Challenges & Design Space in Wireless Video Sensor Networks

LIUPPA
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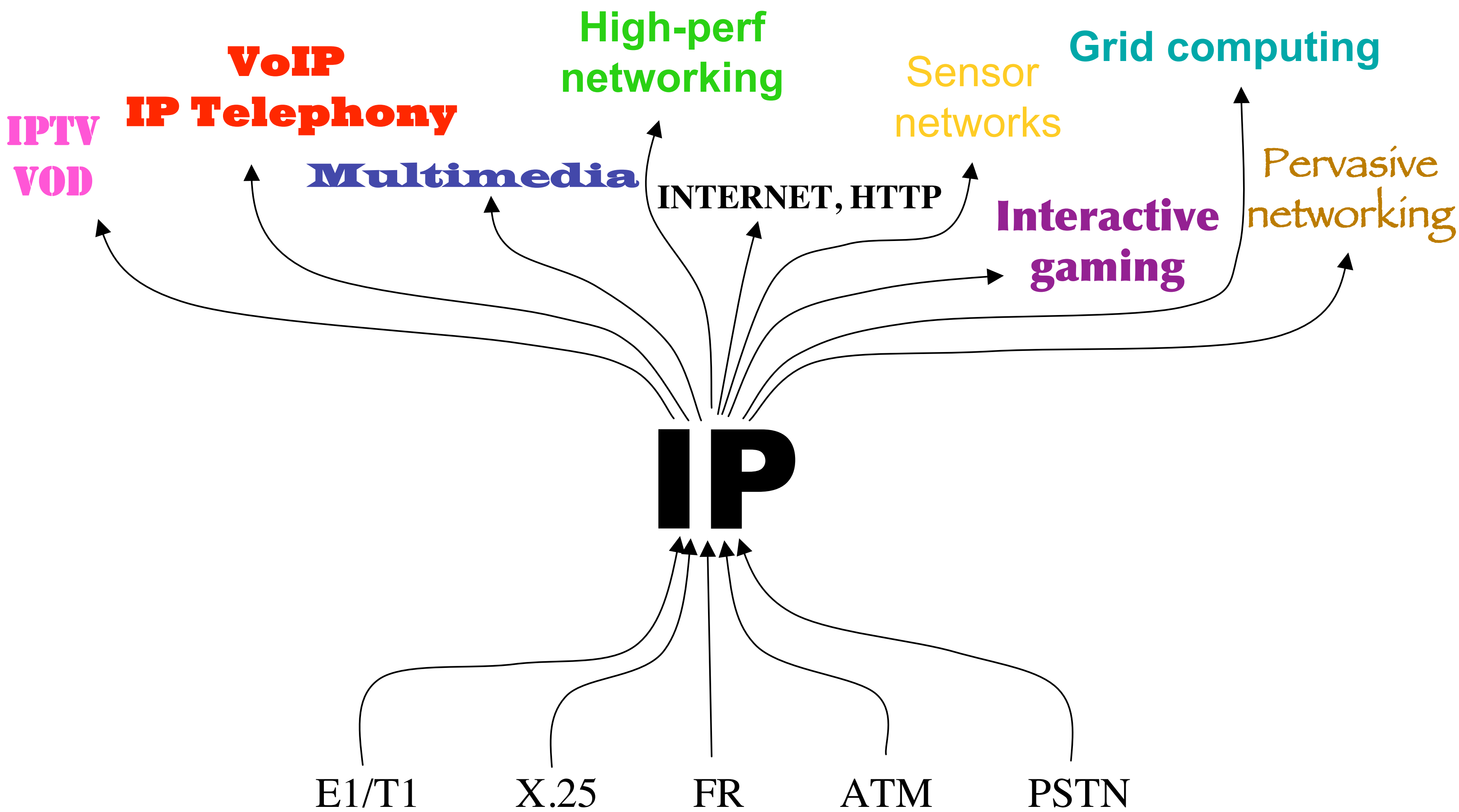
The work & ideas developped in these slides have been done with B. Kechar from the University of Oran, Algeria, during his visit in the LIUPPA laboratory, Oct-Nov 2007.

Towards all IP



Now, what's up?

Internet-1

Internet-2

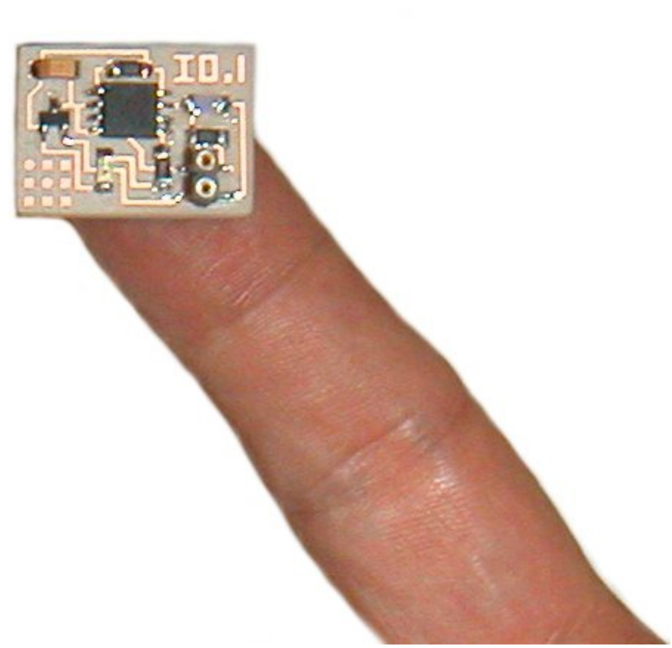
Internet-~~3~~ 0

Internet-0: the Internet of Things

Borrowed from N. Gershenfeld

ON THE INTERNET NOBODY KNOWS YOU'RE A LIGHT BULB!

Internet Hosts

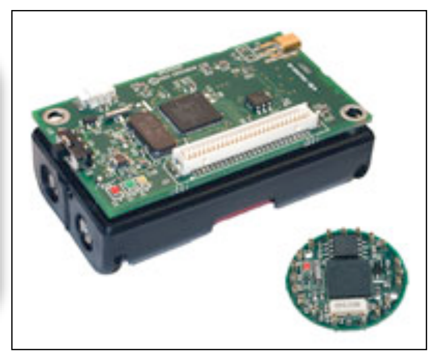


1974 **2004**

Borrowed from N. Gershenfeld

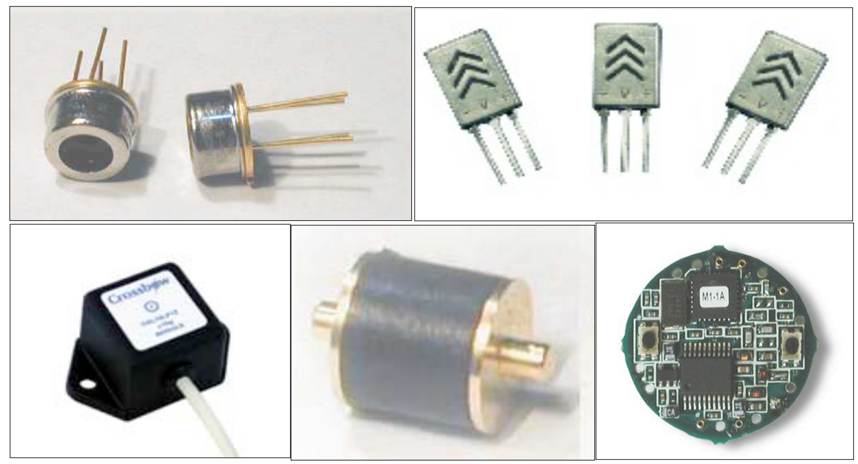
What's missing?

Between the PDA and the RFID tag of Internet-0, is the wireless autonomous sensor



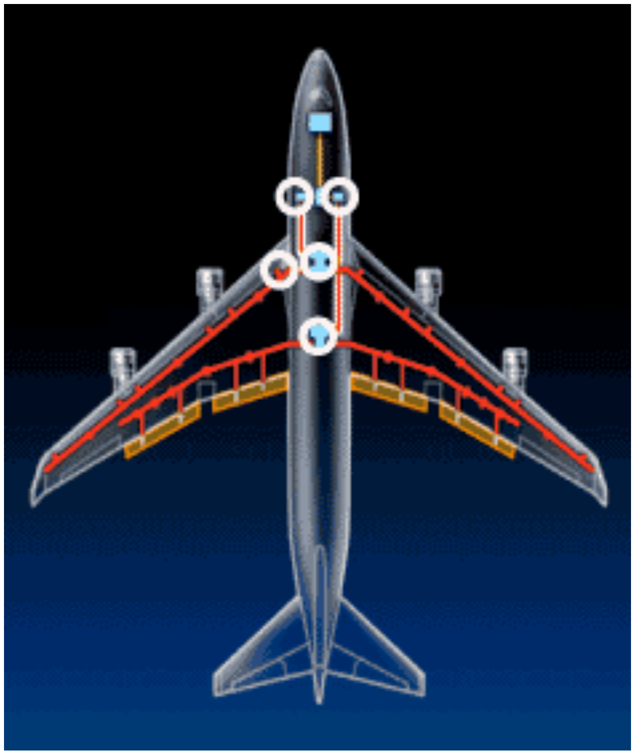
What Is A Sensor Node?

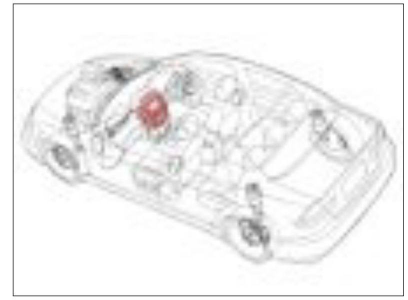
- Sensor nodes could monitor a wide variety of ambient conditions that include the following:
  - temperature,
  - humidity,
  - vehicular movement,
  - lightning condition,
  - pressure,
  - soil makeup,
  - noise levels,
  - the presence or absence of certain kinds of objects,
  - mechanical stress levels on attached objects, and
  - the current characteristics such as speed, direction, and size of an object.



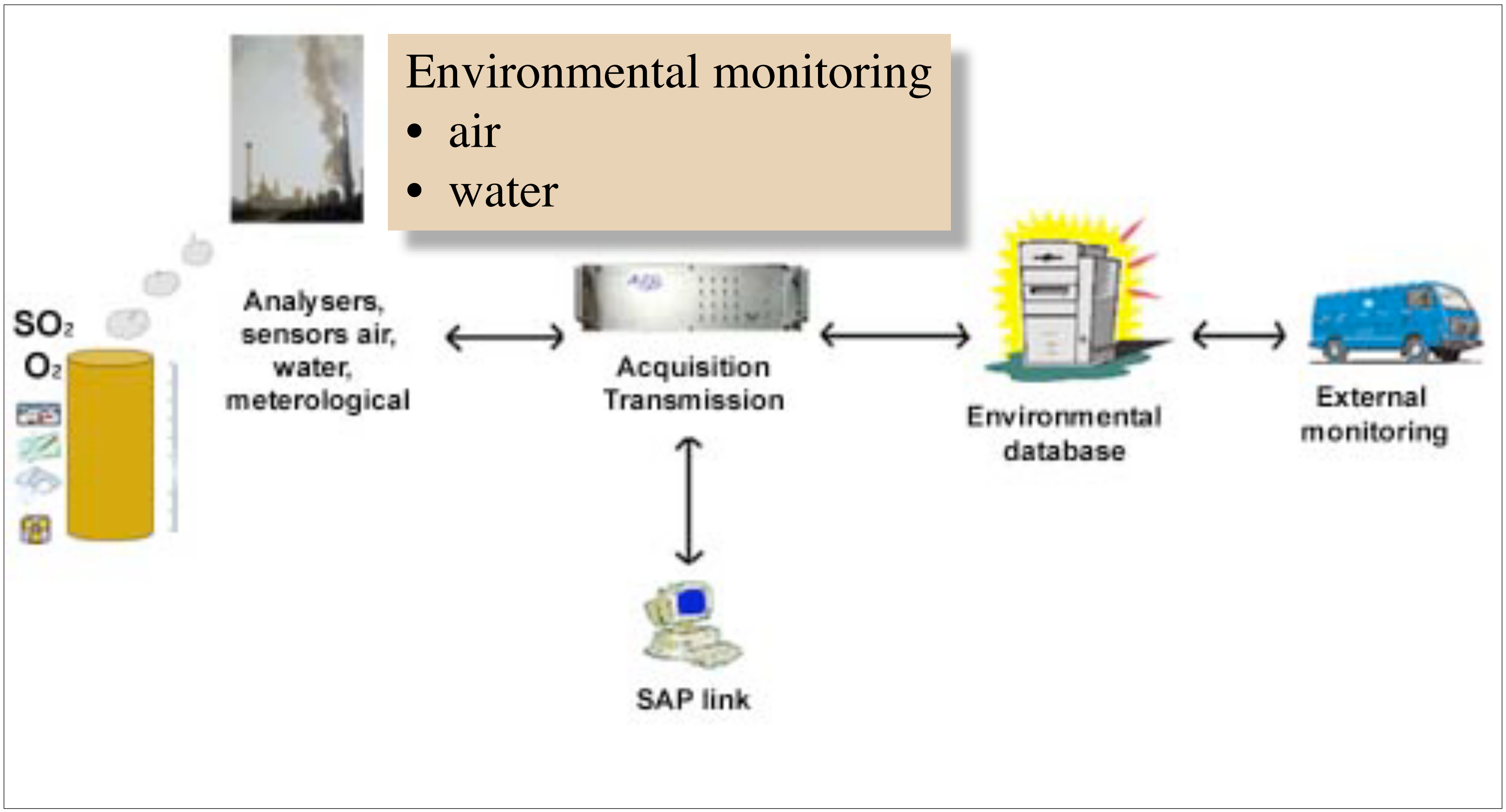
- Sensor nodes can be used for continuous sensing, event detection, event ID, location sensing, etc.

Traditional sensing applications





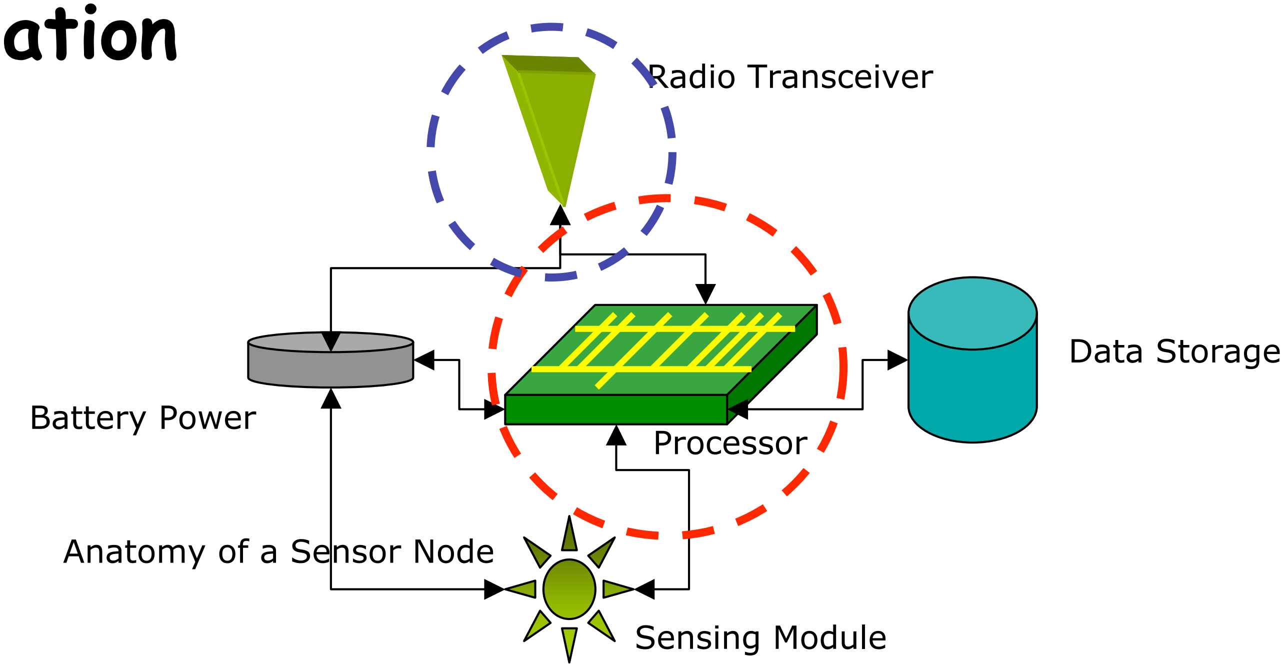
Traditional sensing applications (contd.)



