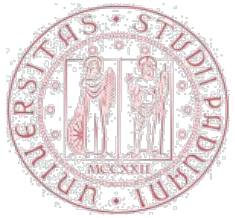

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Smart Cities: potential & challenges

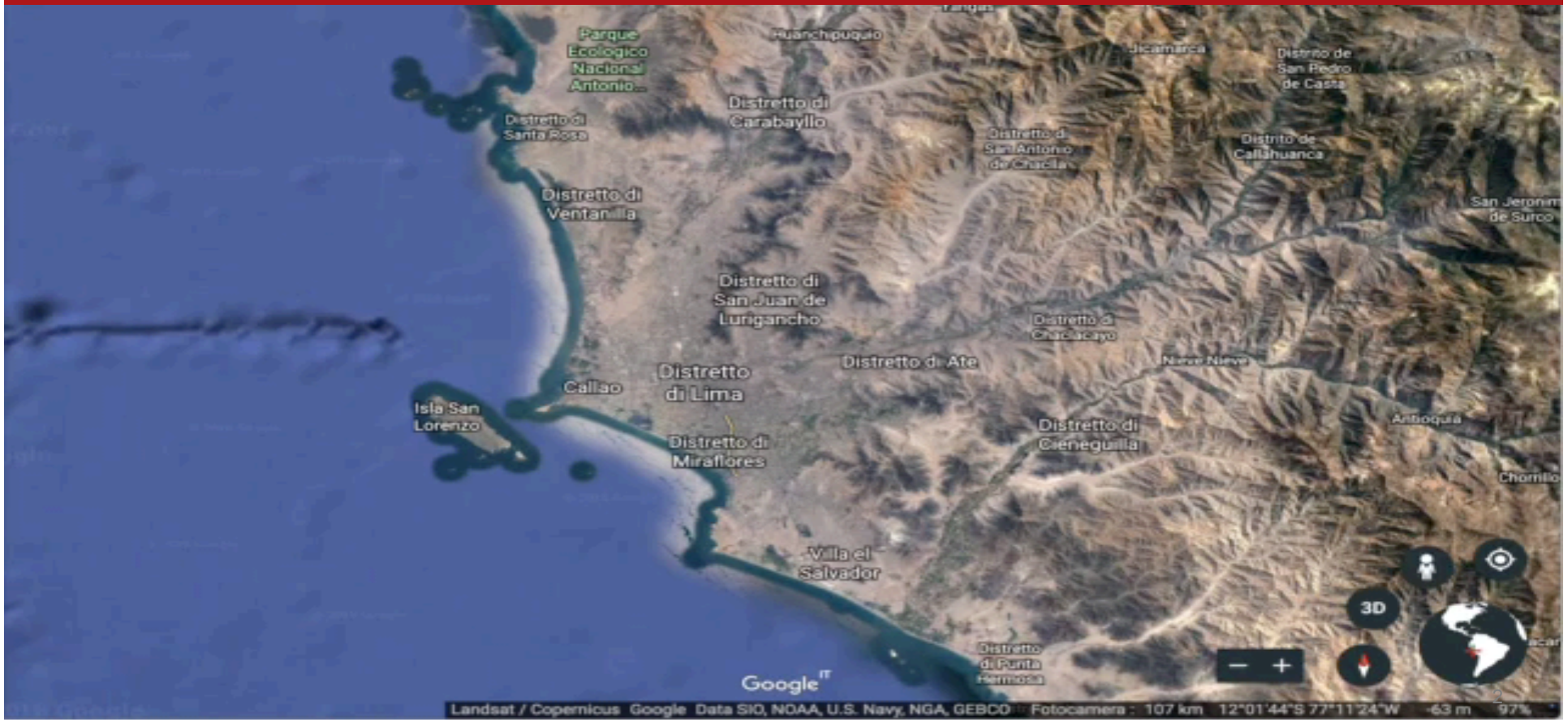
Andrea Zanella

zanella@dei.unipd.it

International Congress of Systems Engineering

CIIS 2018 – Lima - Perù

From Lima to Padova



Smart Cities:

potential & challenges

One (supposedly) successful story

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The key to success

Internet of Things for Smart Cities

Andrea Zanella, *Senior Member*, *IEEE*, Nicola Bui, Angelo Castellani,
Lorenzo Vangelista, *Senior Member*, *IEEE*, and Michele Zorzi, *Fellow*, *IEEE*

***Abstract*—The Internet of Things (IoT) shall be able to incorporate transparently and seamlessly a large number of different and heterogeneous end systems, while providing open access to selected subsets of data for the development of a plethora of digital services. Building a general architecture for the IoT is hence a very complex task, mainly because of the extremely large variety of devices, link layer technologies, and services that may be involved in such a system. In this paper, we focus specifically to an urban IoT system that, while still being quite a broad category, are characterized by their specific application domain. Urban IoTs, in fact, are designed to support the Smart City vision, which aims at exploiting the most advanced communication technologies to support added-value services for the administration of the city and for the citizens. This paper hence provides a comprehensive survey of the enabling technologies, protocols, and architecture for an urban IoT. Furthermore, the paper will present and discuss the technical solutions and best-practice guidelines adopted in the Padova Smart City project, a proof-of-concept deployment of an IoT island in the city of Padova, Italy, performed in collaboration with the city municipality.**

sensors, actuators, displays, vehicles, and so on, the IoT will foster the development of a number of applications that make use of the potentially enormous amount and variety of data generated by such objects to provide new services to citizens, companies, and public administrations. This paradigm indeed finds application in many different domains, such as home automation, industrial automation, medical aids, mobile healthcare, elderly assistance, intelligent energy management and smart grids, automotive, traffic management, and many others [2].

However, such a heterogeneous field of application makes the identification of solutions capable of satisfying the requirements of all possible application scenarios a formidable challenge. This difficulty has led to the proliferation of different and, sometimes, incompatible proposals for the practical realization of IoT systems. Therefore, from a system perspective, the realization of an IoT network, together with the required backend network services and devices, still lacks an established best practice because

The fundamental question…

What **is** a Smart City?

Your point of view

1. An ideal place, where life is good, air is clean, and there is no traffic… and all people work and live together in harmony, cooperating for a better world

