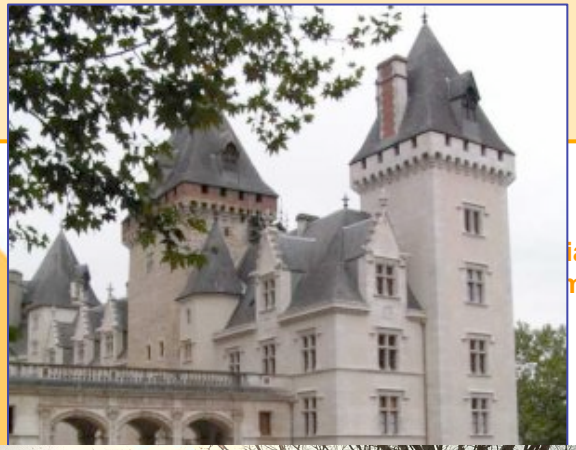
Wireless Sensor Networks and their application to surveillance: towards ambient and cooperative intelligence

Université Gaston Berger
February 15th, 2012
Saint-Louis, Senegal

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

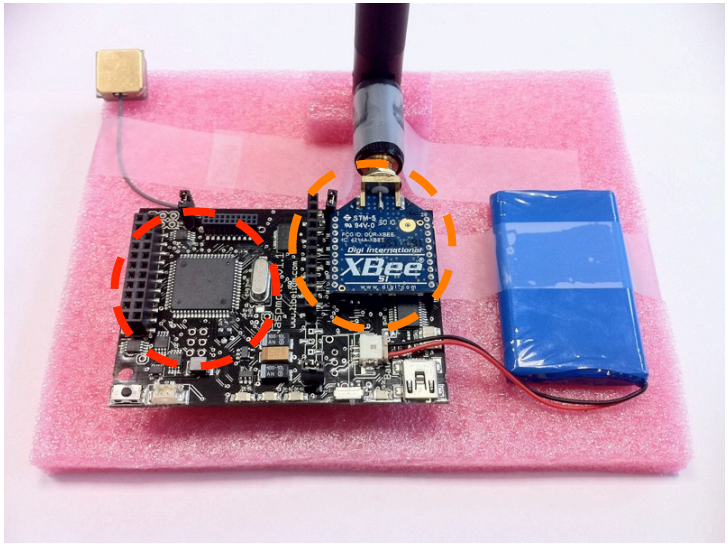
Y OF PAU

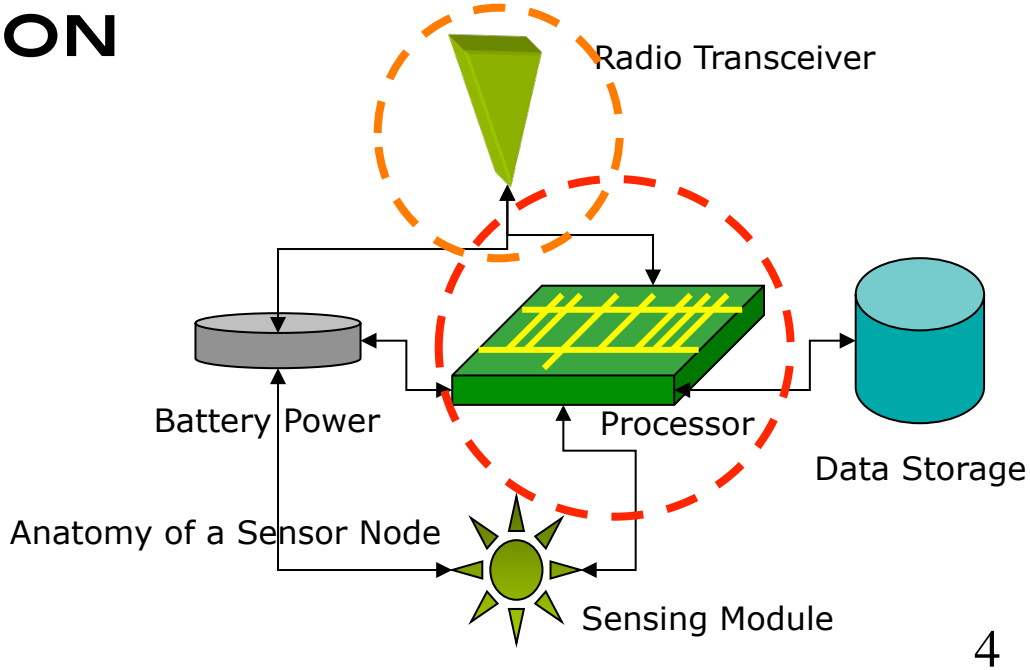


iaporama des
mpus de l'UPPA

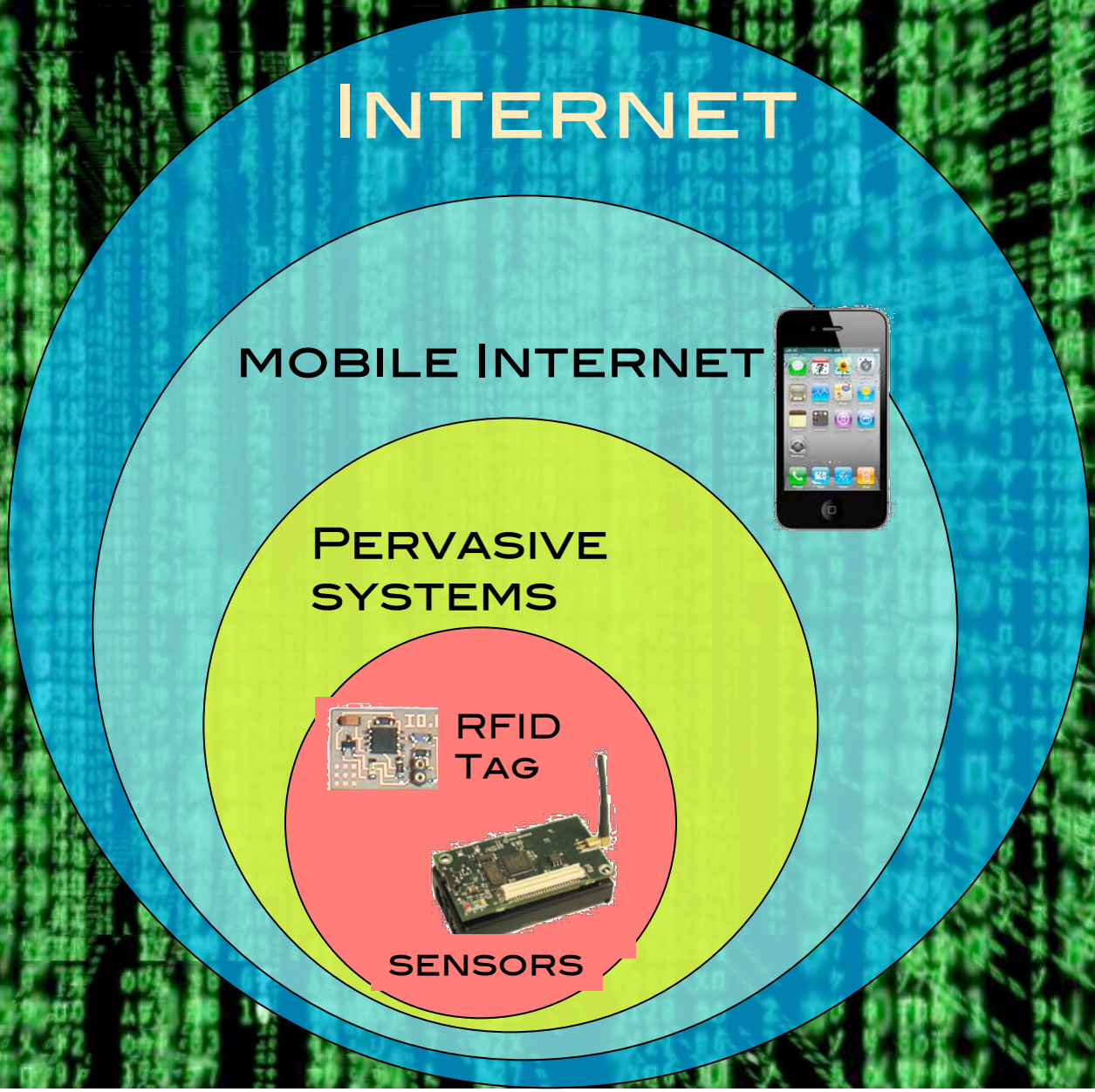
Wireless autonomous sensor

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

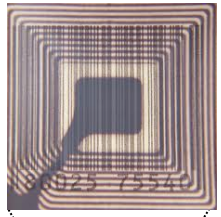


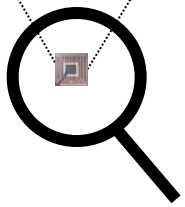


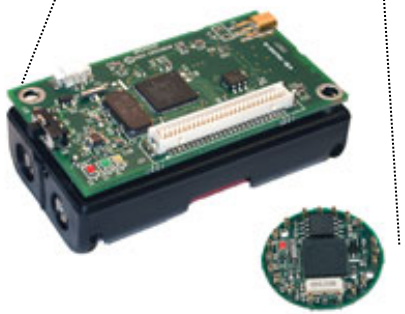
Digital Wireless World



SMALL, SMART DEVICES!







Autonomous sensors and RFID tag can be embedded in various structures or objects of our daily life to enhance localization, tracking and information collection.

From sensing...

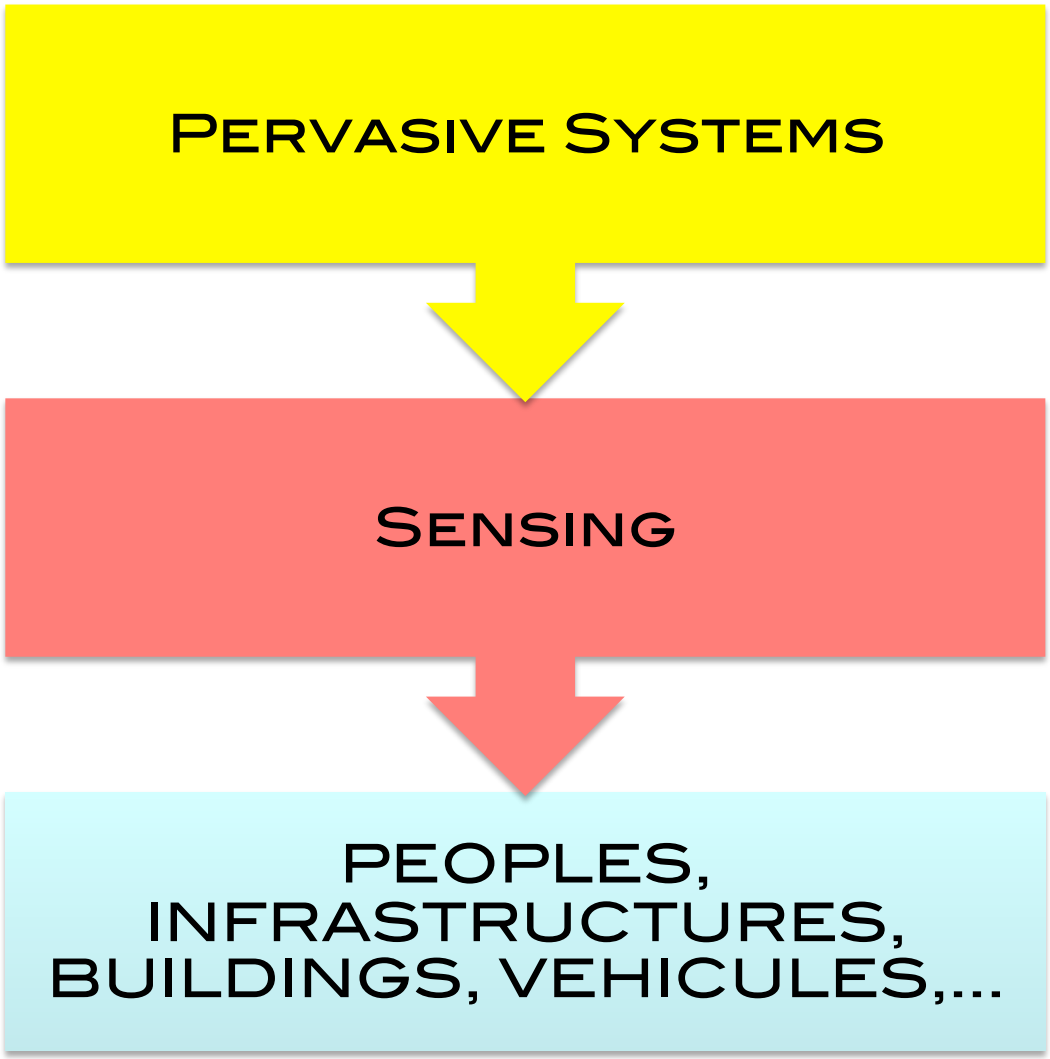
Sensing

...TO DIGITAL SOCIETY...

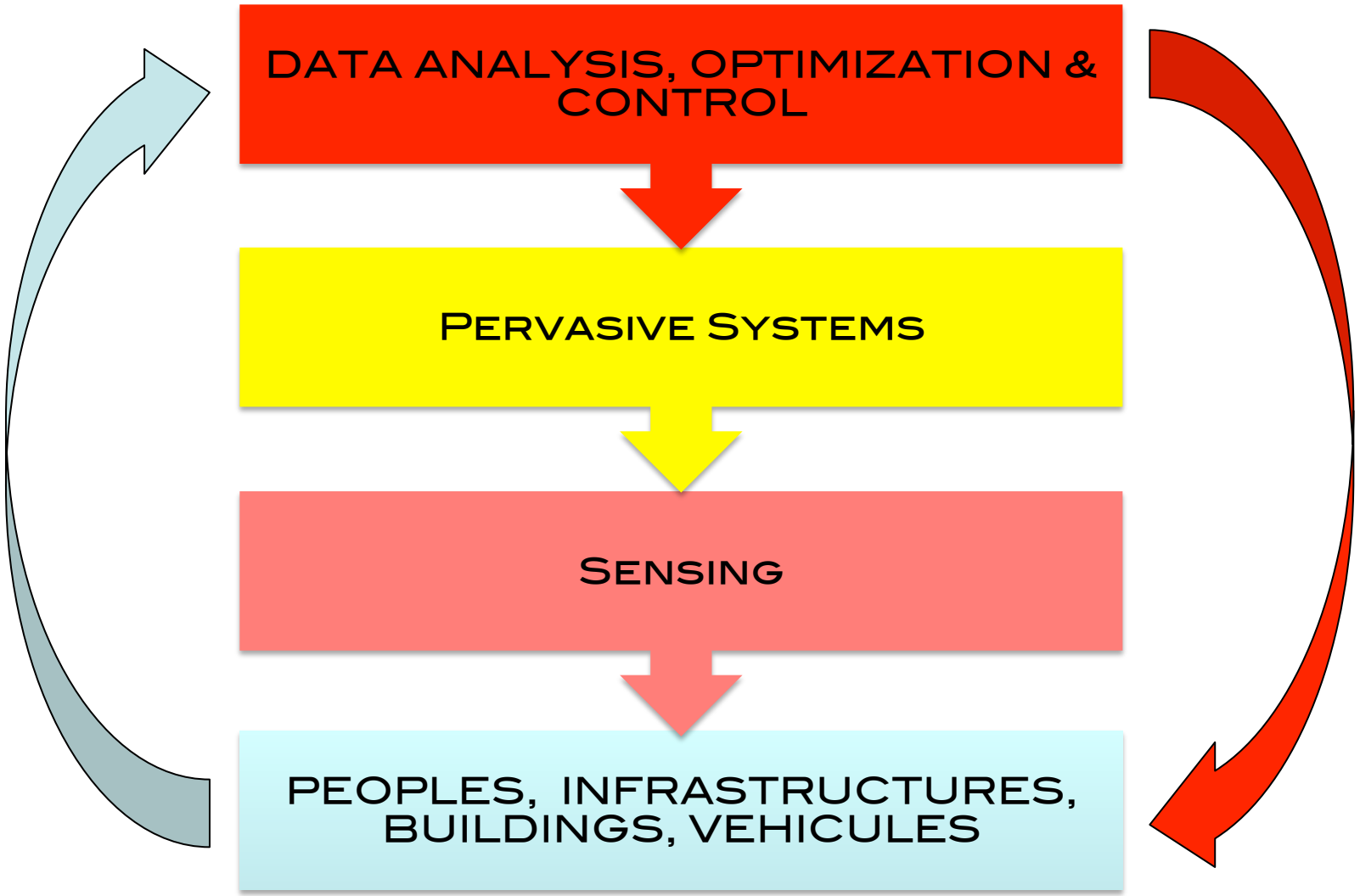
PERVASIVE SYSTEMS

SENSING

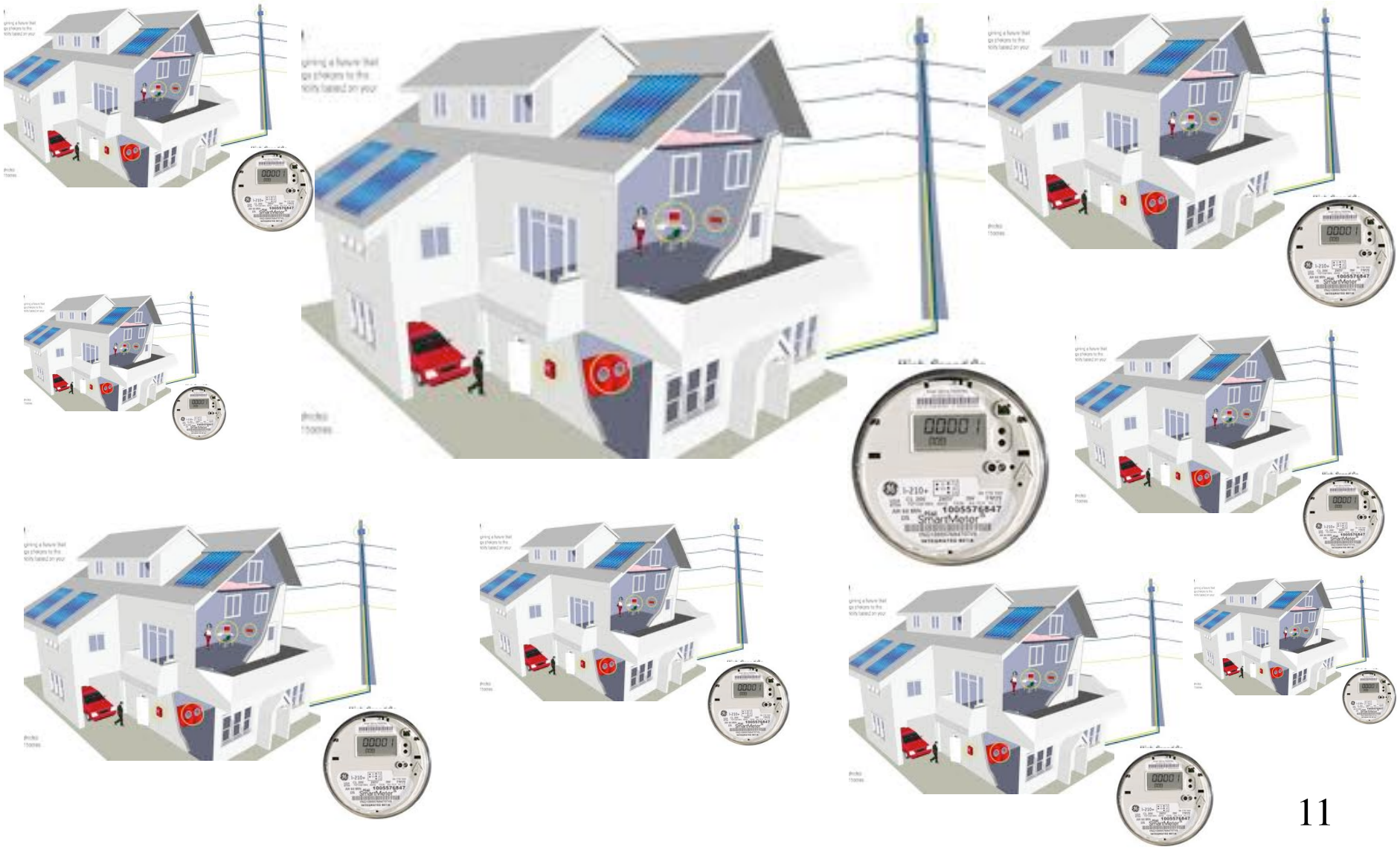
...TO UBIQUITOUS WORLD...



