RECHERCHE

INSTITUT NATIONAL DES SCIENCES APPLIQUÉES DE LYON

Wireless Sensor Networks in a Nutshell

Saisons Croisées France – South Africa
Stellenbosch University, August 2012

Pr. Fabrice Valois, Université de Lyon, INSA-Lyon, INRIA
fabrice.valois@insa-lyon.fr

membre de UNIVERSITÉ DE LYON

Inria — INVENTEURS DU MONDE NUMÉRIQUE

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Agenda

- A short overview of the CITI lab
- Wireless Sensor Networks : Key applications & constraints
- Energy consumption and network *lifetime*
- Radio channel properties
- Key results
  - Resources sharing
  - Routing protocol and data gathering
- Conclusions & Open problems

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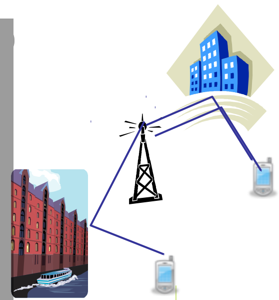
A short introduction to the CITI lab.

Details on: http://citi.insa-lyon.fr/

Research areas in the CITI lab.

- Software radio
- Green radio
- Cooperation & relaying
- RF architectures



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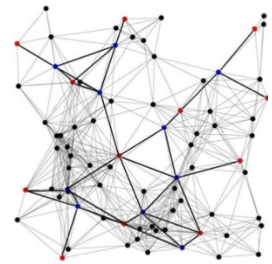


- Multi-hop networks
- Self-networking
- Routing
- Green networking
- Real time

Networking

Ambient networking

Security

- Secured protocols
- Trust mecanisms
- Code generation
- Privacy

Embedded systems

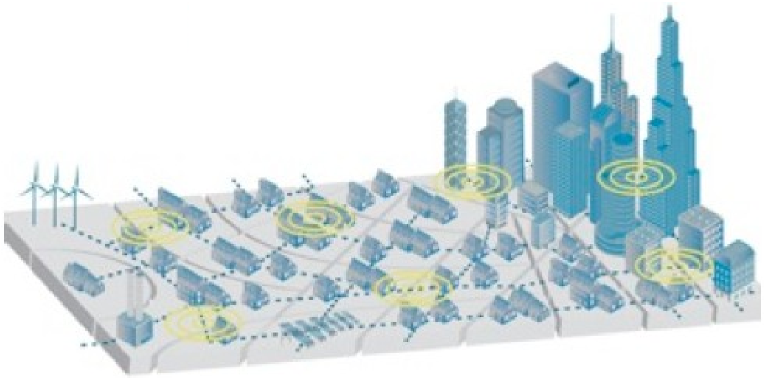
- SoC , NoC
- Software radio
- Simulation & testbeds
- sensors

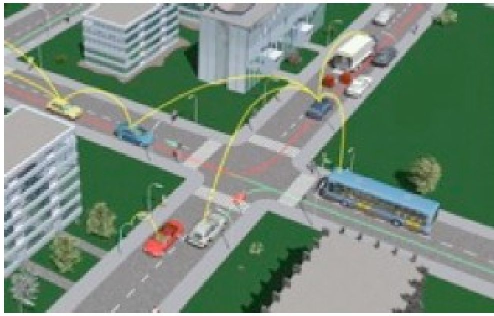
Middleware

- Component based software platform
- OSGi
- Service oriented development

Urbanet, INRIA research team

- Urbanet (leader: Dr. H. Rivano) focuses on
  - Context: Smart cities, digital societies
  - Focus on *capillary networks* (generally speaking: wireless sensor and actuator networks + wireless multi-hop mesh networks)
  - Goal: to provide networking optimization mechanisms and networking protocols to support ambient services





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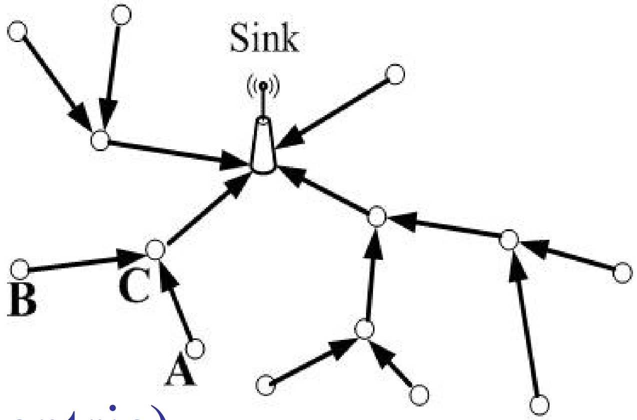
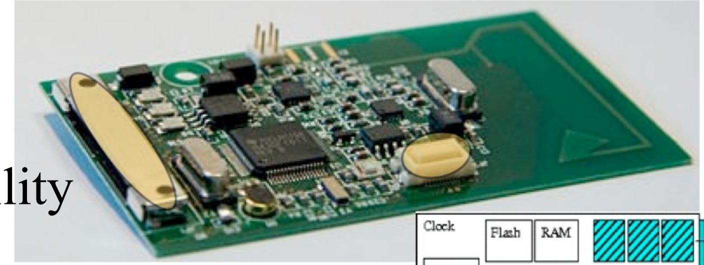
Wireless Sensor Networks: Applications & Constraints



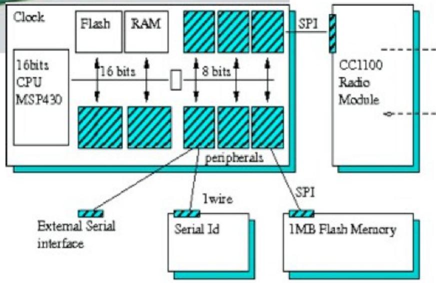
- Key entities for the Internet of Things
- Application-based networks (*aka* data-centric)
  - Physical measures using a physical sensor (water-metering, temperature control, etc.)
  - Coverage problem on a monitored area (intrusion detection, environment monitoring, wild animals tracking, etc.)
- Convergecast trafic to reach the sink node(s):
  - Alarms; periodical monitoring; request/response
  - Multi-hop paradigm from source to destination
  - Nodes to nodes trafic is limited

Wireless Sensor Networks: Applications & Constraints (cont'd)

- WSN networks topology properties
  - Random or regular (grid, line)
  - Network degree vary from 4/5 nodes (agricultural sensors) to thousand (urban networks for water-metering)
  - Network diameter varies from 3/4 hops to 10
  - Static nodes but the topology may be dynamic (to due sleeping mode, the volatility of the radio channel, etc.)



