Are We Ready to Go Large-Scale?

Embedded Technologies for Smart Cities

Prof. Dr. Pedro José Marrón

Krakow, FedCSIS Conference, September 11th, 2013

European Center for Ubiquitous Computing
and Smart Cities

UNIVERSITÄT DUISBURG ESSEN

Open-Minded

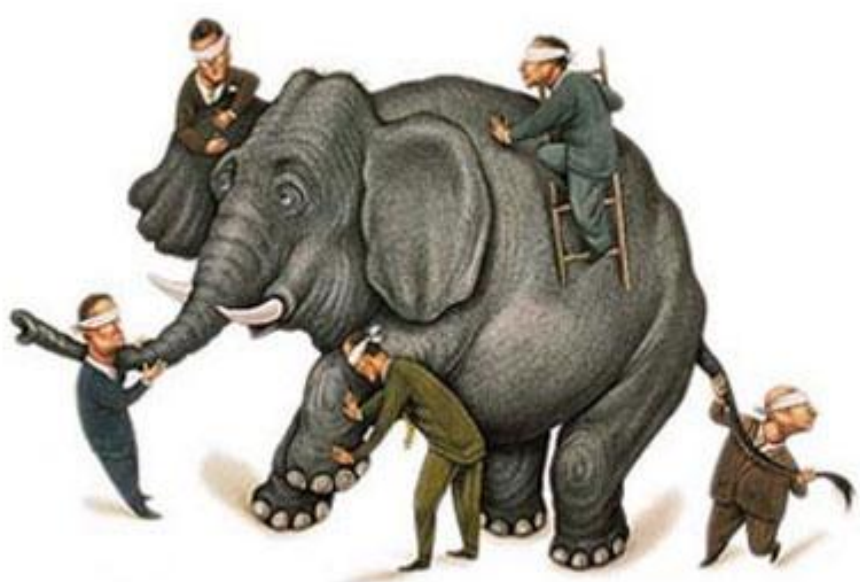
Are We Ready to Go Large-Scale?

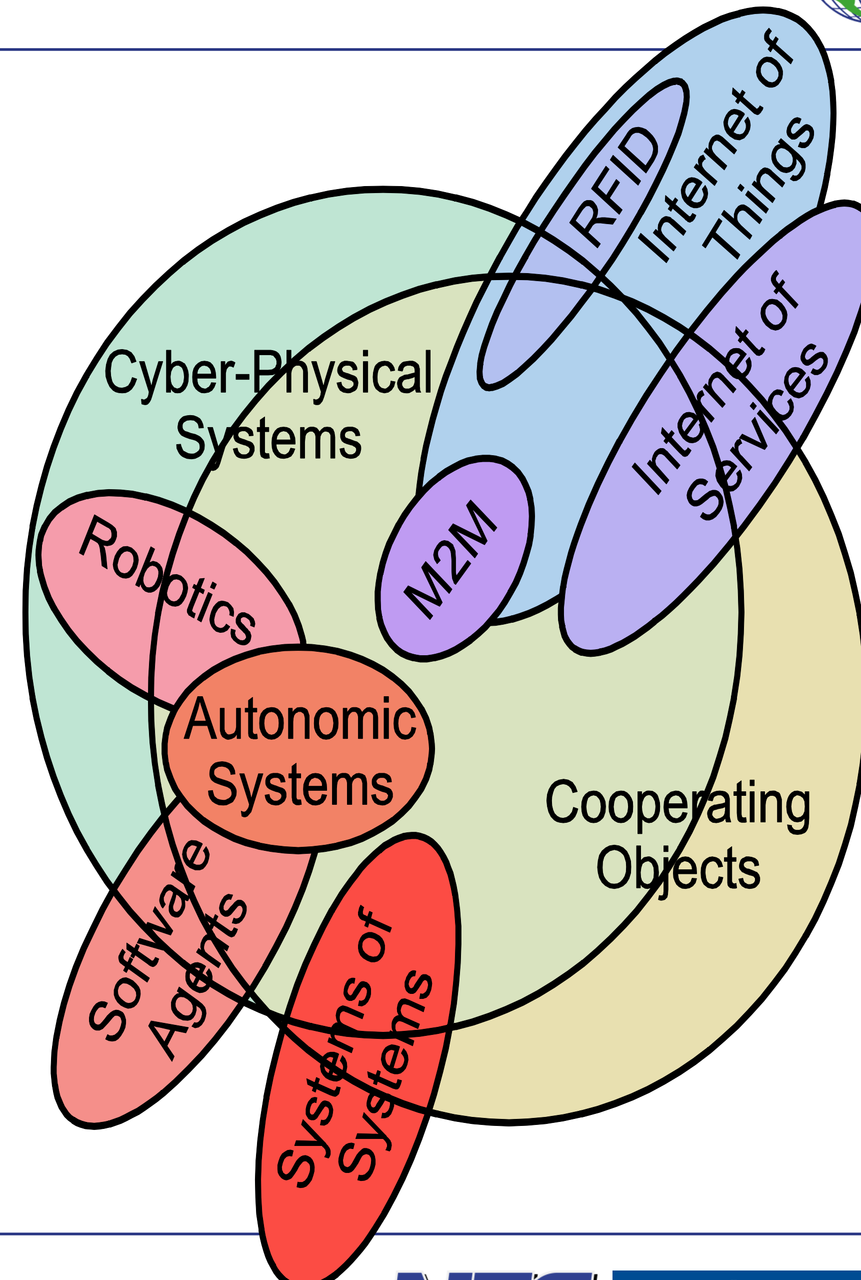
NO!

Thank you for your attention!

Preliminaries: Terminology

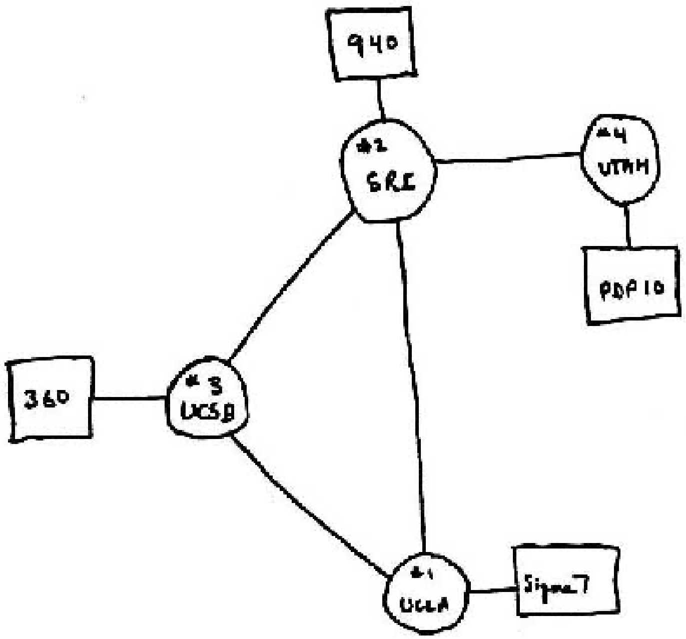
- Cooperating Objects
  - Smart embedded systems
- Internet of Things
  - RFID systems
- Cyber-Physical Systems

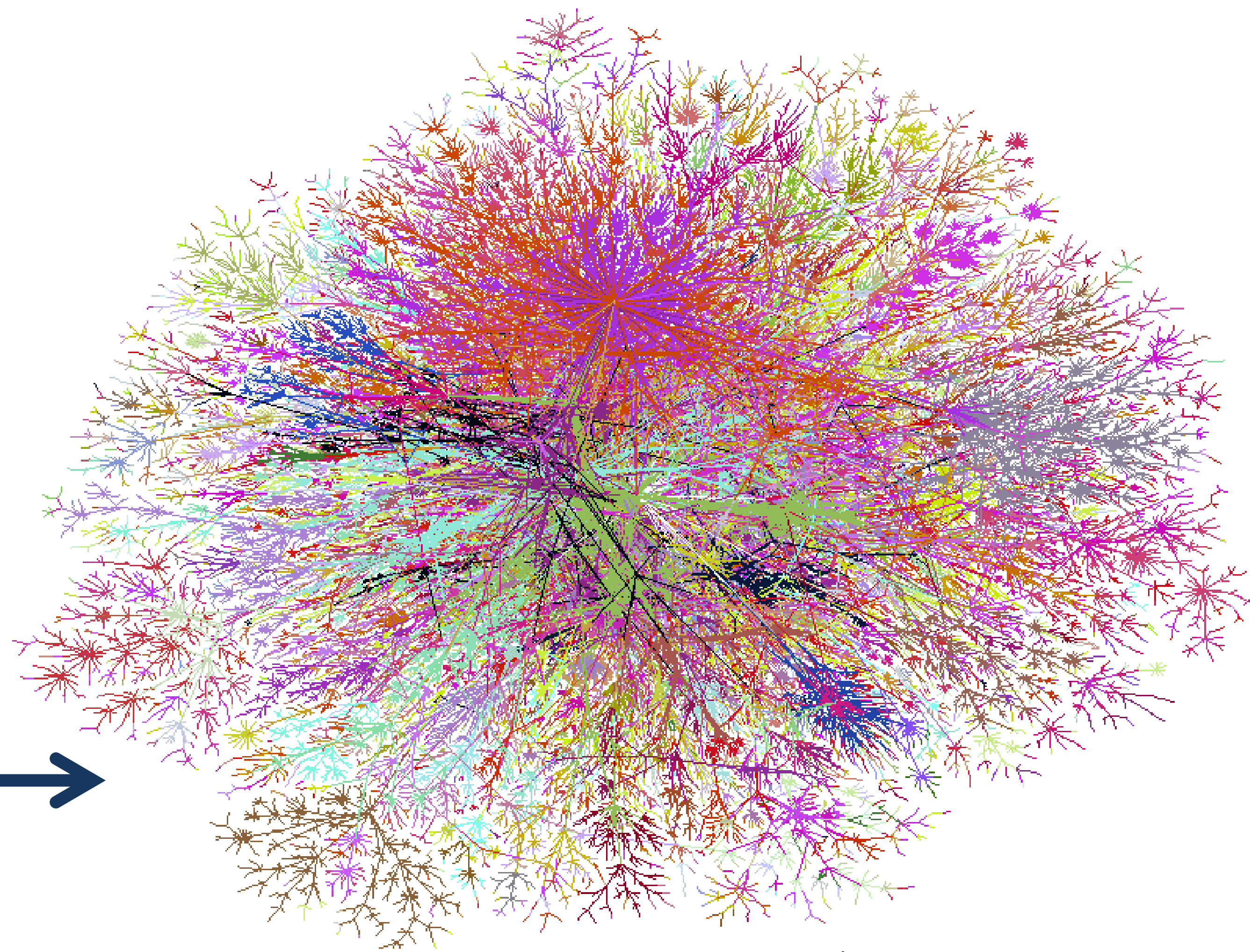




Comparison to “normal” Internet

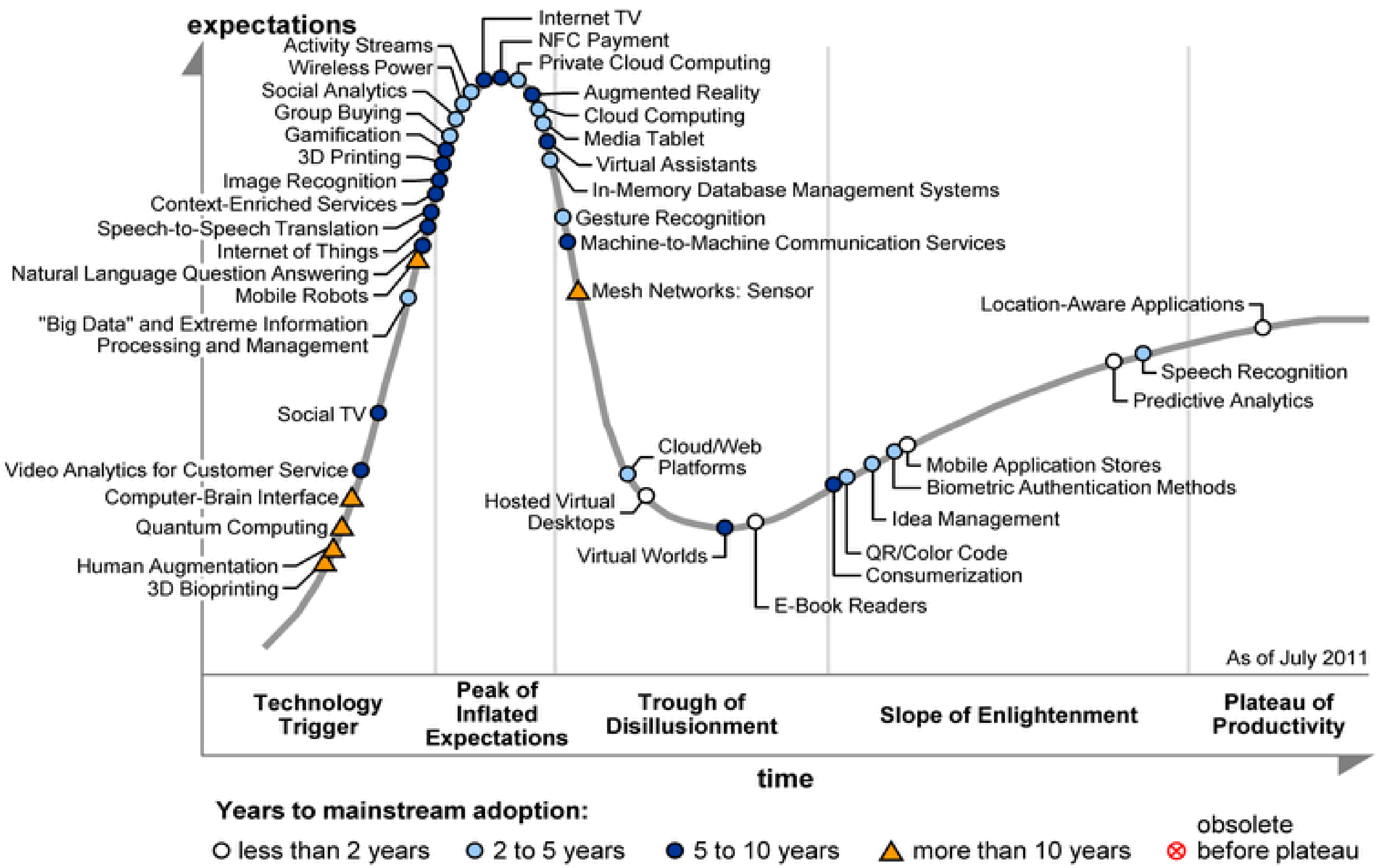
From Computer Desktop Encyclopedia
Reproduced with permission.
© 2000 The Computer Museum History Center





Source: Plyojump – Computer History

Current Status of the Hype



Source: Gartner 2011

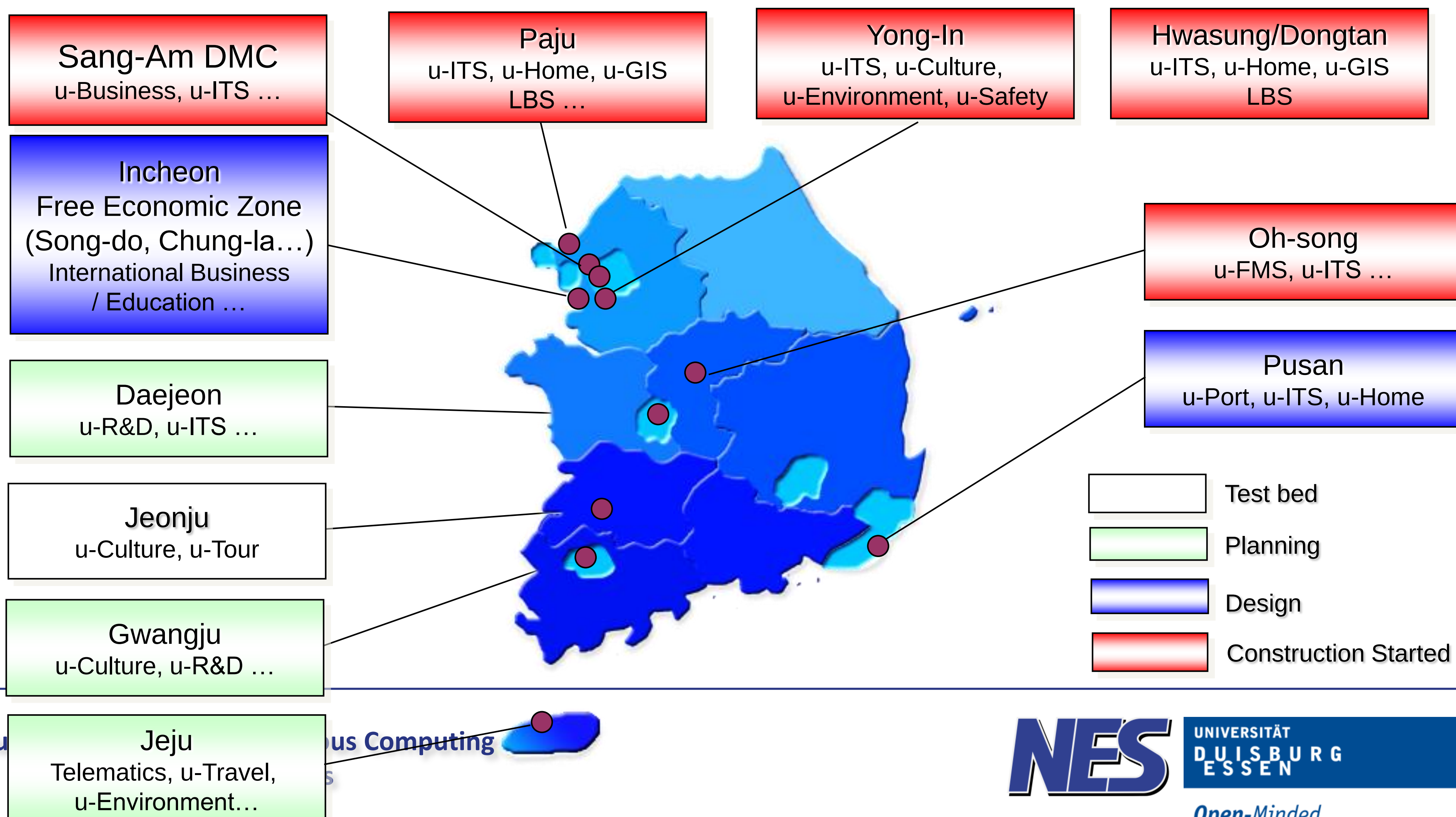
u-Cities in Korea

- New Songdo City to be finished in 2014
- $25 billion approved budget
- Based on smart-cards, RFID technologies, etc.

