Capillary networks for Smart Cities

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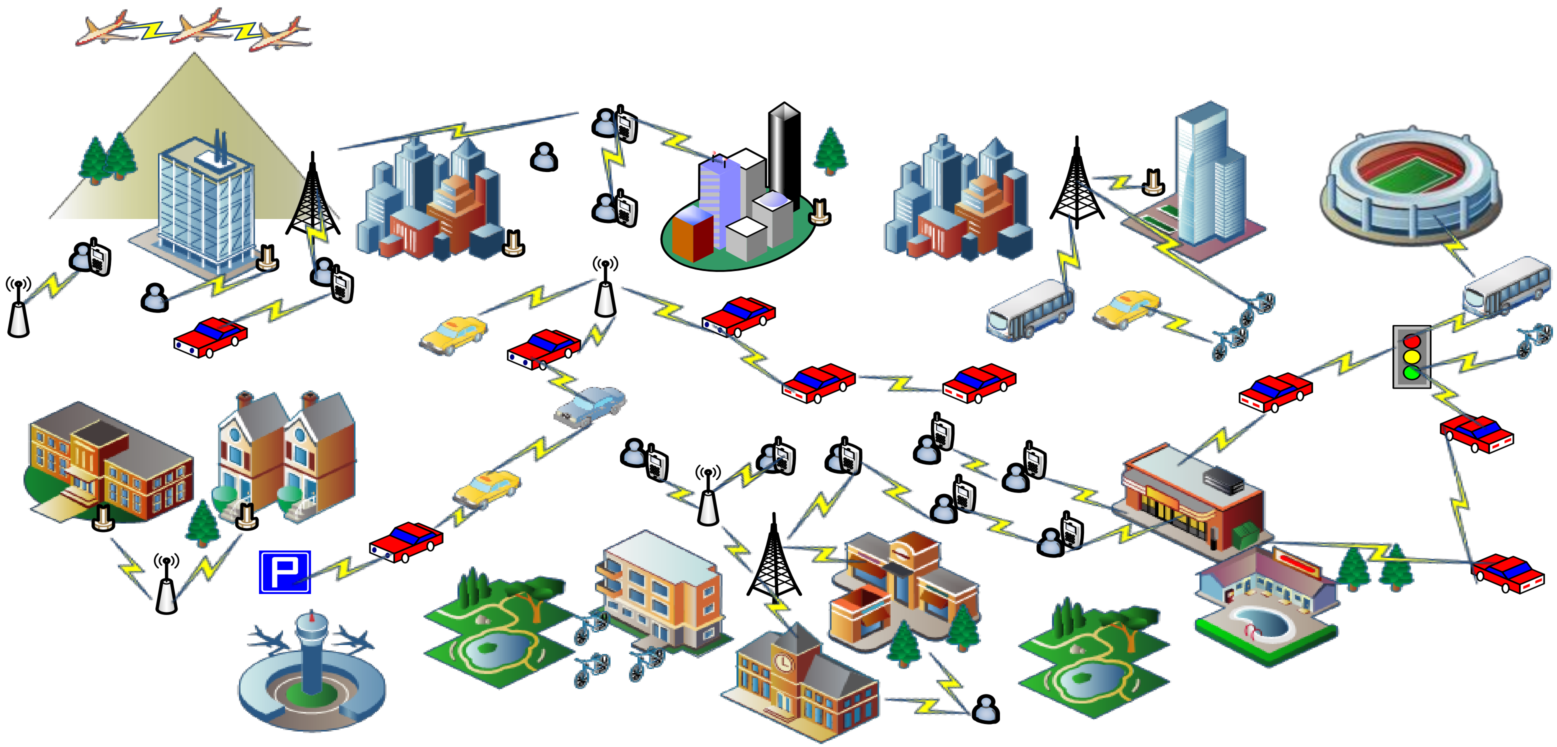
Merci à Anis, Dominique, Fabrice, Guillaume, Hervé, Ibrahim, Isabelle, Karel, Quentin, Razvan, Soukaina, Trista, Walid

membre de UNIVERSITÉ DE LYON

Capillary Networks?



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Agenda

- A big picture
- From applications to network constraints
- Environment constraints (aka radio sucks!)
- (wireless) Capillary networks
  - From multi-hop to single-hop
  - From symmetric trafic opportunities to asymmetric one
  - From telco networks to application-centric networks
  - …
- Concluding remarks, questions

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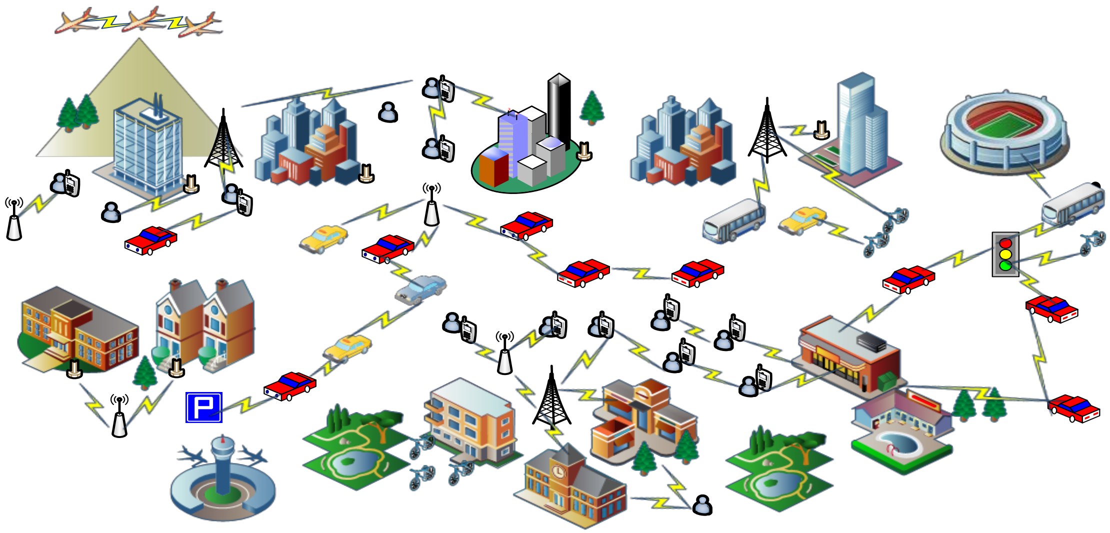
Capillary networks: a big picture



- Radio networks merging cellular and multihop networks
  - Radio coverage and extension
  - Data collection
  - Offloading
- For capacity reasons, networks are denser and denser
  - Close to human activities
  - Digital/physical continuum
  - Scalability, localized and adaptation
- Citizen-centric
  - Smart cities apps.
  - Mobility
  - New services

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Applications

Application
Water metering
Gas metering
Waste Management
Pollution monitoring
Pollution alerting
Public lightning
Parking management
Watering
Self-service bike renting
Total

