# Réseaux de capteurs, recherche ou industrialisation ?

Orange Labs

Dominique Barthel, Recherche & Développement
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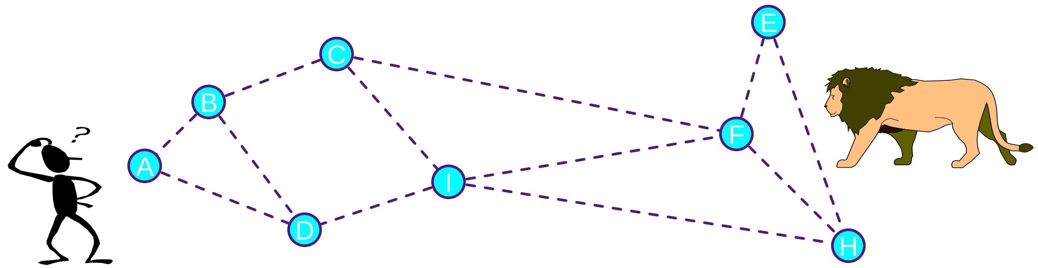
# Sommaire

# Wireless Sensor and Actuator Network intro

- An ad hoc network of nodes
- Interact with significant area/volume of physical world
  - collects measurements over some sensing range
- React onto the physical world
  - energy cost
- Pertains to some
  - area/volume
  - timeframe
  - type of information




- Application known from start
  - not a generic Information Technology problem
  - data gathering and reporting period
  - data statistics, temporal correlation (rate of change), spatial correlation
  - QoS requirements
    - latency, tolerance to packet loss

# Projets fondateurs

# DARPA SensIT project (1999-2002)

- Thousands to billions of nodes
- Homogeneous nodes, flat topology
  - "Smart dust"
- No address, data-centric routing
- Distributed, local algorithms
- Redundant sensing, distributed signal processing, information fusion
- Estimation, tracking, detection


http://www.darpa.mil/sensit/index.htm

# Great Duck Island

- Leach Storm Petrel habitat monitoring
  - What environmental factors make for a good nest? How much can they vary?
  - What are the occupancy patterns during incubation?
  - What environmental changes occurs in the burrows and their vicinity during the breeding season?
- UCB motes, 802.11b, satellite

R. Szewczyk, J. Polastre, A. Mainwaring, D. Culler, 1st European Workshop on Wireless Sensor Networks (EWSN '04) Berlin, Germany, January 19-21, 2004

# Vision industrielle

# WSANs commercial scenarios
# IETF ROLL routing requirements

- Urban sensor networks
  - Monitoring consumption, wastes, pollution, parking, actuating lights
  - http://tools.ietf.org/wg/roll/draft-ietf-roll-urban-routing-reqs/
- Industry automation
  - Non-critical feedback loop, preventive maintenance, asset tracking
  - http://tools.ietf.org/wg/roll/draft-ietf-roll-indus-routing-reqs/
- Building automation
  - Lighting, Shutters, HVAC, Security, Fire, Elevators
  - http://tools.ietf.org/wg/roll/draft-ietf-roll-building-routing-reqs/
- Home automation
  - Lighting&Entertainment, Energy Conservation, Security, Healthcare
  - http://tools.ietf.org/wg/roll/draft-ietf-roll-home-routing-reqs/

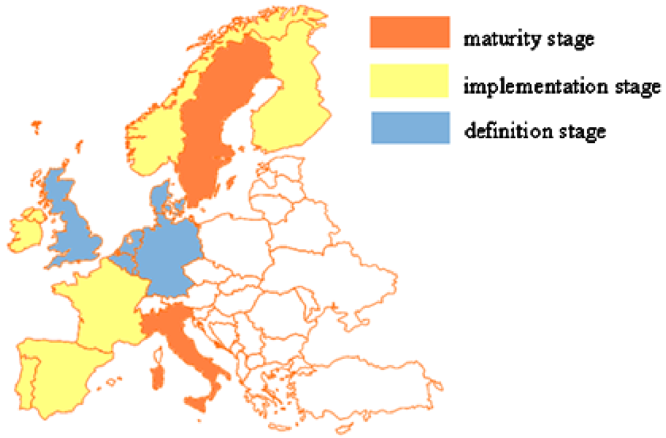
# AMI market sizes

- 571 million meters in Europe*
  - 252 million electricity meters**
  - 130 million water meters
  - 105 million gas meters
  - 3 million public heating meters

- Electricity metering boosted by European mandate on Smart Metering
  - 2020: 80% meters
  - 2022: 100% meters

- Public lighting
  - 90 million street lamps***
  - Less than 1% of these lamps are connected to a network.
  - Up to 45% energy savings and a considerable reduction in maintenance costs.

| Country | Compl. Year | Electricity Metering Pts |
|---|---|---|
| Sweden | 2009 | 5,200,000 |
| Italy | 2011 | 36,000,000 |
| Ireland | 2013 | 2,000,000 |
| Norway | 2013 | 2,600,000 |
| Finland | 2013 | 3,100,000 |
| Netherlands | 2016 | 7,900,000 |
| France | 2017 | 34,000,000 |
| Spain | 2018 | 26,300,000 |
| UK | 2020 | 29,100,000 |




*ABS Energy Research, World water meter market report, 2008
**Smart Metering and Wireless M2m – Berg Insight August 2008
***Monitored Outdoor Lighting – Echelon White Paper March 2007