http://www.bournmoor.durham.sch.uk/globe-heart/

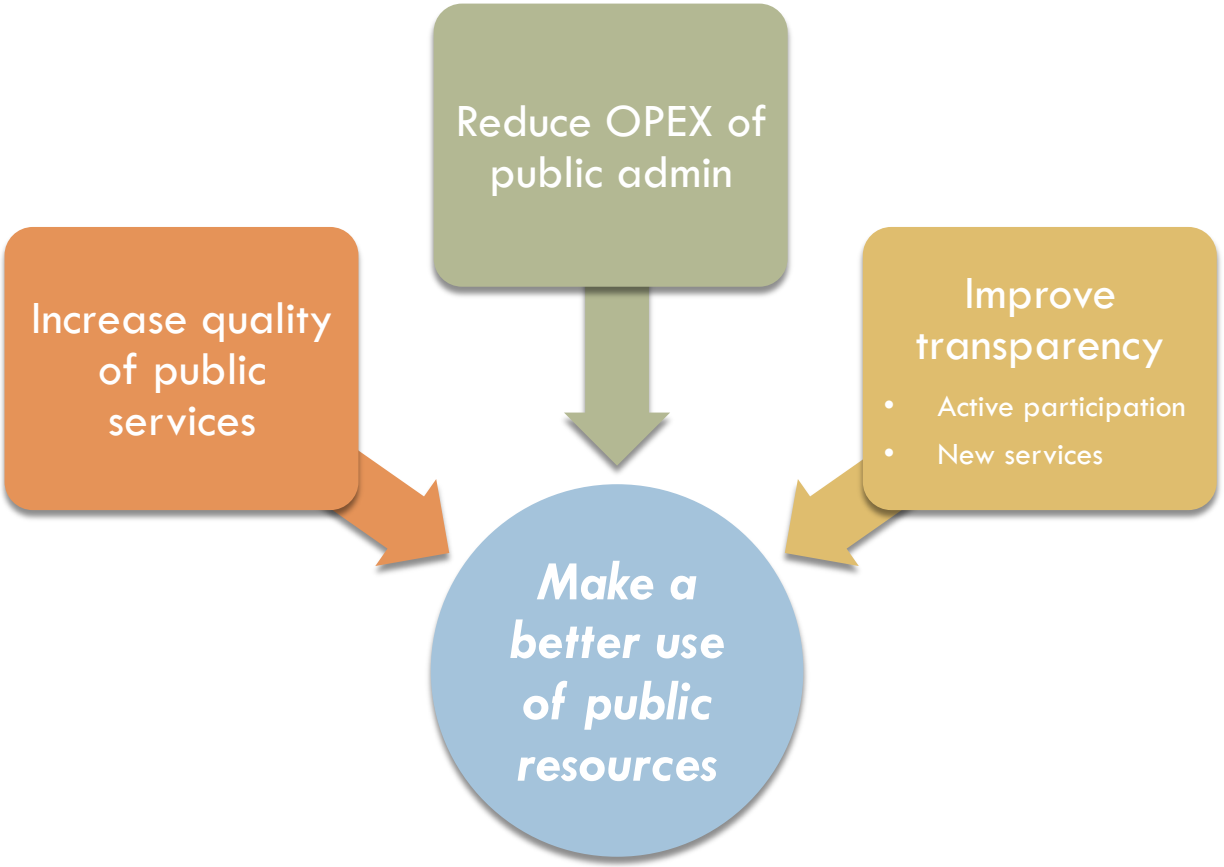
2. A more efficient city, with more fluid traffic, reduced pollution, increased safety, fast and slim bureaucracy, ... no matter how all this is obtained

https://www.researchgate.net/profile/Diane_Cook2

3. A modern city that applies cutting-edge information and communication technologies to collect data, process data, provide digital services… no matter which services

https://internetofbusiness.com/toronto-pilots-new-smart-city-technologies/

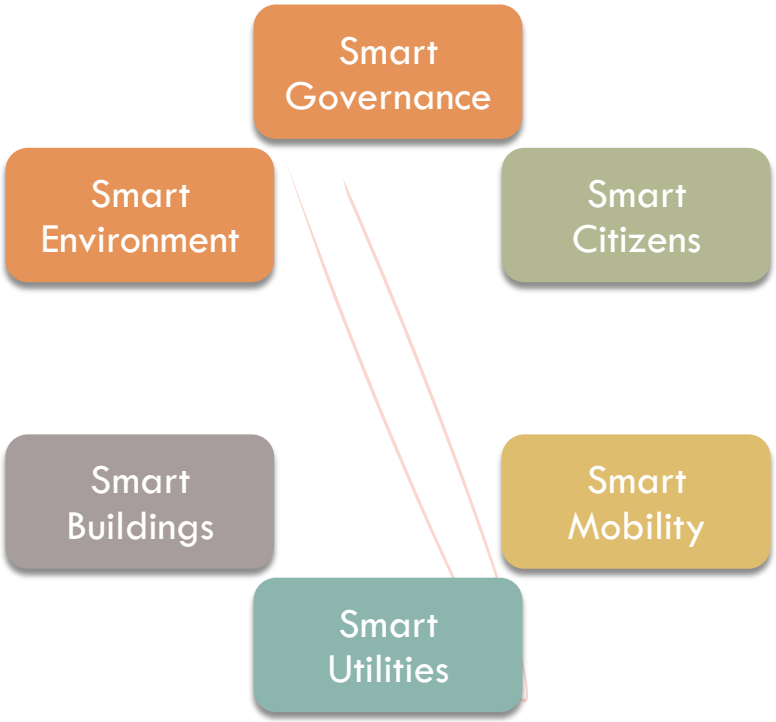
High level Smart City goals



Smart Cities:

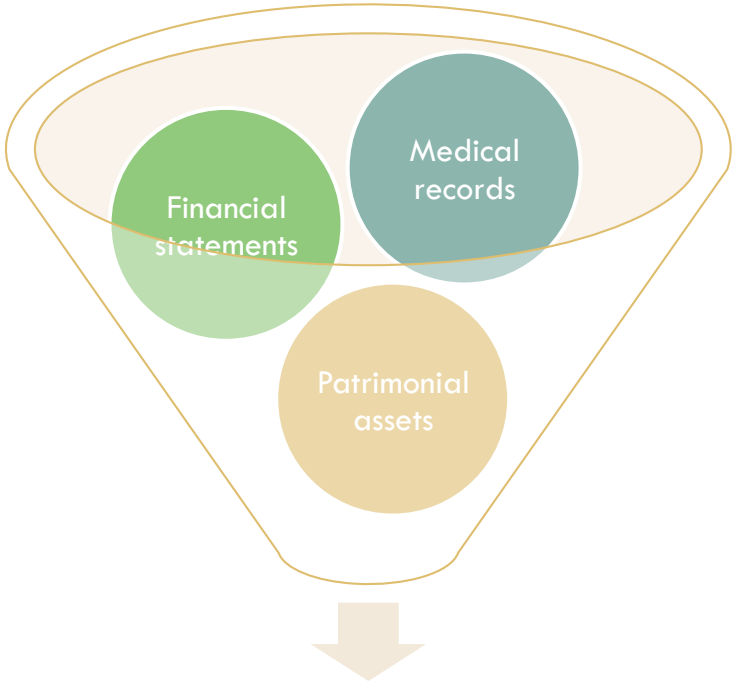
potential & challenges

The 6 pillars of city smartness



On-line public services access today (in Italy)

E-government



One single digital platform

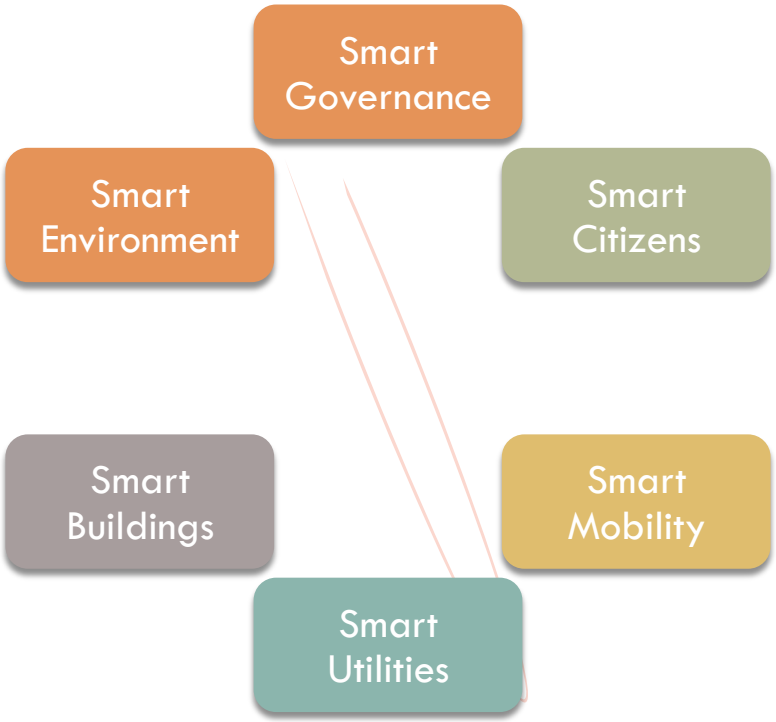
E-government

- **For the citizens**
  - Easy access to all their data (personal, fiscal, education, medical,…)
  - Avoid misalignments among different databases
  - Reduce waste of time (and frustration) of interaction with public offices