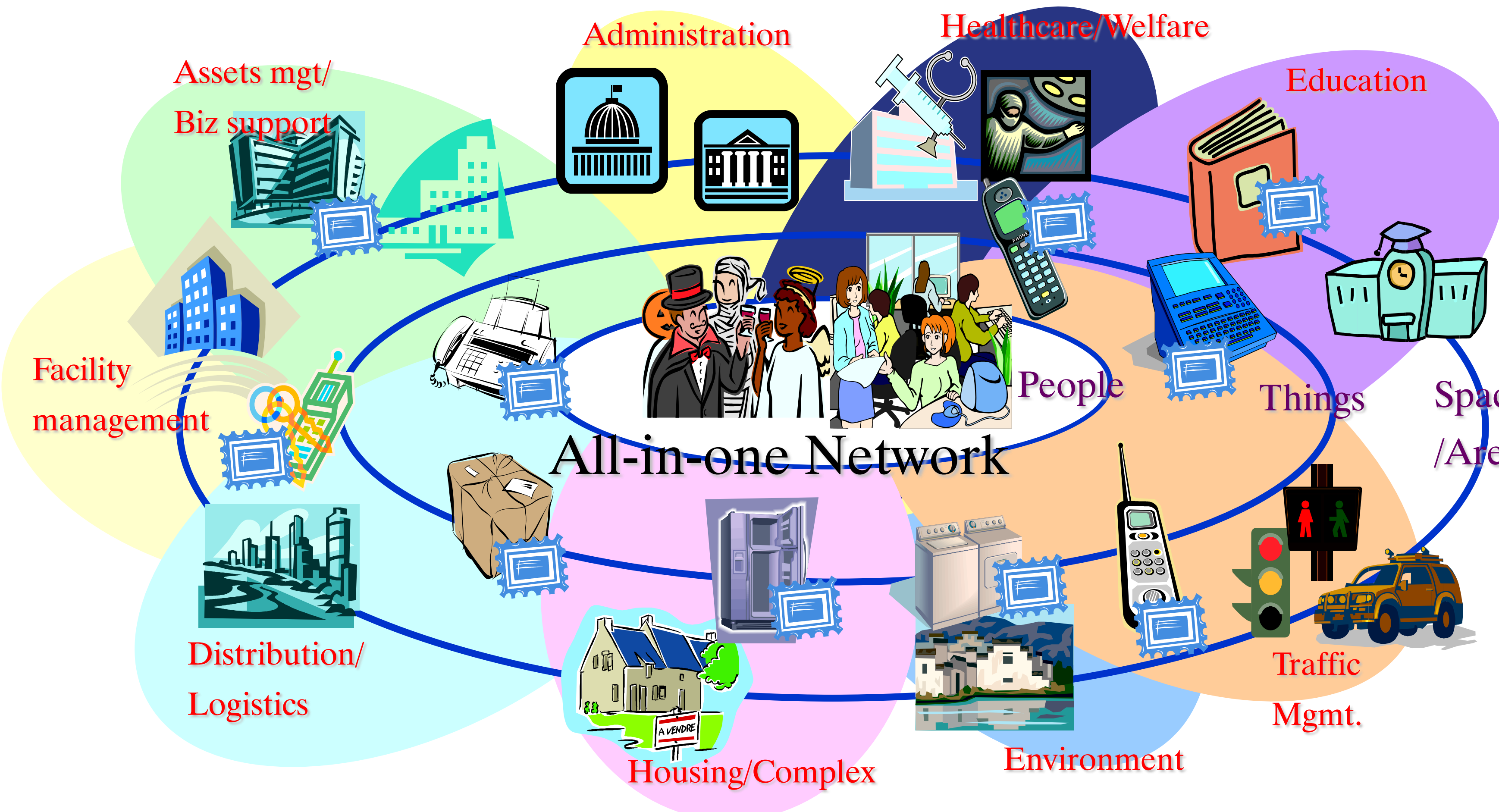
New Songdo City

Status of u-City Trials in Korea

- u-City trial projects activated in 22 cities
  - 14 existing cities and 8 cities under construction
- Interoperability and over-construction problem
  - Local province driven construction of u-City without common service model/standards



u-City: Conceptual Framework



BcN, FTTH, GPS, UWB, Bluetooth, Zigbee, SoC, RFID, MEMS, Embedded SW, IPv6, Cryptograph /Security

22@Barcelona

Smart City concept

- A high-tech intensive and advanced city
- Connects people, information and city elements using new technologies as: RFID, USN, BcN, w-Lan, ...
- Increase quality of life
- Makes management and maintenance easier and cheaper

22@Barcelona

Infrastructure **Barcelona**

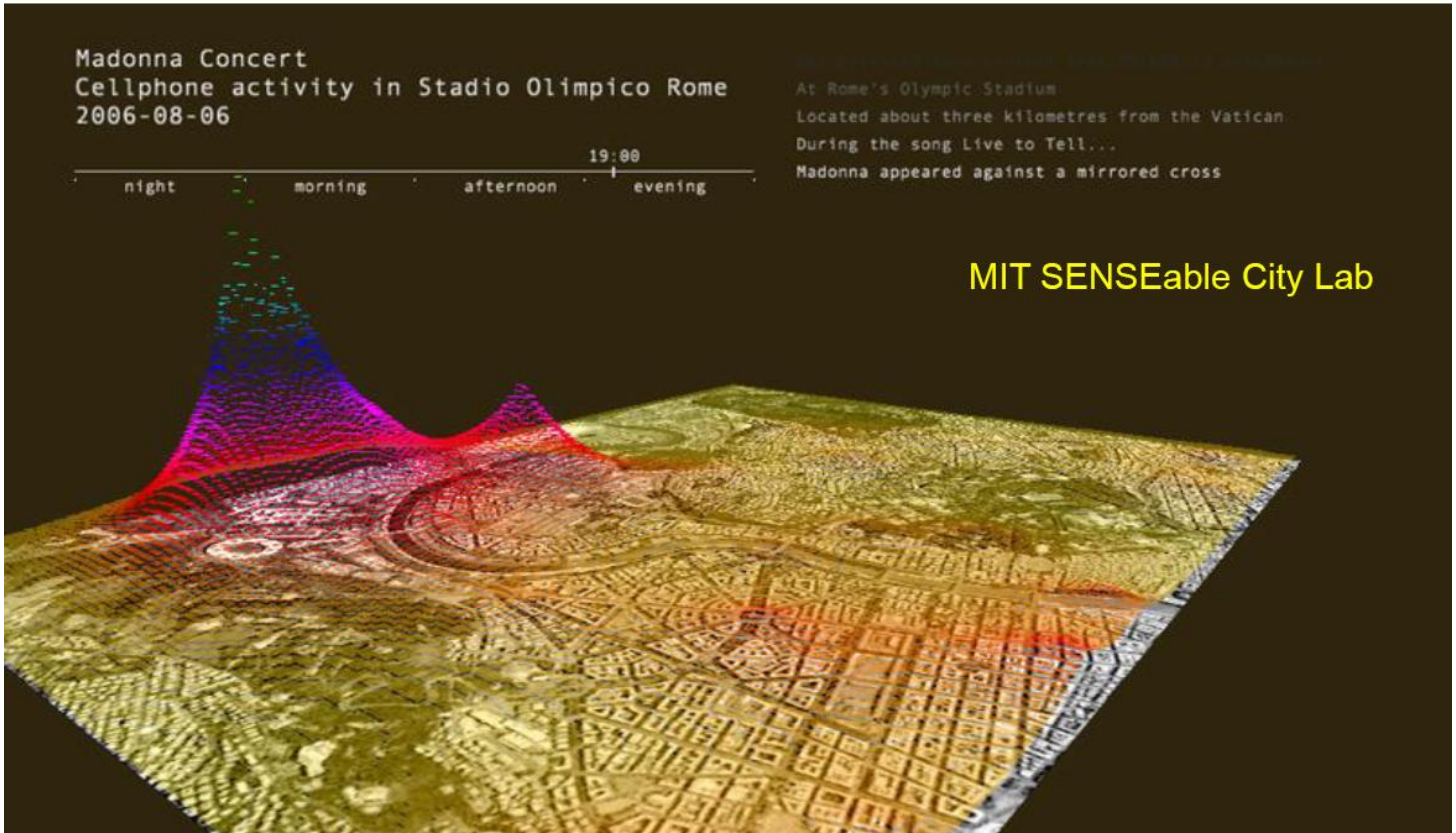
Municipal WiFi mesh network

For internal use, corporative services and to connect sensors and city elements

680 nodes 20 services

Mobile Phones as Sensors

Citizen's information — Rome

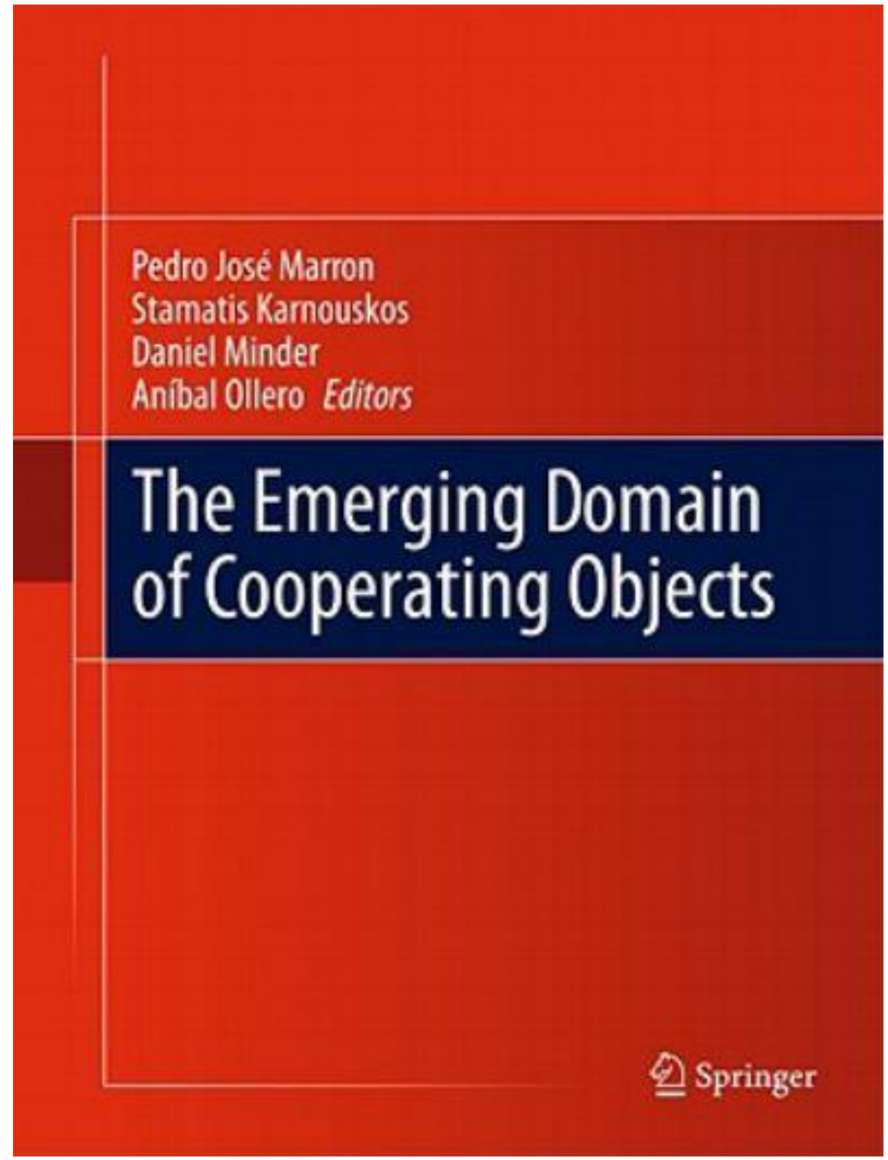


Mobile phone calls distribution

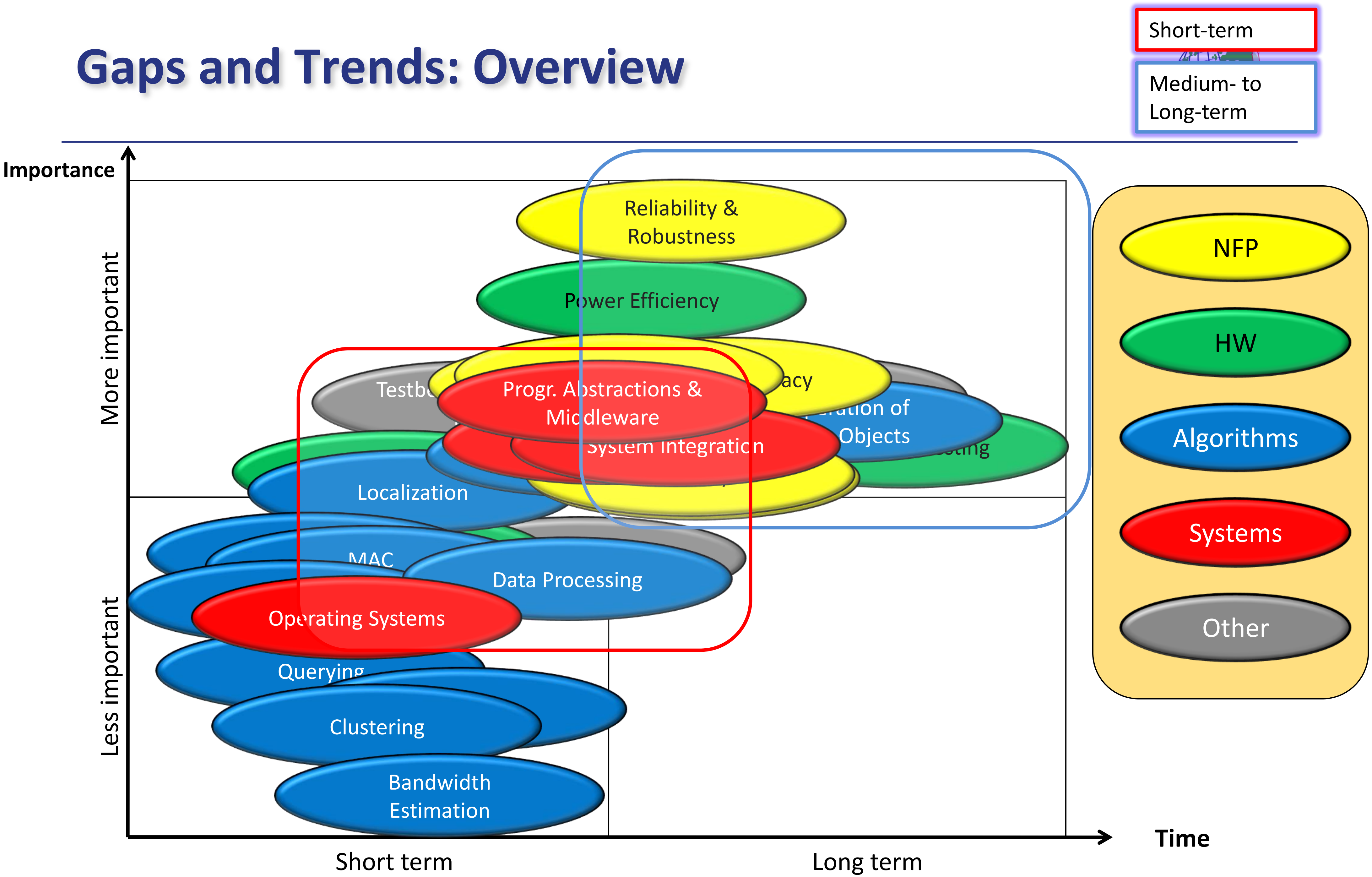
Crowds management...

Research Roadmap on Cooperating Objects

- One of the main results of the Cooperating Objects Network of Excellence (CONET)
- First edition published by the European Commission
  - Updated every year
- State of the art for Cooperating Objects
- Current gaps and trends
- Main research topics and predominant work areas



Gaps and Trends: Overview

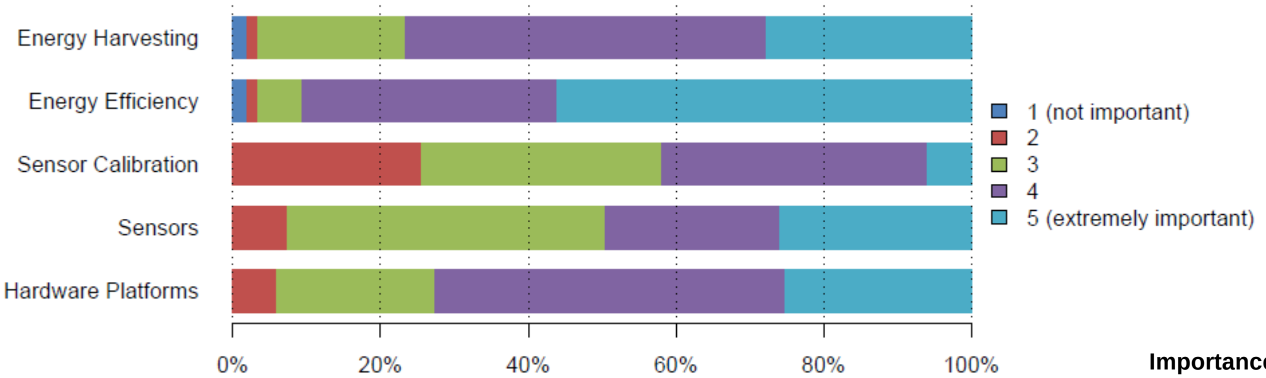


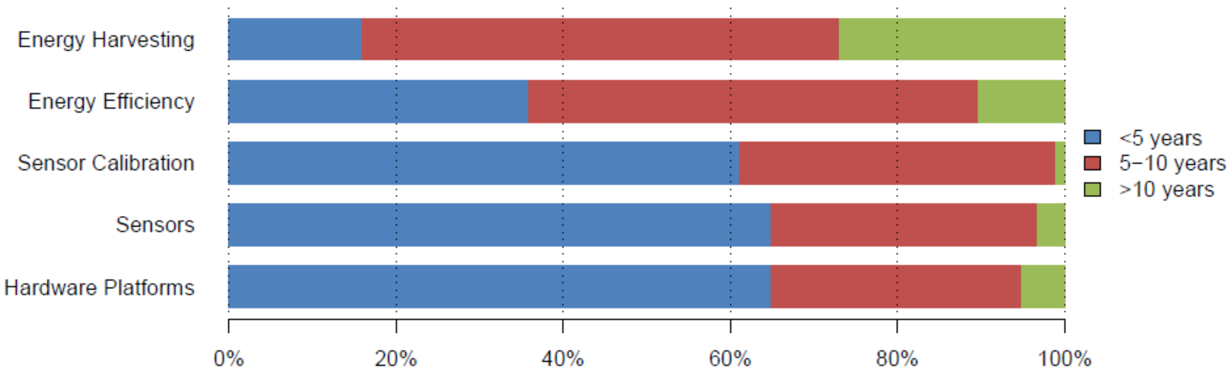
NES UNIVERSITÄT DUISBURG ESSEN Open-Minded