Applications

Application	Number of End Point	Uplink			Daily Uplink load (kbytes)	Downlink			Daily downlink load (Kbytes)
		Periodicity	Dataset (bytes)	Long preamble		Periodicity	Dataset (bytes)	Long preamble	
Water metering	37 500	1/day	200	Option	7 324	1/week	50	Yes	262
Gas metering	37 500	4/hour	100	Option	351 652	1/week	50	Yes	262
Waste Management	100	1/hour	50	Option	117	none	none	none	0
Pollution monitoring	150	1/hour	1 000		3 515	2/day	1 000	Yes	293
Pollution alerting	20	4/hour	5000	Option	9 375	1/week	1 000	Yes	3
Public lightning	200	1/day	20 000		3 906	2/day	1 000		390
Parking management	80 000	1/hour	100	Option	187 500	1/day	100	Yes	7812
Watering	200	2/day	100	Option	39	1/day	100	Yes	20
Self-service bike renting	500	4/hour	50	Option	2 344	1/hour	50	Yes	586
Total	156 170				565 684				9 628

© ETSI TR 103 055 : Spectrum requirements for Metropolitan Mesh Machine Networks and Smart Metering applications

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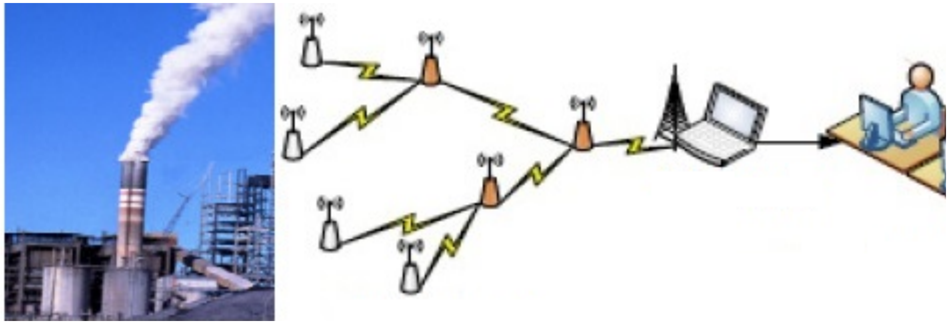
Applications: Pollution monitoring (1/2)

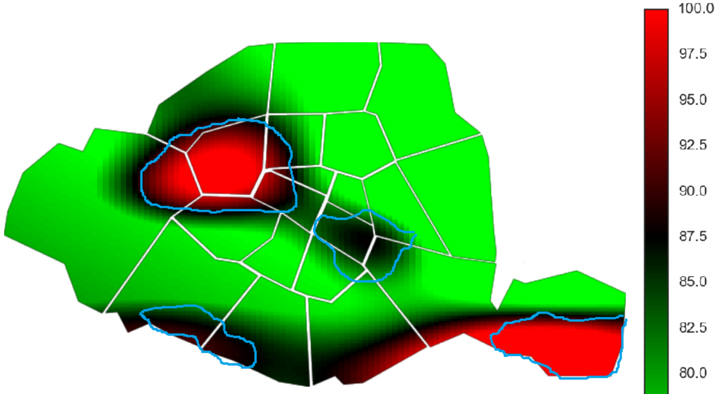
- Currently: about 10 pollution monitoring stations for a city like Lyon, with an average cost of 100’000€/station
- Looking for light, self-organized monitoring architecture providing an higher level of spatial and temporal observations, focused on a district

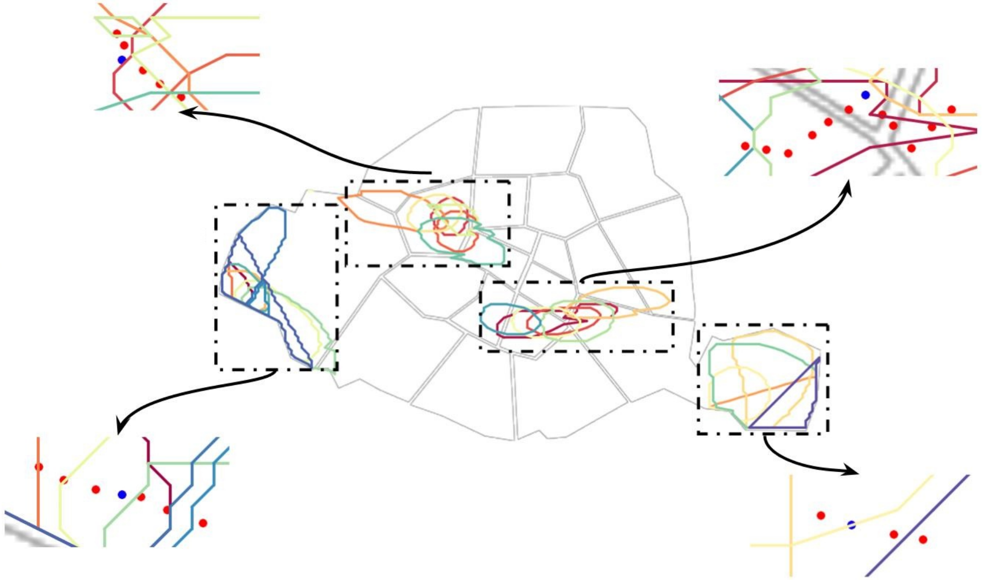
→ Wireless sensor networks

- Challenges: trade-off between accuracy/cost/density? Sensor locations? Data analysis? Pollution model?



Applications: Pollution monitoring (2/2)

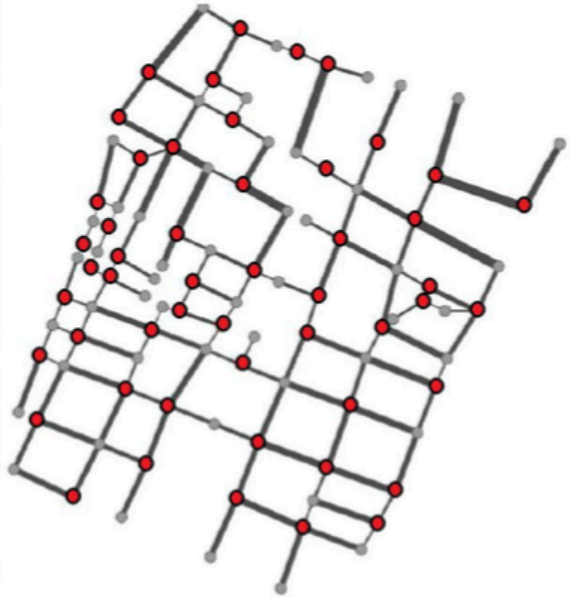




Applications: Smart Parking

- Sensors deployment to monitor the availability of car parking
- About 80’000 urban sensors deployed in an average mid-sized city
- Periodic monitoring or publish/subscribe mechanisms or local dissemination