...TO CONTROLLED SYSTEMS.



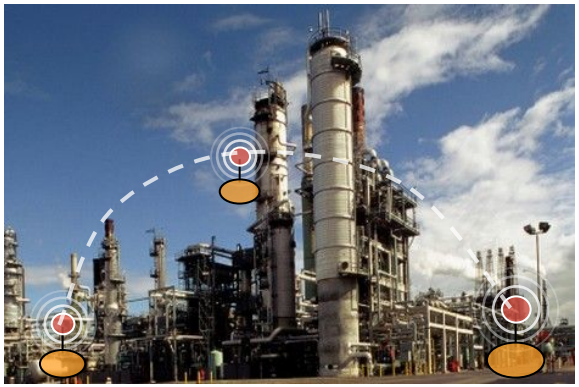
Ex: Smart electricity networks

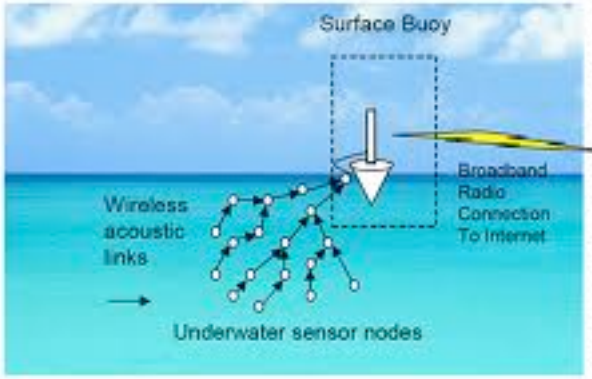


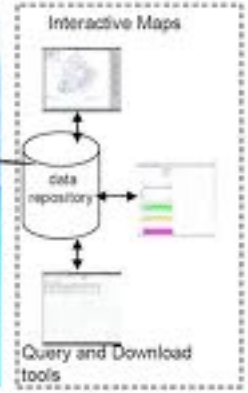
Ex: Smart electricity networks

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

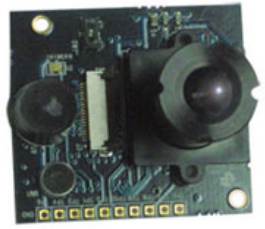




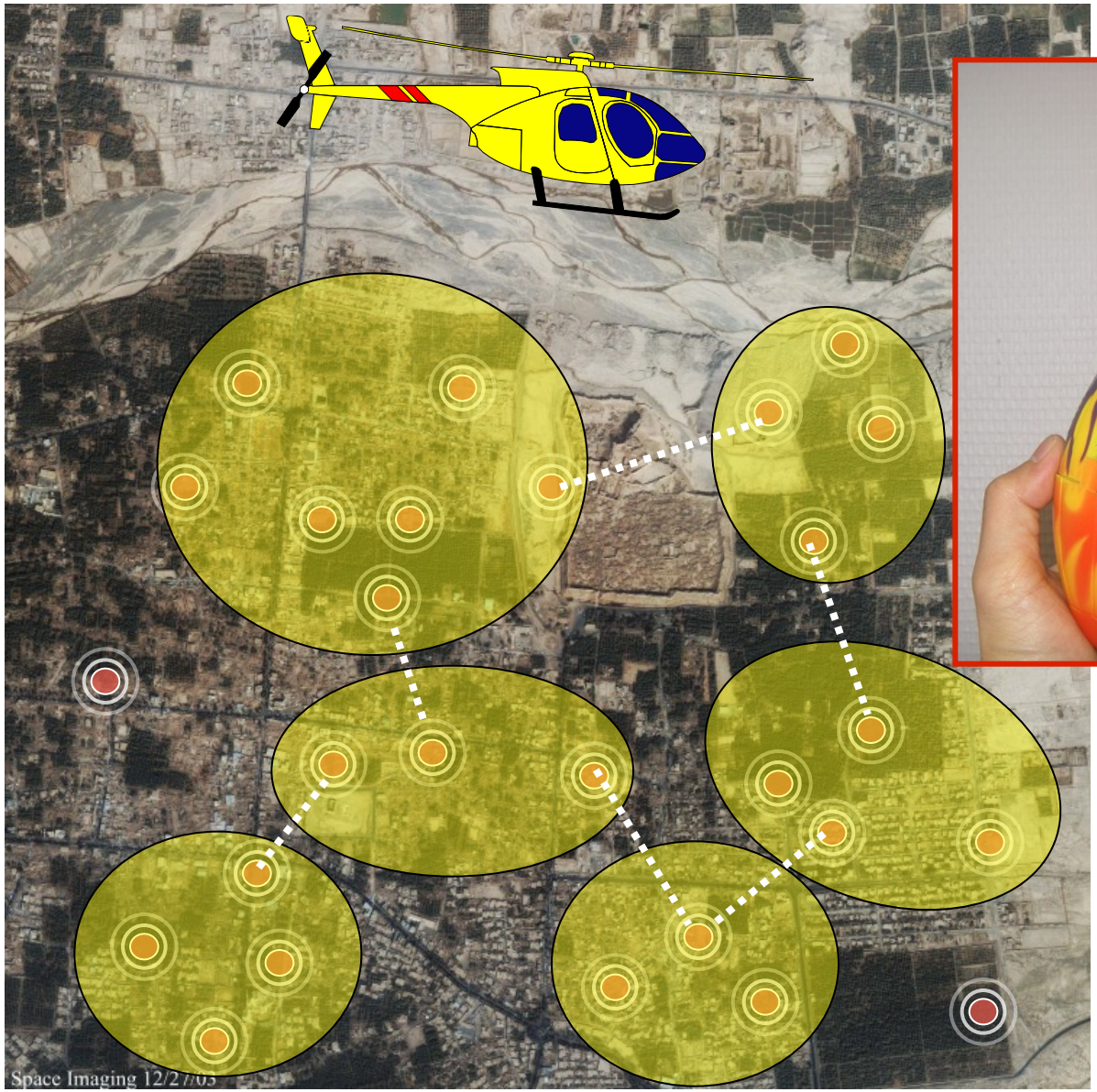


Search&Rescue, security

Imote2

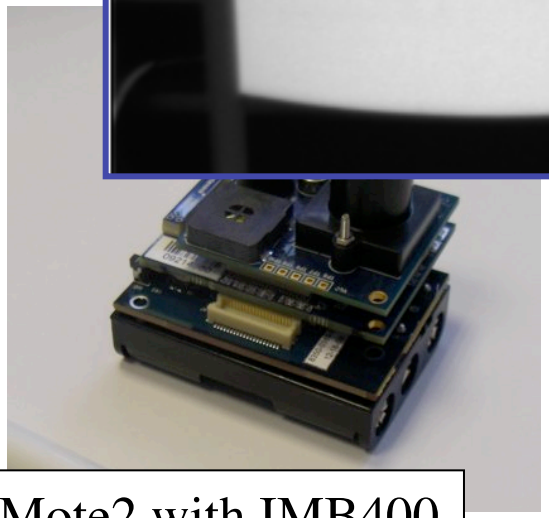


Multimedia board

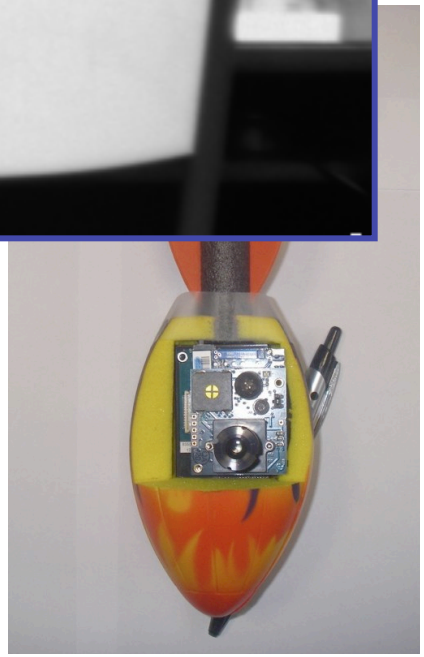


Crossbow motes of our testbed

iMot

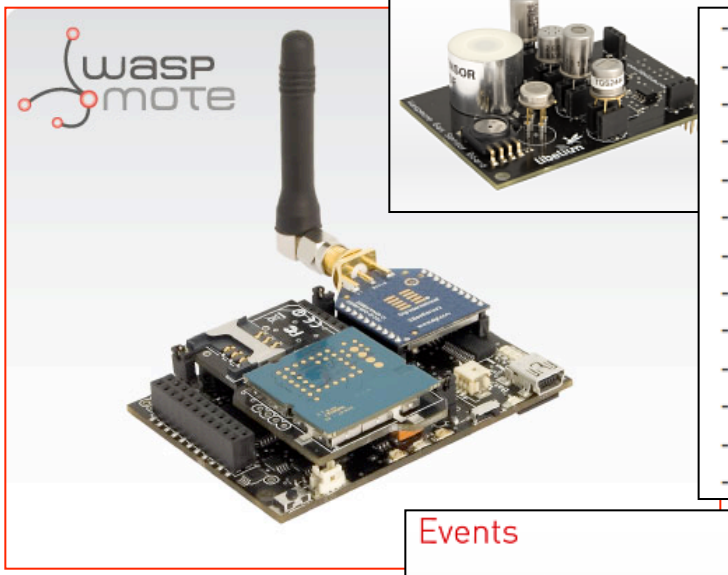


iMote2 with IMB400 multimedia board



libelium
comunicaciones inalámbricas distribuidas

- ATmega1281 microcontroller
- 8K RAM & 1G SD card.
- 2.4GHz IEEE 802.15.4 compatible. RF and GSM/GPRS

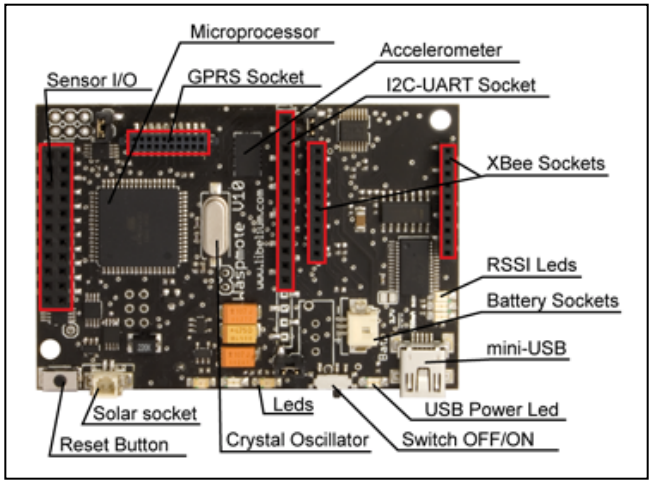


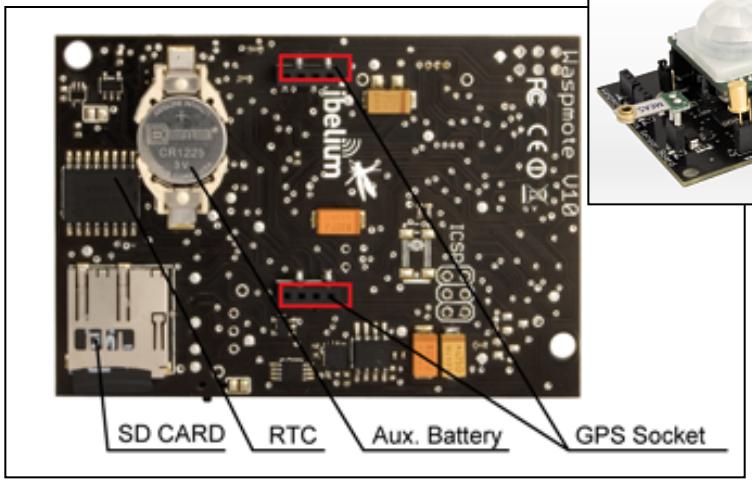
Gases

- 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

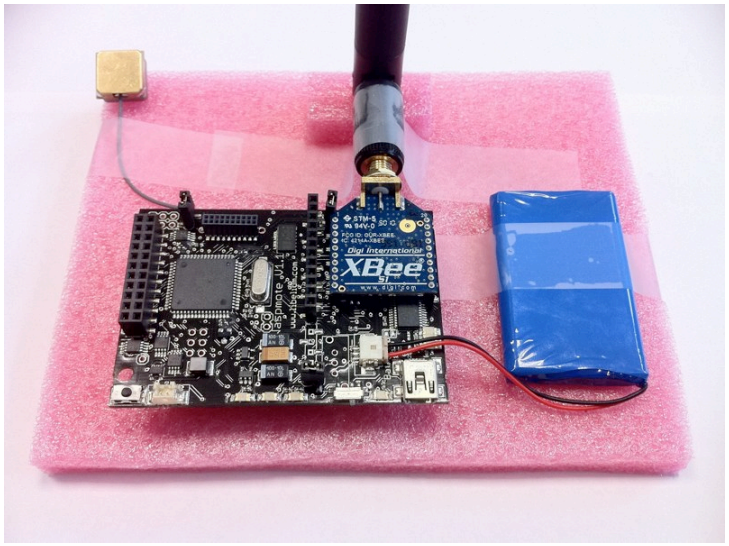
Events

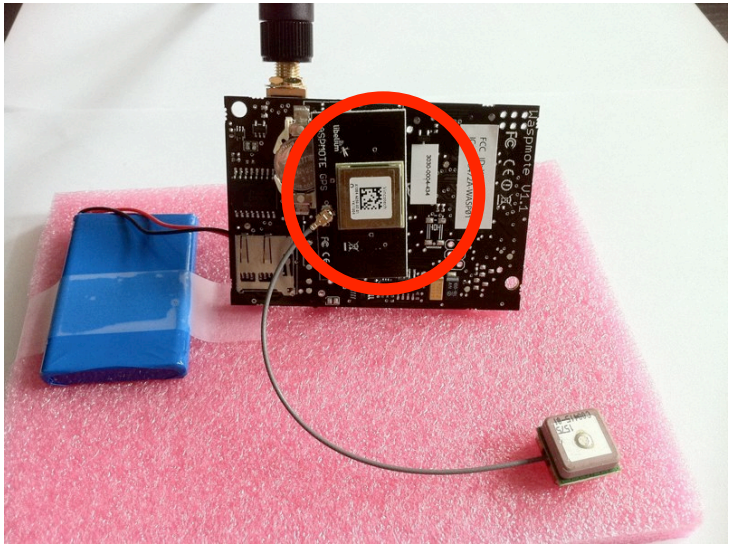
- Pressure/Weight
- Bend
- Vibration
- Impact
- Hall Effect
- Tilt
- Temperature (+/-)
- Liquid Presence
- Liquid Level
- Luminosity
- Presence (PIR)
- Stretch

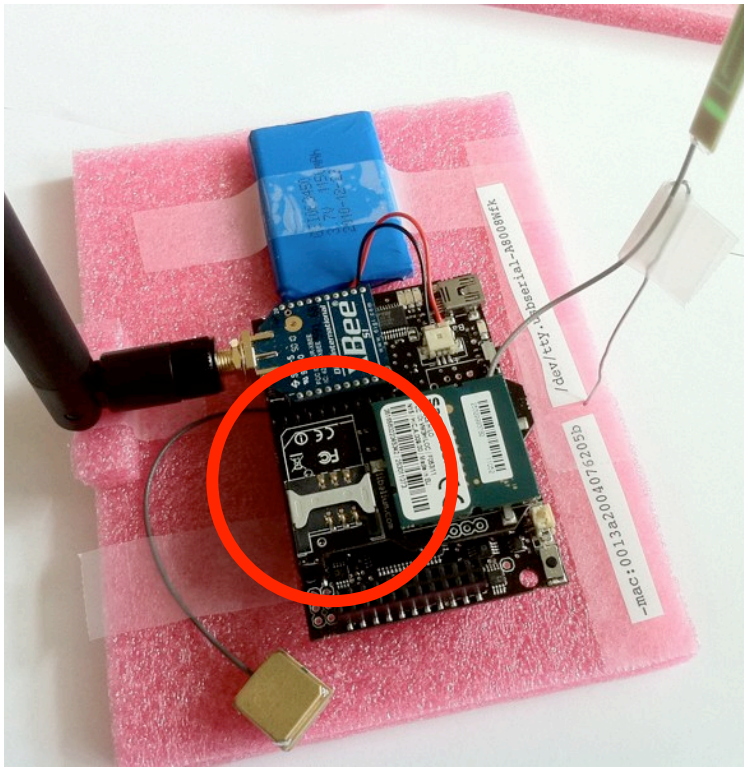




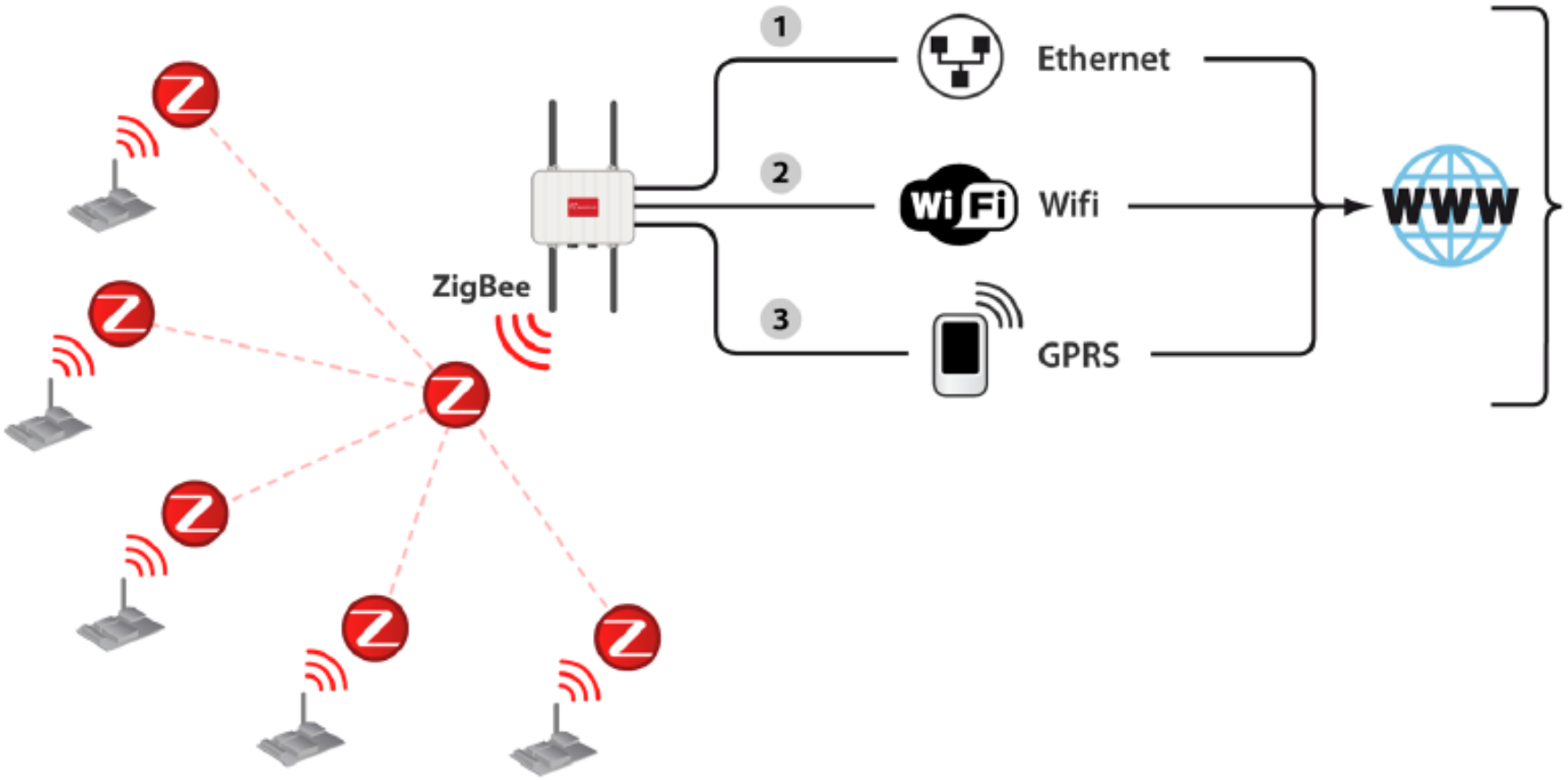
Libelium WaspMote (1)