# European mandate for Smart Metering

EUROPEAN COMMISSION
ENTERPRISE AND INDUSTRY DIRECTORATE-GENERAL

New Approach Industries, Tourism and CSR
**Construction, Pressure Equipment, Metrology**

Brussels, 12th March 2009
**M/441 EN**

**Standardisation mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability**

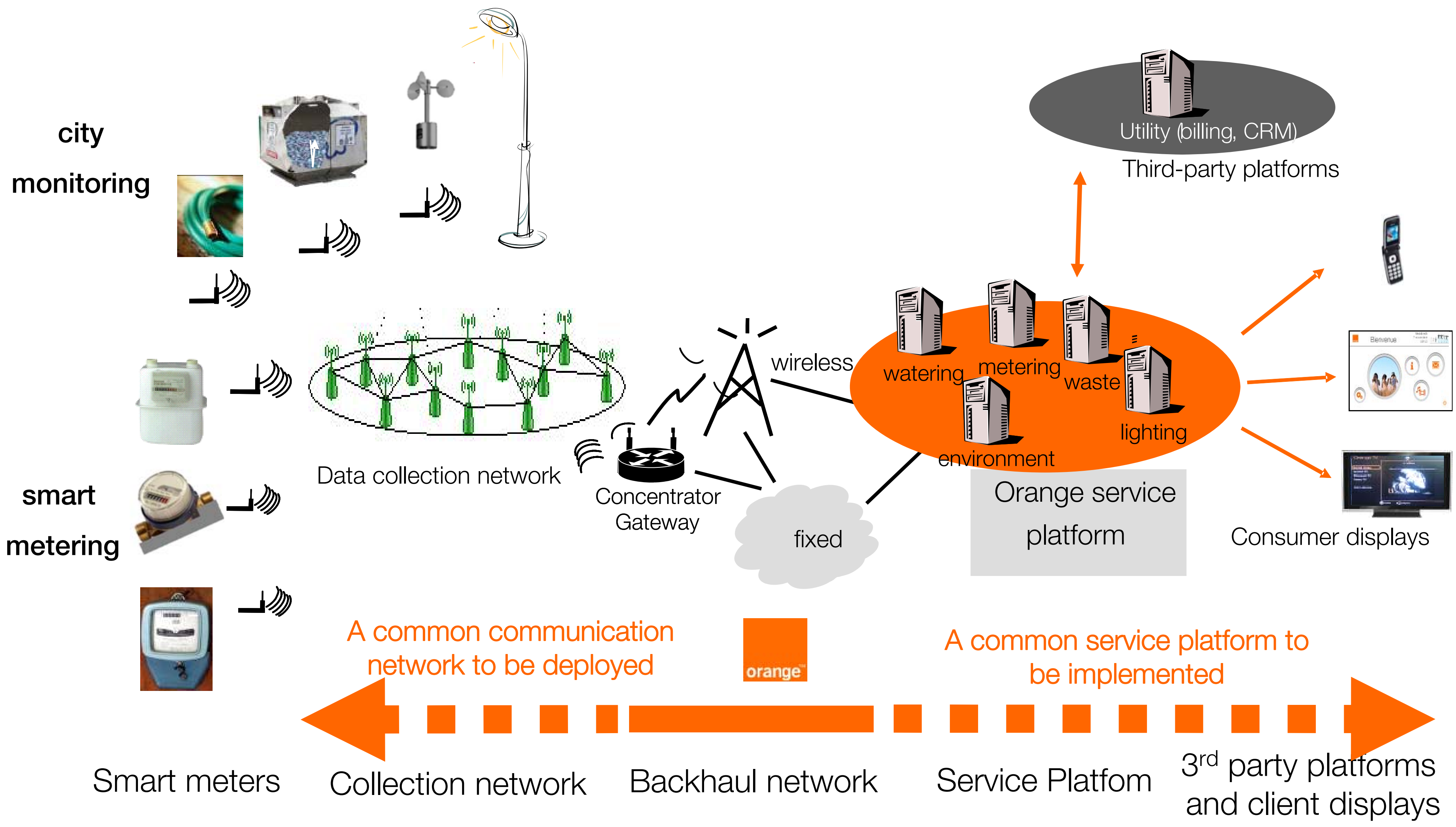
**Objective**

The general objective of this mandate is to create European standards that will enable interoperability of utility meters (water, gas, electricity, heat), which can then improve the means by which customers' awareness of actual consumption can be raised in order to allow timely adaptation to their demands (commonly referred to as 'smart metering').

# Market drivers

- Productivity
  - Marginal in water metering due to remote metering infrastructure maintenance
  - Substantial in public lighting
- Sustainable Development
  - Attractive in Electricity – peak detection and forecast, peak shaving
  - More in terms of image than in real savings in water management
  - Substantial in public lighting
- New boom of services
  - Electricity: 41 new services thanks to electricity smart metering, EDF
  - Water: Detailed bills, leak detection, public health, …
- *« L'information liée à l'eau prendra autant de valeur que l'eau elle-même »*
  - Antoine Frérot
  - Directeur Général de Veolia Eau