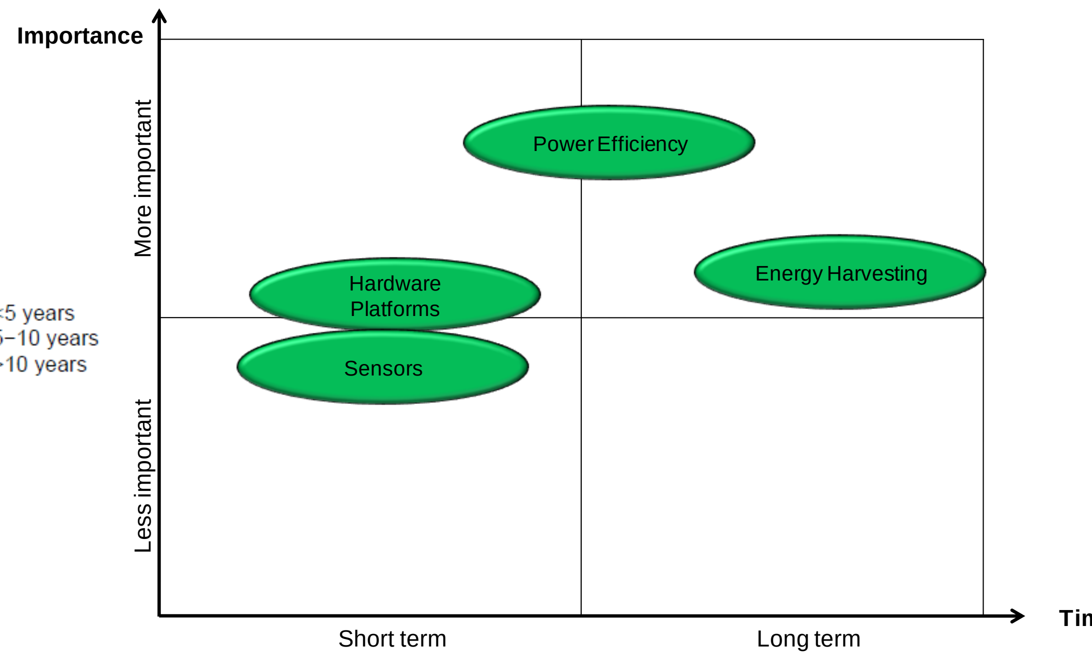
Some Fundamental Challenges

- Hardware-related
  - Energy harvesting
- Planning and Simulation
- Installation and System Integration
- Network Operation
  - Real-world conditions
  - Amount of generated data
  - Monitoring of the network
  - User interfaces
- Repairing and network healing

Gaps and Trends: Hardware

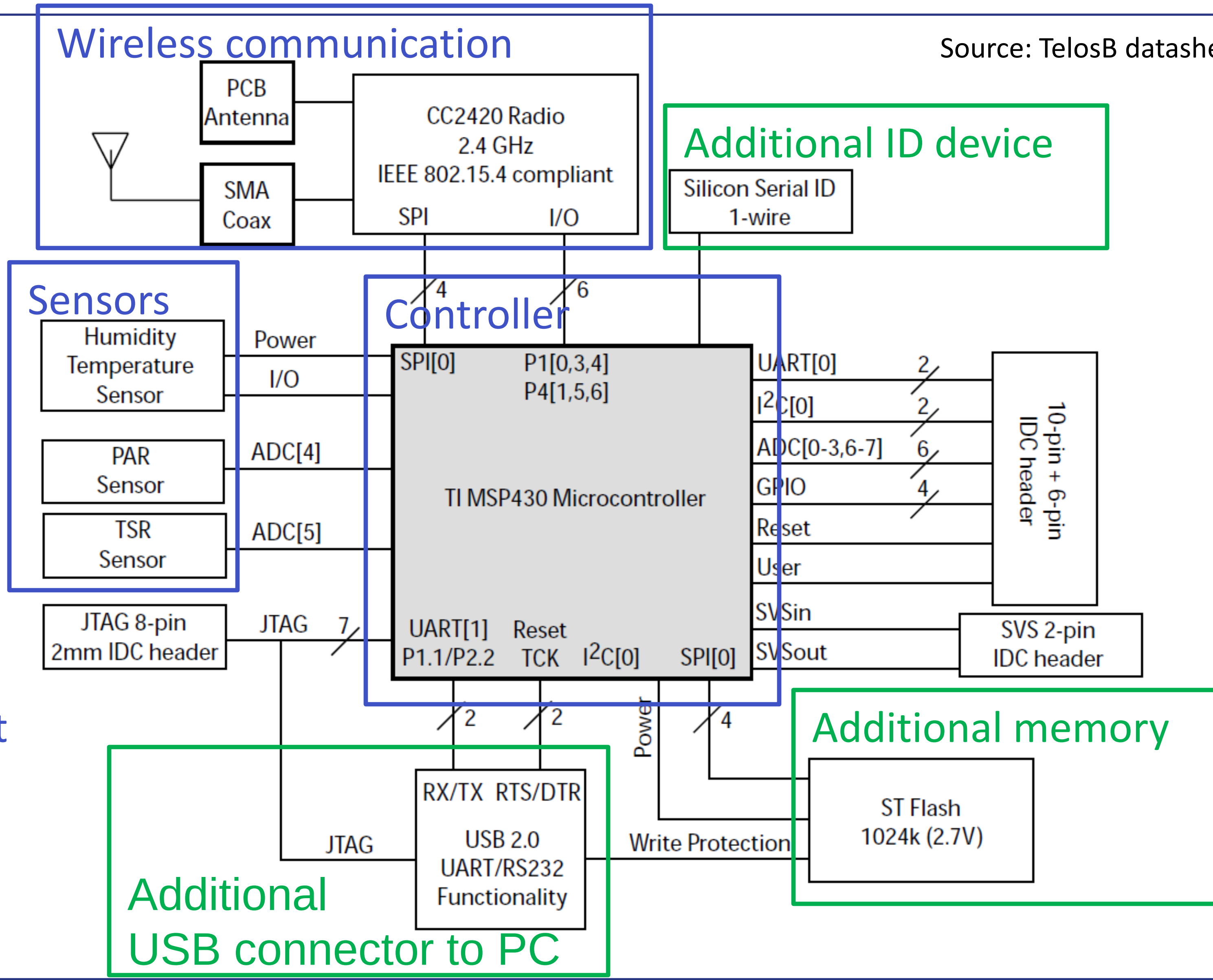






Cooperating Objects Hardware

Example: TelosB



Battery not shown

Example Sensor Platforms

- TelosB (Crossbow)
  - Texas Instruments MSP430, 8 MHz
  - Chipcon CC2420, 2.4GHz
  - 10kB RAM
  - 48kB Program Flash
  - 1MB external Flash
- IMote2 (Crossbow)
  - Marvell PXA271 ARM
  - TI CC2420 802.15.4 / ZigBee compliant radio
  - 32MB SDRAM
  - 32MB Flash

TelosB

Imote2

Power Consumption

[Landsiedel, 2005]

- Consumption depends on power mode of devices
  - power safe modes of CPU
  - transmit power levels of radio
  - different sensors
- Mica2 with CPU on and radio receiving draws 16mA

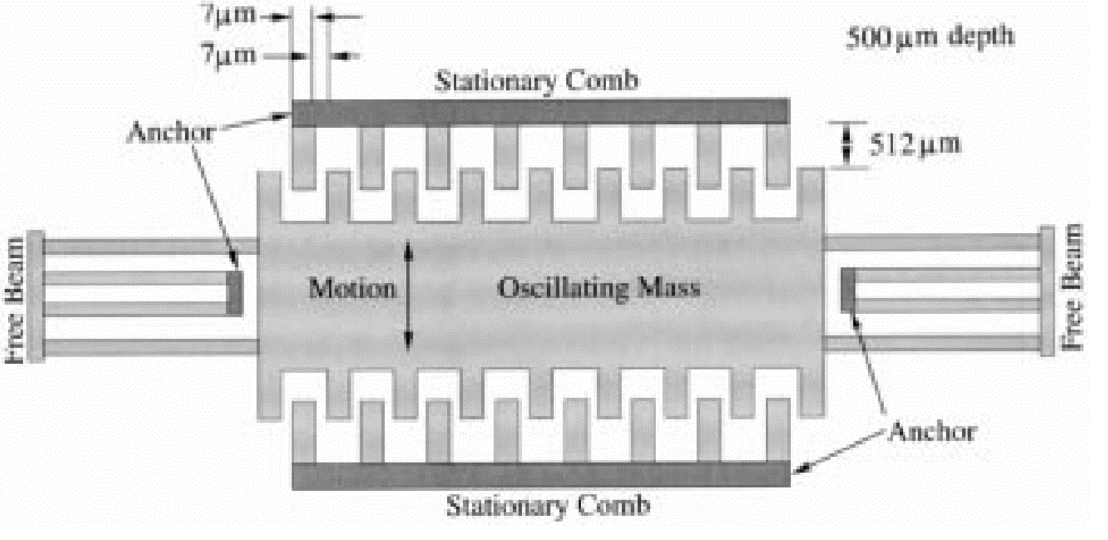
Device	Current	Device	Current
CPU		**Radio** (900 MHz)	
Active	$7.6\,mA$	Core	$60\,\mu A$
Idle	$3.3\,mA$	Bias	$1.38\,mA$
ADC Noise	$1.0\,mA$	Rx	$9.6\,mA$
Power down	$116\,\mu A$	Tx (-18 dBm)	$8.8\,mA$
Power Save	$124\,\mu A$	Tx (-13 dBm)	$9.8\,mA$
Standby	$237\,\mu A$	Tx (-10 dBm)	$10.4\,mA$
Ext Standby	$243\,\mu A$	Tx (-6 dBm)	$11.3\,mA$
		Tx (-2 dBm)	$15.6\,mA$
LED (each)	$2.2\,mA$	Tx (0 dBm)	$17.0\,mA$
		Tx (+3 dBm)	$20.2\,mA$
Sensor Board	$0.7\,mA$	Tx (+4 dBm)	$22.5\,mA$
		Tx (+5 dBm)	$26.9\,mA$

- With standard batteries (2500mAh) it could run for 6.5 days
  - use of sleep modes, turn off radio, sensors, … if possible
  - process (i.e. compress, aggregate) data before transmitting

Energy Scavenging

[Paradiso, 2005]

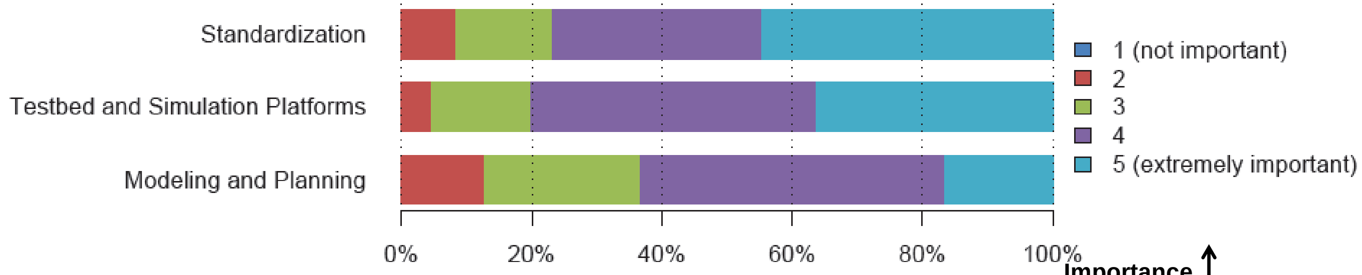
- Light → solar cells: between 100 µW/cm^2 (office desk) and 100 mW/cm^2 (direct sun)
- Temperature gradients: 60 µW/cm^2 from 5K difference
- Acoustic noise: 0.003µW/cm^2 at 75 dB
- Vibrations: between 4 and 800 µW/cm^3
- Pressure variation (piezo-electric): 330 µW/cm^2 from the heel of a shoe
- Air/liquid flow: 1mW/cm^2

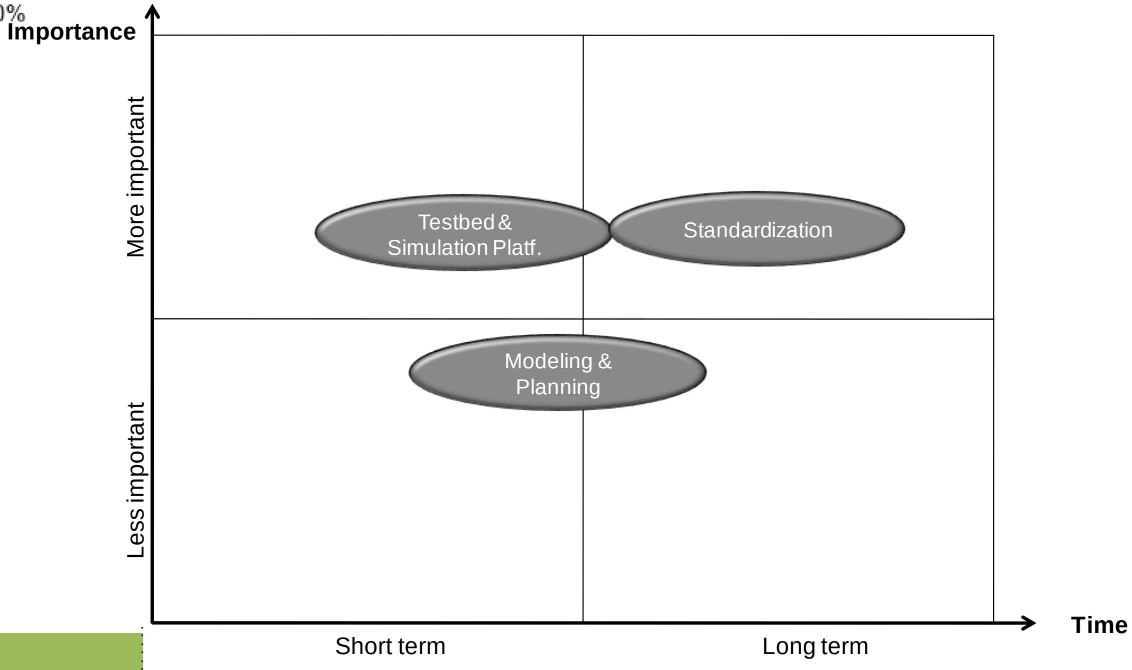


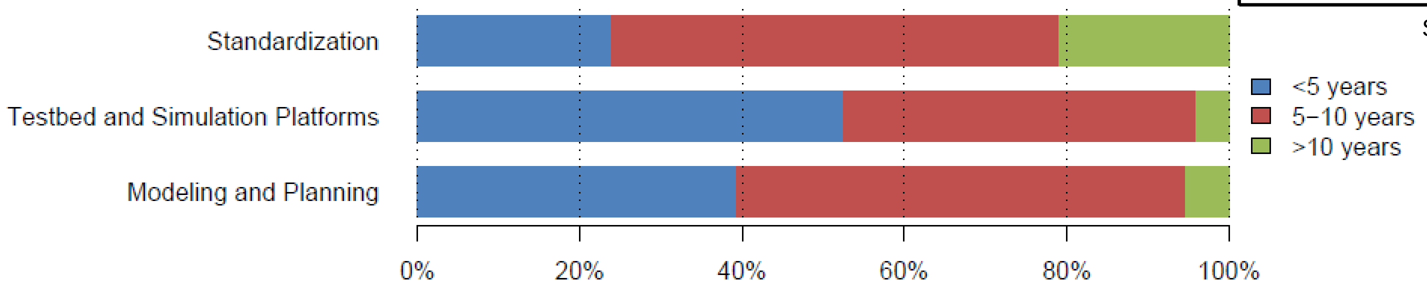
Some Fundamental Challenges

- Hardware-related
  - Energy harvesting
- Planning and Simulation
- Installation and System Integration
- Network Operation
  - Real-world conditions
  - Amount of generated data
  - Monitoring of the network
  - User interfaces
- Repairing and network healing