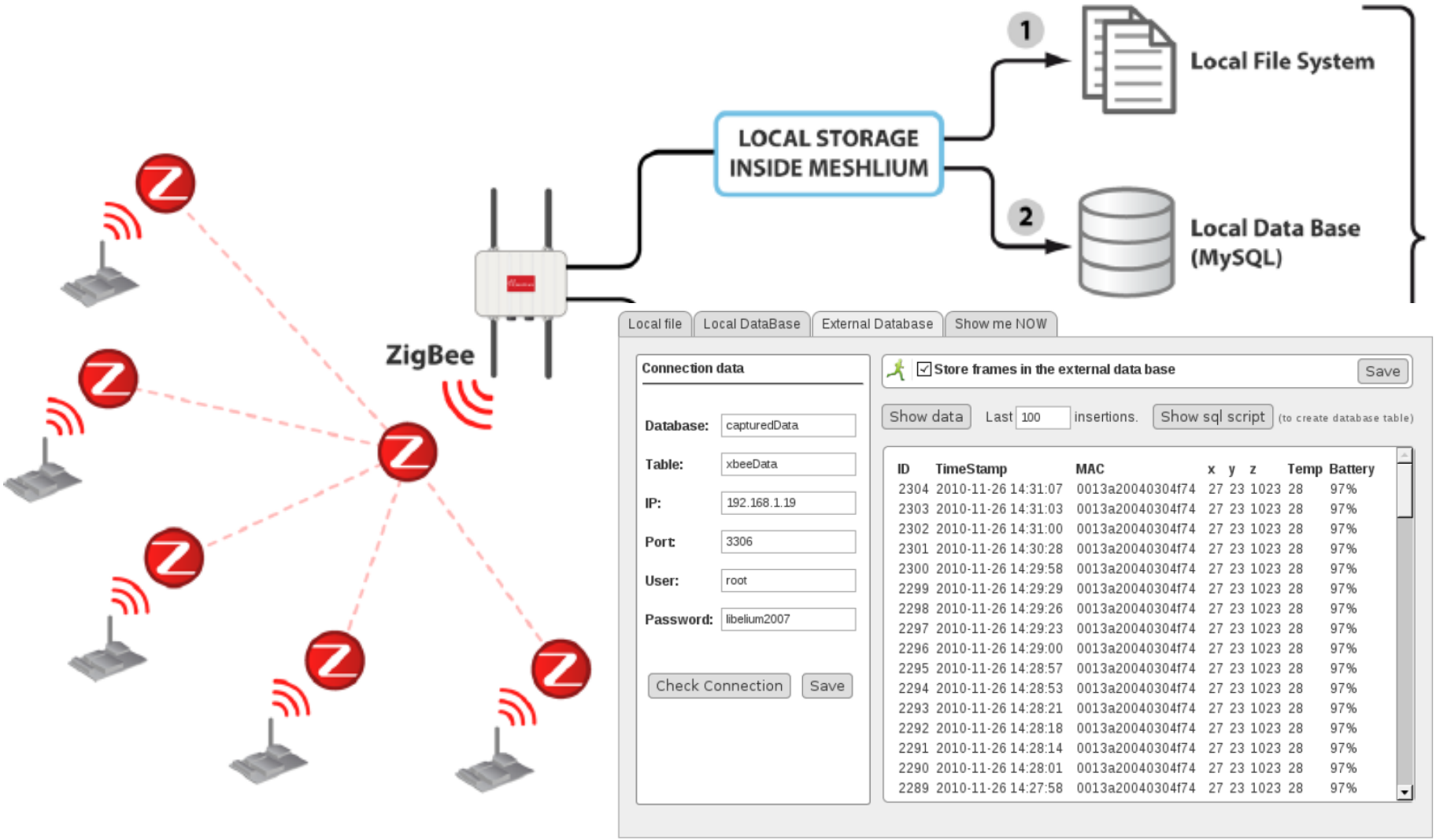




Advanced connectivity



Advanced database features

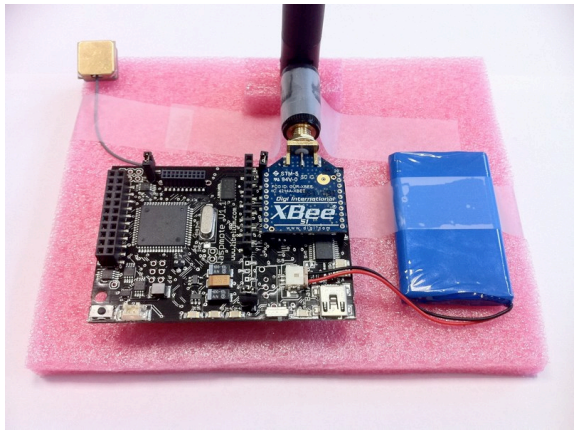


The full testbed

Custom behavior

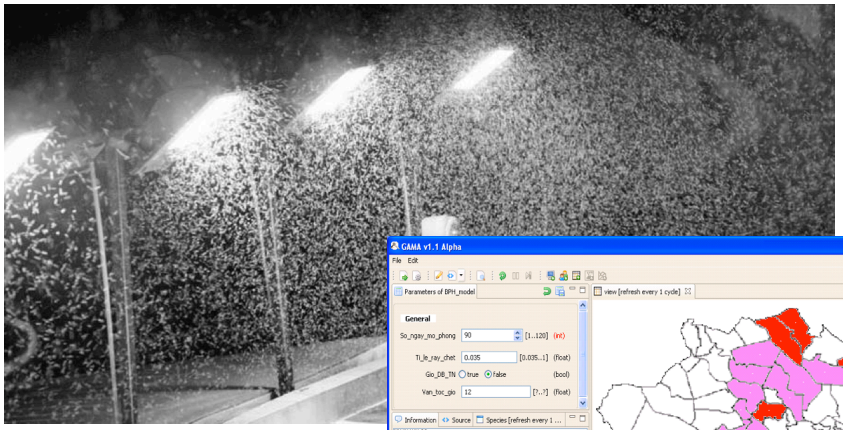
```
void setup()
{
  ACC.ON();
  USB.begin(); // starts u
}
```

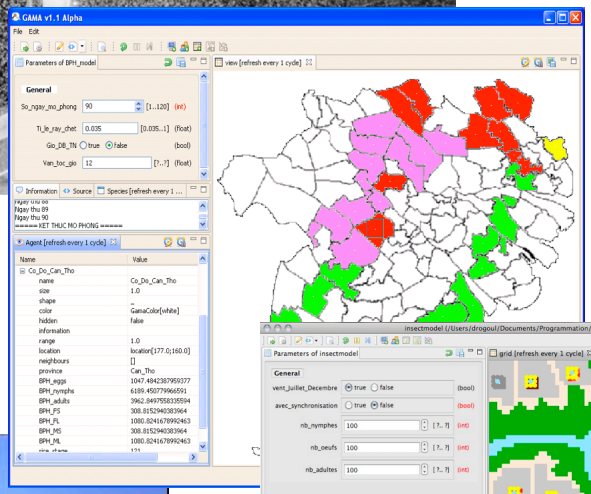
```
void loop()
{

  //----------Check Register-----------------------
  // should always answer 0x3A, it is used to check
  // the proper functionality of the accelerometer
  byte check = ACC.check();

  //----------X Values-----------------------
  int x_acc = ACC.getX();

  //----------Y Values-----------------------
  int y_acc = ACC.getY();

  //----------Z Values-----------------------
  int z_acc = ACC.getZ();

  //------------------------------
```