# Orange to deploy city-wide data collection networks

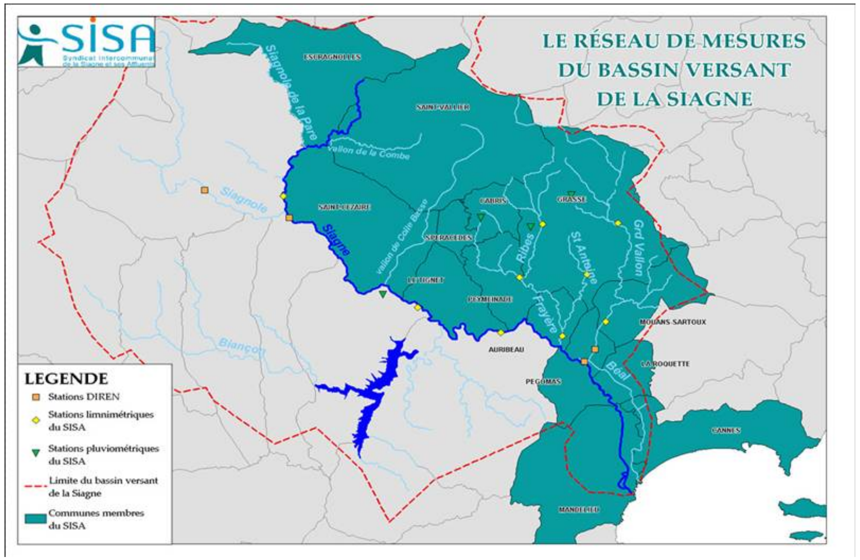


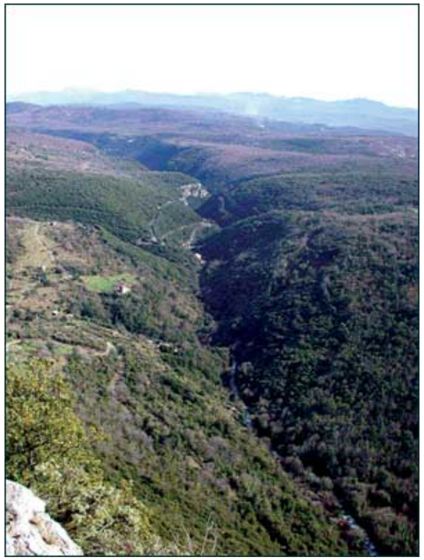
# Technical challenges

| Challenge | Description |
| --- | --- |
| Scalability | Networks can contain a huge number of nodes and can be very dense (upto 20000 per sq.km). Marketing estimates a breakeven point of 200,000 nodes. The technology needs to be able to handle such large numbers and densities. |
| Adaptability and low maintenance | Minimizing manual intervention to maintain the network is critical for ROI. Networks need to be largely self-organizing and self-healing. |
| Low energy use and long lifetime | For many urban services, the end device is battery operated. Ensuring a long lifetime for the end devices is a necessity (often contractual). This imposes a major constraint on the candidate technology. |
| Ease of deployment | Deployment is typically in stages. Start small for a given service. Then expand for the same service and add other services. Tools are needed to facilitate the initial deployment and subsequent re-dimensioning of the network providing an appropriate compromise between cost and coverage. |
| Security | Multiple services are deployed within the same geographical zone (in virtual sub-networks). The actors involved for these services are different. It is critical that appropriate security is provided to ensure data integrity, access control and in some cases data privacy. |
| QoS Management | Multiple services imply the need to support different requirements. Electricity metering requires more frequent meter reading as compared to gas. It also needs to support demand response (or real time pricing) which involves low latency and bidirectionality. |
| Network Topology | Different network topologies need to be supported in terms number of repeaters and gateways involved for a subnet. Dense urban environments and sparsely populated suburban areas may use different topologies for instance. |

# Orange pilot projects, collaborative research

- Field trials
  - 2005 : Natural risks management in Cagnes/Mer
  - 2006 : Recycling containers monitoring in Voiron
  - 2007-2008 : Public lighting in Cagnes/Mer
  - 2009-2011 : Le Havre, Cagnes/Mer: multi-service projects