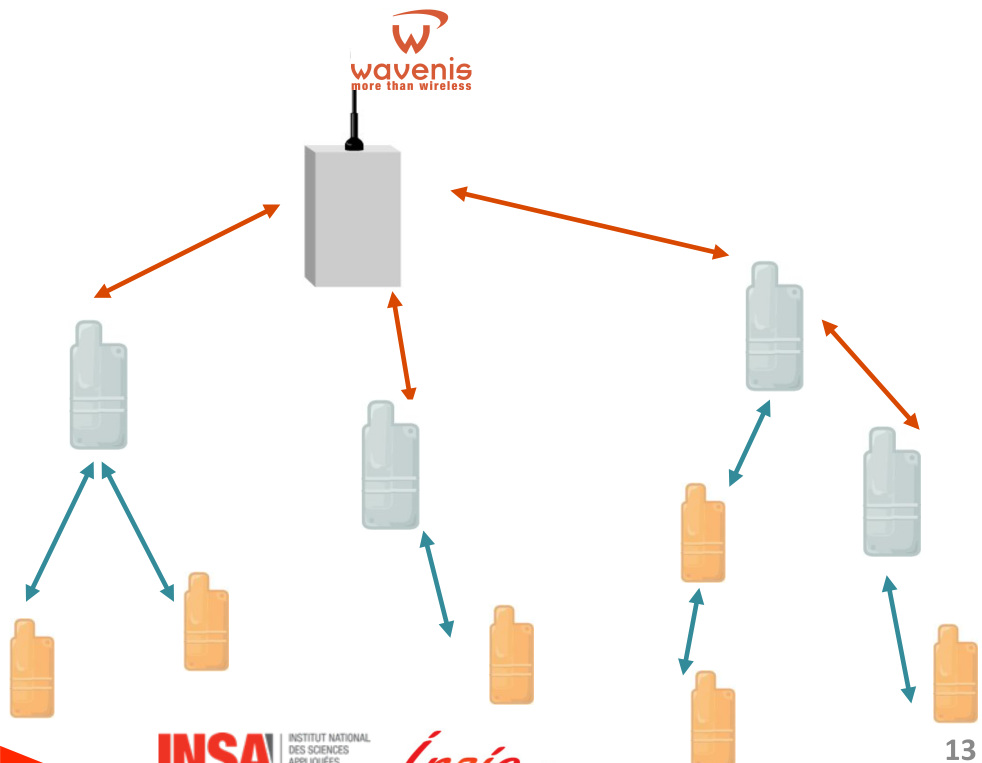
- Challenges: connectivity maintenance due to vehicle? NLOS conditions? Deployment cost?

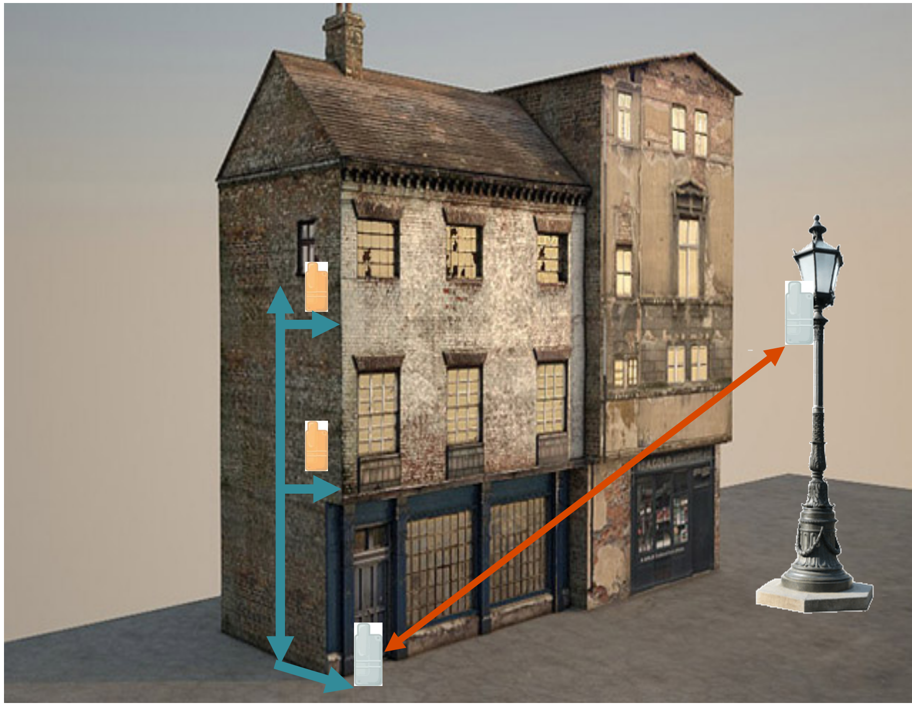


Applications:Water metering

- Automatic and periodic water metering (1 data/day to 1 data/week)
- Self-organized and self-configuration network

- Challenges: high network degree (~100…~1000), poor radio propagation properties, clustering, resource allocation, (privacy)





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Environment constraints

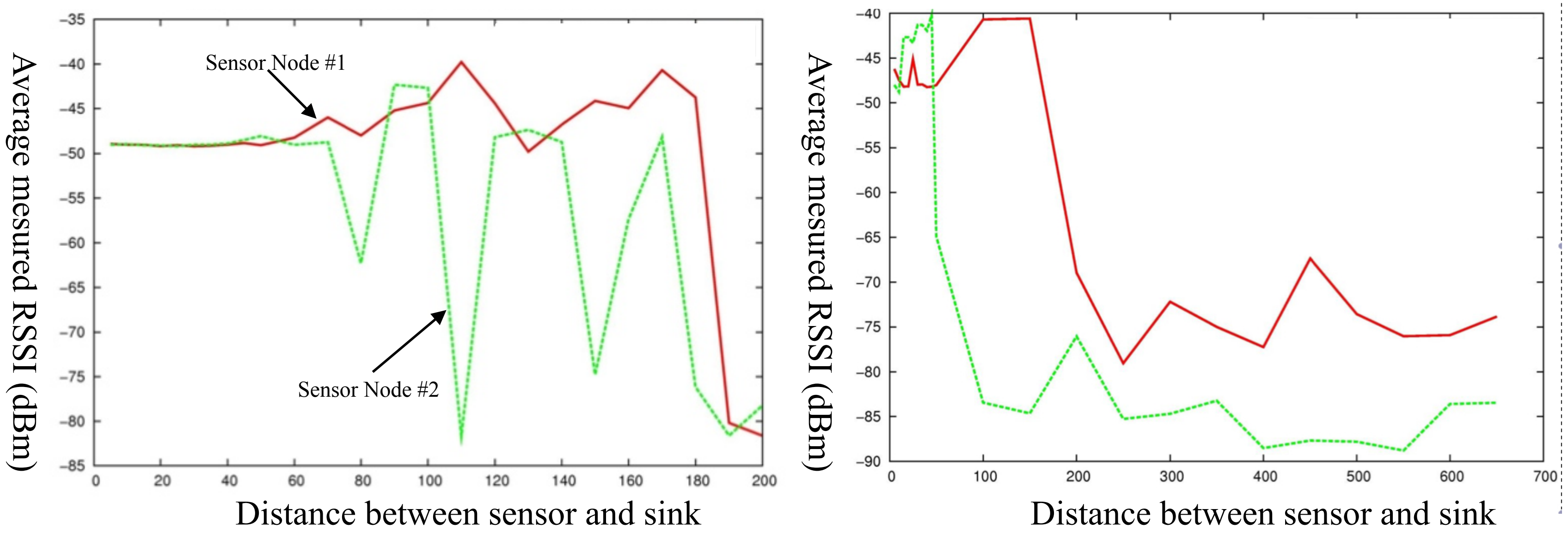
- Never forget!
  - ✓ Performances are material-dependent
  - ✓ Opportunistic radio links, asymmetric property
  - ✓ Radio channel is not stable in space and time
  - ✓ Other well-known phenomenon : fading, shadowing, interferences