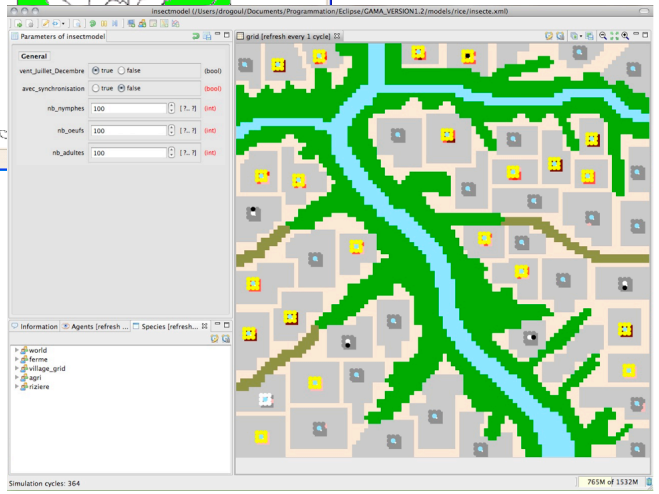


Air quality monitoring

Specific applications

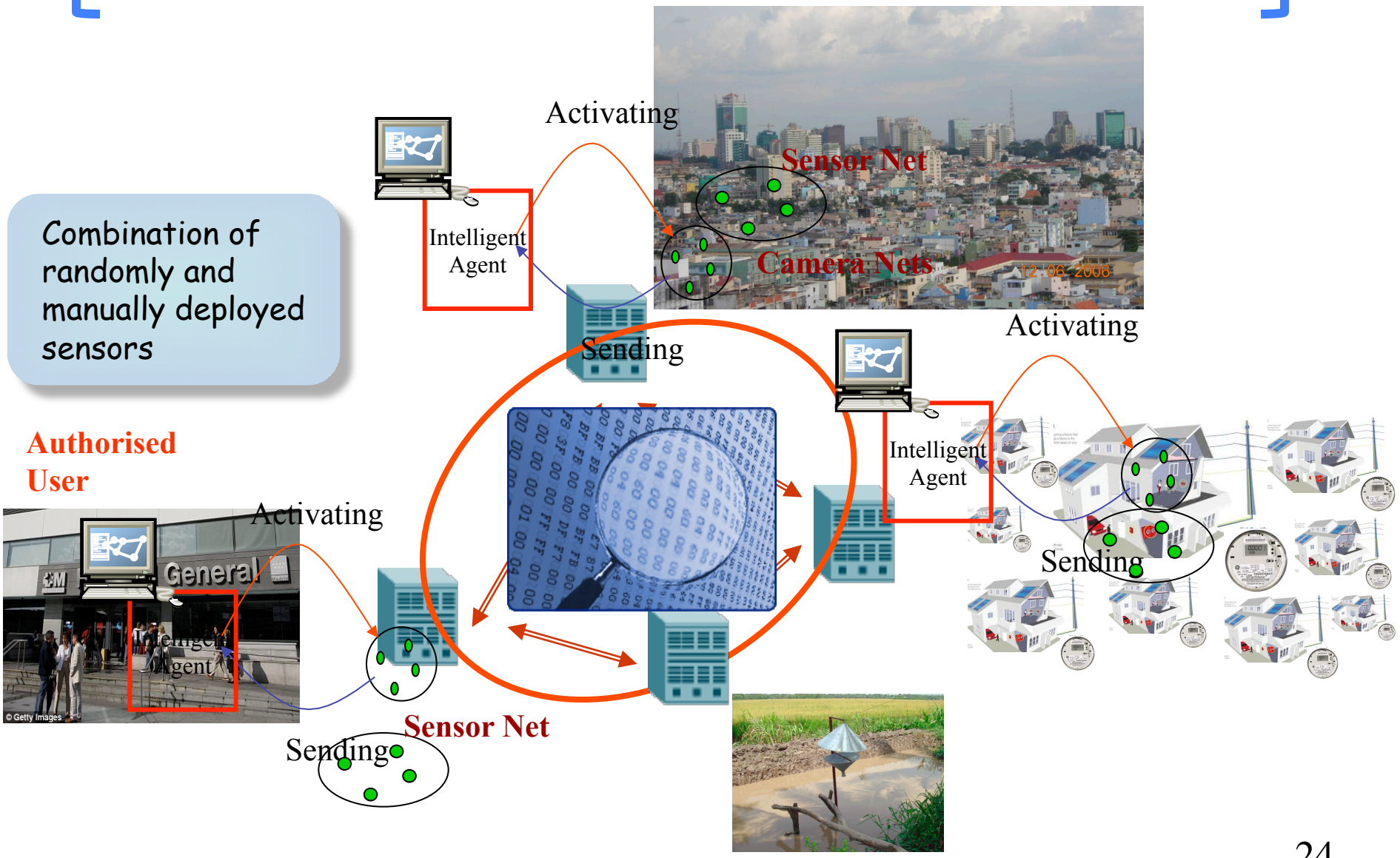






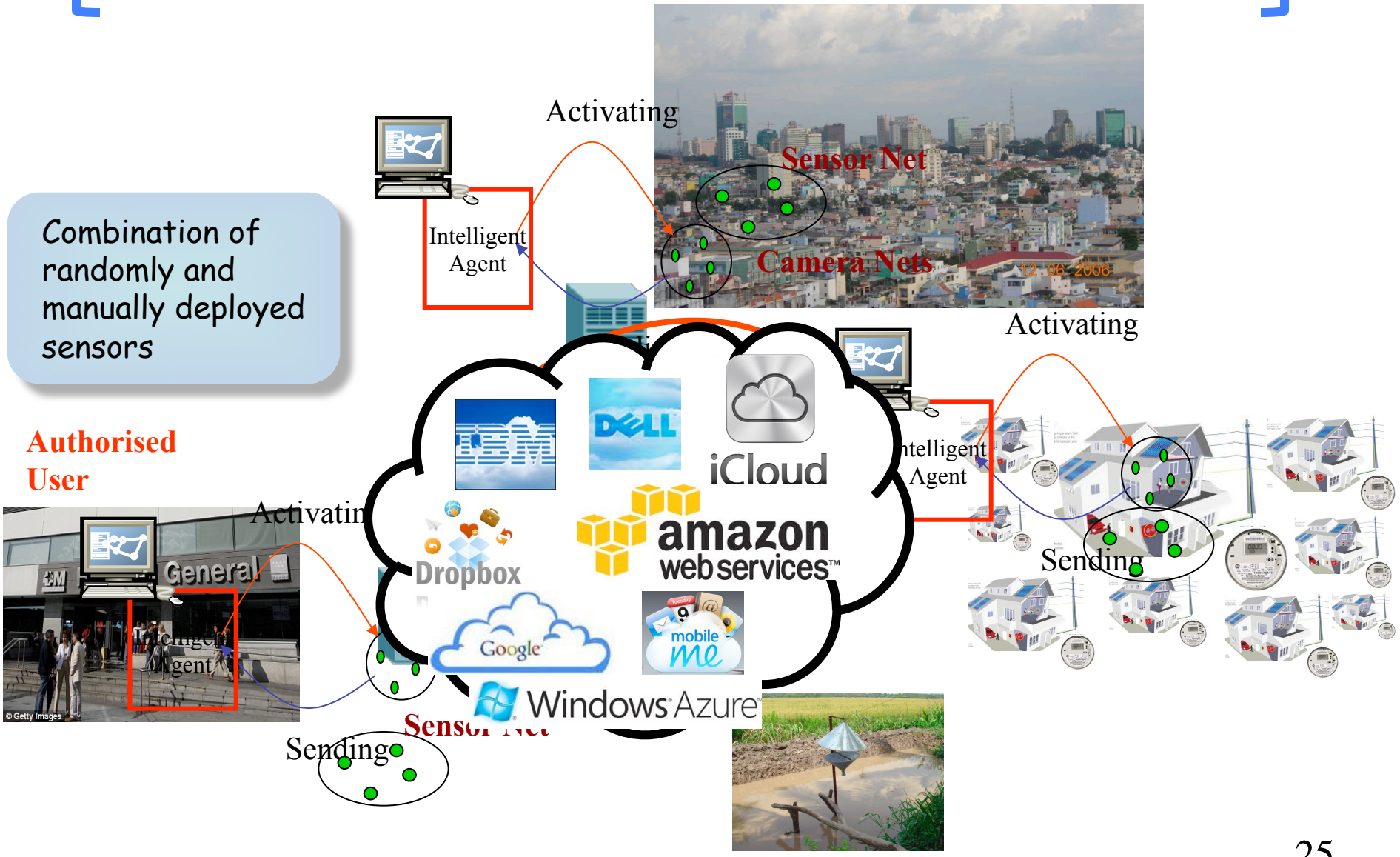
Towards Global Sensing

Combination of randomly and manually deployed sensors

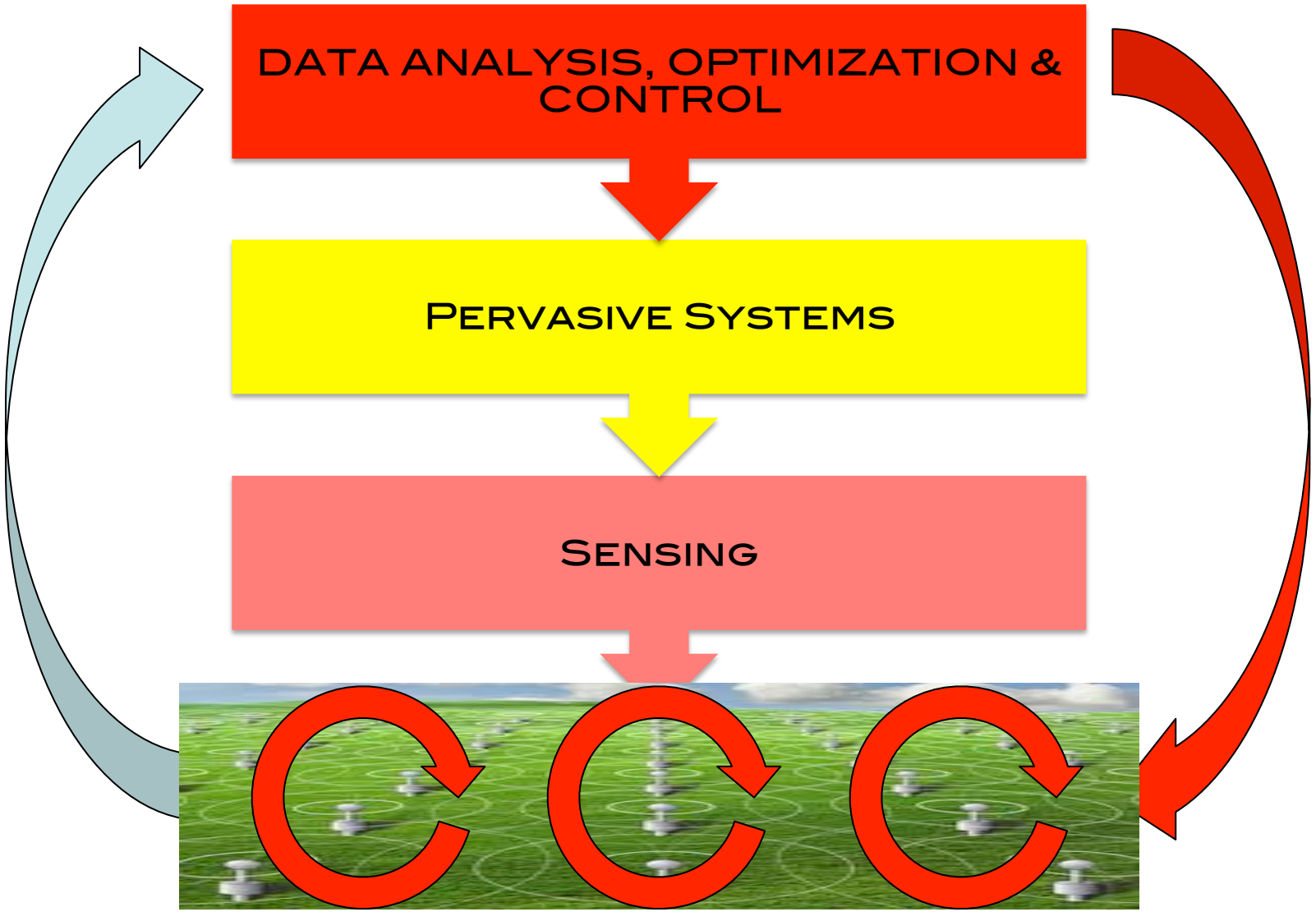


Where Clouds come in!

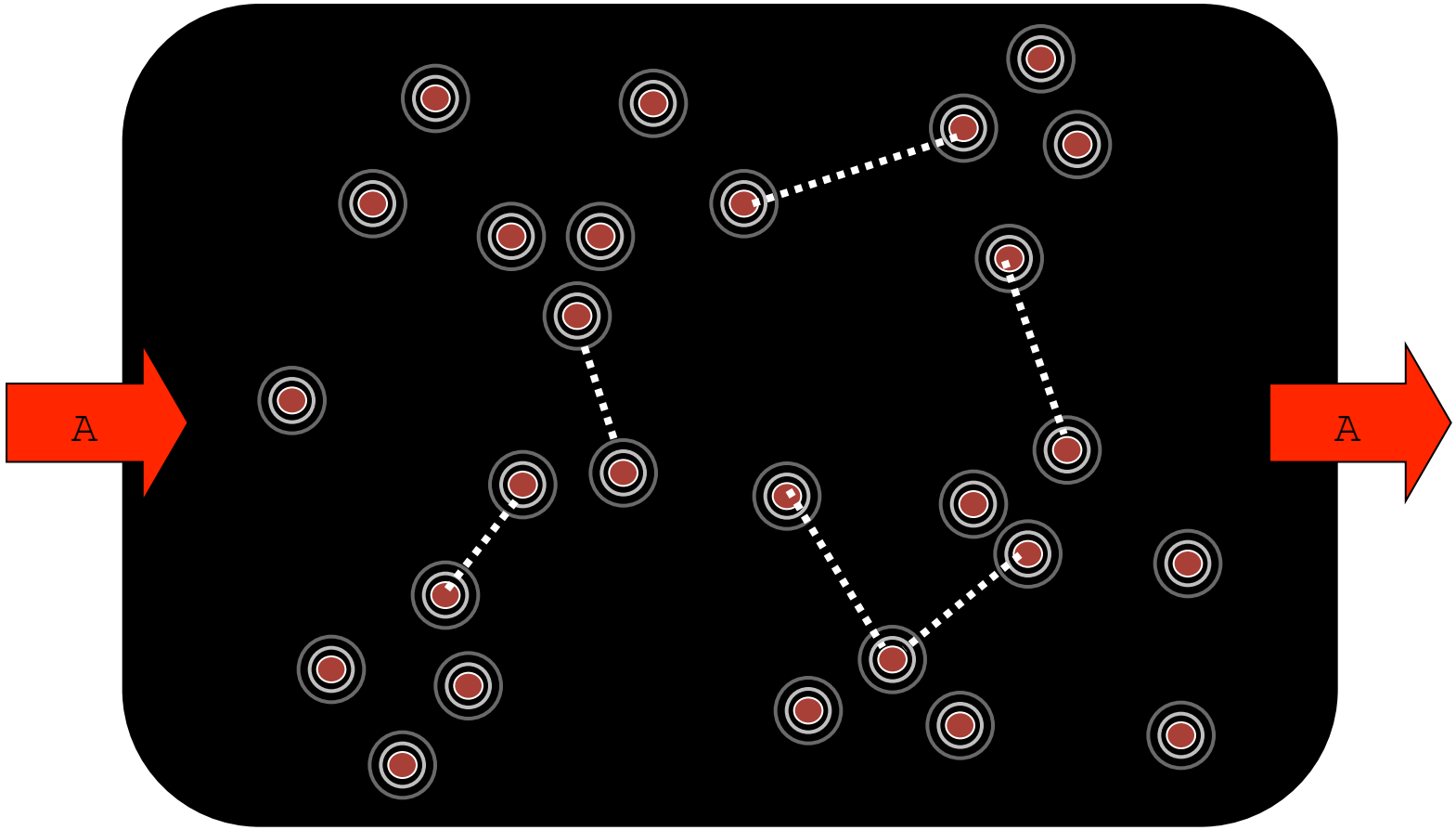
Combination of randomly and manually deployed sensors



Ambient Intelligence?

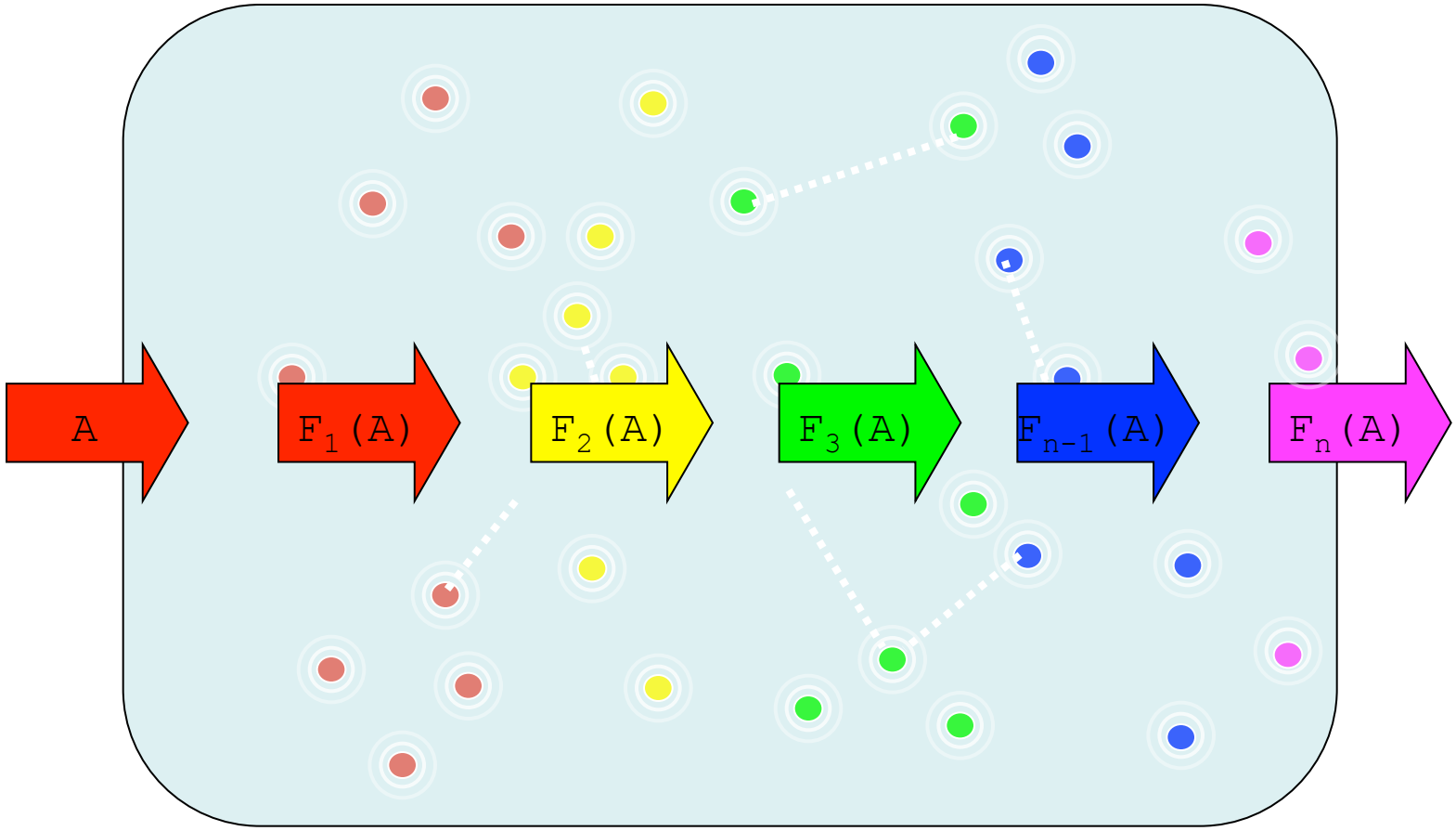


Enabling ambient intelligence (1)



FROM A BLACK-BOX VISION…

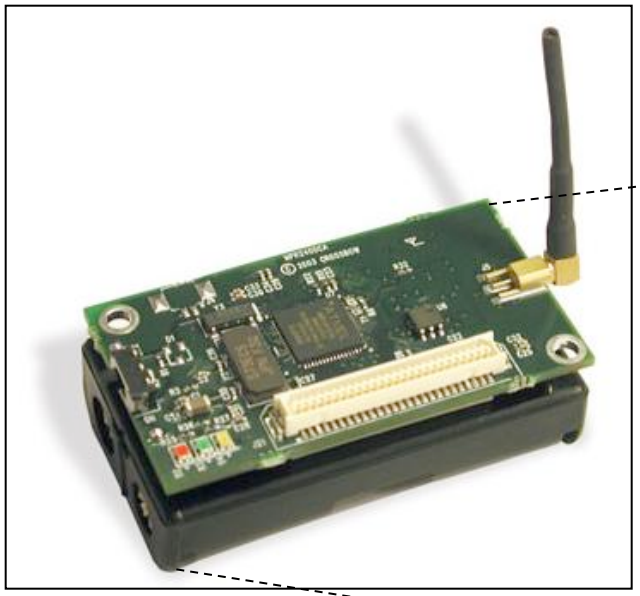
Enabling ambient intelligence (2)

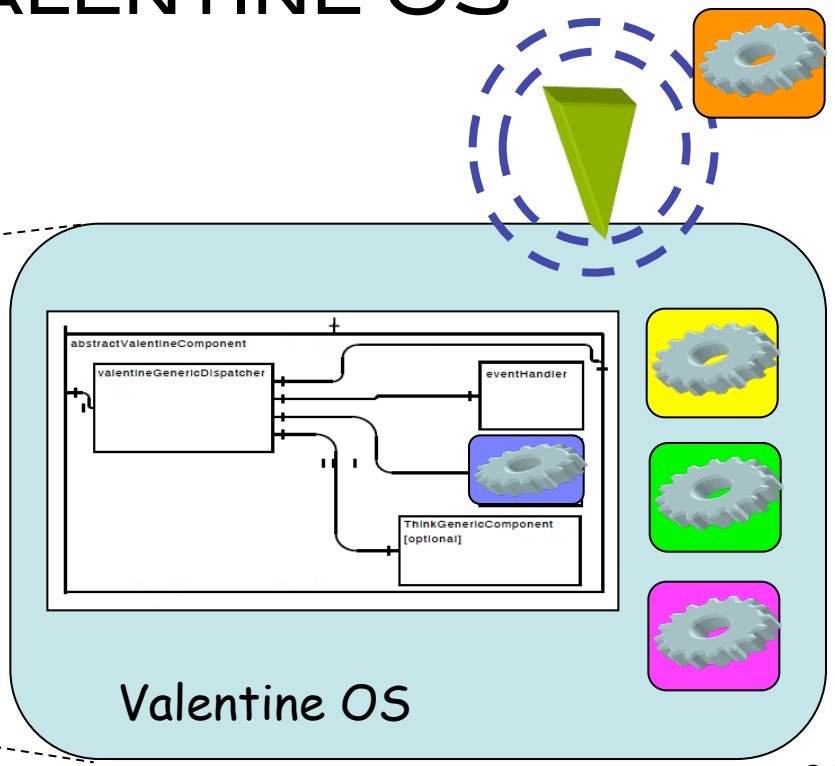


…TO A DYNAMIC, ADAPTIVE BEHAVIOR

Dynamic reconfiguration

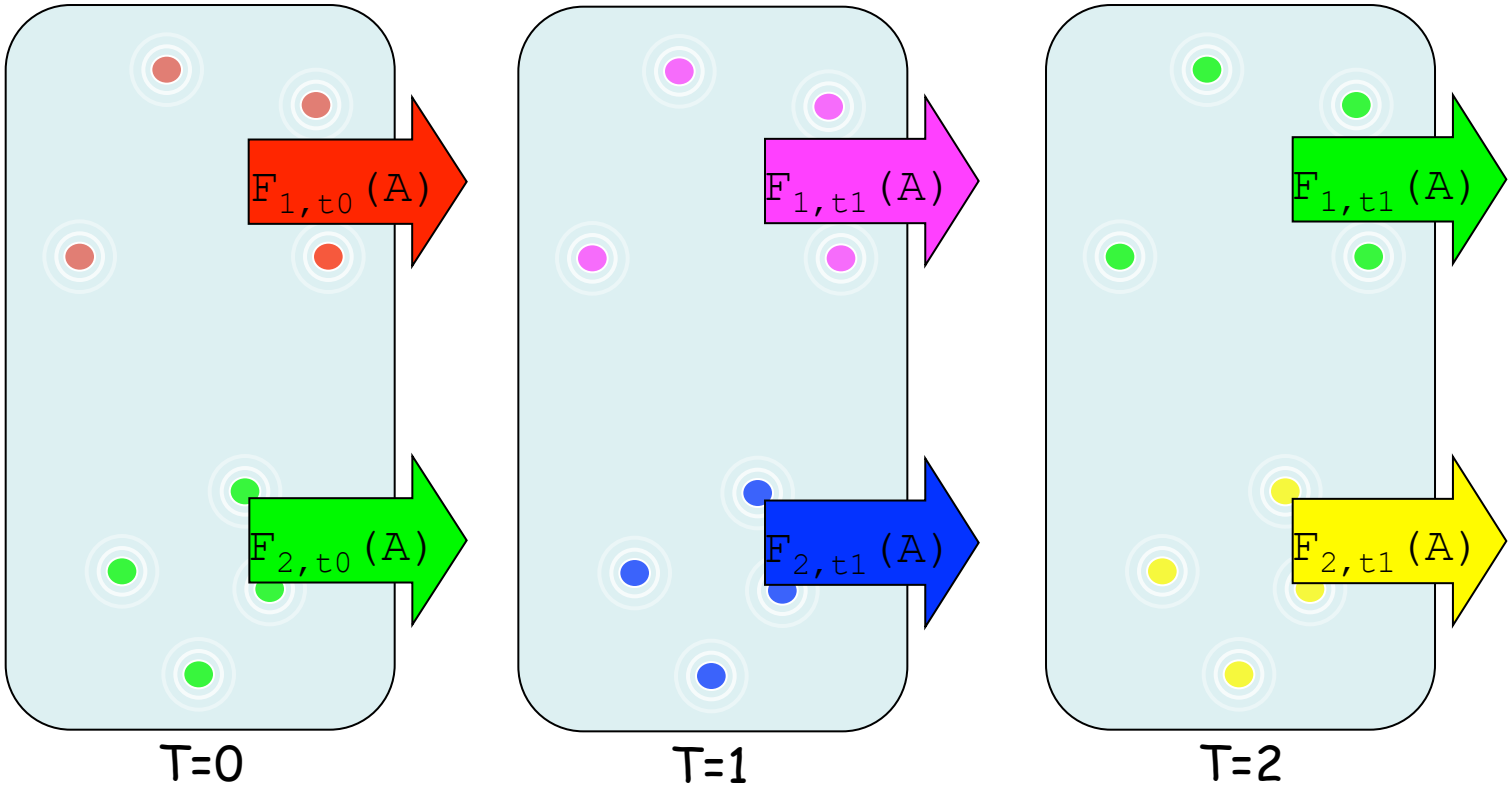
- Target platform: MicaZ
- Extension of the Think generic components ➔Valentine OS