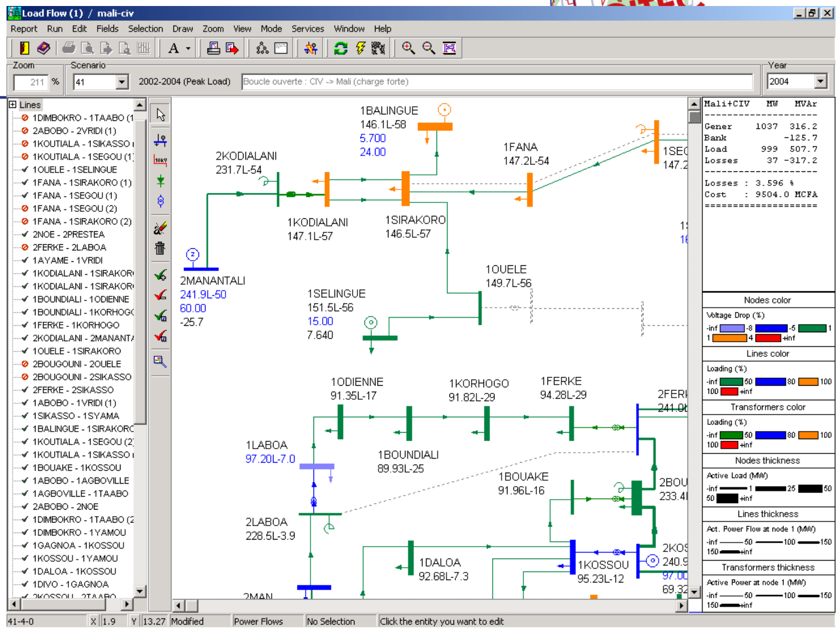
Gaps and Trends: Other



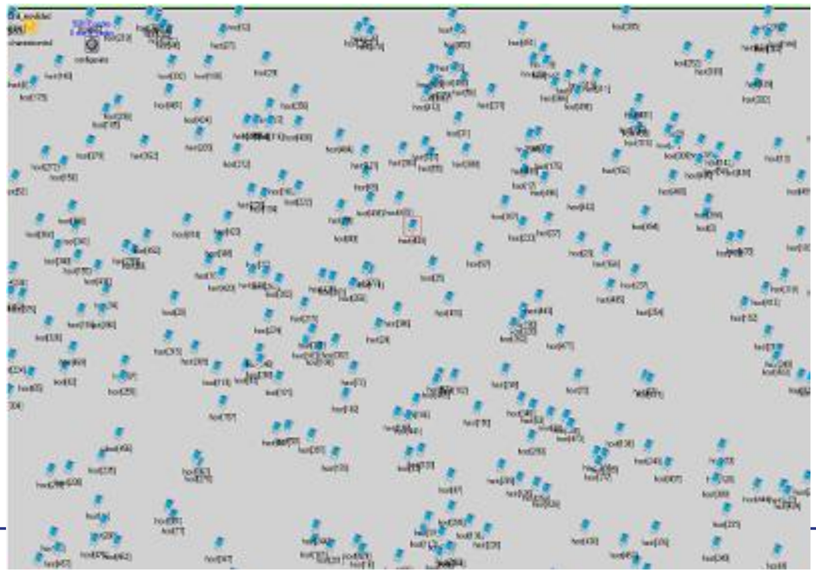


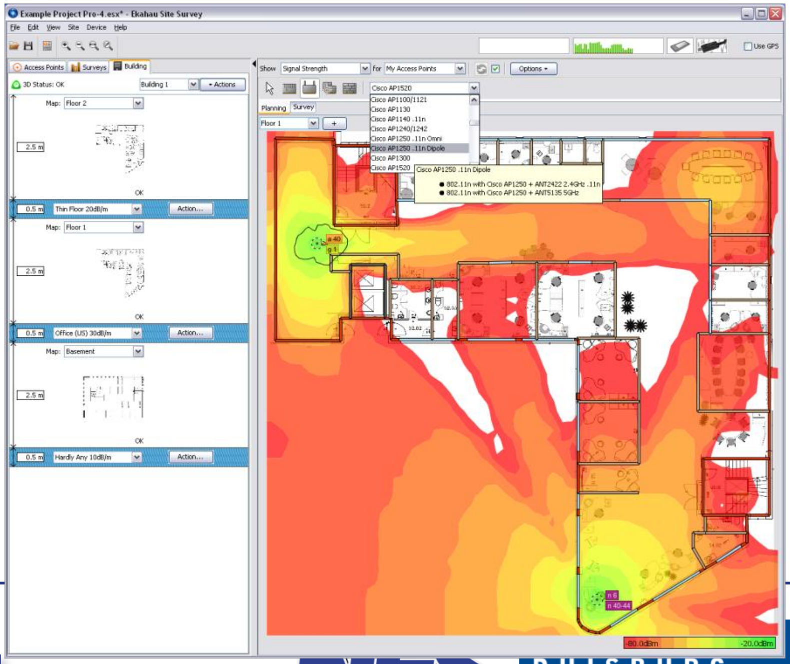


Planning / Simulation



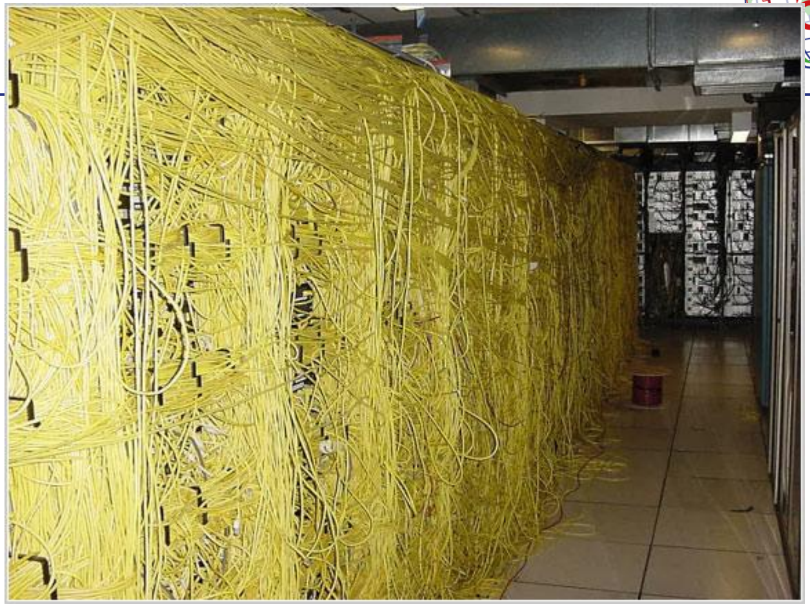
- Topology constraints
- Coverage of the area
  - Sensing range ≠ communication range
- Change in environmental conditions

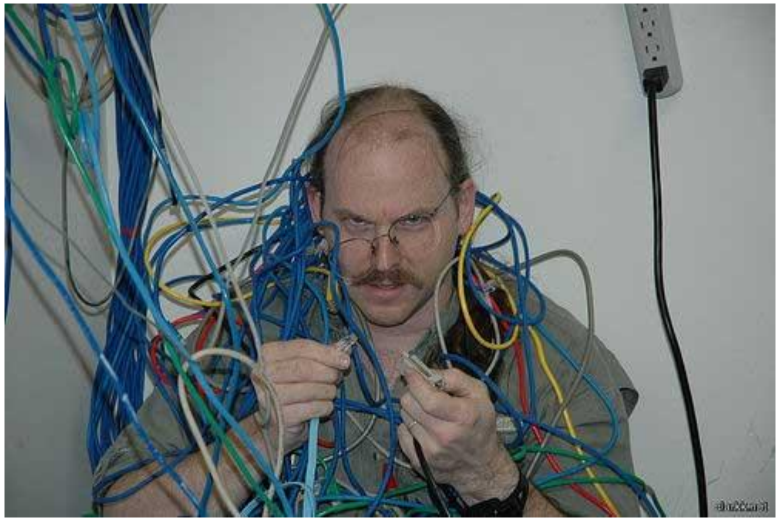


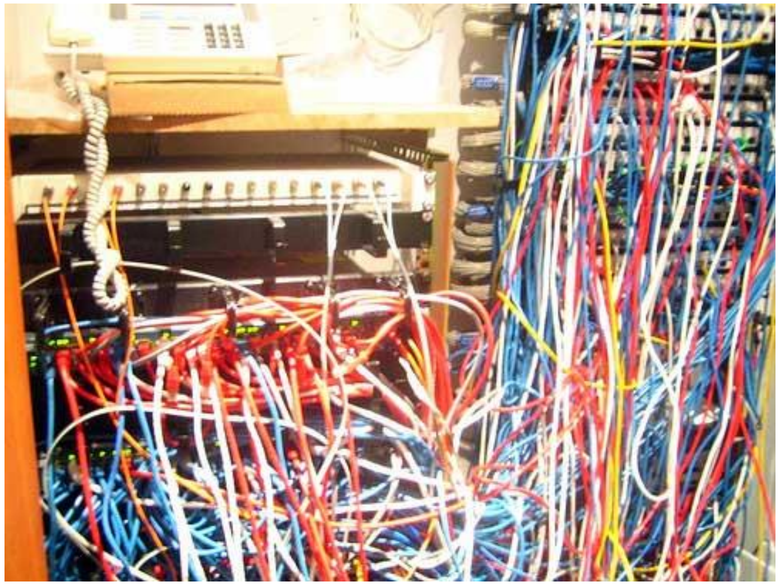


Installation

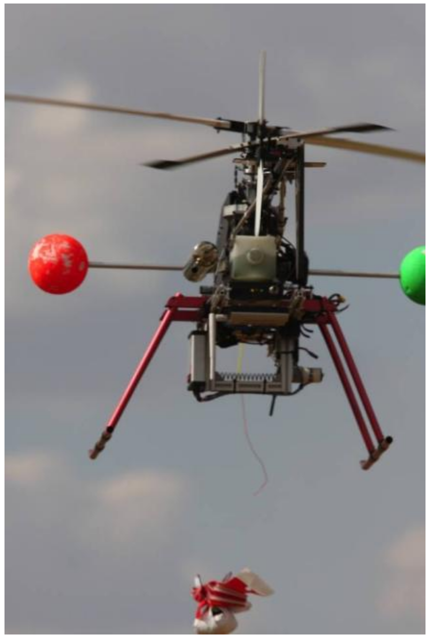
- Not a computer science problem
  - Tools are critical
- Maintenance is the key problem
- Integration with existing systems

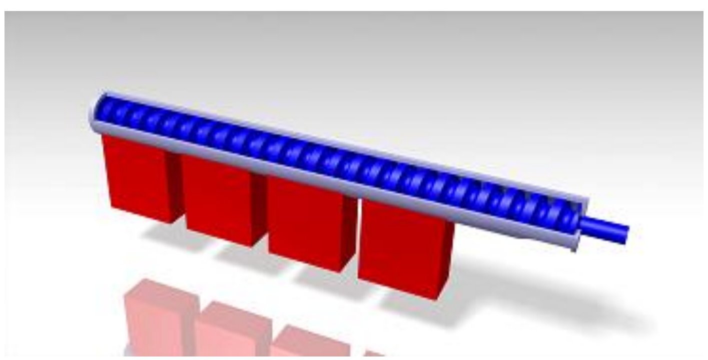






Installation

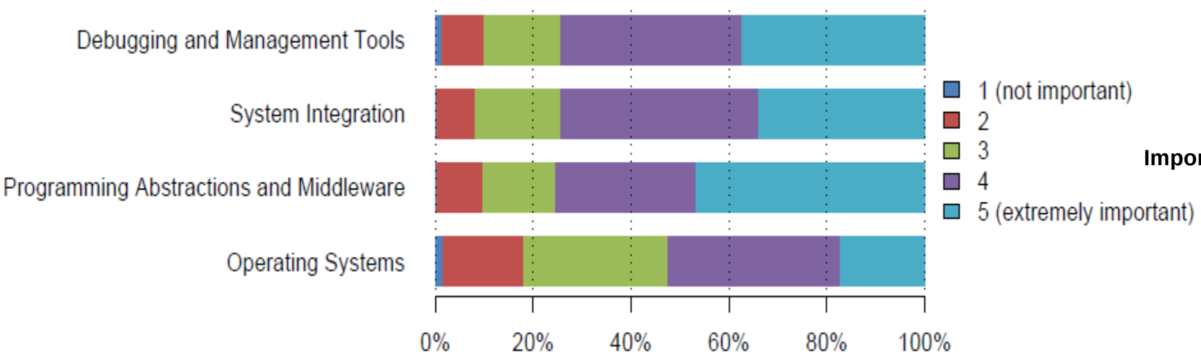


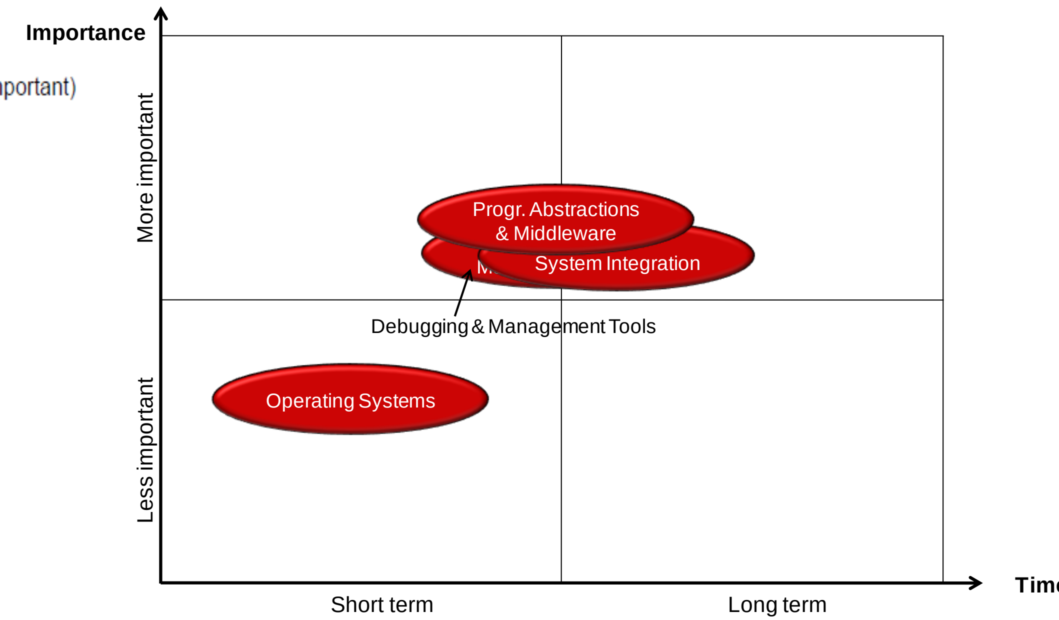


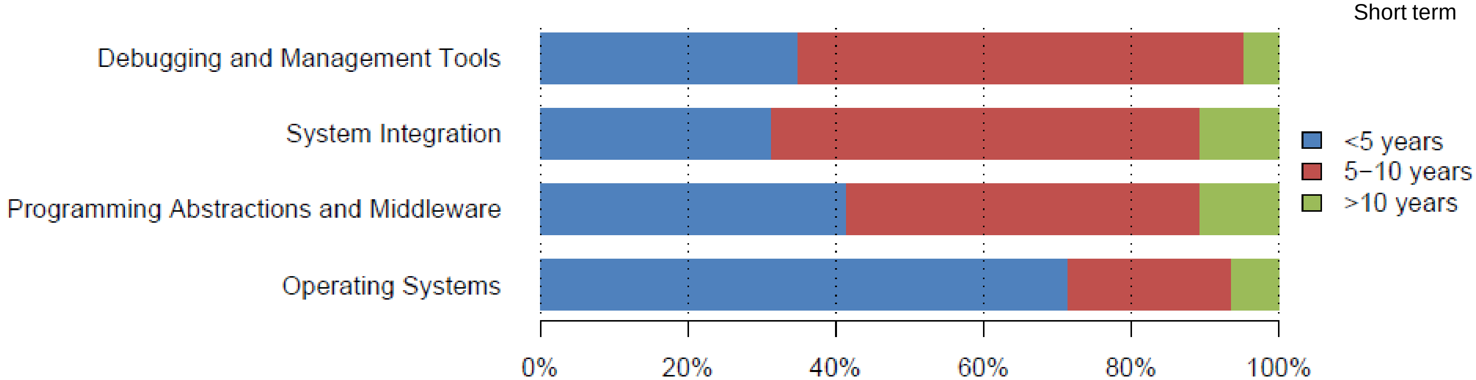
Some Fundamental Challenges

- Hardware-related
  - Energy harvesting
- Planning and Simulation
- Installation and System Integration
- Network Operation
  - Real-world conditions
  - Amount of generated data
  - Monitoring of the network
  - User interfaces
- Repairing and network healing