- Results from:
  - ✓ ANR ARESA,
  - ✓ Ph.D. Thesis of Karel Heurtefeux
  - ✓ Orange Lab Meylan and SensorLab testbed
  - ✓ FIT/IoT Lab (Strasbourg)

Environment constraints (cont'd)

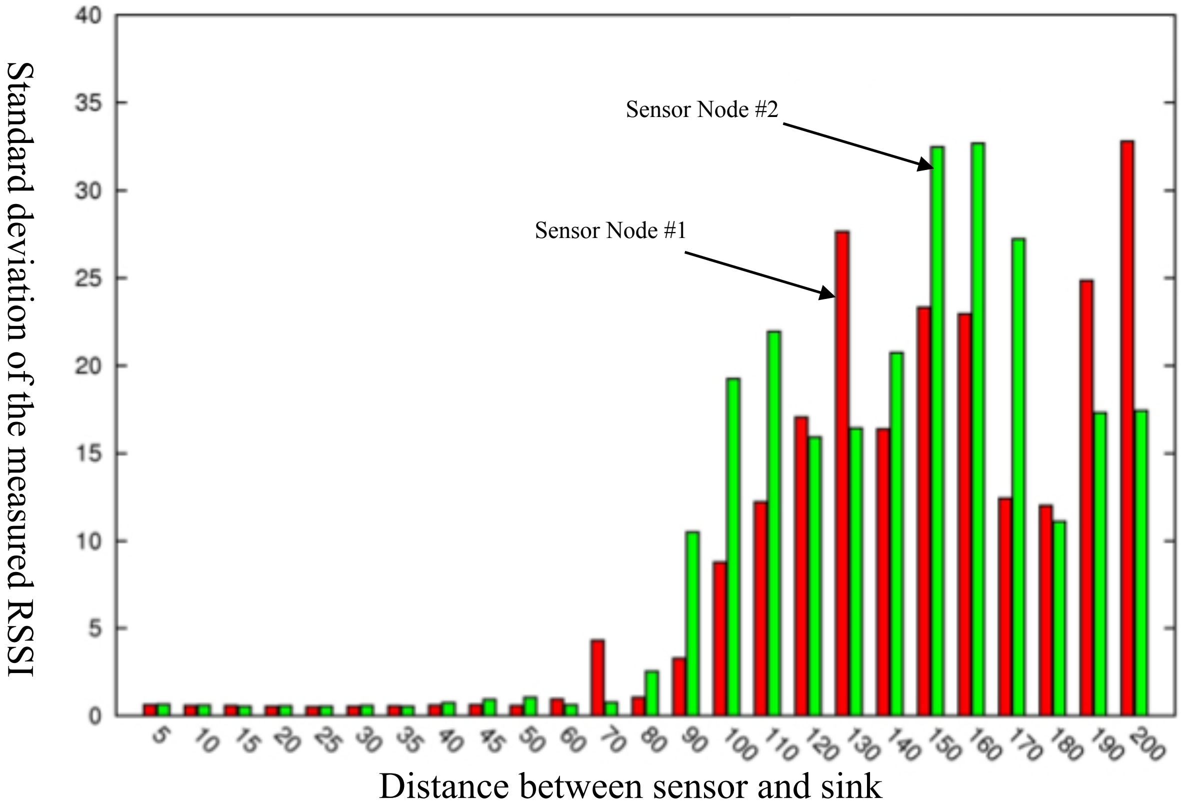
- Some RSSI exemples (appartment, CITI lab)
  - Hardware-dependent
  - Environment-dependent

RSSI face to the distance



Environment constraints (cont'd)

- ✓ RSSI variability (standard deviation)



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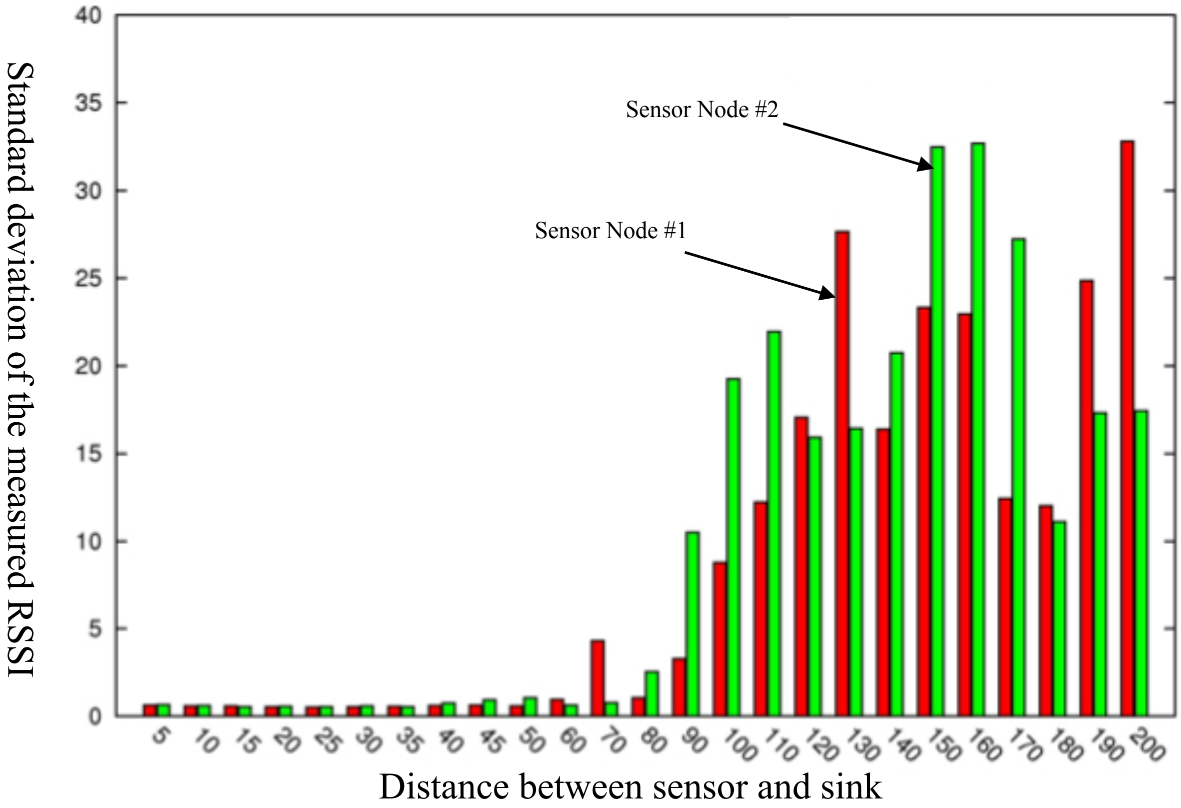
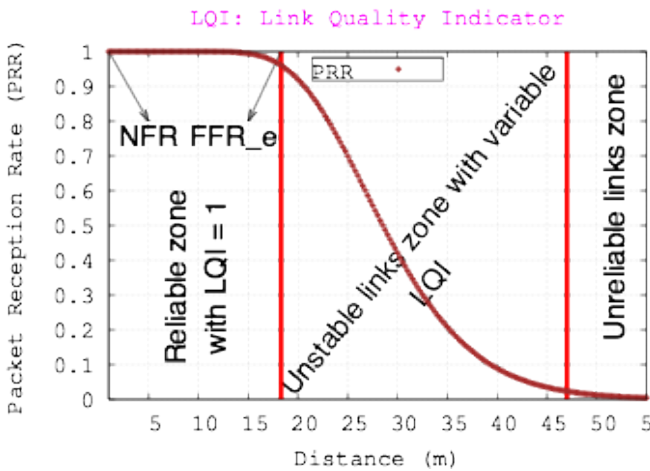
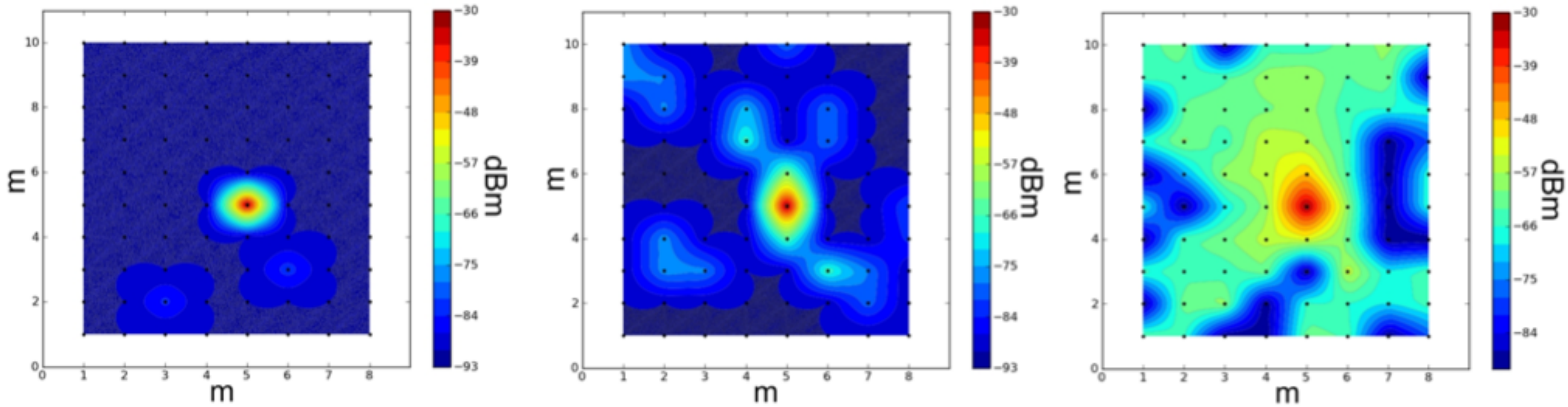