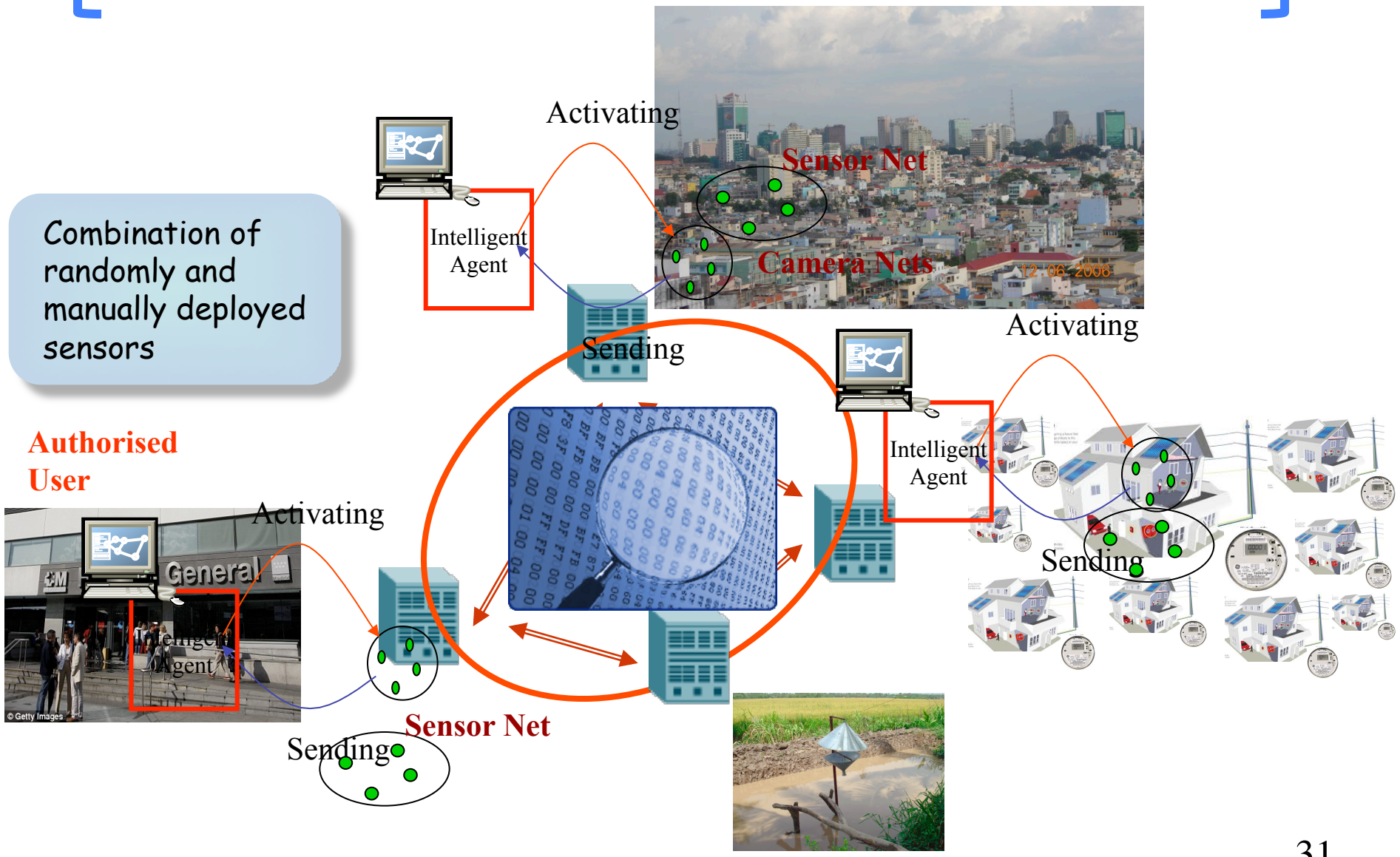
Towards Service Oriented Architecture

- Fast reconfiguration enables dynamic and on-the-fly new services deployment

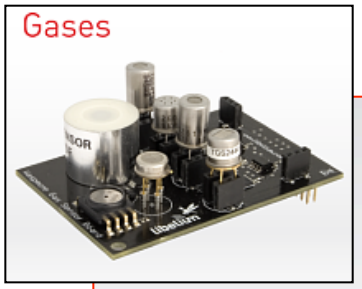


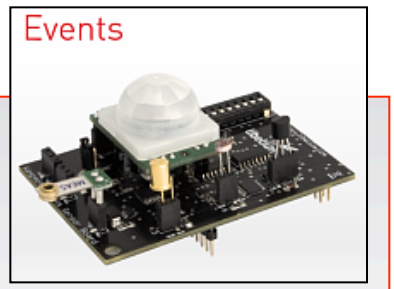
Cooperative intelligence?

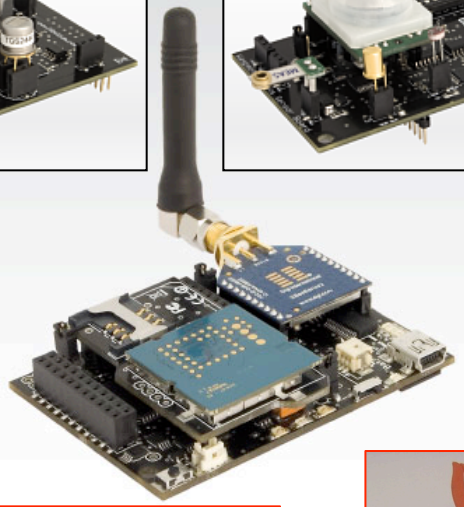
Combination of randomly and manually deployed sensors

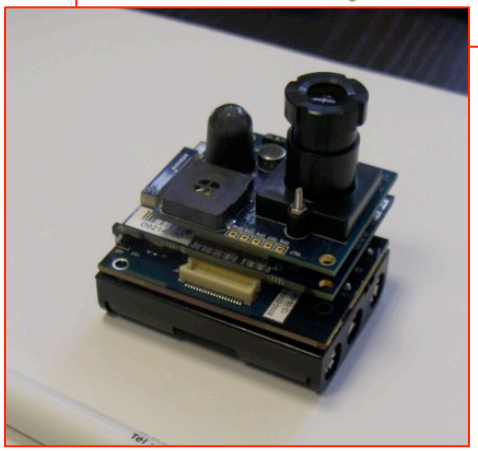


Challenging cooperation implies differences!



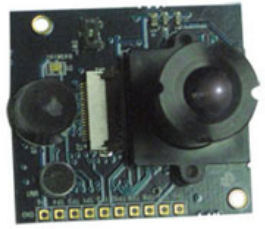




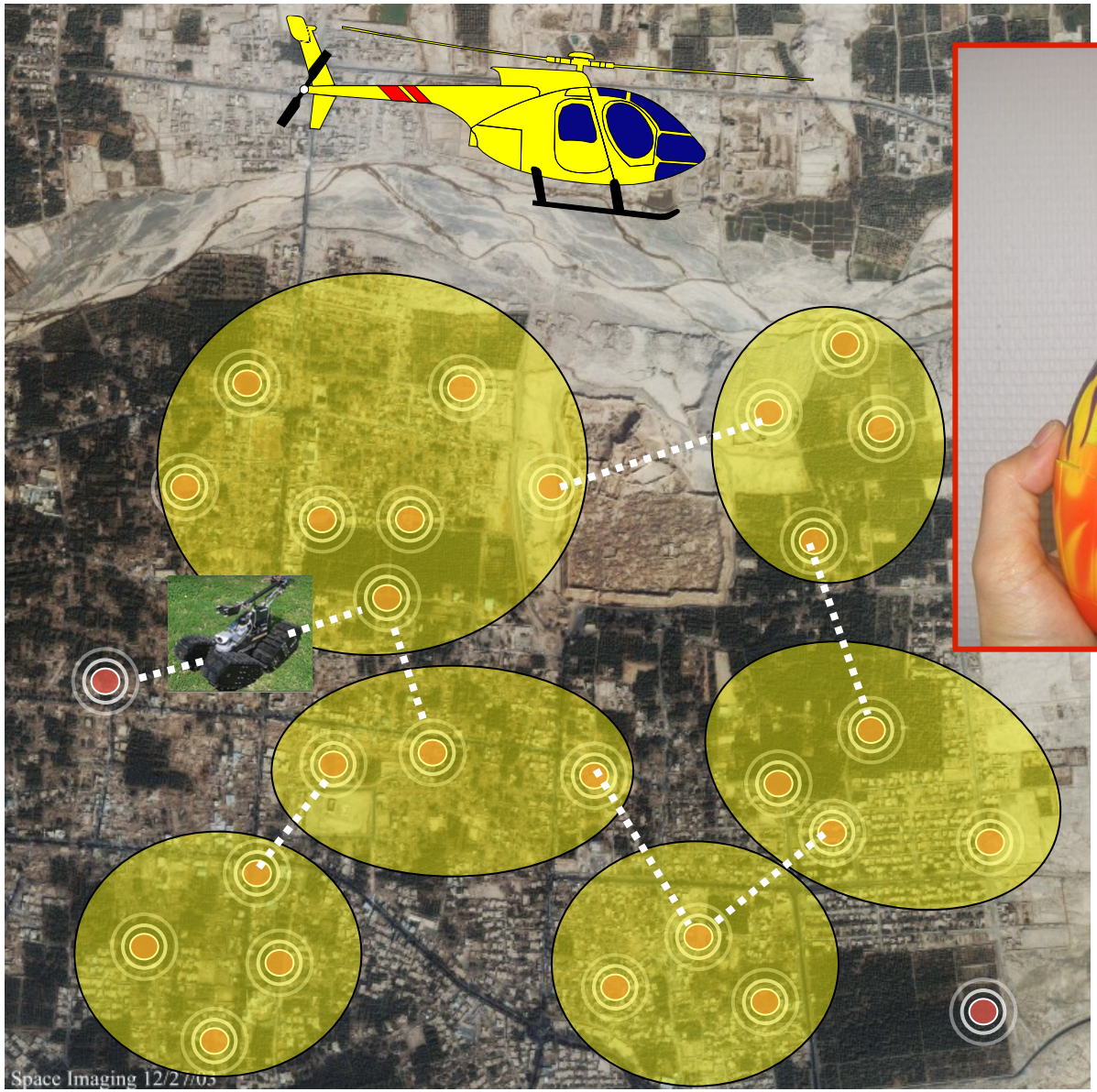


Robot's mobility to preserve connectivity

Imote2



Multimedia board



Sensor & Robots Search & Rescue

- Rescue could be operated in several phases (1)

Deploy in mass a WSN to get a first snapshot of the situation: images, radiation level, targets,…

Sensor & Robots Search & Rescue

- Rescue could be operated in several phases (2)

Based on collected data, optimize deployment/ selection of autonomous robots

Sensor & Robots Search & Rescue

- Rescue could be operated in several phases (3)

Robots could serve as relay or install communication gateways to maintain WSN connectivity and increase data storage capability

Sensor & Robots Search & Rescue

- Rescue could be operated in several phases (4)

Sensor & Robots will contineously collaborate during the rescue process: localization, path optimization, remote sensing,…

Criticality and risk-based scheduling

Basic approach: PM2HW2N/ACM MSWIN 2009
Current approach: IEEE WCNC2010
With intrusion detection results: IEEE RIVF2010
With re-inforcement: IEEE ICDCN2011
Journal paper in JNCA, Elsevier

Don't miss important events!

Whole understanding of the scene is wrong!!!

What is captured

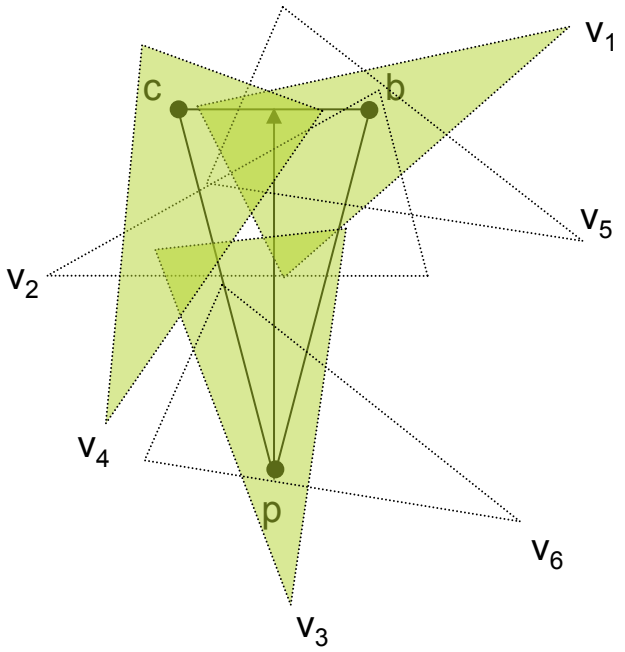
How to meet surveillance app's criticality

- Capture speed can be a « quality » parameter
- Capture speed for node v should depend on the app's criticality and on the level of redundancy for node v
- v's capture speed can increase when as v has more nodes covering its own FoV - cover set

Node's cover set

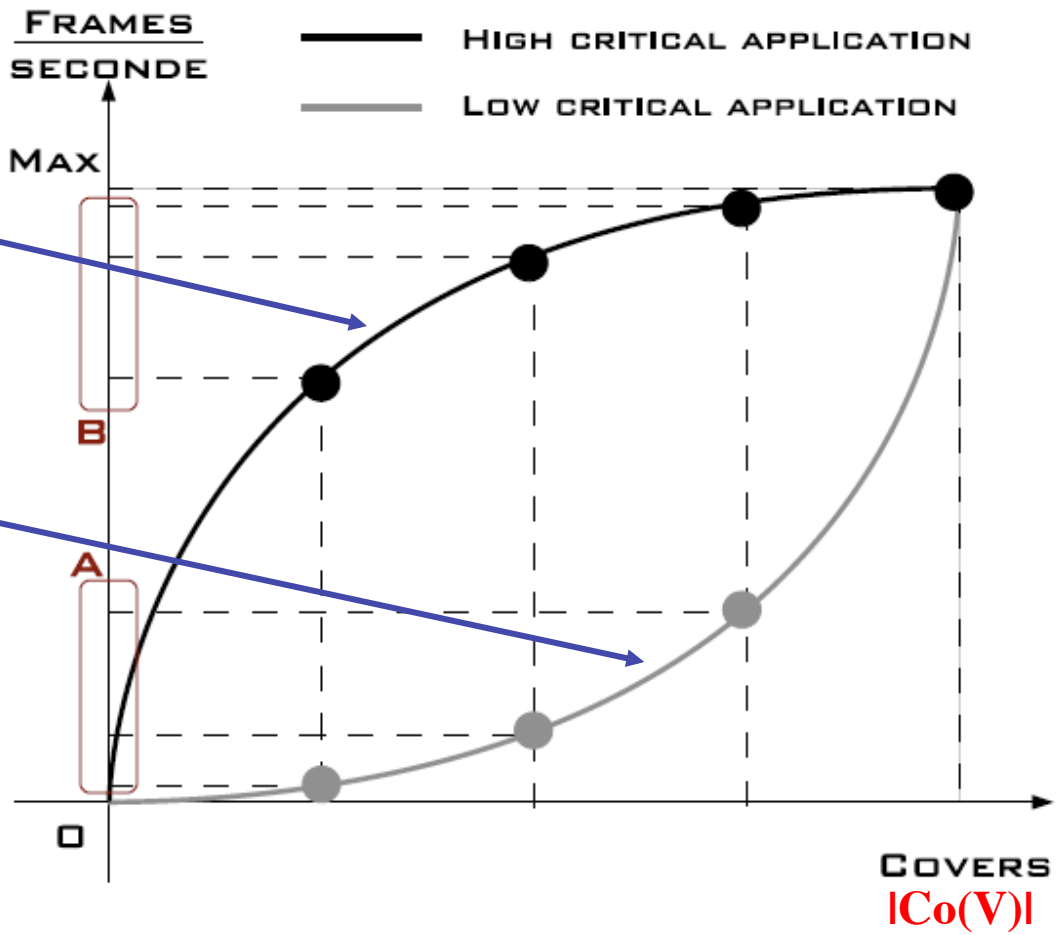
Co(V)= {
{V },
{V_1, V_3, V_4},
{V_2, V_3, V_4},
{V_3, V_4, V_5},
{V_1, V_4, V_6},
{V_2, V_4, V_6},
{V_4, V_5, V_6}
}

|Co(V)| = 7



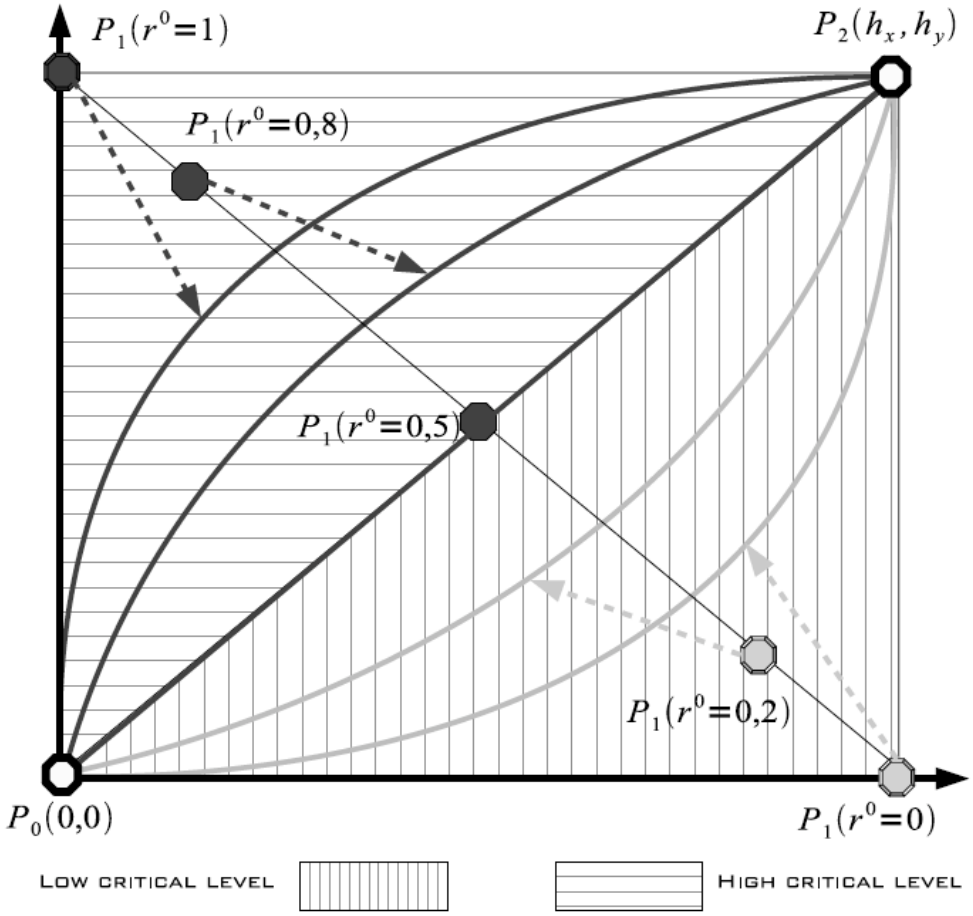
Criticality model (1)

- Link the capture rate to the size of the cover set
- High criticality
  - Convex shape
  - Most projections of X are close to the max capture speed
- Low criticality
  - Concave shape
  - Most projections of X are close to the min capture speed
- Concave and convex shapes automatically define sentry nodes in the network