- Hardware properties
  - Limited computation capability
  - Low memory
  - Embedded system
  - Lifetime
  - Low cost (low quality??)



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Energy issue

- Key issue: to maximize the network liftetime, defined as
  - Dead of the 1st wireless sensor node
  - or... Loss of connectivity between node(s) and the sink(s)
  - or... Coverage problem failed
- 

  → Network lifetime = 10 years

Energy issue (cont'd)

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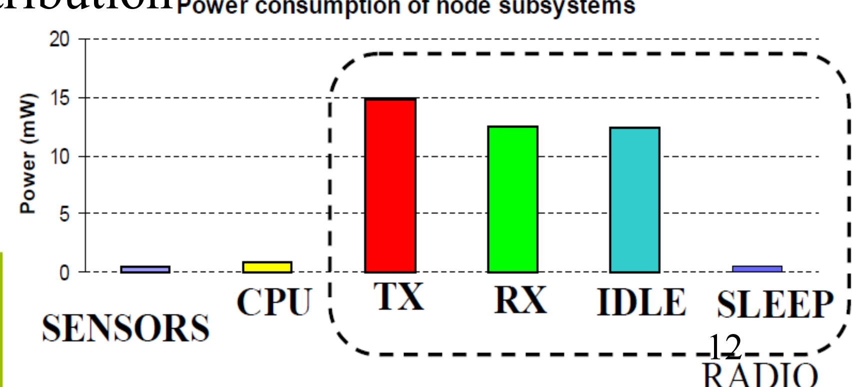
- 

  → Network lifetime = 10 years
- Focus on the radio transmission
  - In terms of energy consumption, to transmit 1 bit requires more than 1'000 CPU-cycles
  - Energy consumption distribution



Energy issue (cont'd)

- Network lifetime optimization:
  - Less for more!
    (less transmission for more duration)
- All the opportunities we have:
  - Low energy consumption hardware system
  - Energy harvesting system
  - Energy-efficient radio interfaces
  - Sleeping mode for sensor nodes and efficient ressource sharing
  - Energy-aware routing protocol (or, at least, energy-efficient routing protocol)
  - Data-aggregation

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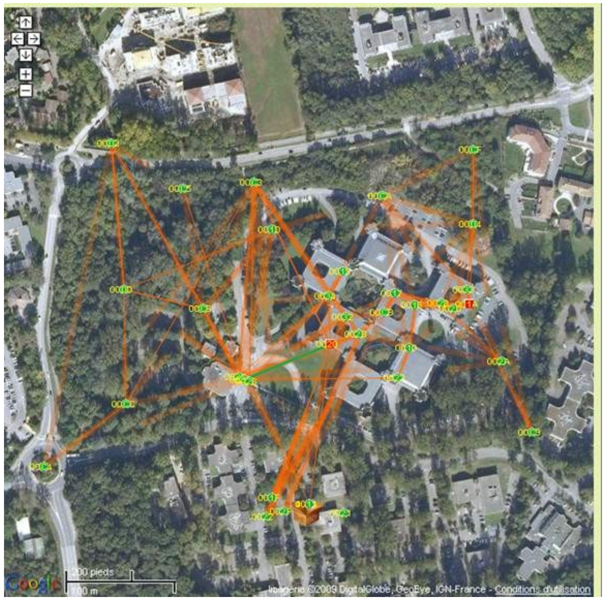
Radio channel properties

- French project ANR ARESA (2006-2009):
  - More than 40 nodes (indoor/outdoor)
  - Trace with more than 400'000 packets
- Ph.D. of K. Heurtefeux (2009):
  - Appartment, CITI, soccer playground
- We investigate the RSSI behavior (Radio Strenght Indicator)