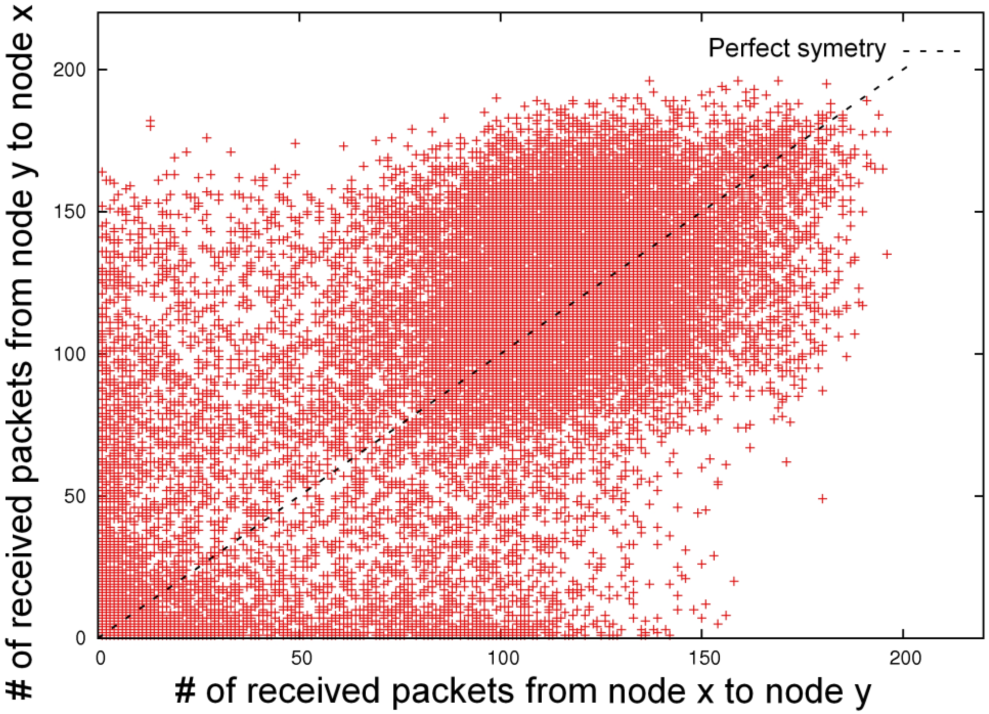
Environment constraints (cont'd)

- Environment leads to non-isotropic connectivity



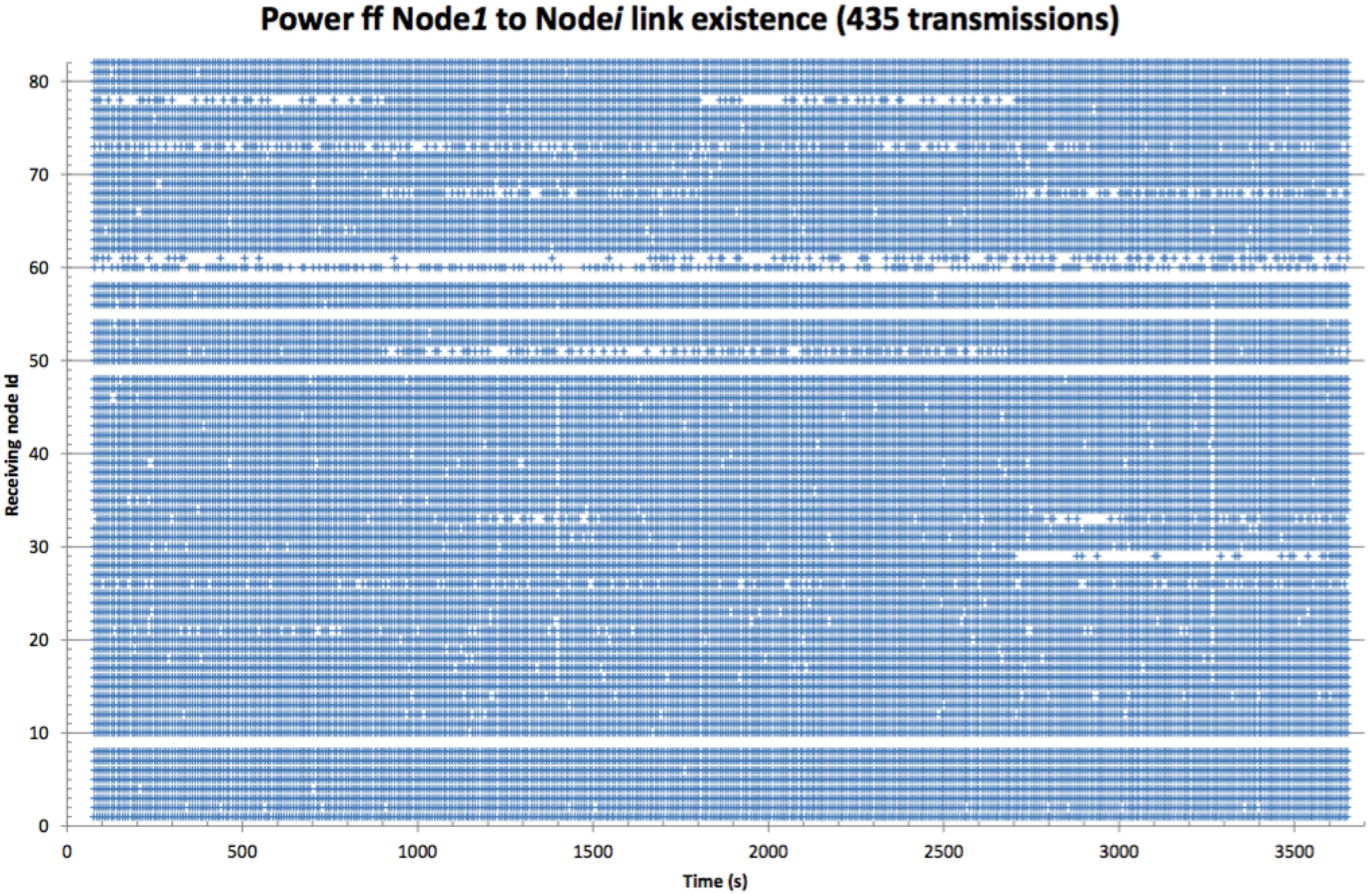
Environment constraints (cont'd)

