Wireless Sensor Networks and Their Applications

Matsuno Lab Seminar
November 9th, 2011
Kyoto University

LIUPPA
T2I team

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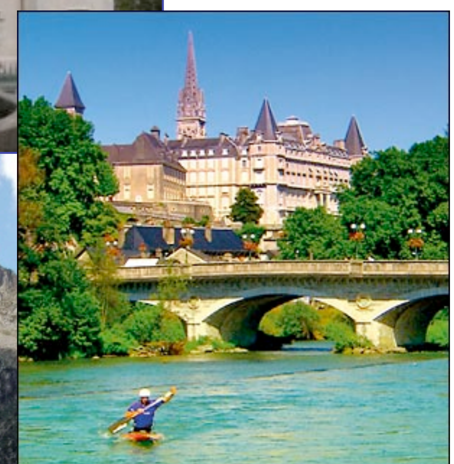

iaporama des
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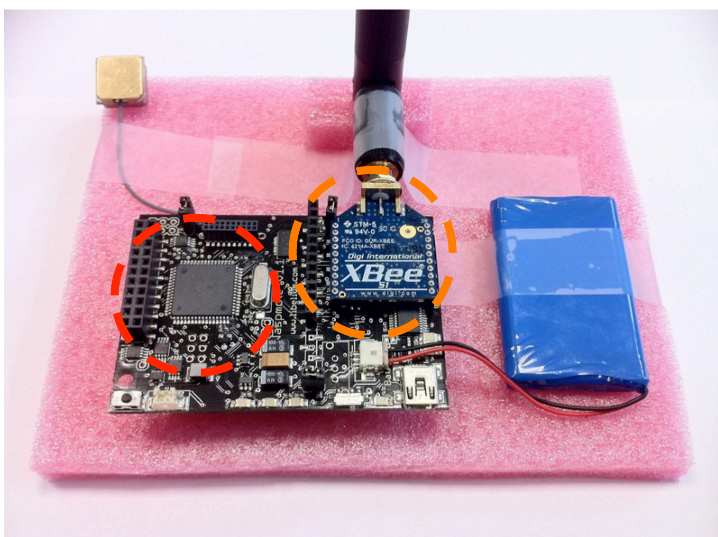
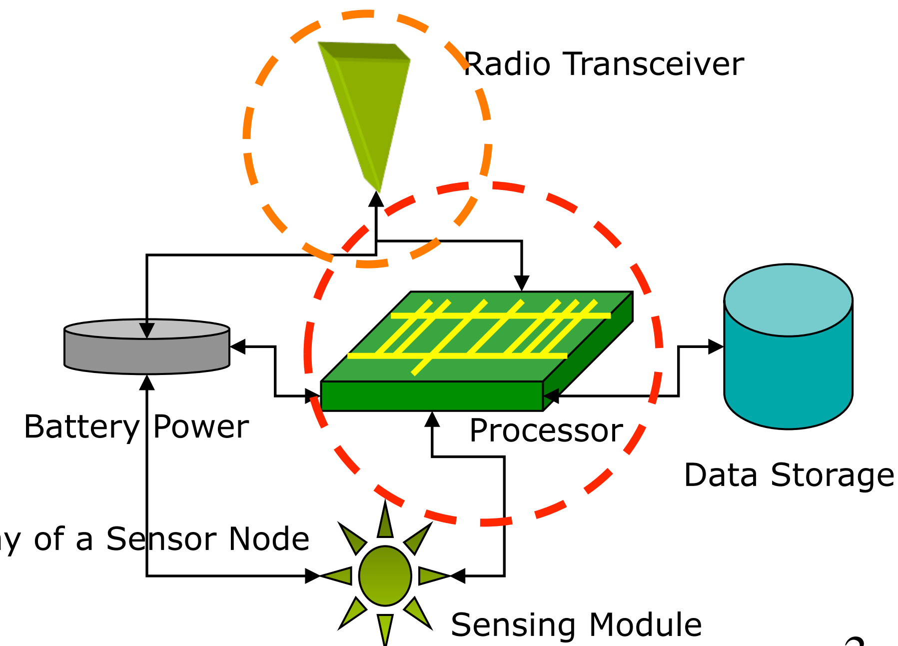
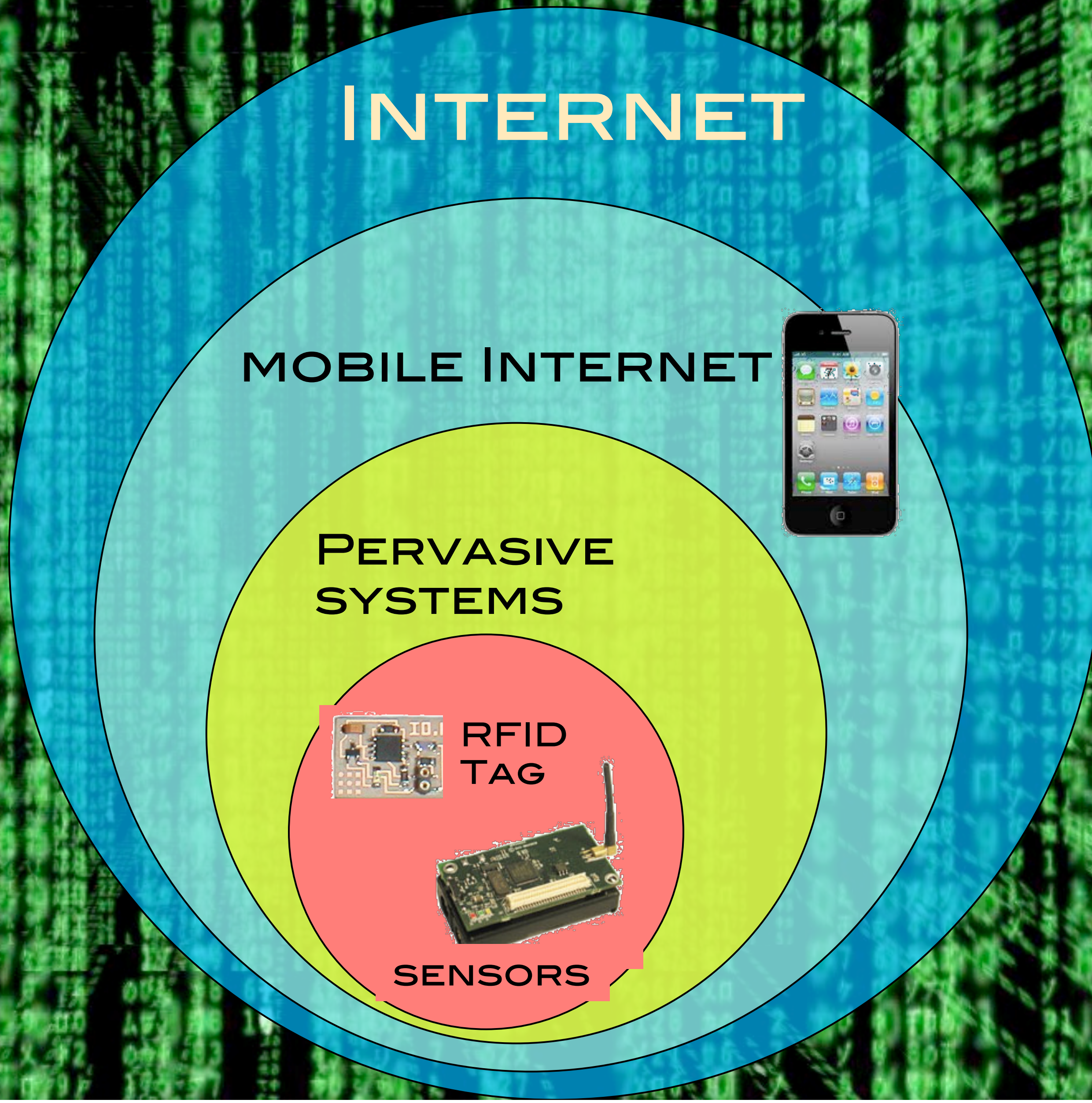
Wireless autonomous sensor

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



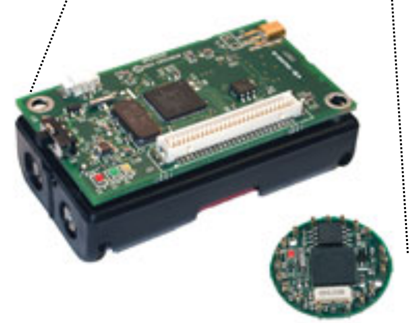


Digital Wireless World



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...

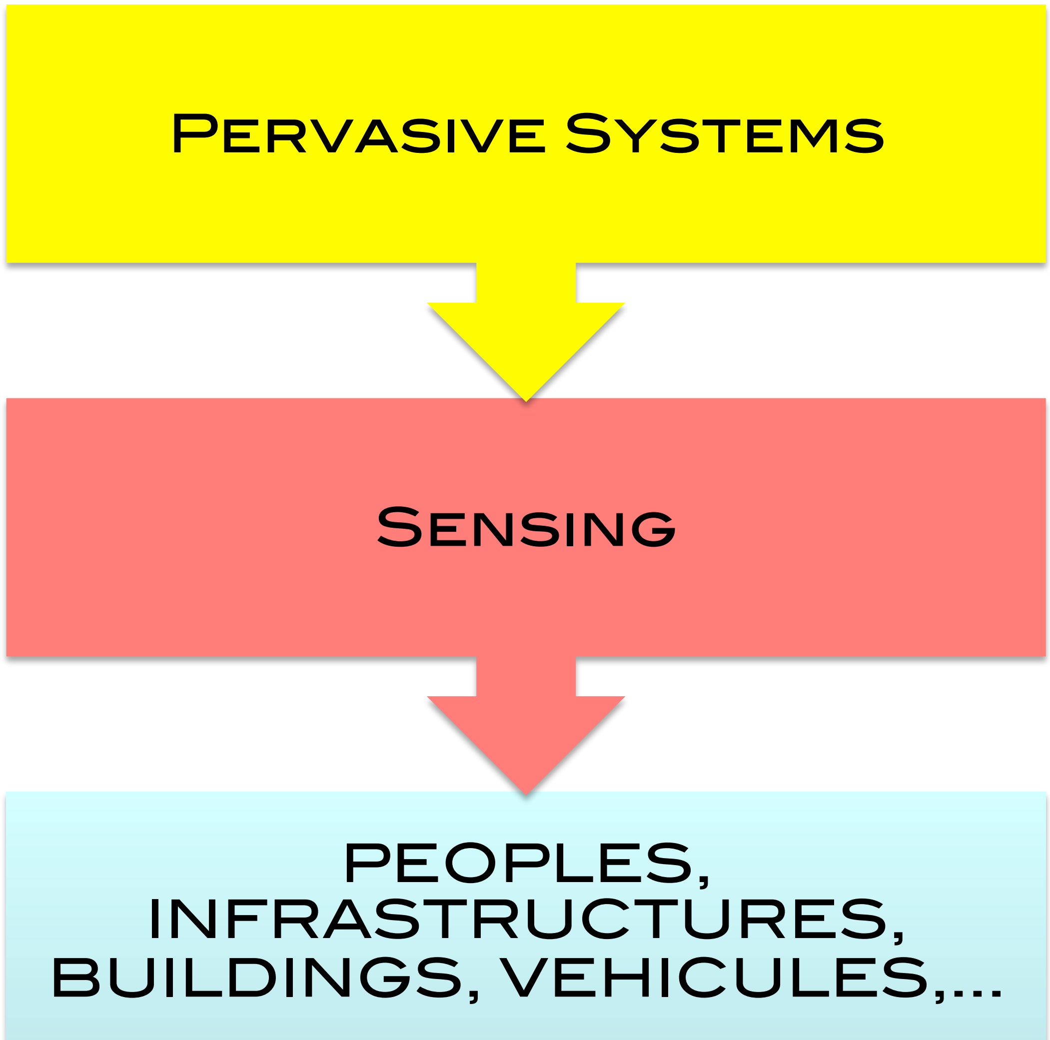
Sensing

...TO DIGITAL SOCIETY...

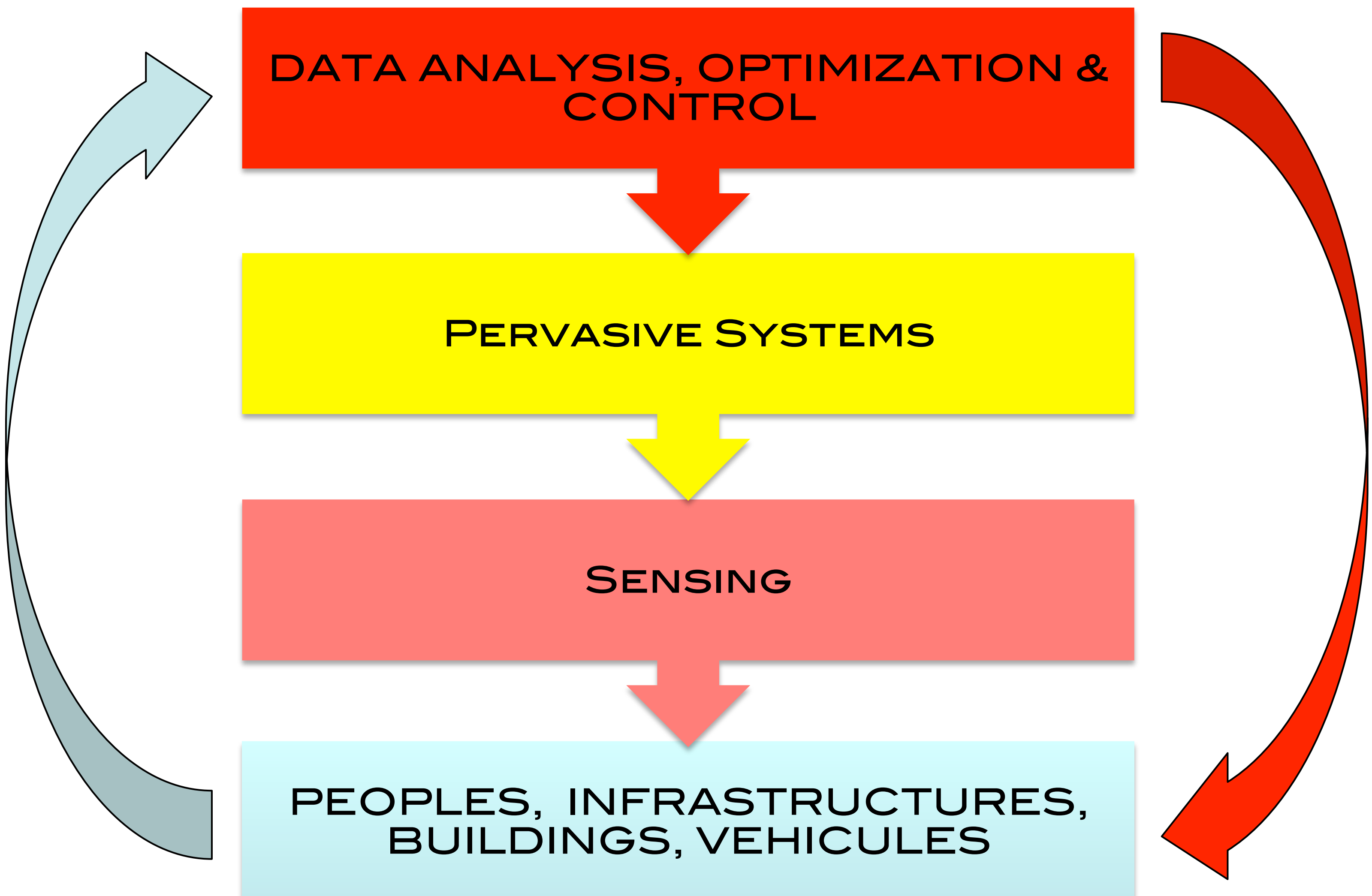
Pervasive Systems

Sensing

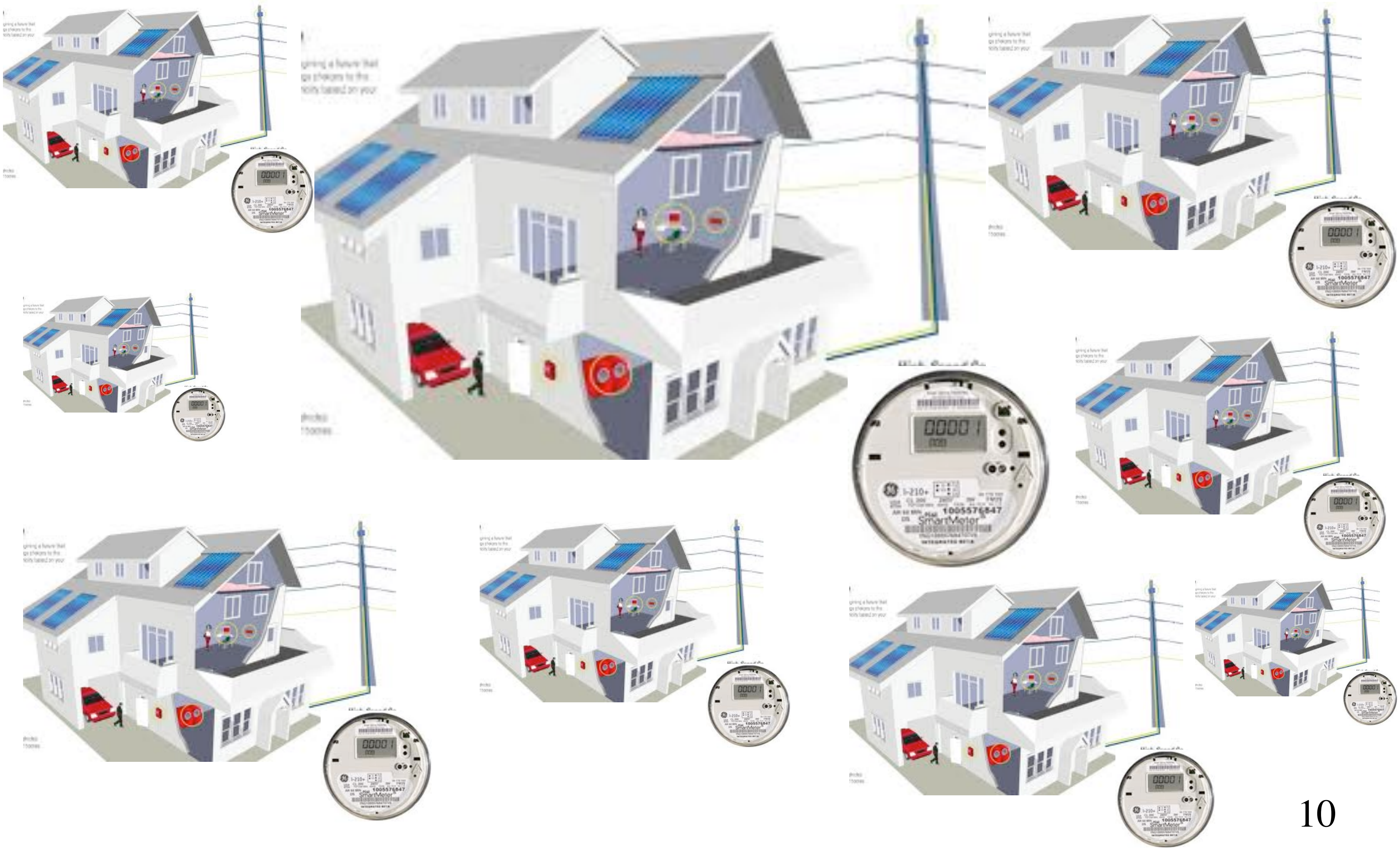
...TO UBIQUITOUS WORLD...