E-government

- **For the public admin**
  - Easy access to collective demographic data, corporate data, urban spatial occupancy data, spontaneous communities, …
  - Reduce costs by exploiting the Infrastructure/Platform/Software-as-a-Service (IaaS, PaaS, SaaS) paradighms

Smart city services: smart citizens

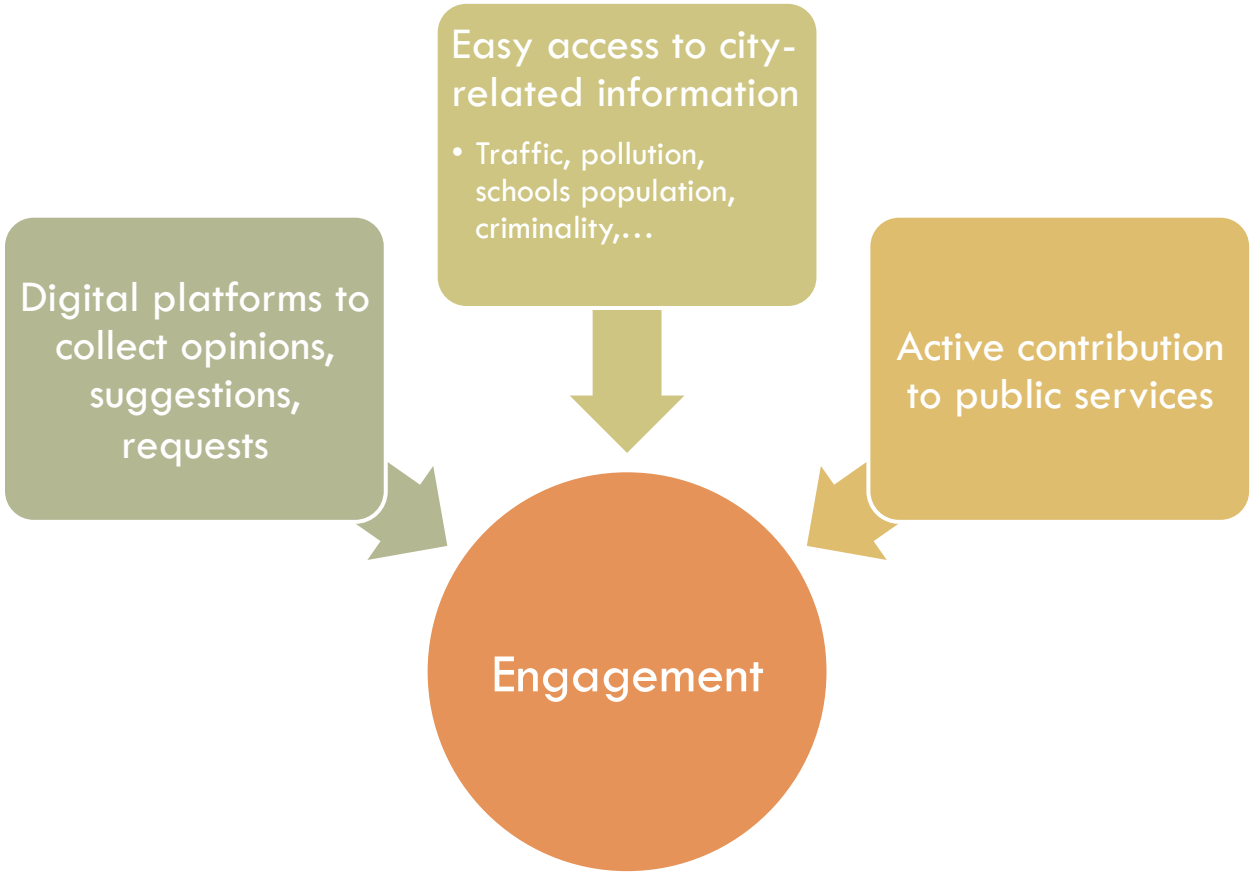


Citizens engagement

- To justify investments, public administrators need to make clear to citizens the long-term vision and the expected return

- Citizens must become an integer part of the Smart City

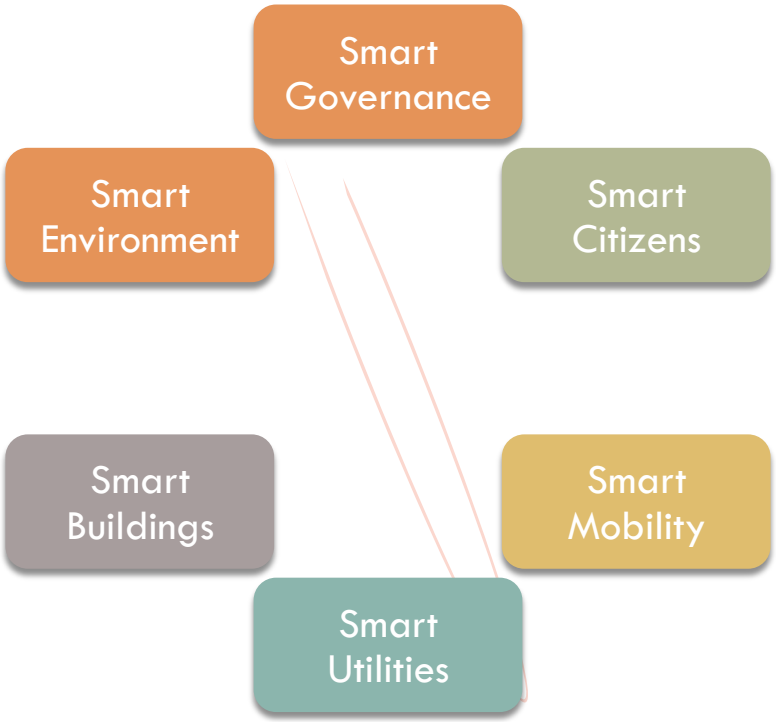
Involving citizens in decision making processes



Example: amsterdam mobypark

- *Amsterdam Smart City Challenge*
- **Mobypark app**
  - owners of parking spaces rent them out to people for a fee
  - data generated from this app can then be used by the City to determine parking demand and traffic flows in Amsterdam