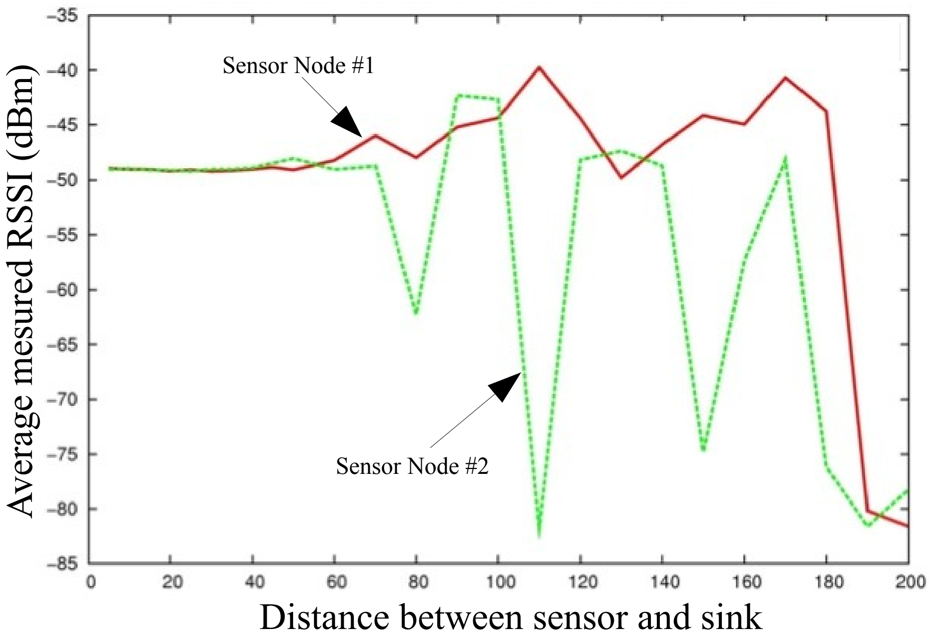


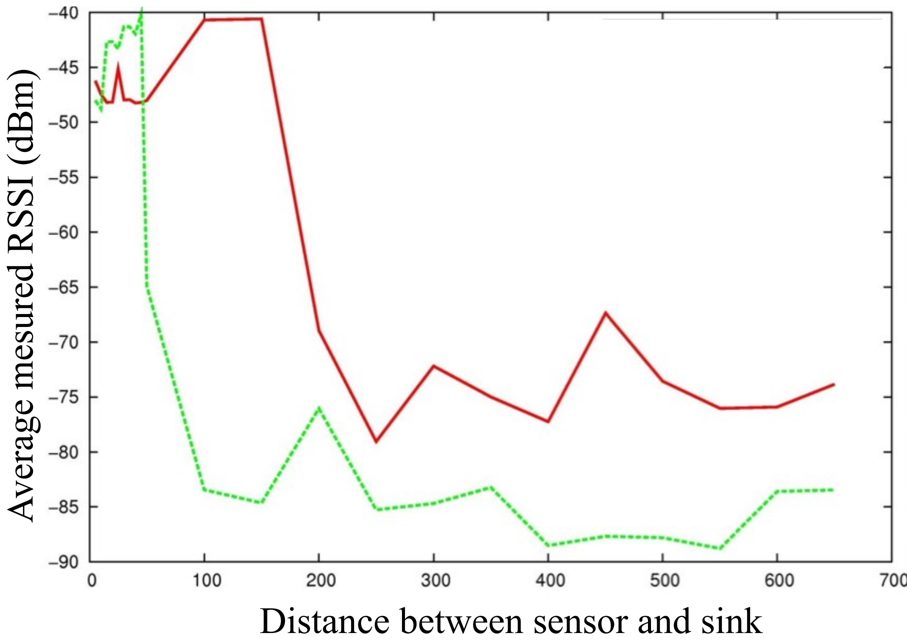
- What we have learned:
  - Results are material-dependent
  - Opportunistic radio links, asymmetric property
  - Radio channel is not stable in space and time
  - Other well-known phenomenon : fading, shadowing, interferences

Radio channel properties (cont'd)

- ✓ Some RSSI exemples (appartment, CITI lab)
  - Hardware-dependent
  - Environment-dependent

RSSI face to the distance





Radio channel properties (cont'd)

- ✓ RSSI variability (standard deviation)

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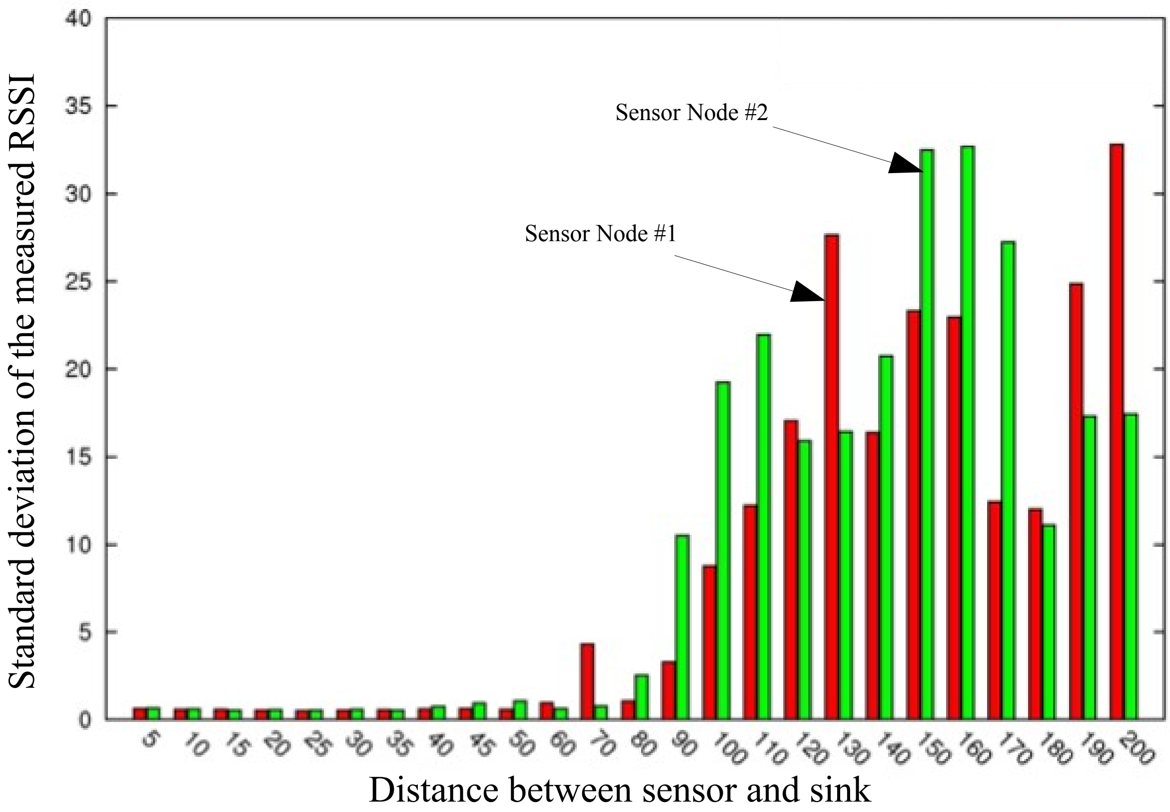
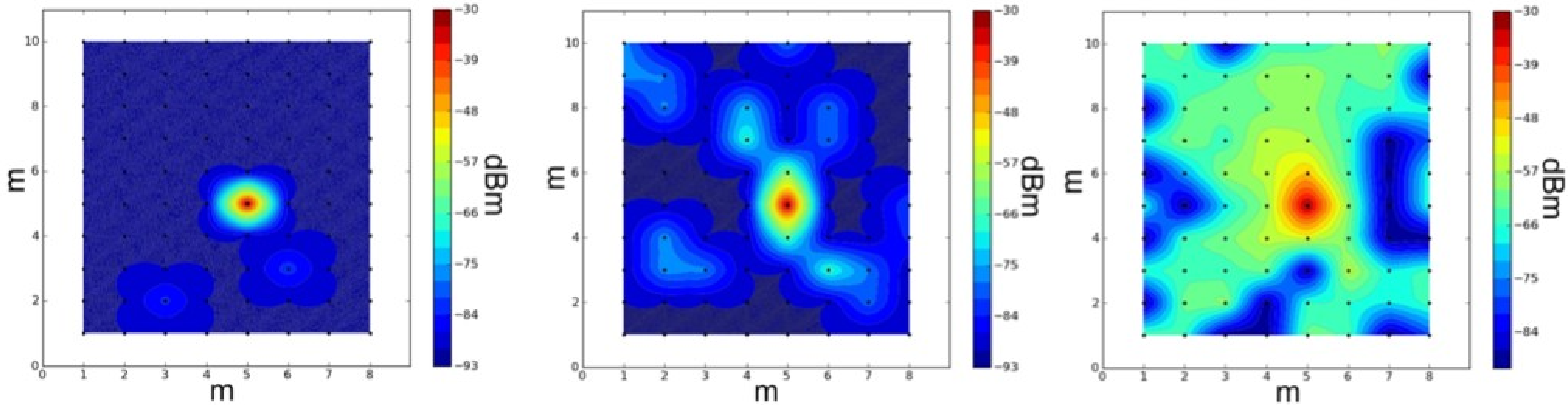


