Researching Research

Are we going the right way?

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Nature's Magic – Northern Lights

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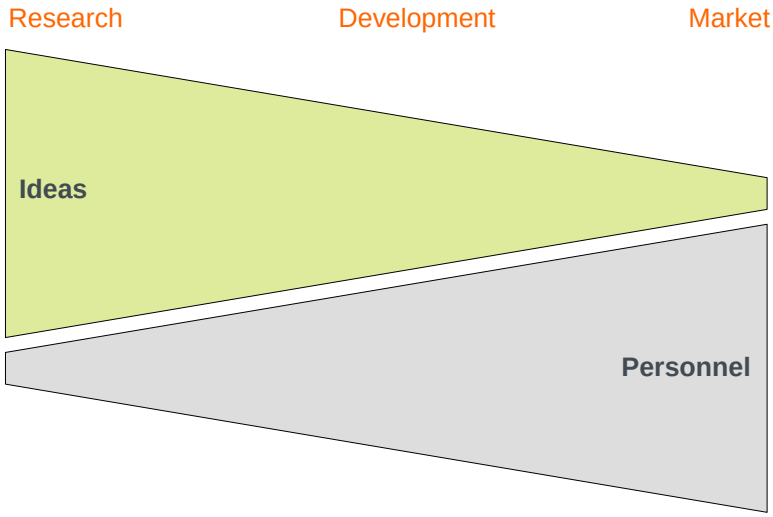
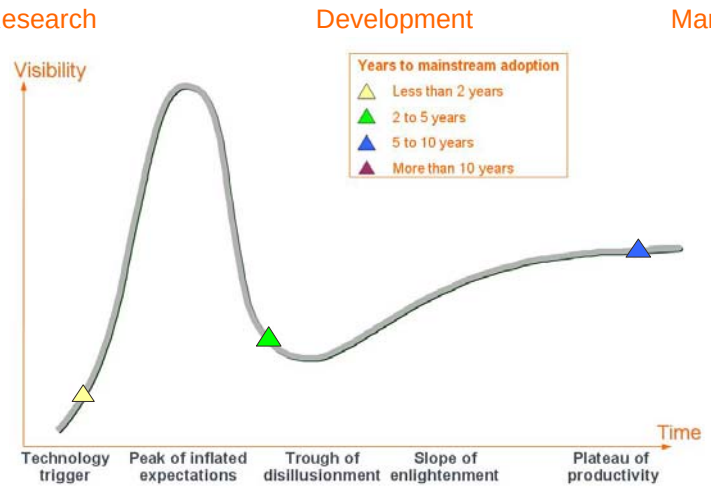
The Ideas Pyramid



Time-to-Market



R versus D versus M

- Research:
  - *… is the process of going up alleys to see if they are blind*
  - infinite number of problems but only finite resources
  - challenges is to say no
- Development:
  - *… is too boring for research and never sufficiently fast for marketing*
  - Murphy's law loves development as the devil lies in the detail
  - challenge is to deliver
- Market:
  - *… is to make people buy things they don't actually need*
  - marketing has much more in common with research than with development
  - challenge is to predict

1
Academic Efforts

Problems First, Please! [1/5]

