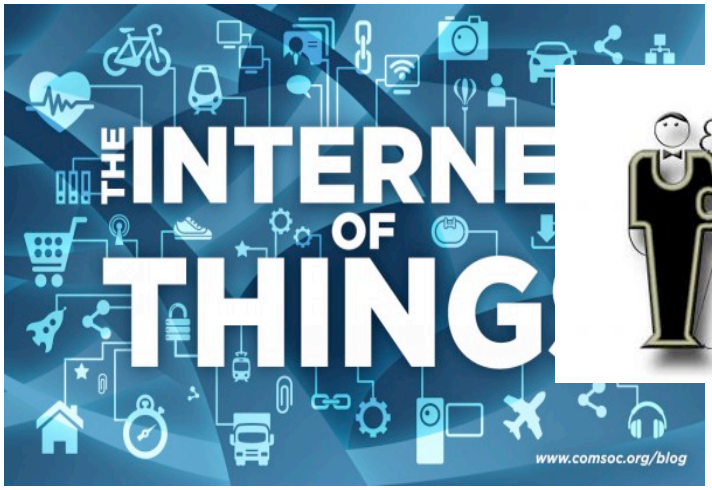


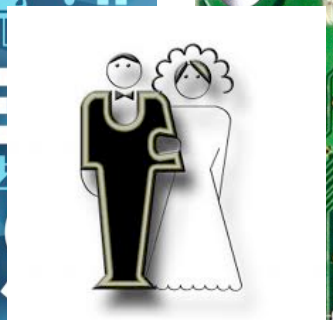
Interaction can takes many (unexpected) forms!

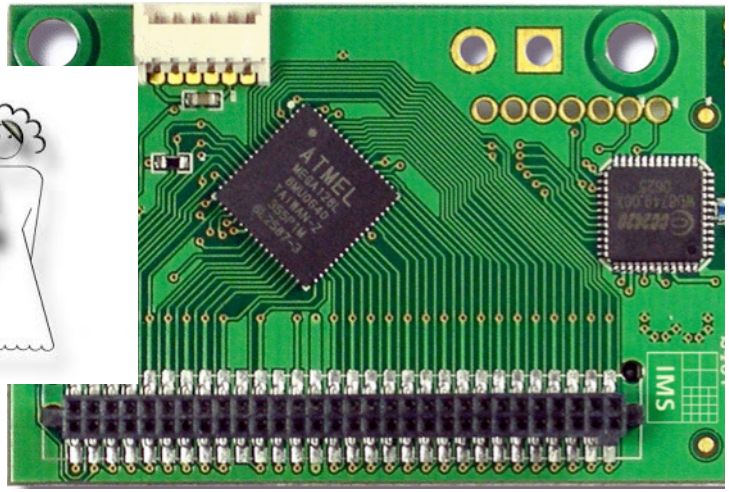




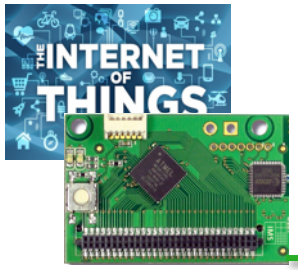
Where is the future?





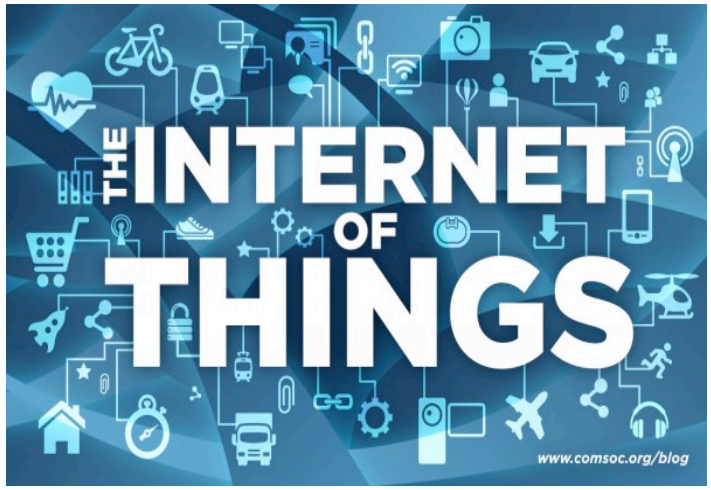


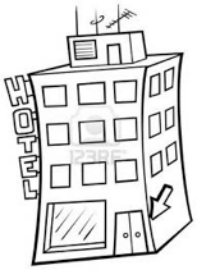
OR ...?



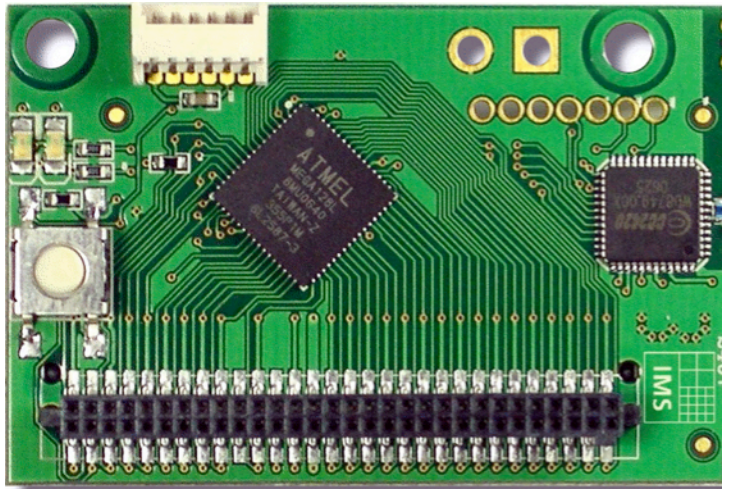
Where is the future?

HOME
Sweet
HOME

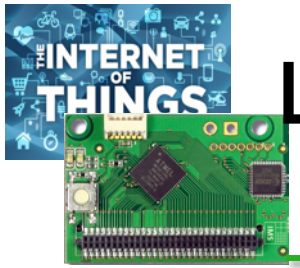




HOME
Sweet
HOME

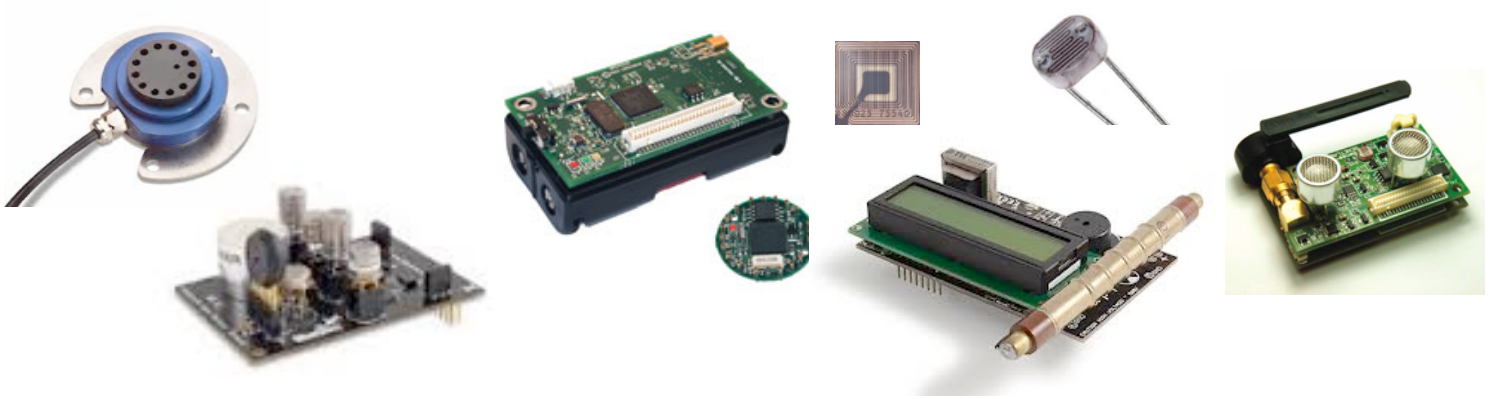


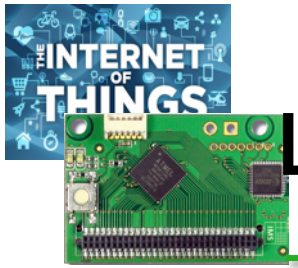
Enjoy my own home but can meet at some occasion



Level 0: measuring the physical world

Sensing

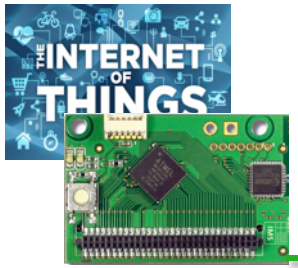




Level 1: Store, Process

Pervasive Systems

Sensing

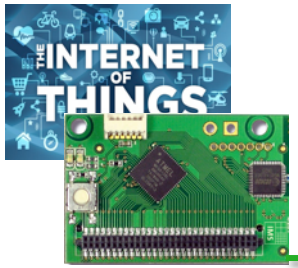


Level 3: connect, interact

Pervasive Systems

Sensing

PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES,...



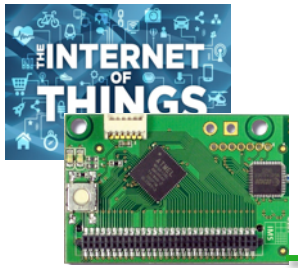
Level 4: control, instrument !

DATA ANALYSIS, OPTIMIZATION & CONTROL

PERVASIVE SYSTEMS

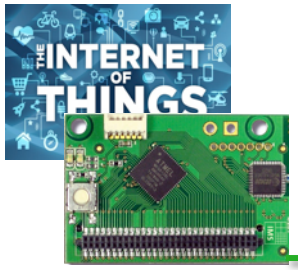
SENSING

PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES

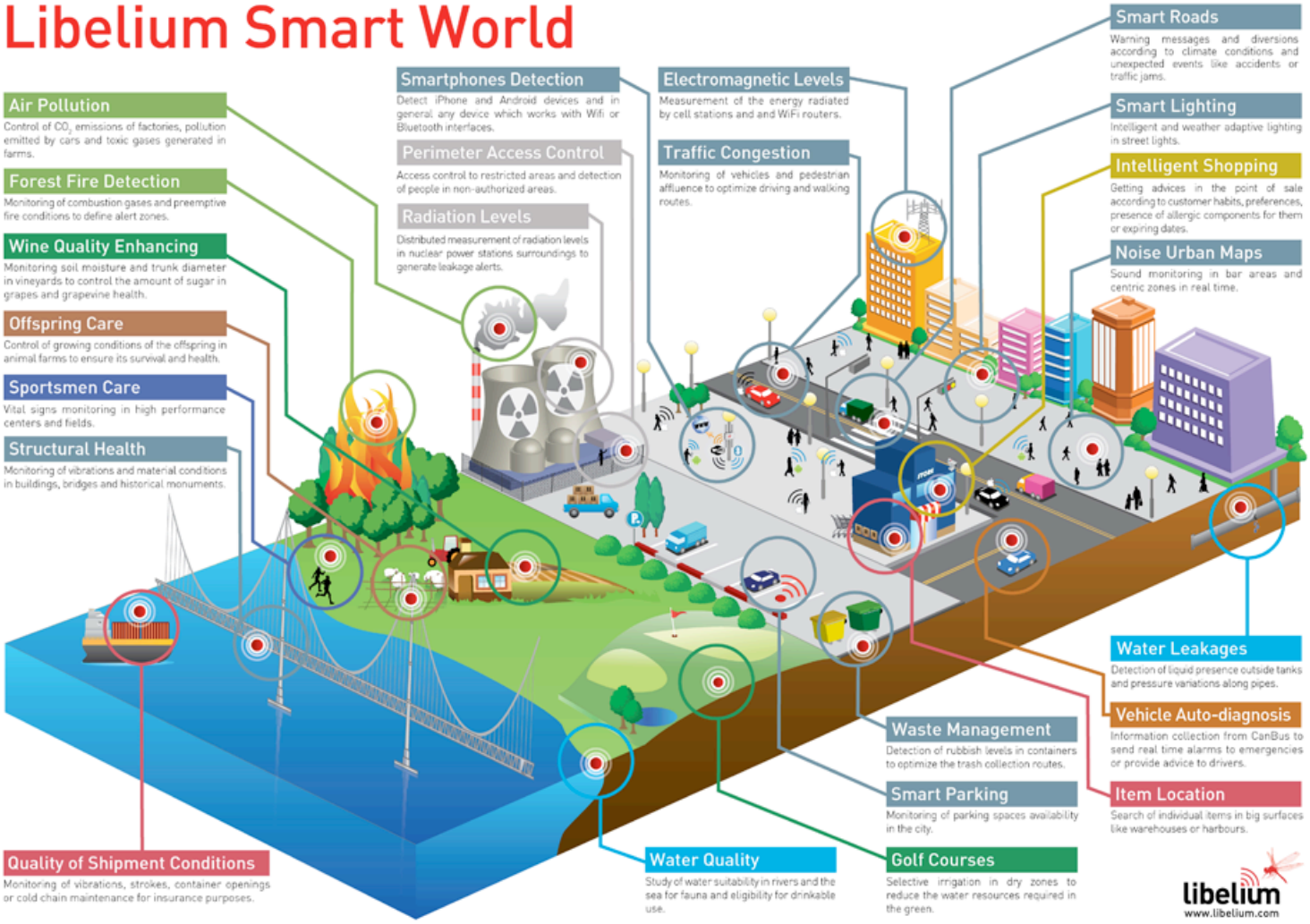


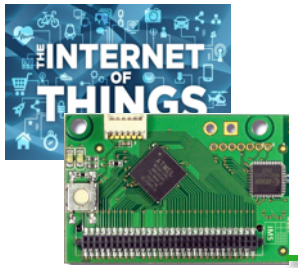
Be Smart* !