...TO CONTROLLED SYSTEMS.



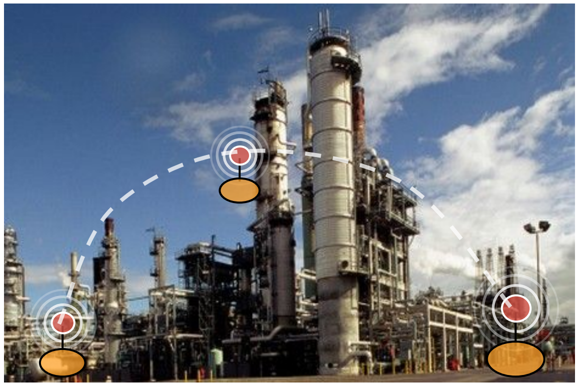
Ex: Smart electricity networks

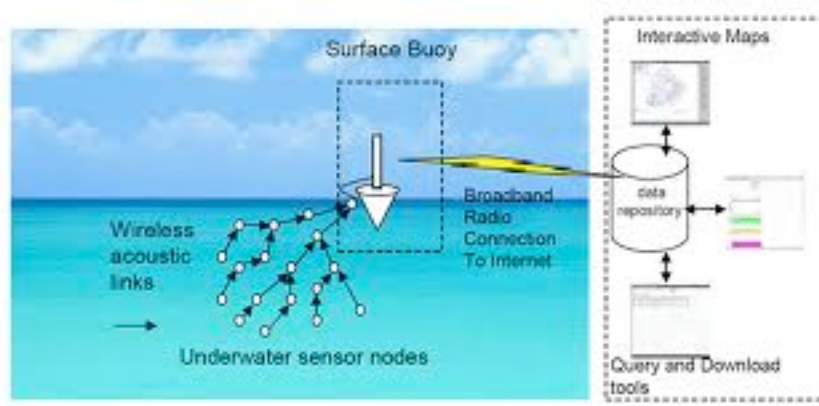


Ex: Smart electricity networks

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).

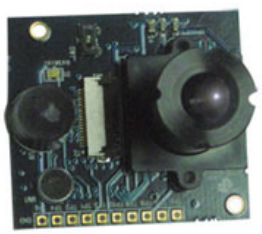
Monitoring/Surveillance



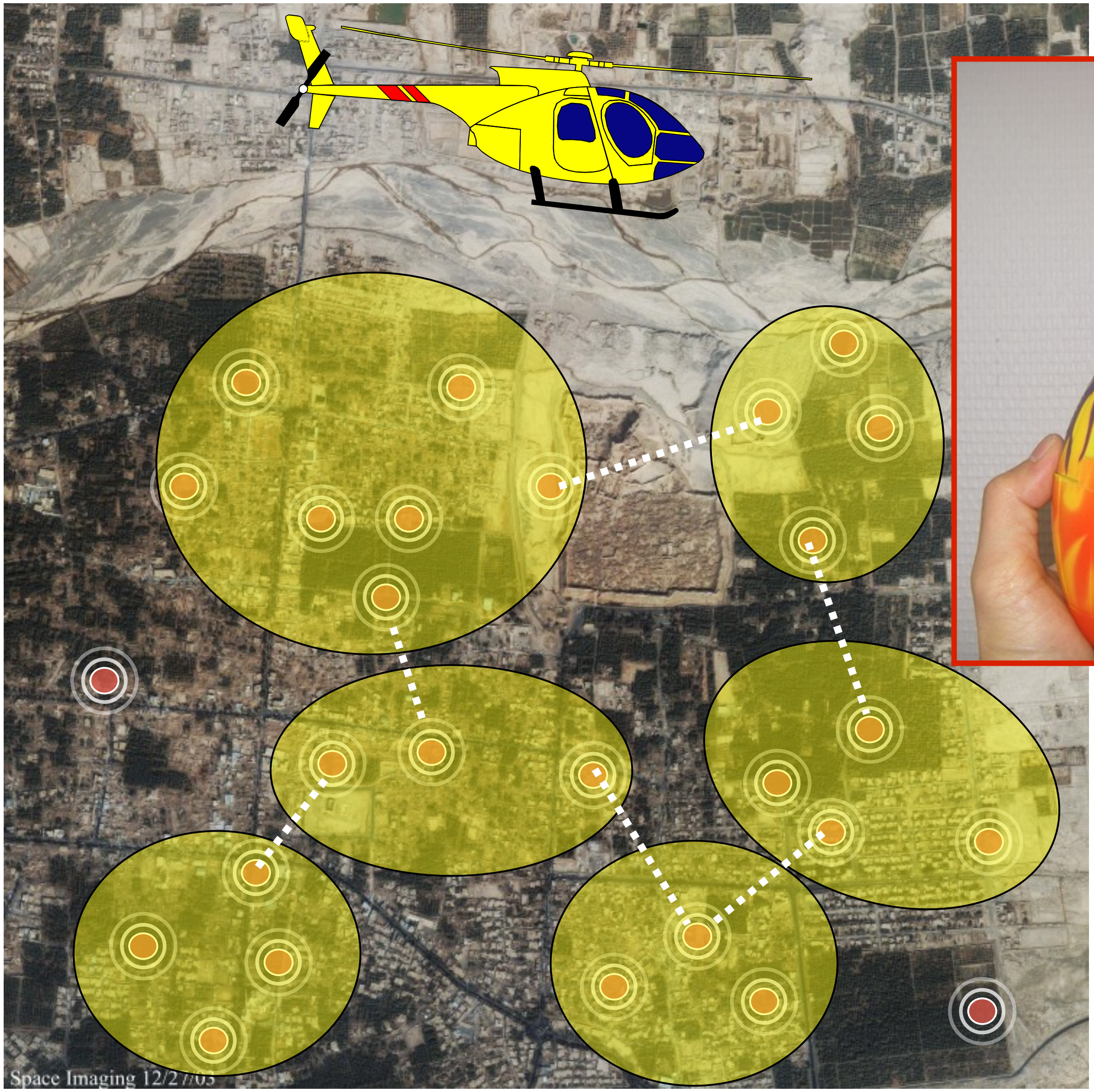


Search&Rescue, security

Imote2



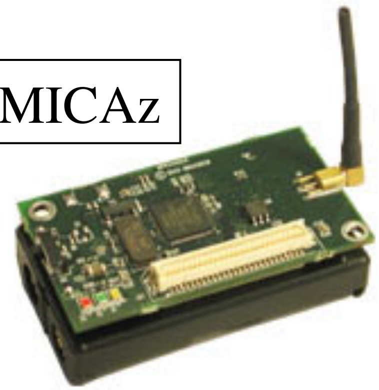
Multimedia board

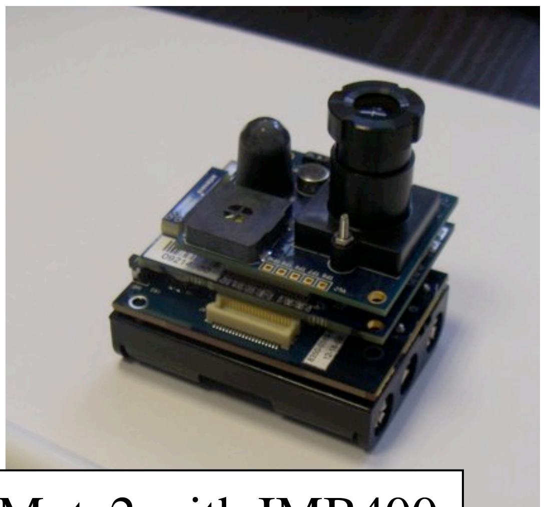


Crossbow motes of our testbed

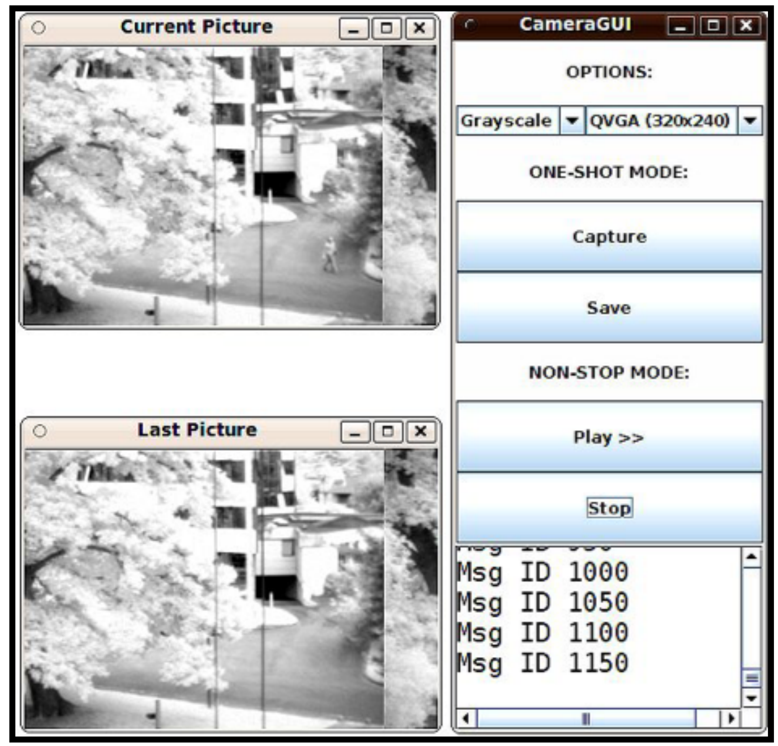
iMote2

MICAz

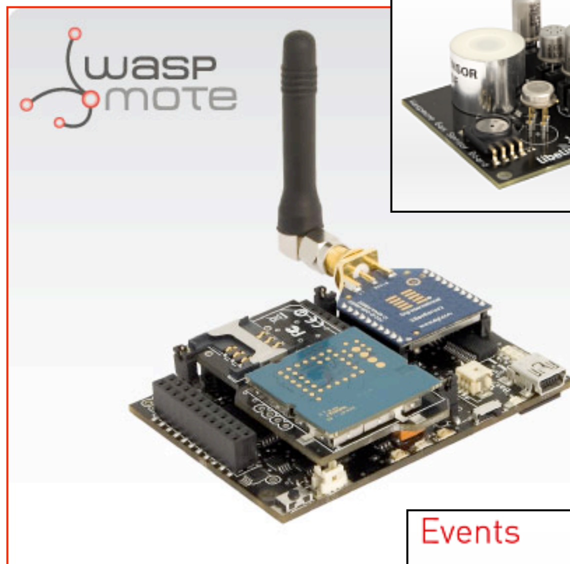




iMote2 with IMB400 multimedia board



- ATMEGA1281 MICROCONTROLLER
- 8K RAM & 1G SD CARD.
- 2.4GHz IEEE 802.15.4 COMPATIBLE. RF AND GSM/GPRS

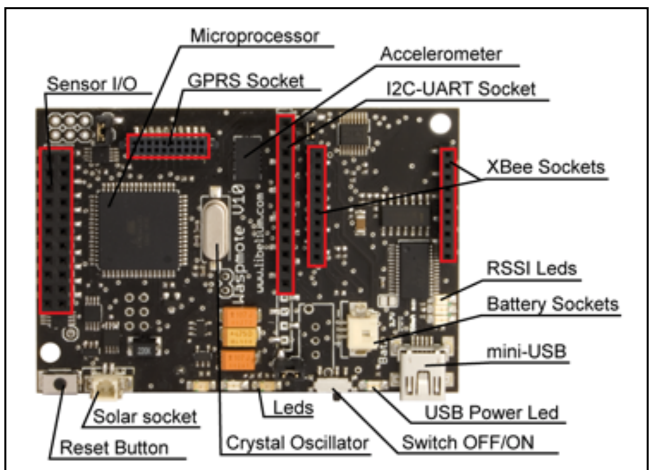


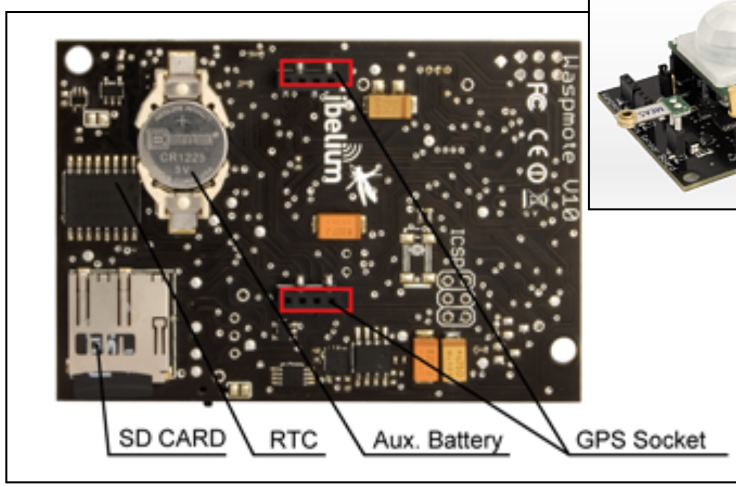
Gases

- 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

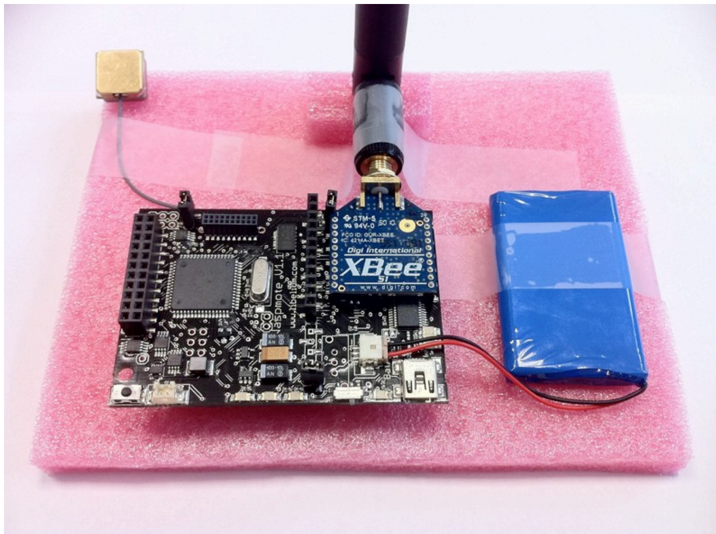
Events

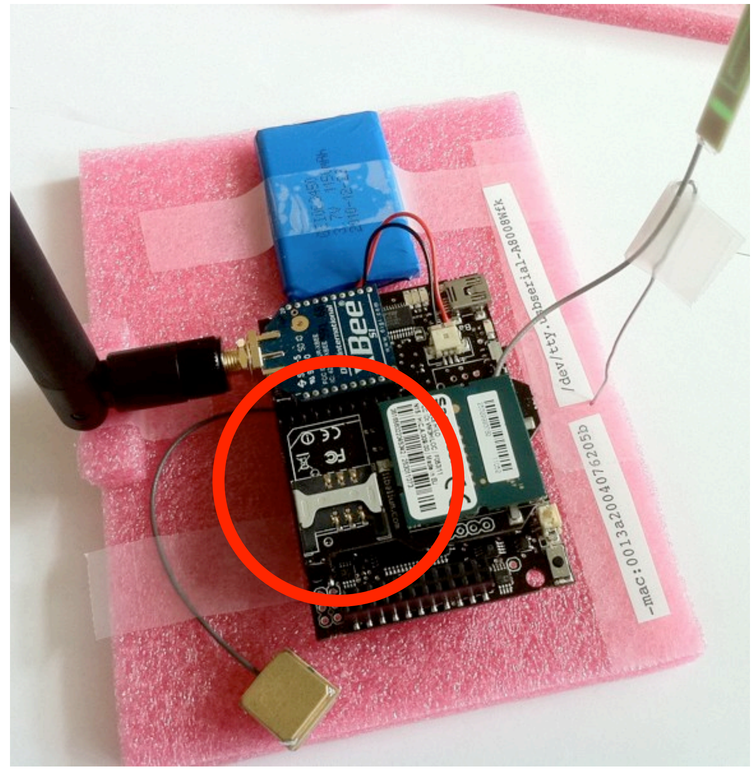
- Pressure/Weight
- Bend
- Vibration
- Impact
- Hall Effect
- Tilt
- Temperature (+/-)
- Liquid Presence
- Liquid Level
- Luminosity
- Presence (PIR)
- Stretch