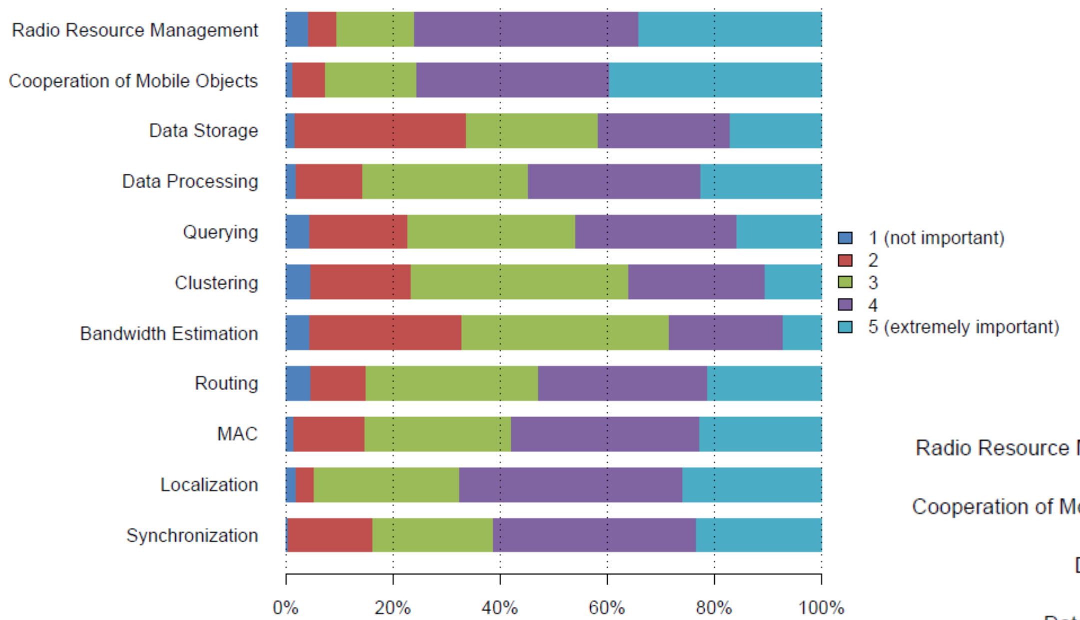
Gaps and Trends: Systems

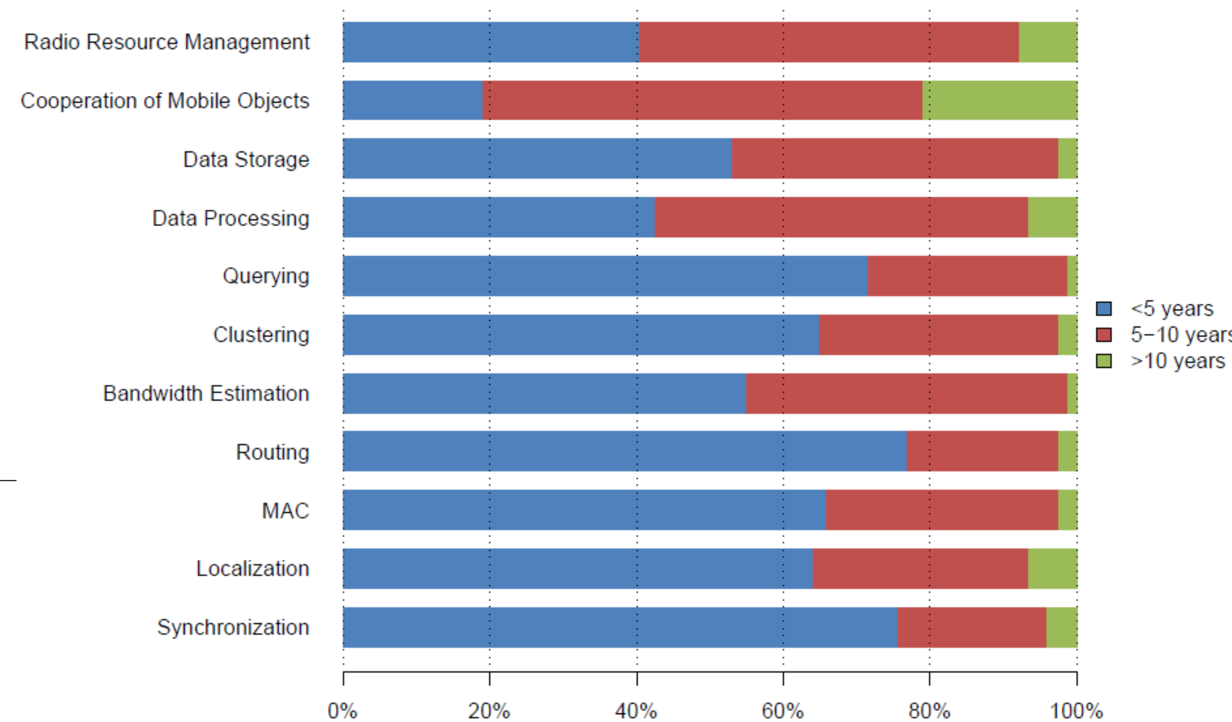


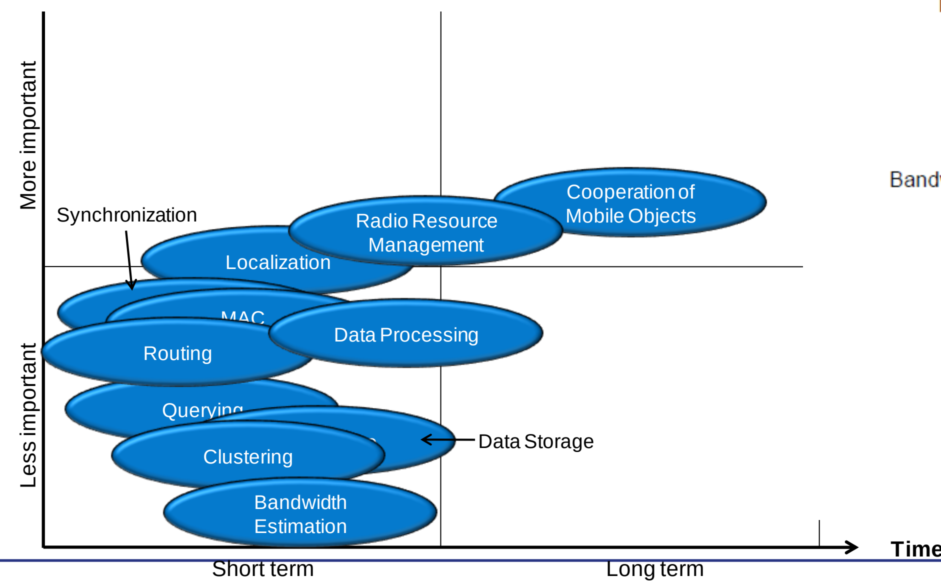




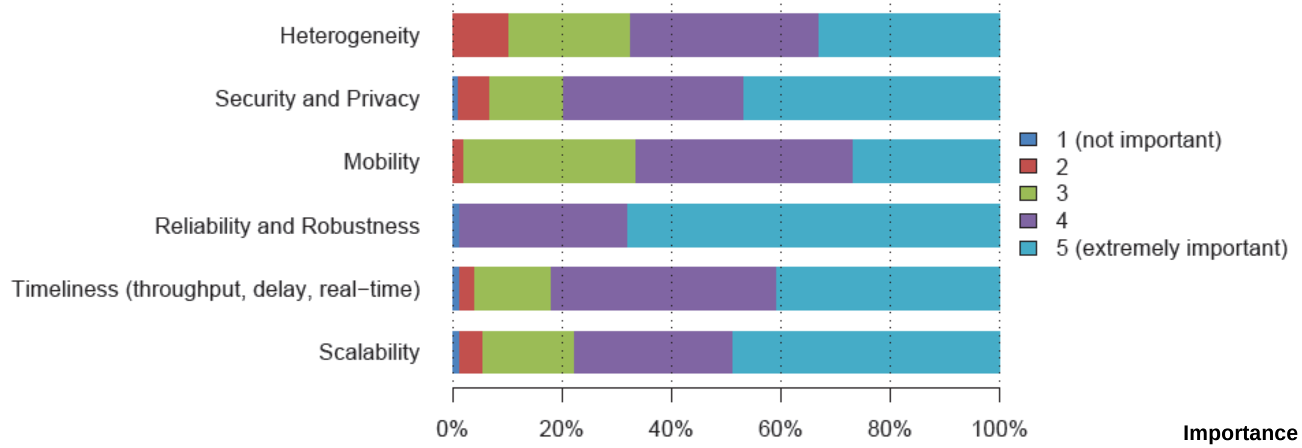
Gaps and Trends: Algorithms

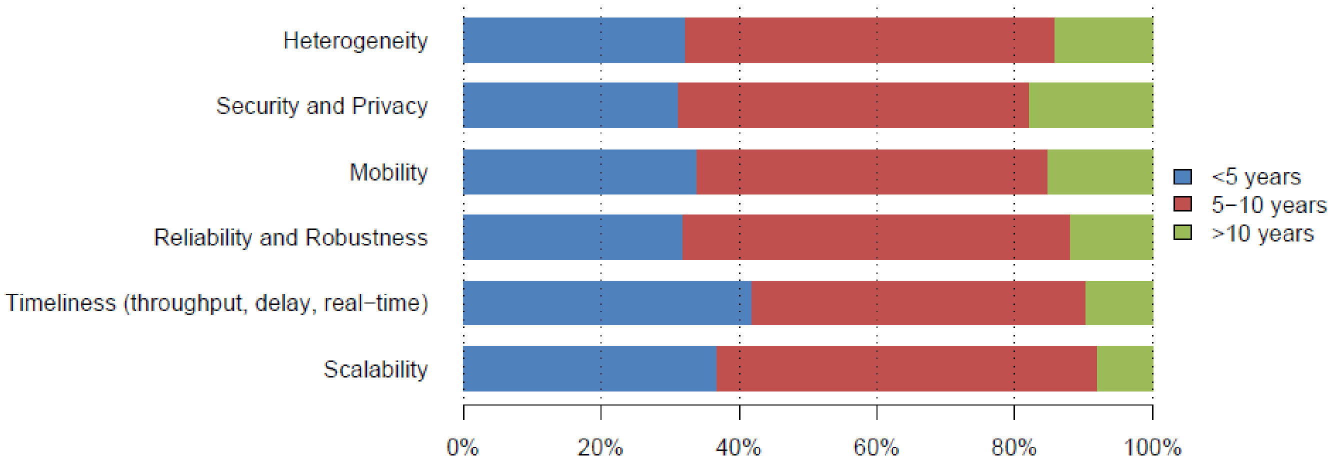


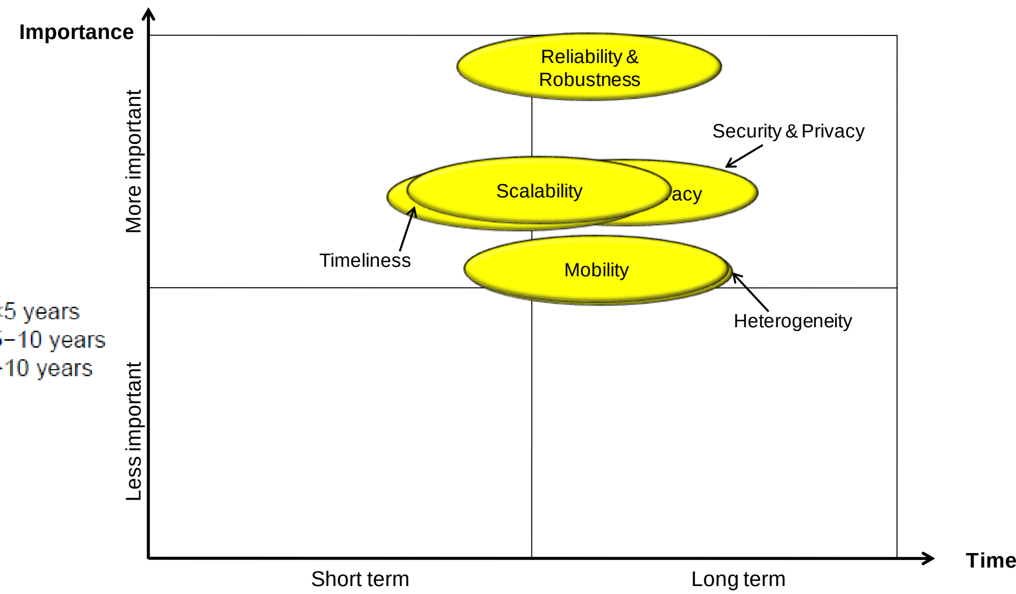




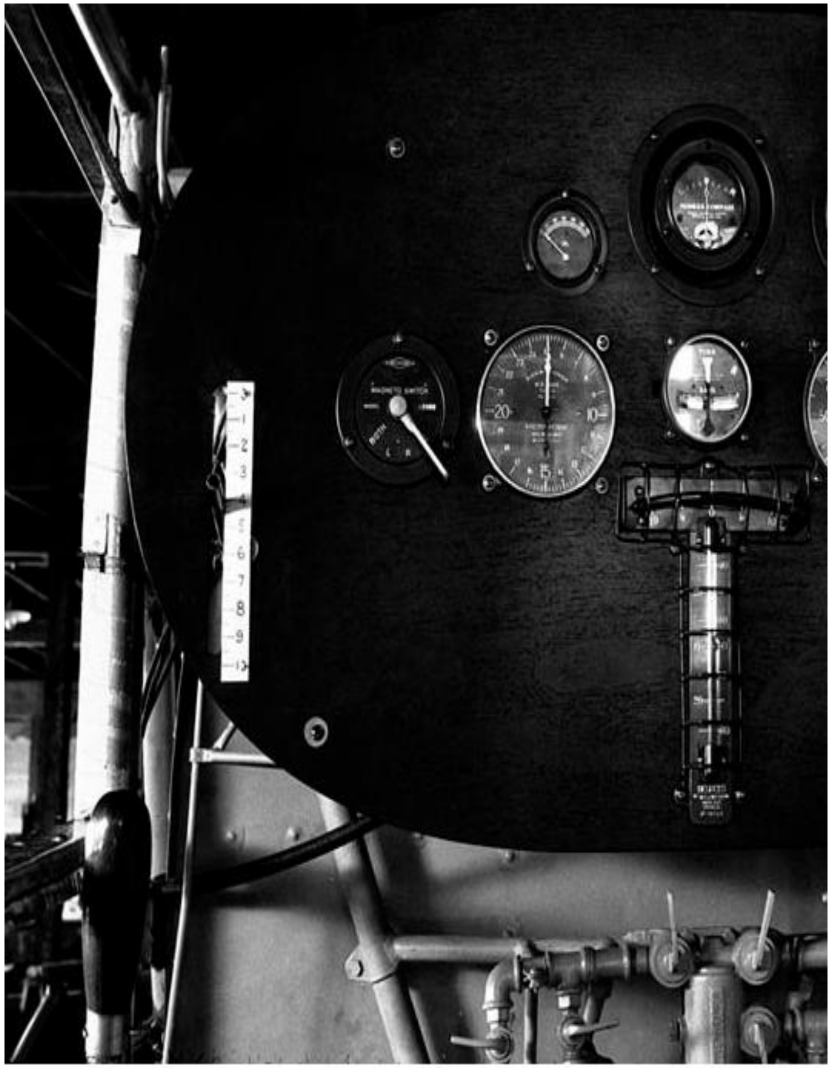
Gaps and Trends: NFP







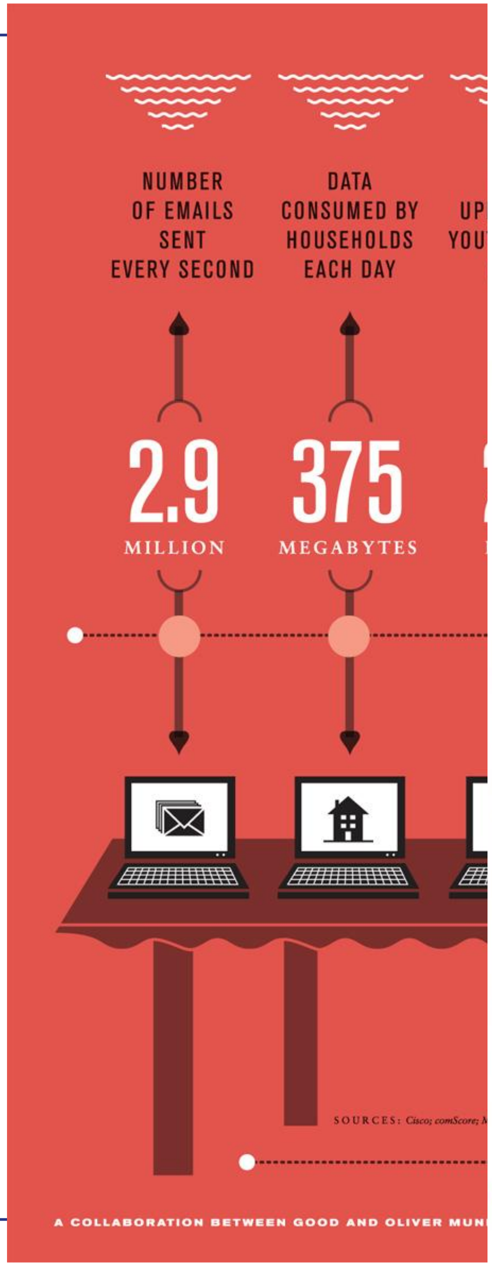
Network Operation



The Spirit of St. Louis (1927)
Source: www.charleslindbergh.com

Airbus A380 (2005)

Main Limiting Factors of Ubiquity



Eric Schmidt: Every 2 Days We Create As Much Information As We Did Up To 2003

MG SIEGLER | Wednesday, August 4th, 2010 | 2 Comments

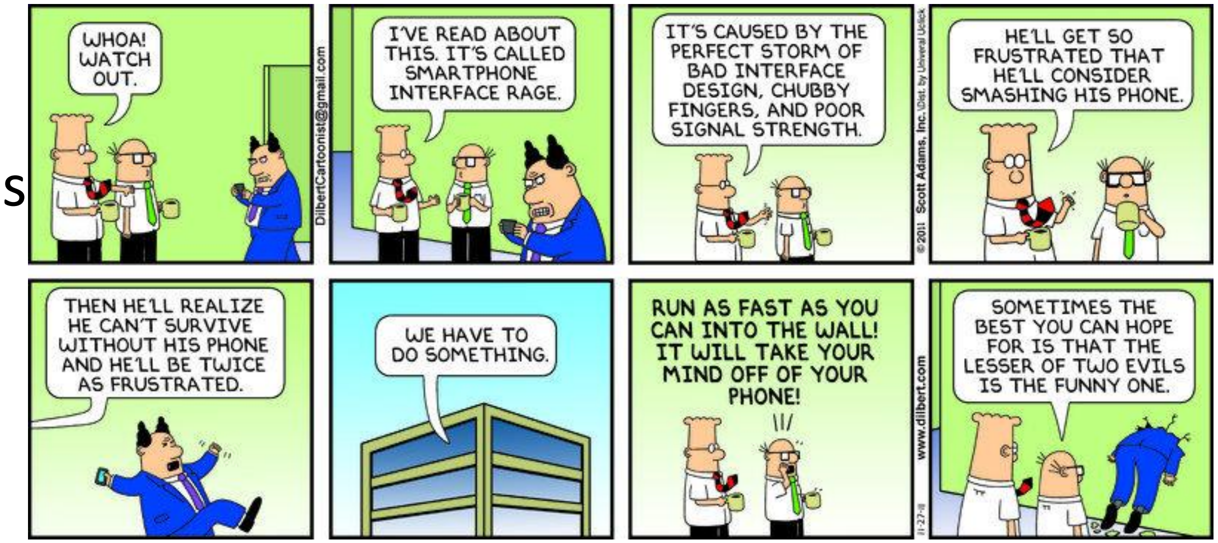
Today at the **Techonomy** conference in Lake Tahoe, CA, the first panel featured Google CEO **Eric Schmidt**. As moderator David Kirkpatrick was introducing him, he rattled off a massive stat.

Every two days now we create as much information as we did from the dawn of civilization up until 2003, according to Schmidt. That's something like five exabytes of data, he says.

Let me repeat that: we create as much information in two days now as we did from the dawn of man through 2003.

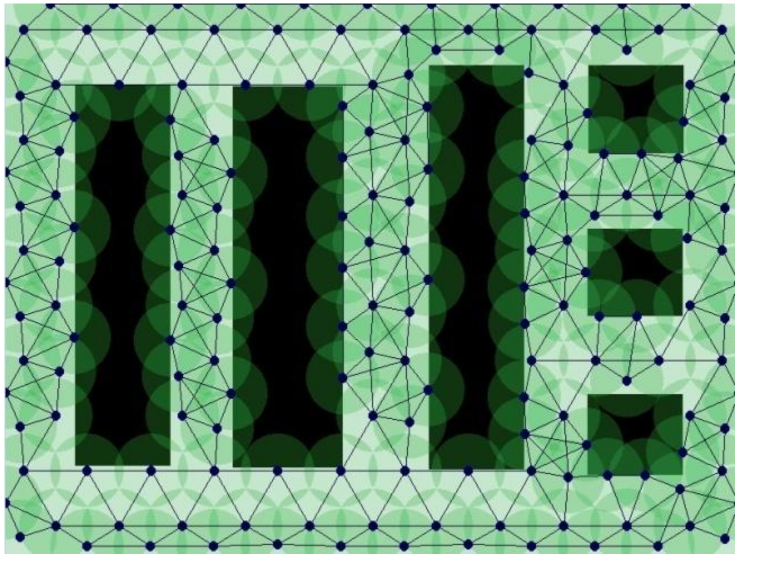
User Interface Design

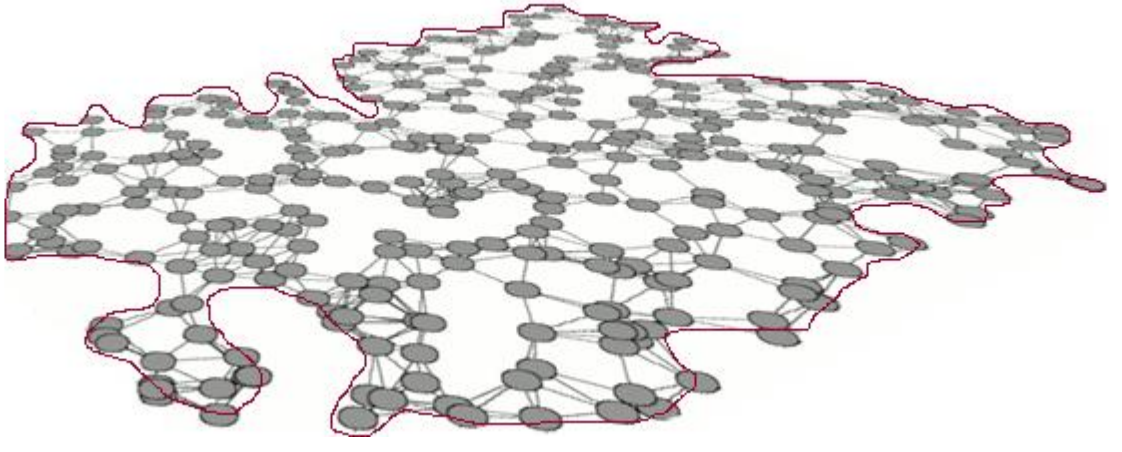
- Ubiquity makes it hard
- Millions of embedded devices
  - On/off button?