Smart city services: smart mobility

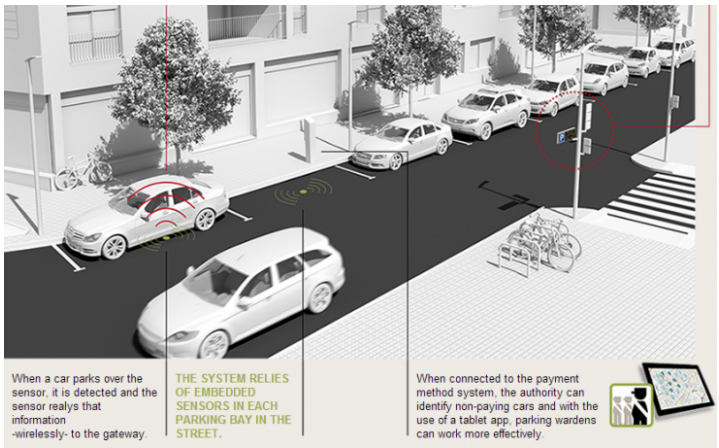


Traffic monitoring

- Many cities already use traffic monitoring cameras in critical points
- Real time accurate traffic monitoring can help
  - administration to discipline traffic and better public transport services
  - citizens to better plan their trip to office
  - street police to promptly detect anomalies in traffic
- Furthermore, traffic flows tell a lot about the city
  - Number and origin of inbound/outbound commuters
  - Crossing traffic
  - City night life…

Smart Parking

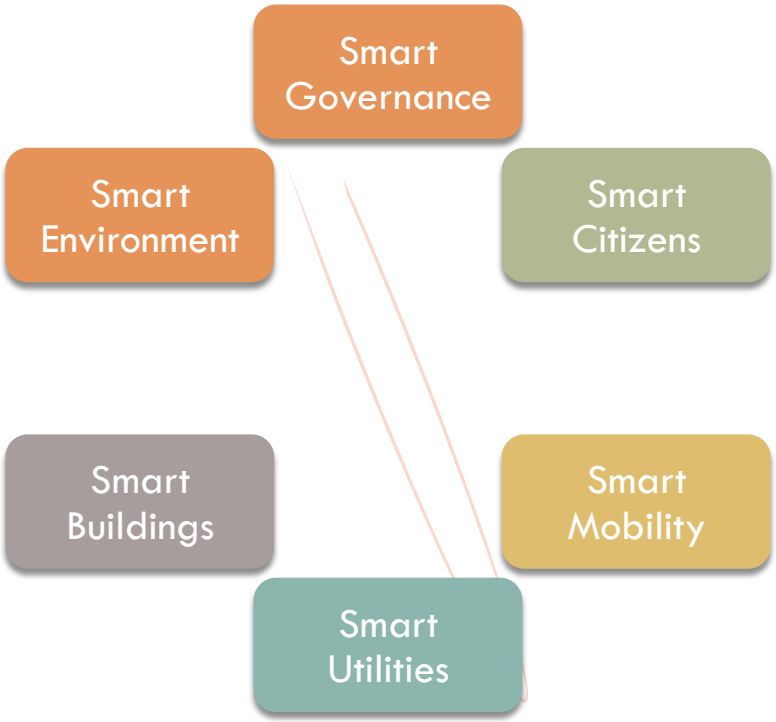
- Place sensors on each parking lot
- Place intelligent boards along the streets
- Provide app for smartphones



Example: smart mobility in Barcelona

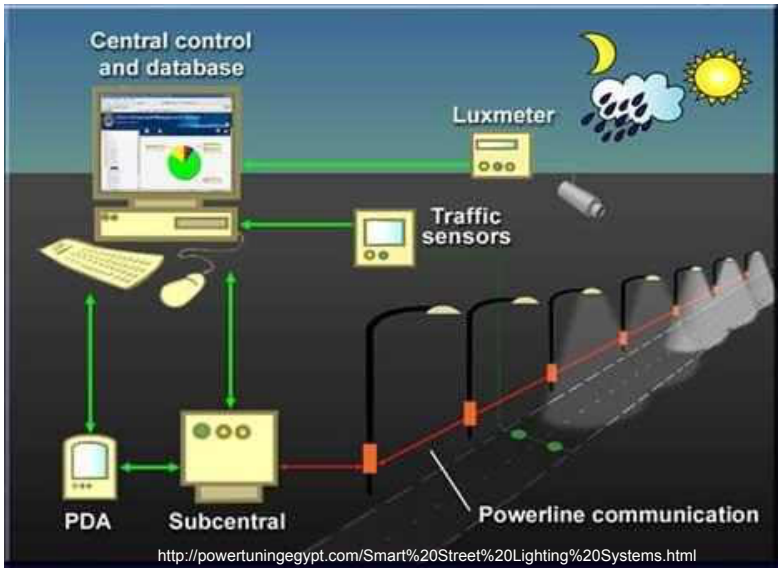
- New bus network
  - vertical, horizontal and diagonal routes with a number of interchanges, based on data analysis of the most common traffic flows in Barcelona
- Smart traffic lights
  - turn green as buses run
  - set up a green-light path in case of emergency, through a mix of GPS and traffic management software

Smart city services: smart utility

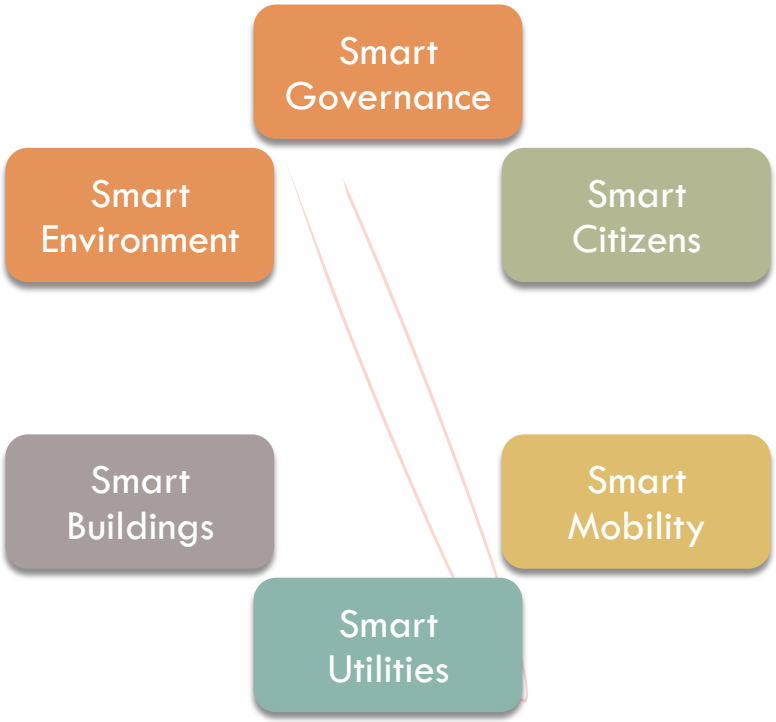


Smart lighting

- Place sensors on street lamps along the road
- Optimize the light intensity according to
  - Time of the day
  - weather conditions
  - presence of people
- Automatically find burned bulbs
  - Reduce replacement time
  - Reduce costs
- Provide WiFi access