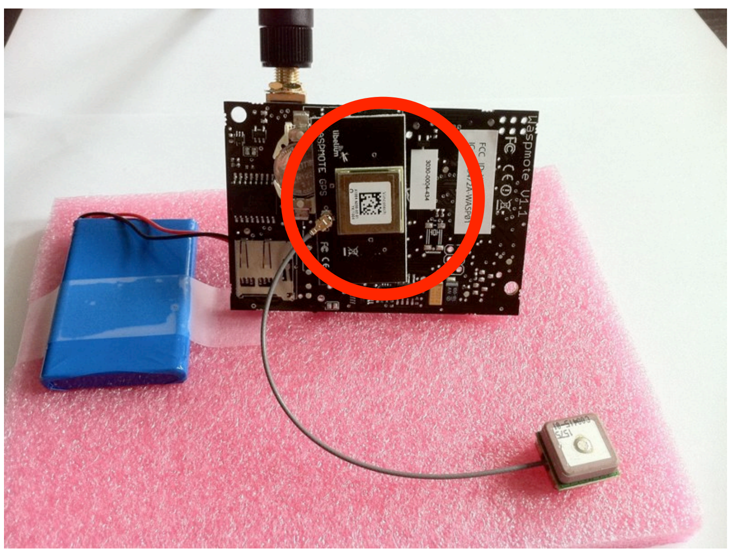




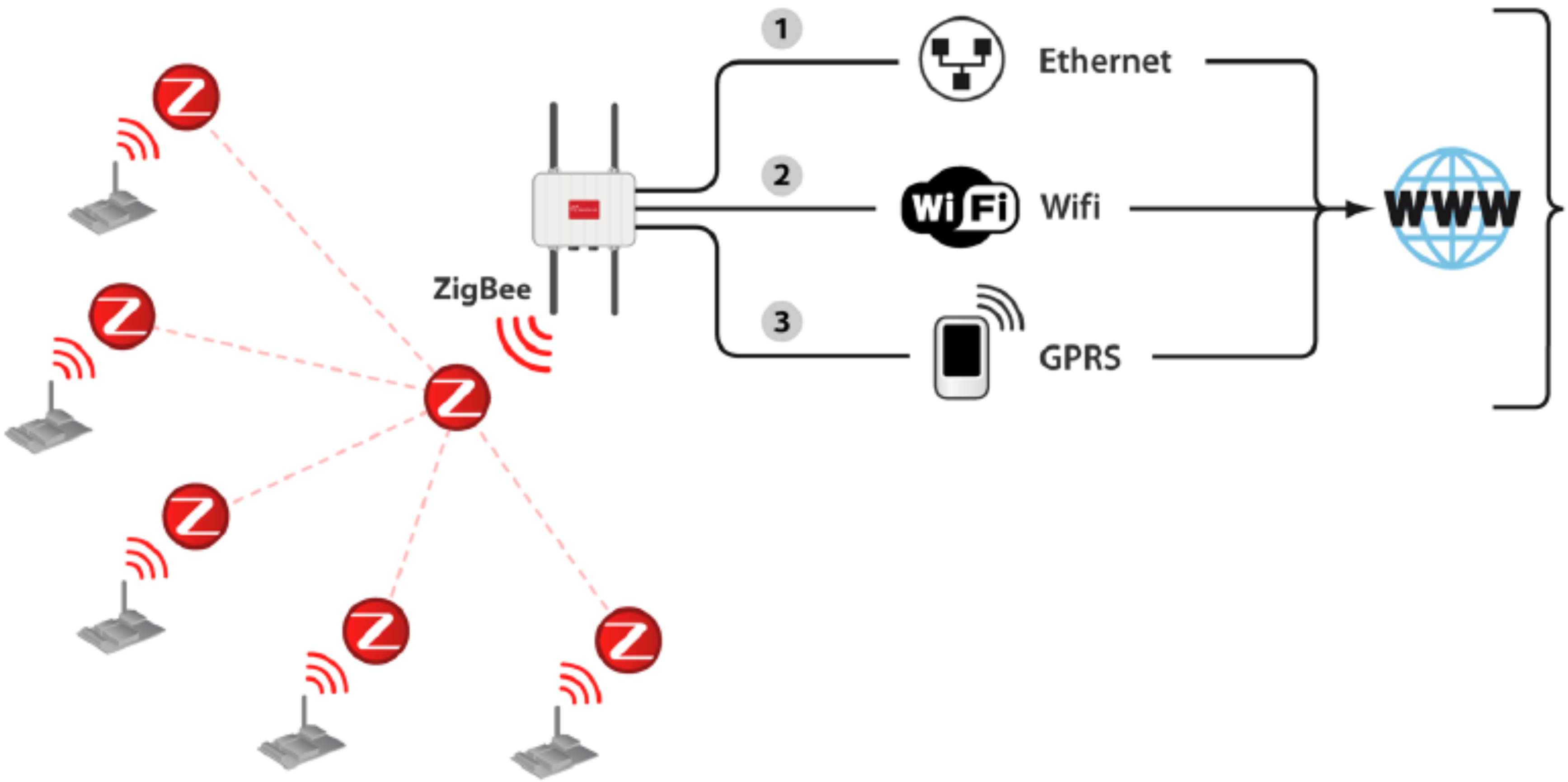
Libelium WaspMote (1)



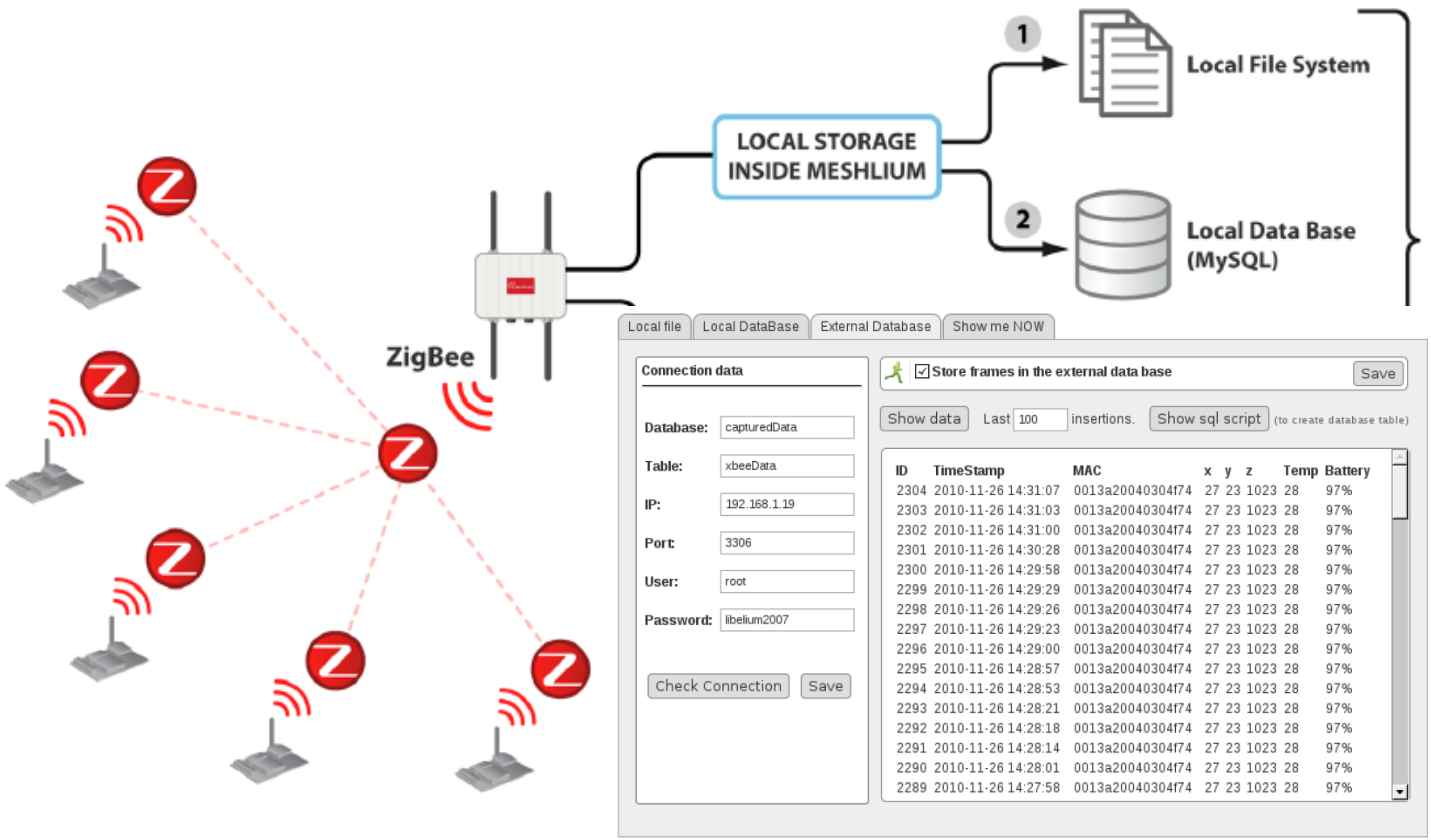




Advanced connectivity



Advanced Database Features

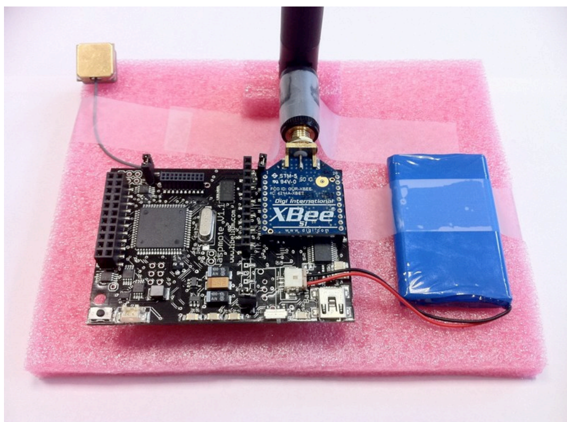


The full testbed

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();

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



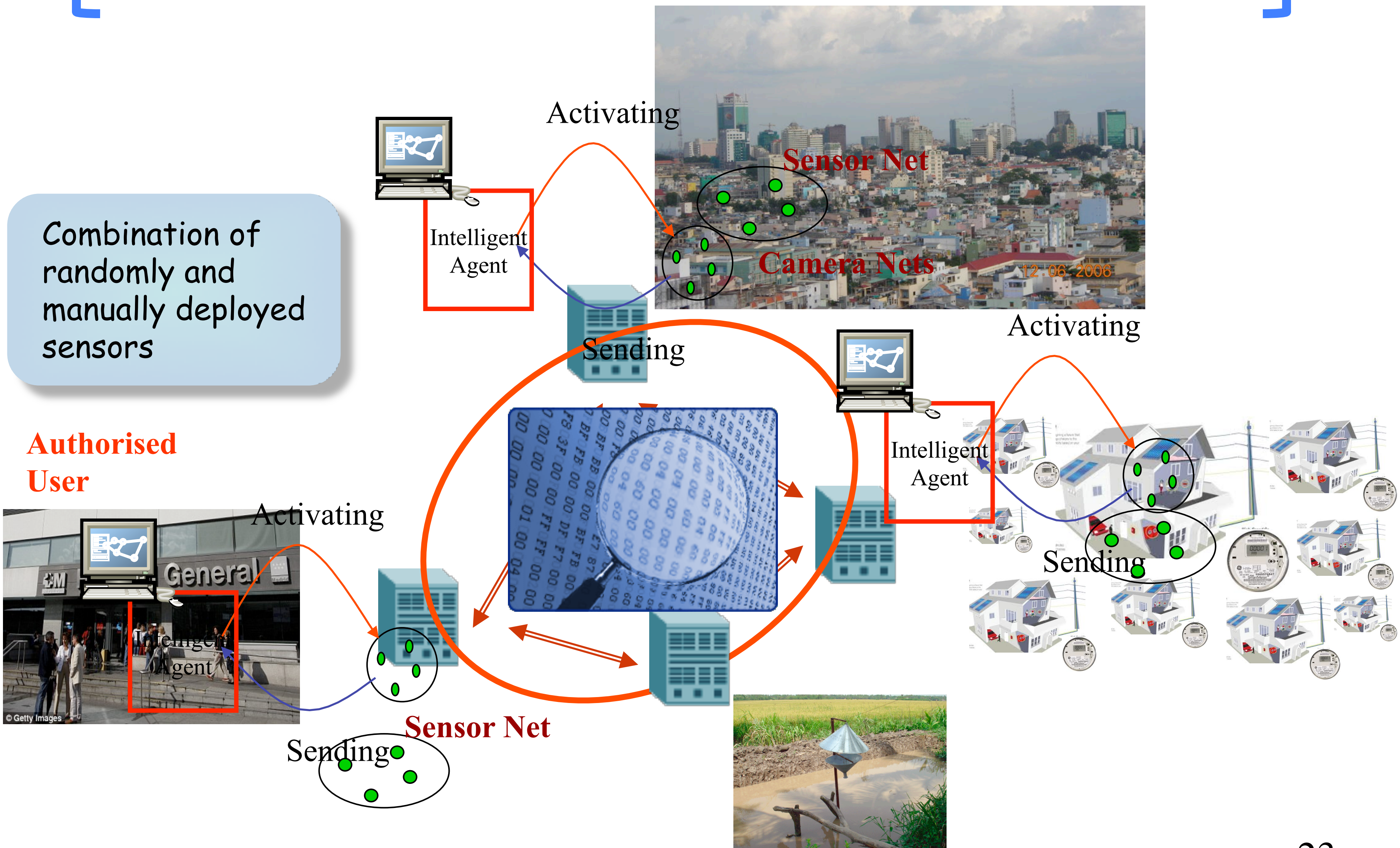
Air quality monitoring

Specific applications

Source JEAI DREAM, U. Can Tho

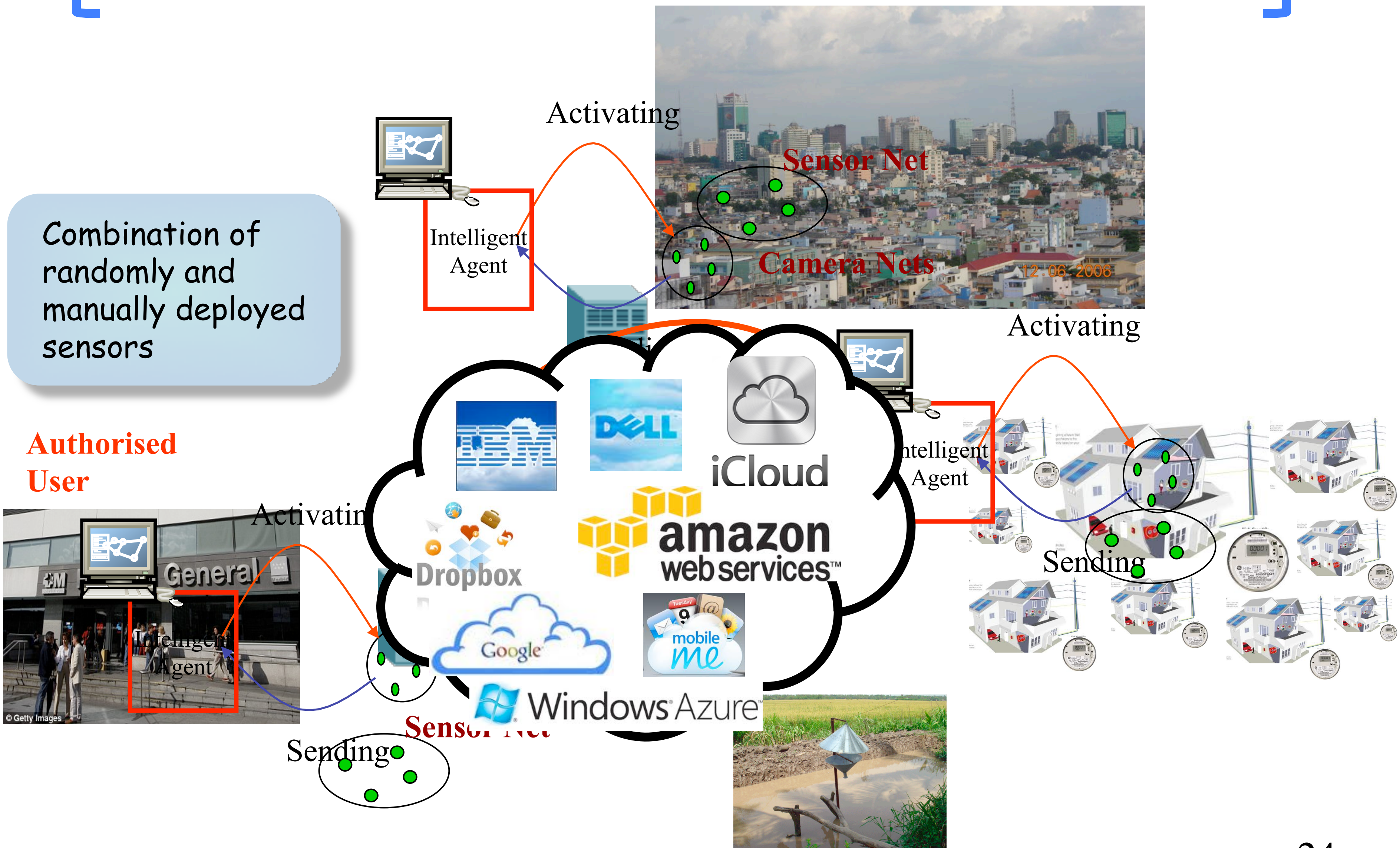
Towards global sensing

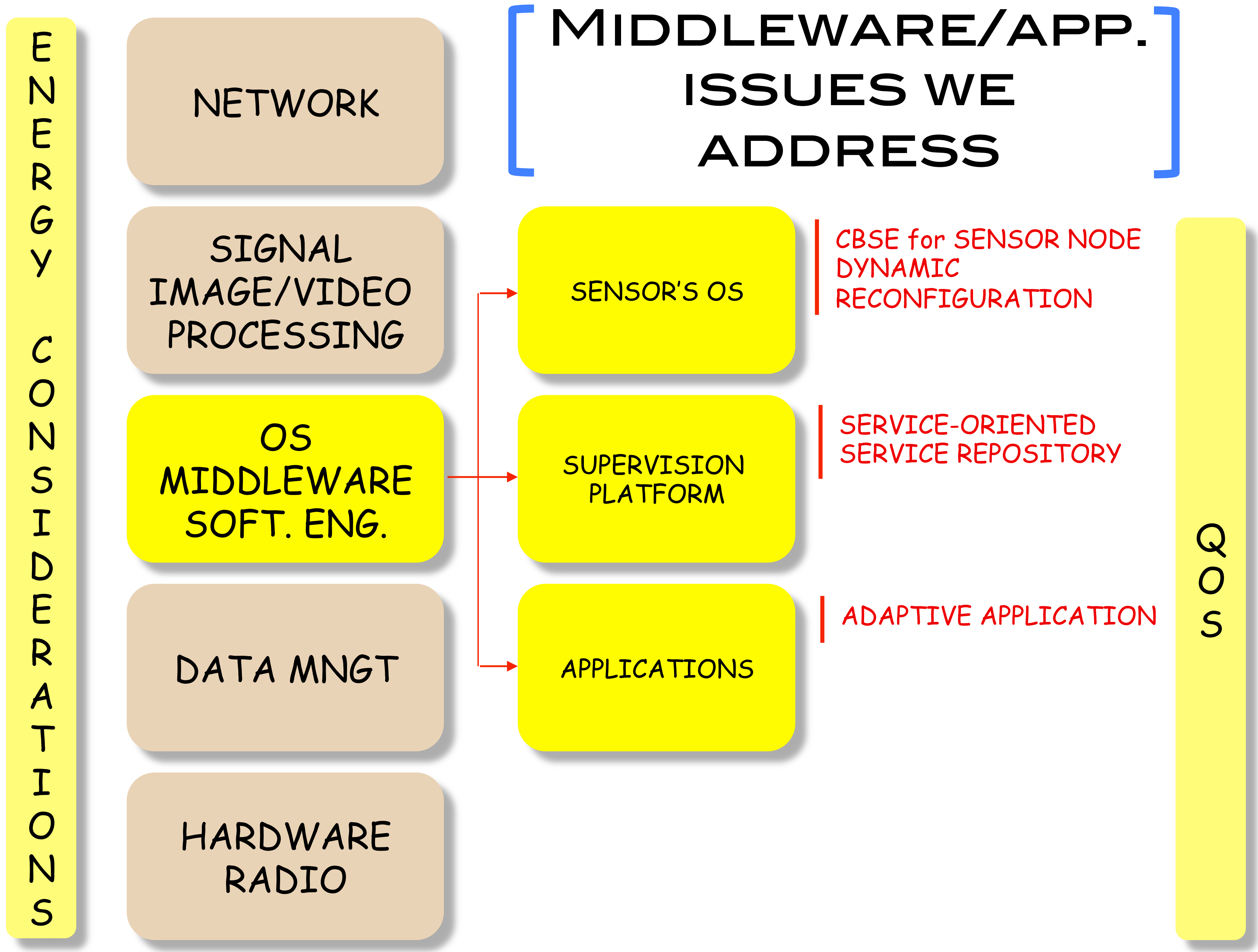
Combination of randomly and manually deployed sensors