- Smart…
  - City, Building, Road, Traffic
  - Agriculture
  - Farming
  - Environment: Water, Forest
  - Energy, Electricity Grid
  - Vehicule & Transportation
  - Transport & Logistic
  - Surveillance, security, safety
  - …


THE INTERNET OF THINGS

Cities

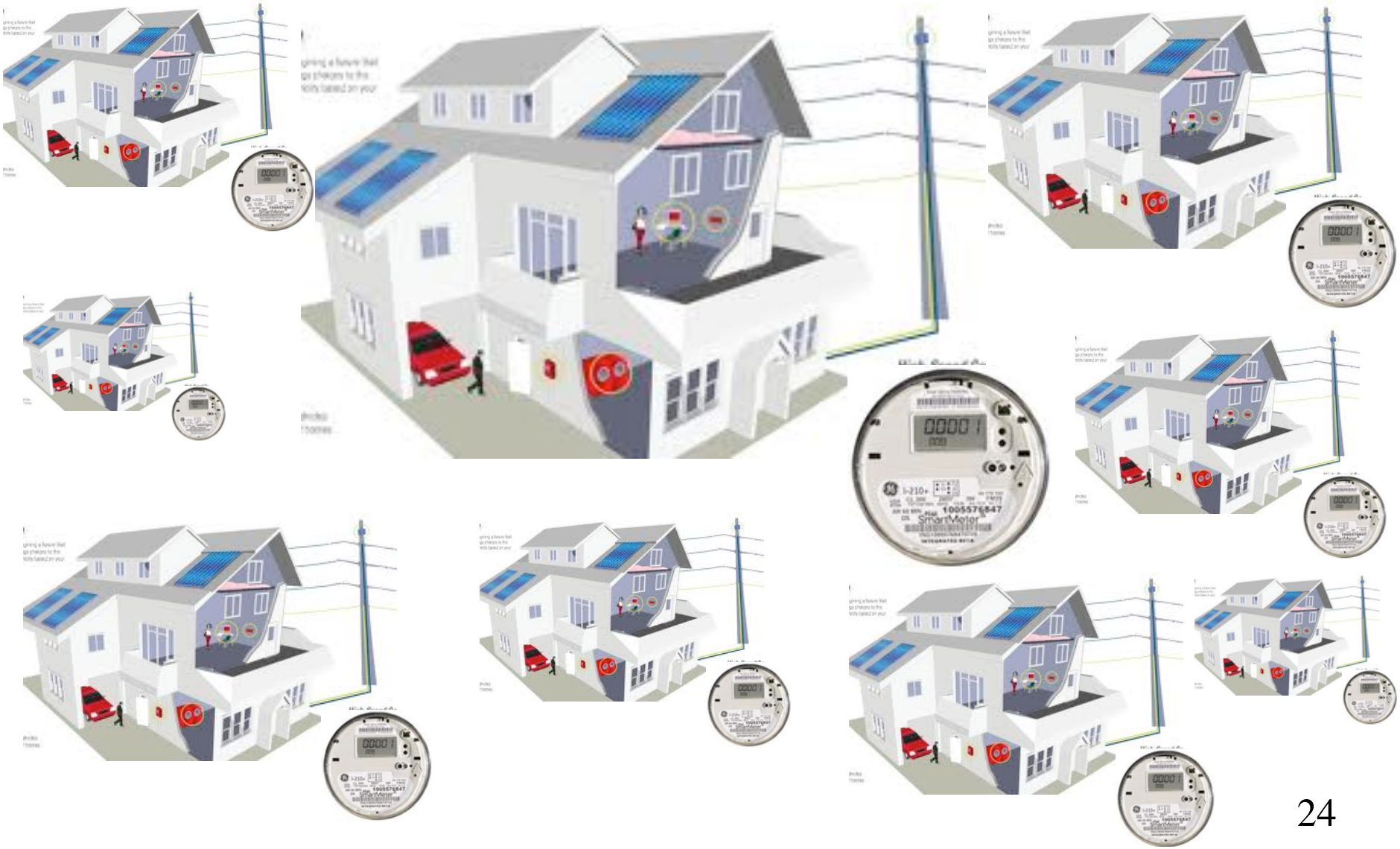

Libelium Smart World
Air Pollution
Control of CO_2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.
Forest Fire Detection
Monitoring of combustion gases and preemptive fire conditions to define alert zones.
Wine Quality Enhancing
Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.
Offspring Care
Control of growing conditions of the offspring in animal farms to ensure its survival and health.
Sportsmen Care
Vital signs monitoring in high performance centers and fields.
Structural Health
Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.
Quality of Shipment Conditions
Monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes.
Smartphones Detection
Detect iPhone and Android devices and in general any device which works with Wifi or Bluetooth interfaces.
Perimeter Access Control
Access control to restricted areas and detection of people in non-authorized areas.
Radiation Levels
Distributed measurement of radiation levels in nuclear power stations surroundings to generate leakage alerts.
Electromagnetic Levels
Measurement of the energy radiated by cell stations and and WiFi routers.
Traffic Congestion
Monitoring of vehicles and pedestrian affluence to optimize driving and walking routes.
Water Quality
Study of water suitability in rivers and the sea for fauna and eligibility for drinkable use.
Golf Courses
Selective irrigation in dry zones to reduce the water resources required in the green.
Waste Management
Detection of rubbish levels in containers to optimize the trash collection routes.
Smart Parking
Monitoring of parking spaces availability in the city.
Smart Roads
Warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.
Smart Lighting
Intelligent and weather adaptive lighting in street lights.
Intelligent Shopping
Getting advices in the point of sale according to customer habits, preferences, presence of allergic components for them or expiring dates.
Noise Urban Maps
Sound monitoring in bar areas and centric zones in real time.
Water Leakages
Detection of liquid presence outside tanks and pressure variations along pipes.
Vehicle Auto-diagnosis
Information collection from CanBus to send real time alarms to emergencies or provide advice to drivers.
Item Location
Search of individual items in big surfaces like warehouses or harbours.
libelium
www.libelium.com

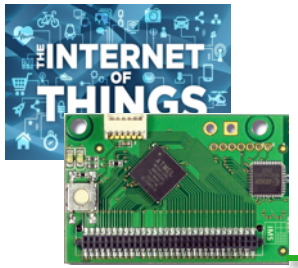


SmartSantander

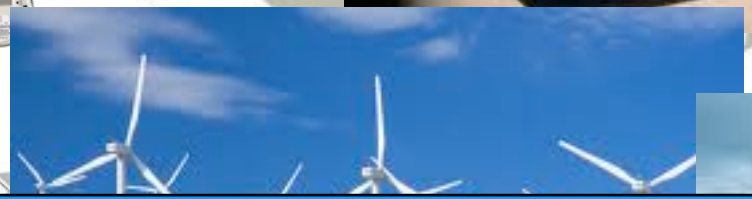
www.smartsantander.eu

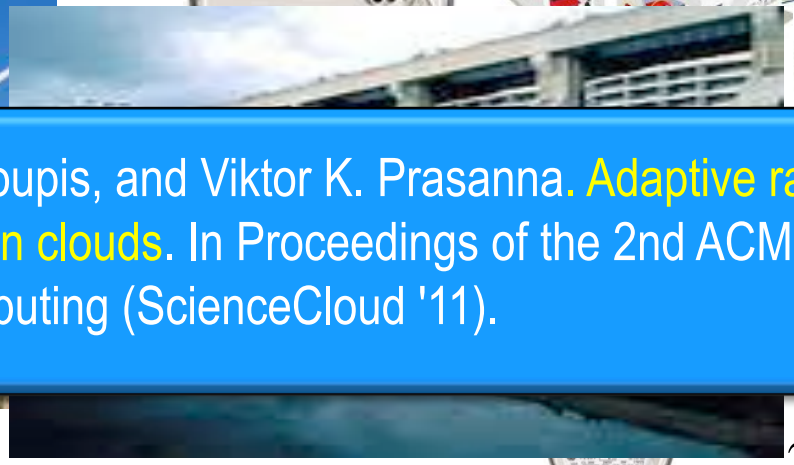
Energy & Electricity Grids





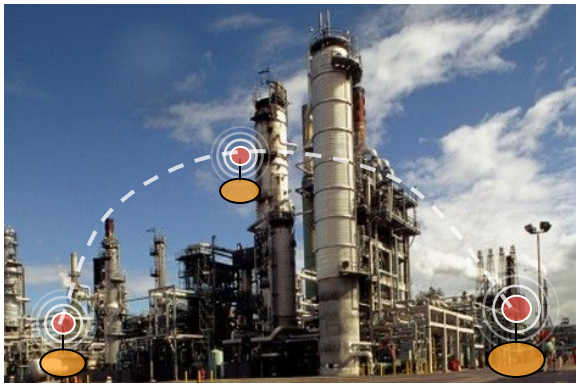
Energy & Electricity Grids

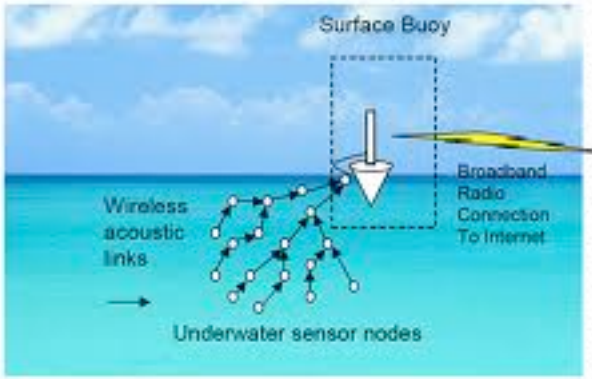




Yogesh Simmhan, Baohua Cao, Michail Giakkoupis, and Viktor K. Prasanna. Adaptive rate stream processing for smart grid applications on clouds. In Proceedings of the 2nd ACM international workshop on Scientific cloud computing (ScienceCloud '11).