Smart city services: smart buildings



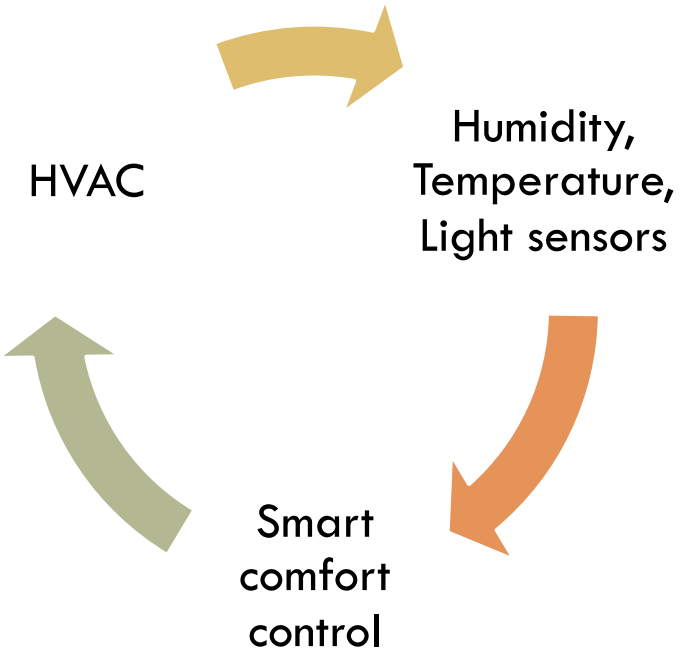
Smart buildings

- Monitoring of conditions of (historical) building
  - Polluting levels
  - Humidity/temperature
  - Vibrations
  - Tension sensors in the structure
- Improve energy efficiency
  - Control temperature, humidity, lighting to enhance comfort while reducing costs
- Keep an eye on structural health of the building
  - E.g., schools, historical buildings…

Comfort and healthiness of living environments

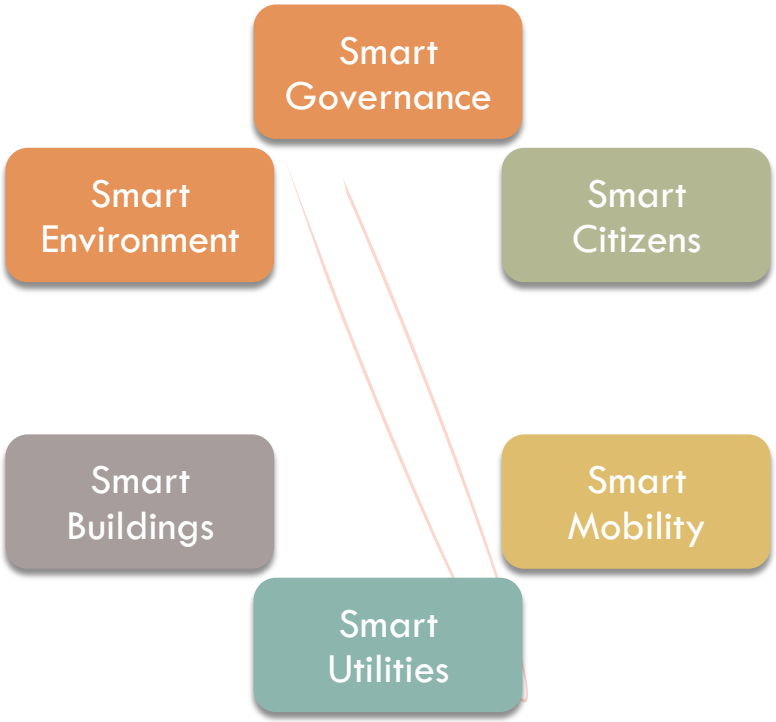
- Closed room
  - CO_2 < 600 ppm
  - CO_2 >1000 ppm
  - CO_2 >2500 ppm
- Experimental study: school Coletti Feb/2009
  - CO_2 level
    - after 30 min → 1950 ppm
    - opening the window for 5 min → 800 ppm
    - outdoor → 600 ppm

Smart living environments



- Same comfort level can be achieved by different combinations of humidy & temperature
- Smart comfort control algorithm finds the configuration that provides the desired comfort level by minimizing the power consumption of Heating Ventilation Air Conditioning (HVAC) system

Smart city services: smart environment



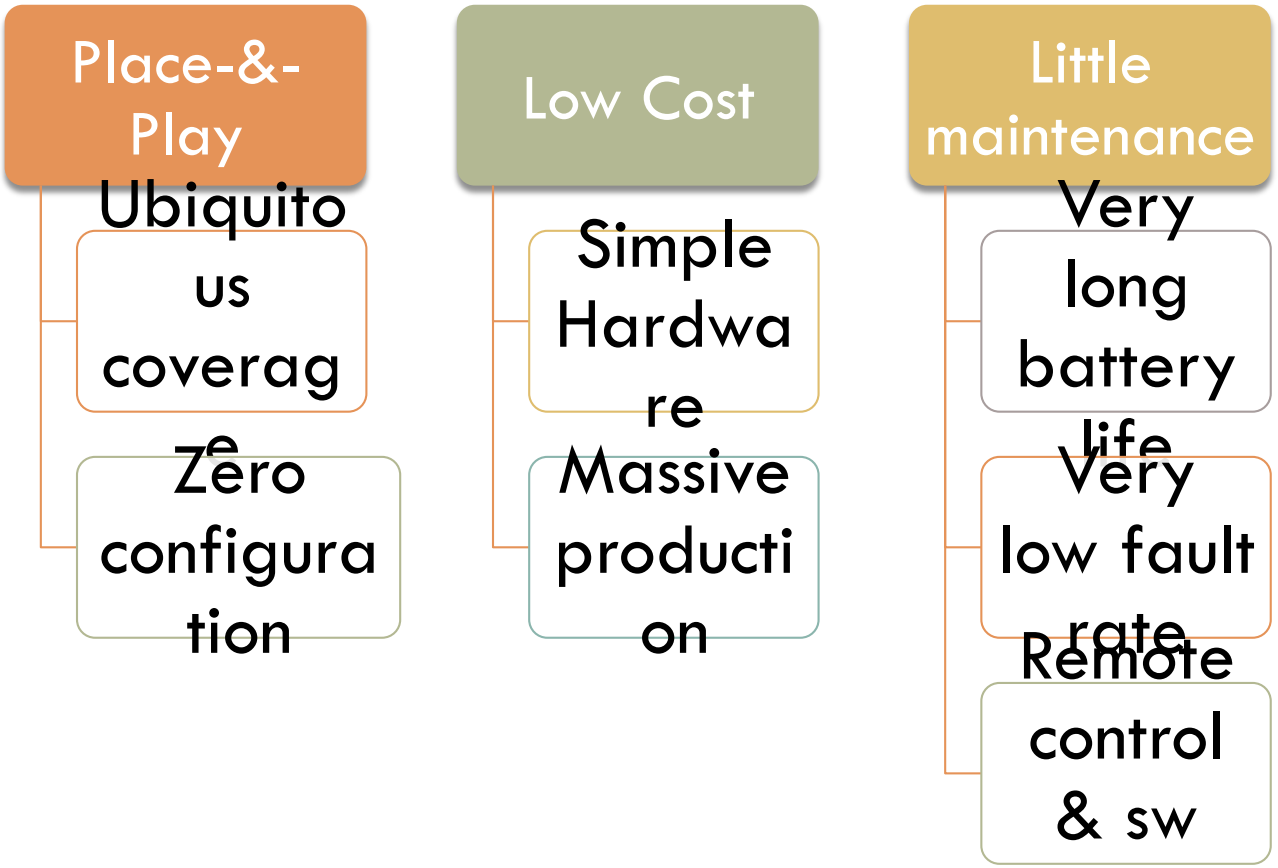
Waste management

- Intelligent waste containers
  - Detect level of load
  - Check quality of garbage
  - Communicate with Internet
- Optimize collector trucks route
  - Reduce costs
  - Improve efficiency
  - Reduce pollution