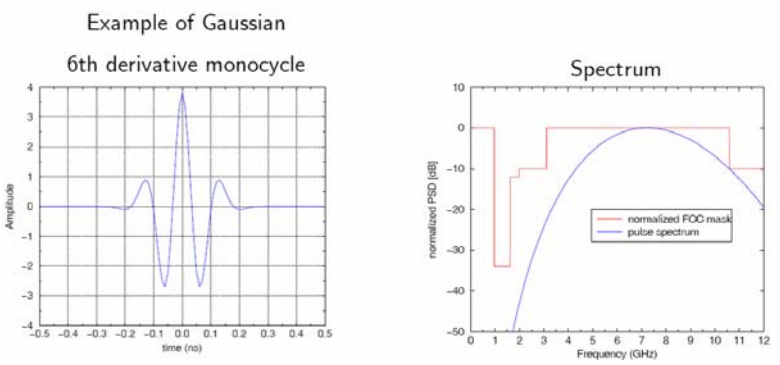
- Problems in Mathematics:
  - Hilbert presented 23 unsolved problems at Mathematician conference in 1900
  - 4 remain unsolved (proof to Riemann's Hypothesis is currently being examined)
  - Mathematics poses problem first and then tries to find solution
- Solutions in Engineering:
  - Engineering often tries to find a solution to a problem which is not yet known
  - as per David Goodman, we would gain rethinking this typical approach
  - leads to hype as solutions are hoped to fit all problems
- Example issues understood but yet still researched/hyped:
  - ad hoc networks
  - ultra-wideband systems
  - cognitive radios and networks
  - green communications

Problems First, Please! [2/5]

- Ad Hoc Networks:
  - 40 years of research has not yielded any mass market application
  - infinite degrees of freedom, hence infinite research
  - research efforts would be better of elsewhere

Problems First, Please! [3/5]

- Ultra-Wideband Systems:
  - 19 years of research has not yielded any mass market application
  - interference onto narrowband was thought problem but inverse is true
  - solutions are neither cheap nor simple (no magic)



Problems First, Please! [4/5]

- Cognitive Radios & Systems:
  - Mitola: best solution in dependency of every possible observable parameter
  - Community: CR = sensing + AI + SDR
  - Suggestion: CR = radio which is working in conditions it was not designed for
  - Actually: OR = sensing + (simple) decision + SDR
- Restraints for cognitive radios and networks:
  - intelligence requires some form of learning over time; however, channel and other conditions decorrelate very quickly
  - in my opinion, cognitive networks should exhibit some form of emergent behaviour; however; in a primary/secondary user scenario this is very unlikely
  - How do you standardize intelligence?
- Enabler for opportunistic radios and networks:
  - wireless systems have inherently a short memory, thereby encouraging usage of resources when there is an opportunity

Problems First, Please! [5/5]

- Green Communications:
  - ICT sector is responsible for about 2% of green house gases
  - telecom sector probably accounts for a small percentage of these 2%
  - Blackle instead of Google likely saves more energy than entirety of all BSs
- Reshaping focus:
  - mobilizing ICT sector to save energy is a great idea
  - however, it would be better off being a facilitator
  - e.g., help decreasing consumption of transportation, even if ICT increases

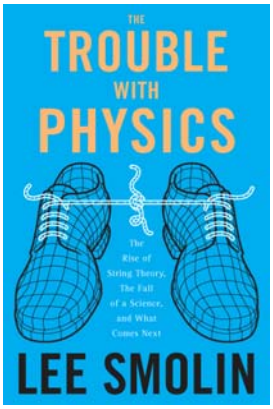


Research Funding [1/5]

- General consensus:
  - funding opportunities are decreasing
  - funding money is never enough
  - application is time consuming
- Example funding bodies:
  - EPSRC (UK): €1 Billion a year
  - NSF (USA): €4 Billion a year
  - EC (Europe): €8 Billion a year
- General problems:
  - how much funding to give
  - to which scientific areas and
  - how to split among research teams

Research Funding [2/5]

- Example of “ad hoc networks”:
  - 100,000 Google Scholar hits
  - assume 2 man-month research for each
  - assume €5k per man-month
  - €1 Billion went into ad hoc
- We are not the only ones with this problem:



Research Funding [3/5]

- Today’s projects and proposals hence focus on:
  - cross-layer approaches
  - inter-disciplinary approaches
- Cross-Layer:
  - layered approach has been labelled as “not good enough” lately
  - however, layers and functionalities have not disappeared as of today
  - cross-layer design mainly depends on sensing capabilities of device
- Inter-Disciplinary:
  - borrowing concepts from info theory, physics, biology, etc. seems promising
  - linguistic barrier is the main challenge