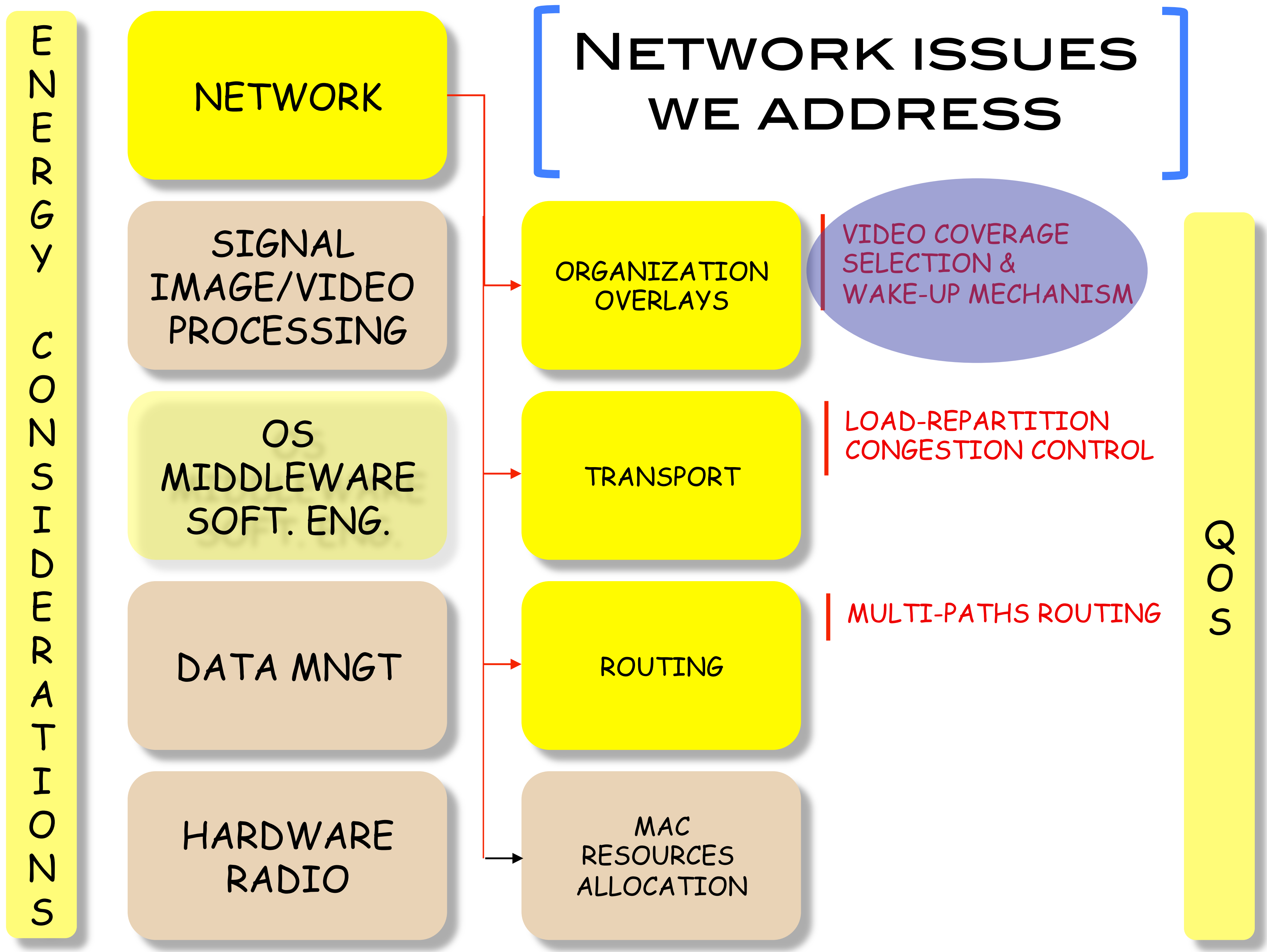


Where Clouds come in!

Combination of randomly and manually deployed sensors




MIDDLEWARE/APP. ISSUES WE ADDRESS
ENERGY CONSIDERATIONS
NETWORK
SIGNAL IMAGE/VIDEO PROCESSING
OS MIDDLEWARE SOFT. ENG.
DATA MNGT
HARDWARE RADIO
SENSOR'S OS
SUPERVISION PLATFORM
APPLICATIONS
CBSE for SENSOR NODE
DYNAMIC RECONFIGURATION
SERVICE-ORIENTED
SERVICE REPOSITORY
ADAPTIVE APPLICATION
QOS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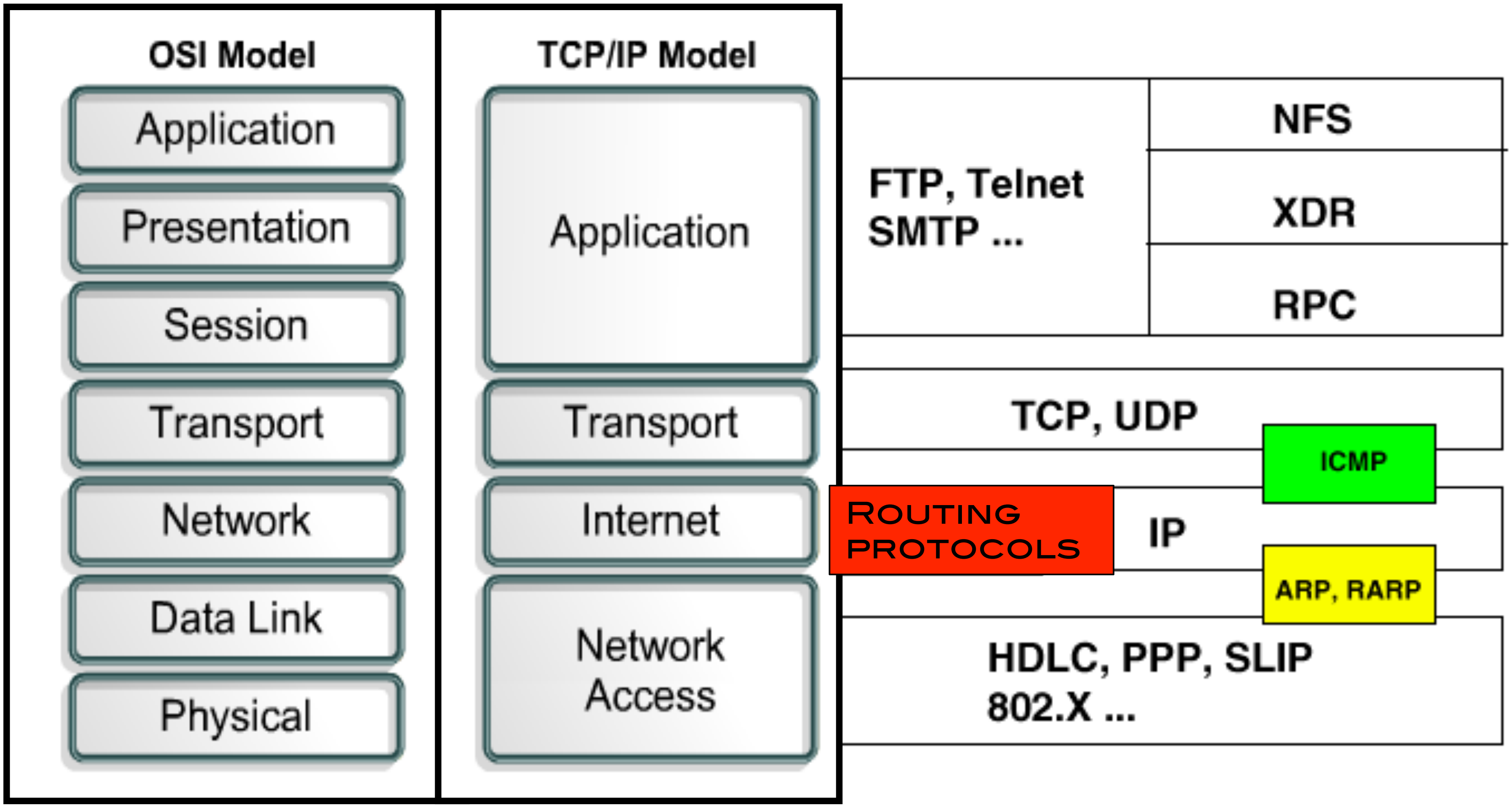
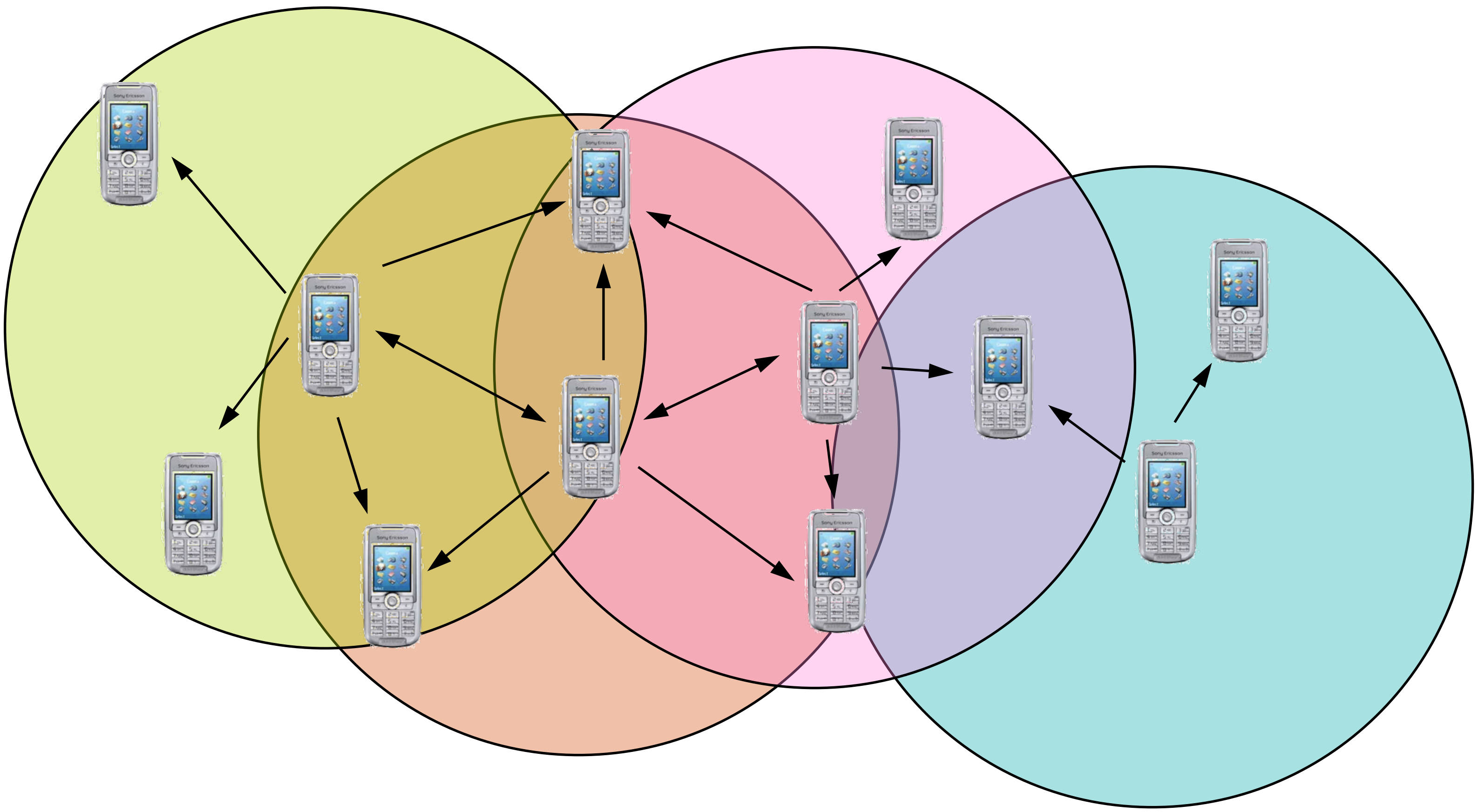
HARDWARE RADIO
ORGANIZATION OVERLAYS
TRANSPORT
ROUTING
MAC RESOURCES ALLOCATION
VIDEO COVERAGE SELECTION & WAKE-UP MECHANISM
LOAD-REPARTITION CONGESTION CONTROL
MULTI-PATHS ROUTING
QOS

Review of Communication Architecture

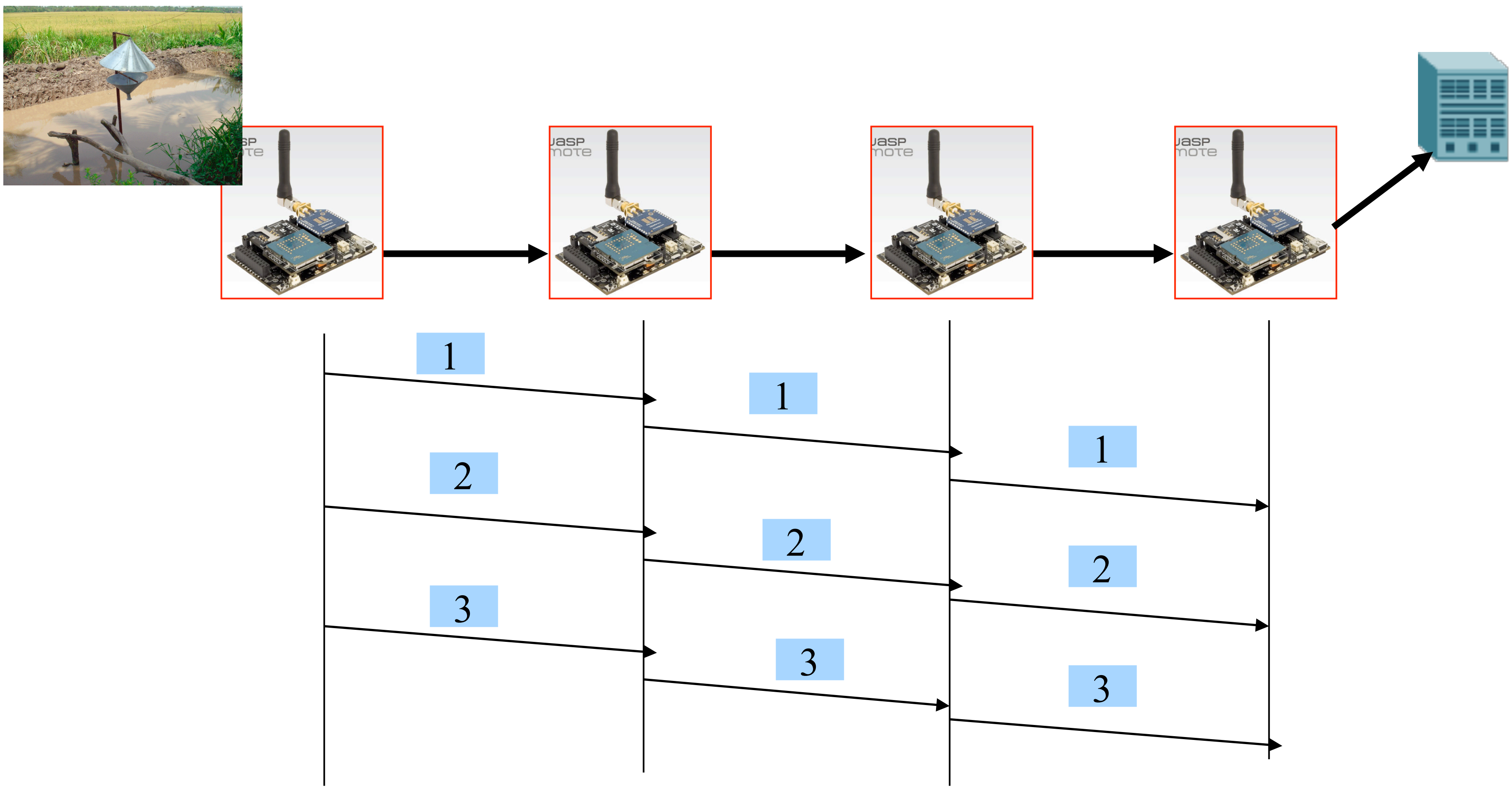


Ad-hoc networks

- Infrastructure-less networks
- MANET (Mobile Adhoc NETworks)