Borrowed from www.iseo.fr

Wireless autonomous sensor

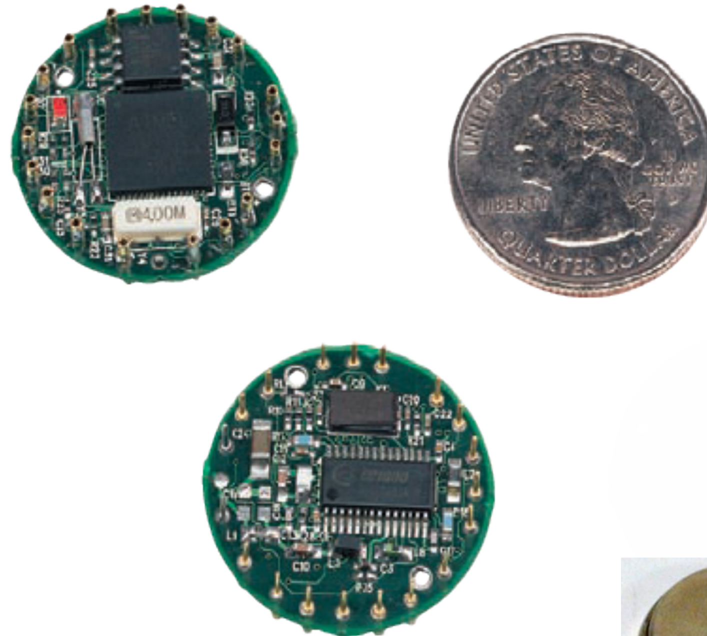
- In general: low cost, low power (the battery may not be replaceable), small size, prone to failure, possibly disposable
- Role: sensing, **data processing**, **communication**



Anatomy of a Sensor Node

Berkeley Motes

- Size: 4cm×4cm
- CPU: 4 MHz, 8bit
- 512 Bytes RAM, 8KB ROM
- Radio: 900 MHz, 19.2 Kbps, ½ duplex
- Serial communication
- Range: 10-100 ft.
- Sensors: Acceleration, temperature, magnetic field, pressure, humidity, light, and RF signal strength



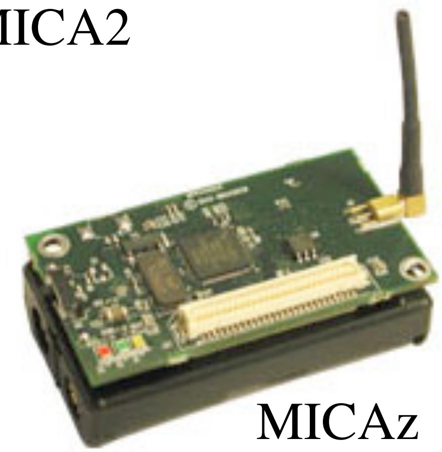
MICA2DOT

Battery
Panasonic
CR2354
560 mAh

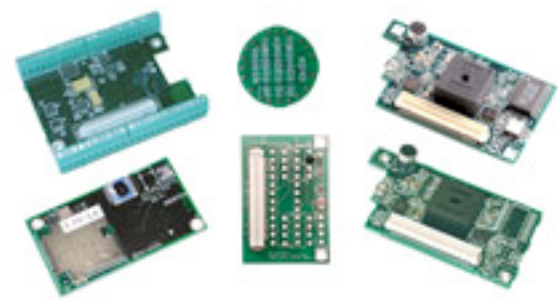
Berkeley Motes (contd.)

- Each Mote has two separate boards
  - A main CPU board with radio communication circuitry
  - A secondary board with sensing circuitry
- Decouples sensing hardware from communication hardware
- Allows for customization since application specific sensor hardware can be plugged-on to the main board

MICA2

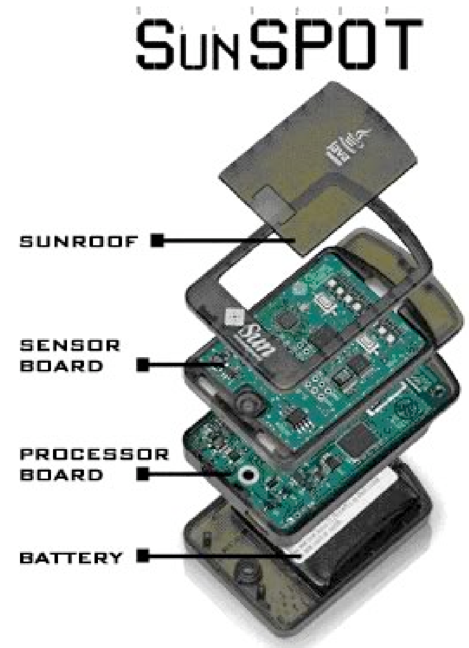


MICAz

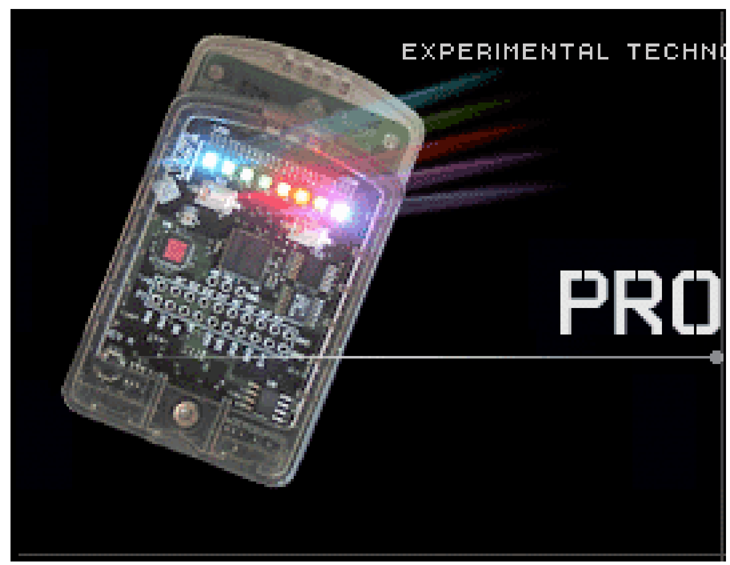


Sensing boards

SUN SPOT



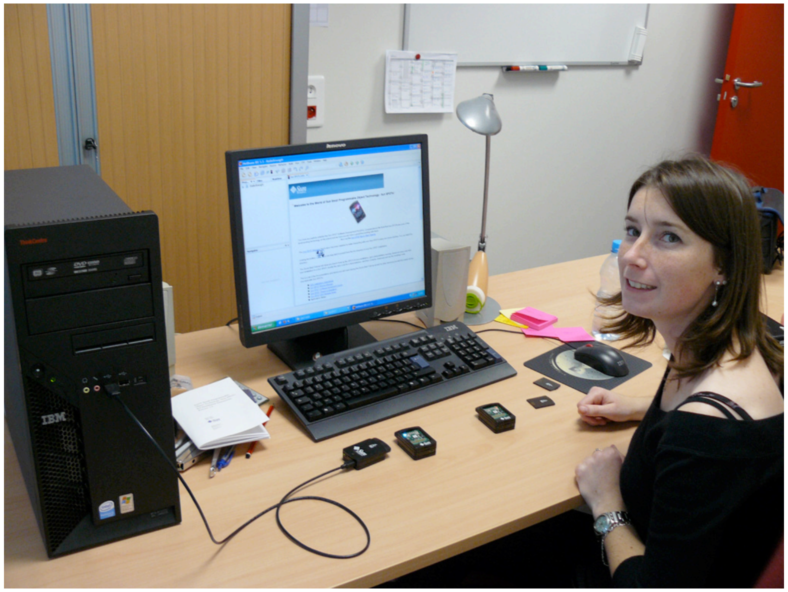
- Processor : ARM920T 180MHz 32-bit
- 512K RAM & 4M Flash.
- Communication : 2.4GHz, radio chipset: TI CC2420 (ChipCon) – IEEE 802.15.4 compatible
- Java Virtual Machine (Squawk)
- LIUPPA is official partner

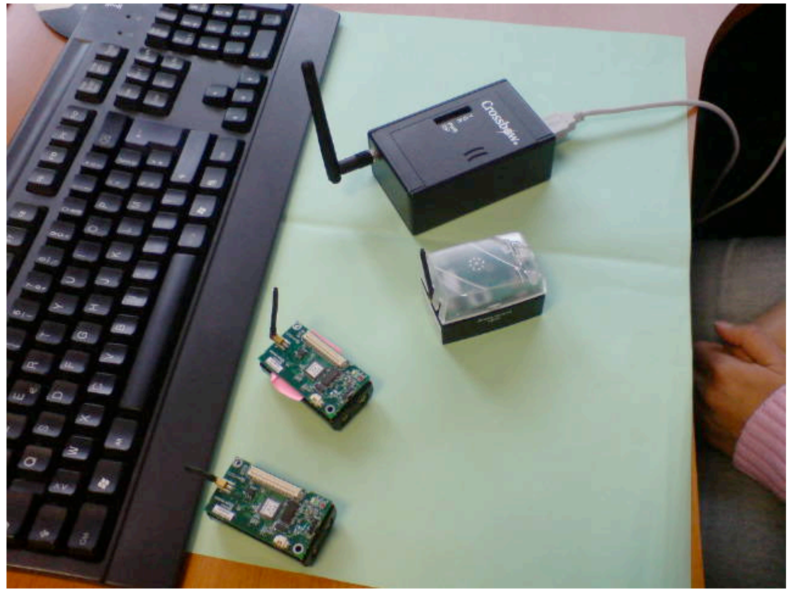


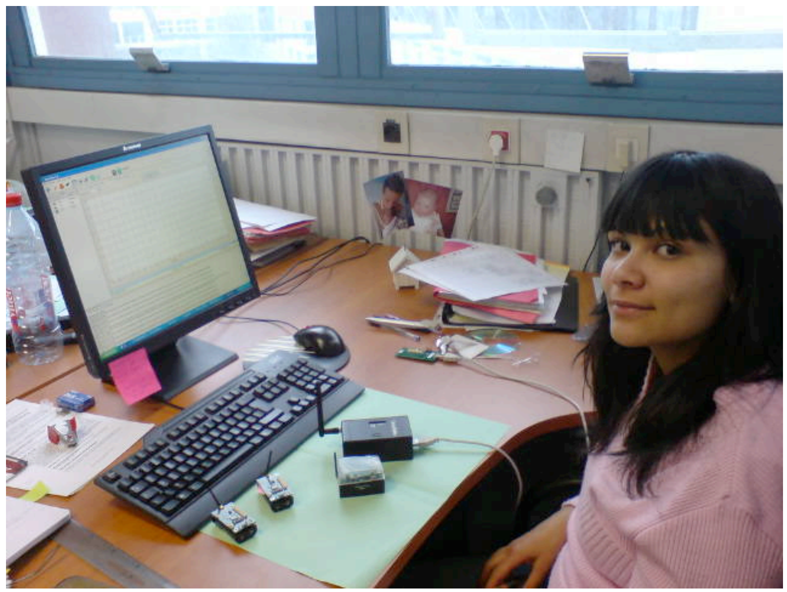
Wireless Sensors Networks

- 1 wireless sensor is better than none!
- 2 wire
- 3 wire
- 4 wire   ter!!!!
- ...
- 10000   better!!!!!
- 10001   incredibly
  bette
- ...