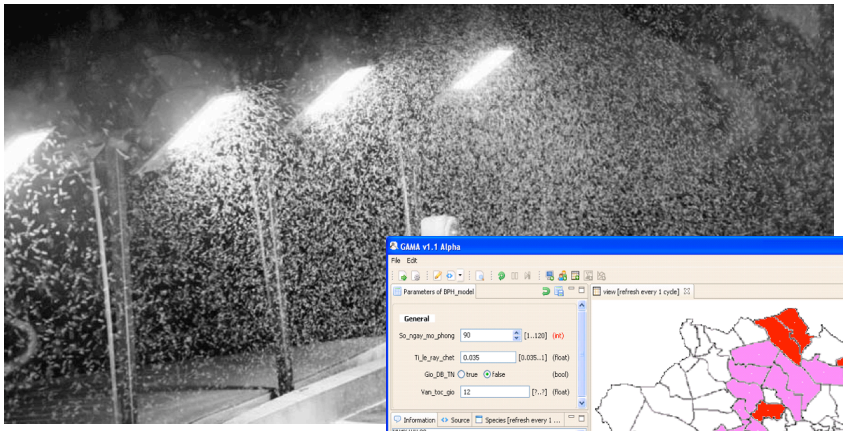
Monitoring/Surveillance

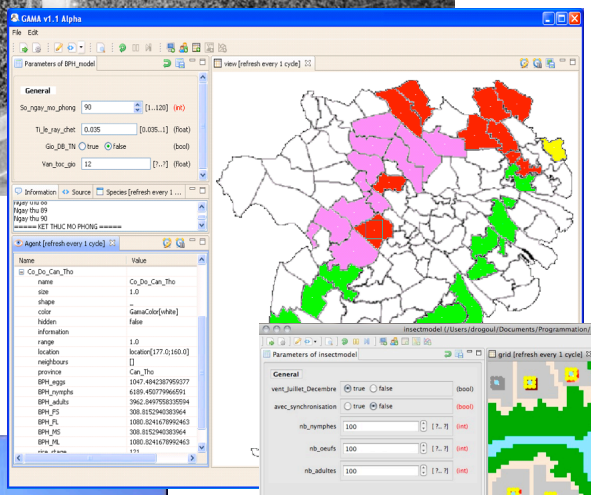


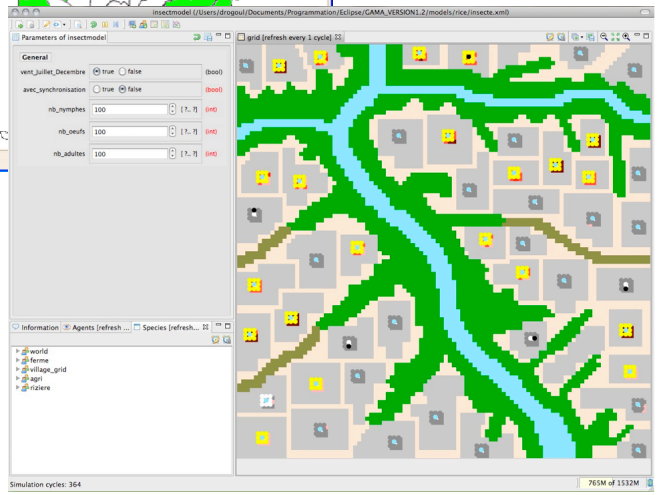


Air quality, pollution

Agriculture, threads







TOWARDS GLOBAL SENSING

Activating

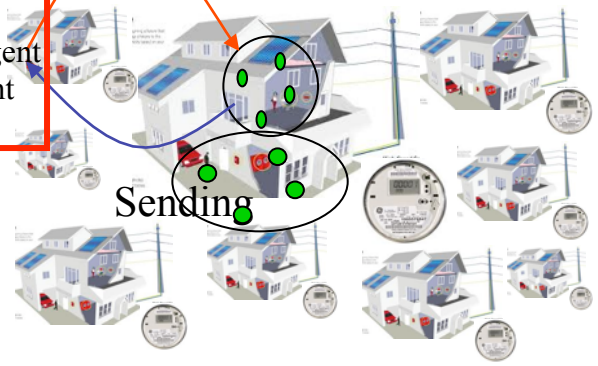
Intelligent Agent

Sending

Activating

Intelligent Agent

Sending



Activating

Intelligent Agent

Sensor Net

Sending

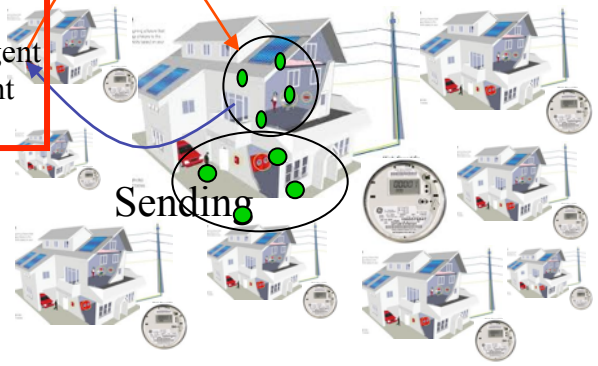
Handle Big Data

Activating

Intelligent Agent

Activating

Intelligent Agent



Sending

Activating

Intelligent Agent

Sensor Net

Sending

iCloud

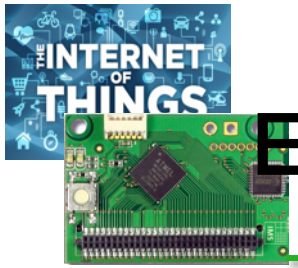
Dropbox

amazon web services™

Google

mobile me

Windows Azure

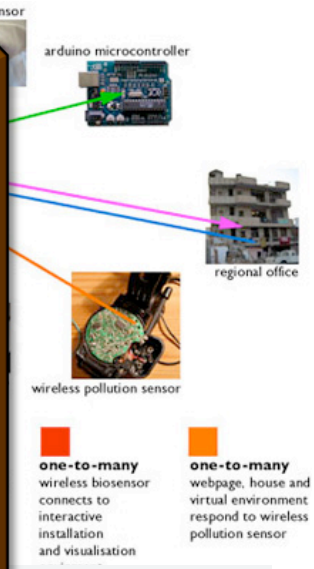


Big actors for big data

HP CeNSE

IBM Smart

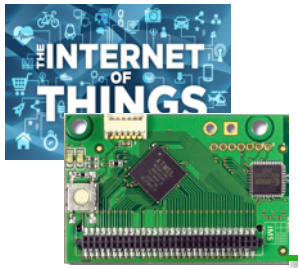
E/Cosm



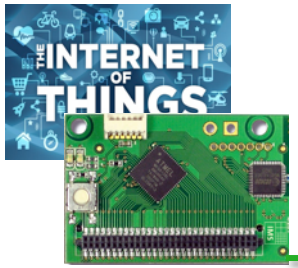
Web Buzzwords

SmartSantander, CALIPSO: Connect All IP-based Smart Objects, IoT6, Cosm/ Pachube: connect your world, HP CeNSE, IBM Smarter Planet, 6LowPan, IPv6, CORE, RPL, CoAP, Libelium, Arduino, AdvanticSys, TST Sistemas, Beagle, Raspberry, FreeScale, ioBridge,…

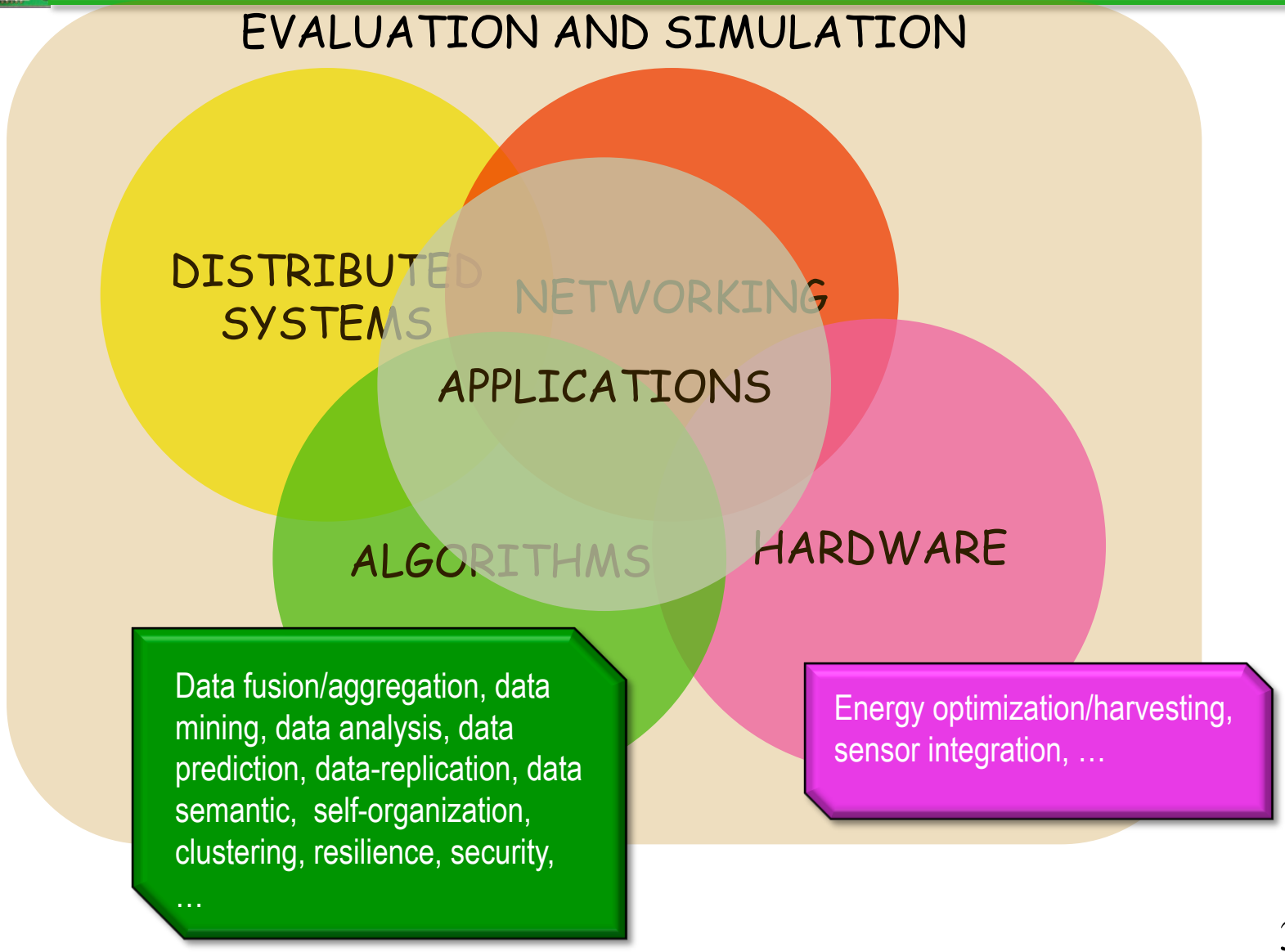
http://readwrite.com/2010/12/15/top_10_internet_of_things_developments_of_2010



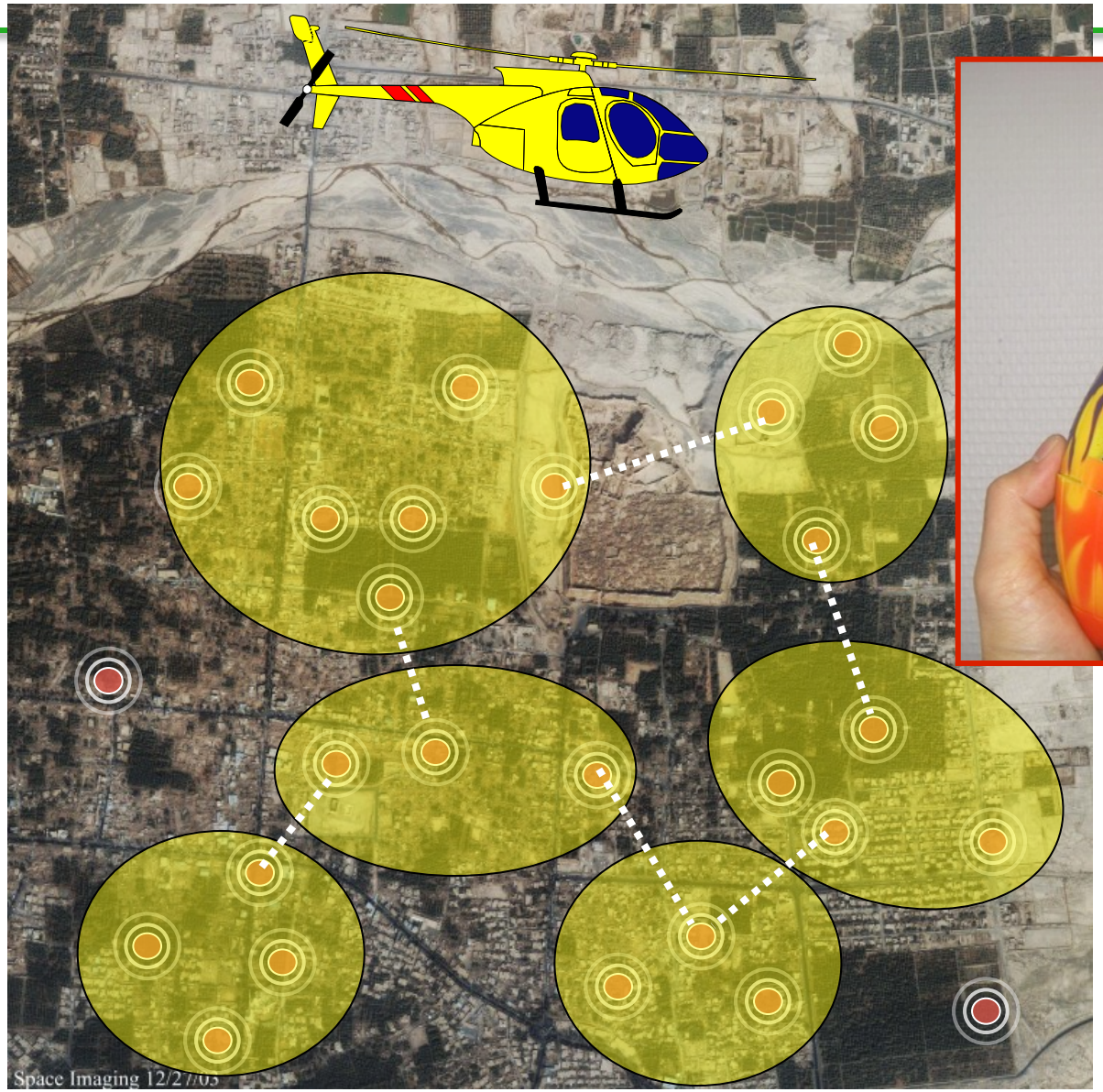
Who is concerned?