Radio channel properties (cont'd)

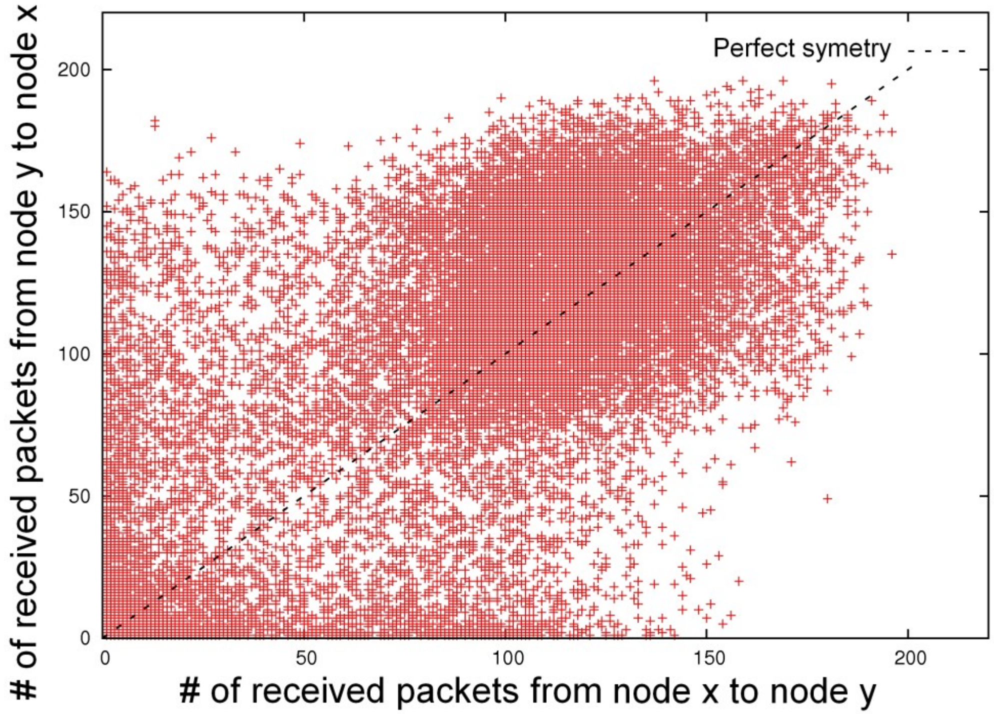
- Radio propagation is non-isotropric



Radio propagation on the SensLab testbed – Strasbourg site – (-30 dBm, -15 dBm, 0 dBm)

Radio channel properties (cont'd)

- Radio links are not always symetric
  - Hardware-dependent, time-dependent, space-dependent
  - On the SensLab testbed (Grenoble site), more than 40% of radio links are non symetric



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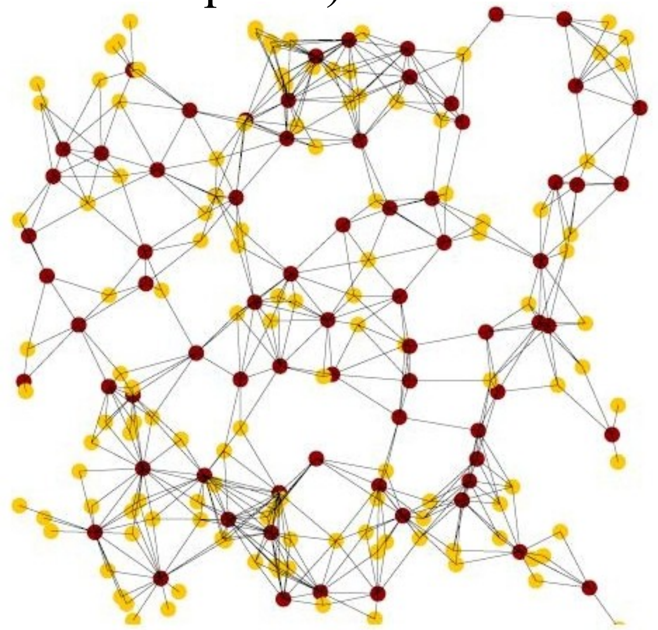
Resource Sharing