Smart Cities:

potential & challenges

Smart City Service Requirements



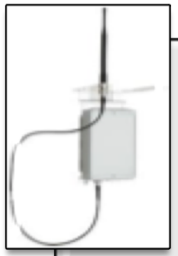
Three main approaches

Short-range multihop

- ZigBee
- WiFi low energy
- RFID

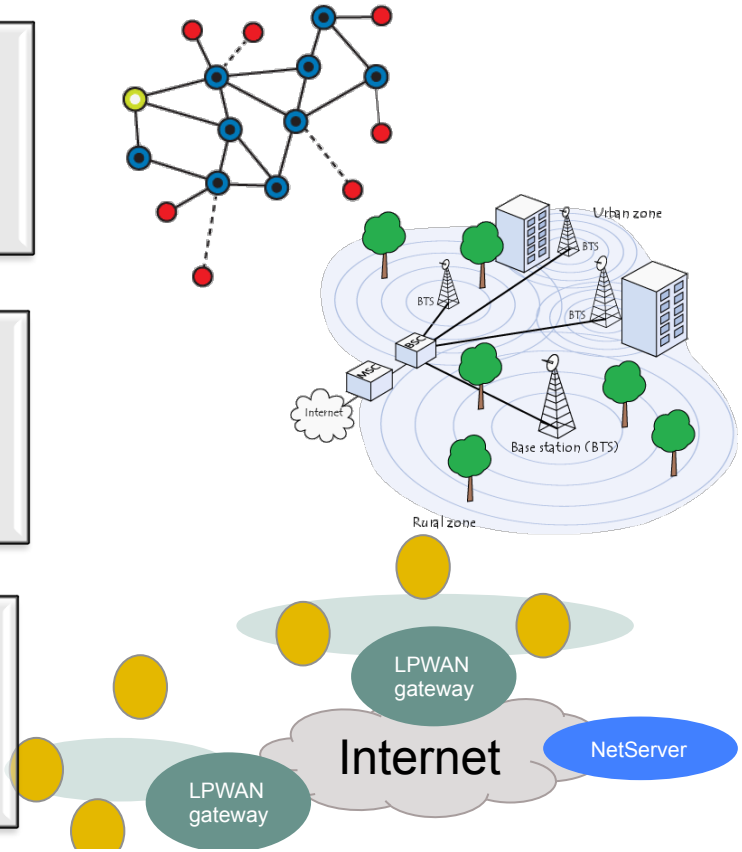
Cellular

- GSM
- LTE-A/NB-IoT
- 5G

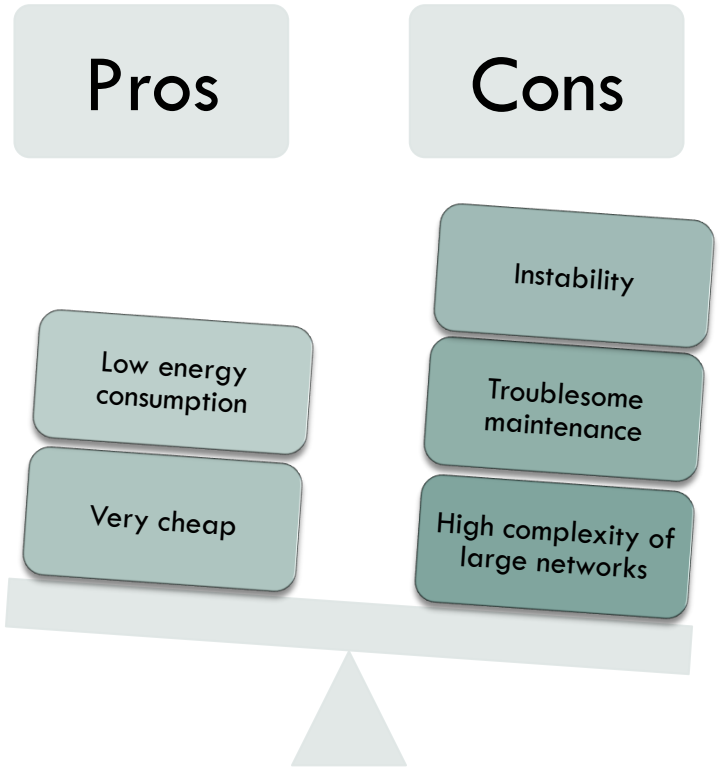


Low Power Wide Area Networks (LPWAN)