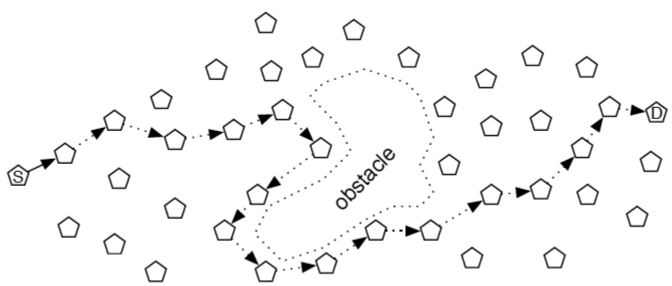
Multi-Hop Packet Forwarding



Energy vs latency

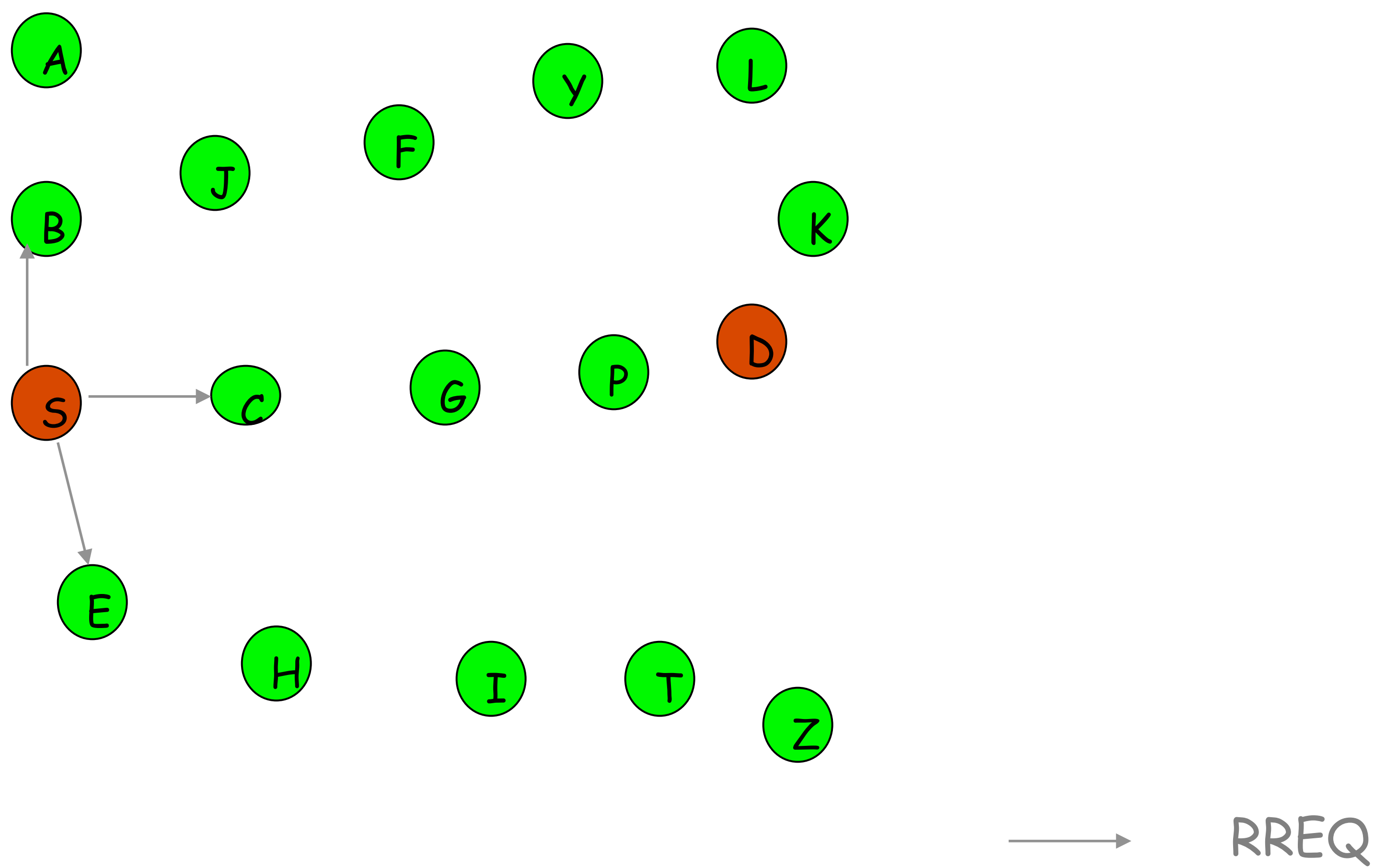
- Proactive?
  - Maintain & update routing table independently of communication needs
  - Periodical updates
  - Same philosophy than in wired-networks (RIP, OSPF)
  - Low latency
  - « Waste » bandwidth and energy
- Reactive, on-demand?
  - On-the-fly discovery of routes, when communication needs appear
  - Save bandwidth and energy
  - Higher latency
  - Generally efficient at low load
- Hybrid?
  - Proactive or reactive depending on the distance

Flat vs Hierarchical

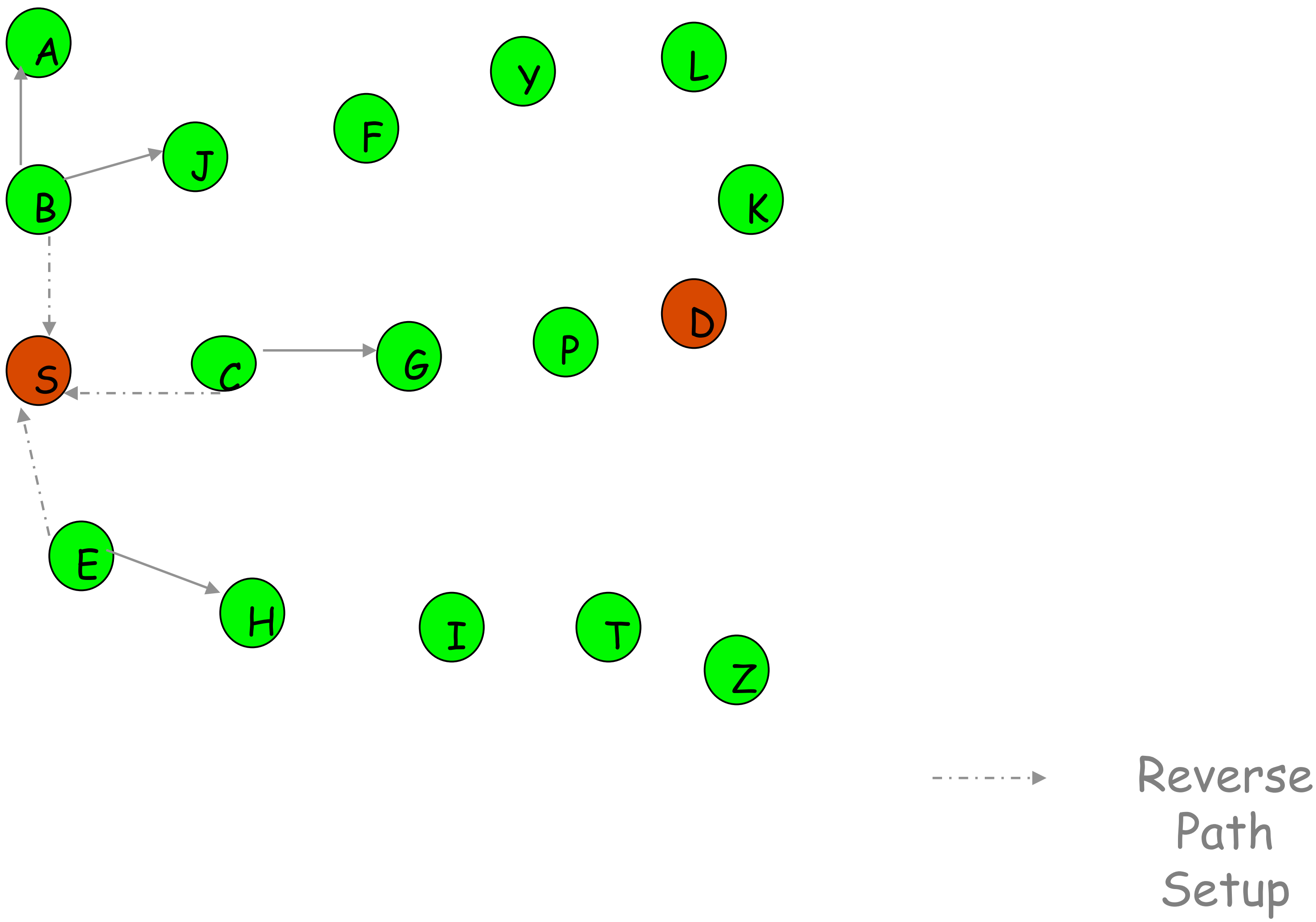


- Flat routing?
  - Simple
  - Not scalable!
- Hierarchical routing?
  - More efficient
  - « leaders » election overhead
  - Mobility cost
  - Multiple hierarchy levels are possible
- Geographical routing?
  - GPS-aided for instance
  - Efficient routing towards the destinations
  - Geographical information are propagated using flooding

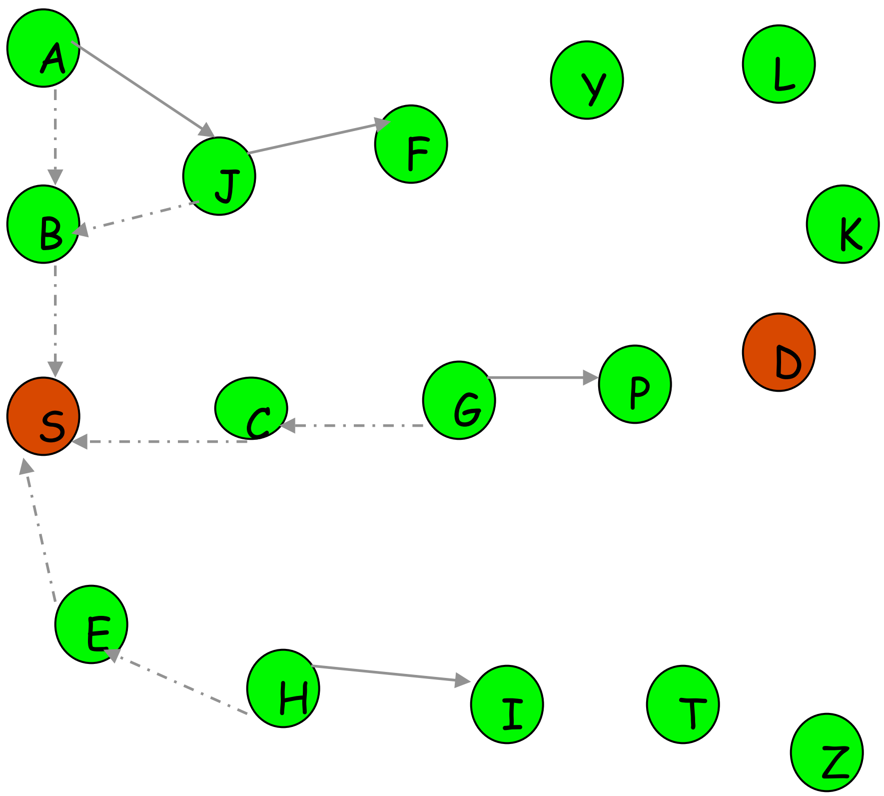
On-demand multi-hop routing illustrated: AODV example



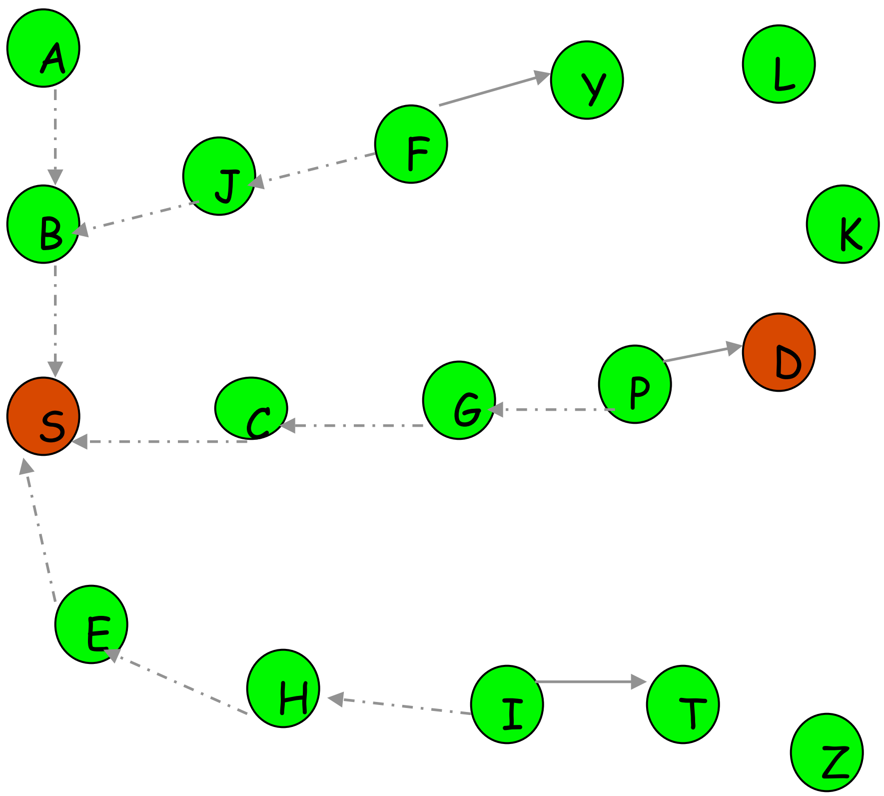
AODV (Example)



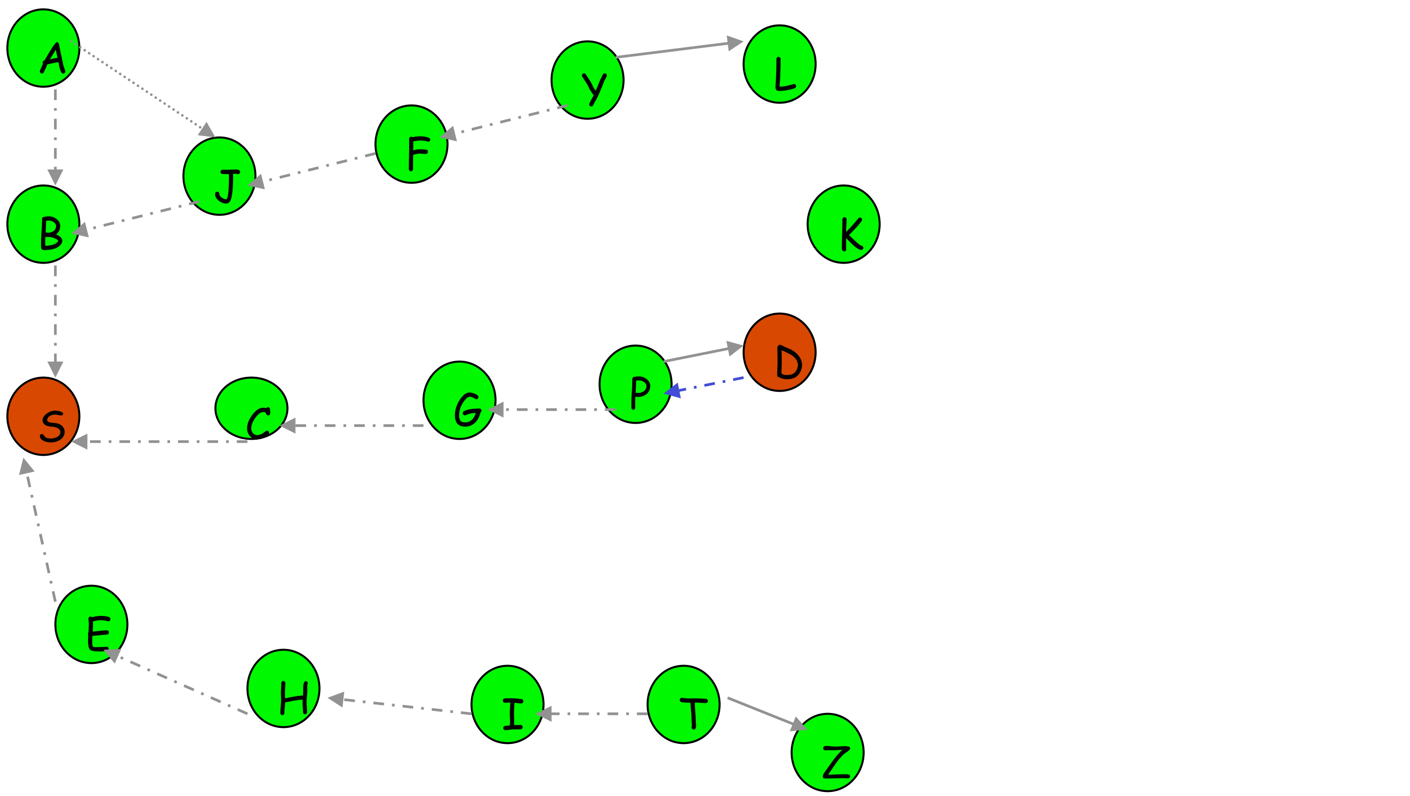
AODV (Example)



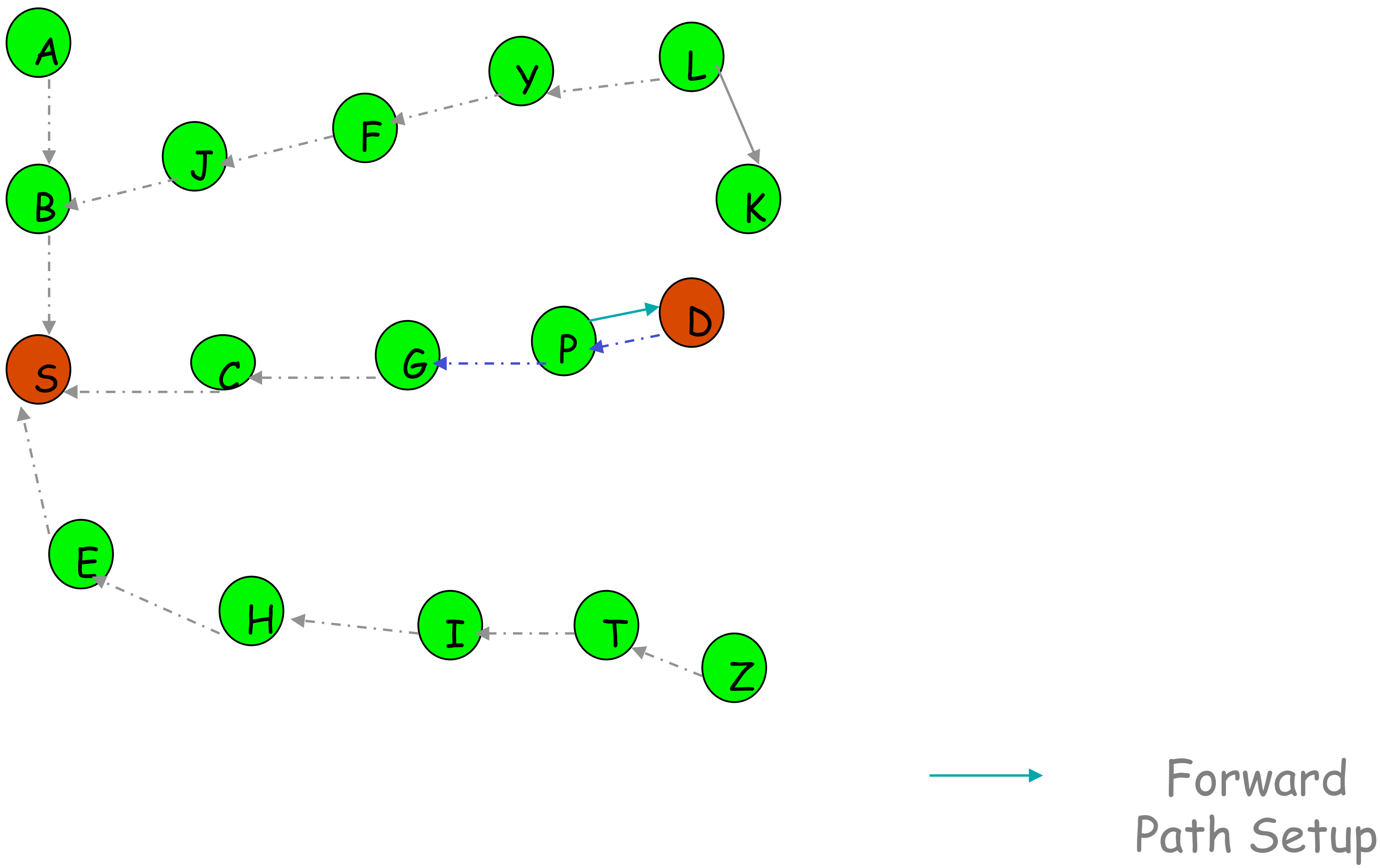
AODV (Example)