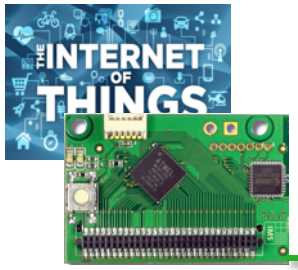


Multi-disciplinary research

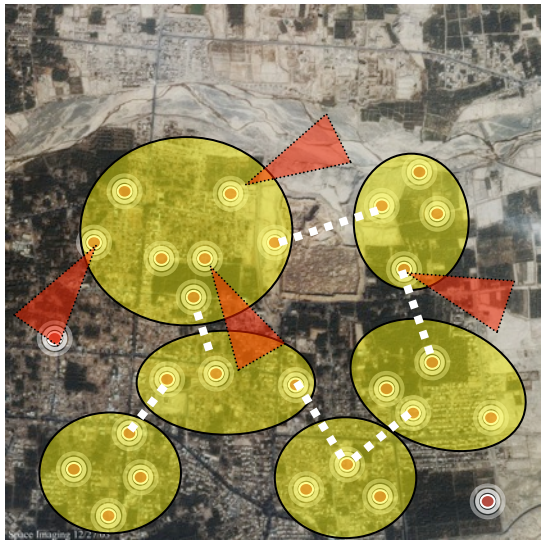


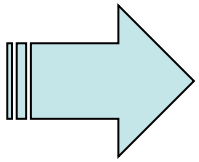
Search&Rescue, security



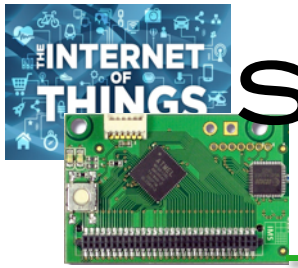


Situation-awareness

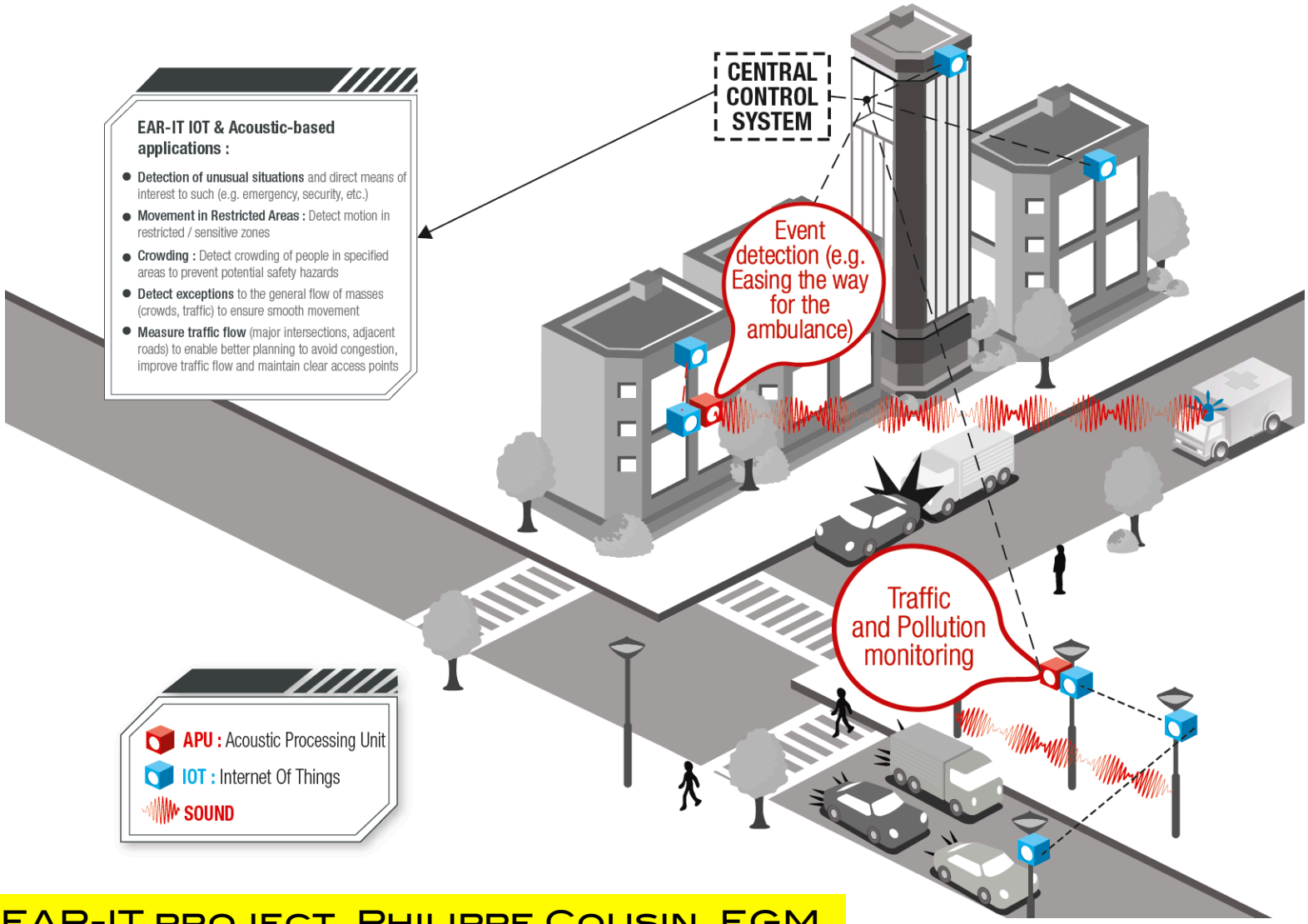




Collect data to improve the responsiveness of rescue operations



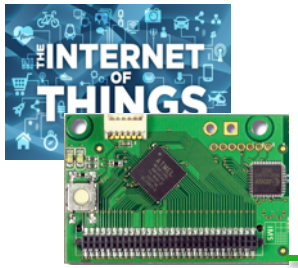
Streaming the sound of SmartCities



From EAR-IT project, Philippe Cousin, EGM

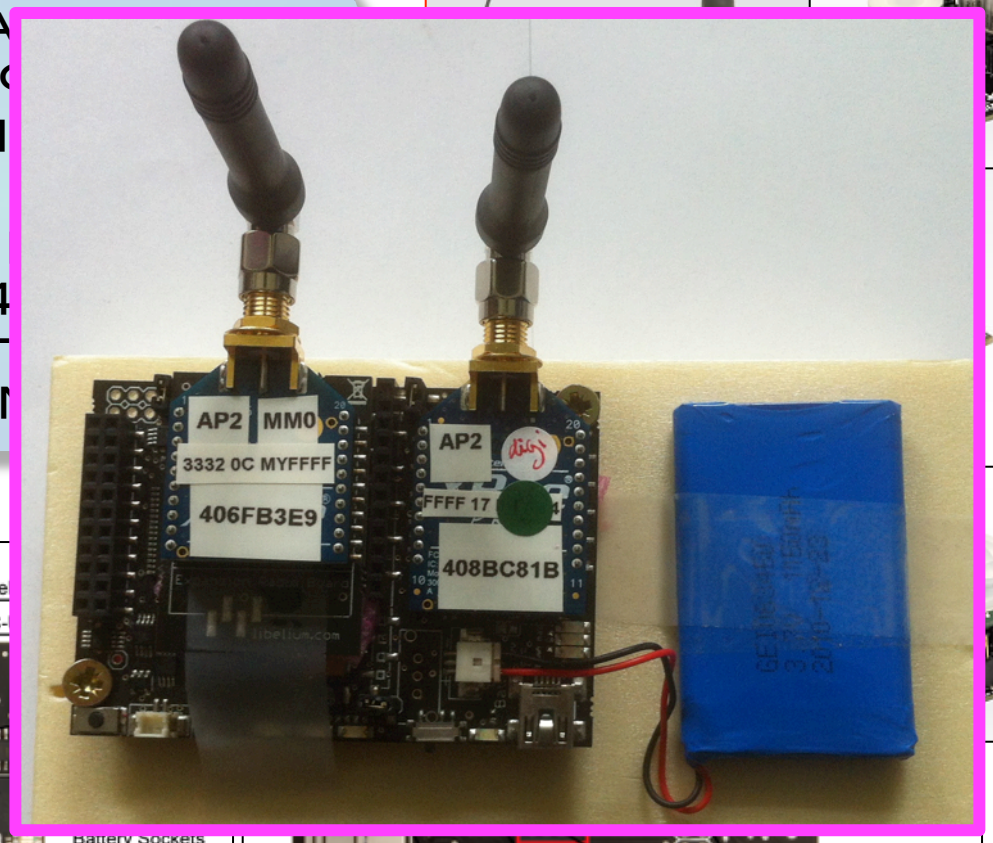
SmartSantander test-bed

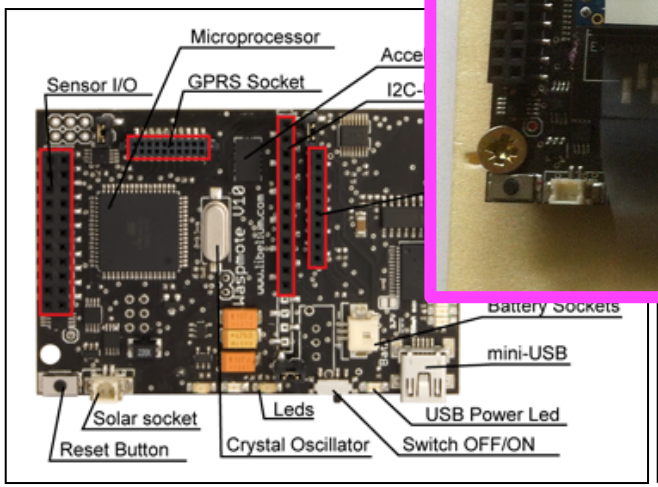
Special thank to the SmartSantander team in U. Cantabria lead by Pr L. Munuoz for all the information provided and the I-o-T node



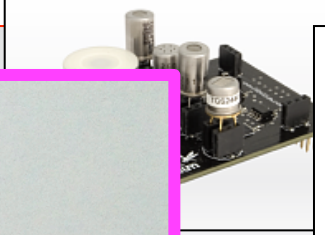
libelium
comunicaciones inalámbricas distribuidas

- ATMEGA MICROC
- 8K RAM CARD.
- 2.4GHz 802.15.4 COMPAT AND GSM





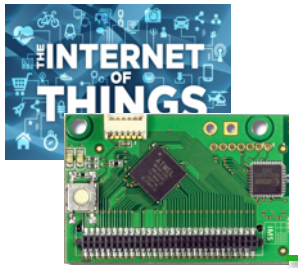
Gases



- Carbon Monoxide – CO
- Carbon Dioxide – CO2
- Oxygen – O2
- Methane – CH4
- Hydrogen – H2
- Ammonia – NH3
- Isobutane – C4H10
- Ethanol – CH3CH2OH
- Toluene – C6H5CH3
- Hydrogen Sulfide – H2S
- Nitrogen Dioxide – NO2
- Temperature
- Humidity

- Pressure/Weight
- Bend
- Vibration
- Impact
- Hall Effect
- Tilt
- Temperature (+/-)
- Liquid Presence
- Liquid Level
- Luminosity
- Presence (PIR)
- Stretch