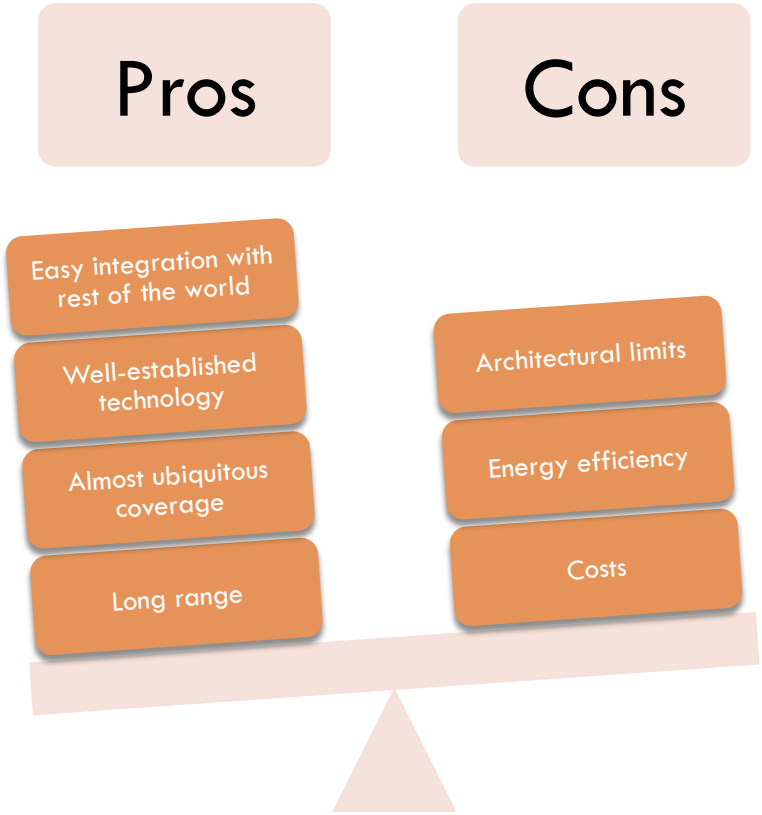
- SIGFOX
- Neul
- LoRa



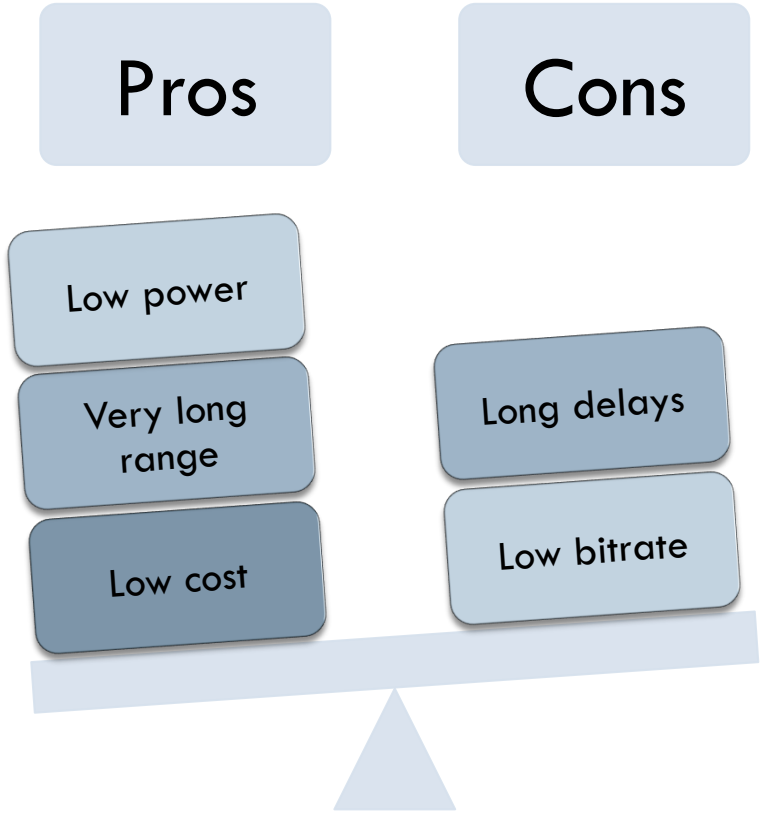
Short range multihop



Cellular-based solutions



LPWAN


Pros
Cons
Low power
Very long range
Low cost
Long delays
Low bitrate

Who is the winner?

- Complementary technologies for different services
- Very likely we will need all of them
- Integration MUST occur at upper layers

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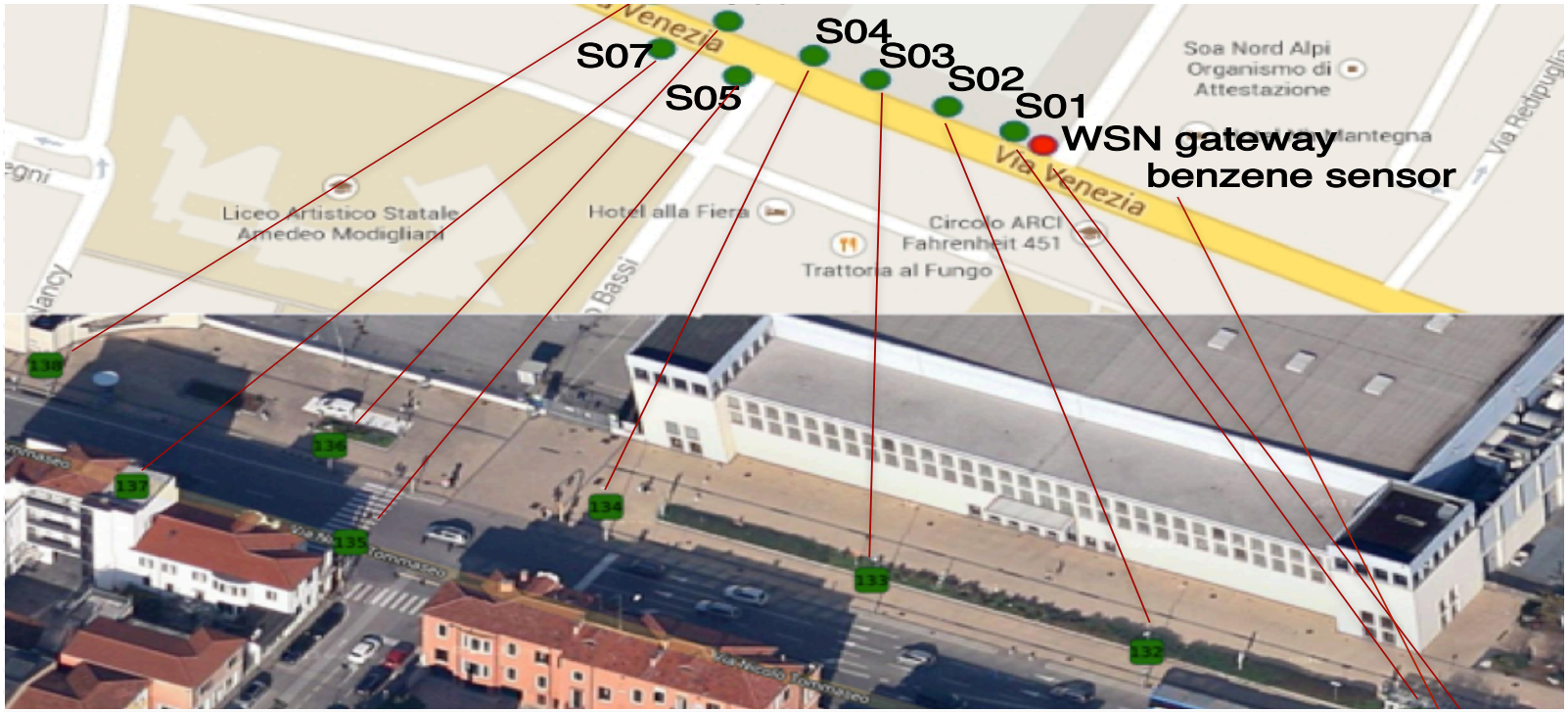
PILOTS AND TRIALS

http://www.keepcalmstudio.com/gallery/poster/L90JKS



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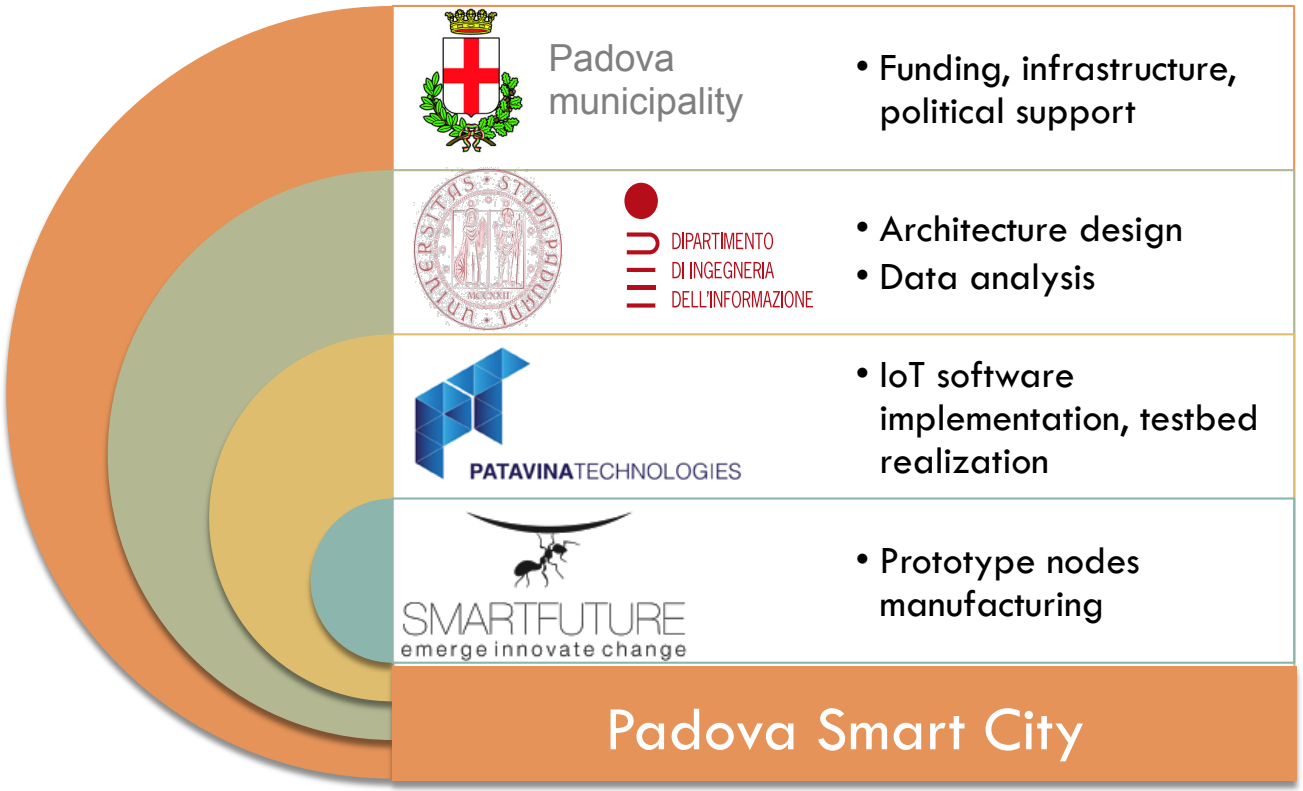
Padova Smart City