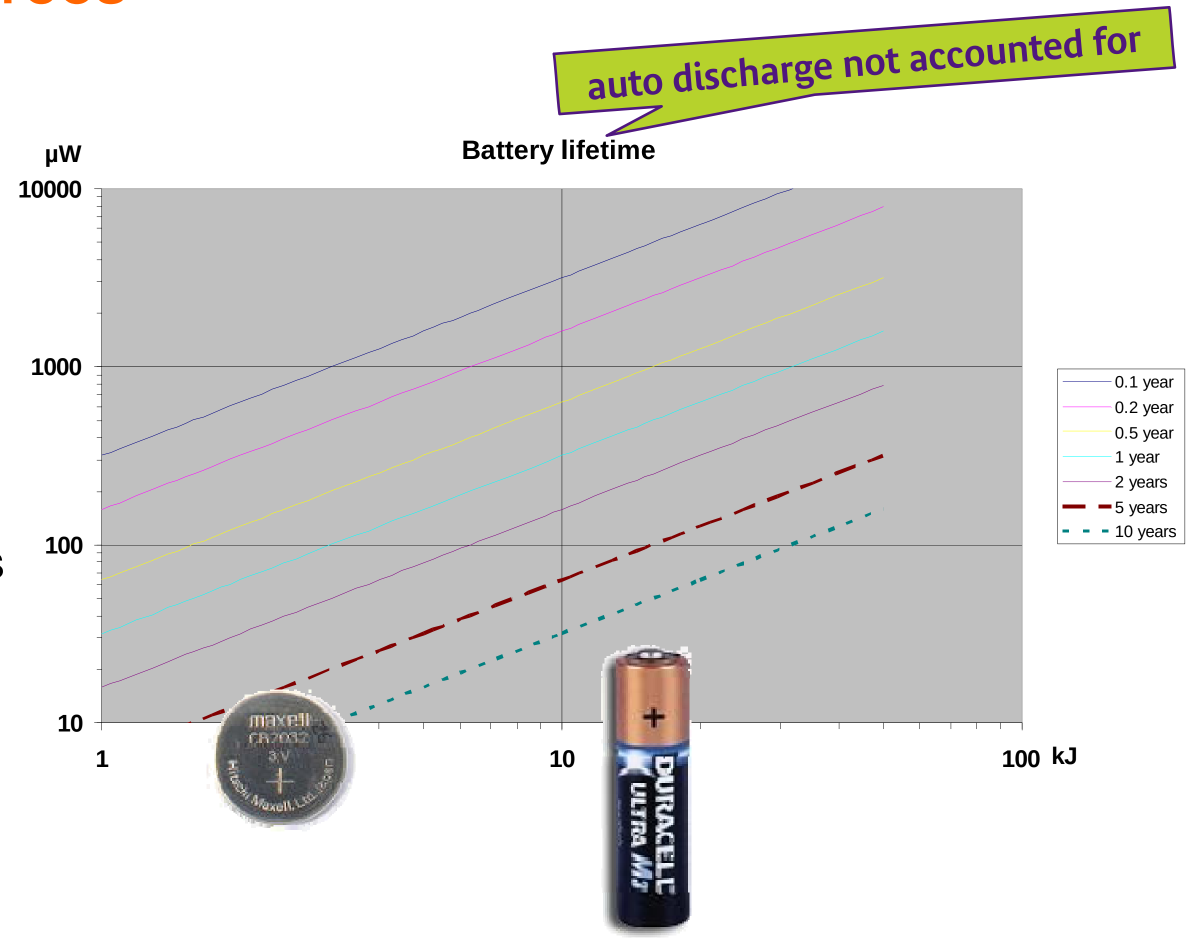
# Collaborative research

- Collaborative projects
  - Aresa (2006 – 2009): technical challenges in low power sensor networks

  - SensCity (2008 – 2011): share the promise of a standard and mutualized infrastructure
  - Aresa 2 (2009 – 2012): convergence towards IP networks, security
- 4 PhD students at Orange Labs on WSANs

# Contraintes techniques

# Local energy sources




- not renewable
  - avg power below 1 mW to use any reasonnable battery
  - Moore's law does not apply to batteries

- harvest energy from the environment
  - Light: 1000 µW/cm2 in direct sunlight, 10-100 µW/cm2 indoor
  - Vibrations: 10-100 µW/cm3 in "noisy" environment