Research Funding [4/5]

- Do you speak Information Theory?

$$
\begin{aligned}
& P\left(E_{m,j,k}(i) \cap F^{c}_{m,j,k-1}(i) \cap F^{c}_{0}(i-1)\right) \\
& \overset{(a)}{=} P\left(E^{u}_{m,j,k}(i) \cap F^{c}_{0}(i-1) \cap F^{c}_{m,j,k-1}(i)\right) \\
& \overset{(b)}{=} P\left(\left\{\exists\, s \in [1, 2^{bR_{m-k}}] \setminus \overline{s}_{m-k;\,i-k+1} \text{ s.t. } s \in \mathcal{L}_{m,j,k;i} \cap S^{m-k+1}_{\overline{s}_{[m-k+1;\,i-k+2}}}\right\} \cap F^{c}_{0}(i-1) \cap F^{c}_{m,j,k-1}(i)\right) \\
& = P\left(\bigcup_{\substack{s \neq \overline{s}_{m-k;\,i-k+1} \\ s \in [1,\, 2^{bR_{m-k}}]}} \left(\left(\left\{s \in S^{m-k+1}_{\overline{s}_{[m-k+1;\,i-k+2}}}\right\} \cap F^{c}_{0}(i-1) \cap F^{c}_{m,j,k-1}(i)\right)\right.\right. \\
& \qquad \left.\left. \cap \left(\{s \in \mathcal{L}_{m,j,k;i}\} \cap F^{c}_{0}(i-1) \cap F^{c}_{m,j,k-1}(i)\right)\right)\right) \\
& \overset{(c)}{\leq} P\left(\bigcup_{\substack{s \neq \overline{s}_{m-k;\,i-k+1} \\ s \in [1,\, 2^{bR_{m-k}}]}} \left\{s \in S^{m-k+1}_{\overline{s}_{[m-k+1;\,i-k+2}}}\right\} \cap \left\{\left(\boldsymbol{x}_{m-k}\left(s \middle| \overline{s}_{[m-k+1,\,M];\,i-k+1}\right),\right.\right.\right. \\
& \qquad \left.\left.\boldsymbol{x}_{m-k+1}\left(\overline{s}_{m-k+1;\,i-k+1} \middle| \overline{s}_{[m-k+2,\,M];\,i-k+1}\right), \ldots, \boldsymbol{x}_{M}\left(\overline{s}_{M;\,i-k+1}\right), x_{F},\right. \\
& \qquad \left.\left. \boldsymbol{y}_{m,j;\,i-k+1}\left(\left\{\boldsymbol{x}_{m'}\left(\overline{s}_{m';\,i-k+1} \middle| \overline{s}_{[m'+1,\,M];\,i-k+1}\right) : m' \in [0, M]\right\}, x_{F}\right) \text{ are jointly } \epsilon\text{-typical}\right\}\right) \\
& \leq \sum_{s} P\left(\left\{s \in S^{m-k+1}_{\overline{s}_{[m-k+1;\,i-k+2}}}\right\}\right) \cdot P\left(\left\{\left(\boldsymbol{x}_{m-k}\left(s \middle| \overline{s}_{[m-k+1,\,M];\,i-k+1}\right),\right.\right.\right.
\end{aligned}
$$

Research Funding [5/5]

- Personal wish-list:
  - funding application process ought to be eased
  - output quality in terms of journals, spin-offs, etc ought to increase
  - encouragement to go beyond being a training program
- Suggestion to funding bodies:
  - give e.g. 80% funding in round-robin to institutions with strong track-record
  - other institutions bid as usual for the remaining budget
- Another suggestion to funding bodies:
  - fund the same project by two competing teams
  - encourages healthy scientific competition
  - encourages quality over quantity

Open Research Issues

- Embedded Systems:
  - truly understand embedded systems (bounds, performance, limits)
  - synthesize optimum protocols and design guidelines
  - facilitator for “Internet of Things”, “Haptic Computing”, “Things That Think”, etc.
- Ubiquitous Communications:
  - make ubiquitous communications reality
  - wireless Internet >> wireless + Internet
  - facilitator for “Ambient Intelligence”, “Everyware”, etc.