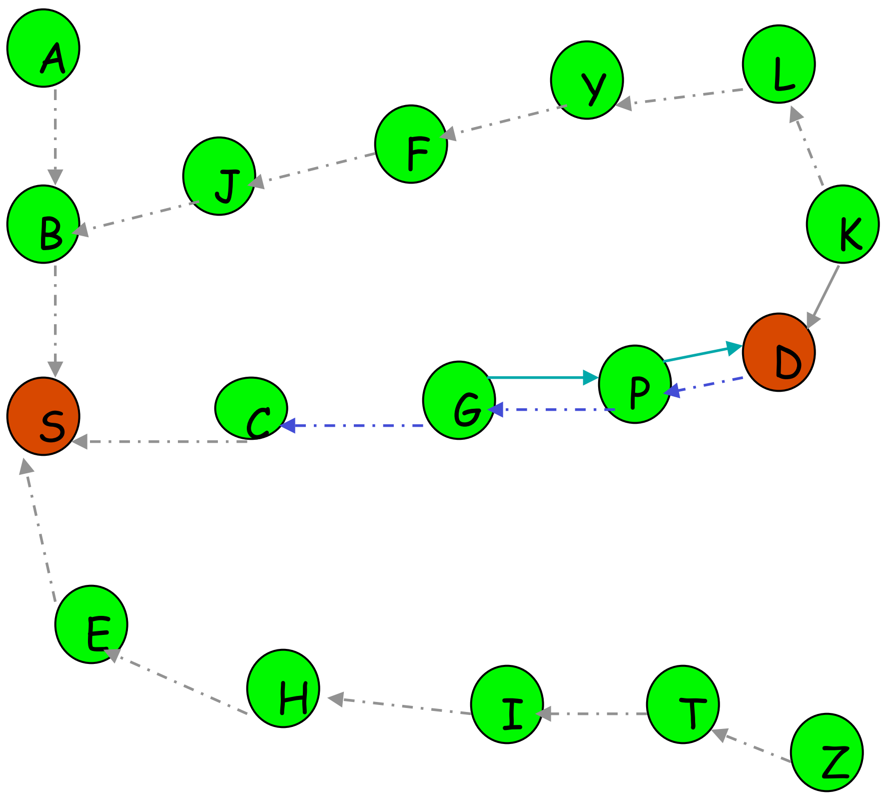
AODV (Example)



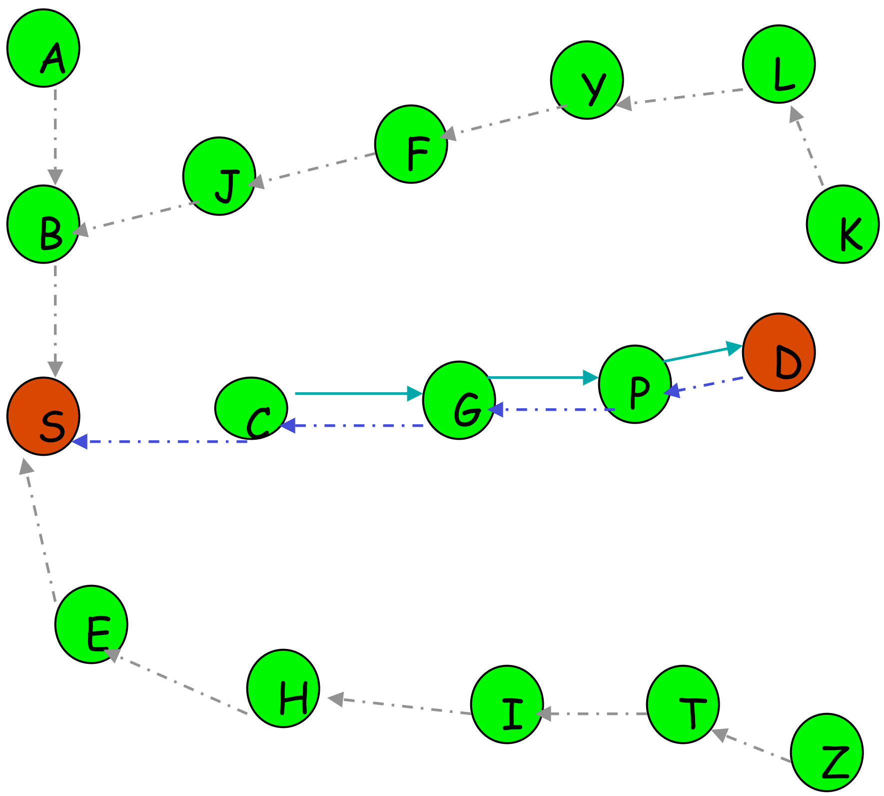
AODV (Example)



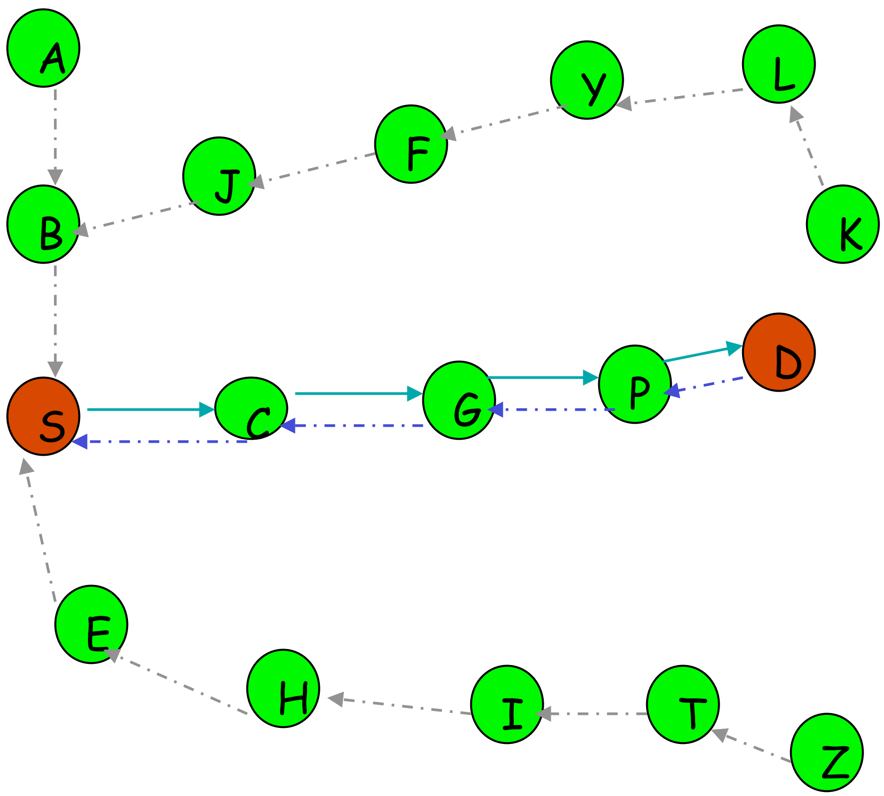
AODV (Example)



AODV (Example)

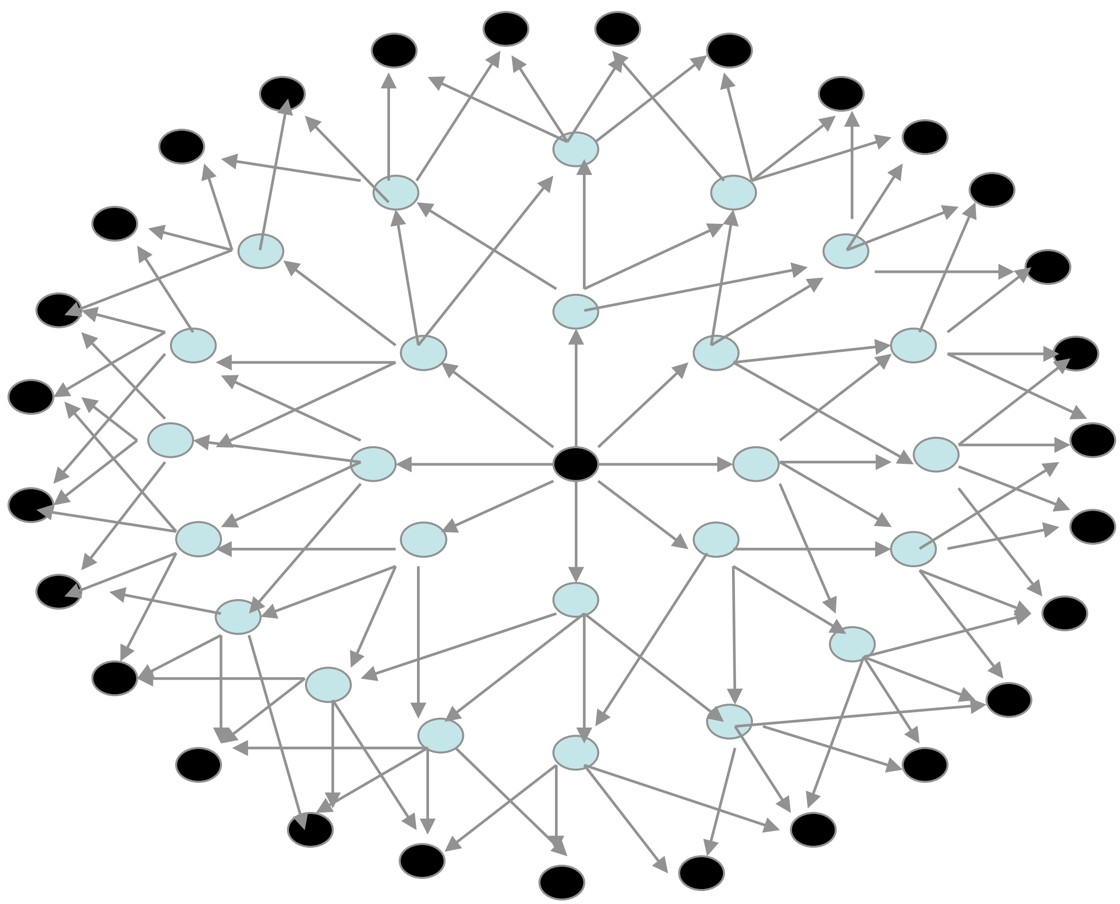


AODV (Example)



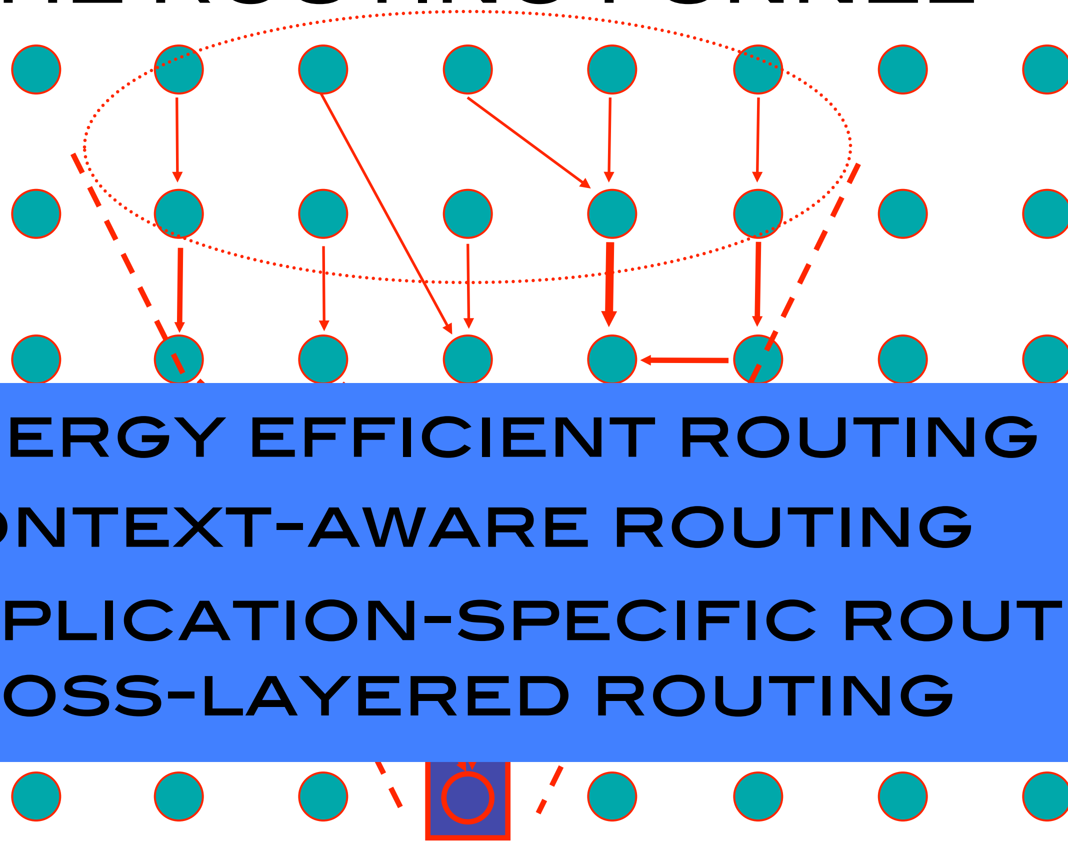
Broadcast overhead

- Quite high in large networks!