# A typical WSAN radio chip (CC1020)

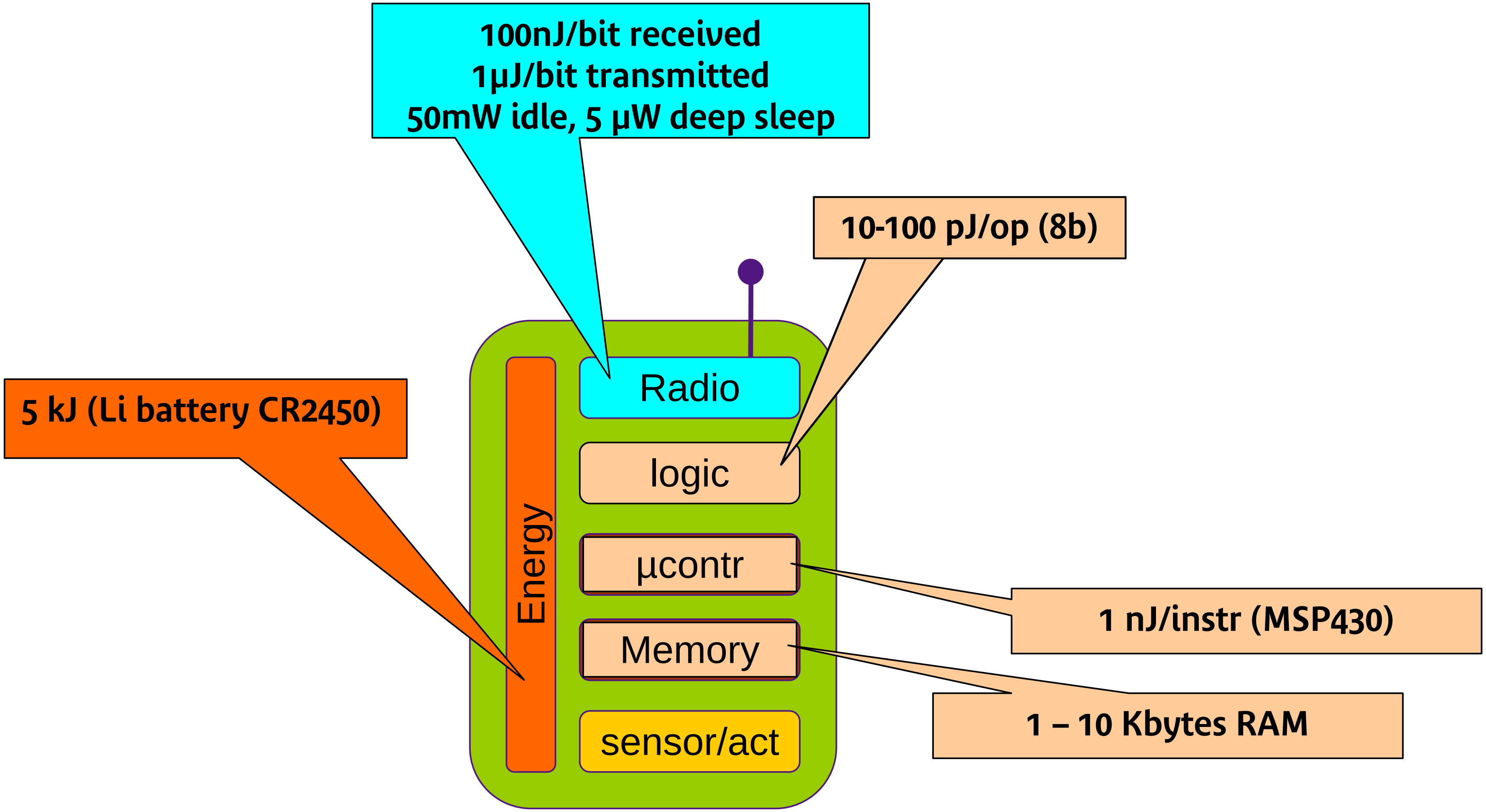
at 2.7 V

50 mW

100 nJ/bit

| | | | | | |
|---|---|---|---|---|---|
| **Current Consumption** | | | | | |
| Power Down mode | | 0.2 | 1.8 | µA | Oscillator co[illegible] |
| Current Consumption, receive mode 434/868 MHz | | 17.3/17.9 | | mA | |
| Current Consumption, transmit mode 434/868 MHz: | | | | | |
| P = −20 dBm | | 10.3/13.7 | | mA | The output power is delivered to a 50 Ω single-ended load, see also page52. |
| P = −5 dBm | | 12.1/18.1 | | mA | |
| P = 0 dBm | | 13.7/21.9 | | mA | |
| P = 5 dBm | | 16.8/33 | | mA | |
| P = 10 dBm (434 MHz only) | | 23.7 | | mA | |
| Current Consumption, crystal oscillator | | 77 | | µA | 14.7456 MHz, 16 pF load crystal |
| Current Consumption, crystal oscillator and bias | | 500 | | µA | 14.7456 MHz, 16 pF load crystal |
| Current Consumption, crystal oscillator, bias and synthesizer | | 11.5 | | mA | 14.7456 MHz, 16 pF load crystal |

# Limited resources



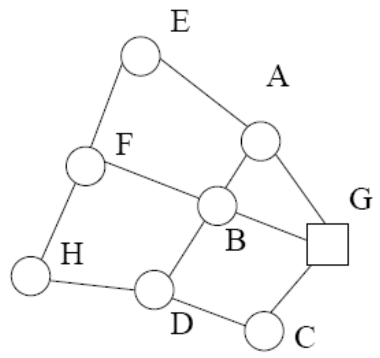
# Protocoles

# WSAN Medium Access

- reasons for wasted energy
  - idle listening
  - overhearing, overtransmitting
  - collisions, congestion
  - traffic overhead (control packets, ACK)
  - memory/computation complexity

# Scheduling-based protocol TSMP example

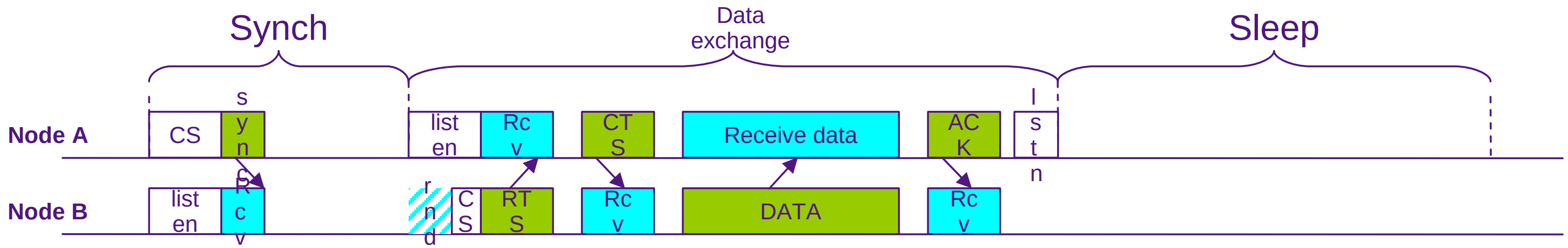
- Dust Inc. 2007
- Industry automation app
  - Delivery ratio and latency constraints
  - 4 hops maximum
- Centralized allocation
  - Channel = frequency and time slot
  - Channel include frequency hopping
  - Timeslots schedules for forwarding paths
- Link layer retransmission




| | t1 | t2 | t3 | t4 | t5 | t6 | t7 | t8 | t9 | t10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ch.15 | | | | | | | | | E->A | |
| ch.14 | A->G | | | G->C | | | | | | |
| ch.13 | | | | | | D->H | | | | |
| ch.12 | | F->E | | | | | B->A | | | |
| ch.11 | | | | | C->D | | | | | F->B |
| ch.10 | | | G->B | | | | | | | |
| ch.9 | | | | | | | | | | |
| ch.8 | E->F | | | | | G->A | | B->G | | |
| ch.7 | | | | D->B | | | | | | A->E |
| ch.6 | | | | | H->F | | | | | |
| ch.5 | | D->C | | | | | C->G | | | |
| ch.4 | | | | | | | | | B->D | |
| ch.3 | | | | | | | | | | |
| ch.2 | H->D | | | | | B->F | | | | |
| ch.1 | | | F->H | | | | | | | |
| ch.0 | | | | | A->B | | | | | |