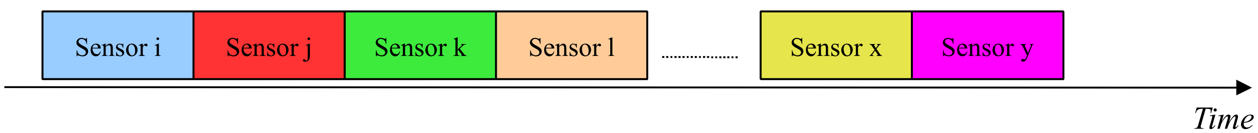
- MAC protocols (*Medium Access Control*)

- Goal: distributed and *fair* sharing of the radio channel using local information (1-hop neighborhood information), and with low collision probability
  - Deterministic Access (synchronisation is required)
  - Random Access (not necessarly using synchronisation)

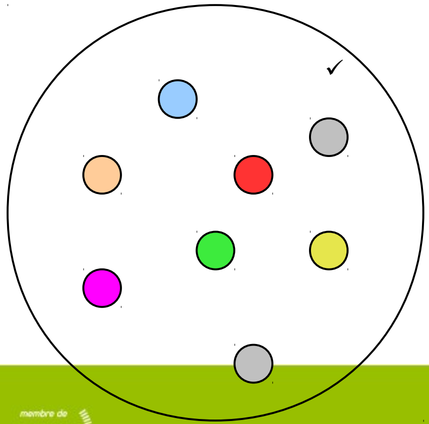


Resource sharing (cont'd)

- Deterministic access:
  - Local scheduling is defined
  - Close to a TDMA approach (*Time Division Multiple Access*)
  - Each slot-time is allocated to a dedicated node



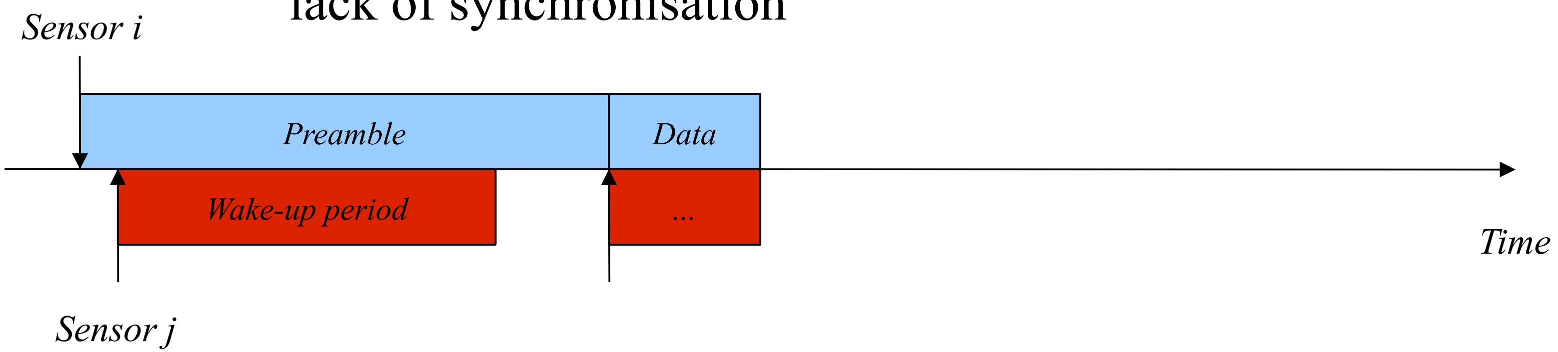
  - Requires a fine synchronisation
  - Non suitable for network dynamicity
  - Not easy to cope with variable trafic intensity



Resource sharing (cont'd)

- Contention-based random access based
  - Based on a CSMA-like protocol but including sleeping mode for sensor nodes (duty-cycle mechanism)
    - 2 families : w/o Synchronisation & w/ Synchronisation

- Without synchronisation (BMAC, XMAC, ...)
  - Using preamble sampling strategy
  - Nodes wake up periodically but at different time due to the lack of synchronisation



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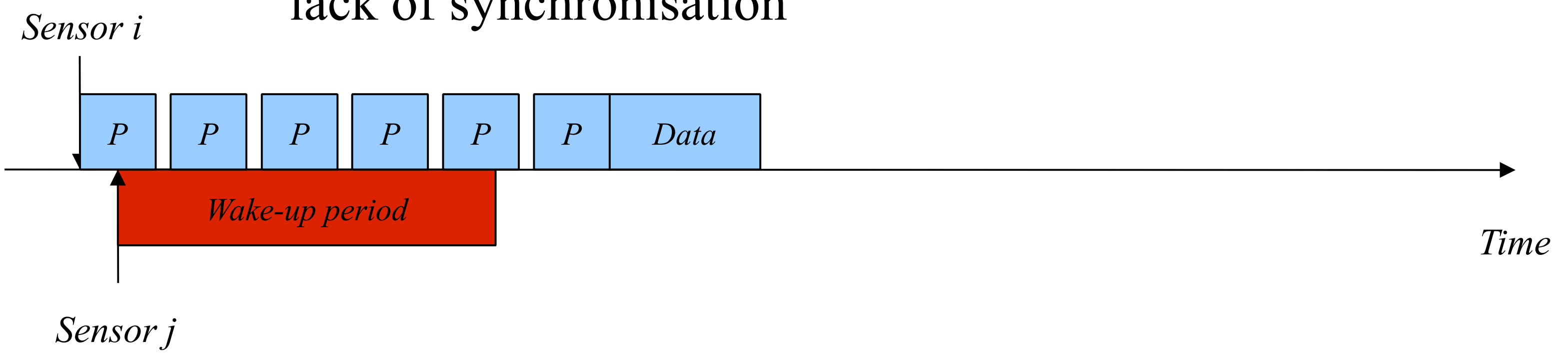