Network Repairing / Healing

- Detection of borders and holes is crucial
- Non-intrusive monitoring needed





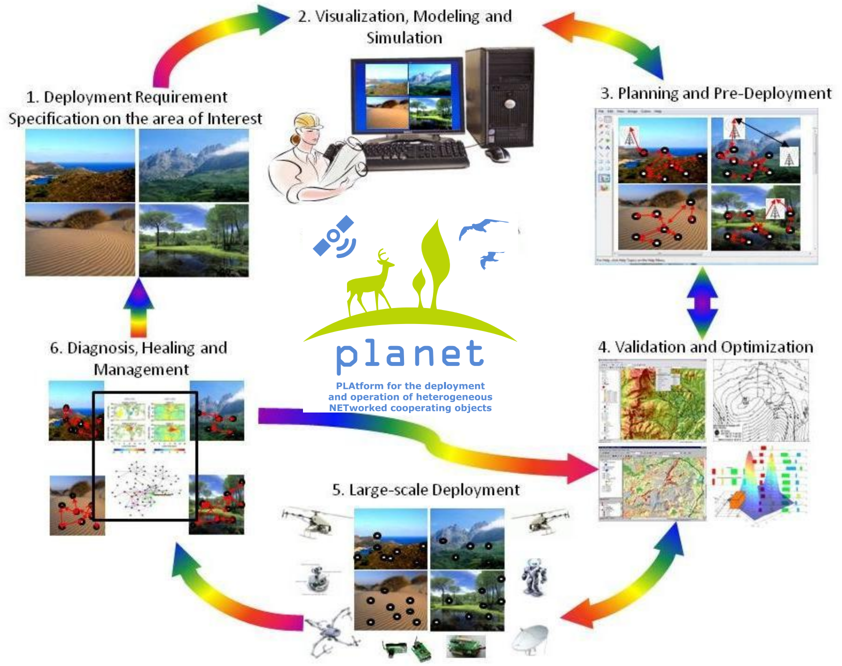
PLANET: PLAtform for the deployment and operation of heterogeneous NETworked Cooperating Objects

EU-FP7 Integrated Project

PLANET Objectives and Approach

The design, development and validation of an integrated platform to enable the smarter deployment, cost effective operation and maintenance of large scale complex systems of heterogeneous networked Cooperating Objects, including Wireless Sensor and Actuator Networks and mobile objects.

Objectives
O1: Design and development of the PLANET platform
O2: Methods for adaptive network deployment
O3: Autonomous systems for deployment
O4: Distributed network-centric computing
O5: Security methods
O6: Validation DBR
O7: Validation Airfield



PLANET Experimental Facilities

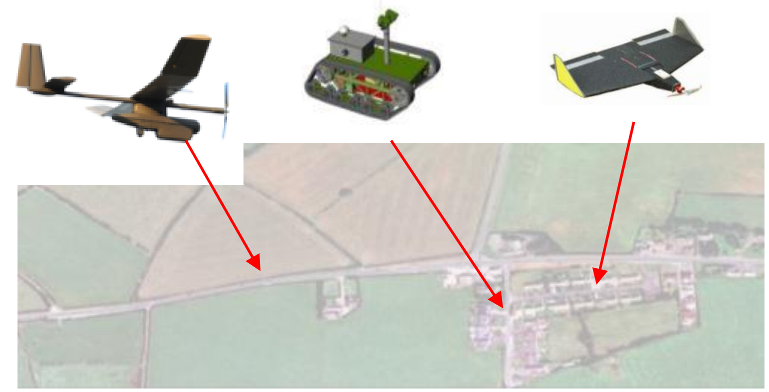
Environment:
Doñana Biological Reserve

Declared World Heritage Site in 1994. Part of the EU Large Scale Facilities.

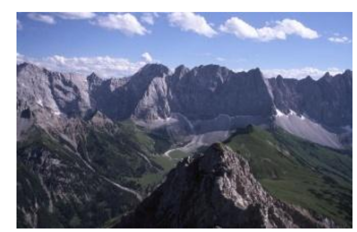
Critical infrastructures and vehicles:
Airfield Scenario

New UAV airfield facility (4.1 M euros) for Air Traffic Management and UAV experimentation.

Other case study Scenarios



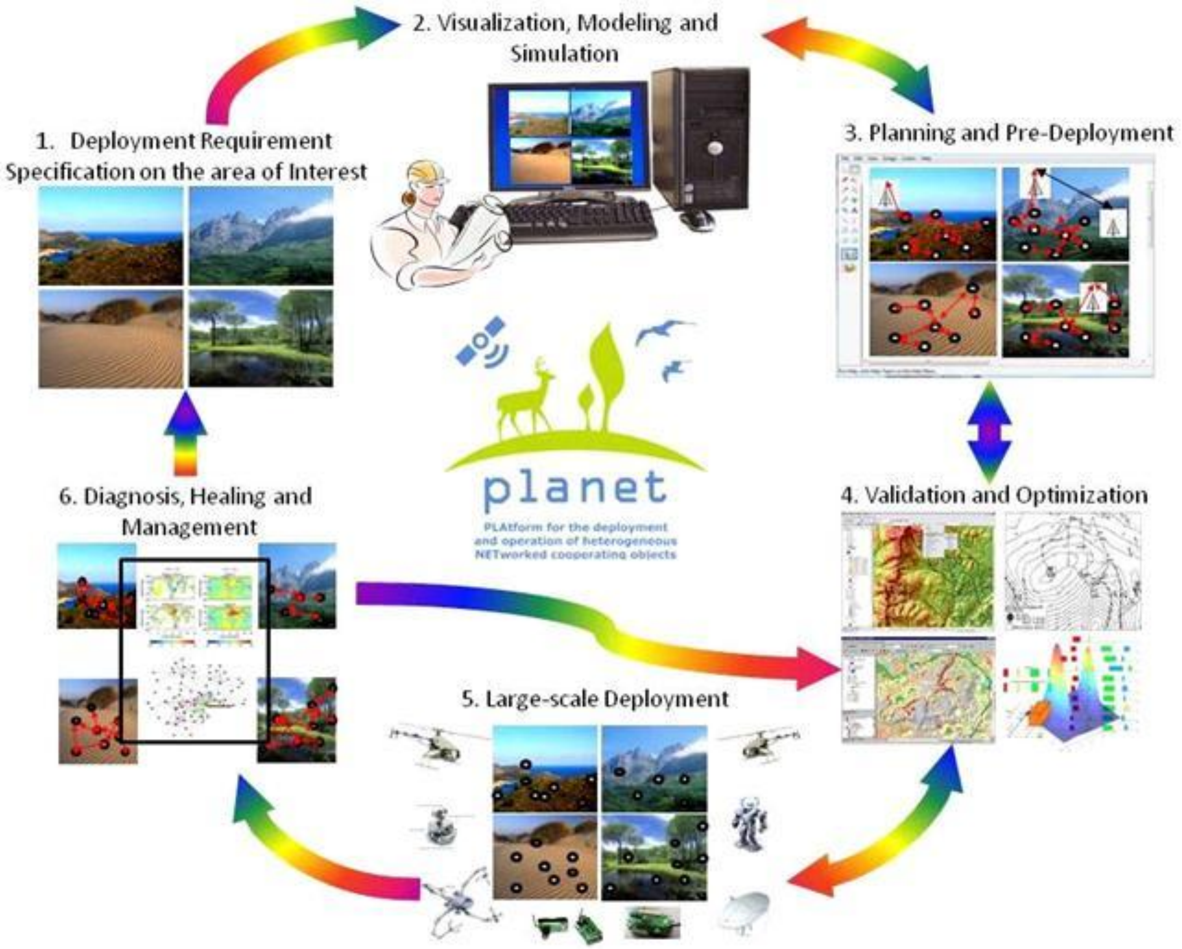
Saturn Scenario, Grand Challenge **, UK**
Bavarian forest monitoring



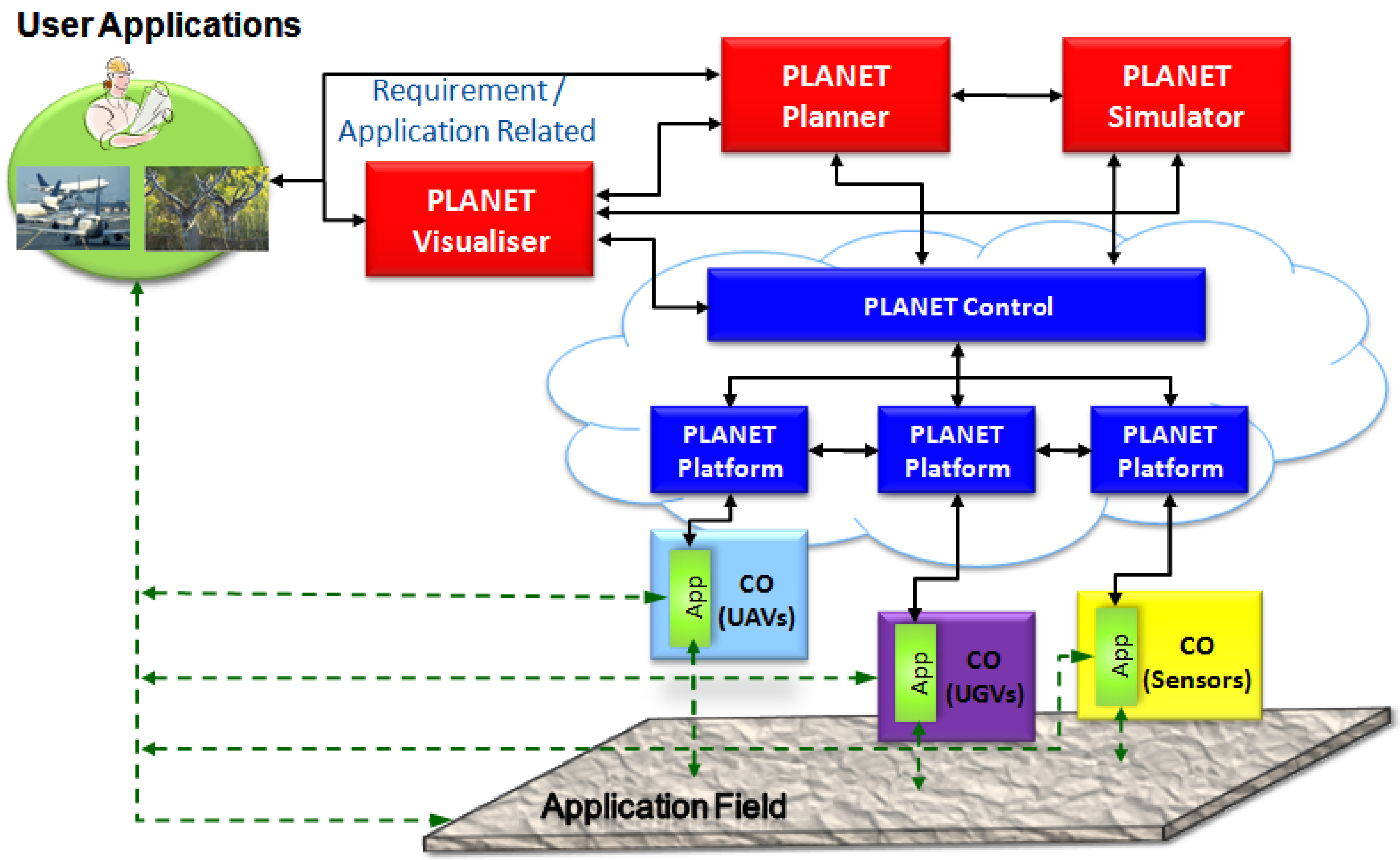
PLANET Metadata

- Integrated Project with number INFSO-ICT- 257649
- Start: October 1st, 2010, End: September 31st, 2014, Duration: 48 months
- EC approved funding: 4.9 Mio. €
- Total Budget: 6.95 Mio. €
- Partners:
  - 7 academic partners
  - 5 industrial partners