# Contention-based MAC protocols
# SMAC example

- local synchronization
  – defines common active and sleep phases
- nodes set up as sync setters or consumers
  – form in-sync clusters, clusters having different schedules
- CSMA/CA contention during data exchange phase

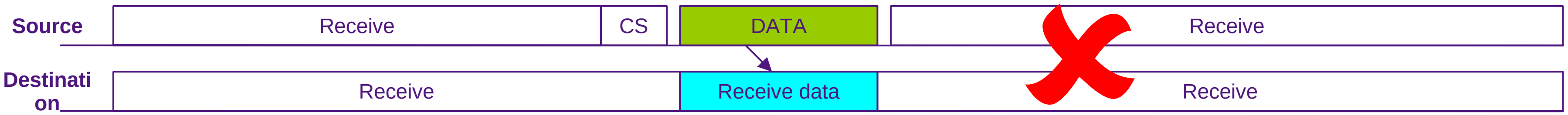



- RTS/CTS advertize exchange length

W. Ye, J. Heidemann, and D. Estrin. "An energy-efficient MAC protocol for wireless sensor networks".INFOCOM, June 2002

# Preamble-sampling

- Instead of keeping receiver on all the time




- Only check in at regular intervals
  - interval known to the transmitters


- Is it a good idea?
  - many receivers for each transmission
  - about same energy for transmission and idle listening
  - low channel utilization rate

# MAC protocol conclusions

- duty cycle the radio
  - slashes the channel bandwith
  - induces deathness
- some form of synchronization required to avoid deathness
  - explicit or implicit
- try to get back adaptability to traffic
  - adjustable duty cycling
- wide range of solutions based on load and QoS constraints
  - Preamble-sampling : at low loads, best energy
  - Contention-based : flexibility
  - Scheduled : deterministic quality of service, high loads

# WSAN network layer

- Low power and lossy links
  - Definitely a need for multi-hop routing
  - Need to cope with transient links
- Not all pairs communicate
  - Few routes to remember
- Application-defined behavior
  - traffic characteristics somewhat known
- Nodes dies when exhaust energy source
  - Remaining energy as node metric
- New : IP-friendliness

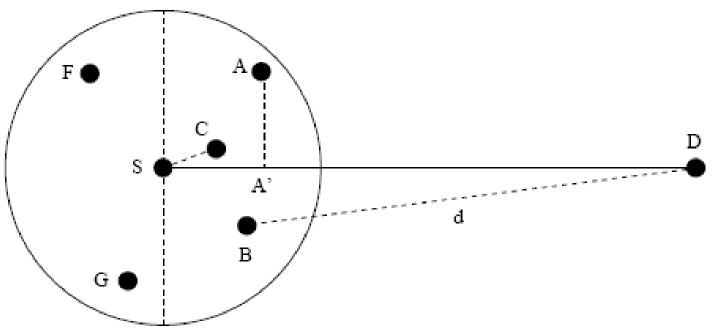
# MANET

- IETF working group [1], launched in 1997
  - routing technologies for mobile wireless networks of computers over IP
  - hundreds of routers, dynamic topology, contrained data rates, limited energy
- not limited to MobileIP (client mobility across fixed infrastructure)
- Where are we in 2009 ?
  - 6 competing routing solutions
  - RFCs : AODV, OLSR, TBRPF, DSR; Drafts : DYMO, OLSRv2
- Solutions not compatible with WSAN constraints

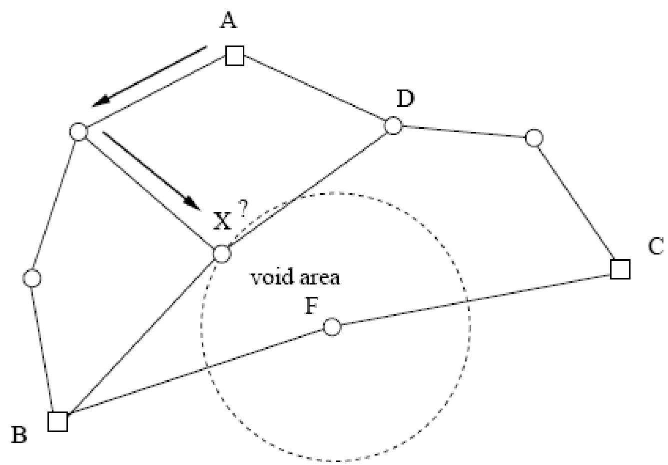
[1] http://www.ietf.org/html.charters/manet-charter.html

# Geographic routing

- All positions assumed known
  - Destination known by position
- Greedy geographic routing
  - Forward to neighbor closest to destination
  - No node state