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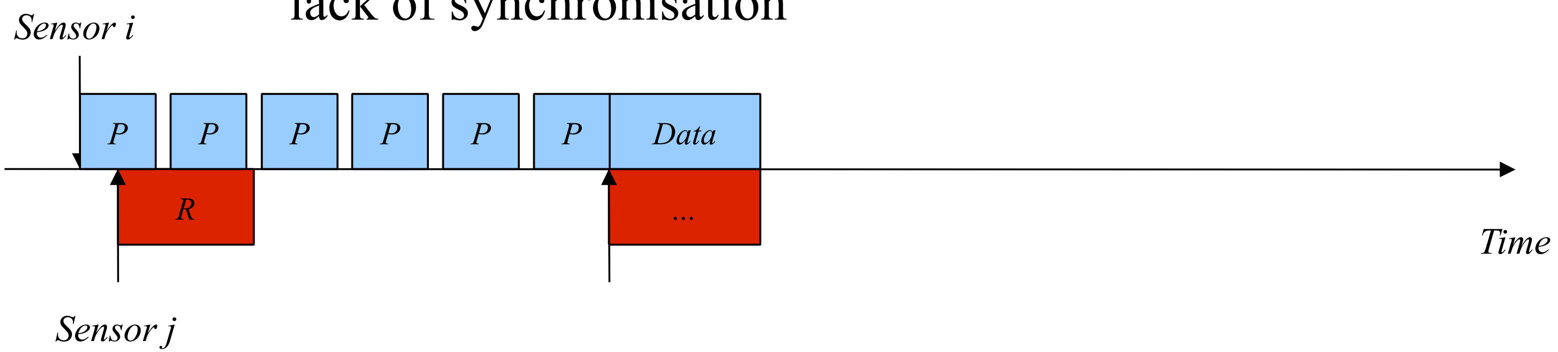

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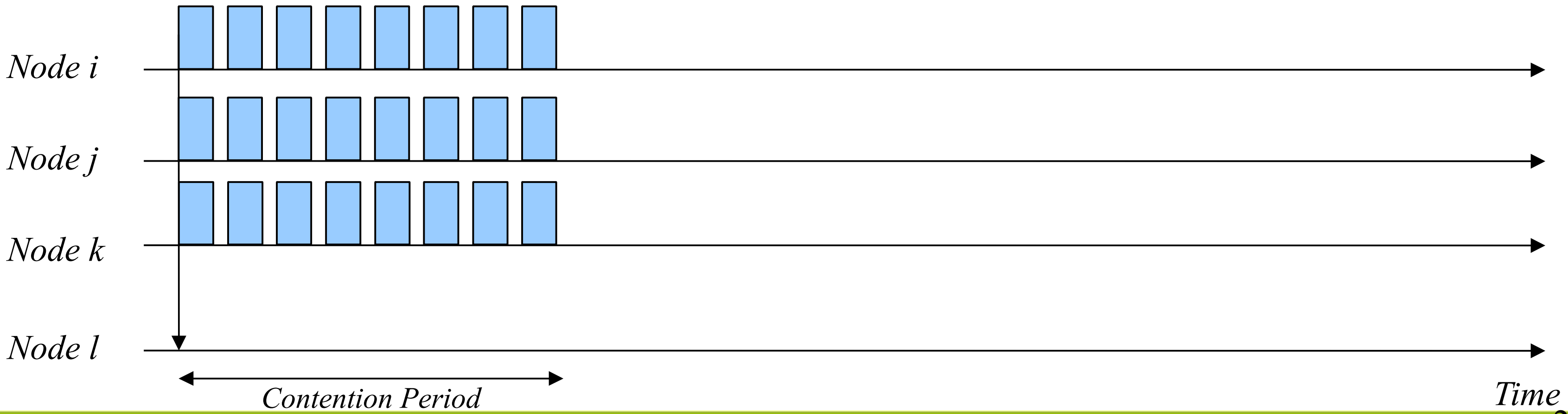
- Synchronised (SMAC, Sift, ...)
  - Common clock
  - Periodical rendez-vous point



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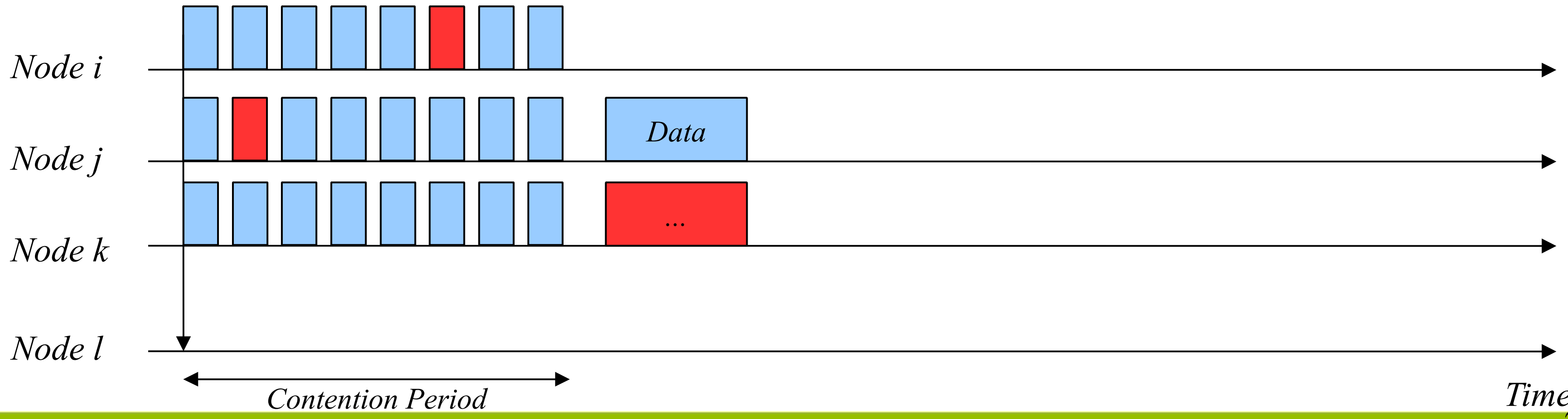
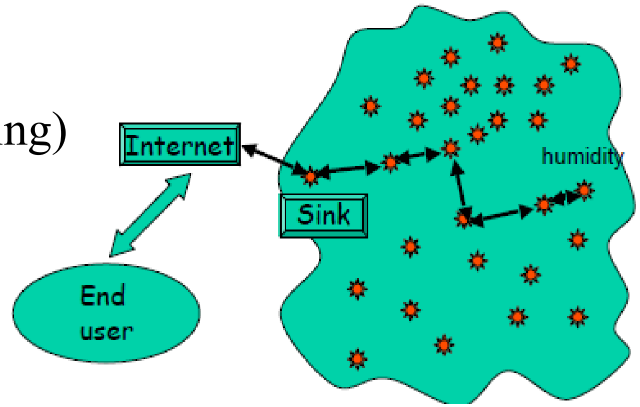