IMAGES ARE FROM LIBELIUM COMPANY



IEEE 802.15.4

Caractéristiques Radio dans les réseaux de capteurs

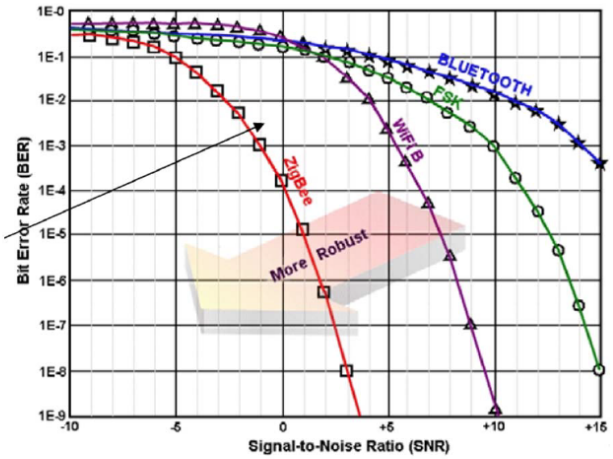
- Norme ZigBee (IEEE 802.15.4 PHY)

La norme IEEE802.15.4a, adaptées aux réseaux de capteurs, au contrôle industriel et aux dispositifs médicaux (CMI)

IEEE802.15.4 (couches 1 et 2):
- Three bands, 27 channels specified
  - 2.4 GHz: 16 channels, 250 kbps
  - 868.3 MHz : 1 channel, 20 kbps
  - 902-928 MHz: 10 channels, 40 kbps

Protocole	Zigbee	Bluetooth	Wi-Fi
IEEE	802.15.4	802.15.1	802.11a/b/g
Besoins mémoire	4-32 Kb	250 Kb +	1 Mb +
Autonomie avec pile	Années	Jours	Heures
Nombre de nœuds	65 000+	7	32
Vitesse de transfert	250 Kb/s	1 Mb/s	11-54 et + Mb/s
Portée	100 m	10-100 m	300 m

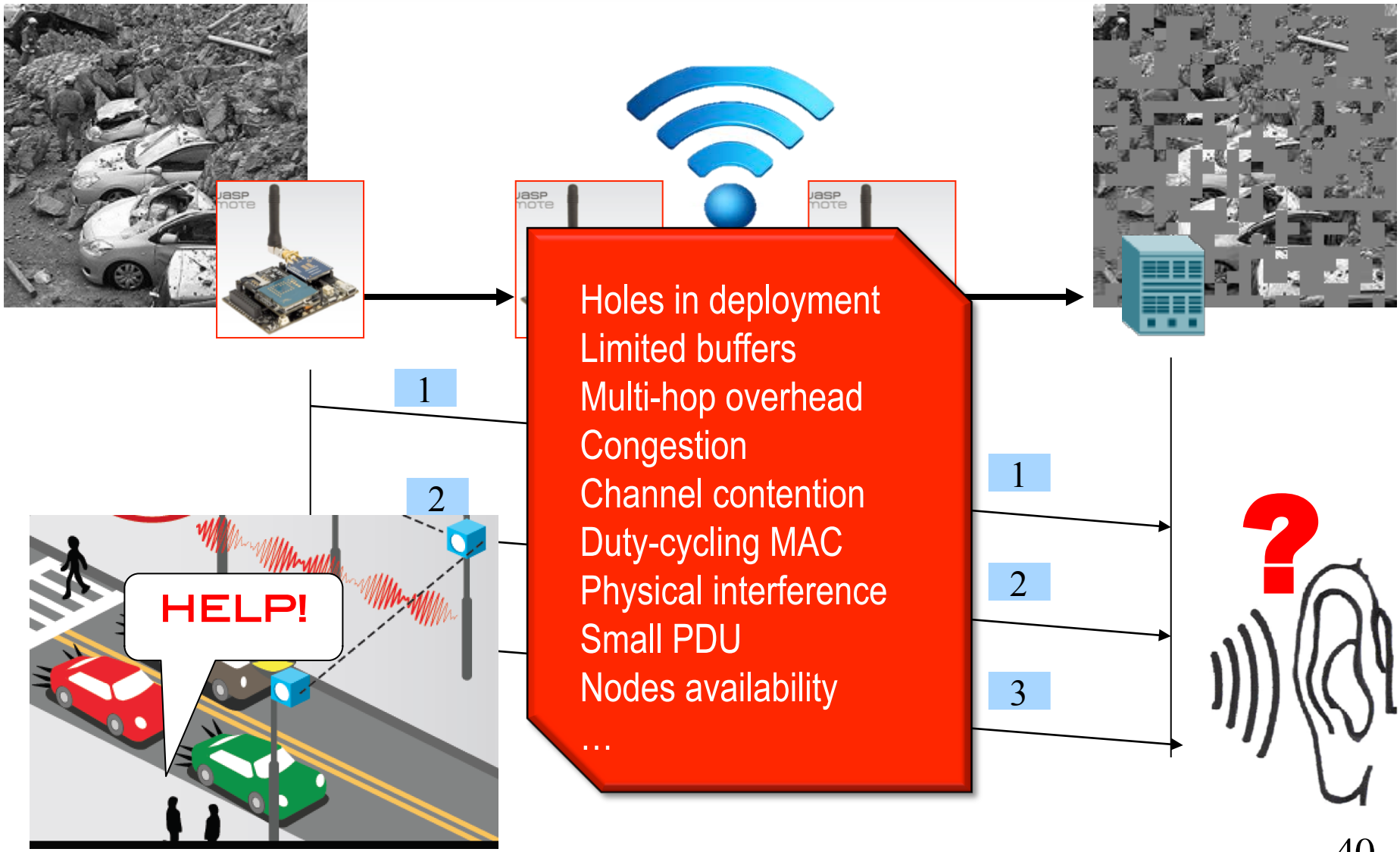
- Comparaison entre les normes ZigBee, Bluetooth et Wifi



5

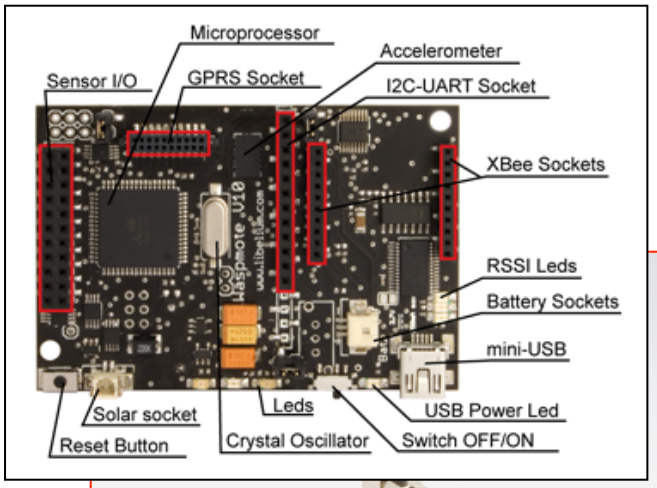
K.C. Yao, CommRadio dans les RxCapteurs

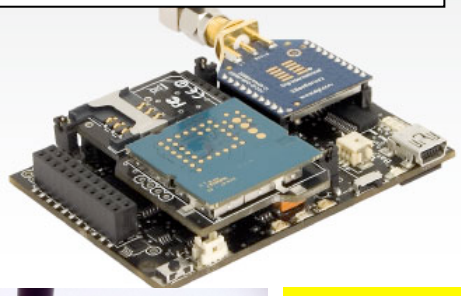
Multi-Hop Packet Forwarding?