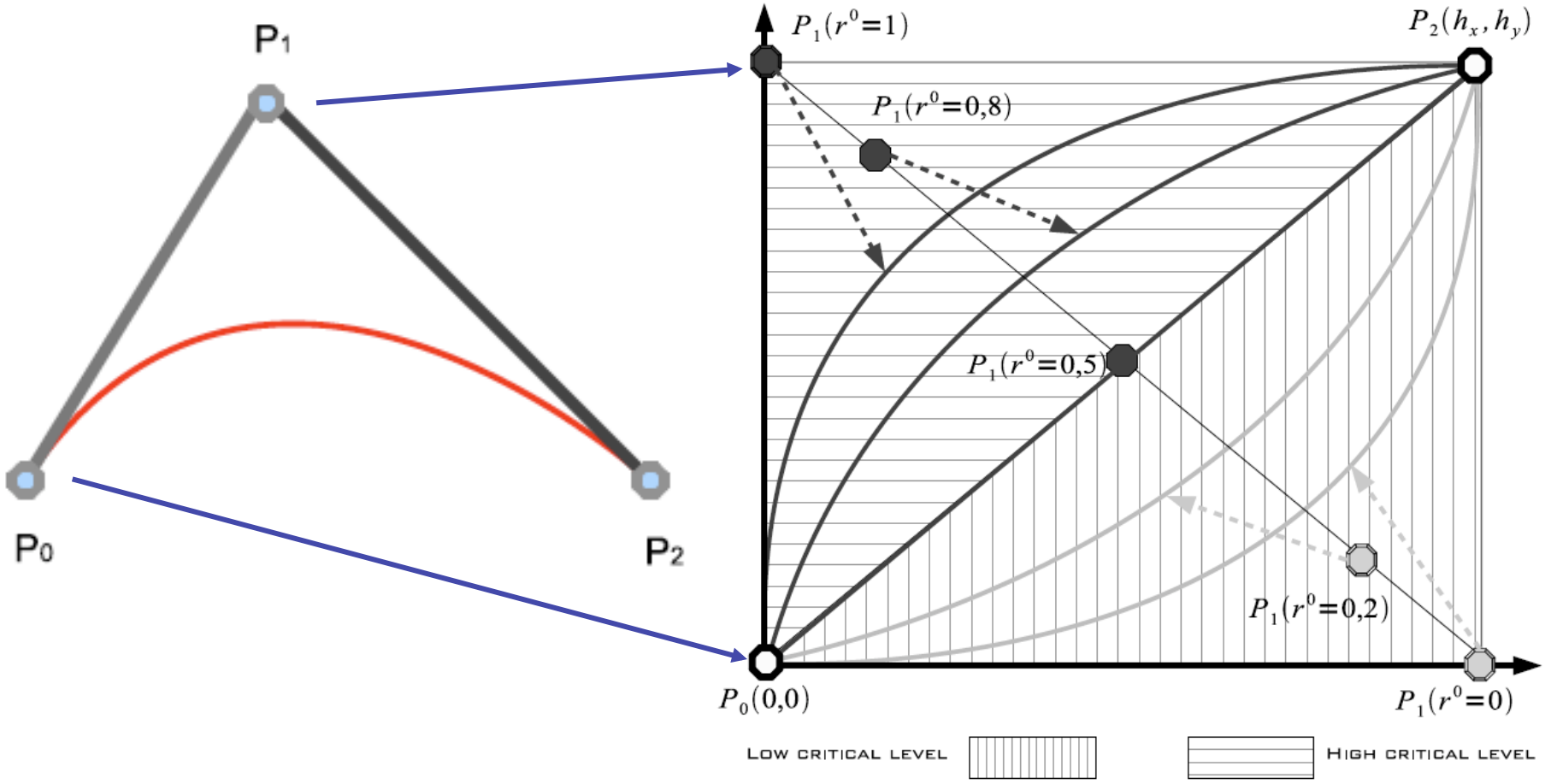
Criticality model (2)

- r^0 can vary in [0,1]
- Behavior functions (BV) defines the capture speed according to r^0
- $r^0 < 0.5$
  - Concave shape BV
- $r^0 > 0.5$
  - Convex shape BV
- We propose to use Bezier curves to model BV functions



BehaVior function

$$B(t) = (1-t)^2 * P_0 + 2t(1-t) * P_1 + t^2 * P_2$$

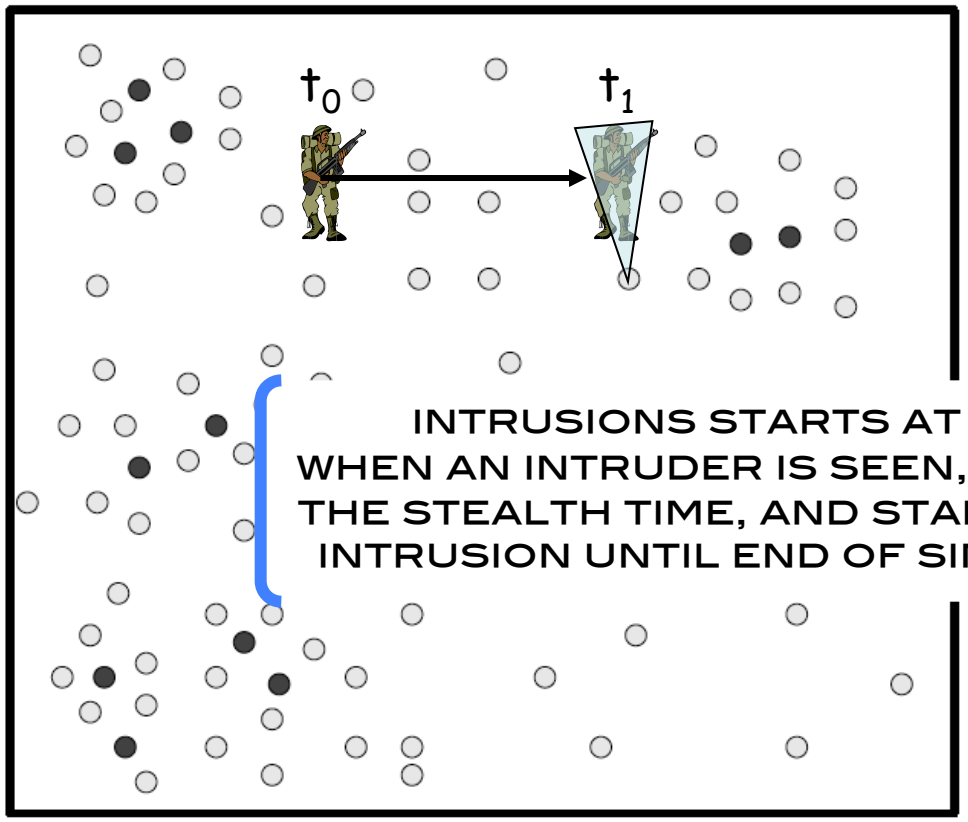


Risk-based scheduling

- Static risk-based scheduling
  - r°=Cte in [0,1]
- Dynamic risk-based scheduling
  - Starts with a low value for r° (0.1)
  - On intrusion, alert neighborhood and increases r° to a R_{MAX} value (0.9)
  - Stays at R_{MAX} for T_A seconds before going back to r°
- Dynamic with reinforcement
  - Same as dynamic but several alerts are needed to get to r°= R_{MAX}
  - Going back to r° is done in one step

MEAN STEALTH TIME

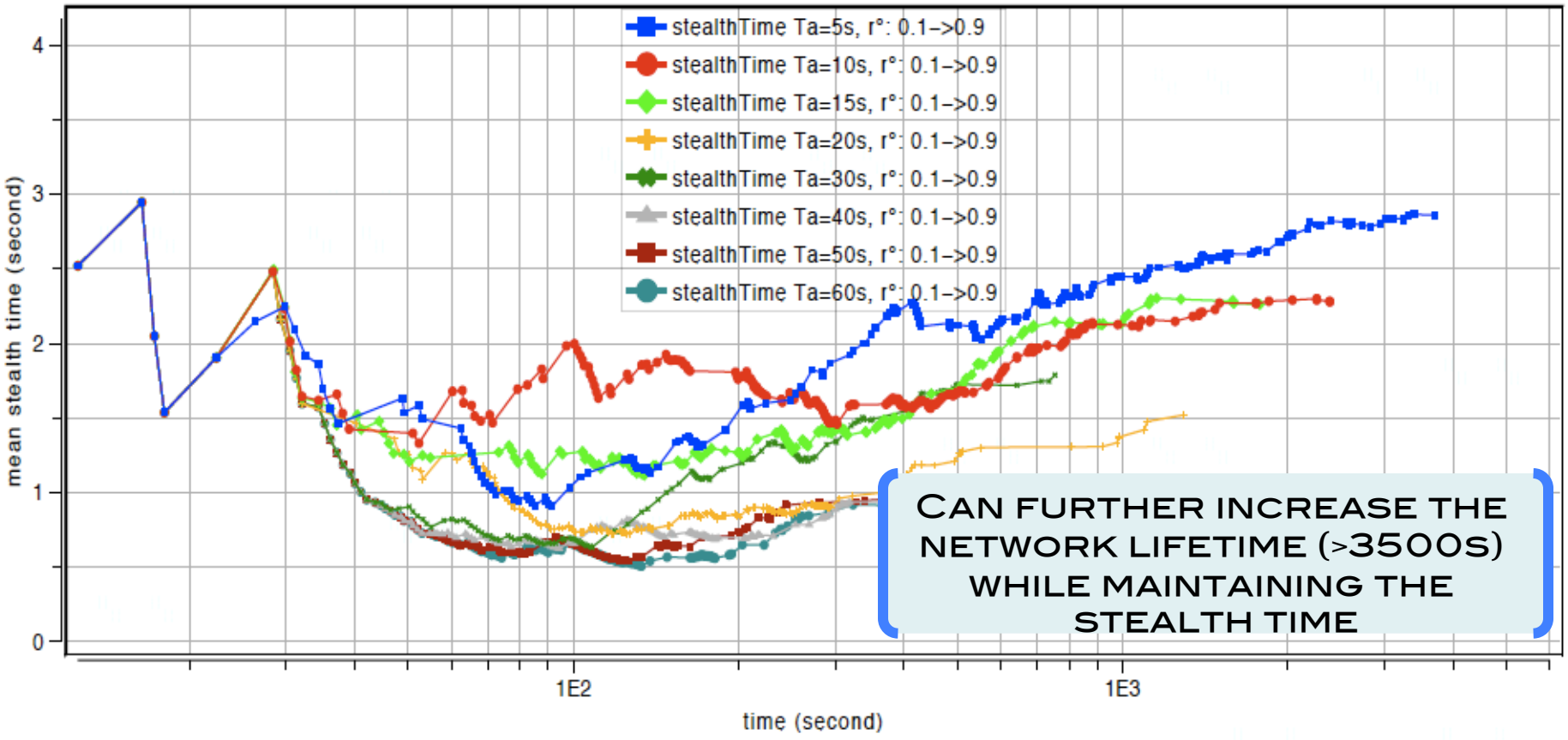
T_1-T_0 IS THE INTRUDER'S
STEALTH TIME
VELOCITY IS SET TO 5M/S



INTRUSIONS STARTS AT T=10S
WHEN AN INTRUDER IS SEEN, COMPUTE
THE STEALTH TIME, AND STARTS A NEW
INTRUSION UNTIL END OF SIMULATION

Dynamic scheduling

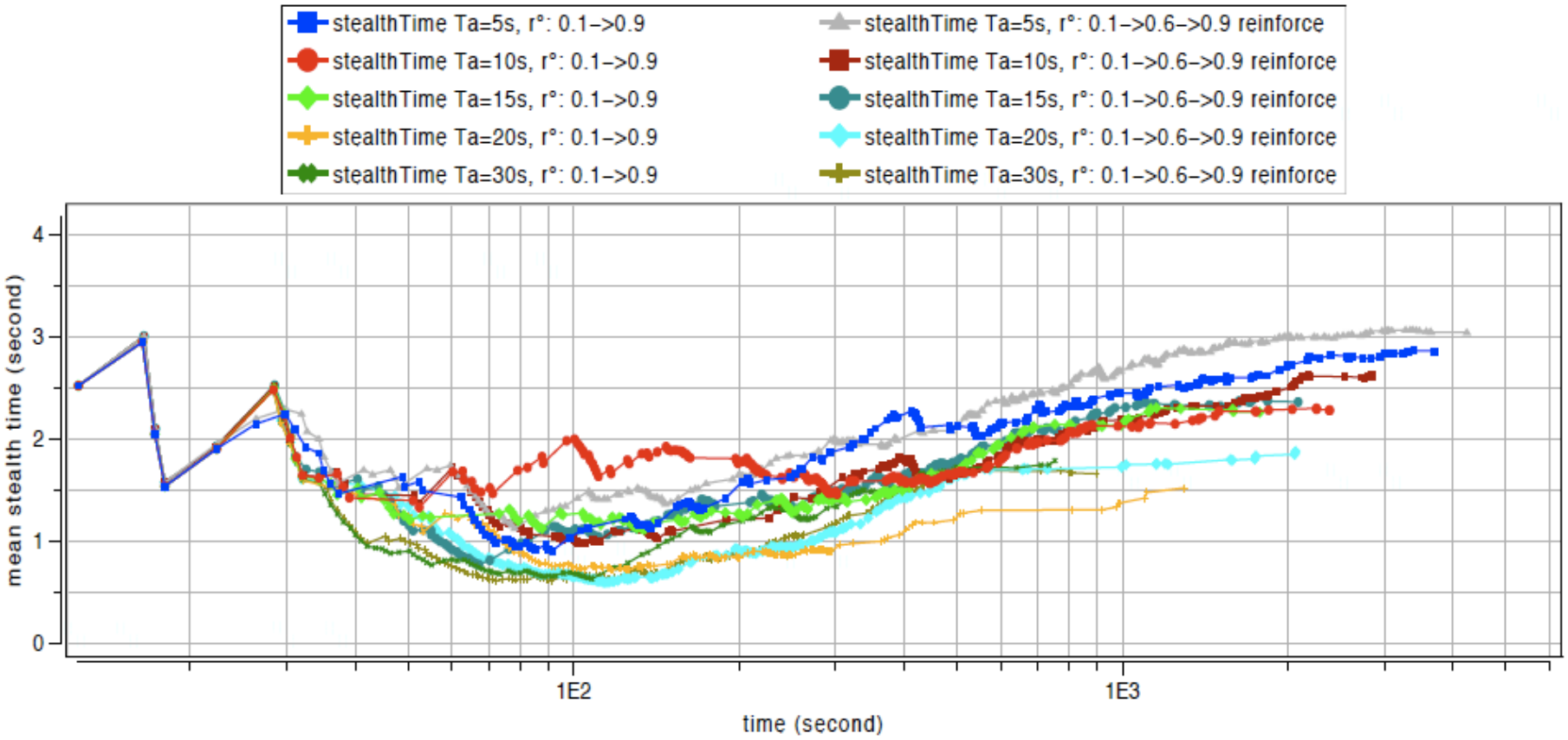
- $r°=0.1$, $R_{MAX}=0.9$, $T_A=5,10,15,20..60s$



Can further increase the network lifetime (>3500s) while maintaining the stealth time

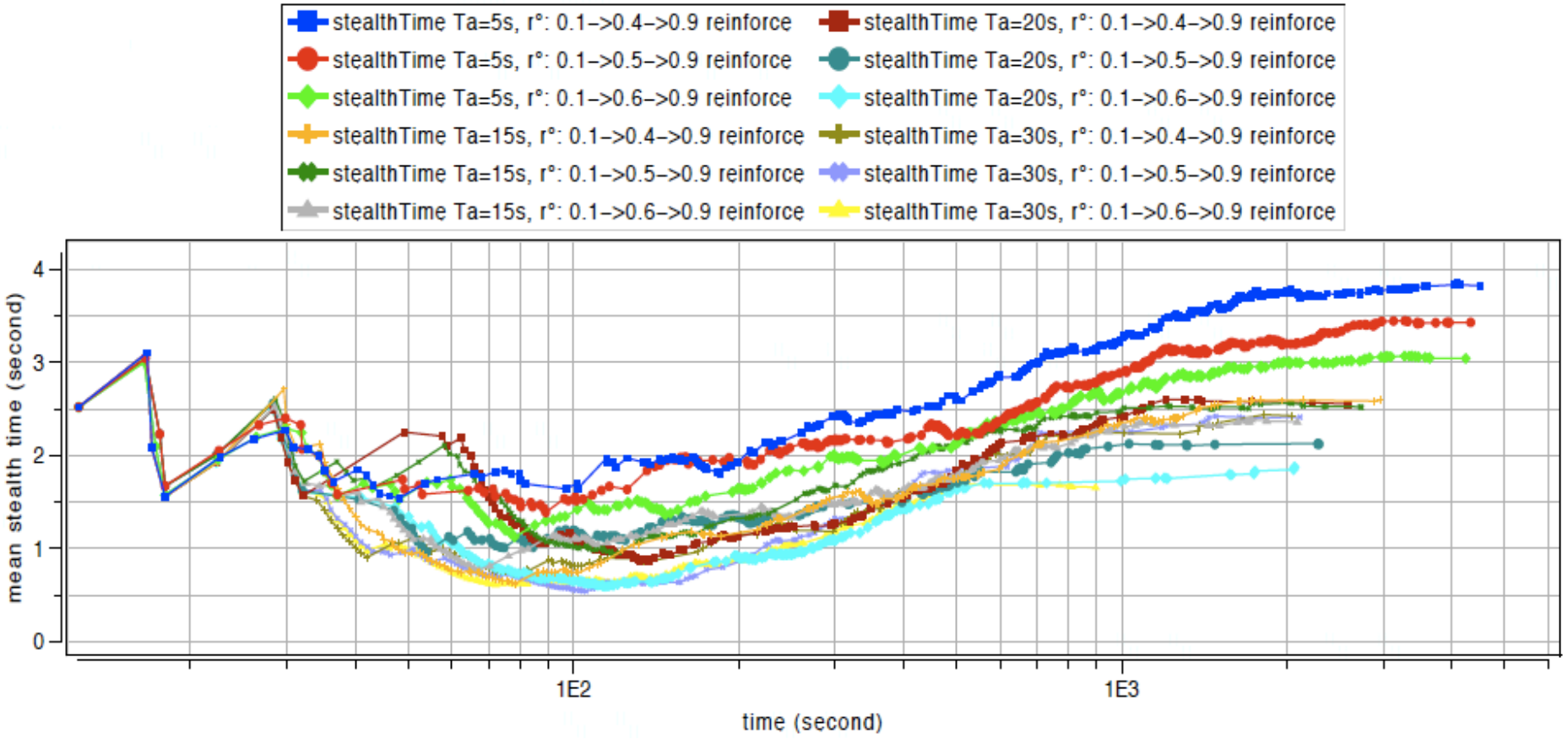
Dynamic with reinforcement (1)

- $R°=0.1 \rightarrow I_R=0.6 \rightarrow R_{MAX}=0.9$
- 2 alert msg to have $I_R=I_R+0.1$