WSN at LIUPPA

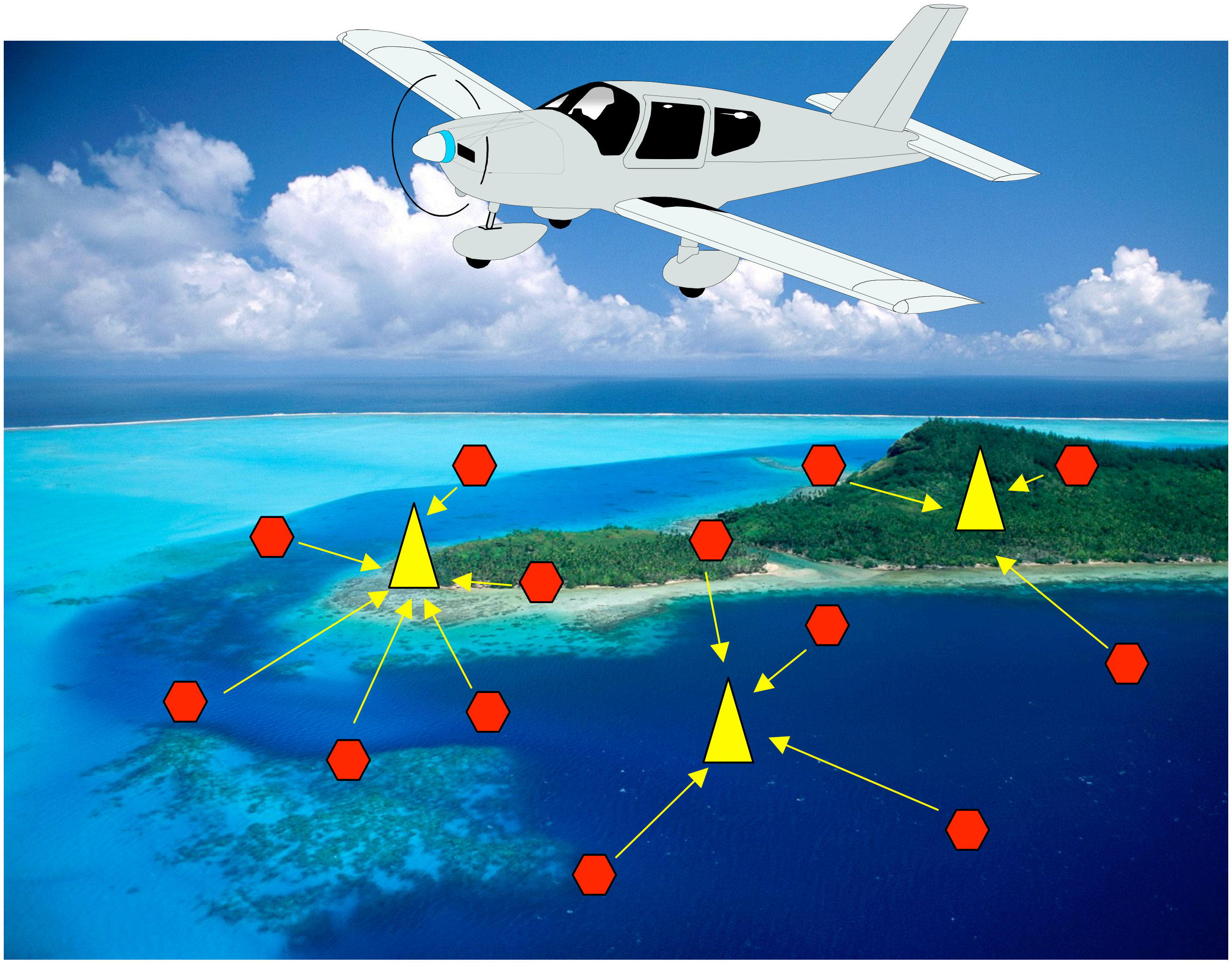


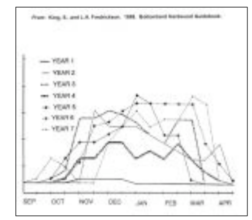




New sensor applications

environmental

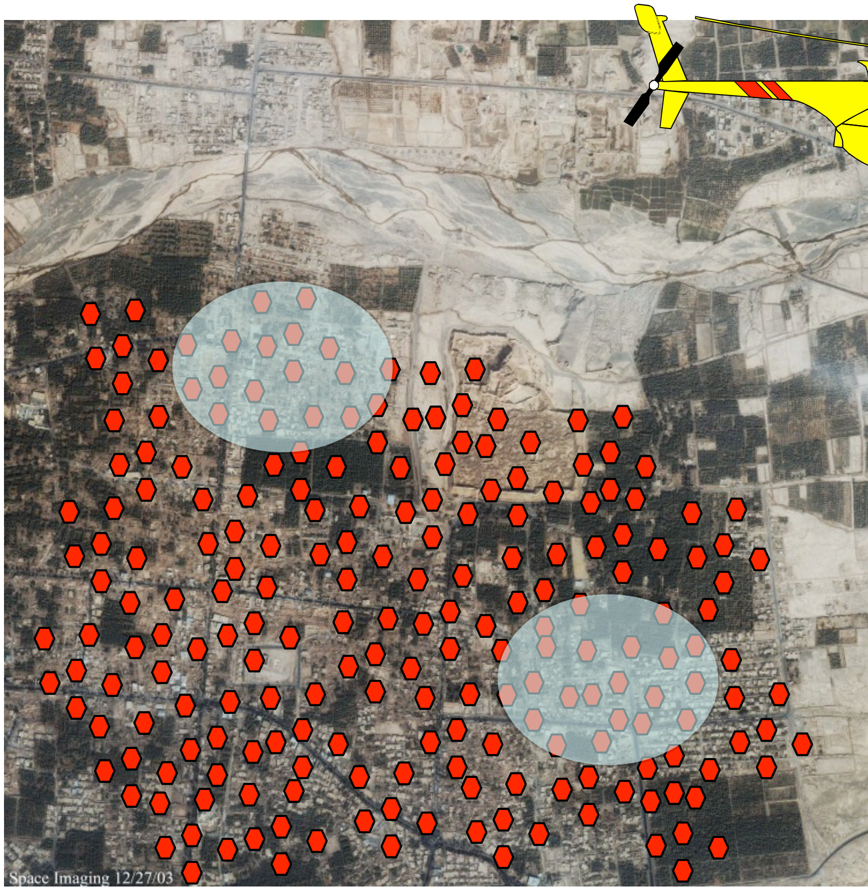


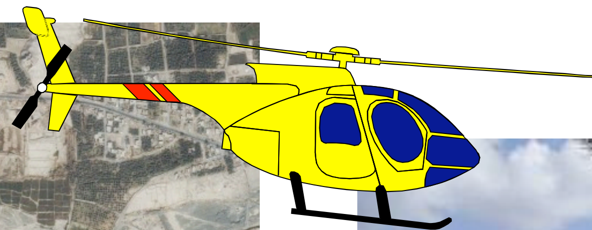


On-the-fly deployment of environmental monitoring's network

New sensor applications

disaster relief - security

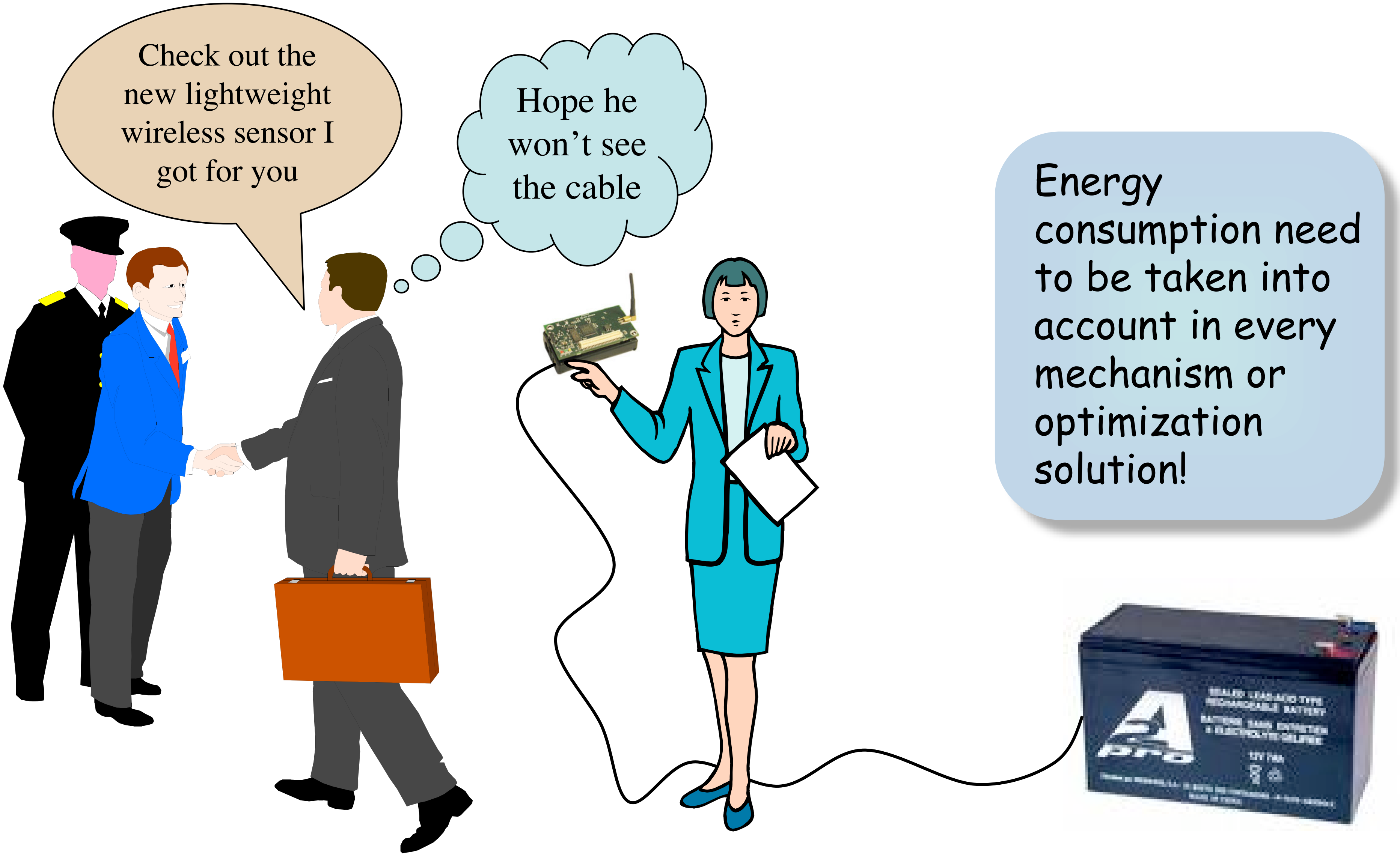




Real-time organization and optimization of rescue in large scale disasters

Rapid deployment of fire detection systems in high-risk places

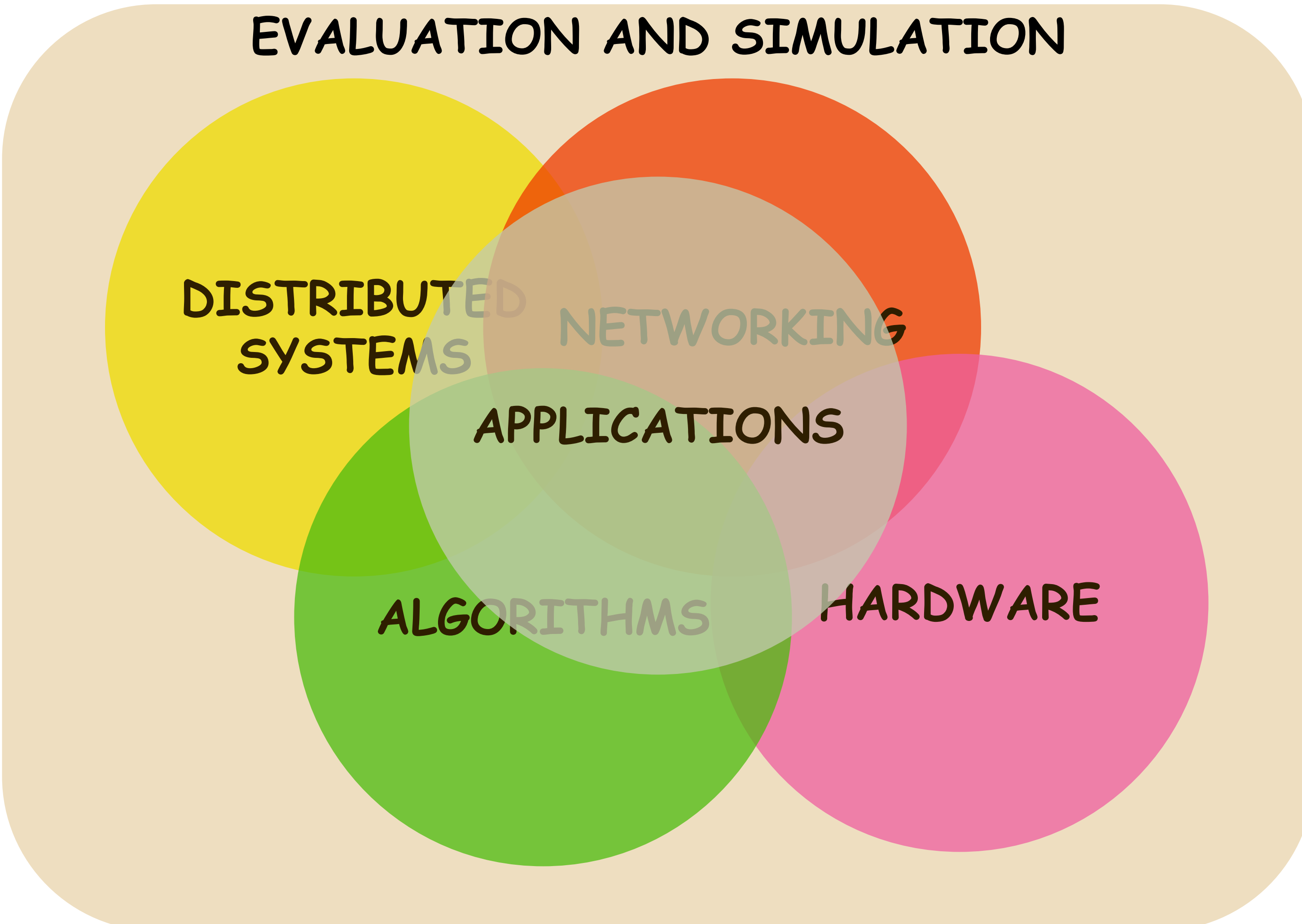
« The weakest link »



Research in WSN

- Communications
  - Routing, naming, localization, reliability, communication models, congestion control, organization, radio, MAC,…
- System
  - Operating systems, middleware, languages (Java), software architecture,…
- Hardware
  - Electronics, integration, ad-hoc design

Research in WSN

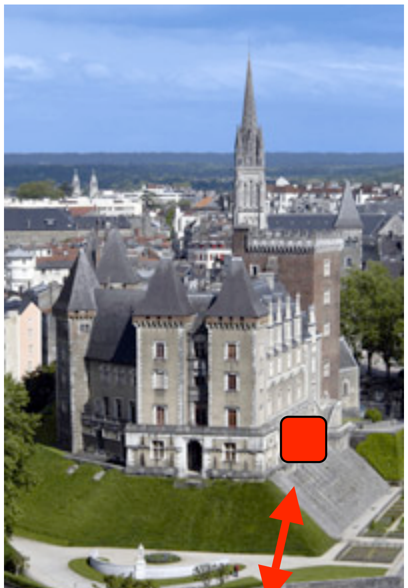


REGION AQUITAINE
EN AQUITAINE & EN AVANCE

SiCoP project

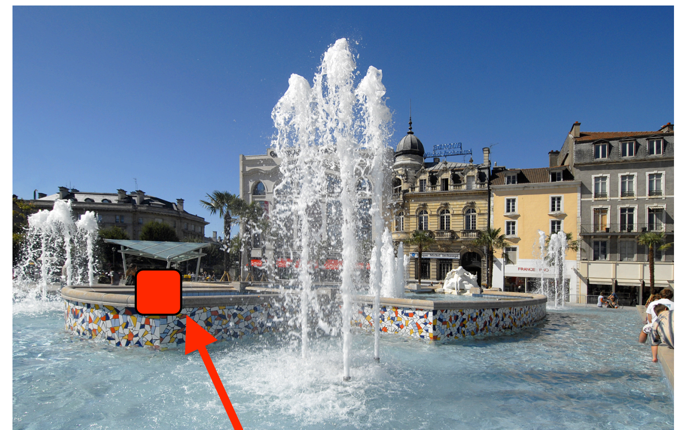
Sensors in the City of Pau

PAU-PYRÉNÉES
COMMUNAUTÉ D'AGGLOMÉRATION



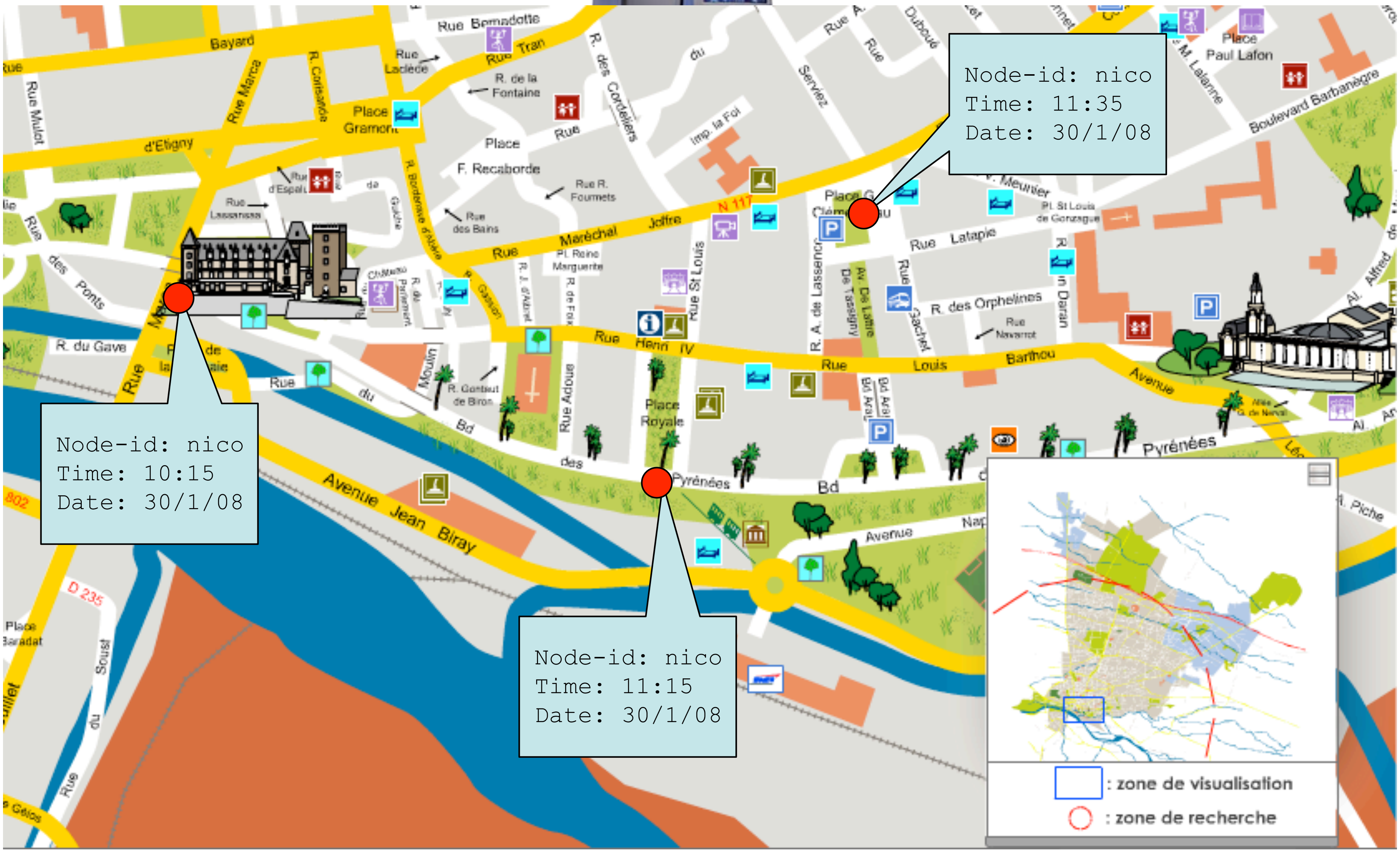
Ref: SN-01
Node-id: nico
Time: 10:45
Date: 30/1/08
Temp: 23.4 °C
Lum: 2300
Hum: 56%

Ref: SN-02
Node-id: nico
Time: 11:15
Date: 30/1/08
Temp: 24 °C
Lum: 2350
Hum: 55%



Ref: SN-03
Node-id: nico
Time: 11:35
Date: 30/1/08
Temp: 23 °C
Lum: 2460
Hum: 65%