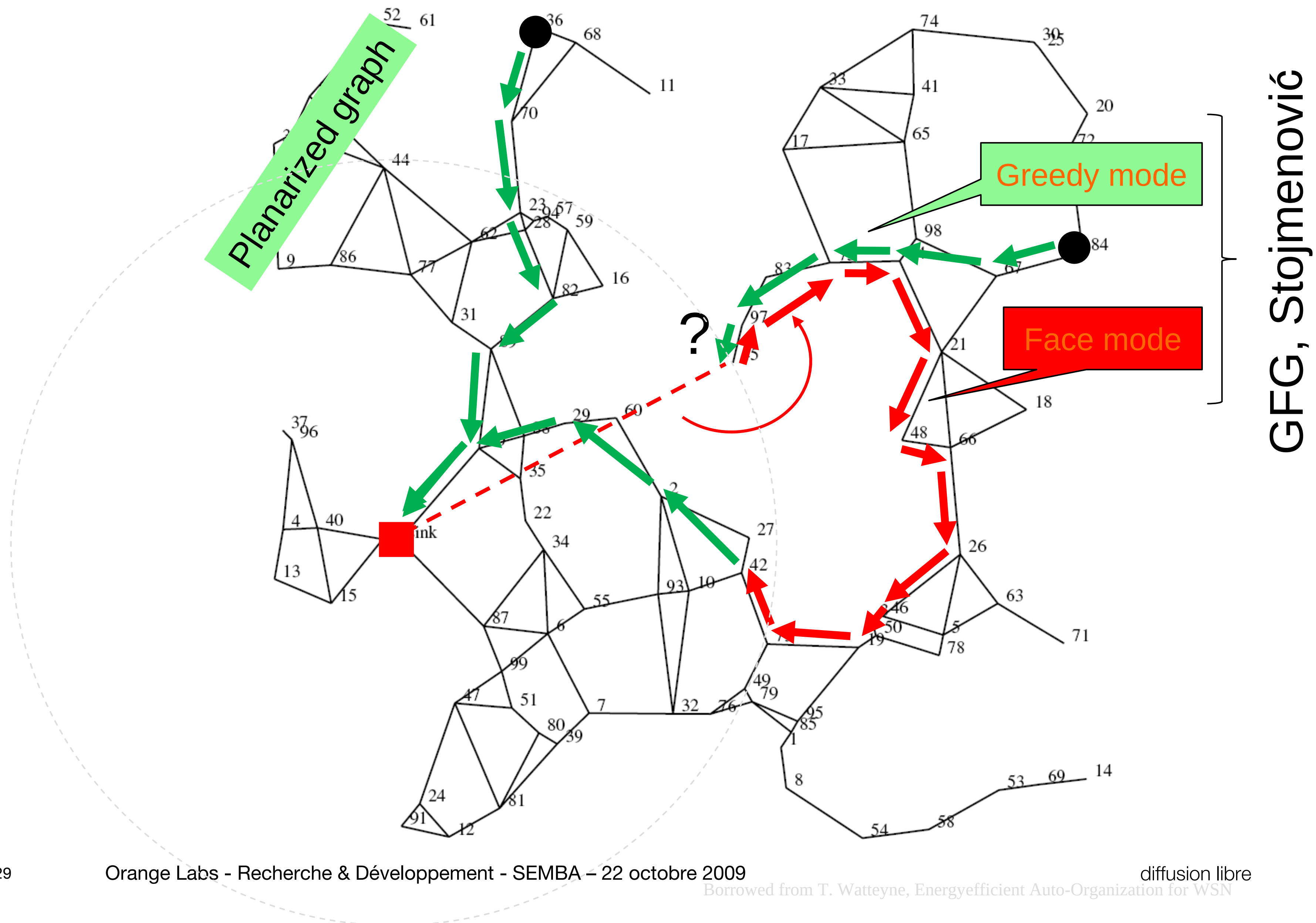
(a) Different ways of defining distance to destination.



(b) Geographic routing fails when a message is sent from $A$ to $F$.

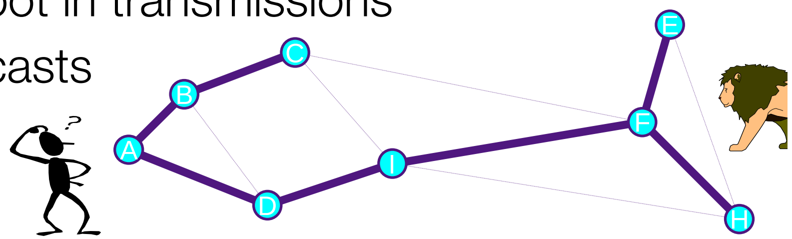
- Greedy routing fails at voids

# Greedy-Face-Greedy geographic routing



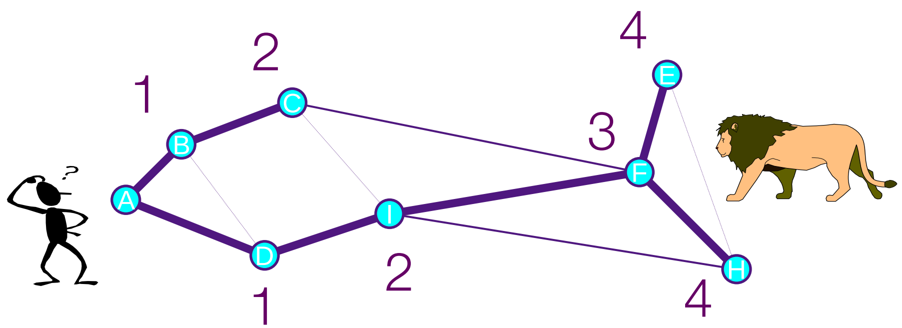
# Tree-based organization and routing

- Trivial if data collection only
  - all messages destined to the root
  - for routing, just forward anything to parent in tree
- Point-to-point routing possible
  - up and down the tree (tree-based addresses)
- Tree building and maintenance is the issue
  - root can flood network with periodic beacons
  - nodes pick parent from which beacon received first, parent assigns address
  - nodes can simply overhear other nodes' transmissions
  - nodes advertize their hop-count to root in transmissions
  - root seeds network with local broadcasts
  - nodes pick parent among neighbors