- 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



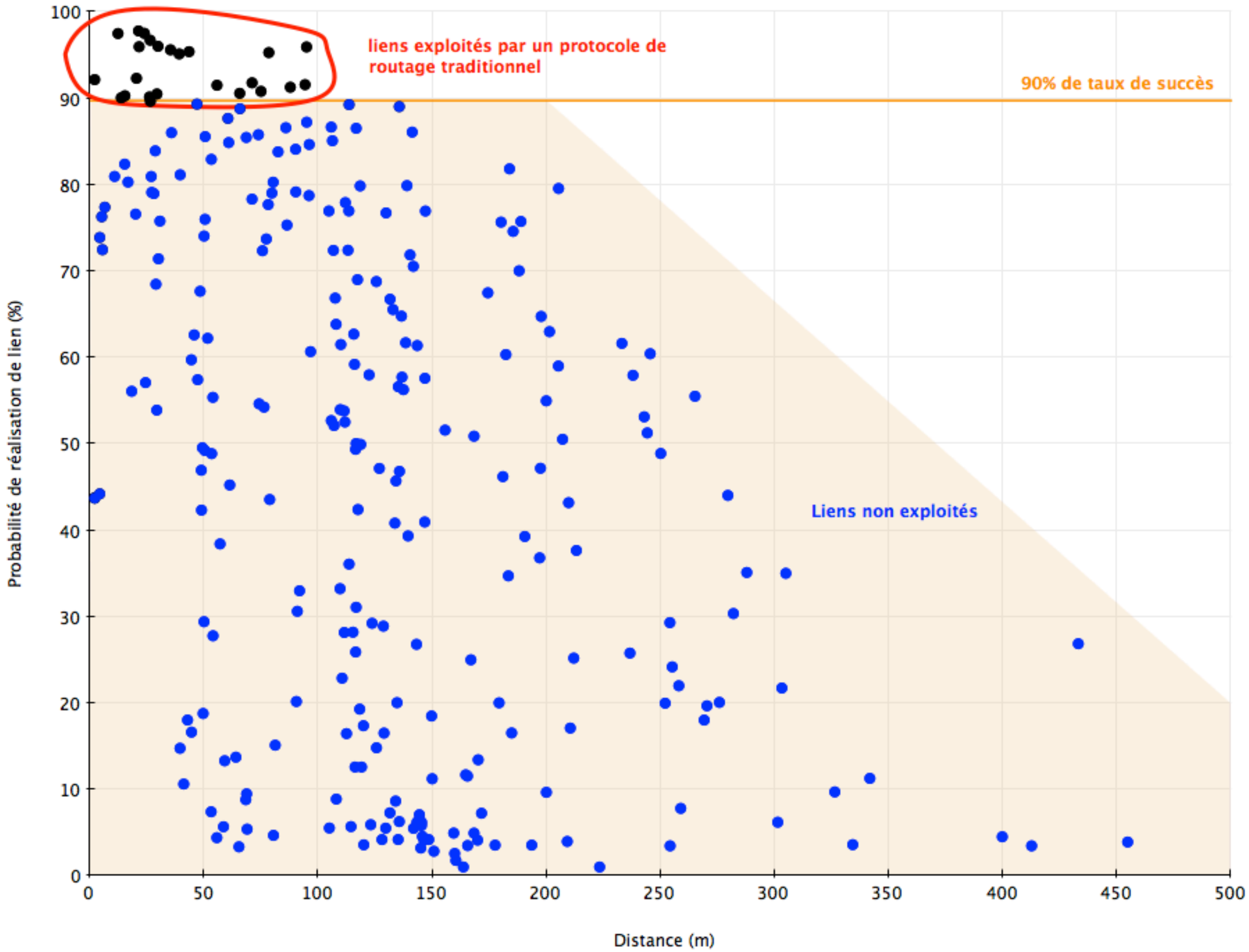
Environment constraints (cont'd)

- ✓ Sensor node behavior is not stable!



Environment constraints (cont'd)

- How routing protocols use radio links?



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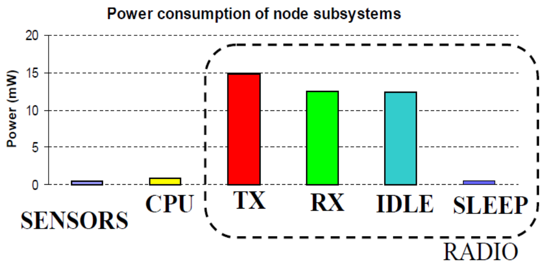
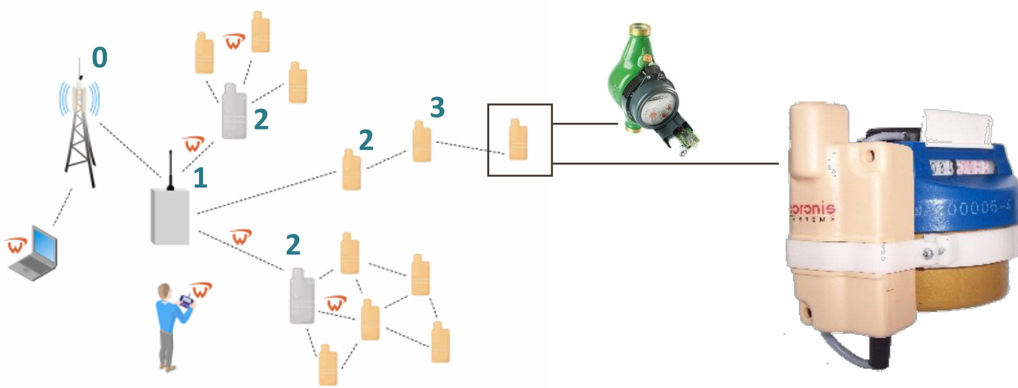
From multi-hop…

- Deployment of thousands of battery-powered wireless sensor nodes!