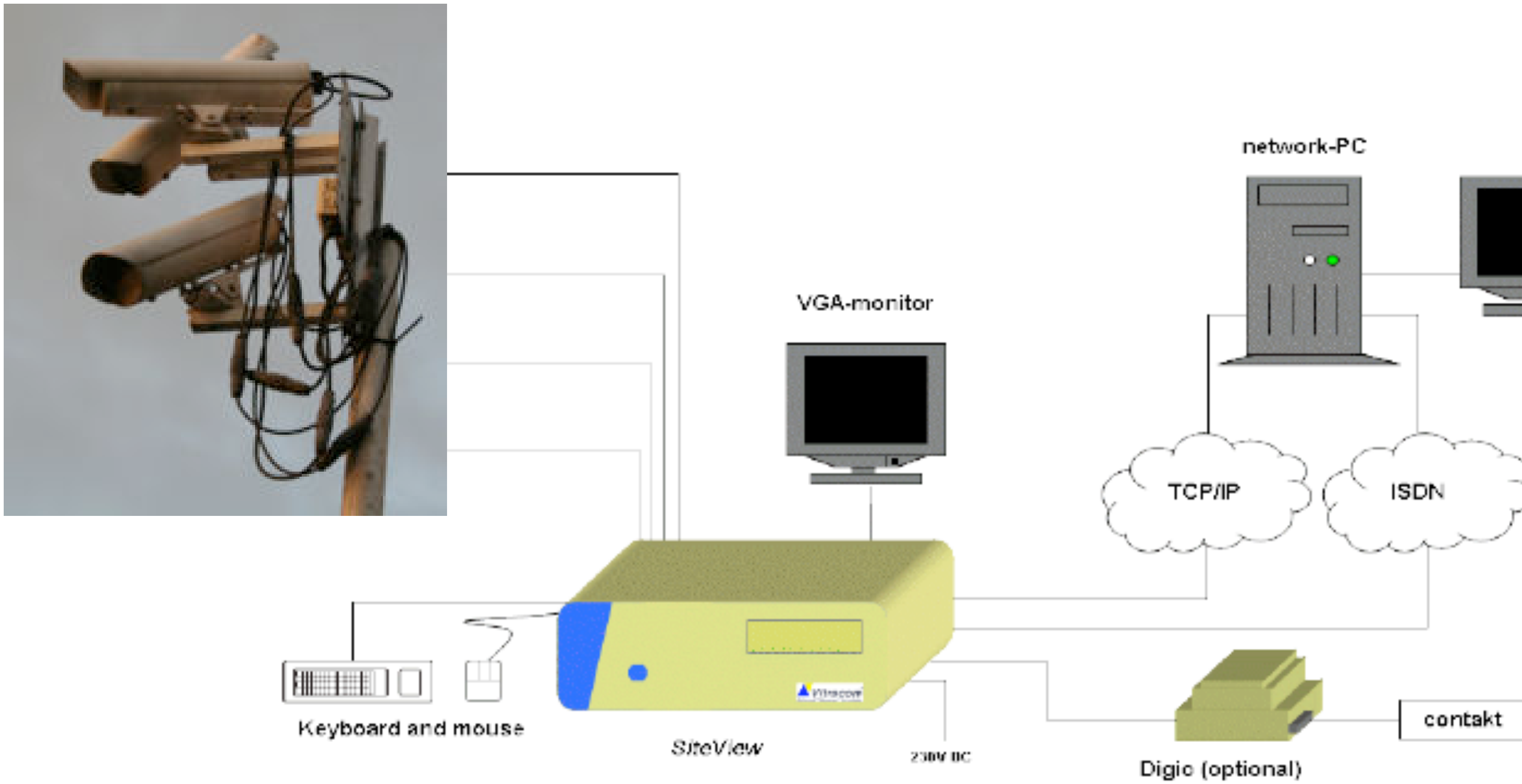
Database
Search by node, day, …

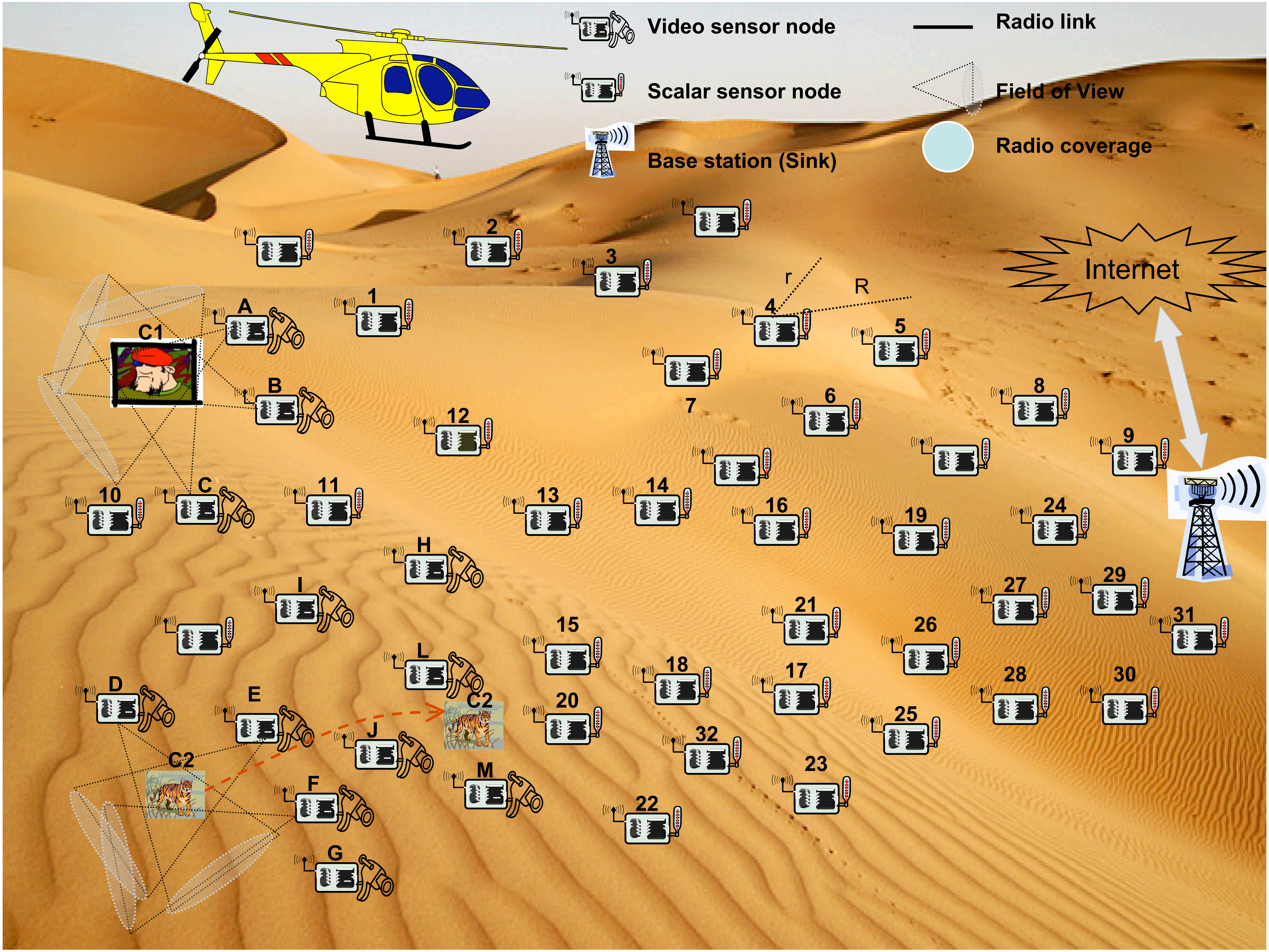


TCAP project

- « Transport de flux vidéo sur réseaux de CAPteurs pour la surveillance à la demande »
- LIUPPA
  - Software architecture for multimedia integration, supervision plateform, transport protocols & congestion control
- CRAN (Nancy)
  - Video coding techniques, multi-path routing, interference-free routing

Traditionnal surveillance infrastructure




Video sensor node
Scalar sensor node
Base station (Sink)
Radio link
Field of View
Radio coverage
Internet
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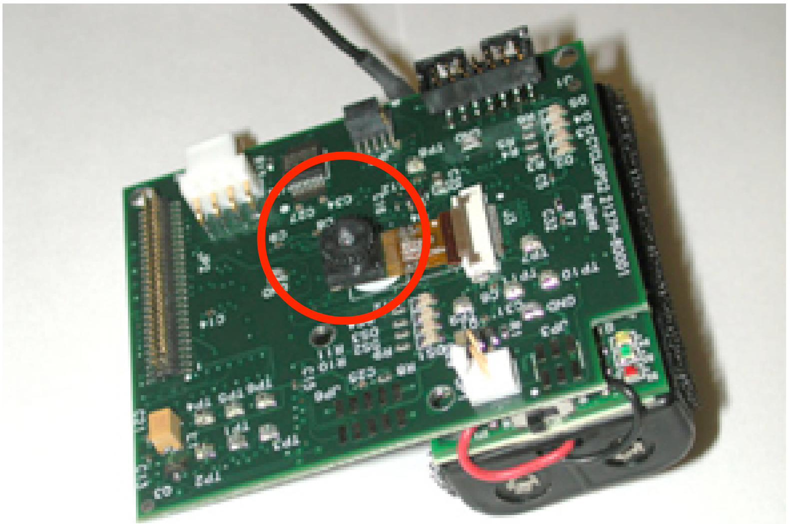
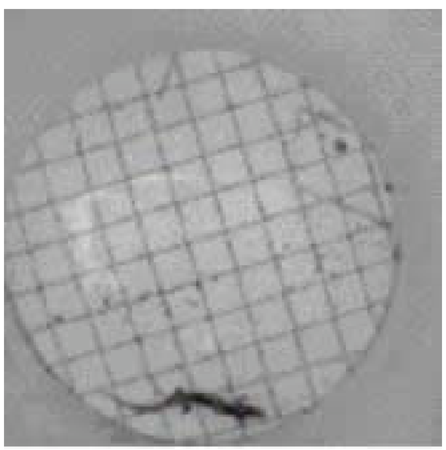
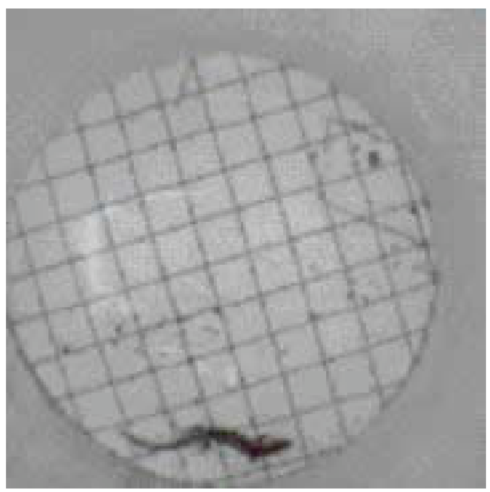
Wireless Video Sensors



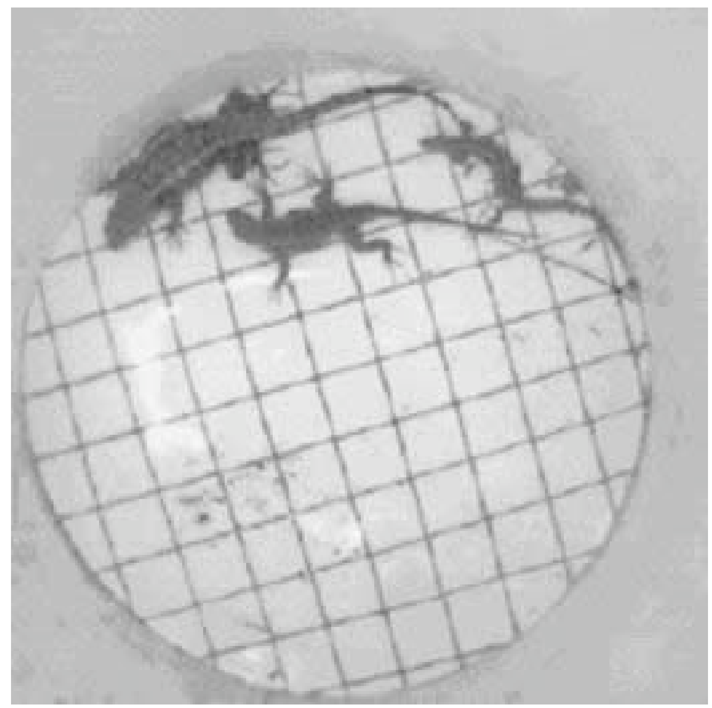
Cyclops video board on Mica motes



128x128



140x140



240x240

Challenges?

- Wireless Scalar Sensor Networks
  - Small size of events (°C, pressure,…)
  - Usually no mobility
  - Data fusion, localization, routing, congestion control
- Wireless Video Sensor Networks
  - What's new?
  - Video needs much higher data rate
- WVSN for Surveillance
  - What's new?
  - Where are the challenges?

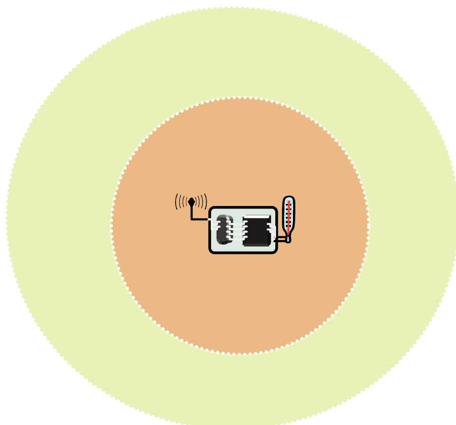
Research in WVSN

- Much works derive from scalar sensors works with video coding specificities
  - High data rate needs high compression ratio
  - Specific image/data fusion algorithms
  - Real-time flows are loss-tolerant➔spacial redondancy codes (FEC) rather than temporal redondancy (ARQ)
- Very little contribution on what is specific to sensors with embedded cameras
- No real settlement of the design space

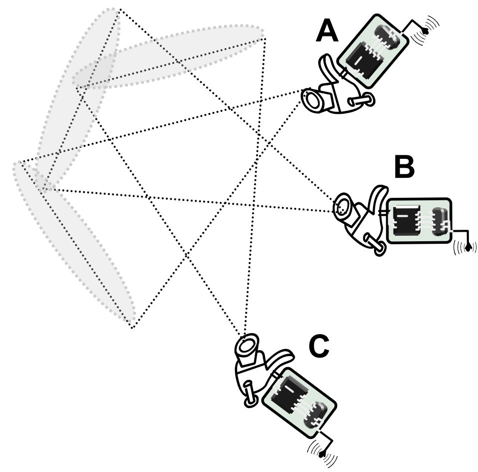
How to get started?

- What are the functionalities of a Wireless Video Sensor?
- Which one are specific to video sensor?
- Which one are specific to surveillance applications?
- What is the design space?