Routing protocol and data dissemination

- Key idea: shortest path (in terms of either number of hops or euclidian distance or energy consumed)

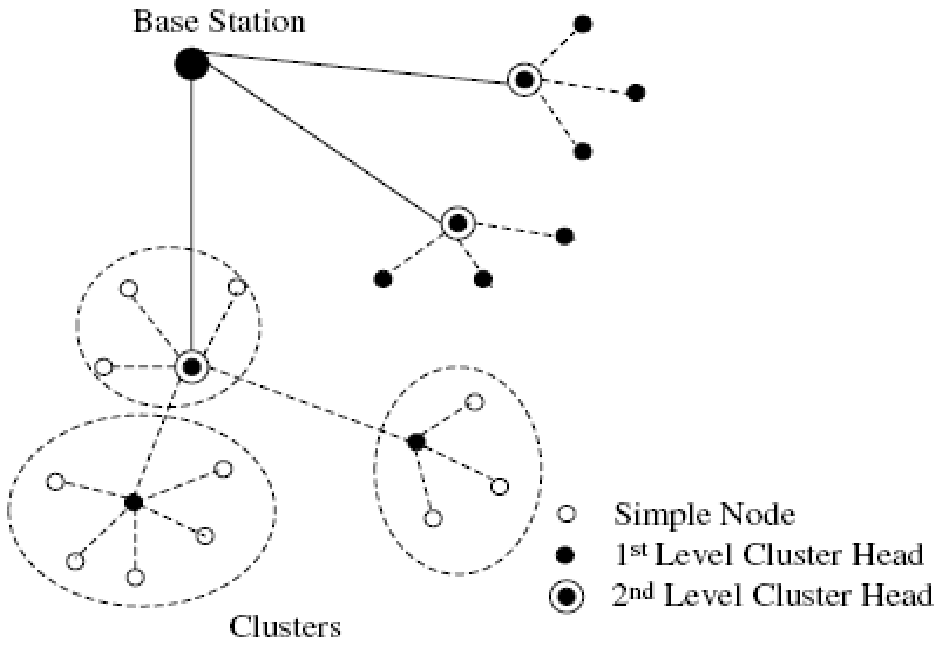
- Some protocols come from mobile ad hoc networks (MANET)
  - But not really suitable because of too important overhead, huge *signalling* (periodical beacon and route management), energy wasting

- Dedicated protocols:
  - Hierarchical approaches
  - Location of Interests (content based routing)
  - Gradient-based routing protocols
  - Geographic (using GPS coordinates)
  - But also: multi-paths, QoS based, etc.



Routing protocol and data dissemination (cont'd)

- Hierarchical approaches
  - Using clusters, virtual backbone, cluster-tree, etc.



Routing protocol and data dissemination (cont'd)

- Location of interests
  - Content-based routing protocols
  - Publish / subscribe policies

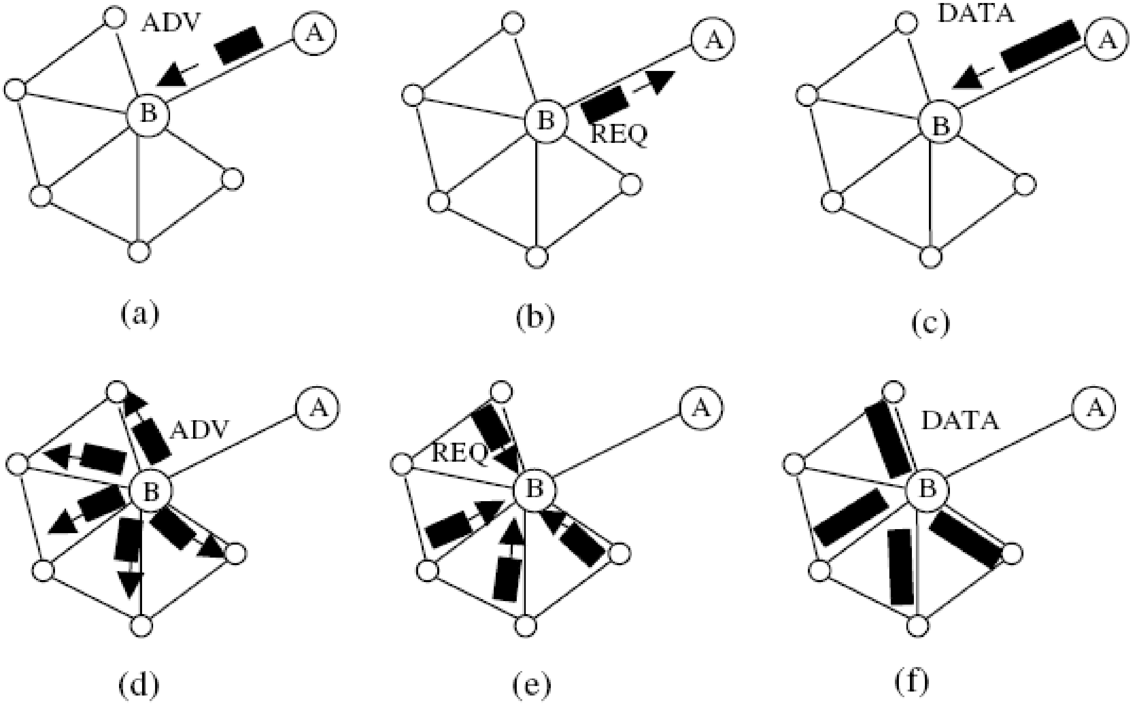
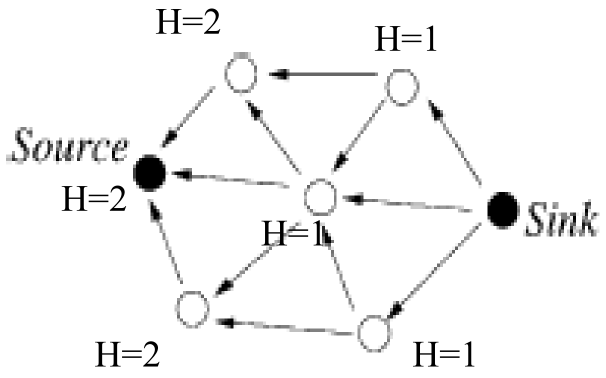