  - Multi-hop paradigm
  - Application centric
  - Transmission of 1 bit ~ energy comsumption of 1'000 CPU cycles
  - Network lifetime (take care of the definition!)



- Challenges:
  - Routing, data gathering, medium sharing, synchronisation, self-organization, capacity, etc.
  - Energy efficient!
- Main idea for routing: gradient-based!



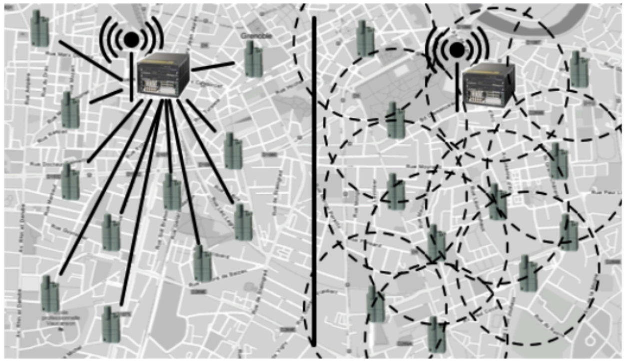
… to single hop!

- 15 years of both academic and industrial researches focused only (~99.99%) on mutli-hop wireless sensor networks… and….
- 1 hop (large area) cellular network wins the market (e.g. SigFox, LoRa)

- Ideas:
  - Low power, low data rate, long range, mainly upload smart metering

- Challenges: resource sharing, interferences management, reliability, etc.

Multi *versus* Single (hop)?



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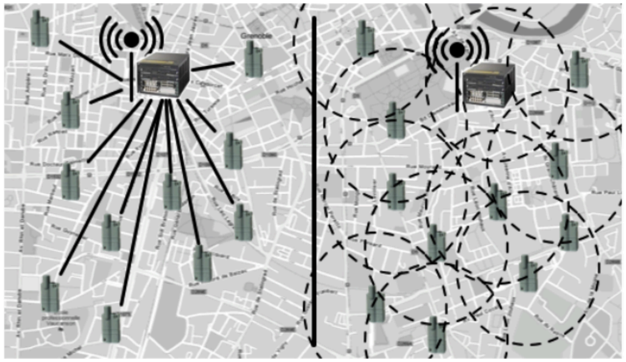
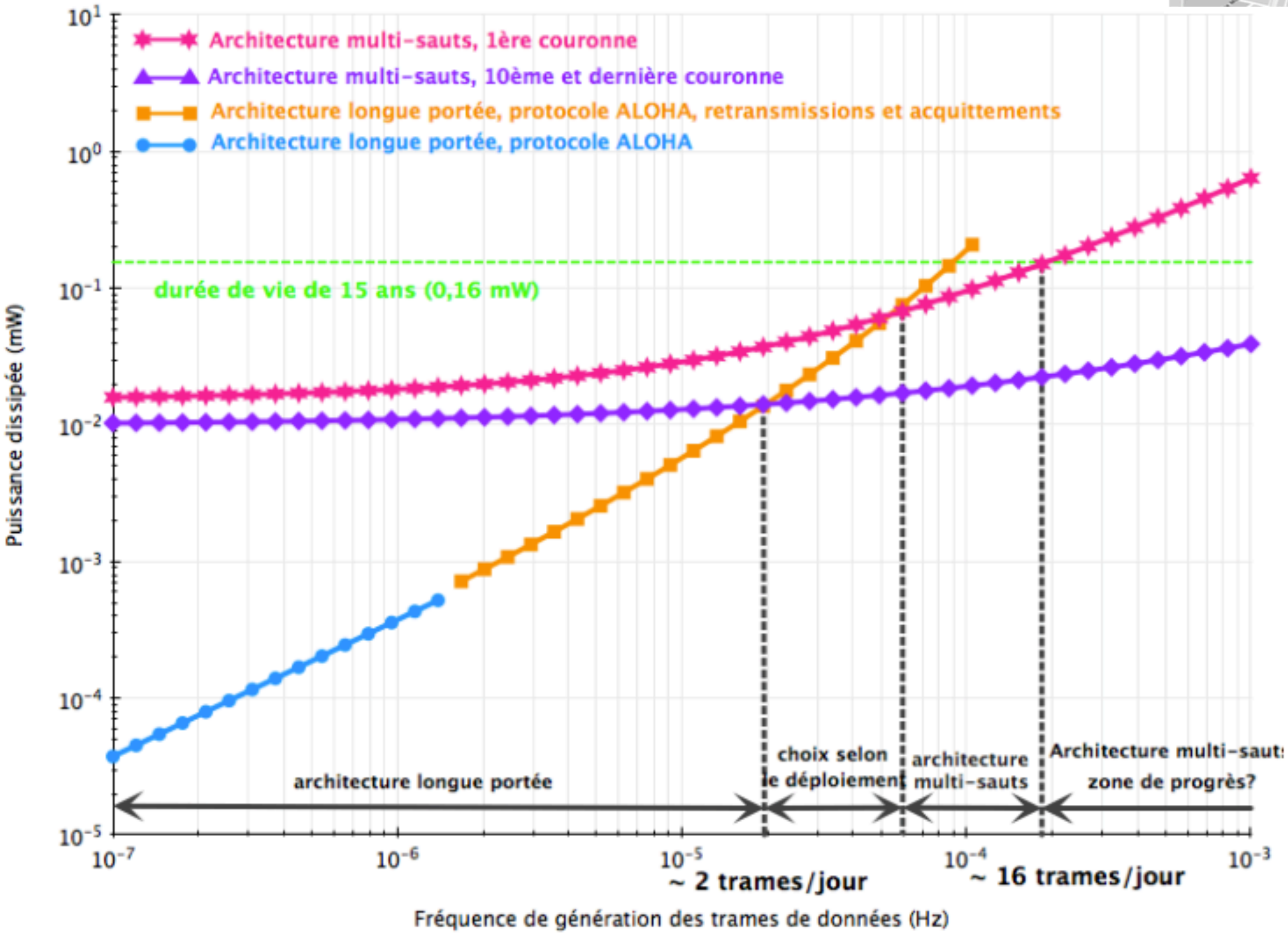
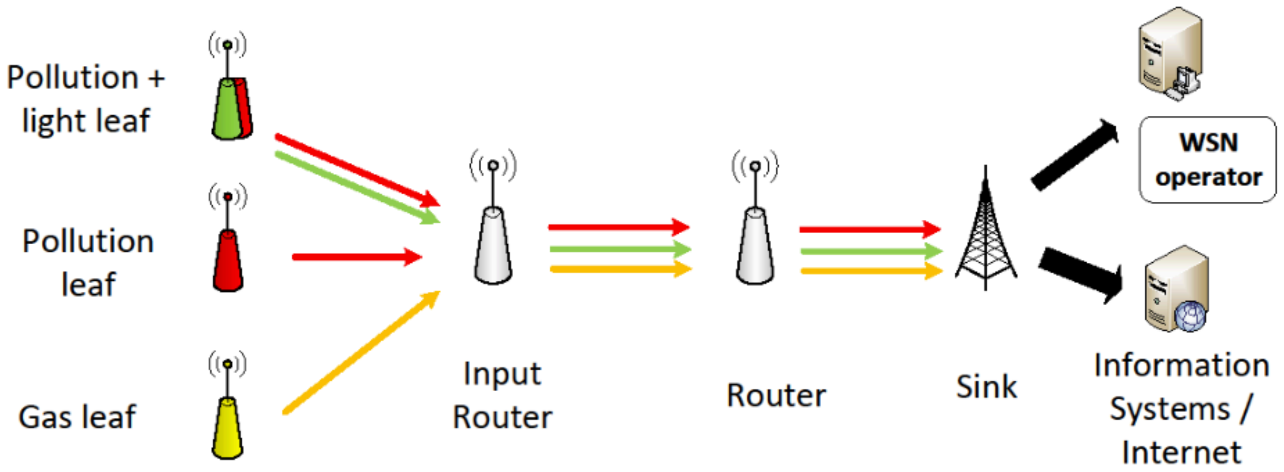