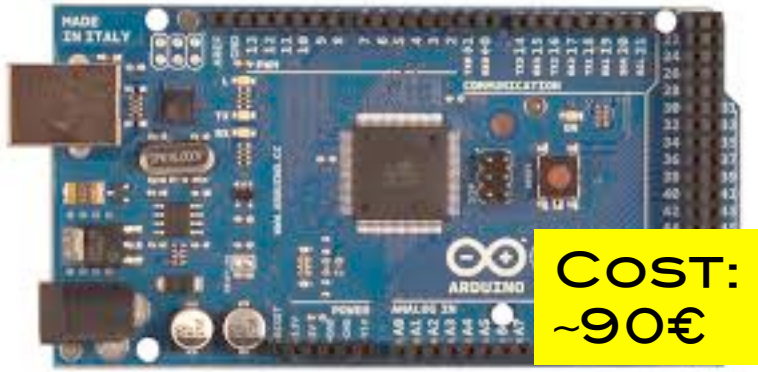
From EAR-IT project

Experimentation platforms

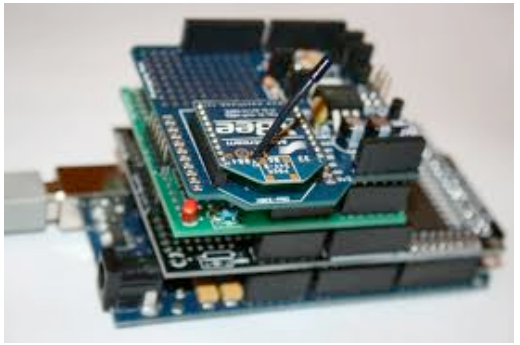


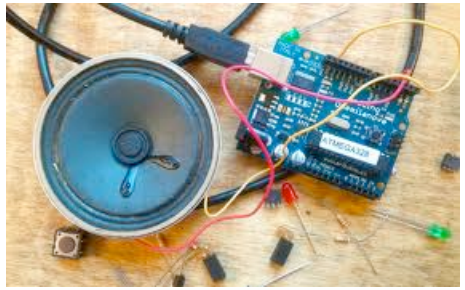


Cost: ~135€



Cost: ~90€

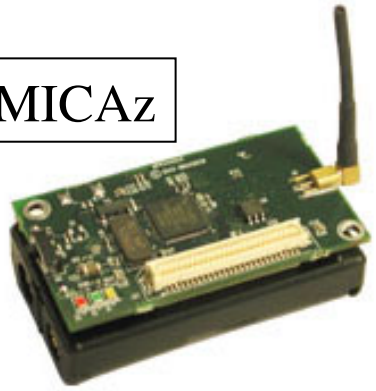


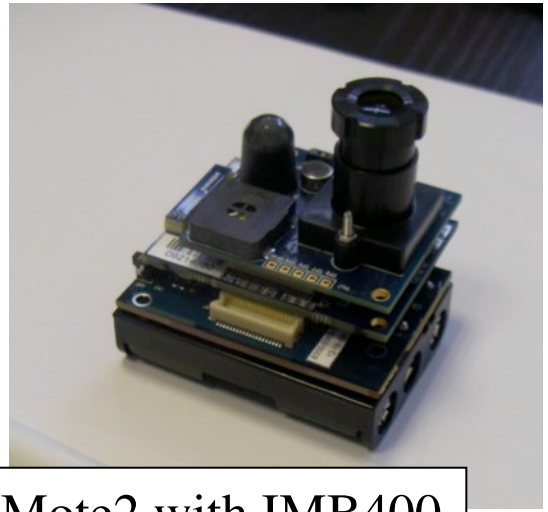


Previous Image sensor motes

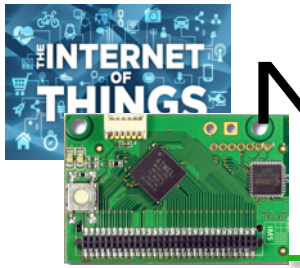
iMote2

MICAz





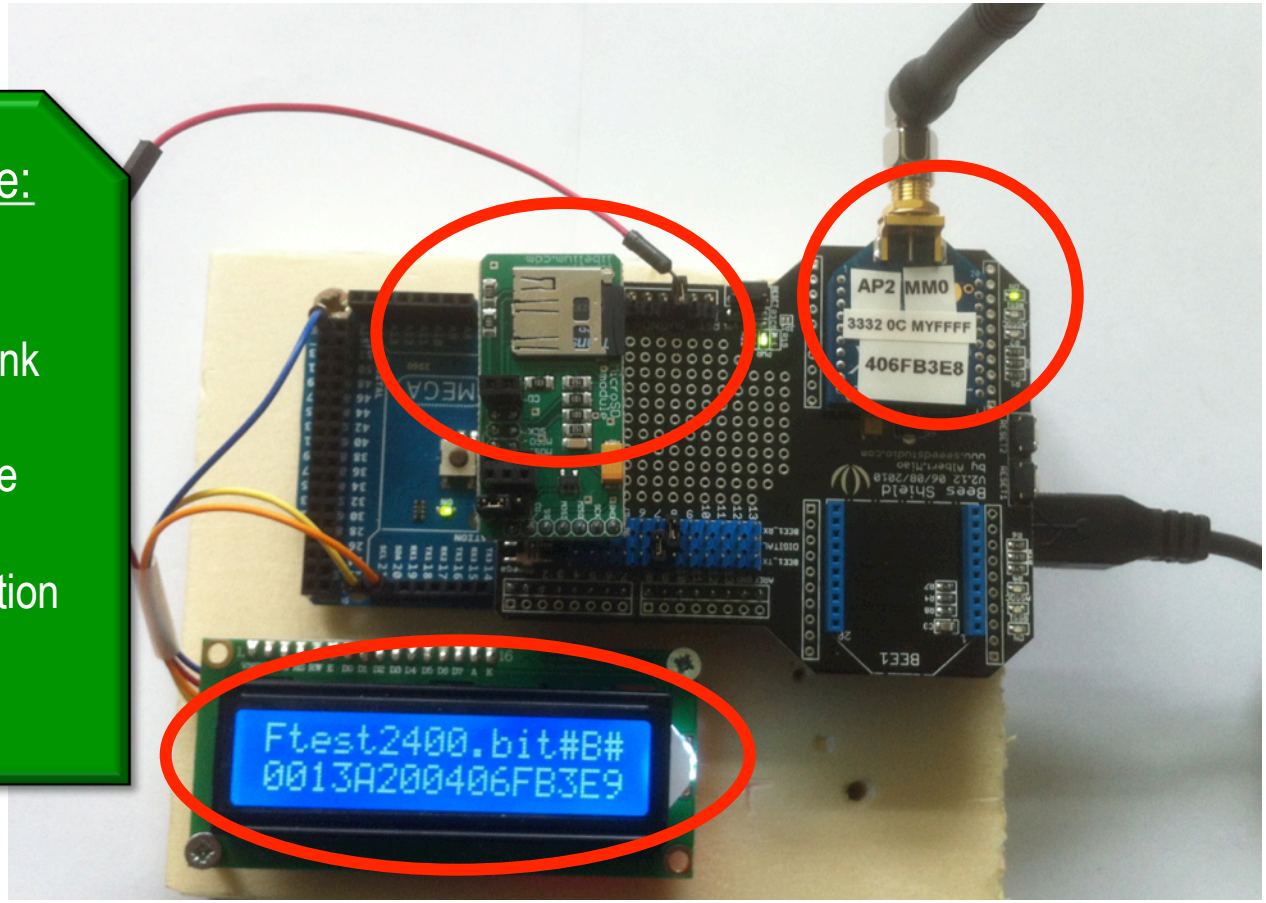
iMote2 with IMB400 multimedia board



More generic solution: file sender node

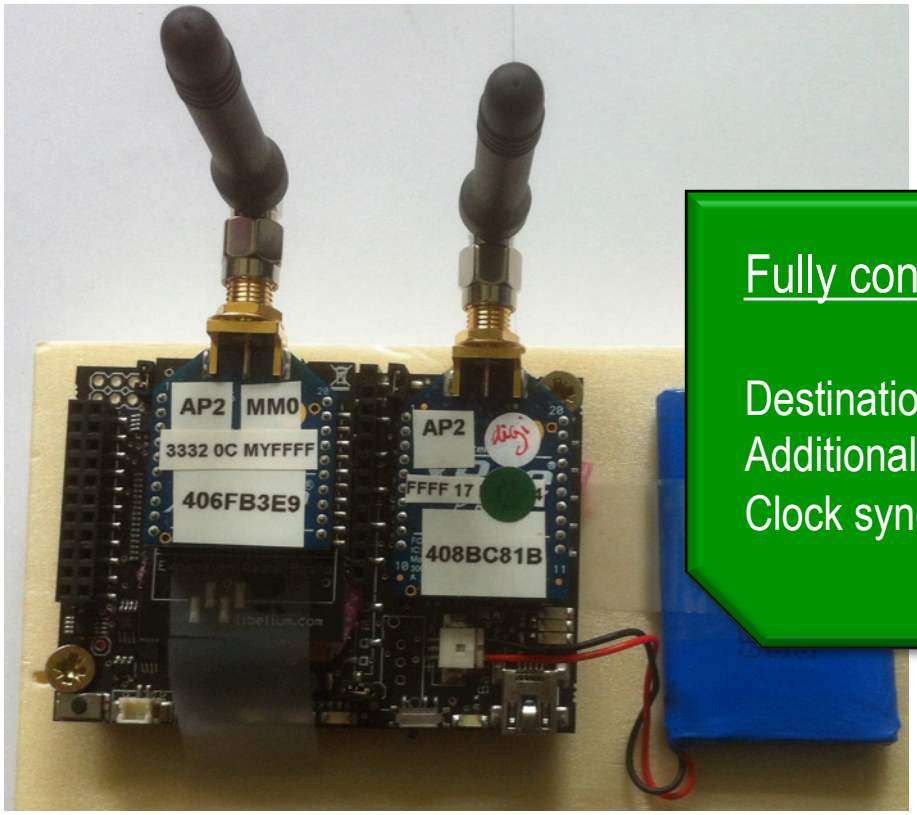
Fully configurable:

File to send
Size of packet chunk
Inter-packet delay
Image/Binary mode
Destination node
Clock synchronization



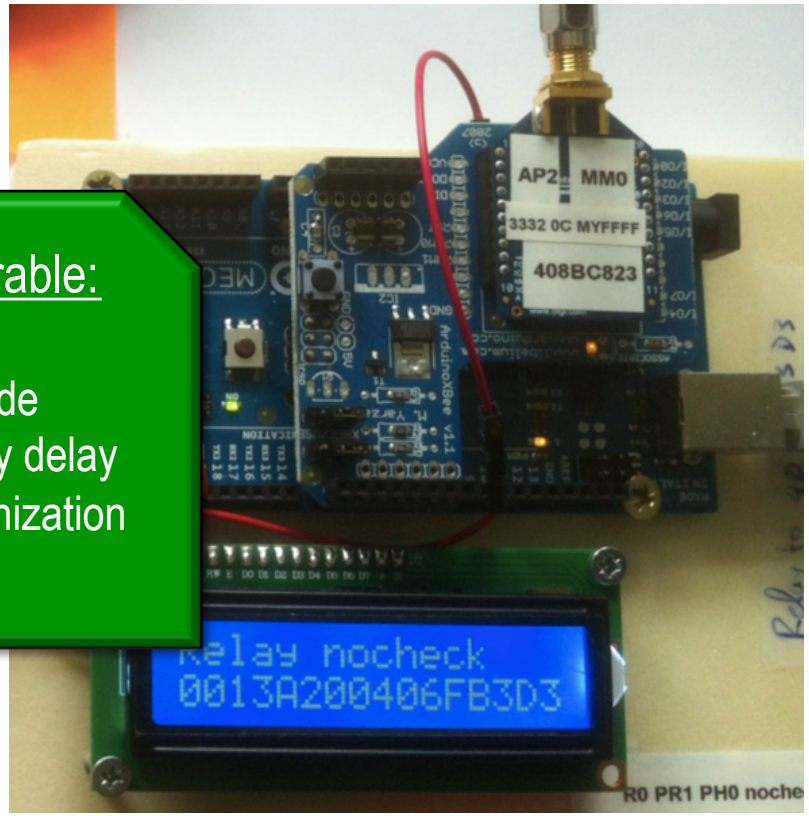
Cost: ~132€

Relay nodes



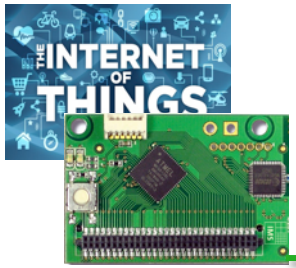
Fully configurable:

Destination node
Additional relay delay
Clock synchronization



Libelium WaspMote

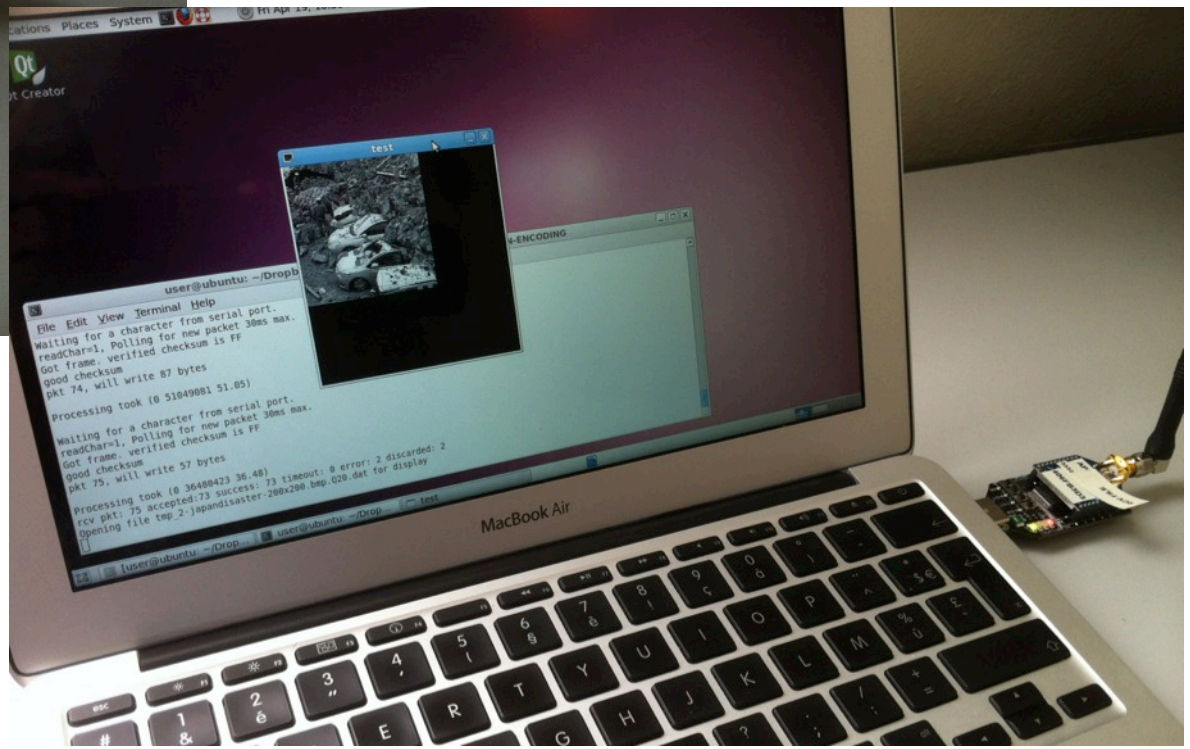
Arduino Mega2560



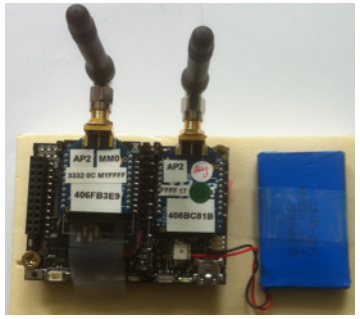
Sink node

Cost: ~42€

Linux PC/Laptop with USB/Serial gateway

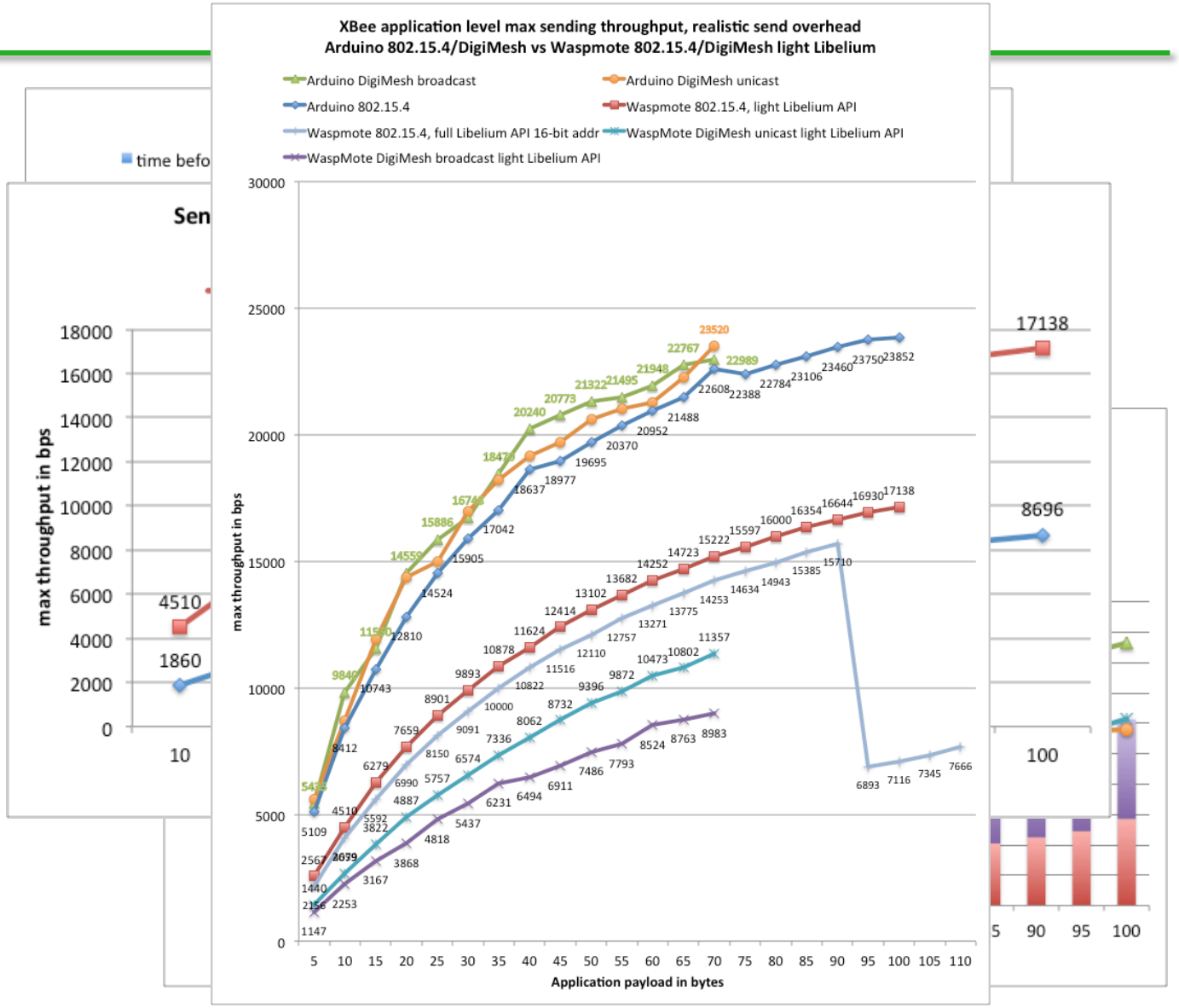


Node qualification



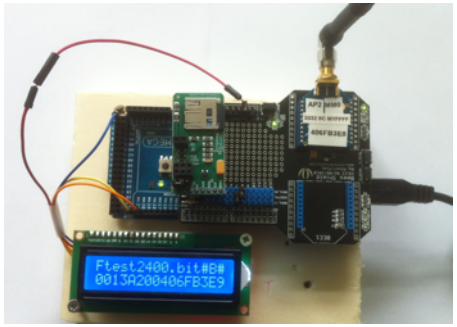
Libelium WaspMote

Arduino Mega2560

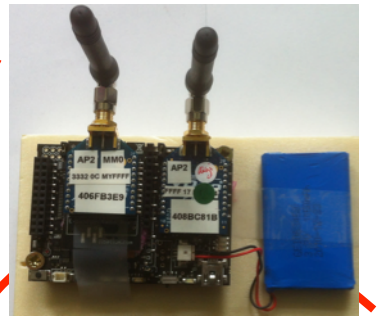


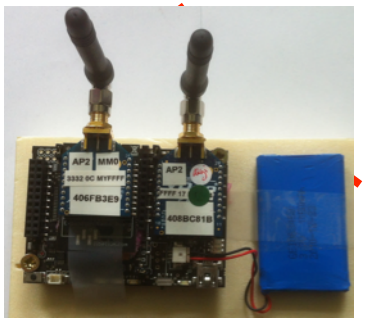
Qualification done in the context of the EAR-IT project

Test-bed

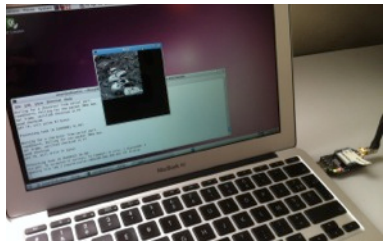

Ftest2400.bit#B#
0013A200406FB3E9

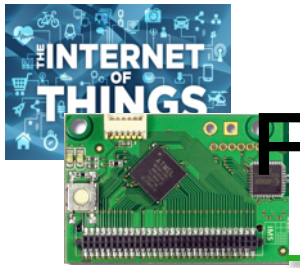

Relay nocheck
0013A200406FB3D3






Relay nocheck
0013A200406FB3D3



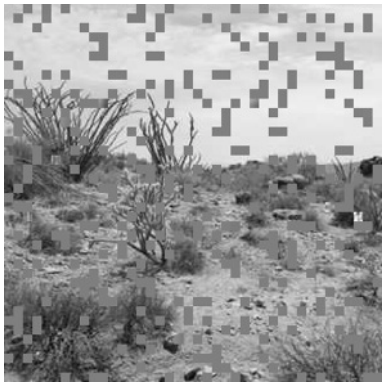


Robust Image Encoding

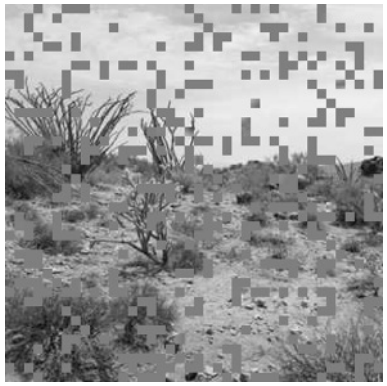
302 packets, 64 bytes payload, one Hop
Loss rate: 20%, No loss bursts (radio), No duty-cycling

Original 320x320
256 gray levels,
WSN specific 17199 bytes

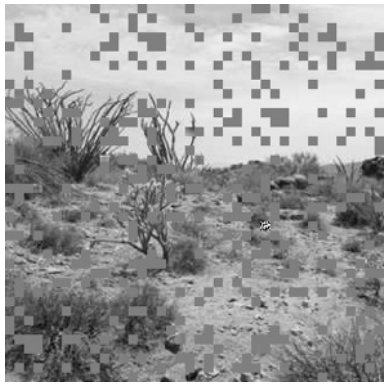
Max TX rate = 250 kps
(IEEE 802.15.4)



248 out of 302
packets received

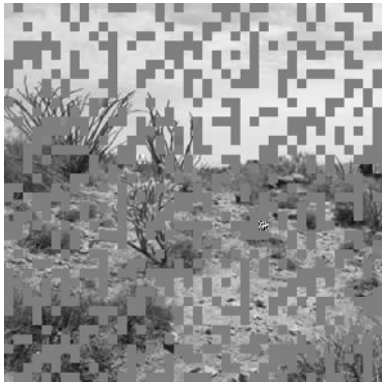


236 out of 302
packets received

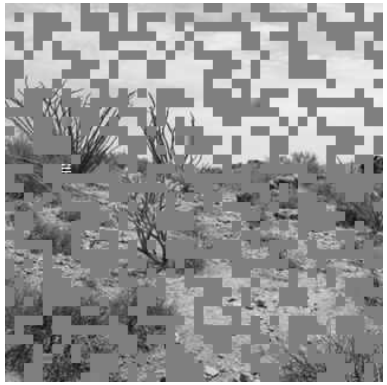


243 out of 302
packets received

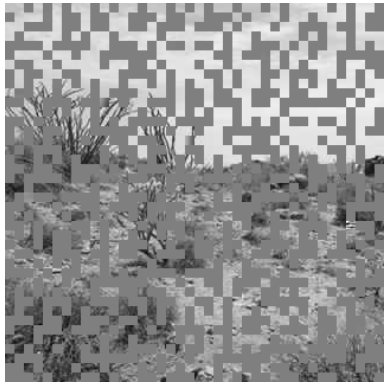
With loss bursts (radio)



188 out of 302
packets received

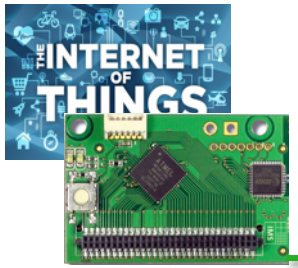


167 out of 302
packets received



158 out of 302
packets received

Collaboration with CRAN laboratory, Nancy, France. Very robust image encoding techniques against packet losses



Adjustable Quality Factor (1)

128x128, suitable for intrusion detection

Original BMP 16384b

Q=50 S=4800b 63pkts

PSNR=24.6765

Q=40 S=4268b 56pkts

PSNR=23.4172

Q=30 S=3604b 46pkts

PSNR=22.0078

Q=20 S=2781b 34pkts

PSNR=20.4087

Q=15 S=2268b 28pkts

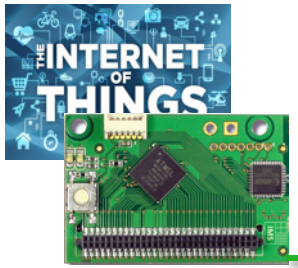
PSNR=19.5864

Q=10 S=1757b 12pkts

PSNR=18.6861

Q=5 S=1006b 12pkts

PSNR=17.3283



Adjustable Quality Factor (2)

200x200, suitable for Situation-Awareness

Original BMP 40000b

Q=50 S=11045b 142pkts

PSNR=25.1661

Q=40 S=9701b 123pkts

PSNR=24.2231

Q=30 S=8100b 101pkts

PSNR=23.2264

Q=20 S=6236b 76pkts

PSNR=22.1293

Q=15 S=5188b 63pkts

PSNR=21.4475

Q=10 S=3868b 47pkts

PSNR=20.5255

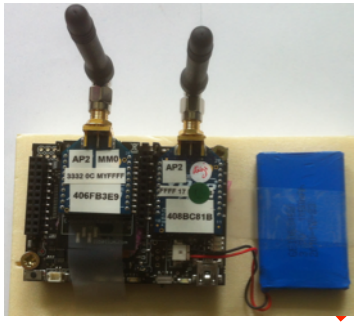
Q=5 S=2053b 24pkts

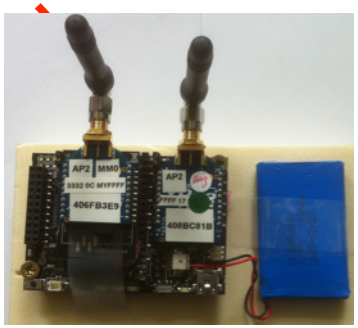
PSNR=18.937

Some results
Image transmission (1)

128x128
Q=20

Libelium WaspMote



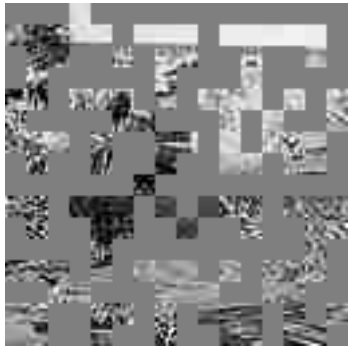


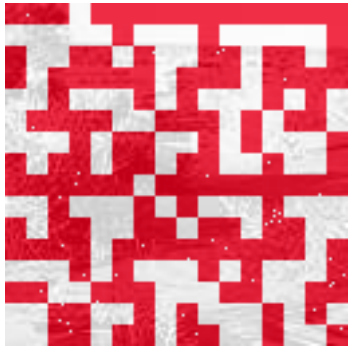
Libelium WaspMote

100ms
PSNR=25.2272

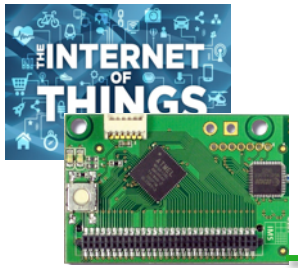
Image sending time: 3.52s
Each relay node adds ~100ms

90ms
PSNR=15.4364





80ms
PSNR=14.1088



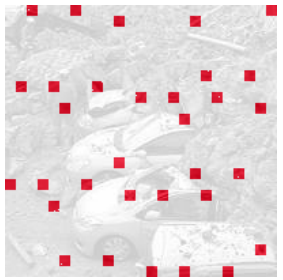
Some results
Image transmission (2)

200x200
76 pkts

Arduino Mega2560

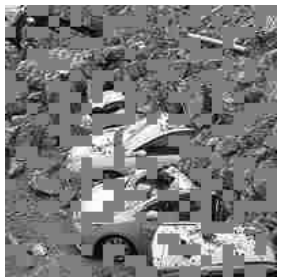
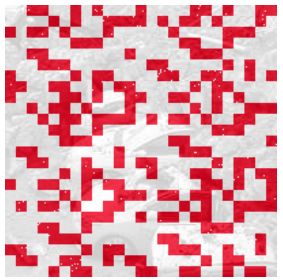
Arduino Mega2560