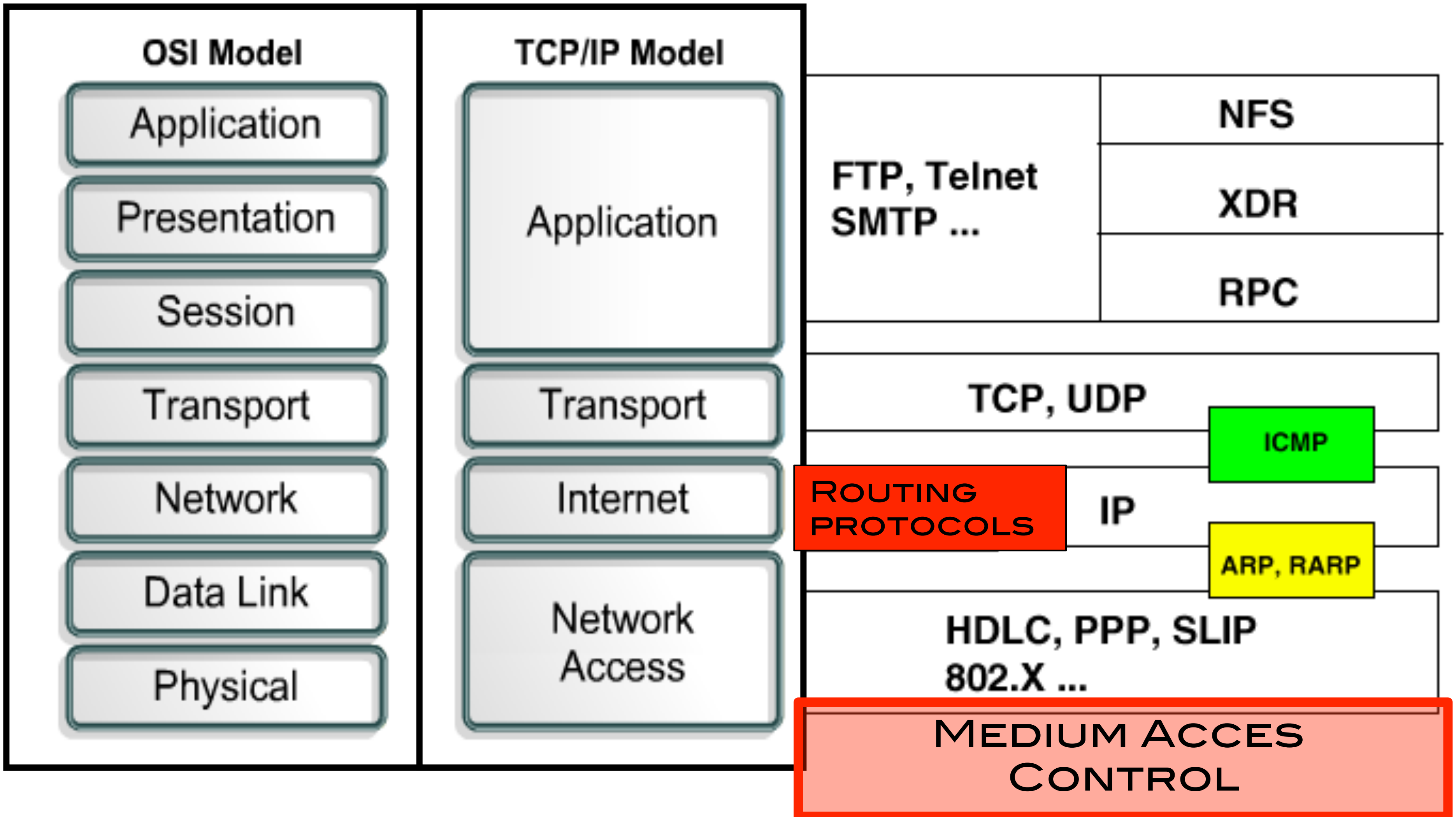
Funneling Effect

- Many-to-one traffic pattern causes congestion in the routing funnel

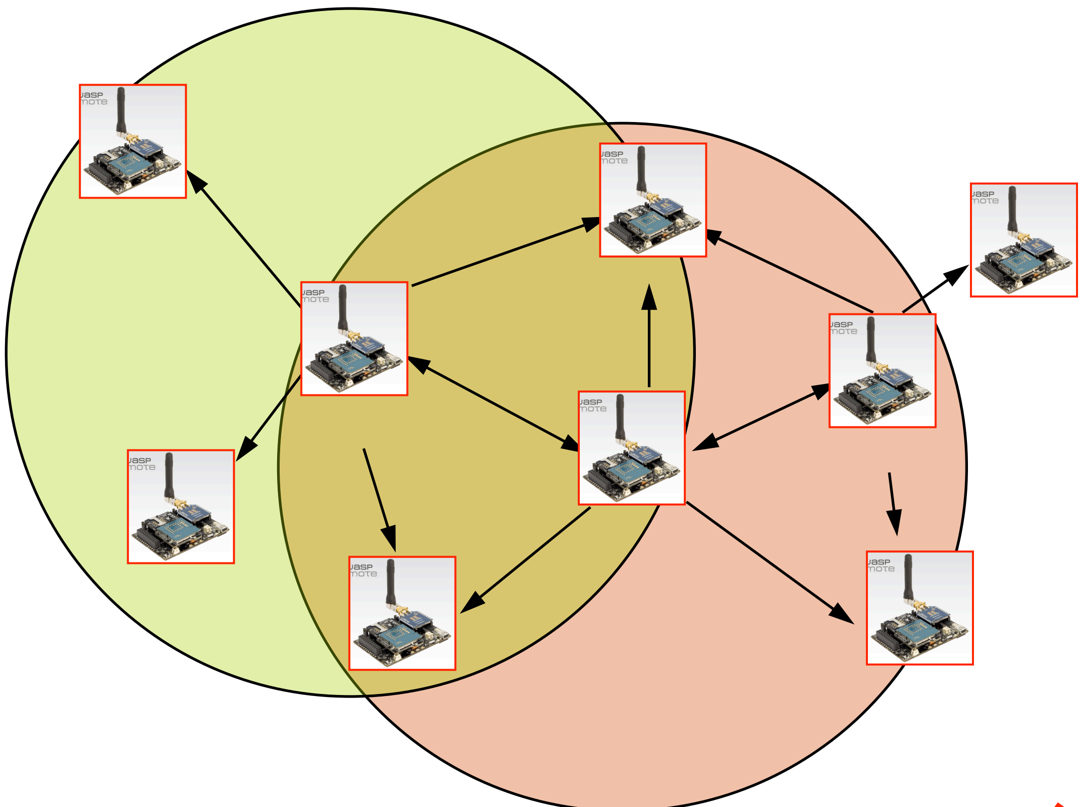


- Energy efficient routing
- Context-aware routing
- Application-specific routing, cross-layered routing

Review of Communication Architecture



Wireless Medium is a Shared Medium



Collisions when multiple transmissions

Hidden terminal problem

WiFi transmission power is too energy-consuming for WSN!

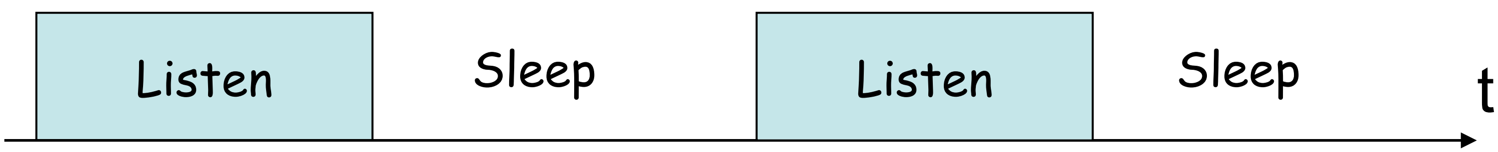
Huge cost of passive listening!

WSN can be idle for a long period!

TDMA is usually not used because of waste of resource

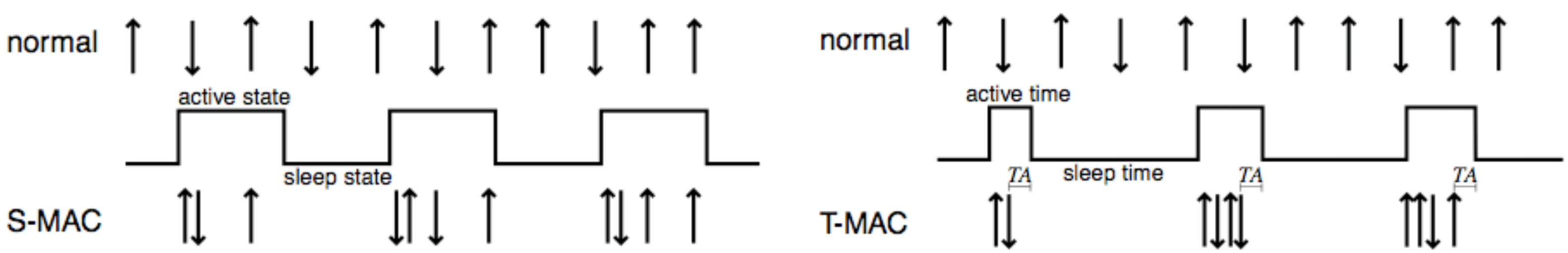
S-MAC - Sensor MAC

- Nodes periodically sleep
- Trades energy efficiency for lower throughput and higher latency
- Sleep during other nodes transmissions



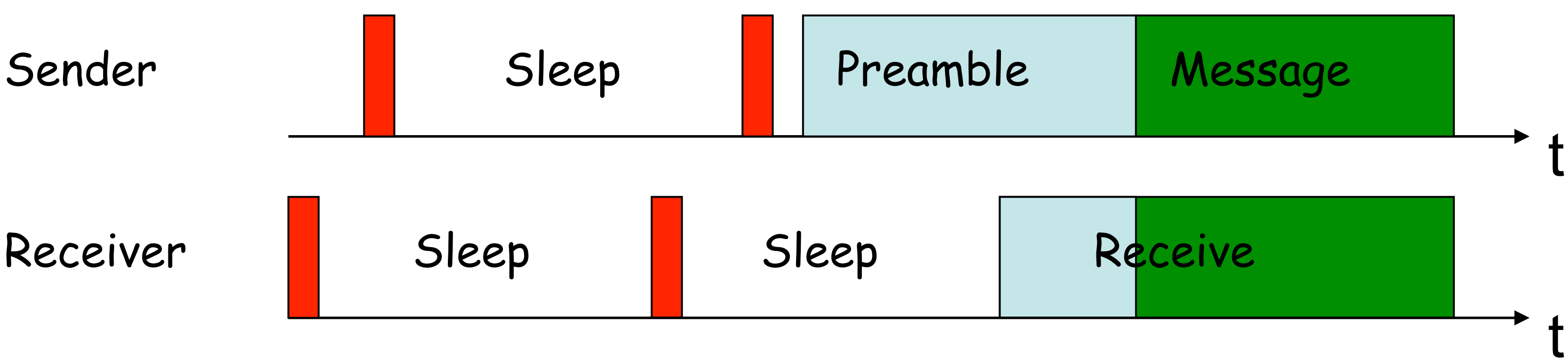
T-MAC - Timeout MAC

- Transmit all messages in bursts of variable length and sleep between bursts
- RTS / CTS / ACK Scheme
- Synchronization similar to S-MAC



B-MAC

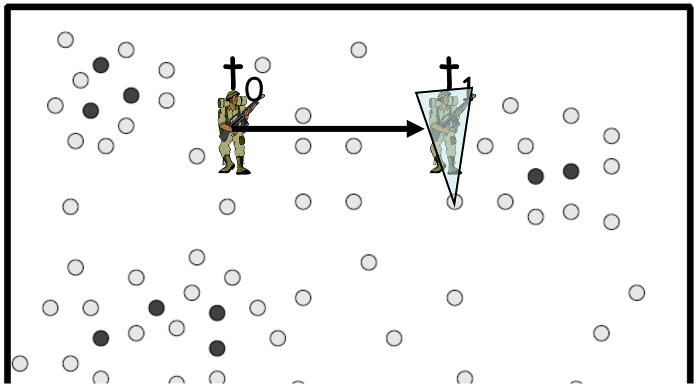
- Low Power Listening (LPL) using preamble sampling
- Hidden terminal and multi-packet mechanisms not provided, should be implemented, if needed, by higher layers



Challenges for MAC protocols in WSN

- Energy efficiency
- Low latencies
- Fairness

A CHALLENGE FOR MISSION-CRITICAL APPLICATION



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!!!

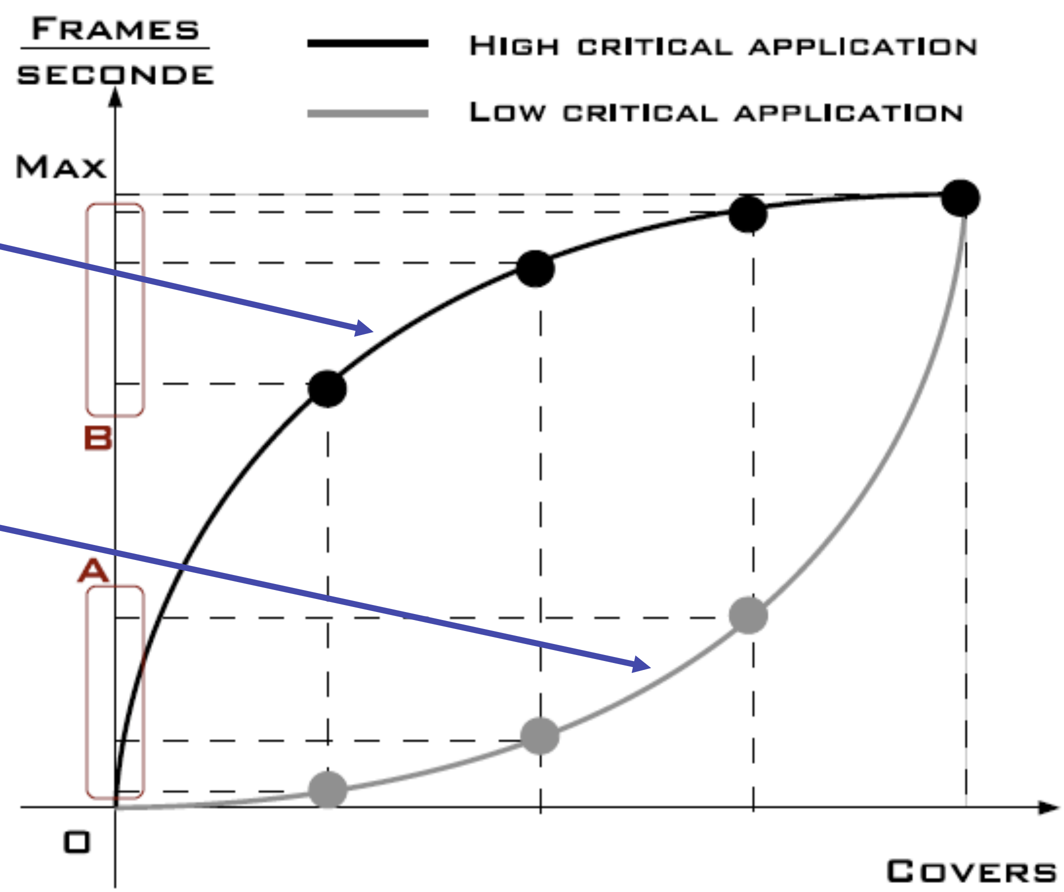
What is captured

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

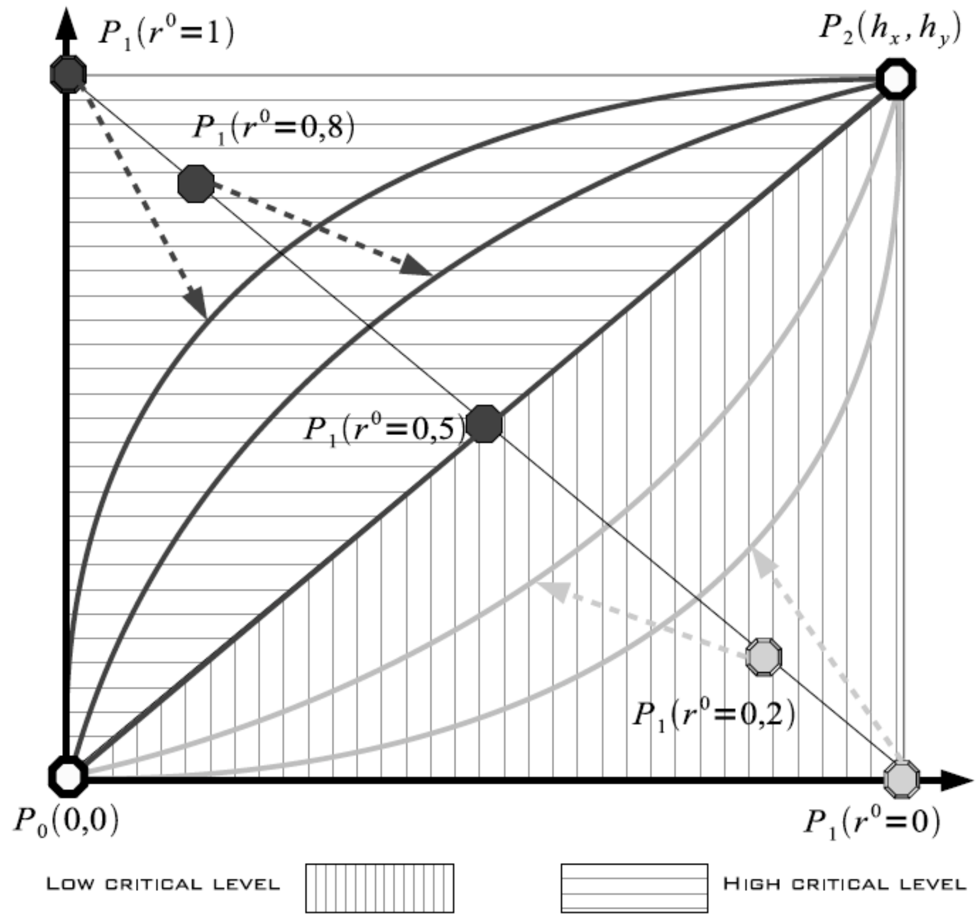
Criticality model (1)

- 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



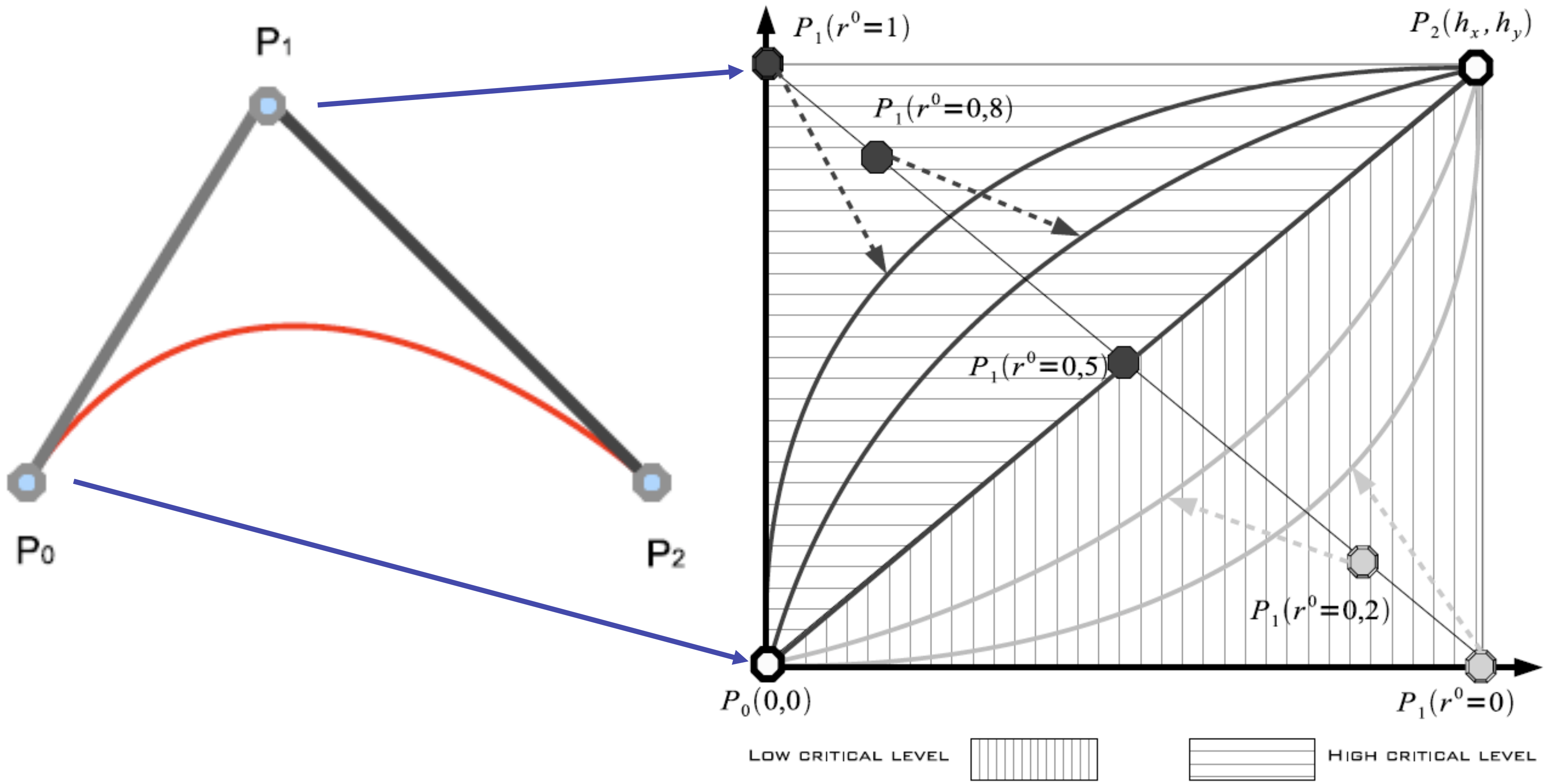
Criticality model (2)