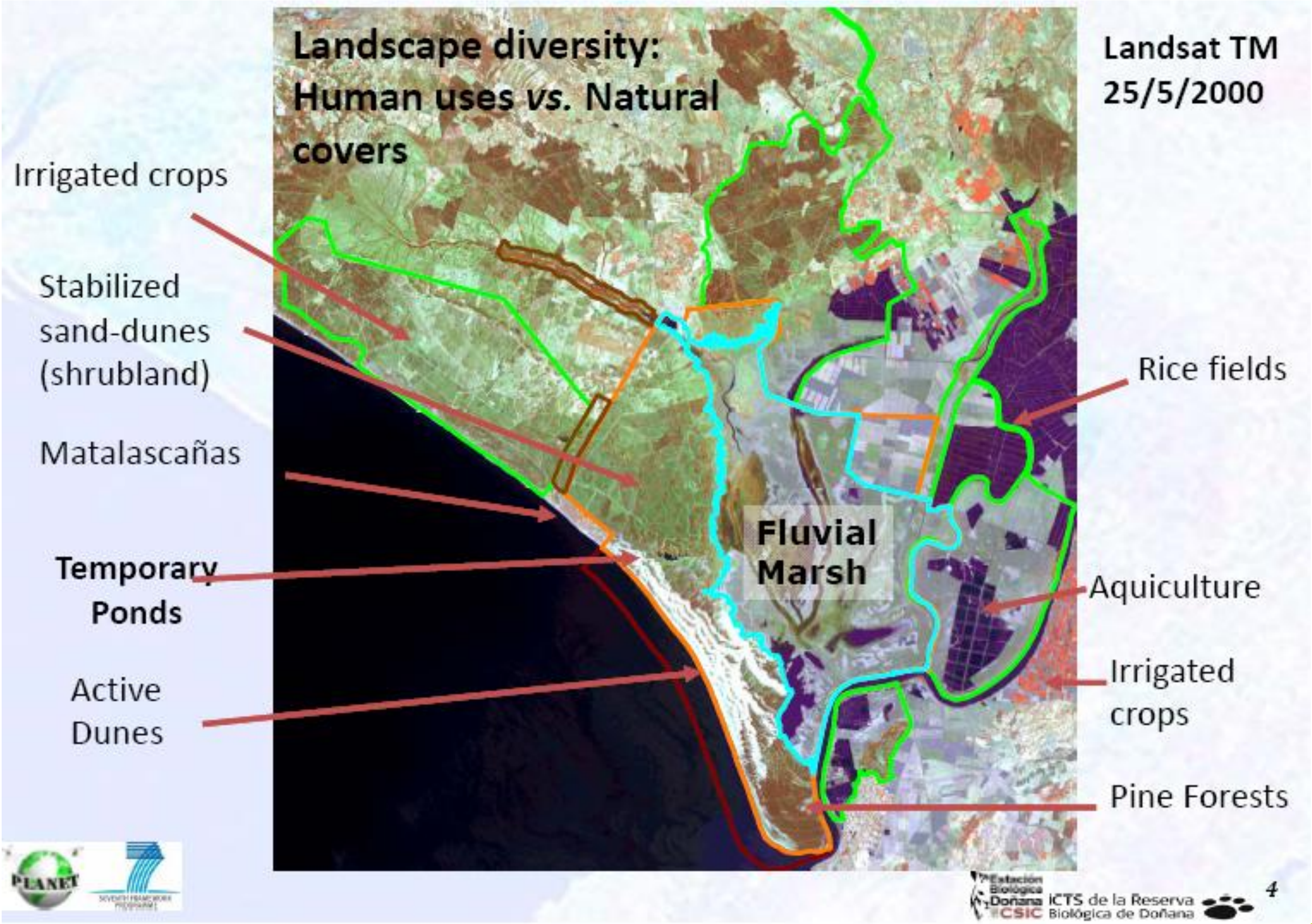
PLANET Approach



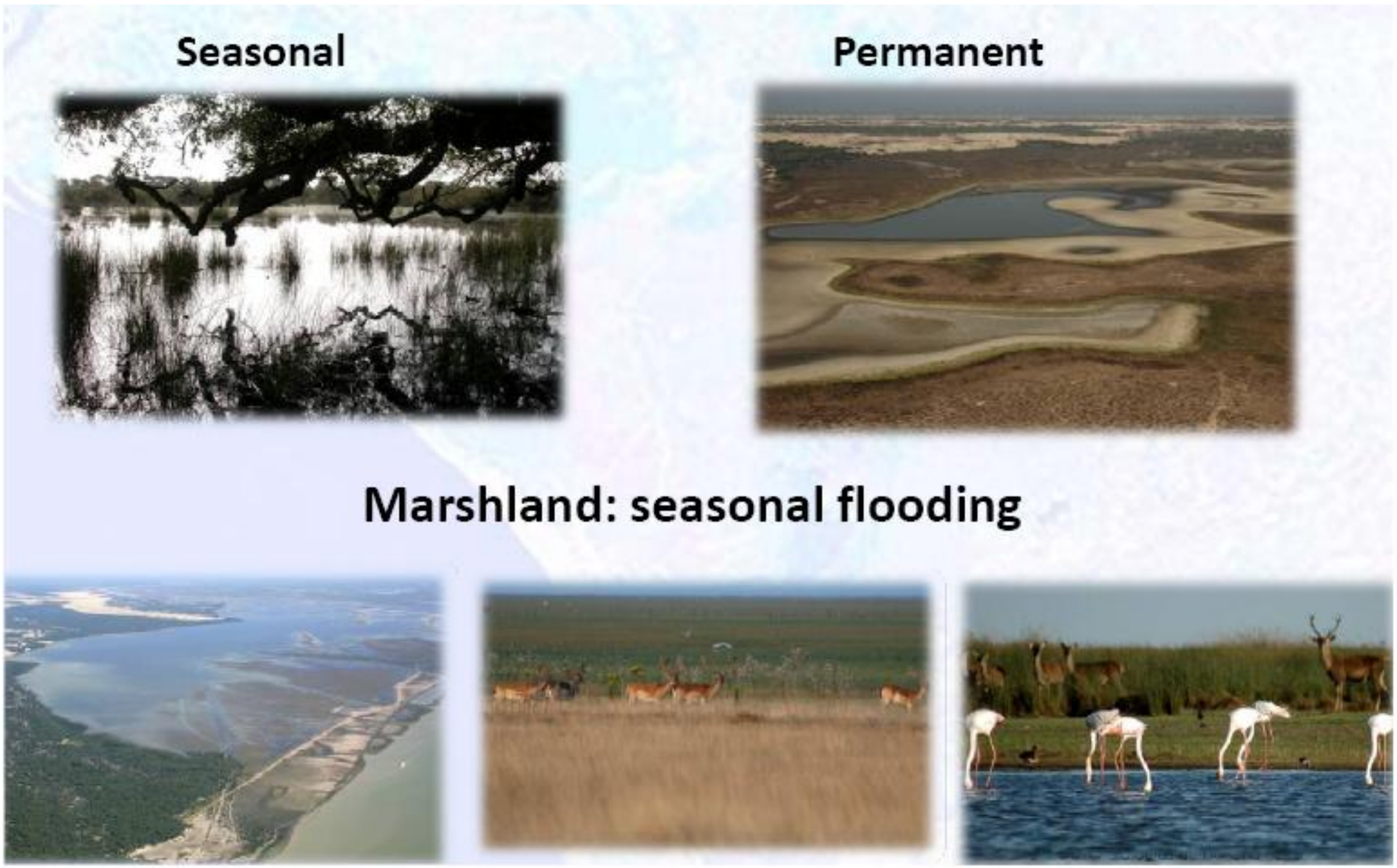
PLANET Architecture



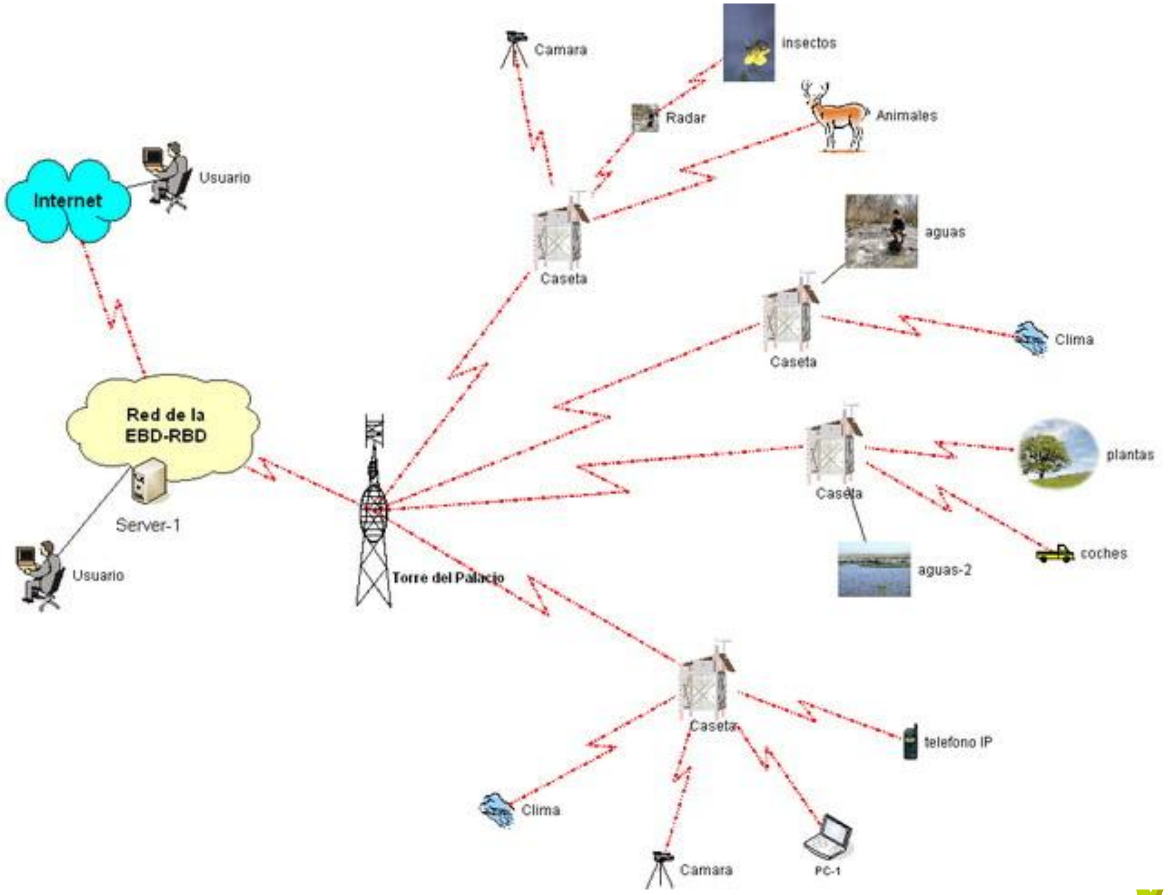
Doñana scenario



Doñana scenario



ICTS Infrastructure at Doñana



Doñana applications

- Pollution monitoring
- Monitoring of groups of animals
- Analysis of transmission of diseases
- Document of Grey Goose
- Aerial stratification of bats and insects

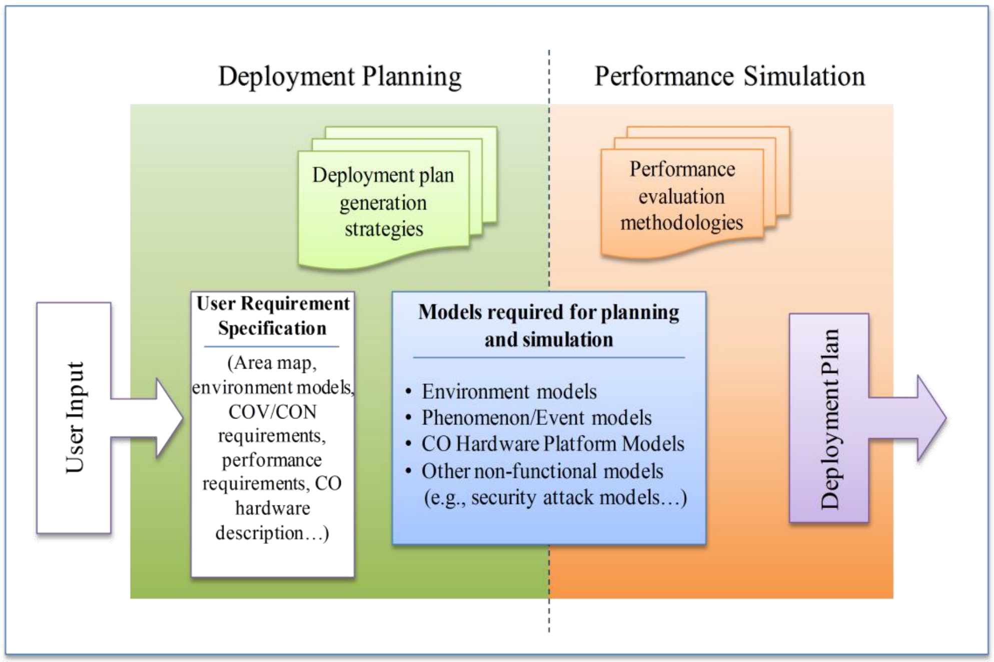
Pollution monitoring application

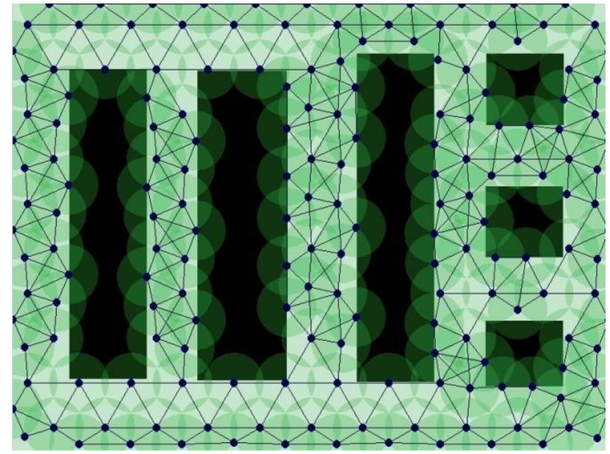
- These situations could be:
  - Episodes of water pollution by pesticides from agricultural activities in the environment: heavy metals, nitrates, phosphates…
  - Untreated water from nearby towns to the environment.
  - Toxic algae blooms, which can cause mass mortality of fish and birds.

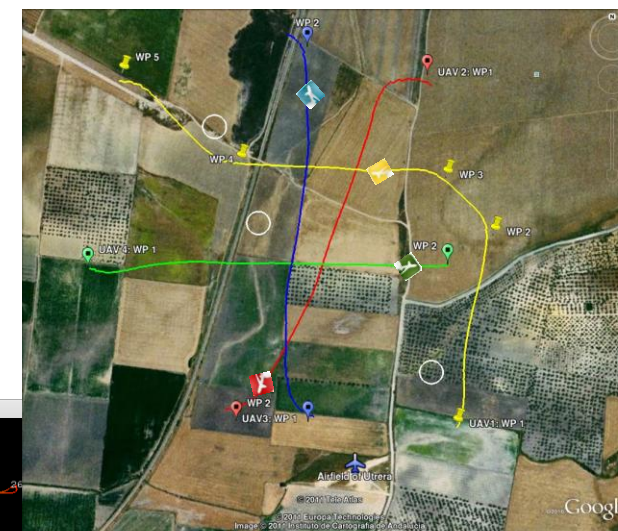
Pollution monitoring scenario

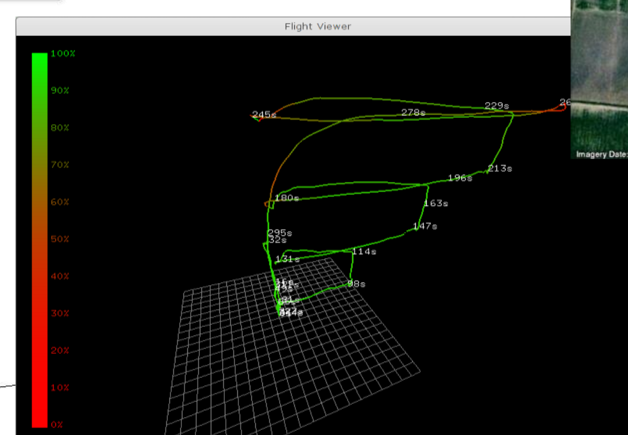
- **Scenario:**
  - **Very large (km^2)**
  - **Difficult accessibility (marshland)**
  - **Global information as well as detailed information**
- **PLANET functionalities:**
  - **Surveillance with Unmanned Aerial Systems**
  - **WSN deployment with Unmanned Aerial Systems**
  - **WSN data collection with Unmanned Aerial Systems**
  - **Pollution sampling using Unmanned Aerial Systems**

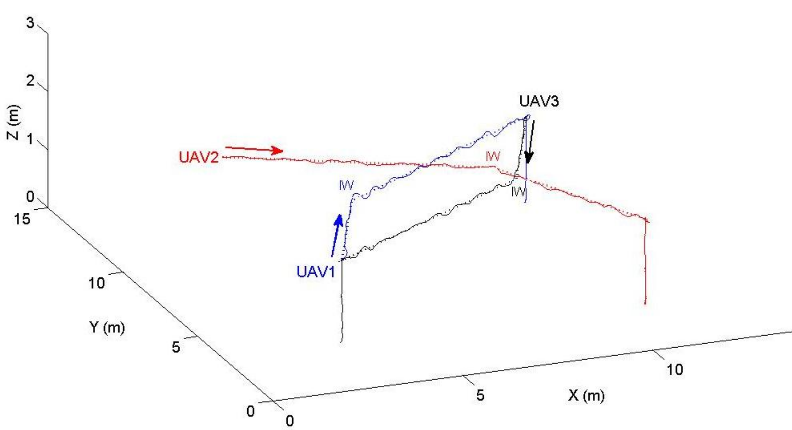
Planning and Simulation











Current Working Problem

- **Deployment planning for pollution monitoring**

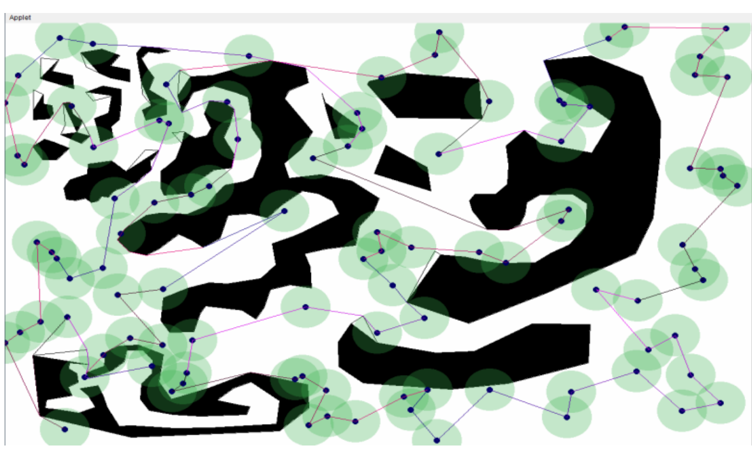
Objectives

- **Minimize the # of sensor to achieve required coverage**
- **Additional consideration: geographical irregularity of sensing events**

→ Mash presentation approaches

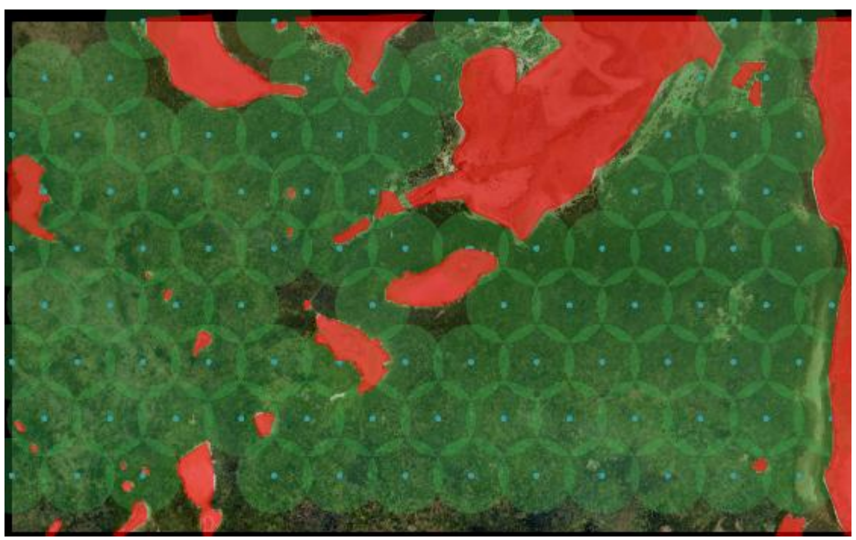
Pre-Deployment Strategies

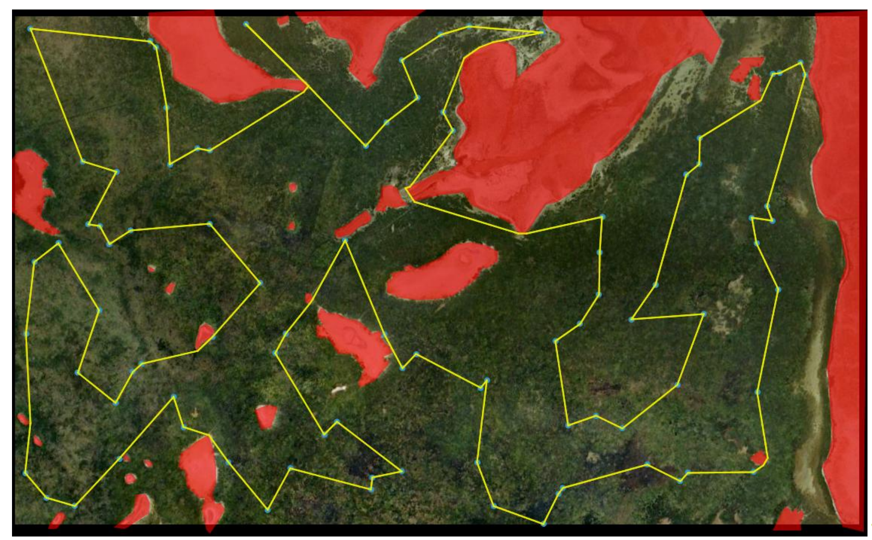
- **Our goal**
  - **To provide deployment planning strategies for the static and mobile WSN applications to meet their requirements with respect to** *sensing coverage, network connectivity* **and** *data collection***.**
- **Two groups of pre-deployment strategies**
  - **Ones for the static sensor networks**
  - **Ones for the mobile sensor networks**



Pre-deployment strategies

- **Static WSN deployment**
  - **Coverage**
  - **Connectivity**
- **Mobile WSN deployment**
  - **Waypoint planning + obstacles**
  - **Dijkistra + TSP + SA**



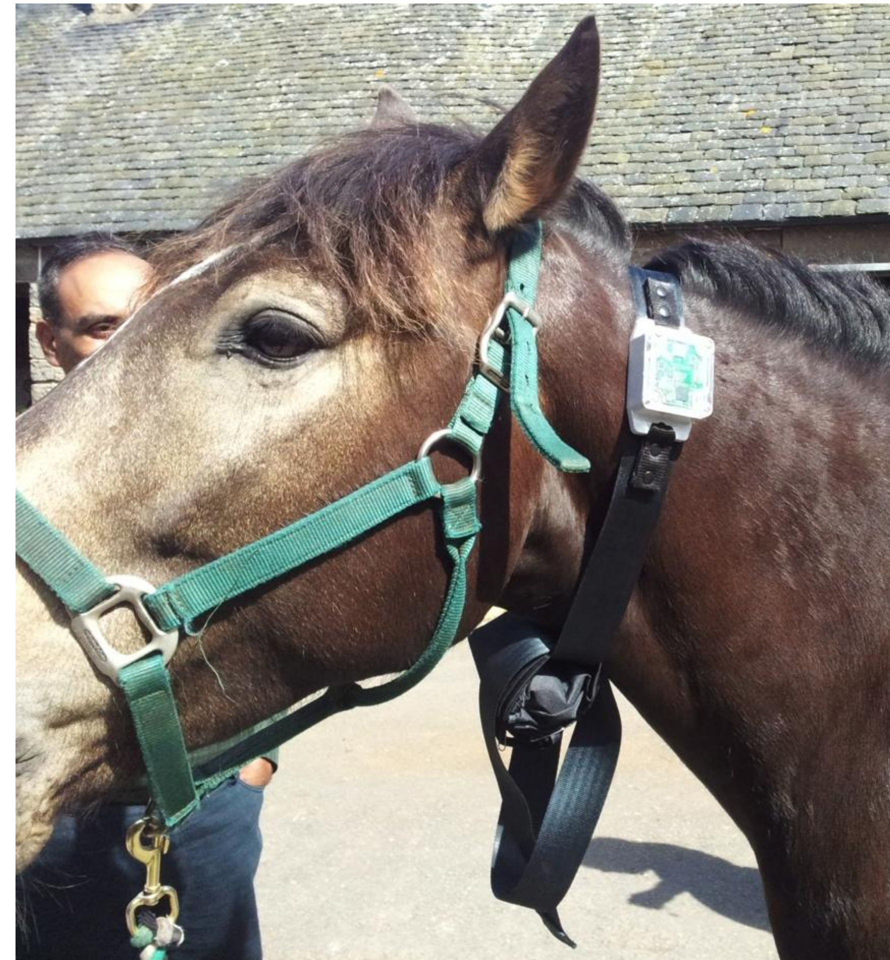


Horse monitoring application

- Biologists are interested in monitor certain groups of animals
- Non-intrusive sensors can be mounted on horses
- Ground data collection stations and UAVs can be used to gather the data
- Horses positions can be tracked and logged to see where they live and when they move