Image sending time: 6.02s
Each relay node adds ~75ms

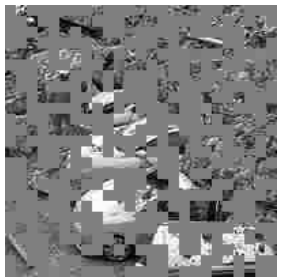
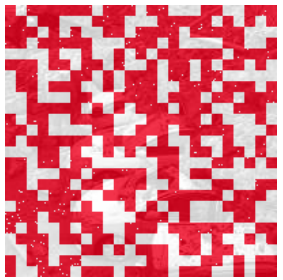



80ms
PSNR=26.2259

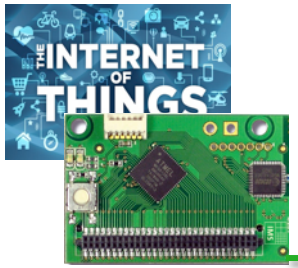

70ms
PSNR=21.9901

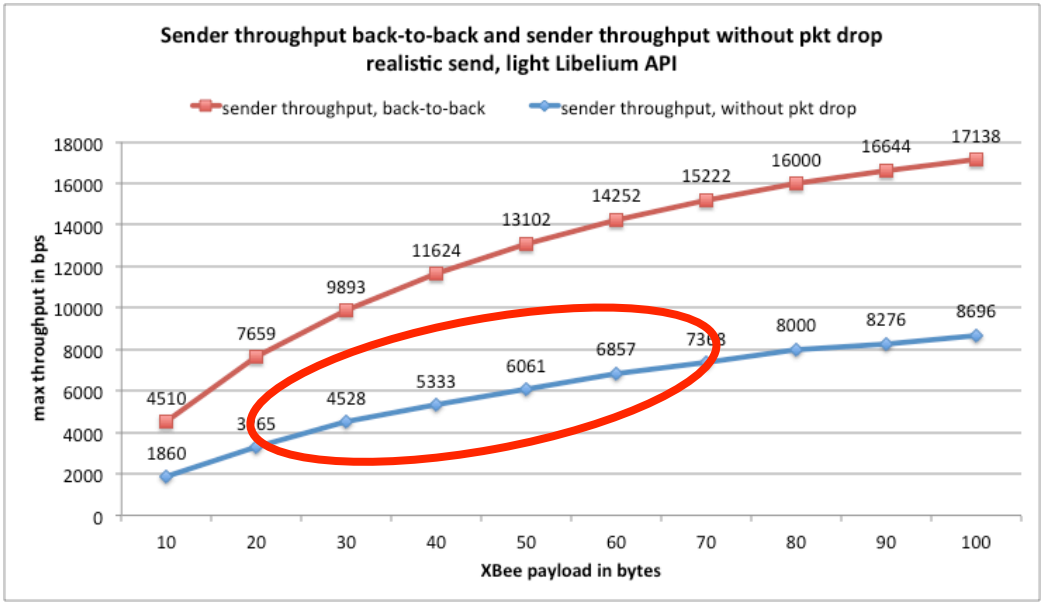
60ms
PSNR=17.265

50ms
PSNR=14.2429



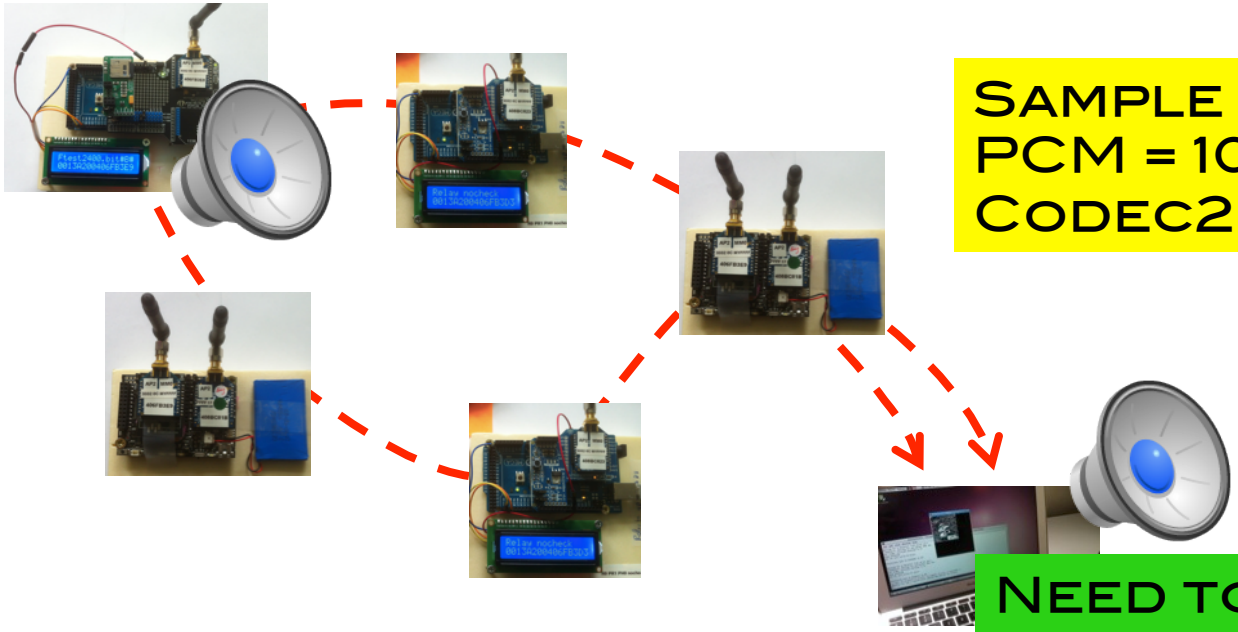
Audio encoding



- Need a really low rate audio encoding scheme
- PCM is 64kbps, GSM 6.1 is 13kbps, can be lowered to 6kbps
- We use an open-source codec
  - codec2: http://codec2.org
  - Can be as low as 1400bps (1600, 2400 and 3400bps available)
  - All encoding/deconding tools are available in code source
  - Encoded file is robust against packet losses

Test on SmartSantander

Some results
Audio Streaming

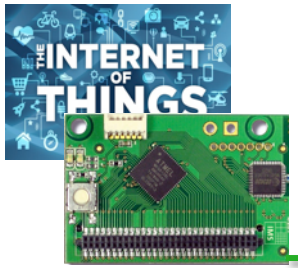


Sample Audio: 13s
PCM = 104000B
Codec2 at 2400 is 3900B

Need to reduce the Packet size to limit Impact of packet losses

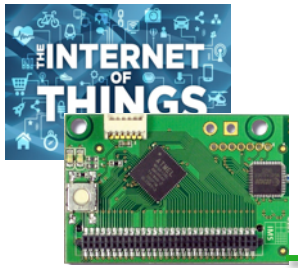
```
> XBeeReceive –B test2400.bit
> c2dec 2400 –B test2400.bit - | play -t raw -r 8000 -s -2 -

> XBeeReceive –B -stdout test2400.bit | bfr -b1k -m2% - |c2dec
2400 - - | play -t raw -r 8000 -s -2 -
```



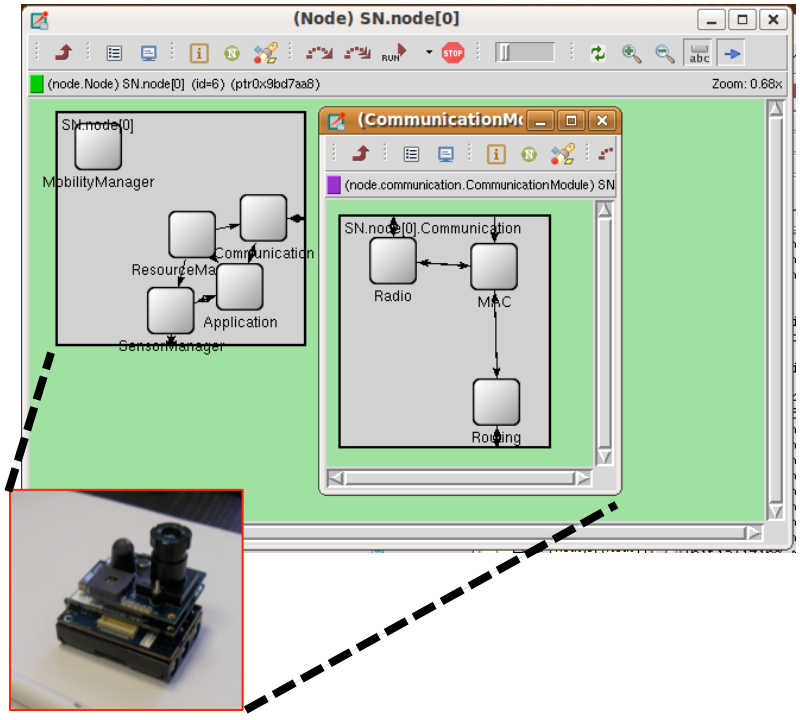
What we've learned?

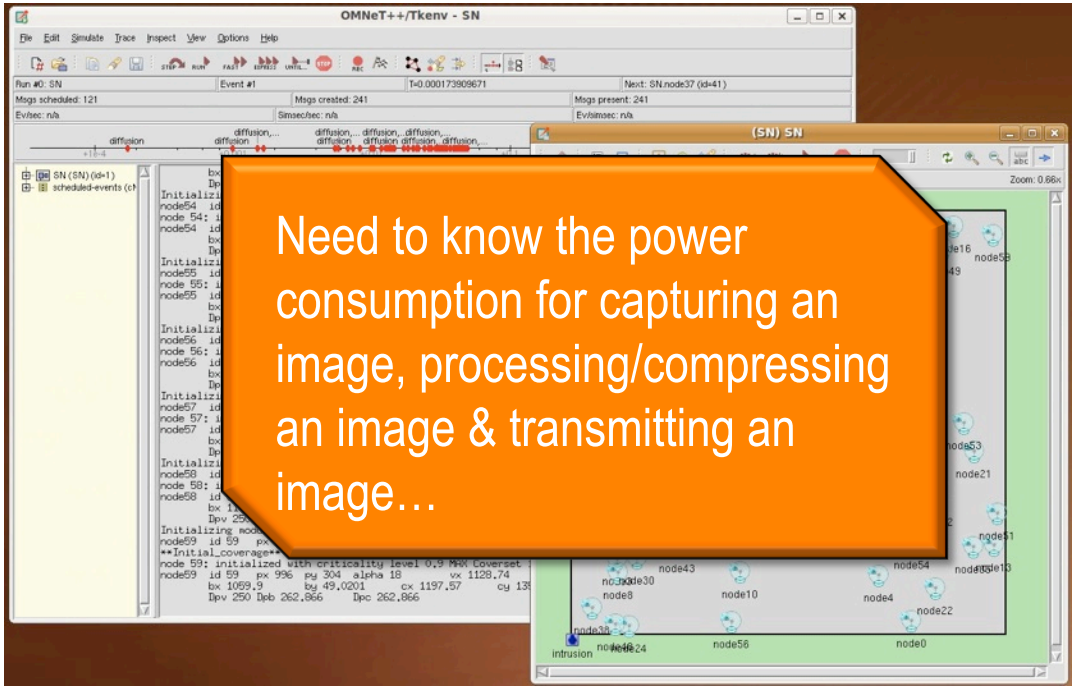
- Image transmission
  - Image transmission is very demanding, latency need to be kept small so buffering is not a solution
  - simultaneous transmissions can be very inefficient, relay capacity are very low
  - Control mechanism should take these issues into account
- Streaming Audio
  - Packet size is important
  - Robustness against packet losses is crucial
  - Sample reconstruction at receiver?

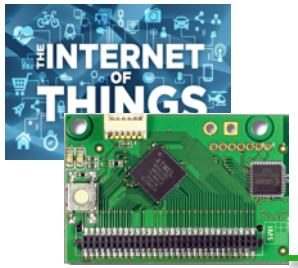


Multimedia sensor simulation model

- Advanced propagation and radio models
- Layered, flexible architecture







Conclusions

- Wireless communication can now be integrated at low-cost to a number of small devices/objects
- Sensor Networks can provide large scale awareness to setup the foundation for AMBIENT INTELLIGENCE to offer new services for SMART SOCIETIES
- Hot topics are multimedia information for enhanced situation-awareness
- Testbed & real experimentations are needed to highlight realistic issues
- Need to propose suitable control mechanisms based on realistic constraints