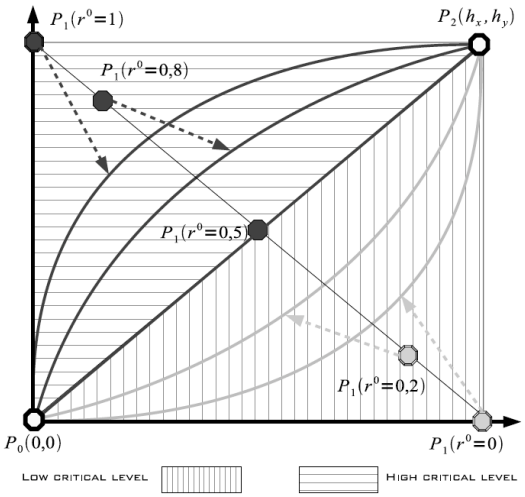
Dynamic with reinforcement (2)

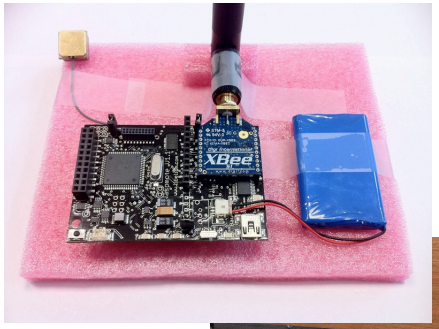
- $r°=0.1 \rightarrow I_R=0.4/0.5/0.6 \rightarrow R_{MAX}=0.9$
- 2 alert msg to have $I_R=I_R+0.1$

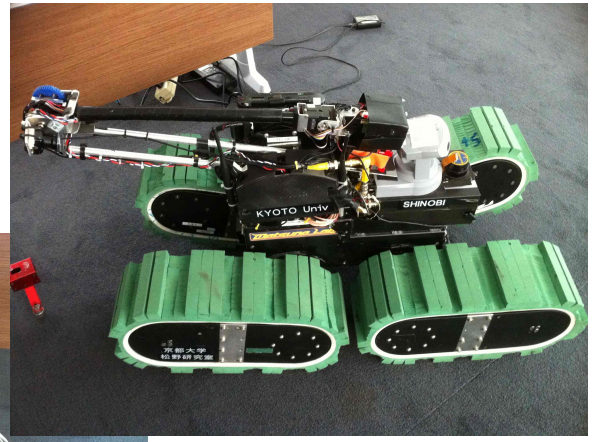


Sensors & Robots Propose new interaction schemes

- Use the criticality model to control both sensors and robots
- Prototyping on real hardware, collaboration with U. Kyoto, Japan

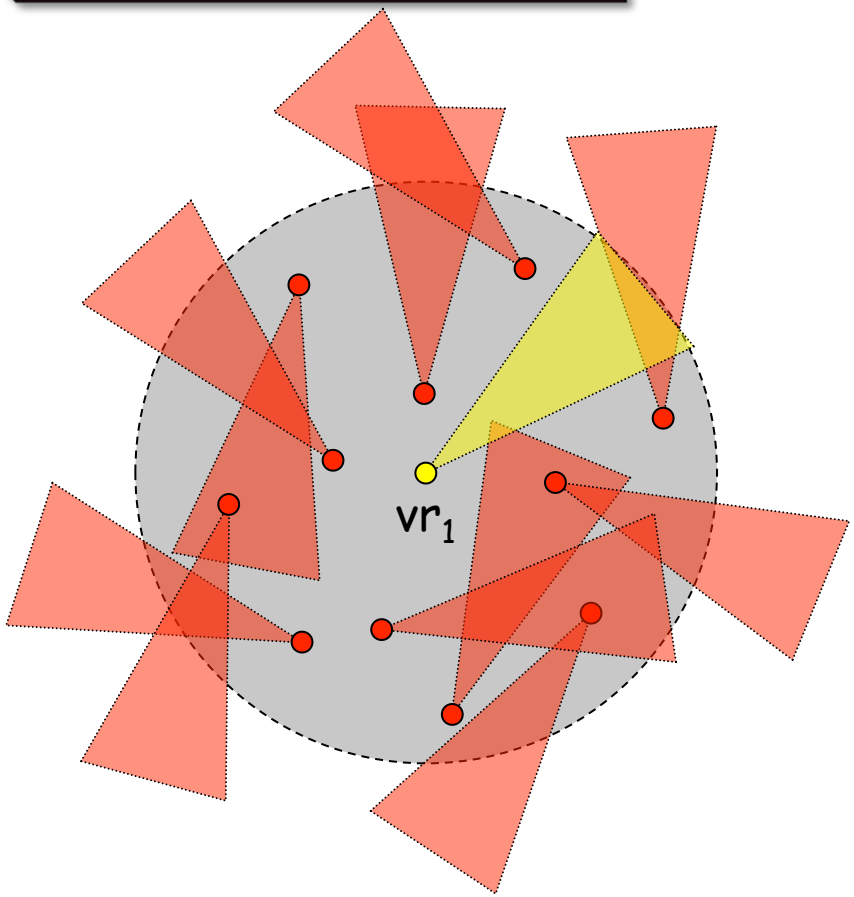




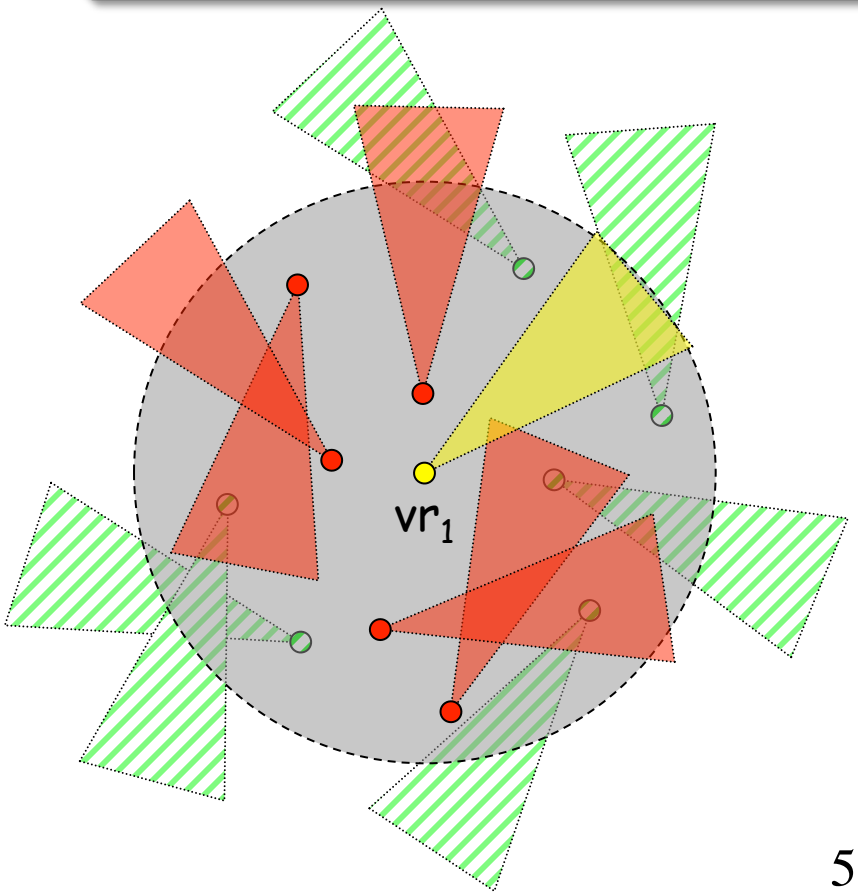


Cooperation with cameras on mobile robots

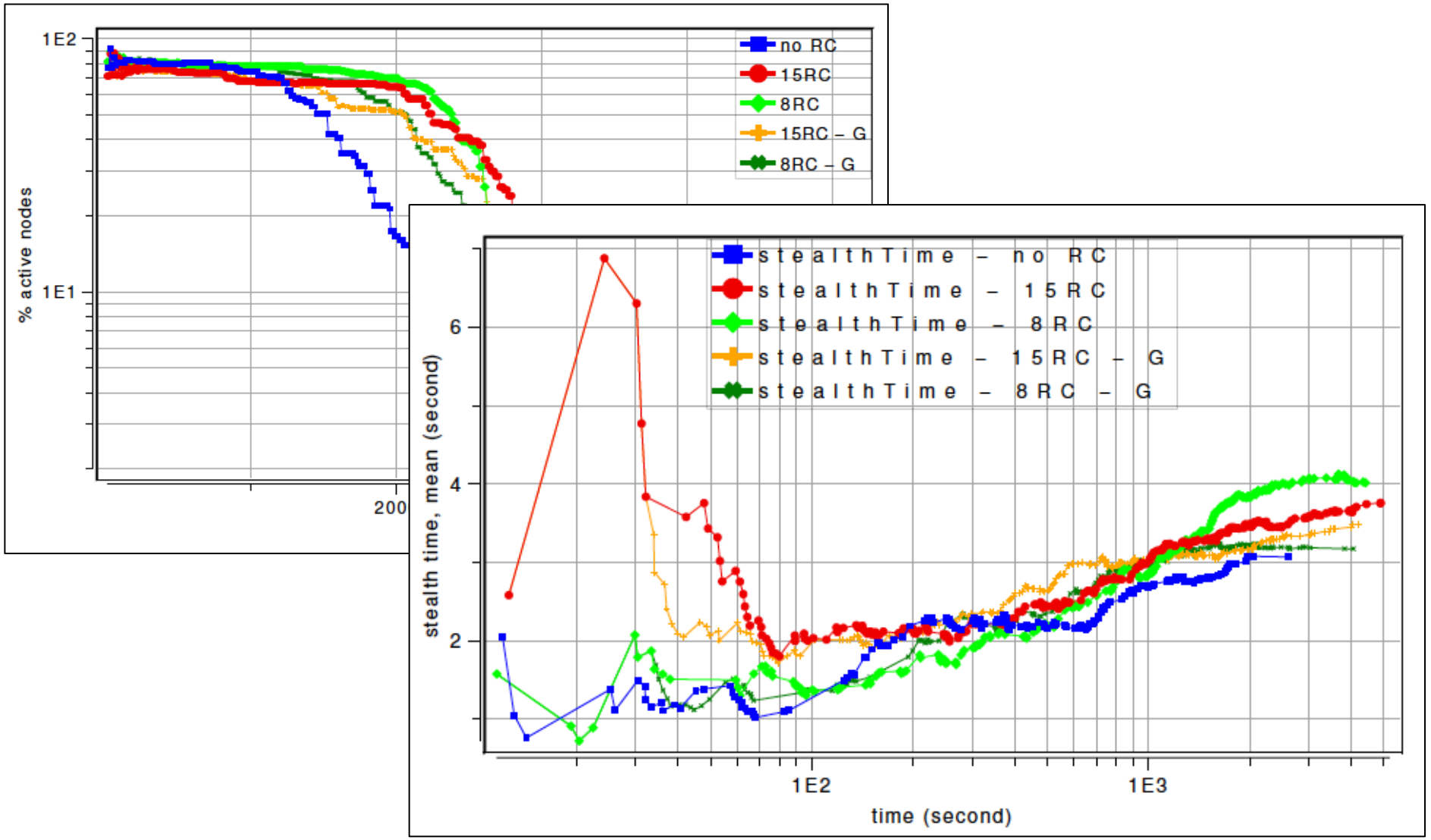
Fixed image sensors near a mobile camera can decrease their criticality level



ONLY fixed image sensors whose FoV's center is covered by a mobile camera **CAN** decrease their criticality level



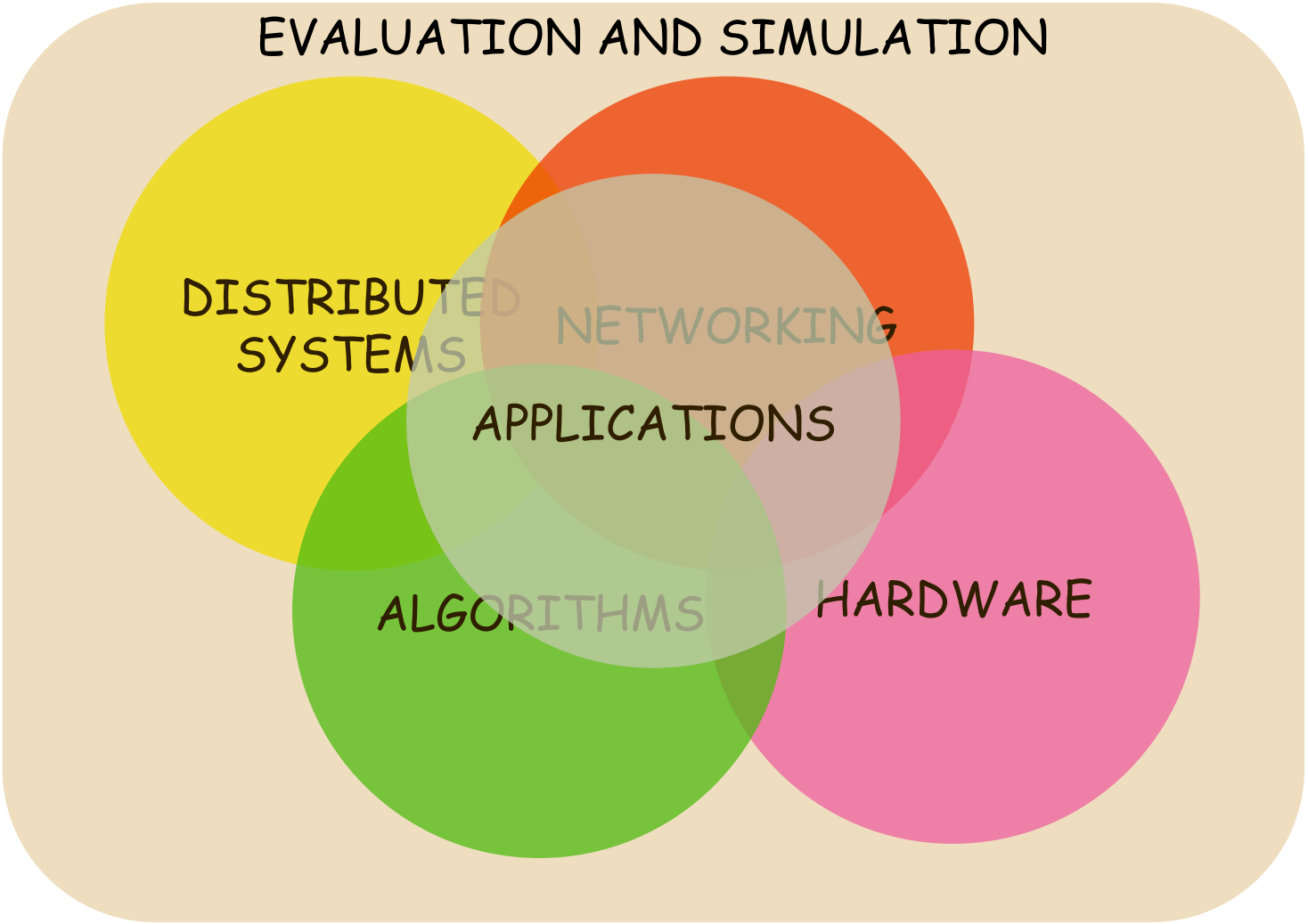
Impact on lifetime & stealth time

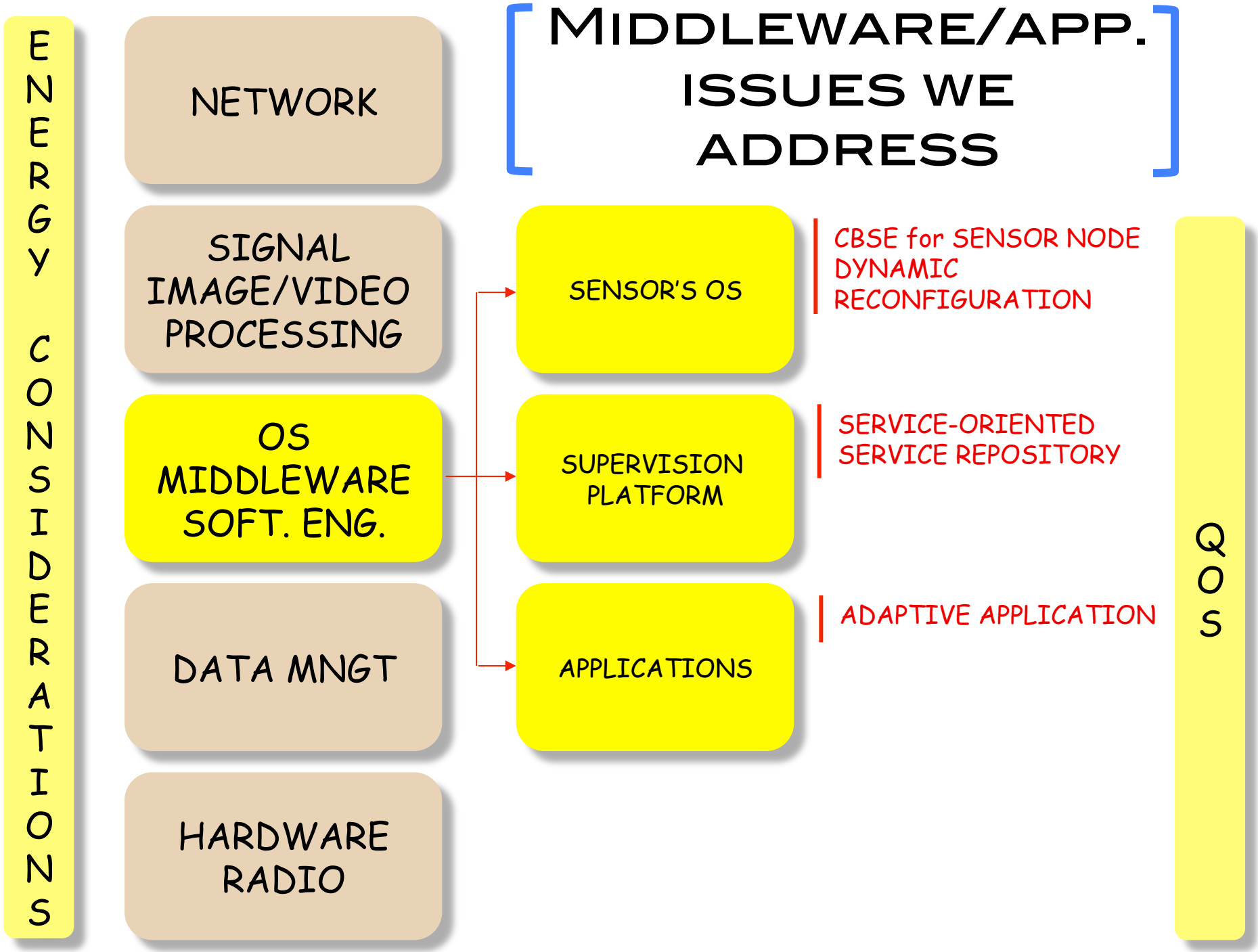


Conclusions

- Sensor Networks can provide large scale awareness to setup the foundation for AMBIENT INTELLIGENCE
- Sensors & Robots interactions are challenging but have very promising COOPERATIVE issues
- Surveillance applications have criticality issues that MUST be taken into account in the design process
- NEED tools to carefully study the entire system