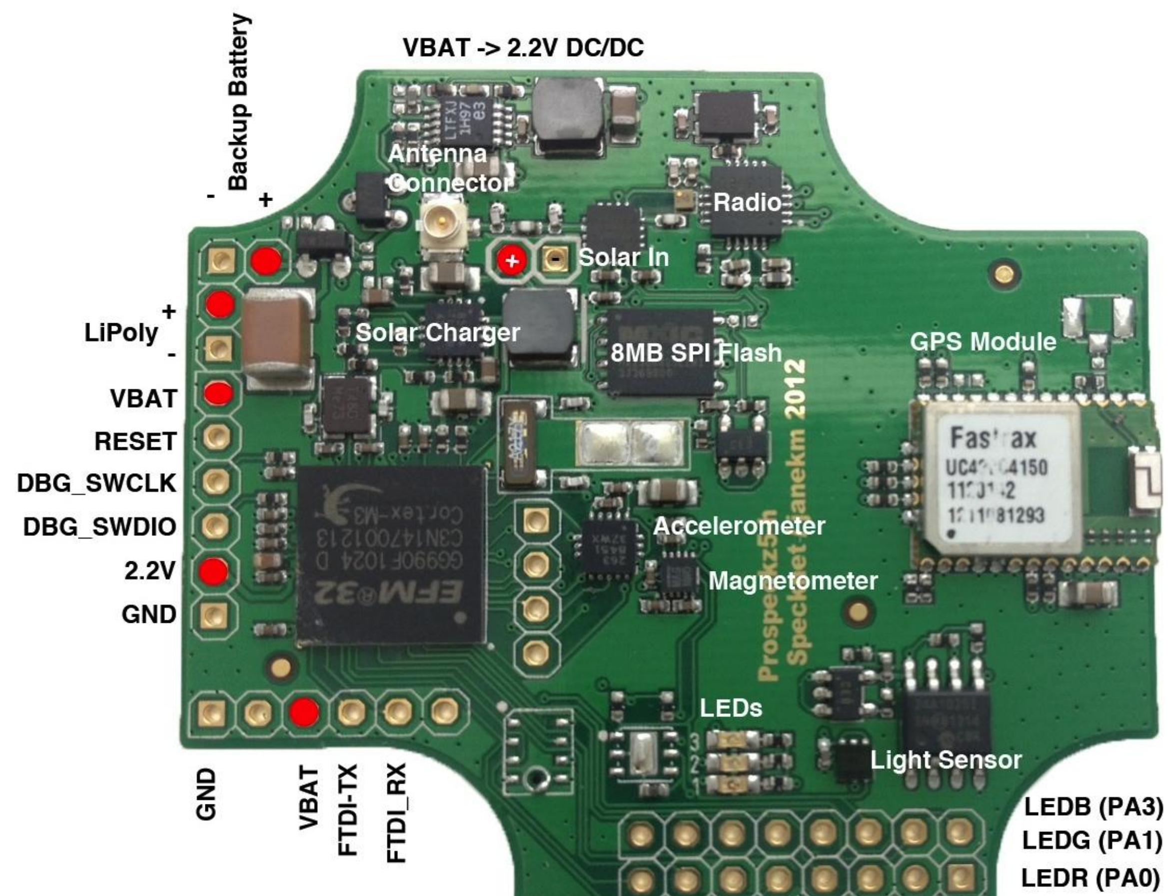
Collar tests





Platform hardware tests with TinyOS port

- **GPS**
- **Accelerometer**
- **Serial communication**
- **Radio communication**
- **Solar cells tests**
- **Battery charging circuit**
- **Flash**
- **Magnetometer**
- **Light sensor**



Environmental Monitoring

- **Biologists are interested in the state of the environment:**
  - **Spatial distribution of environmental factors (i.e. temperature)**
  - **Temporal distribution of environmental factors**
- **Objectives:**
  - **Take advantages of deployed WSNs**
  - **Data Processing: Spatio/temporal interpolation of missing data**
  - **Error estimation of gathered and derived values**

Using a WSN for environmental monitoring

Pros

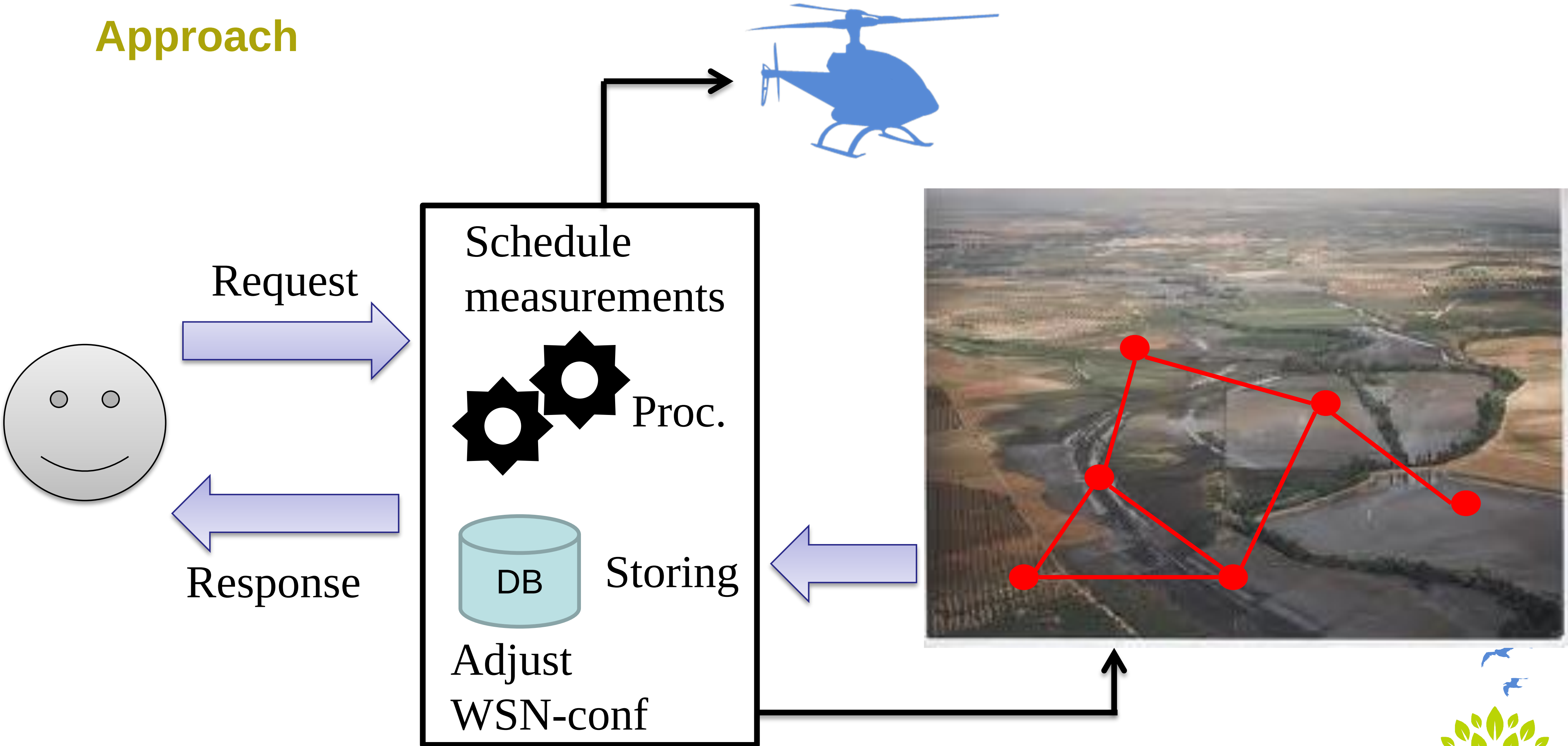
- Easy and cheap to deploy
- Easy and cheap to maintain
- Possible to cover large areas
- Mobile measurements

Cons

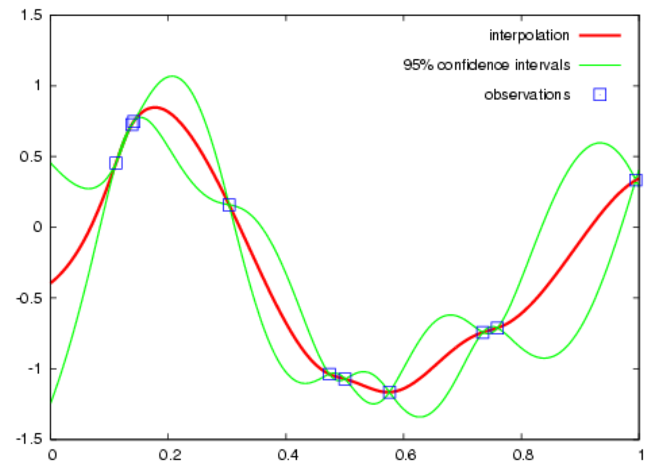
Measurements are

- Sparse
- Inaccurate
- Delayed
- Unreliable
- Timely discrete

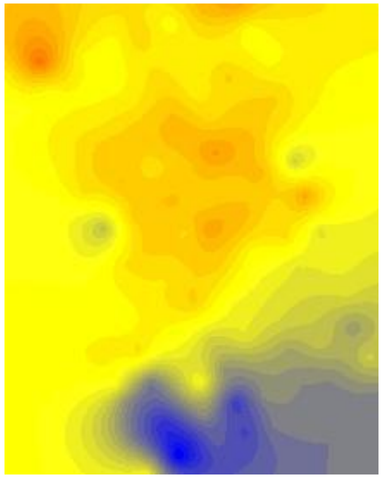
Approach


Request
Response
Schedule
measurements
Proc.
DB
Storing
Adjust
WSN-conf

Approach

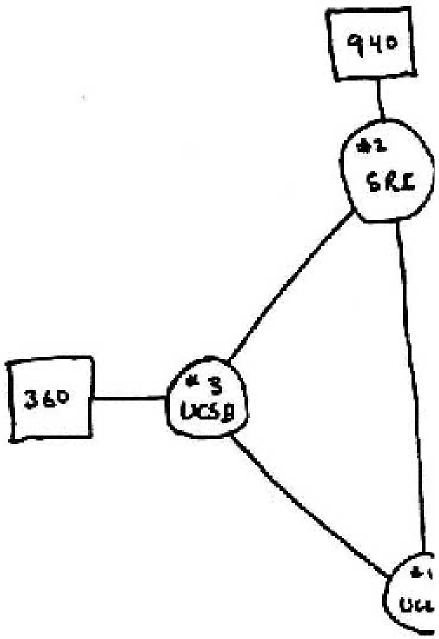


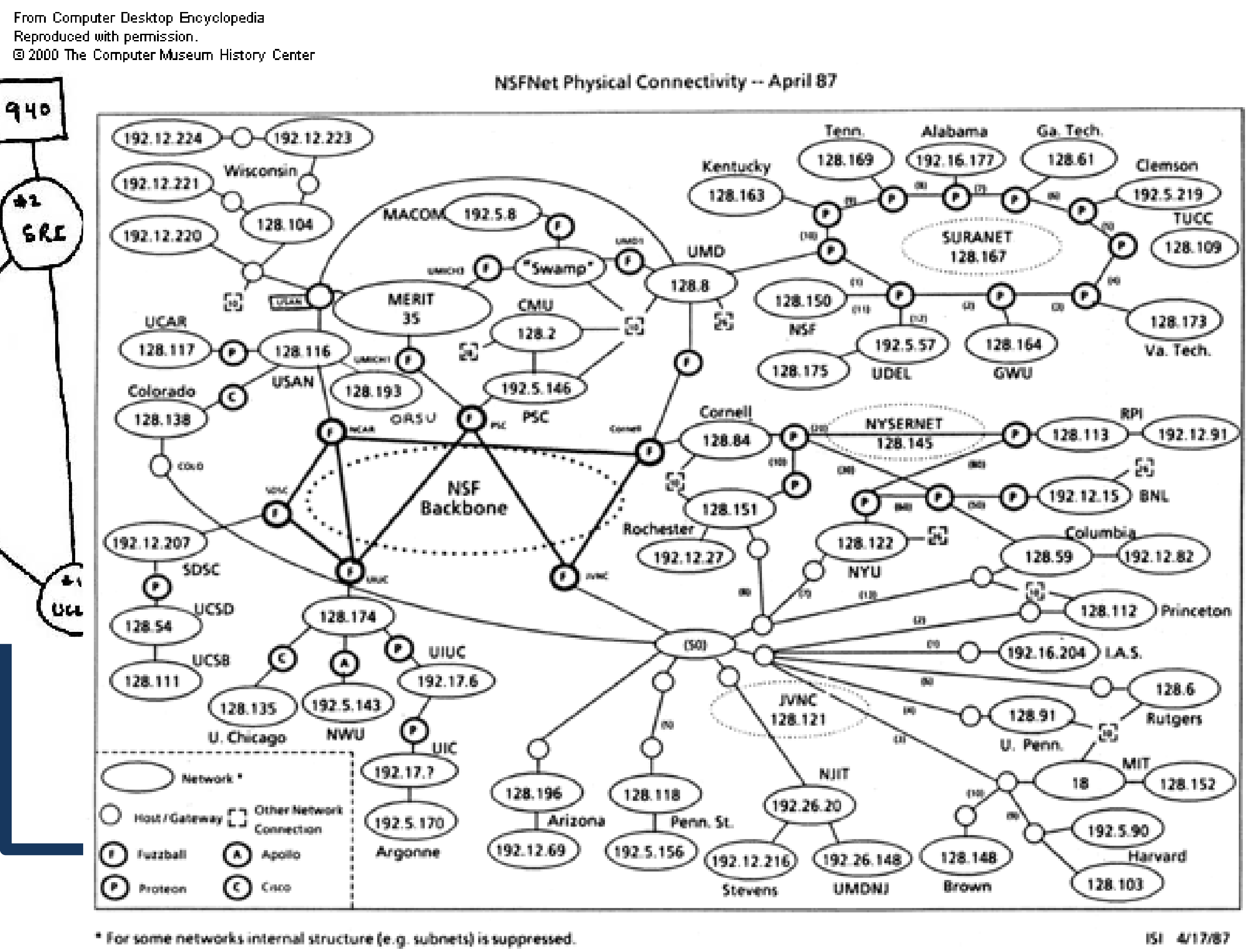
- **Spatio-Temporal Interpolation:**
  - **LMS**
  - **Kalman filters**
  - **Kriging**
  - **Bayesian Based Modelling**
  - **Inverse distance weighting**
  - **Regression**

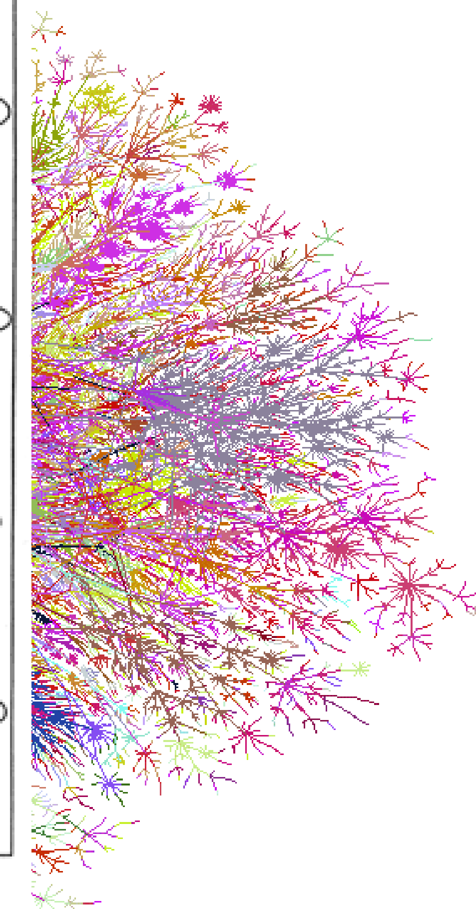


- **Main Research Challenges:**
  - **Distributed/Scalable interpolation**
  - **Quality estimation**
  - **Query planning**

Comparison to “normal” Internet

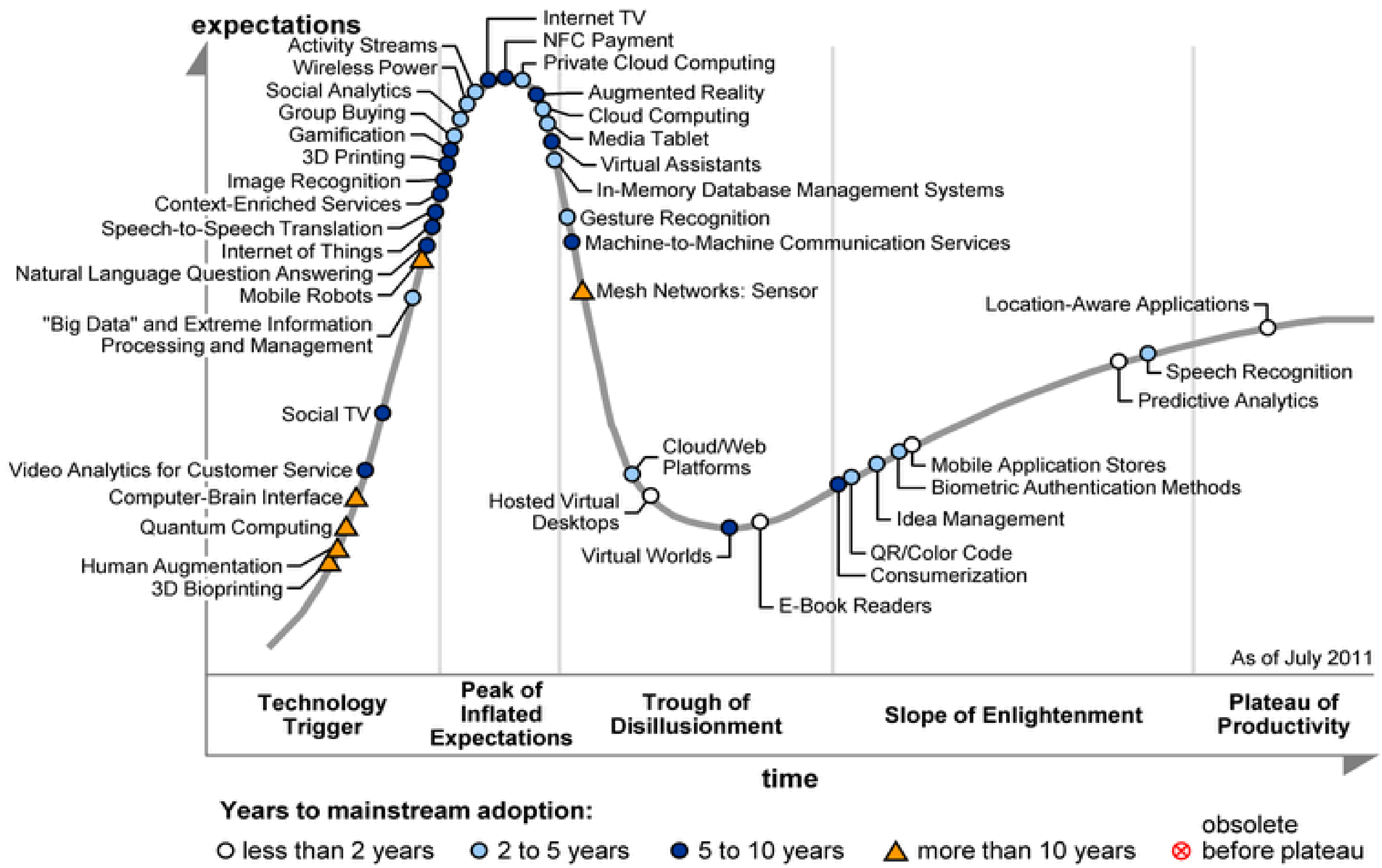






Source: Plyojump – Computer History

Lots of Hard Work Ahead



Source: Gartner 2011

Are We Ready to Go Large-Scale?

Not yet but we are getting there!

Thank you for your attention!