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



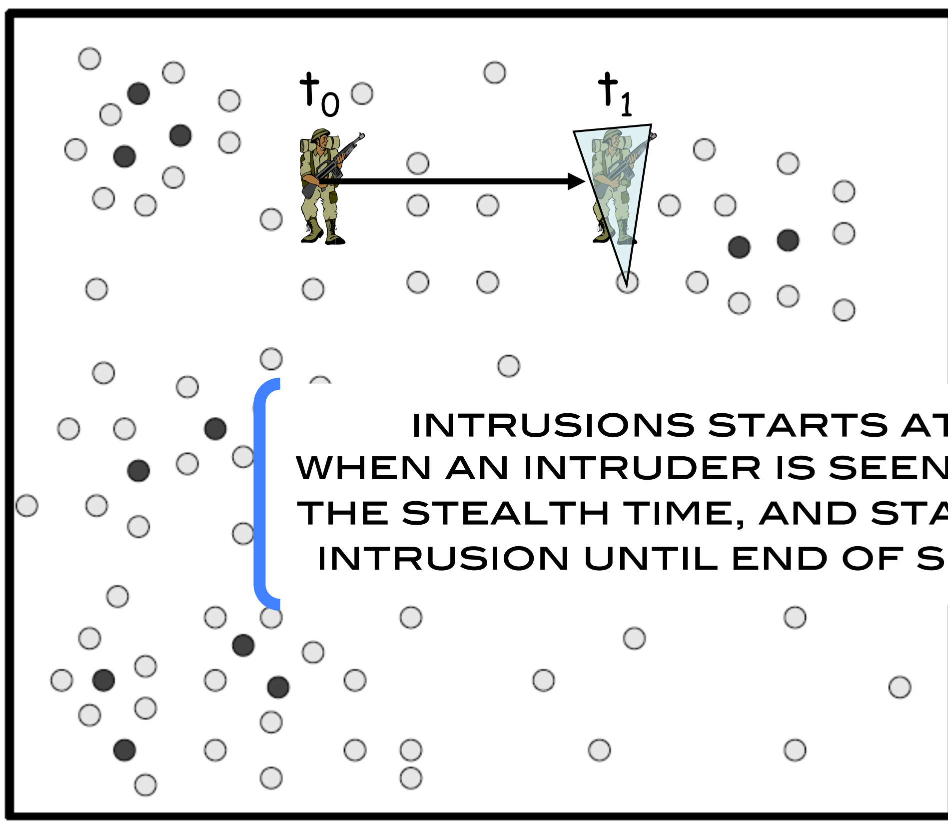
Behavior function

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



MEAN STEALTH TIME

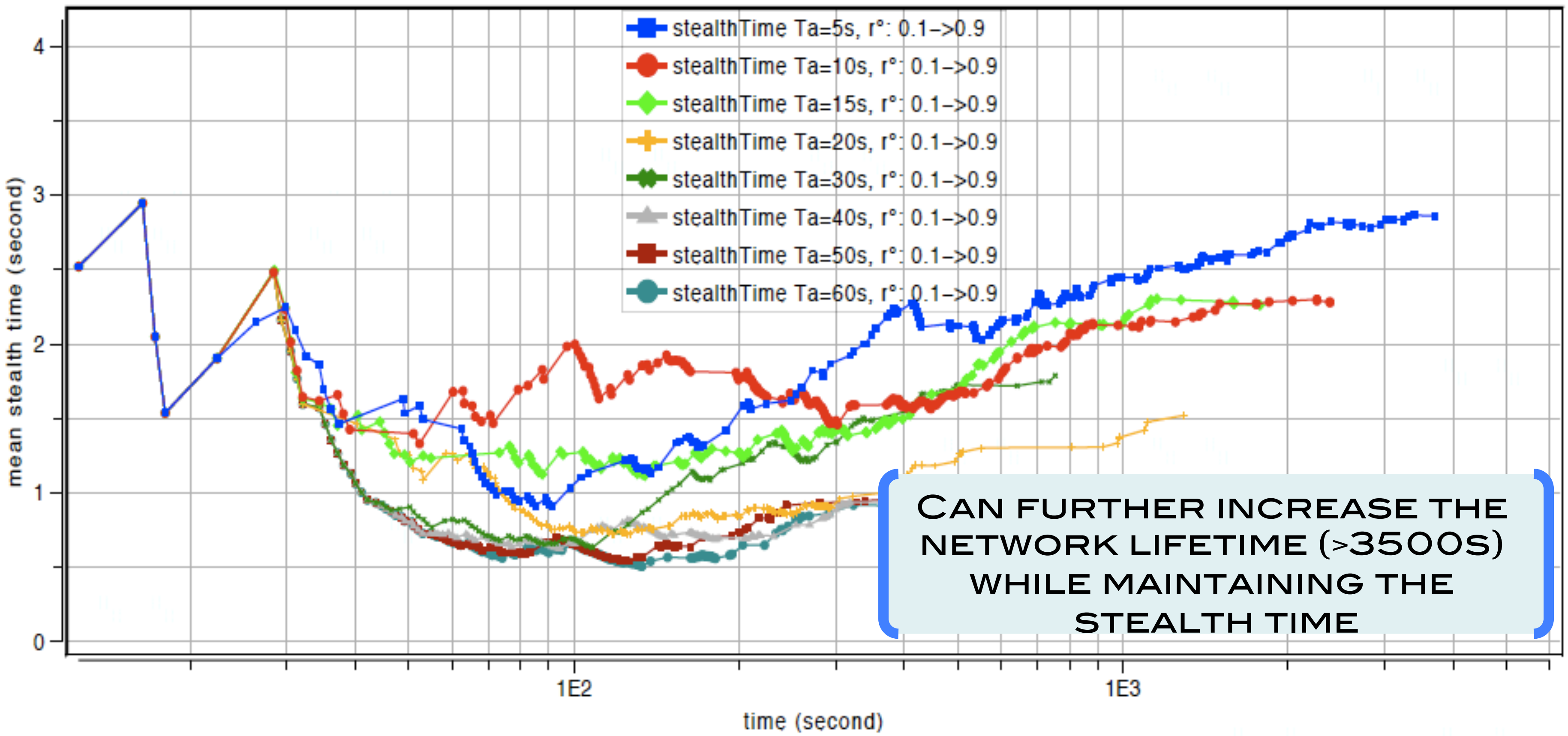
T_1-T_0 IS THE INTRUDER'S
STEALTH TIME
VELOCITY IS SET TO 5M/S



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

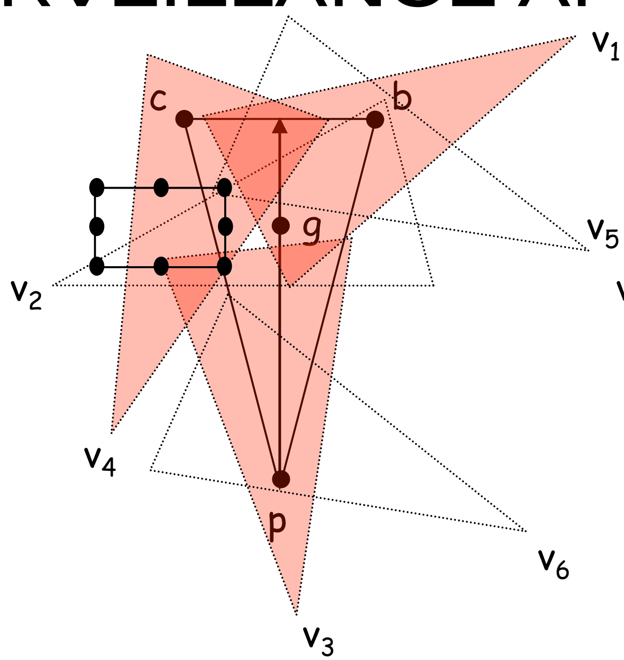
- ❑ $r^{\circ}=0.1$, $r_{MAX}=0.9$, $T_A=5,10,15,20..60s$

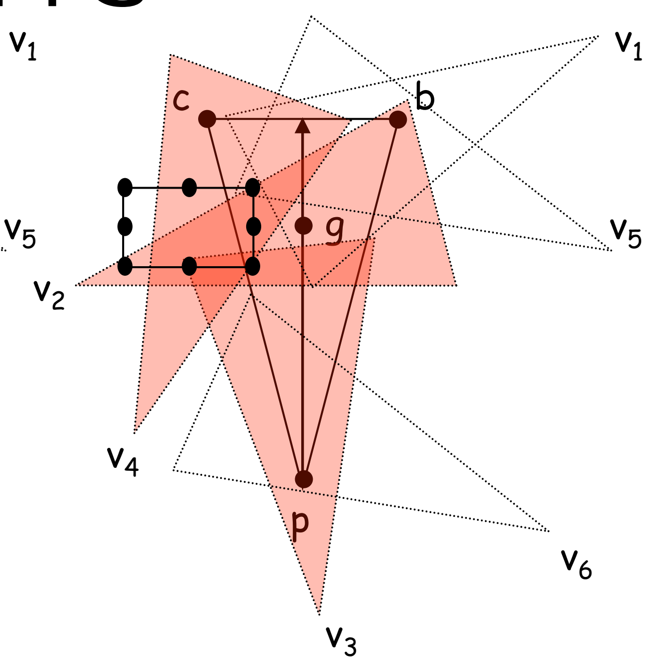


Can further increase the network lifetime (>3500s) while maintaining the stealth time

Research directions at LIUPPA - Routing

- Use cross-layer information (app→ routing & routing→ app) to optimize coverset selection & route selection for surveillance apps





Research directions at LIUPPA - MAC

- Focuses on mission-critical applications (e.g intrusion detection)
- Provide low-latency MAC layer
- Use the criticality model to set schedules of nodes

Sensor & Robots

- Wireless Sensor Networks
  - Large scale sensing
  - Natural collaboration though data aggregation, reporting, ...
  - Mobility is not a priority
- Robots
  - Mobility is a fundamental feature
  - Exploration, rescue
- Sensor & robots
  - WSN provide sensing data to robots
  - Robots maintain connectivity
  - Sensors could help for localization when GPS data are down

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)

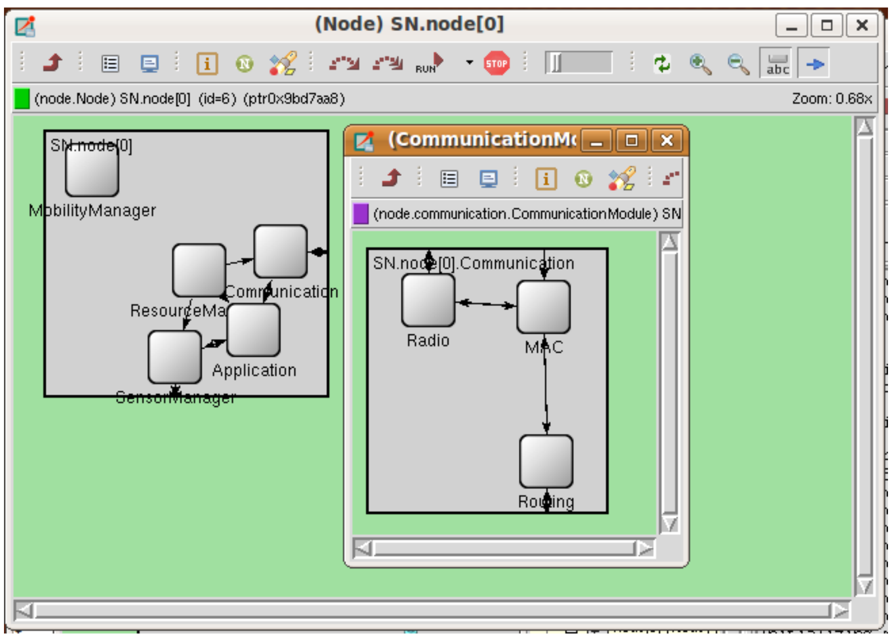
Sensor & Robots will contineously collaborate during the rescue process: localization, path optimization, remote sensing,…

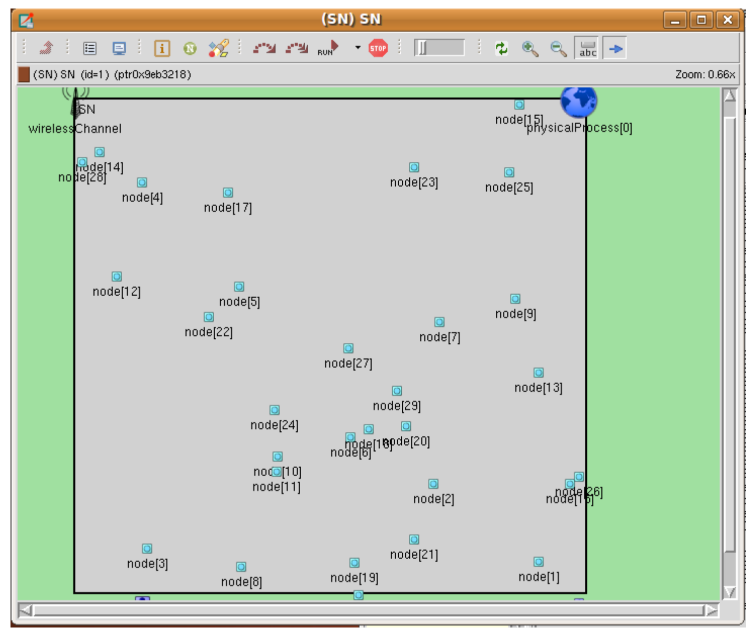
Conclusions

- Sensor Networks can provide large scale awareness
- Sensors & Robots interactions are challenging but promising issues
- Complementary technologies for mission-critical applications

Short term issues (1)

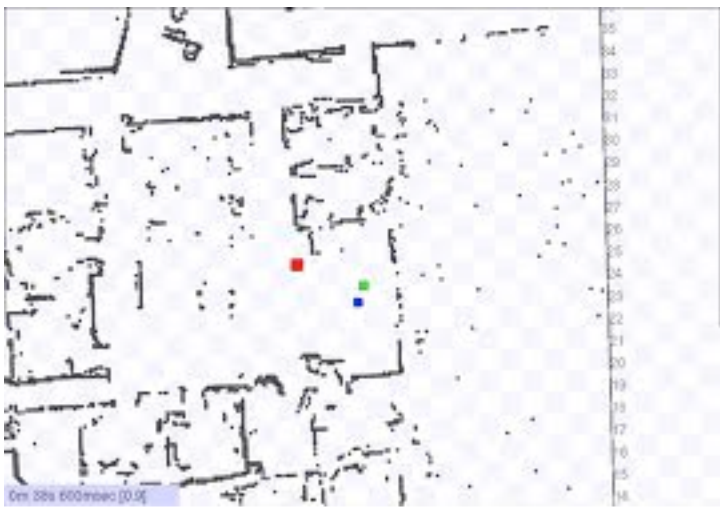
- Communication layers are very important for WSN
- Use specific simulator





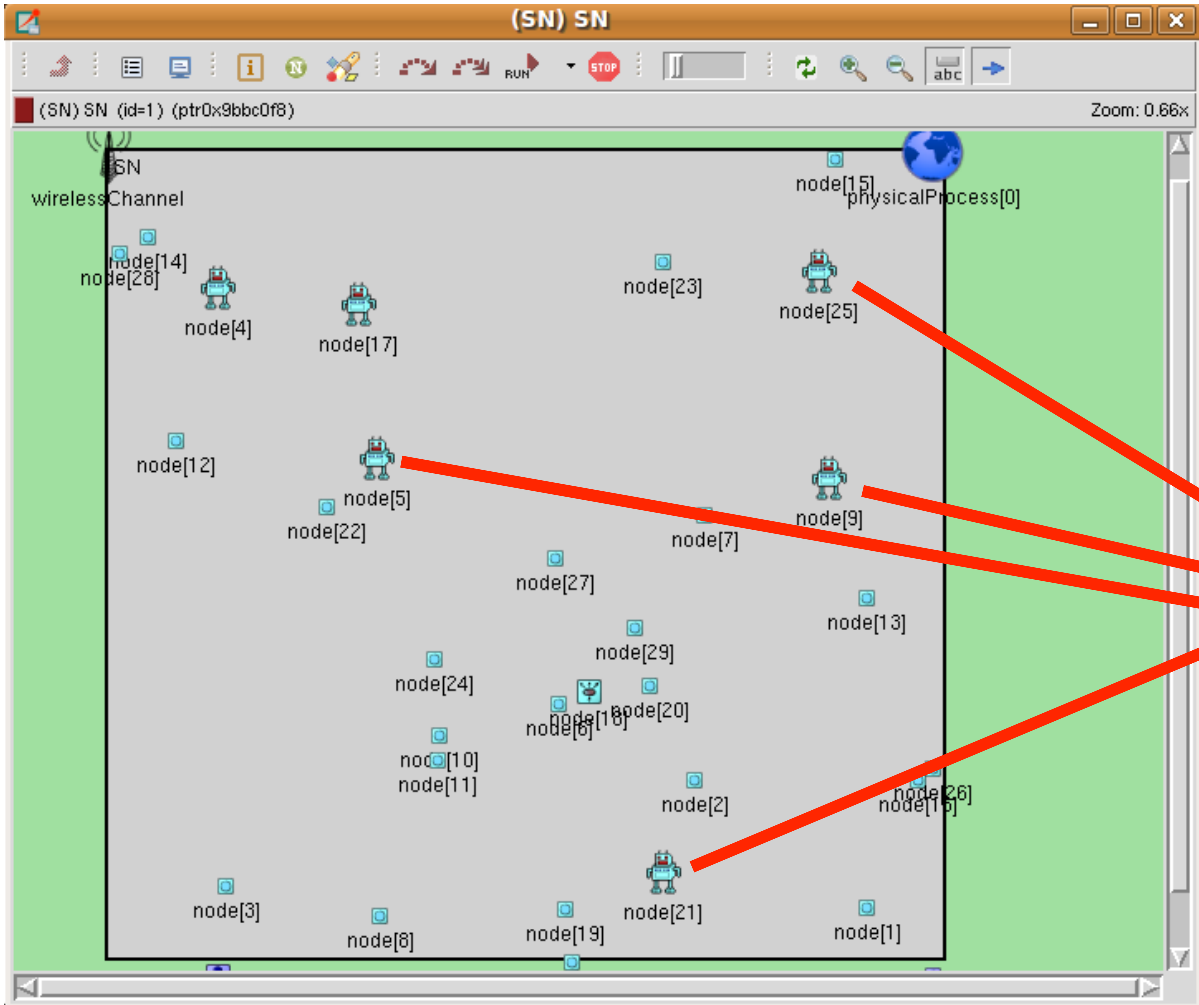
Short term issues (2)

- Mobility, control and design are very important for robots
- Use specific simulator



Sensors & Robots enable interaction studies

Sensor specific simulator for communication stack



Get robot's position from robot simulator

Sensors & Robots Propose new interaction schemes

- Use the criticality model to control both sensors and robots
- Prototyping on real hardware