Fig. 3. SPIN protocol. Node A starts by advertising its data to node B (a). Node B responds by sending a request to node A (b). After receiving the requested data (c), node B then sends out advertisements to its neighbors (d), who in turn send requests back to B (e–f).

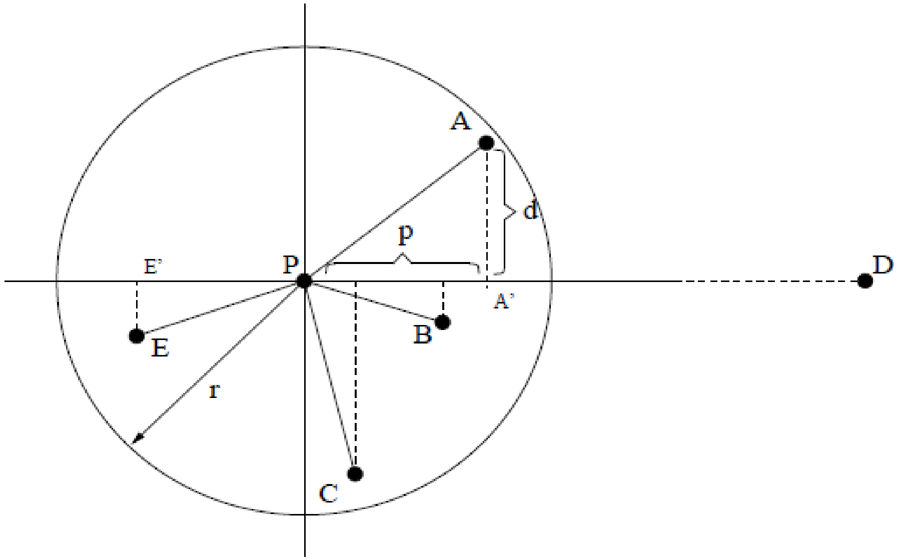
Routing protocol and data dissemination (cont'd)

- Gradient routing protocol:
  - Flooding of an *init* packet, from the sink to the whole network
  - At each step, to increment the counter value



Routing protocol and data dissemination (cont'd)

- Geographic approaches
  - Each node owns a unique Id. and a coordinate (x,y,z)"
  - Absolute coordinates (GPS) or virtual coordinates
  - Assume the sink location / sink coordinates
  - Assume that a *well-known* function f(x) exists such as: *f(Id.) → (x, y)*
  - The next forwarder is a neighor which closer to the destination
    - Beacon-based (neighborhood is known a priori)
    - Beaconless (neighborhood is never known)



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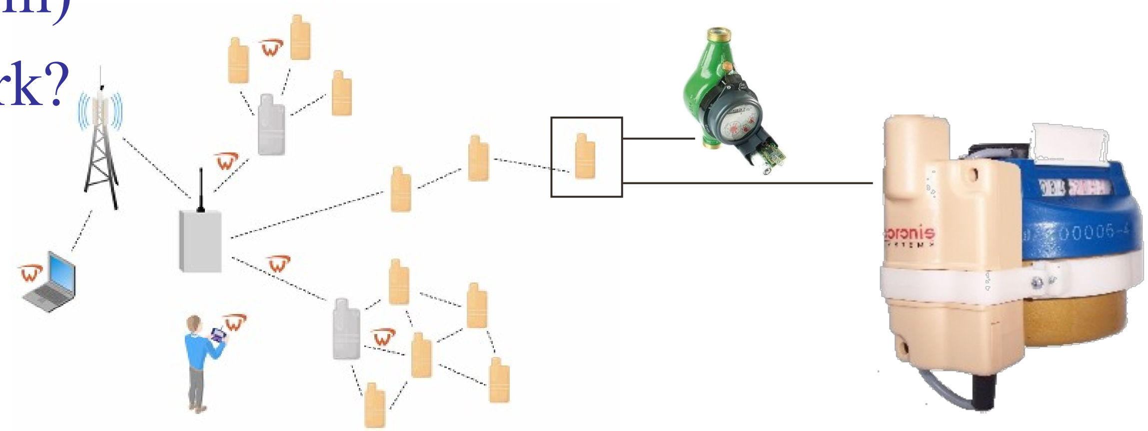
Conclusions & co.

- WSN are data-centric network
- Energy is the main challenge
  - Network lifetime optimization is a major concern
  - Cross-layer approaches (joint MAC/routage schemes)

- New issues: temporal constraints and QoS requirements
- To save energy: transmit less → data-aggregation
- Security (open system)
- IP-compliant network?
- From sensor nodes to dust...



Thank you for your attention, Questions?

Contact: fabrice.valois@insa-lyon.fr
http://fvalois.insa-lyon.fr/