End of multi-hops networks?

- 1-hop cellular network: small data rates, asymmetric trafic, metering.
- Multi-hops networks: D2D trafic support, no more than 3 hops, metering, higher capacity

- WSN operator viewpoint (~Software defined WSN):



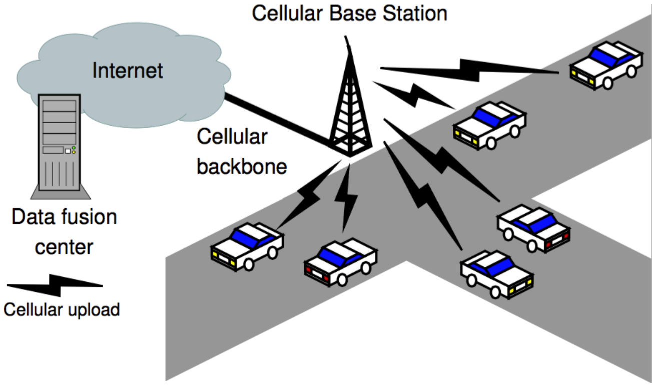
Cellular approach (5G inside)

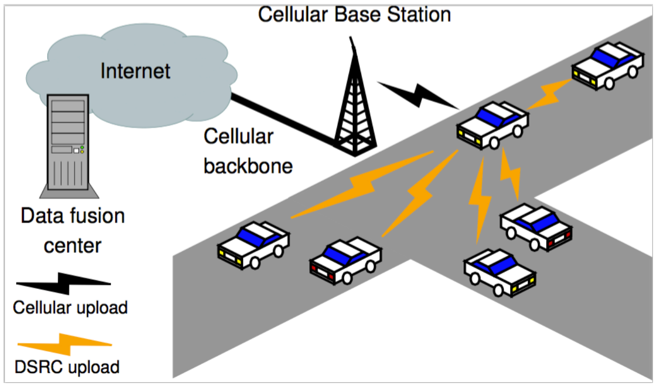
- Use the cellular network for data and voice trafics…. And for M2M trafic for smart-metering applications!

- Several strategies are studied:
  - Request a dedicated resource to provide connectivity and capacity for M2M app.
    - Advantages: guarantee, QoS, performances
    - Weakness: resources waste
  - Use the RACH – Radio Access Channel (defined as an uplink channel) not to request a dedicated resource but for data collection using the (small) payload of few bytes only
    - Advantages: *free* data transmission
    - Weakness: no guarantee, no QoS, impact of classical users

Vehicular networks

- Radio access networks can be saturated if smart cities applications are widely deployed
- Opportunities: taking benefit from mobile networks, e.g. vehicular networks for offloading trafic





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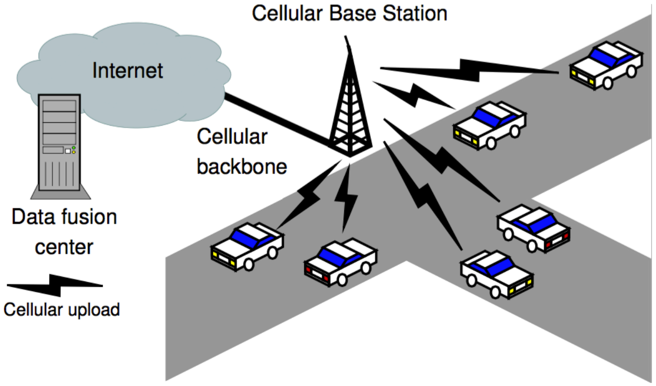

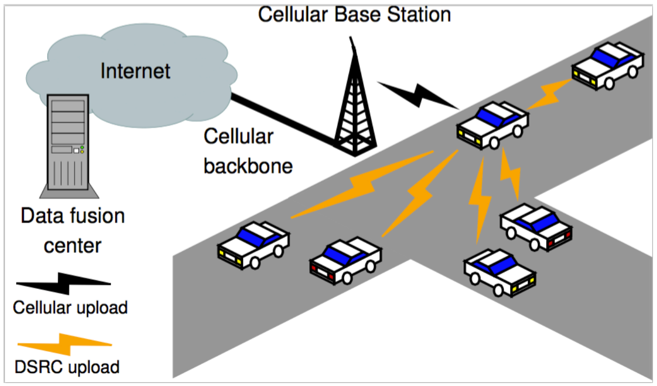

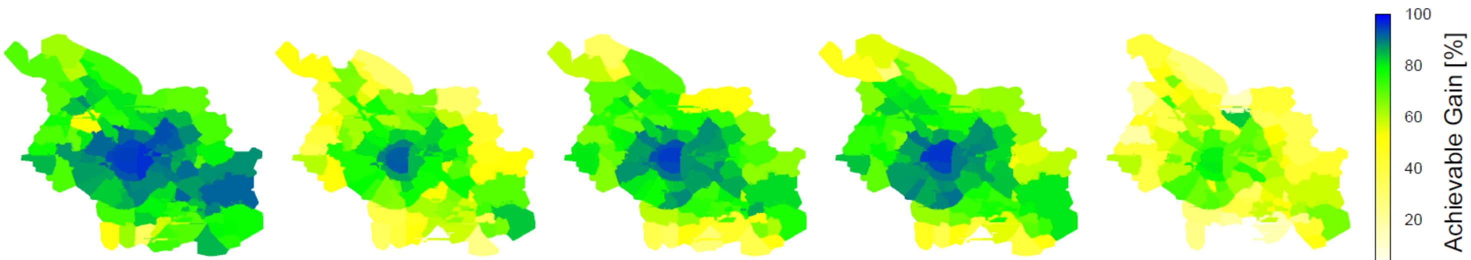

(a) 7:30am (b) 12:30am (c) 4pm (d) 6pm (e) 9pm

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