MULTIDISCIPLINARY RESEARCH




ENERGY CONSIDERATIONS
NETWORK
SIGNAL IMAGE/VIDEO PROCESSING
OS MIDDLEWARE SOFT. ENG.
DATA MNGT
HARDWARE RADIO
MIDDLEWARE/APP. ISSUES WE ADDRESS
SENSOR'S OS
SUPERVISION PLATFORM
APPLICATIONS
CBSE for SENSOR NODE DYNAMIC RECONFIGURATION
SERVICE-ORIENTED SERVICE REPOSITORY
ADAPTIVE APPLICATION
QOS

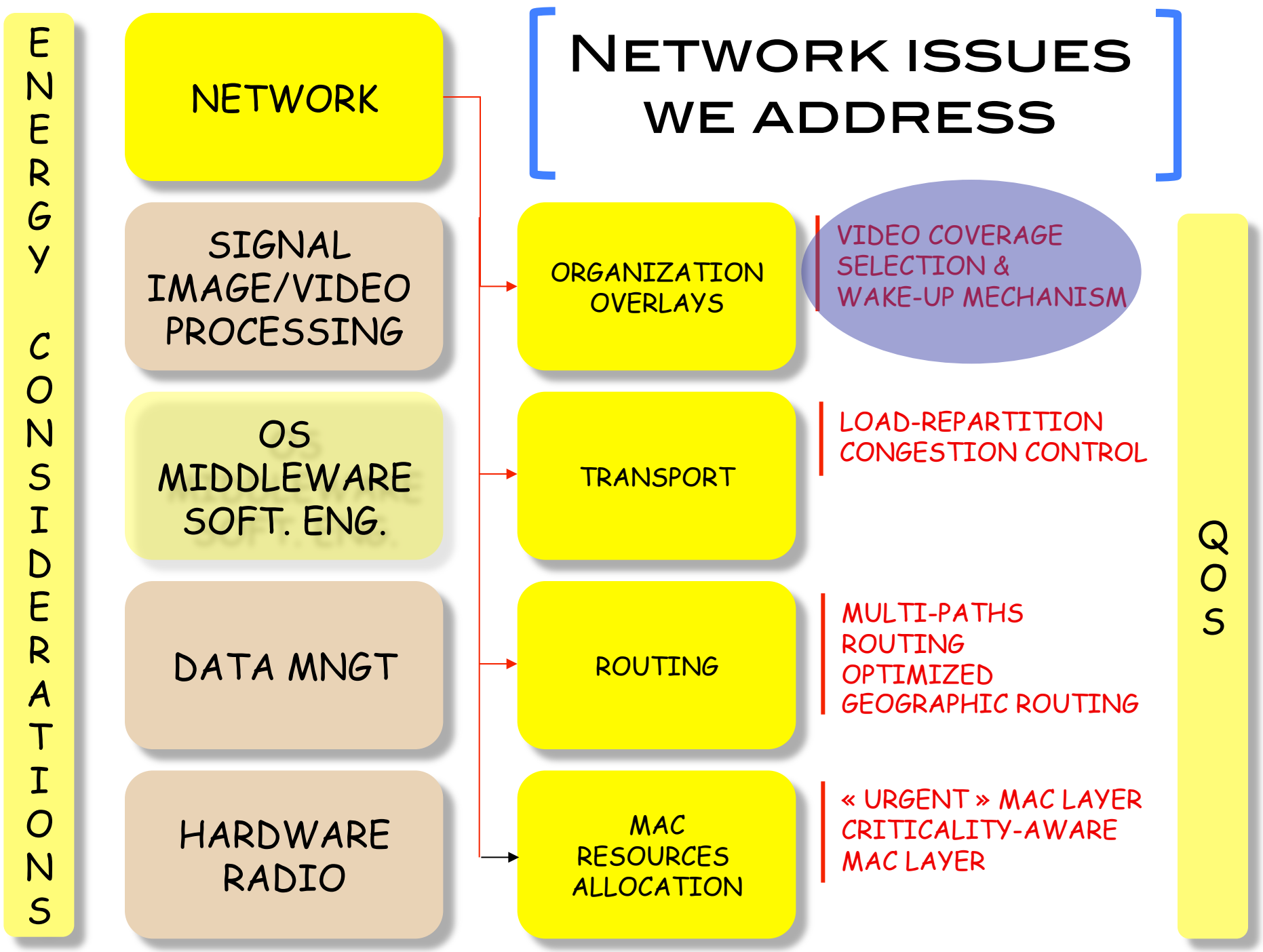
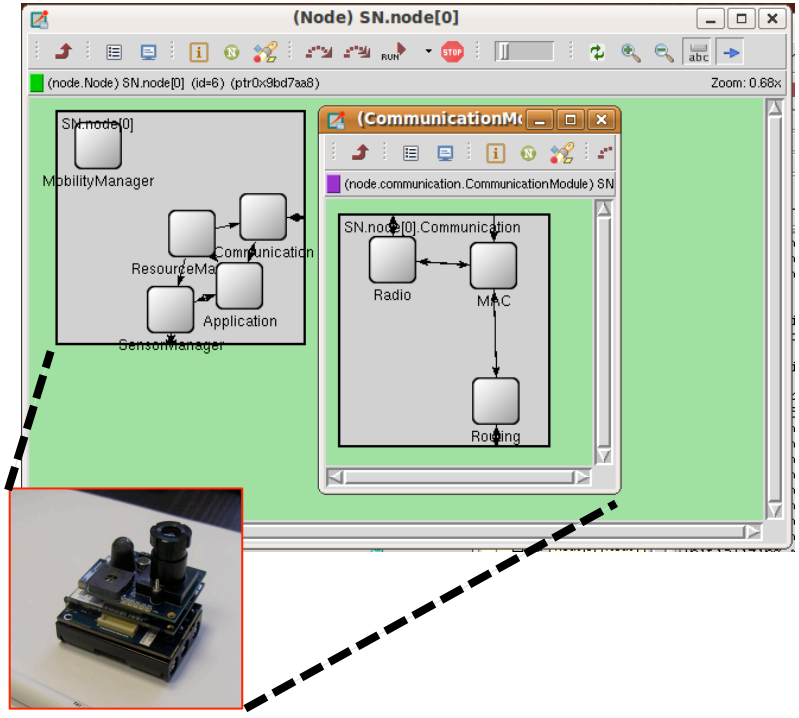
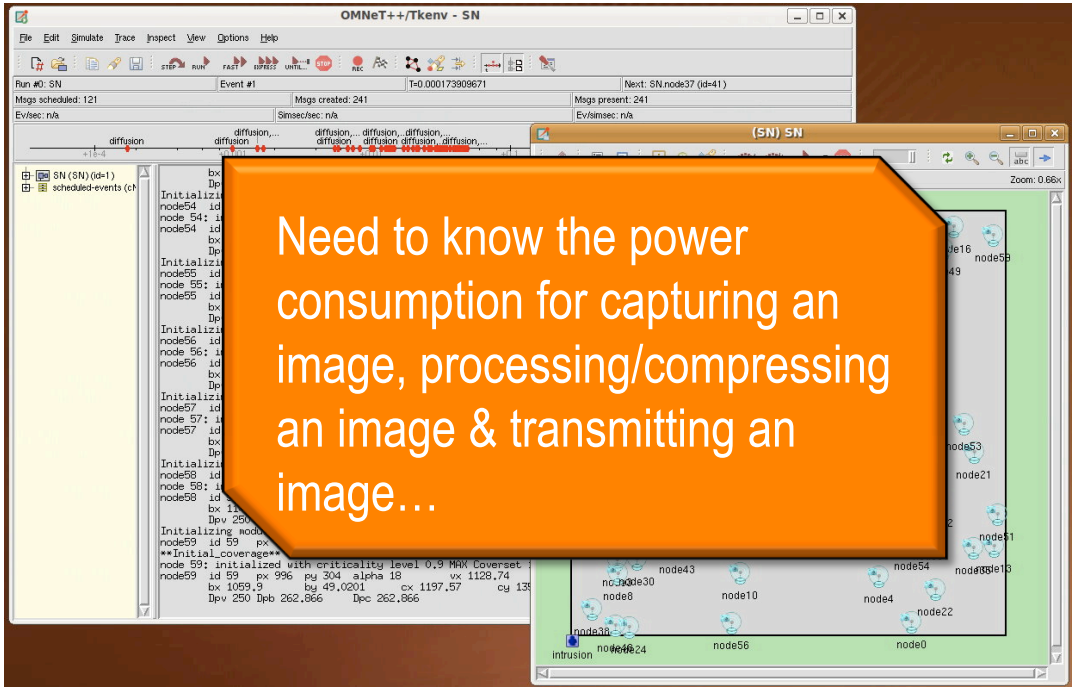

ENERGY CONSIDERATIONS
NETWORK
SIGNAL IMAGE/VIDEO PROCESSING
OS MIDDLEWARE SOFT. ENG.
DATA MNGT
HARDWARE RADIO
NETWORK ISSUES WE ADDRESS
ORGANIZATION OVERLAYS
TRANSPORT
ROUTING
MAC RESOURCES ALLOCATION
VIDEO COVERAGE SELECTION & WAKE-UP MECHANISM
LOAD-REPARTITION CONGESTION CONTROL
MULTI-PATHS ROUTING OPTIMIZED GEOGRAPHIC ROUTING
« URGENT » MAC LAYER CRITICALITY-AWARE MAC LAYER
QOS

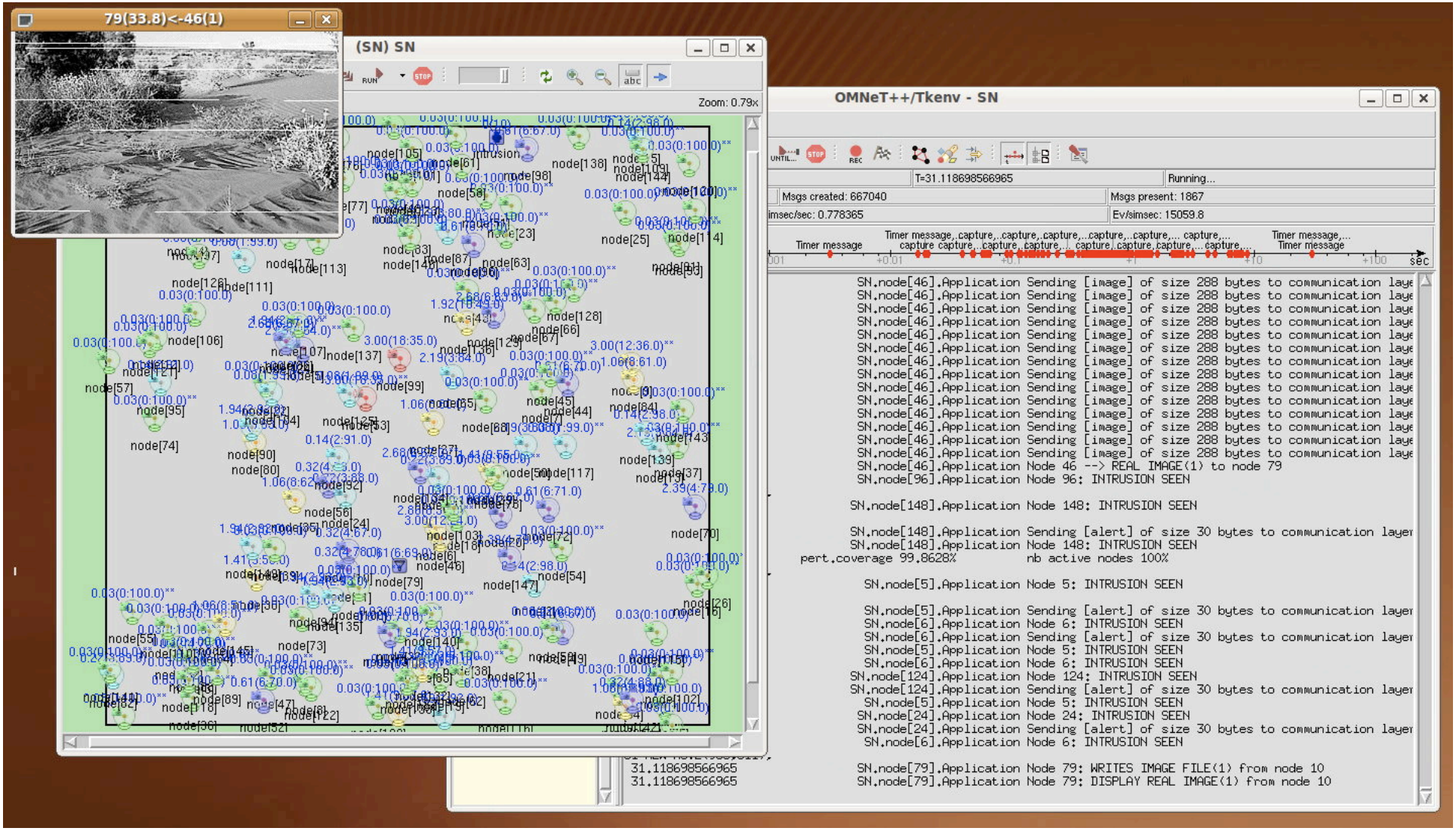
Image sensor simulation model under OMNET++

- Communication layers are very important for WSN
- Use specific simulator



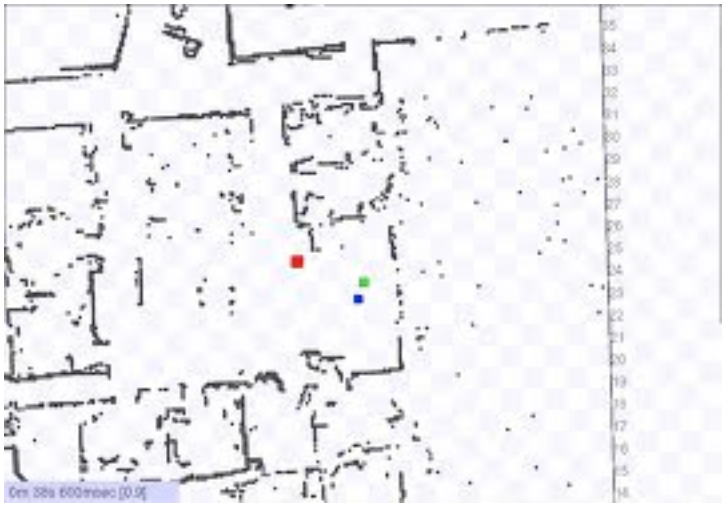


Study the impact of communication layer on surveillance quality



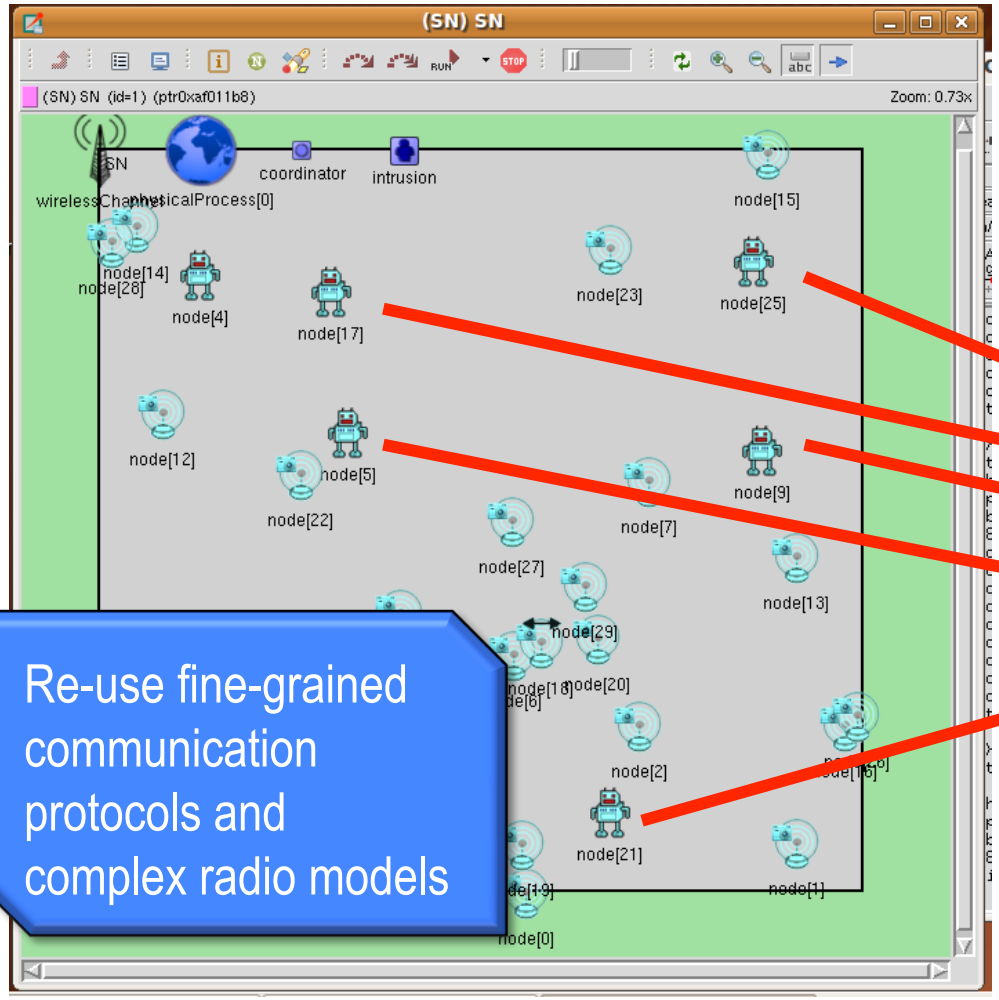
Robot simulators

- Mobility, exploration, navigation, tracking, control and design are very important for robots
- Use specific robot simulators



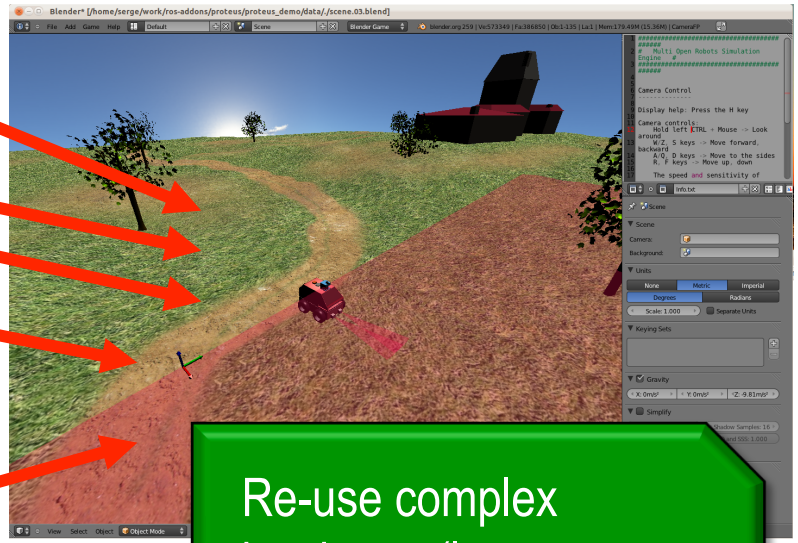
Sensors & Robots enable realistic interaction studies

Sensor specific simulator for communication stack



Re-use fine-grained communication protocols and complex radio models

Get robot's position from robot simulator



Re-use complex hardware (laser scan, …) and control software (navigation stacks,…)

Thank you!

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