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2
Industrial Efforts

Product Development

- There are 4 main approaches to product development:
  - norms & standards
  - forums & associations
  - proprietary solutions
  - open source
- These approaches trade:
  - time-to-market
  - development costs
  - obedience to regulations
  - intellectual property, etc.
- They are all subject to heavy lobbying!

Standards – Benefits

- Service Providers benefit:
  - they can design, develop and operate a wide range of services
  - whatever the underlying but standard-compliant, heterogeneous technologies
- Vendors benefit:
  - they can access markets more easily with standard-compliant products
  - at the risk of blurring competitive differentiation
- Customers benefit:
  - they can access a wide range of services
  - without the burden of being tied to a given service provider or technology
- Regulators benefit:
  - regulation of complex technology space
  - facilitates control and billing (e.g. UMTS spectrum license)

Standards – Corporate View

- Standardization as a profitable business:
  - defend business stakes
  - promote patents through the enforcement of a consistent IPR policy
- Speed up the introduction of new products and/or services:
  - facilitated by a set of available standards
- Slow down the standardization process:
  - to extend the lifetime of an already-introduced yet proprietary product or service
- Encountered problems with standards:
  - different IPRs often lead to stalemates in standardization groups
  - Why not bring ready solutions to standards? [Rob Calderbank, Princeton, USA]

Success & Failure Stories

- Europe:
  - success: GSM
    integrated operators
  - failure: HiperLAN2
- North Americas:
  - success: WLAN
    promotion of CDMA
  - improvable: IS95
- Asia:
  - success: subscriber growth
    manufacturing power
    significant impact on B3G
  - improvable: despite potential, not a driver yet

Yesterday – Today – Tomorrow

- 10 years ago:
  - wireless world was dominated by manufacturers and operators
  - in the news: Nokia, Siemens, France Telecom, Vodafone, etc.
- Today:
  - software giants take liking in extending the Internet to the wireless world
  - in the news: Google, Microsoft, etc.
- 10-20 years from now:
  - if ubiquitous will truly have taken off, then the user will be at the centre
  - in the news: Smith, Allen, Spain, etc.

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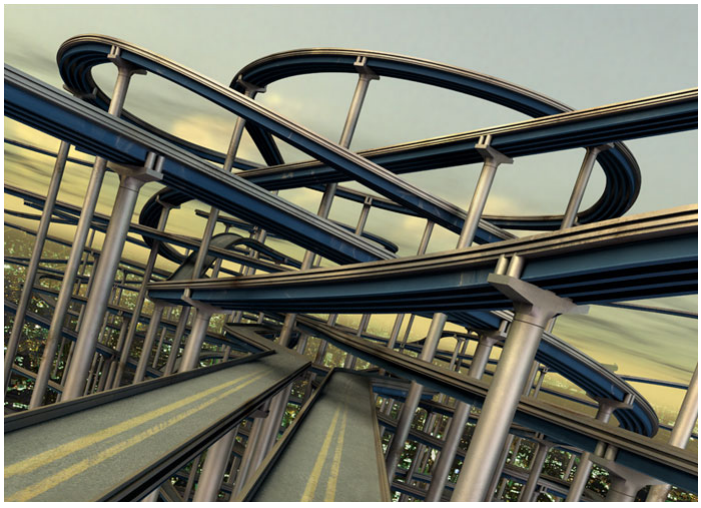
3