Sensing range & coverage



vs

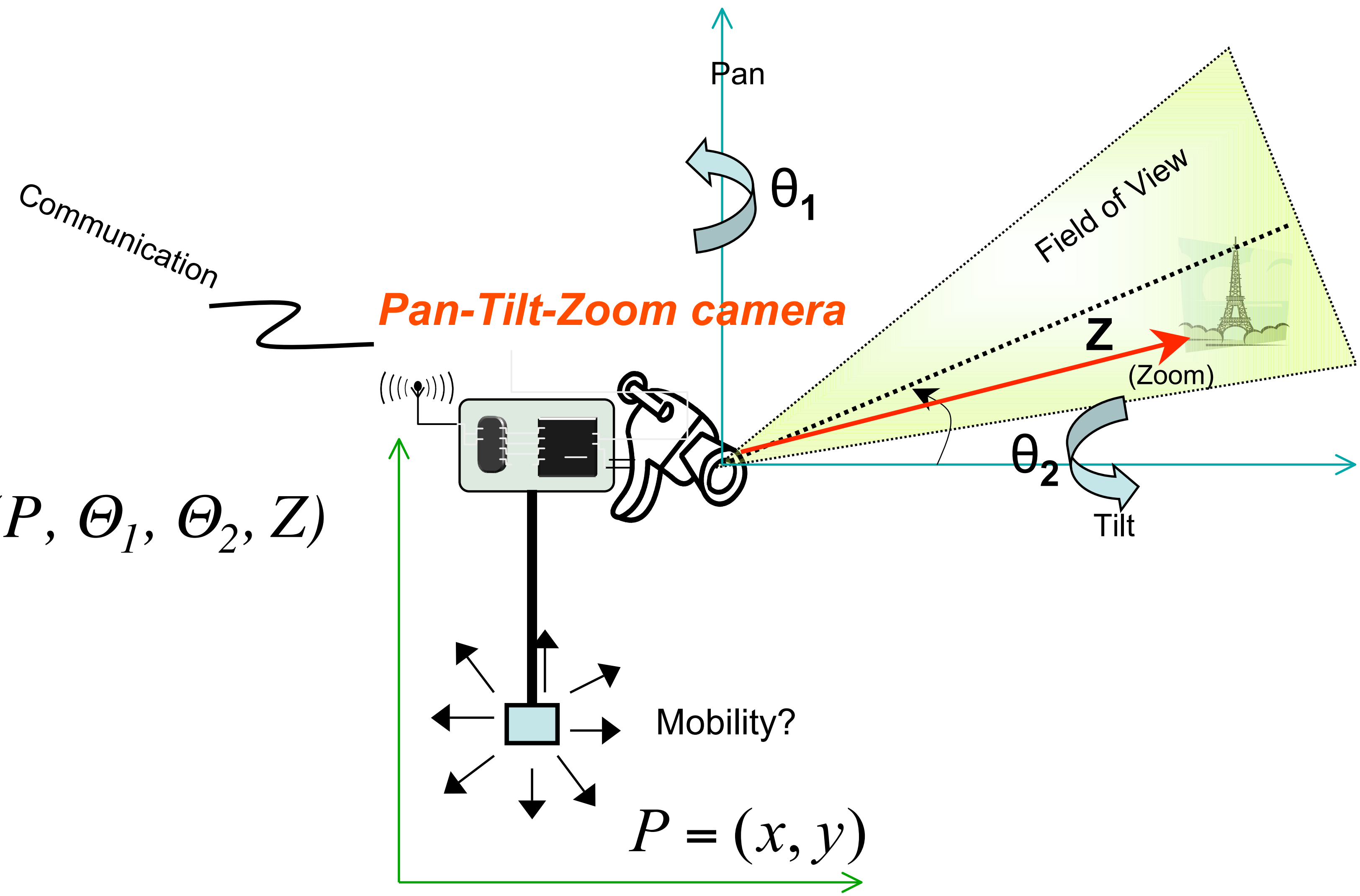


Video sensors capture scene with a Field of View ~ a cone

Zoom feature = Depth of View

Image resolution

A model of video sensor



$N(P, \Theta_1, \Theta_2, Z)$

$P = (x, y)$

Note: P is on a plane, it could be in 3D space: P=(x,y,z)

Surveillance applications (1)

- Lesson 1: don't miss important events

Whole understanding of the scene is wrong!!!

What is captured

Surveillance applications (2)

- Lesson 2: high-quality not necessarily good

333x358 16M colors, no light

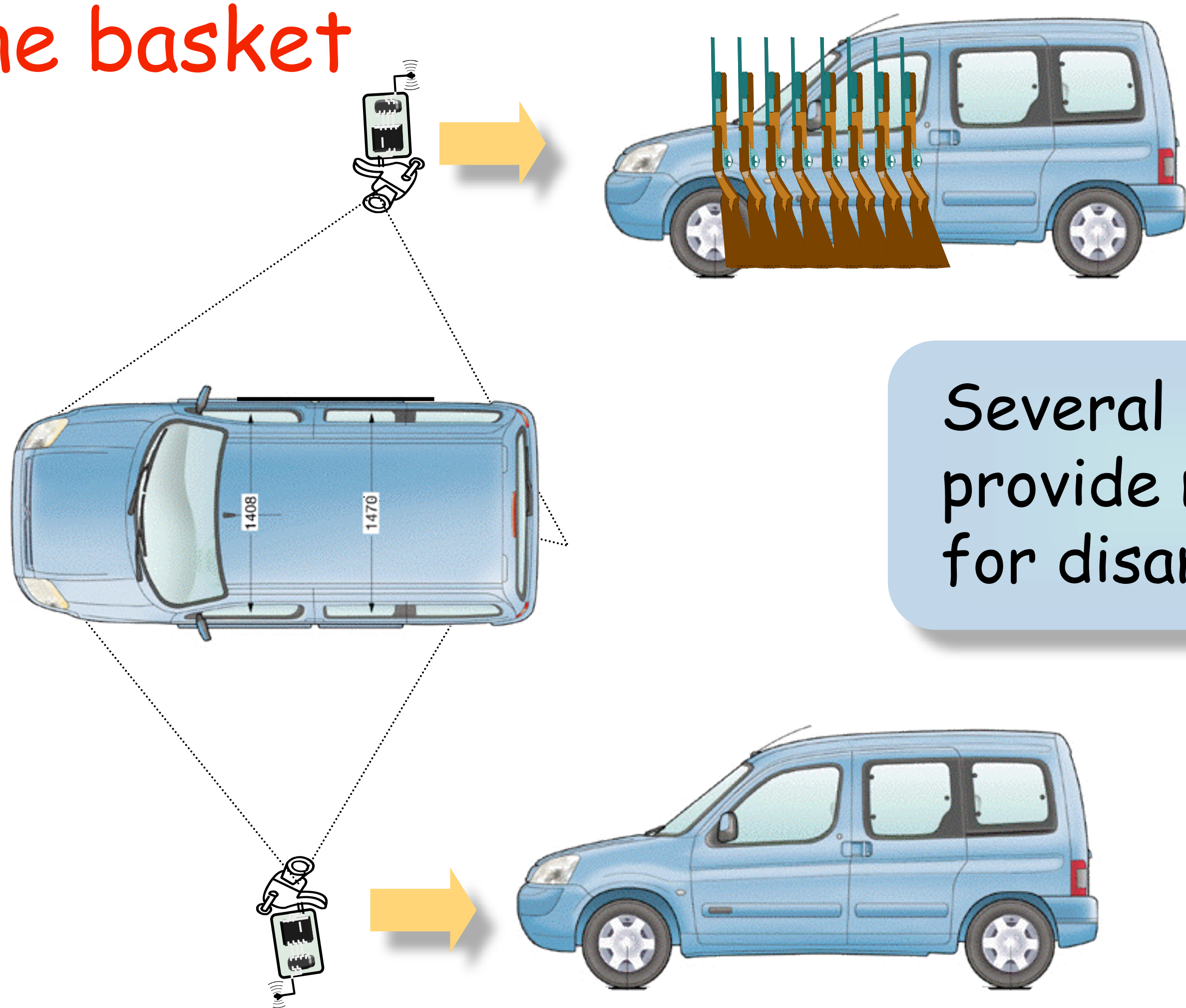
167x180 16 colors, light

Keep in mind the goal of the application!

167x180 BW (2 colors), light

Surveillance applications (3)

- Lesson 3: don't put all your eggs in one basket

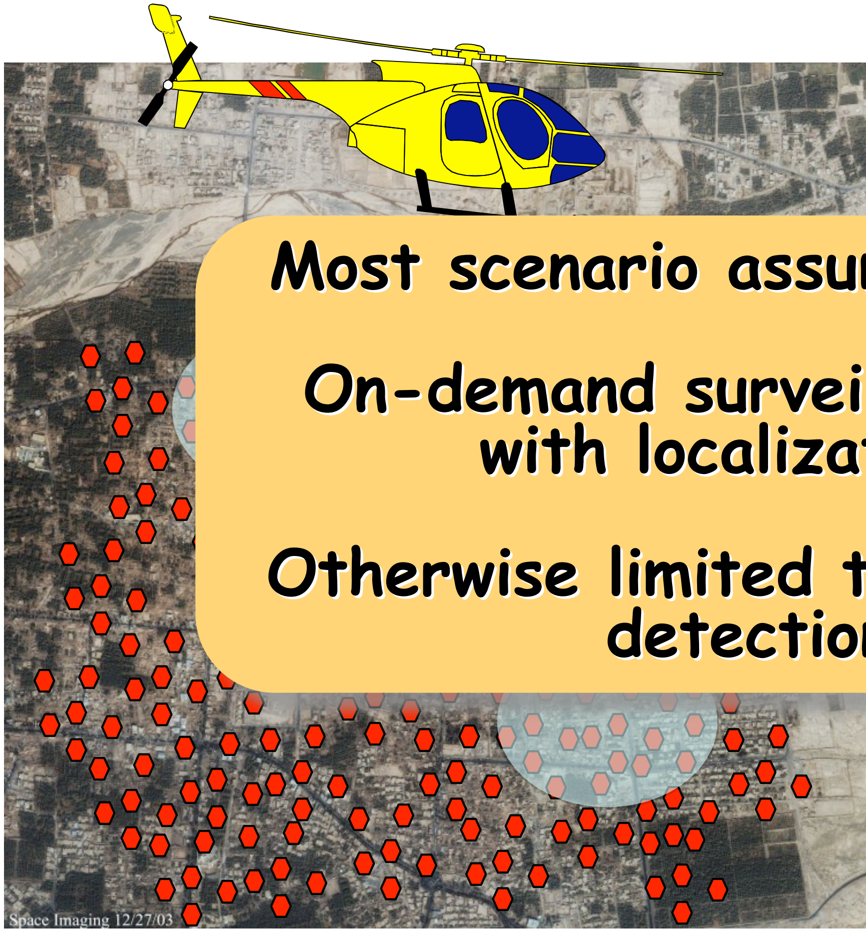


Several camera provide multi-view for disambiguation

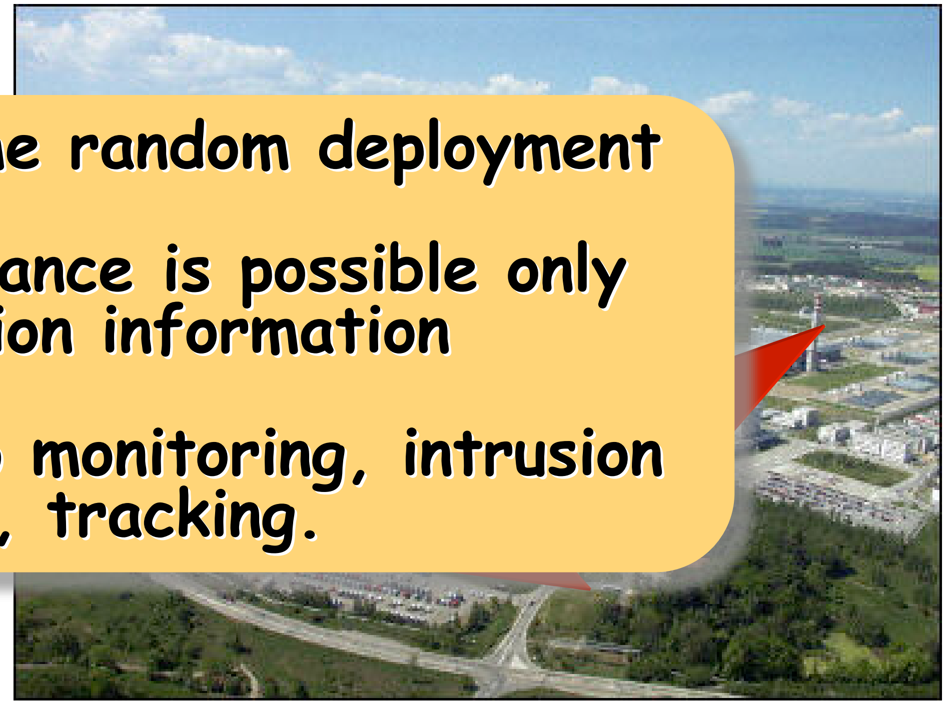
Design space

- Deployment scenario?
- Surveillance models?
- Homogeneous or heterogeneous?
- Stationary or mobility?
- Coverage?
- Energy consumption?
- Quality of Service?
- Synchronization?
- Intelligent vs non intelligent?

Deployment scenario



Random, thrown in mass



*

Fixed, semi-fixed, by hand

Most scenario assume random deployment

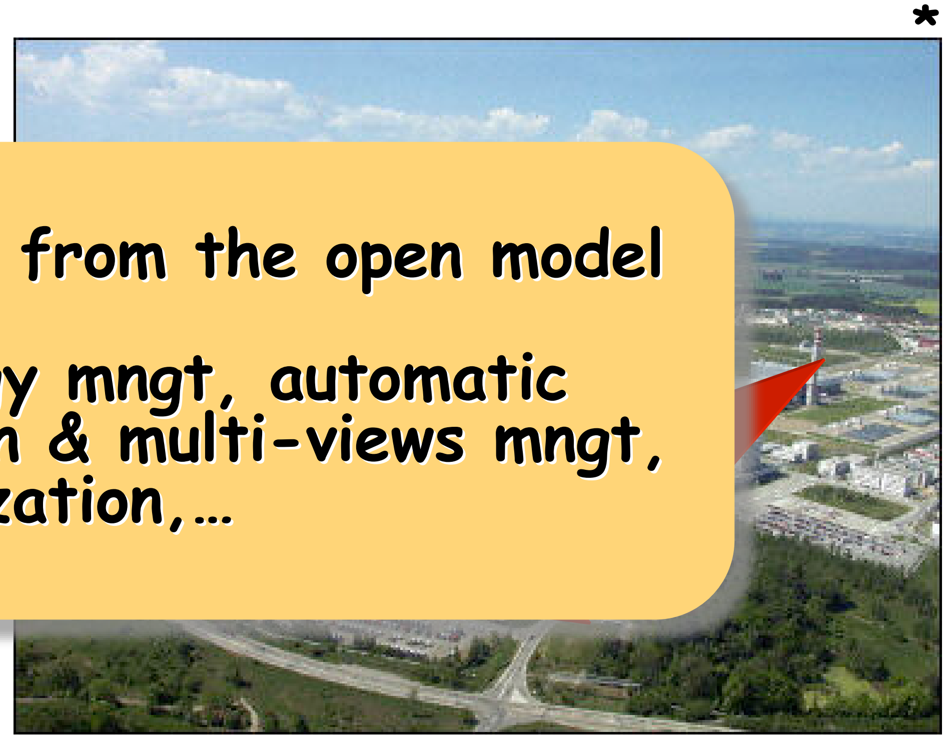
On-demand surveillance is possible only with localization information

Otherwise limited to monitoring, intrusion detection, tracking.

* No nuclear plant in particular

Surveillance models

Open model, no well-defined surveillance area



Infrastructure-oriented model, usually, we know what we are monitoring

Most problems come from the open model

Coverage & energy mngt, automatic redundancy detection & multi-views mngt, organization,…

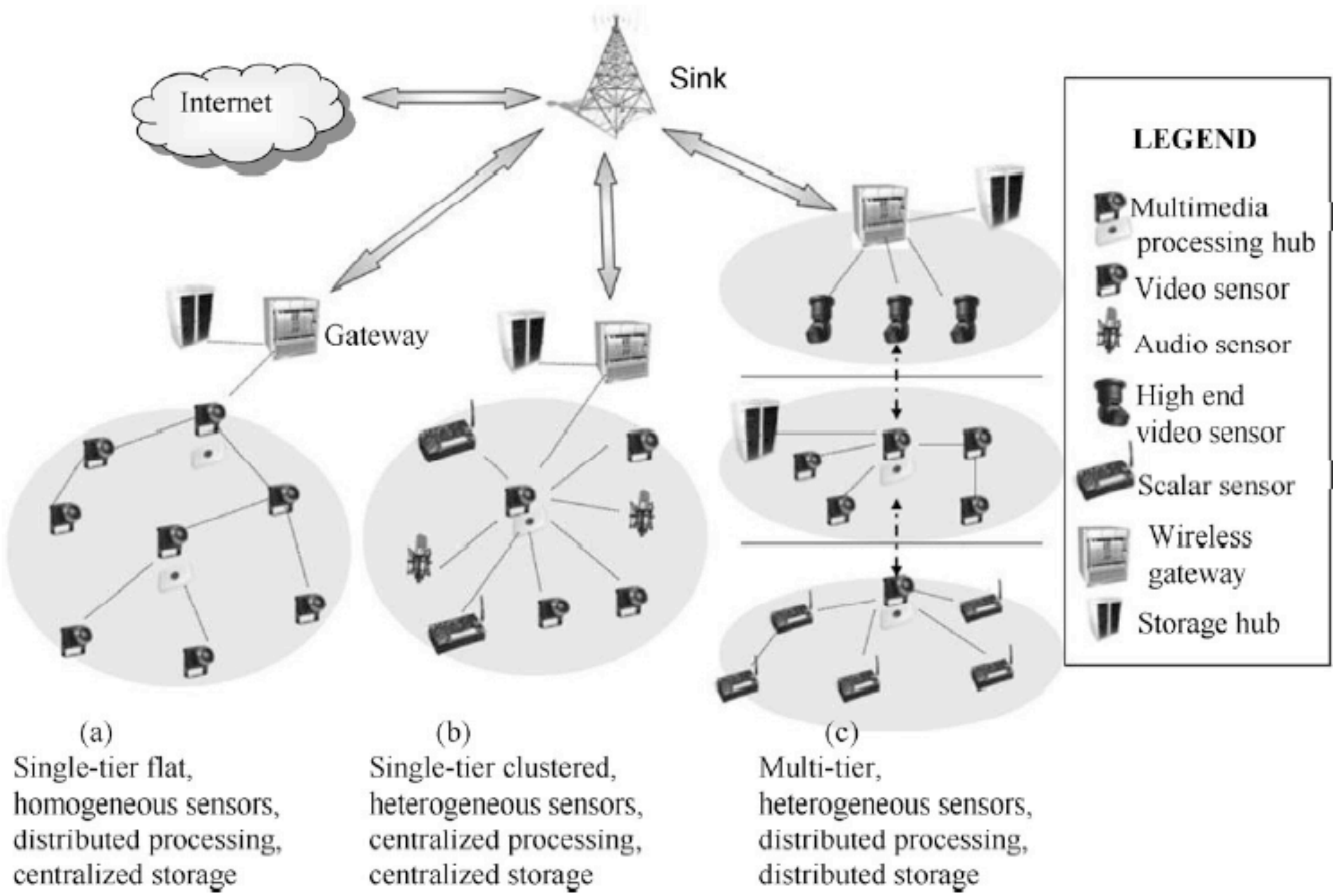
* No nuclear plant in particular

Homogeneity or not?