# Directed Acyclic Graph organization
# IETF ROLL RPL (work in progress)

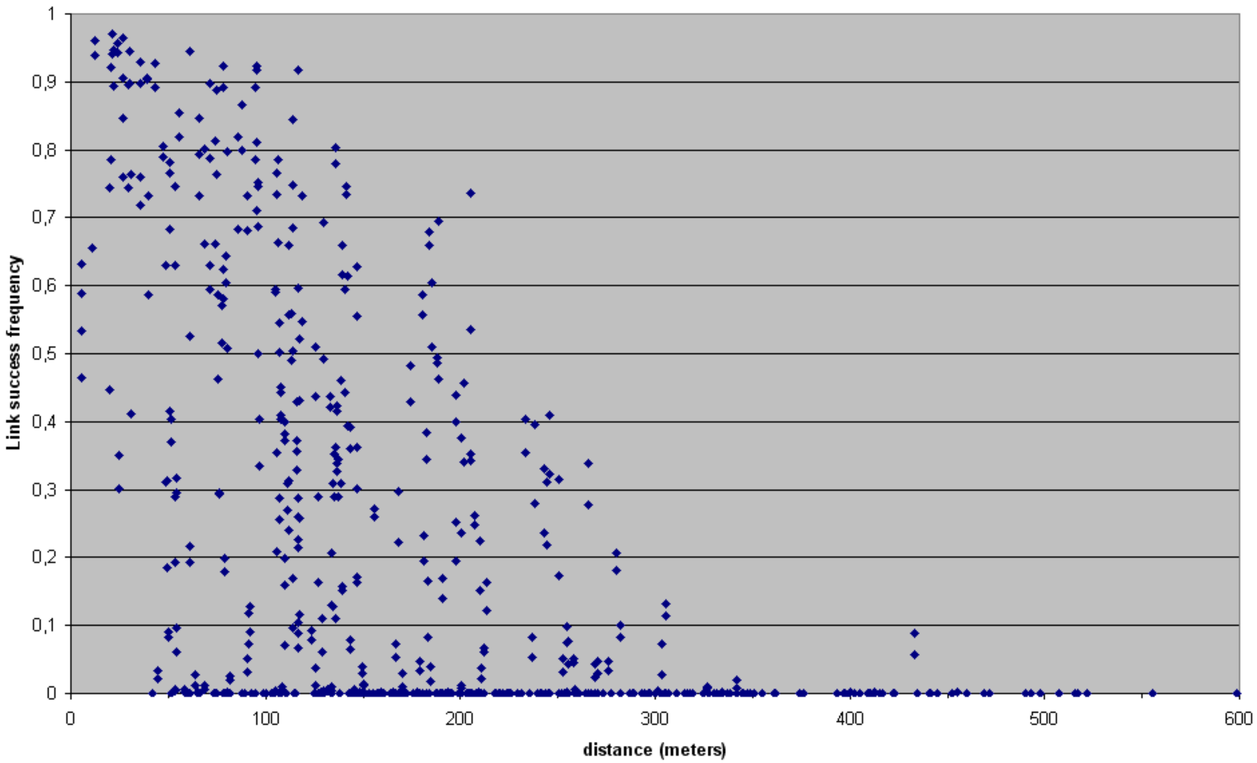
- Maintain redundant paths up
  - Guaranteed loop-free
- Optimize sub-DAG detach and re-attach?
- Routing through siblings?
  - Loop detection needed
- Destination advertisement?
- Node + link metrics ?



# Travaux de recherche en cours

# Meilleure exploitation des liens

- Exploitation opportuniste des liens évanescents




- Retransmission opportuniste en couche 2
- Exploitation des liens unidirectionnels

# Exploitation de l'hétérogénéité matérielle

- Certains noeuds disposent de plus de ressources
  - Énergie renouvelable, énergie infinie
  - Radio plus puissante, antenne dégagée, emplacement choisi
  - Capacité mémoire
- Organisation et assignation de rôle selon capacités
- Voir poster

# Sécurité

- Confidentialité, Intégrité des données
- Disproportion entre capacités de l'attaquant et des noeuds du réseau
- Attaques de Déni de Service par l'énergie
- Absence de protection physique des équipements
- Résilience aux attaques, y compris internes
  - Voir poster

# Qualité de Service

- Réseau multi-saut à lien peu fiables, limités en énergie
- Applications multi-services à contrainte de latence, débit, garantie de livraison
  - Traduction en contrainte d'organisation ?
  - Détection locale de la violation des conditions ?
  - Coût énergétique du respect des contraintes ?

# Conclusions
# WSANs, sujet de recherche ou mature ?

- Des marchés matures
- Des besoins réglementaires
- Des protocoles standards à définir, connectés à Internet
- Une exigence de Qualité de Service, de sécurité
- Une grosse marge de progrès, de la place pour la recherche

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