Concluding Remarks

Music of Chance

- Academic Efforts:
  - can be planned, which means limiting the alleys to be taken
  - however, cannot be predicted nor its success guaranteed
  - challenge is to focus on important issues in research
  - *Imagination is more important than knowledge.*
- Industrial Efforts:
  - can be planned but, again, success is no guarantee
  - success is more likely if you “live” from given technology
  - challenge is to be on time, i.e. not too early and not too late
  - *The economy depends about as much on economists as the weather does on weather forecasters.*
- *The trouble with our times is that the future is not what it used to be.*

The Road Ahead



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4

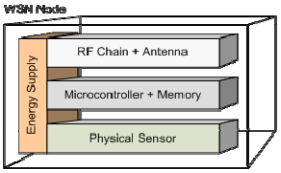
Appendix – Wireless Sensor Networks

Quick Intro

- **Wireless** Sensor Network:
  - facilitated by RF chain, antennas and EM propagation
  - saves a lot of cabling costs
  - research keywords: channel, PHY, MAC, etc
- Wireless **Sensor** Network:
  - sensing of physical information from environment, etc
  - T; light, humidity, wind, rain; radioactivity; pH; chemicals, pressure, etc.
  - research keywords: distributed sampling, coverage, security, localization, etc
- Wireless Sensor **Network**:
  - provision of sensed data to sink via network
  - data flow often exhibits converge-cast behavior
  - research keywords: auto-*, routing protocols, etc.

Wireless Sensor Node

- Each WSN node consists of these basic elements:
  - sensor
  - energy supply
  - microcontroller
  - memory
  - RF



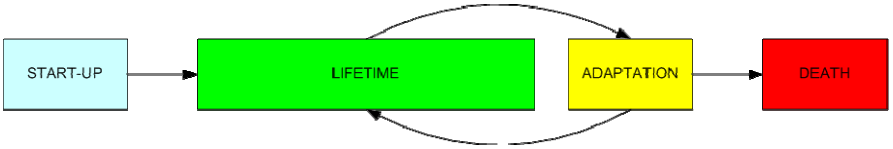
- WSN nodes should be:
  - low – cost
  - low – complexity
  - low – size
  - low – energy

Battery & Data Flow

- Typical WSN node types:
  - non-rechargeable battery
  - rechargeable battery with regular recharging (e.g. sunlight)
  - rechargeable battery with irregular recharging (e.g. energy scavenging)
  - capacitive/inductive energy provision (e.g. active RFID)
  - always on (e.g. powered electricity meter)
- Typical data flows through the network:
  - sensed information from the nodes towards one or a subset of the AP(s)
  - query requests from the AP(s) towards the sensing nodes
  - sometimes reverse flows are needed (e.g. for ACK)
  - (control information from the AP(s) towards the actuators)

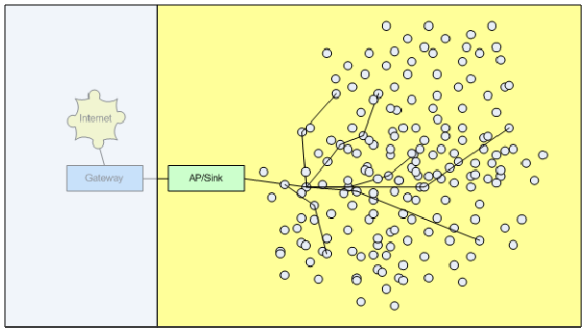
Wireless Sensor Network

- Typical network phases:
  - **start-up**: (self-)organization, configuration etc;
  - **life-time**: maintenance, (self-)healing;
  - **adaptation**: node failure, mobility, etc;
  - **death**: breakdown in connectivity, etc.