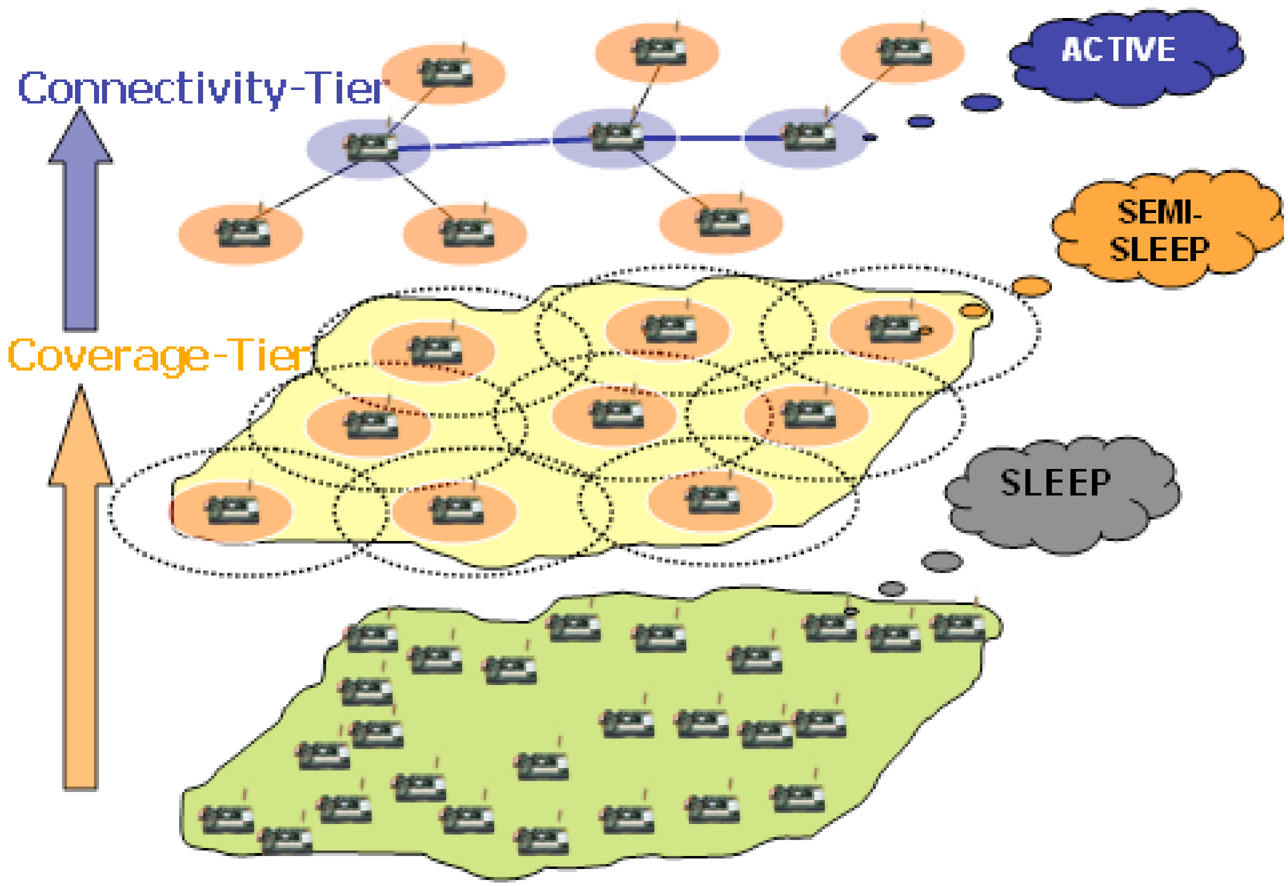
- Video nodes are more expensive
- Large scale WVSN WILL BE heterogeneous!

- Multi-tiers is a common approach
  - Hardware characteristics
  - Functionalities
- Energy management is the prime goal

Reference architecture



Multi-tiers for multi-purposes



TTS: A Two-Tiered Scheduling Mechanism for Energy Conservation in Wireless Sensor Networks. See Nurcan Tezcan's Research Projects

Advanced heterogeneity

- Reliability in surveillance
  - Enhance/validate/disambiguate video information with other sources of information
- 24/24 surveillance
  - Replace video by infrared when it's dark
  - If critical, why not « kamikaze » flash-sensor?

➔SURVEILLANCE SERVICE➔

Surveillance at any price!

Surveillance Service

Buzzword!

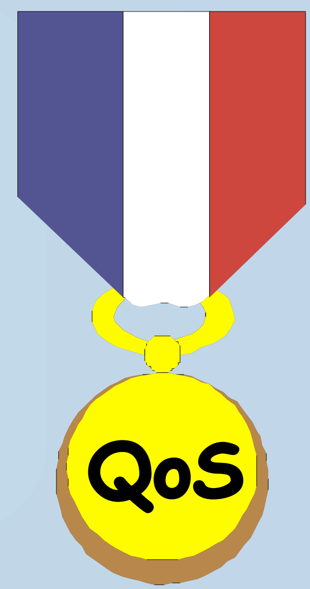
- Similar to Service Level Agreement

➔ SURVEILLANCE AT ANY PRICE ➔

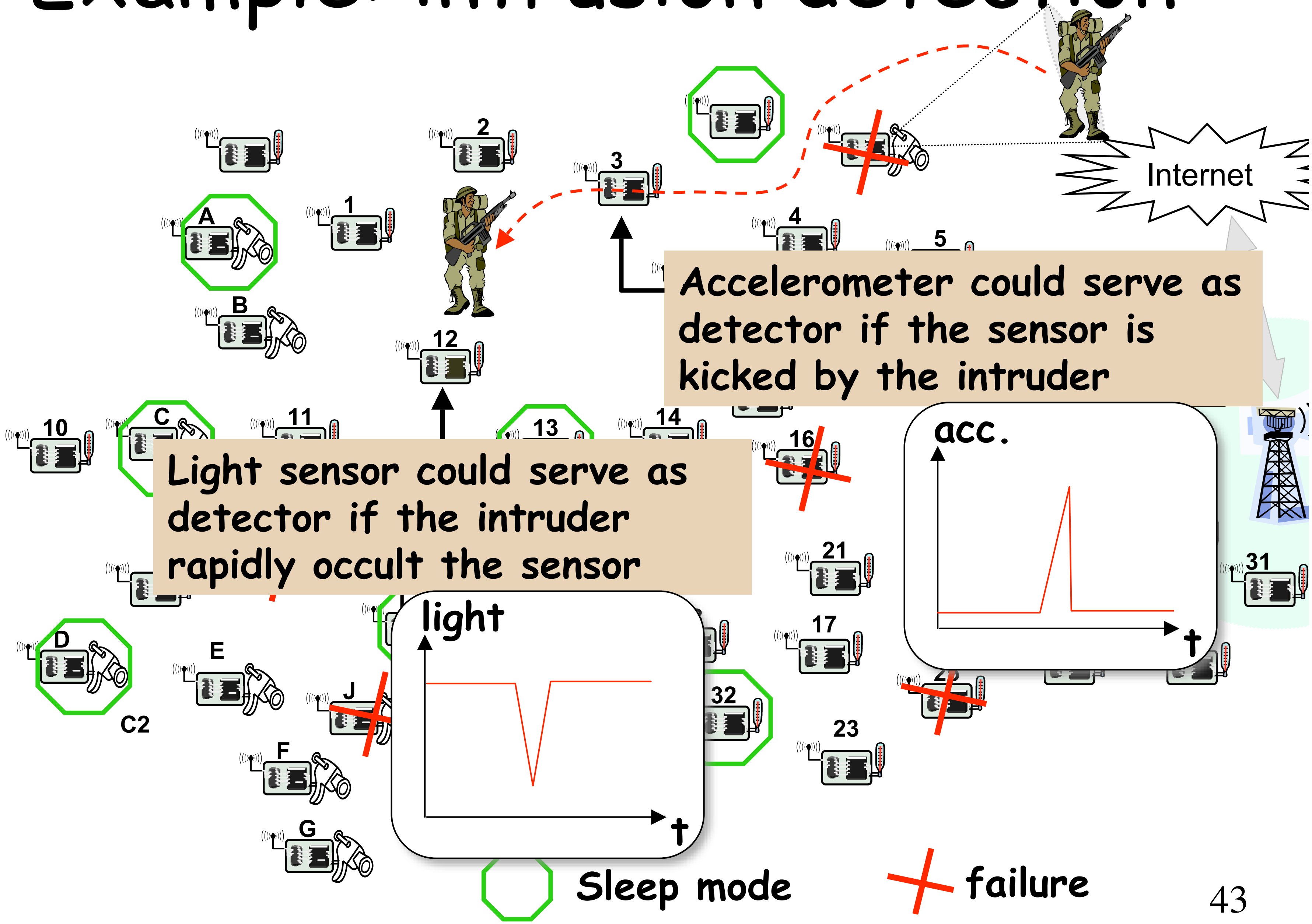
no discontinuity of service against node's failures

collaborative sensors

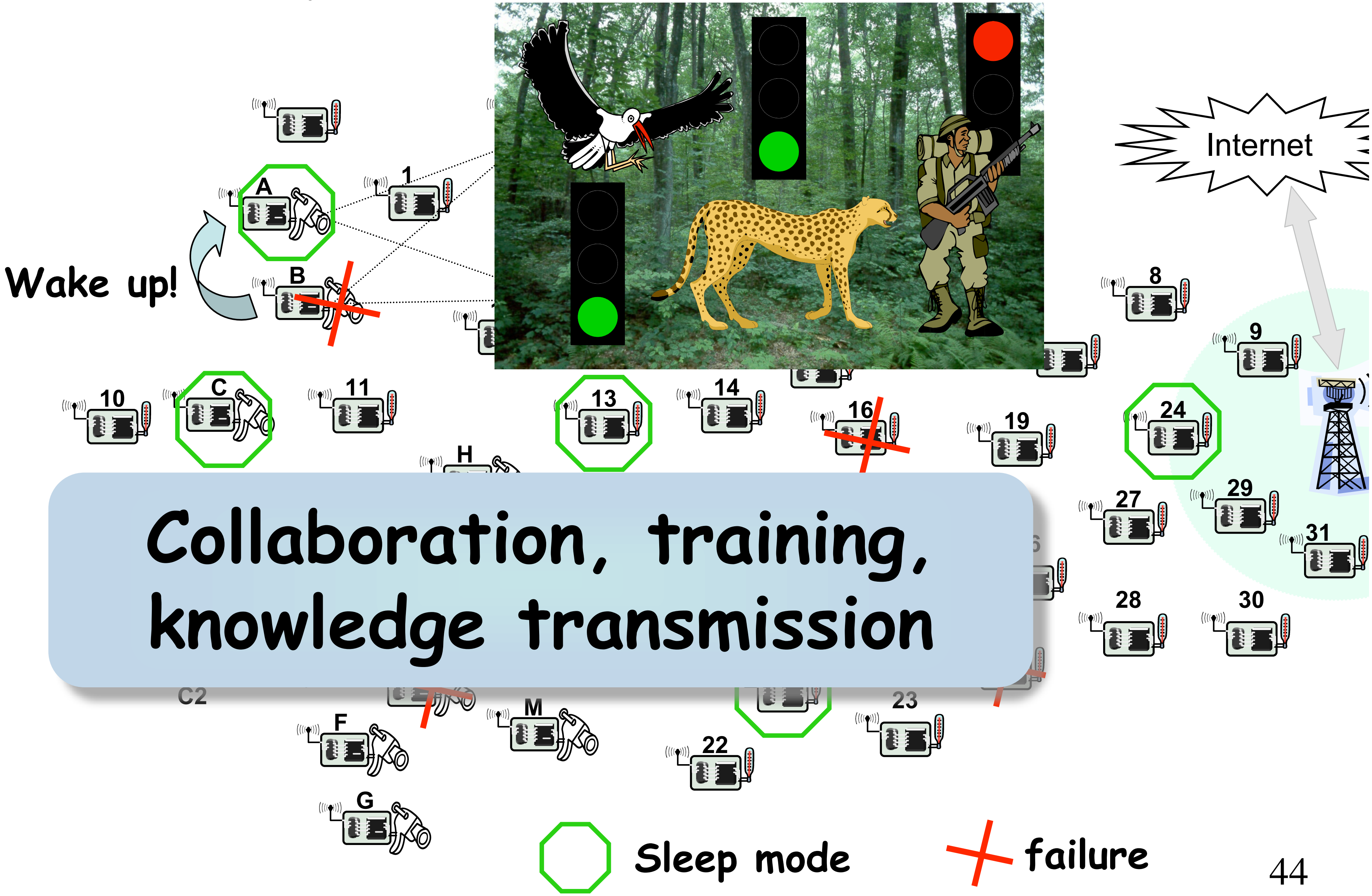
service independant of its implementation



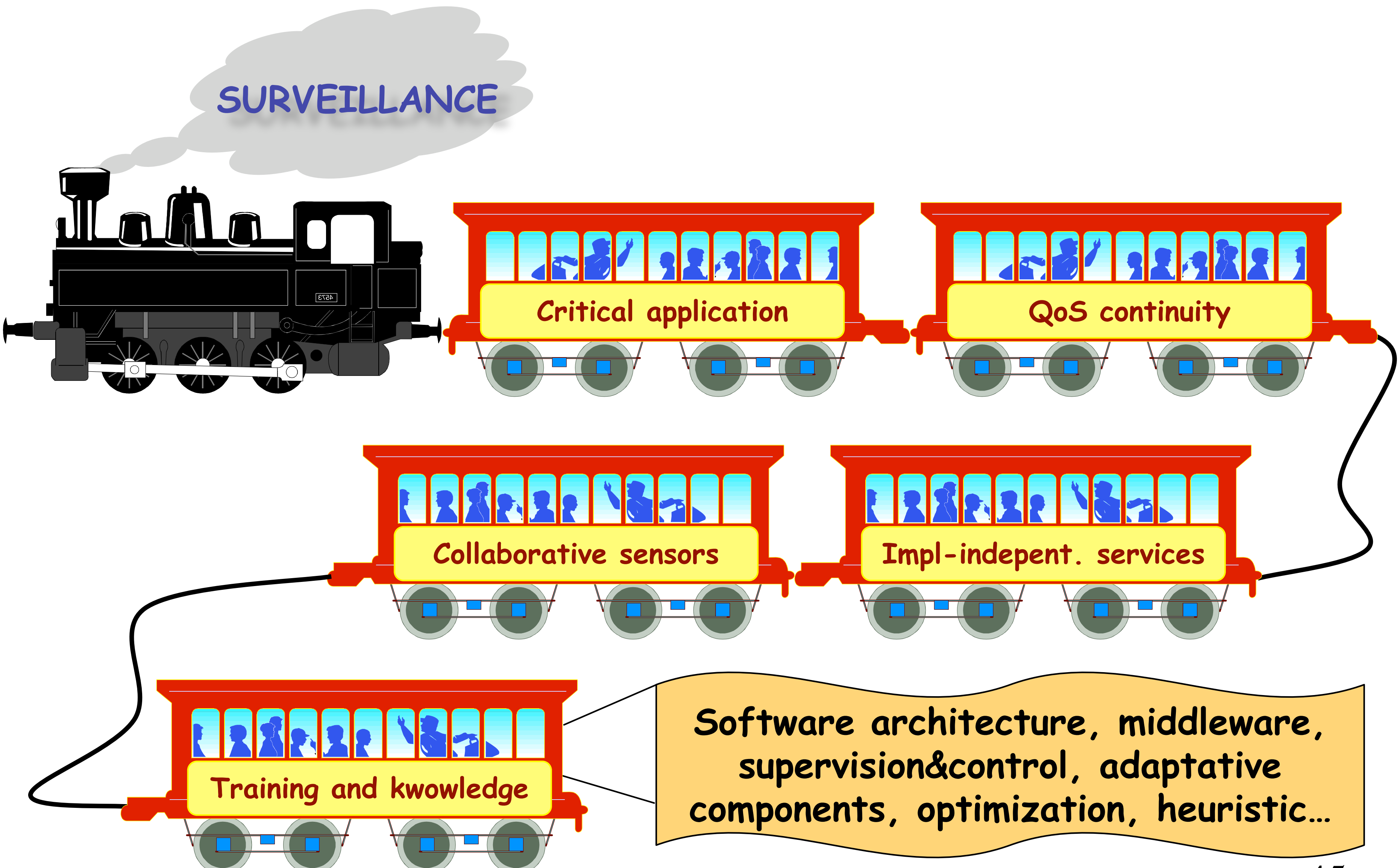
Example: intrusion detection



Example: intrusion detection



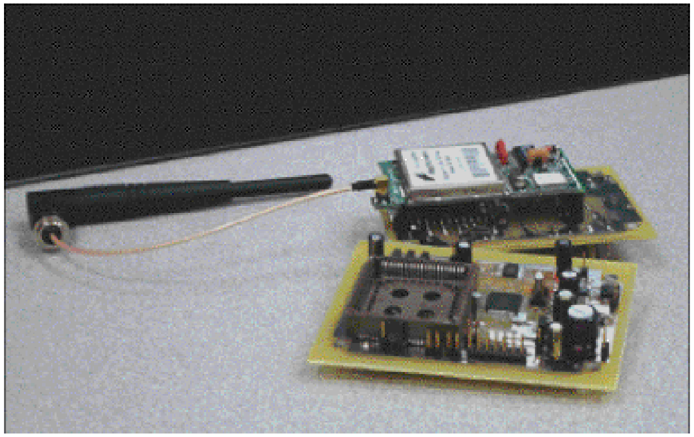
Impacts of QoS



Software architecture, middleware, supervision&control, adaptative components, optimization, heuristic…

Mobility

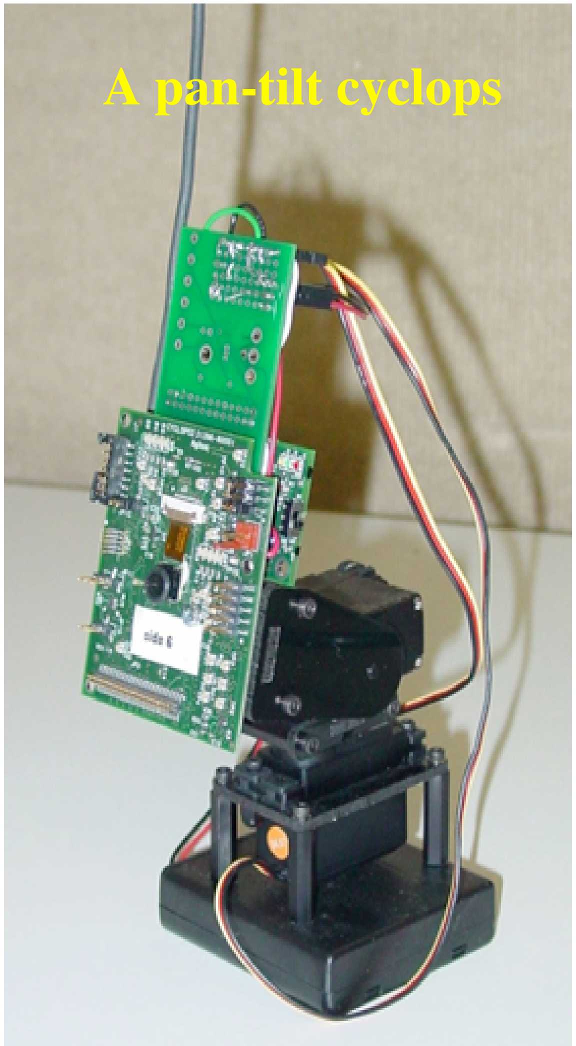
- Mobility for wireless sensor is expensive
  - Size constraints, terrain constraints
  - Energy constraints
- Most WSN have no mobility➔ monitoring, intrusion detection applications
- Non-controllable mobility has limited applications: mostly exploration (ZebraNet) & communication is the main scientific problem



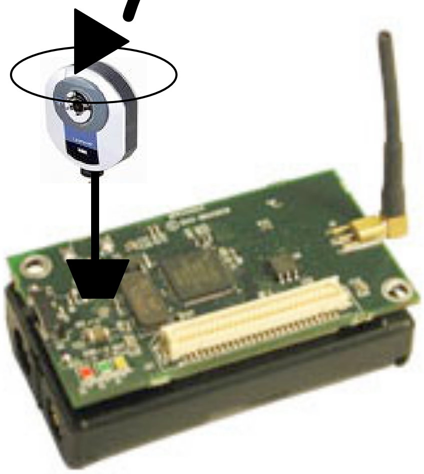
ZebraNet project, university of Princeton: exploring wildlife

We see cheap mobility!

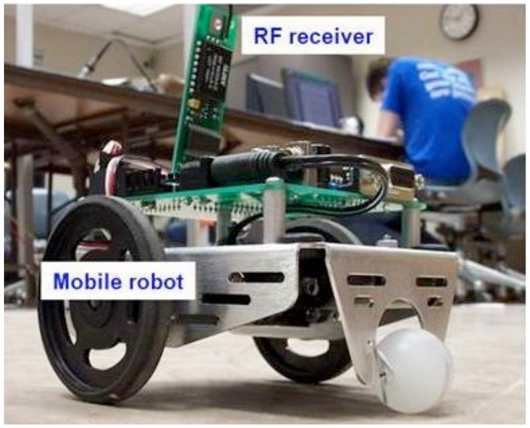
- Video sensors have a cheap mobility feature
- Pan-tilt camera provide multiple views possibility, large variety of app.: monitoring, on-demand exploration, tracking.