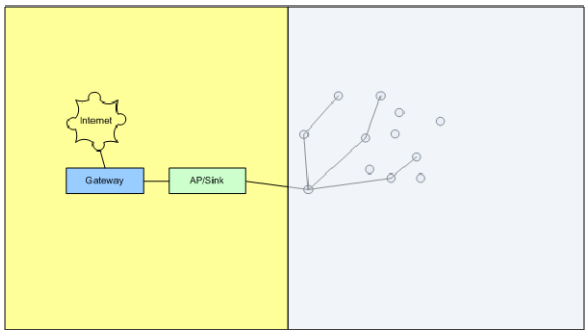
Approach of 'R' Folks

- Prime assumption of research community:
  - above topologies with huge amount of nodes (thousands to millions)
  - emphasis on wireless sensor in-networking (nodes to sink)
  - key words: energy-efficiency, scalability

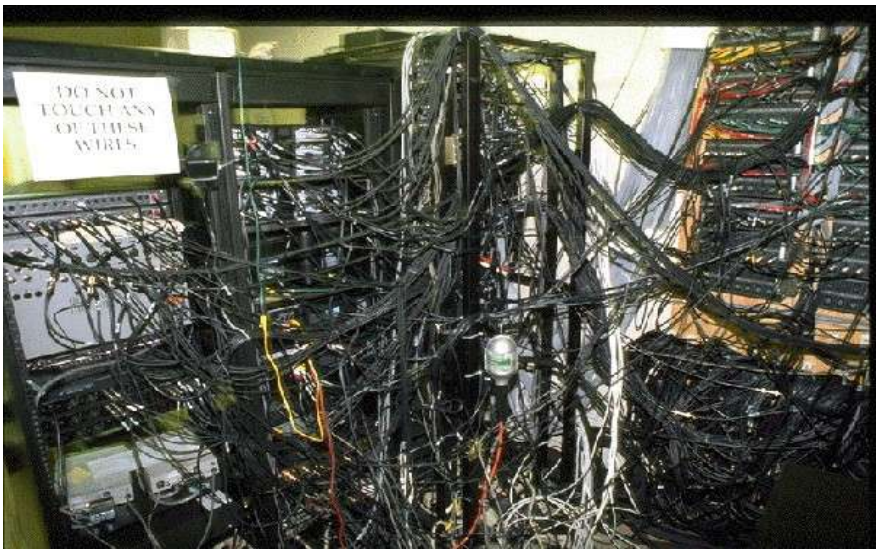


Approach of ‘D’ Folks

- Prime assumption of development community:
  - huge amount of nodes is myth and market is marginal
  - instead, emphasis on wireless sensor out-networking (network to Internet)
  - key words: IPv6, security, data-load on Internet



R&D However Also Agree

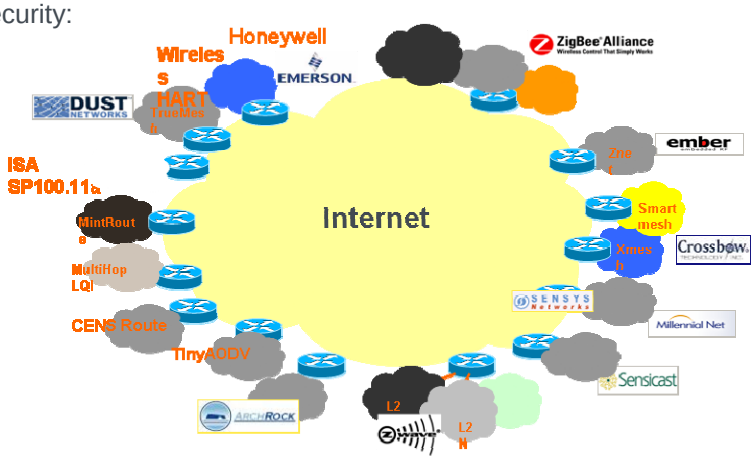


IETF ROLL – Overview

- Routing Over Low-Power and Lossy Networks (ROLL):
  - IETF information discussion started 1 year ago
  - today very active working group
  - website: http://tools.ietf.org/wg/roll
  - mailing list: http://www.ietf.org/mail-archive/web/roll/current/threads.html
- Since WSNs are application specific, 4 scenarios are dealt with:
  - home applications: draft-brandt-roll-home-routing-reqs
  - industrial applications: draft-pister-roll-indus-routing-reqs
  - urban applications: draft-dohler-roll-urban-routing-reqs
  - vehicular applications: draft-wakikawa-roll-invehicle-reqs
  - requirement overview: draft-levis-roll-overview-protocols
  - protocol survey: draft-levis-roll-protocols-survey

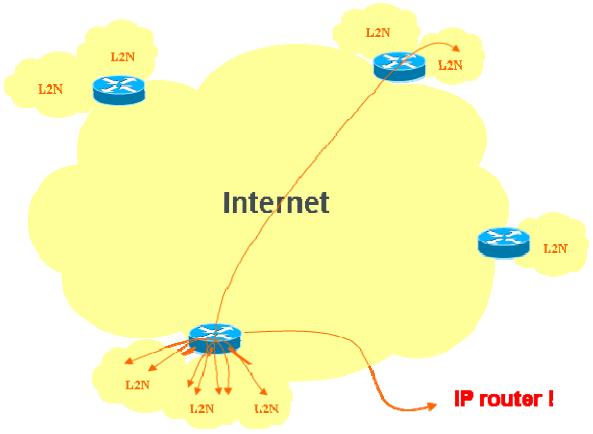
IETF ROLL – If We Did Nothing?

- Lack of end to end consistency in terms of routing, QoS, management, security:



IETF ROLL – We Need To Act

- IP end-to-end:

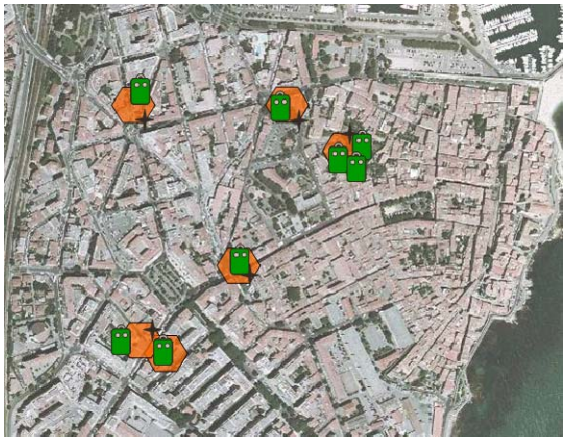


IETF ROLL – BoF Scoping

- IETF has not actively been working on such networks until recently:
  - 6lowpan WG: RFC4944 (IPv6 over IEEE 802.15.4)
  - **Still no routing solution for such networks within IETF!**
- IETF 6LoWPAN Internet Area WG:
  - produced IPv6 header compression RFC over IEEE 802.15.4 making IP practical for this class of networks
  - consensus with 6lowpan that an IP routing solution is needed
- Pragmatic, working implementations have been developed:
  - industrial routing solutions over lossy links at low power available today
  - each defines its format, network, transport, gateway, etc
- IETF routing solutions for ROLL are hence needed.

IETF ROLL – Urban WSNs

Waste containers



Sensors in the containers indicate filling level
➔ application optimize journey to empty containers

Results*

- Productivity (25%)
  - No more unuseful travel
  - Less resources needed (trucks)
- Staff less in contact with waste

* Source Voiron Expé

IETF ROLL – Goals & Milestones

- Followed Timeline:
  - **April 2008:** Submit Use case/Routing requirements for Industrial, Connected Home, Building and Urban networks applications to the IESG to be considered as an Informational RFC.
  - **August 2008:** Submit Routing Metrics and Attributes for ROLLs document to the IESG to be considered as an Informational RFC.
  - **November 2008:** Submit Protocol Survey to the IESG to be considered as an Informational RFC.
  - **January 2009:** Submit Security Framework for ROLLS to the IESG to be considered as an Informational RFC.
  - **February 2009:** Submit the Routing for ROLLs Architecture document (summary of requirements, metrics and attributes, path selection model) to the IESG as an Informational RFC.
  - **March 2009:** Recharter.