NOW

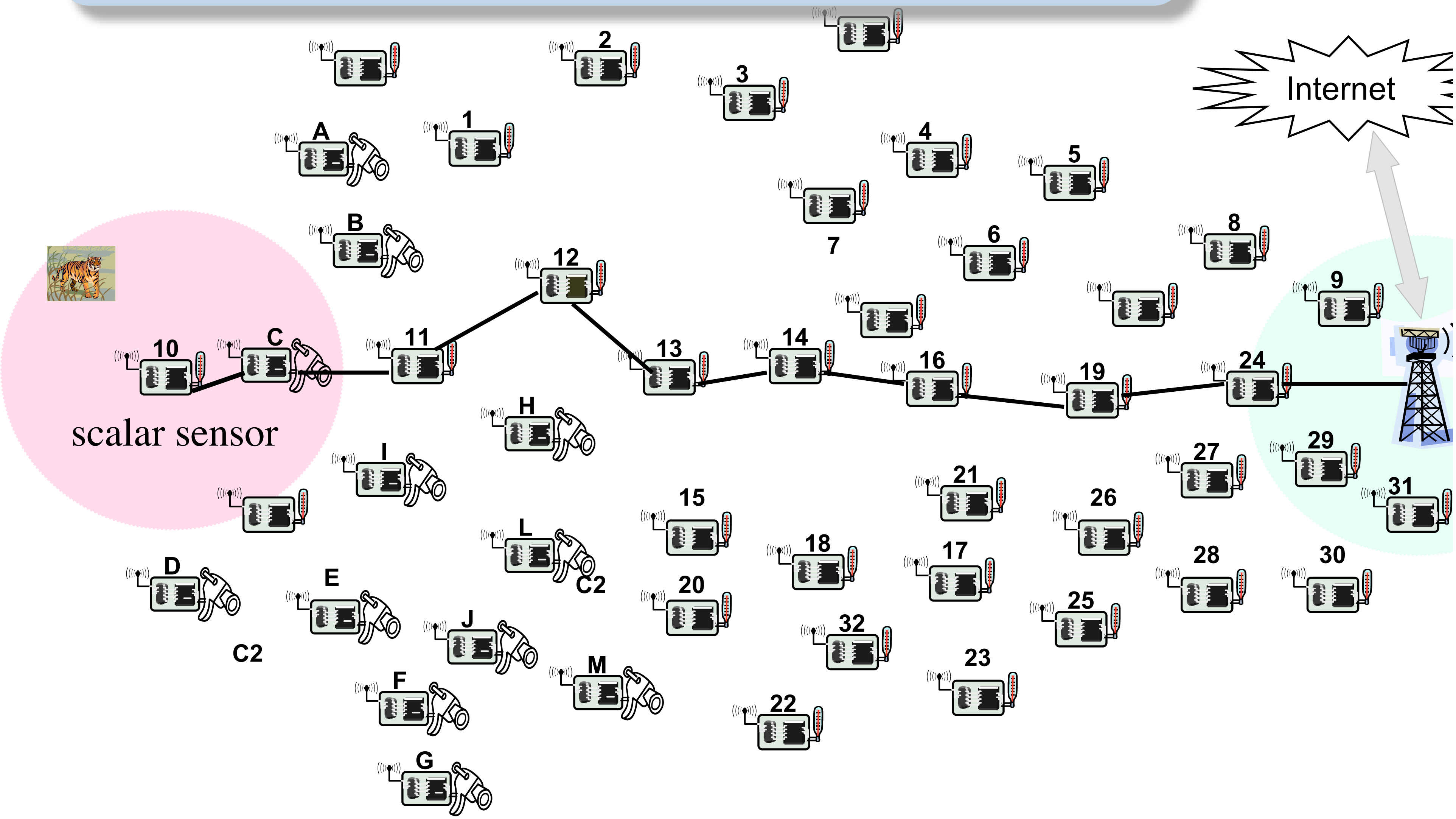


SOON

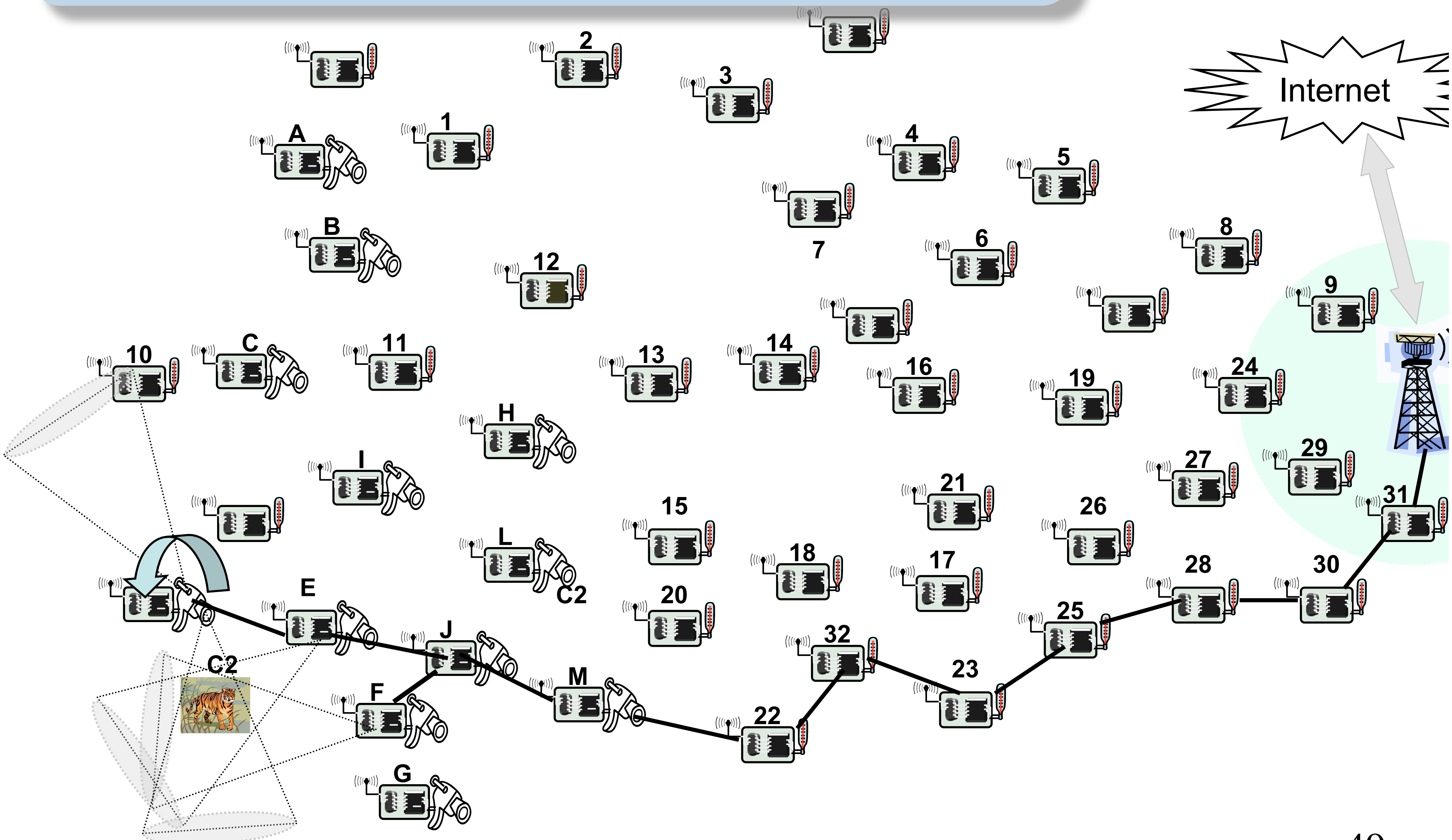


Simpler & less expensive than above

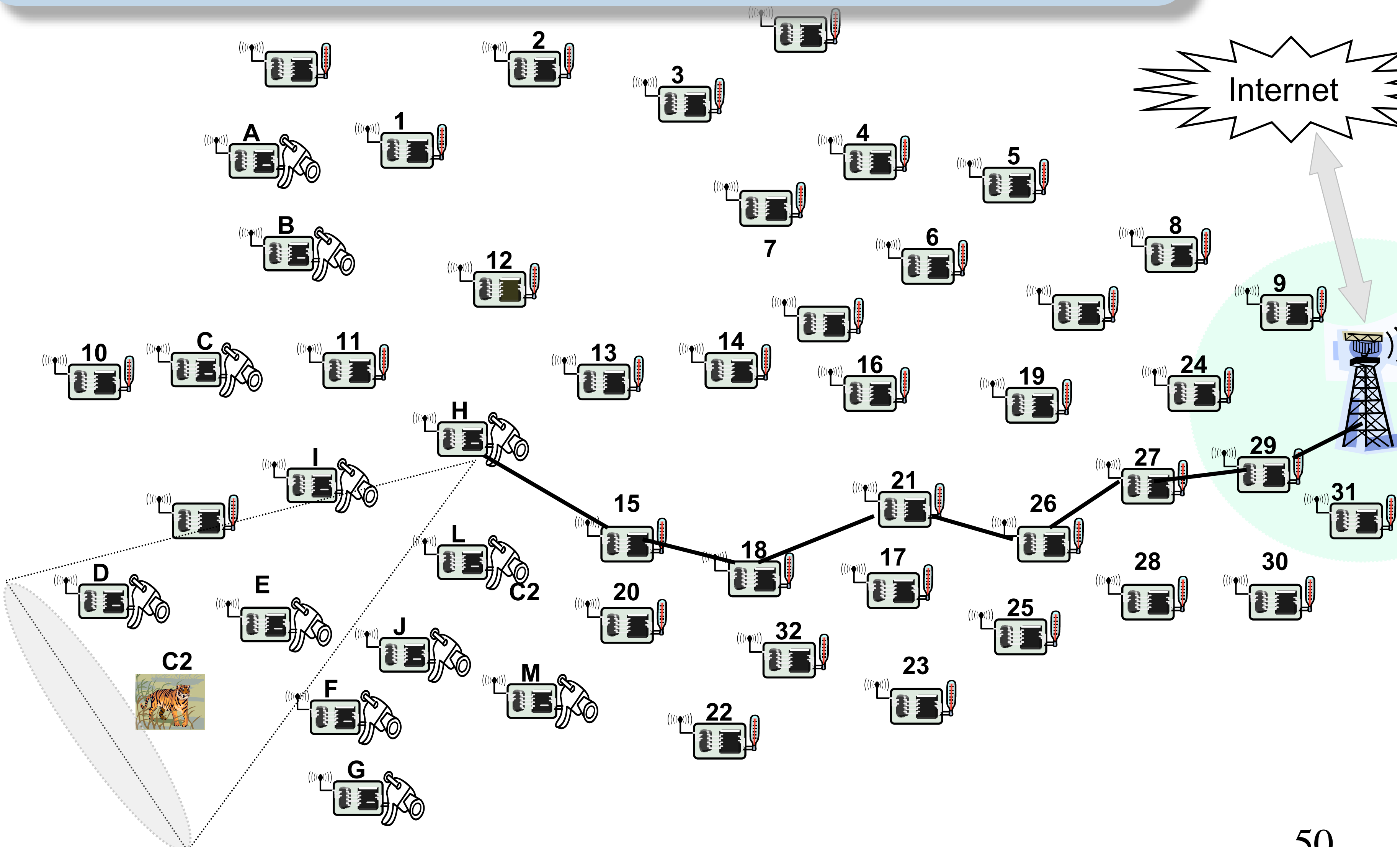
Event's position determines sensors



Mobility (pan-tilt) complexifies coverage problem

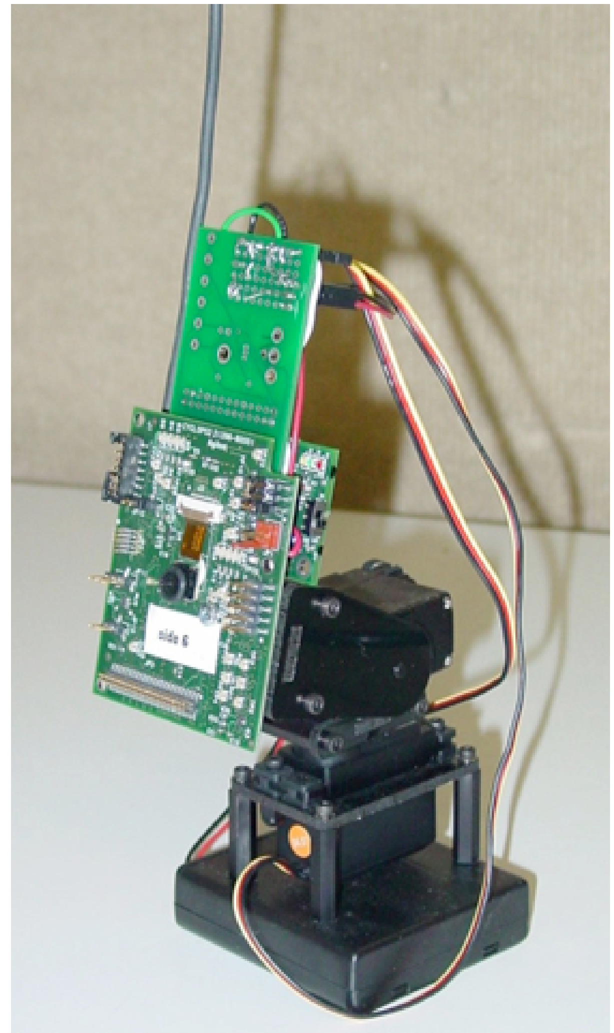


Far sensors can potentially capture the global scene better (weather conditions)!



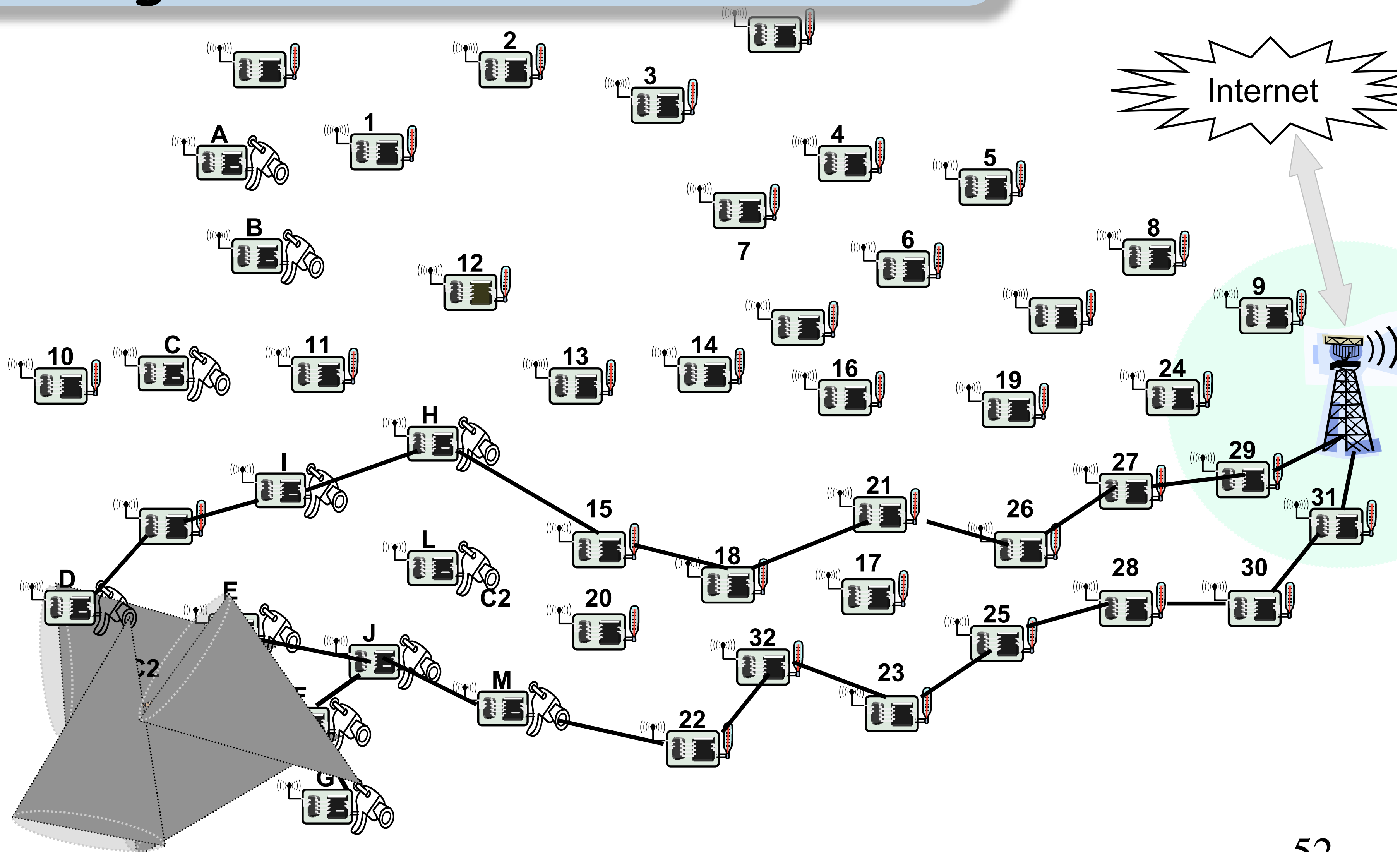
Impact of pan-tilt-zoom mobility

- More parameters, more optimization possibilities
  - Coverage determination and sensor selection procedures
  - Energy-efficient initial configuration settings
  - Quality of service

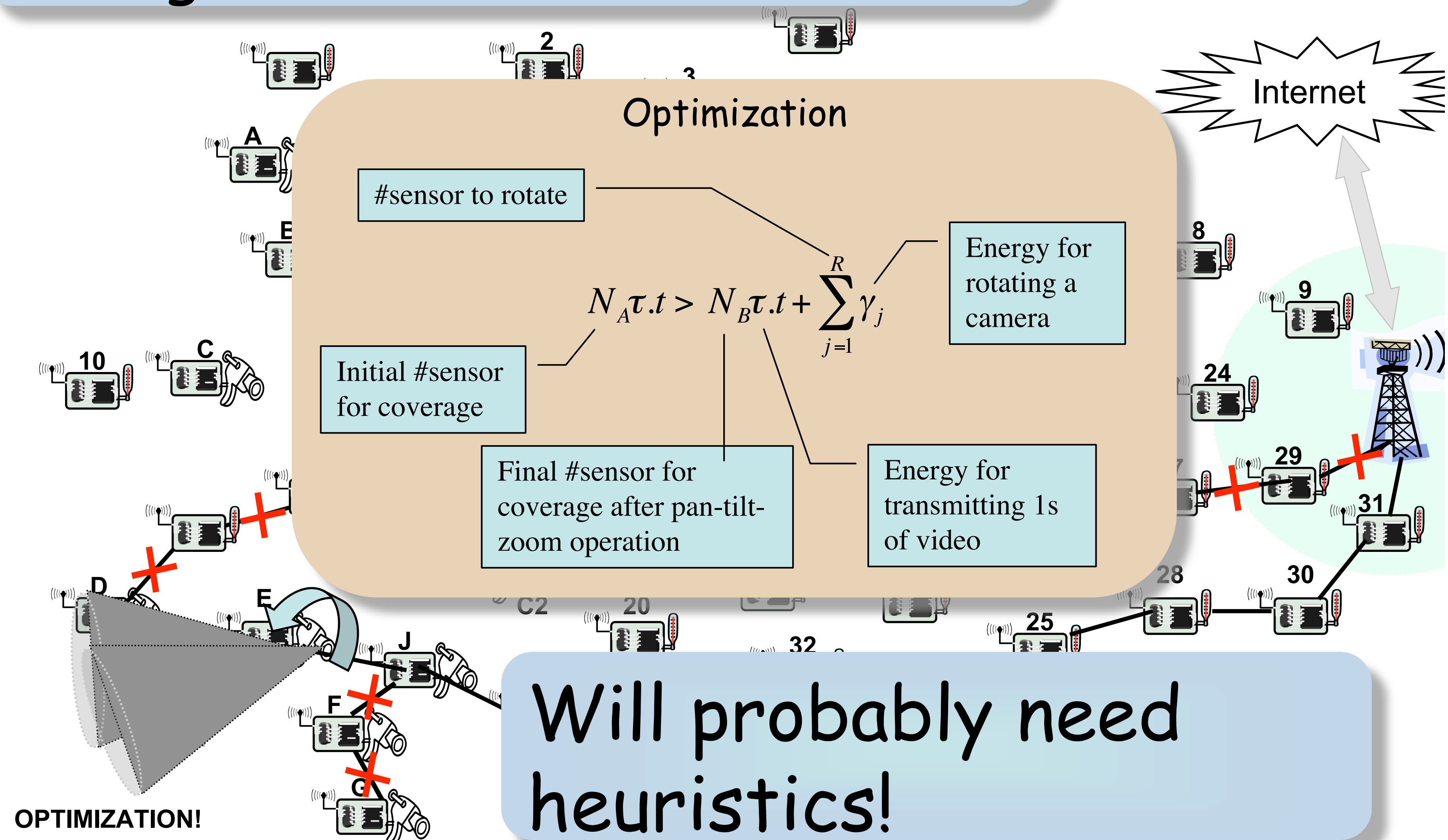


A pan-tilt cyclops

Ex: Energy-efficient initial configuration



Ex: Energy-efficient initial configuration



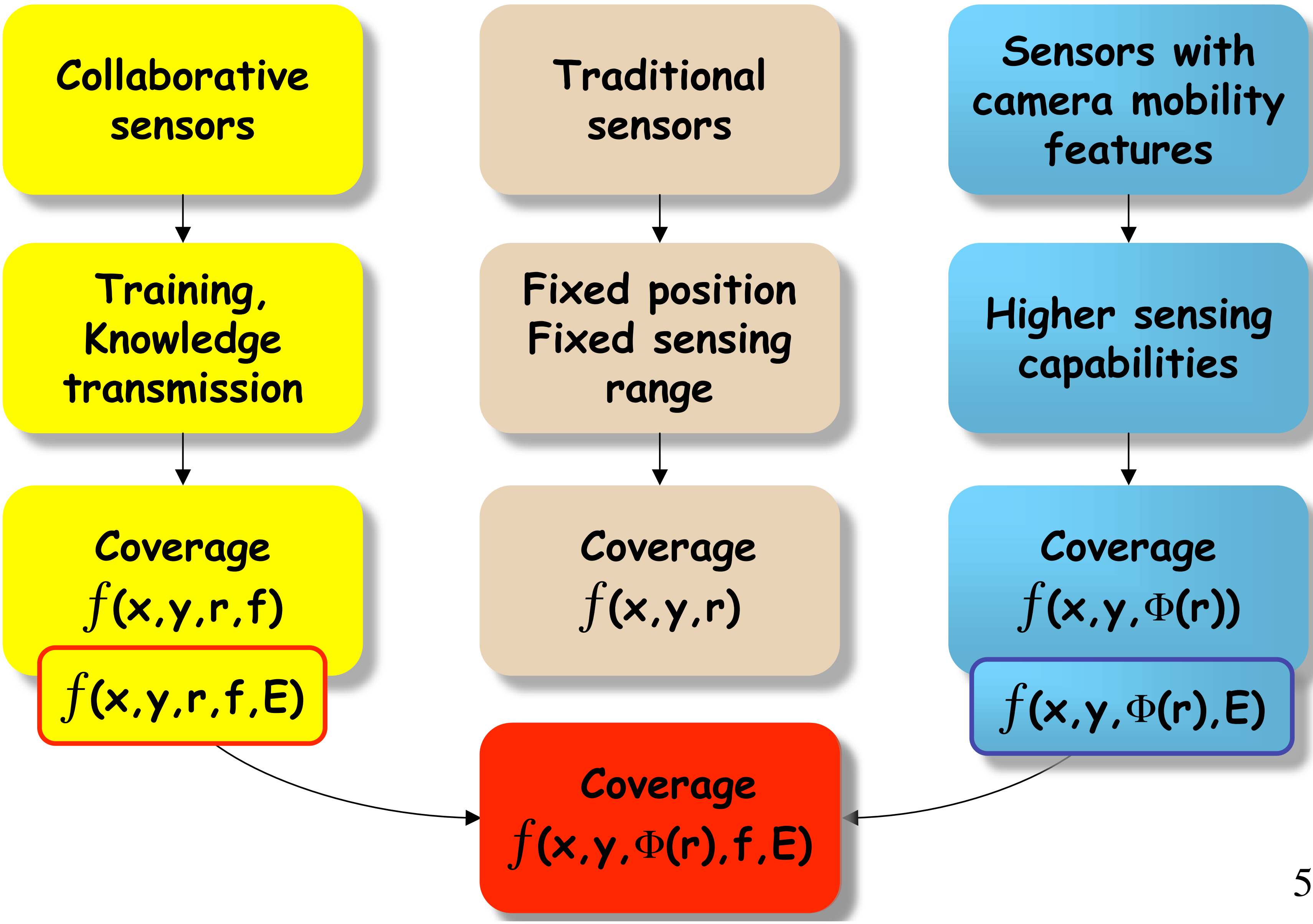
Optimization

$$N_A \tau . t > N_B \tau . t + \sum_{j=1}^{R} \gamma_j$$

- #sensor to rotate
- Energy for rotating a camera
- Initial #sensor for coverage
- Final #sensor for coverage after pan-tilt-zoom operation
- Energy for transmitting 1s of video

Will probably need heuristics!

On the coverage problem



Related domains

- Distributed data fusion algorithms, databases management
- Distributed image processing algorithms
- Distributed target tracking algorithms
- Distributed control & supervision
- Advanced security mechanisms, security in routing, security in information validation
- Energy-efficient transmission

Conclusions

- New domain
- Mentioned scientific problems may be not new, but new parameters to take into account
  - Larger design space than traditional surveillance infrastructures
  - Larger design space than scalar sensors
- Lots of related domains where contributions could be done