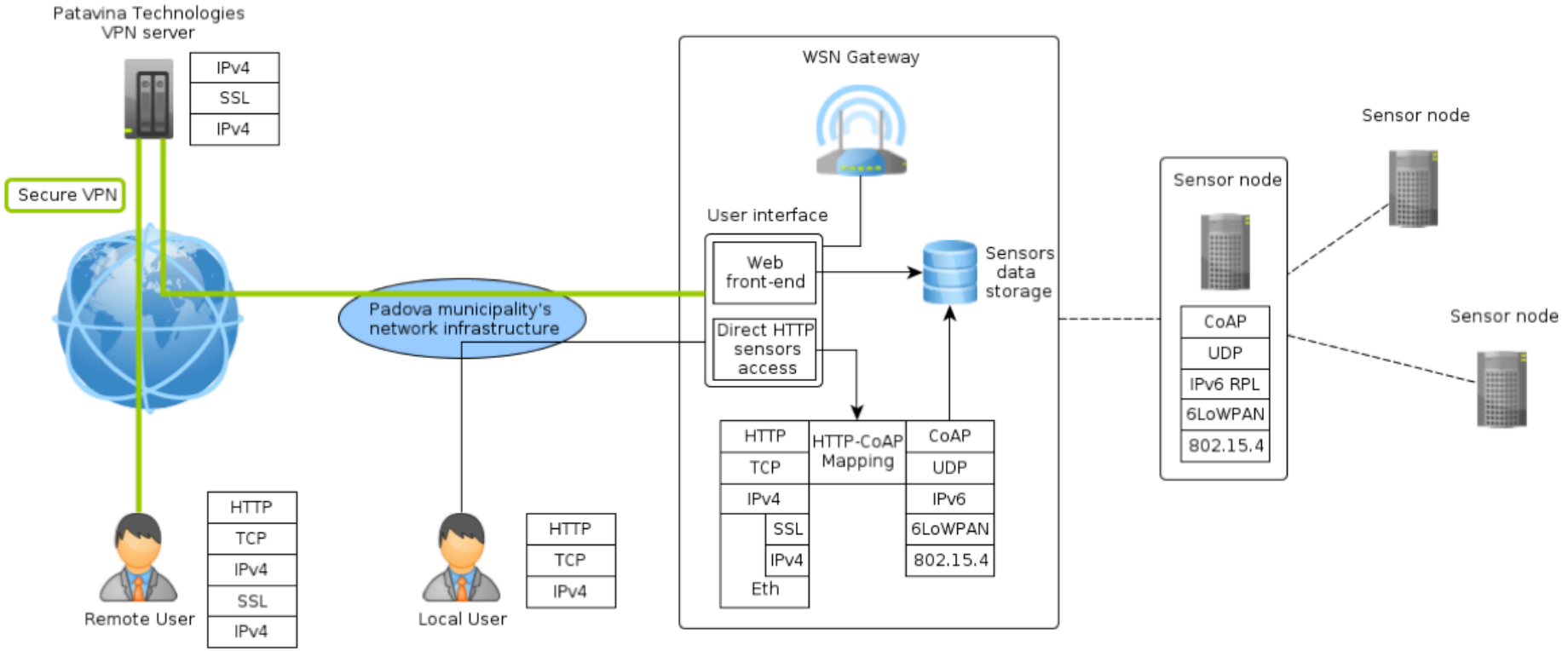
PSC: the players



The project in a nutshell

- **What:** Smart lighting and environmental monitoring
- **How:** TmoteSky sensors + 6lowPAN + basic web app

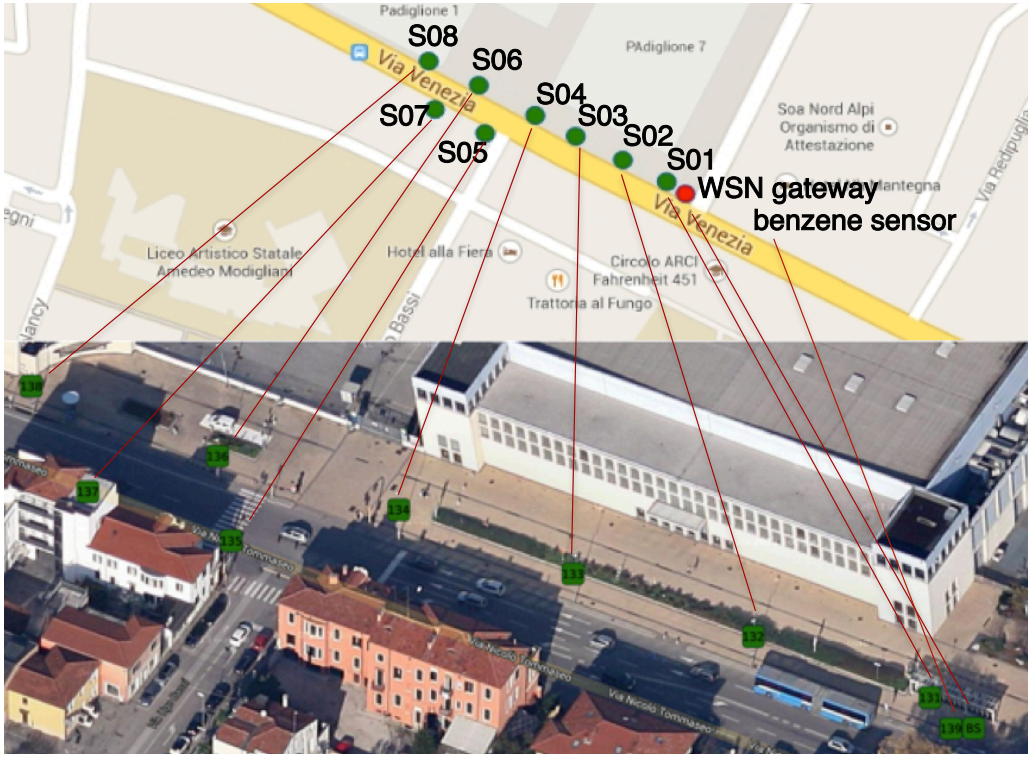
PSC: architecture



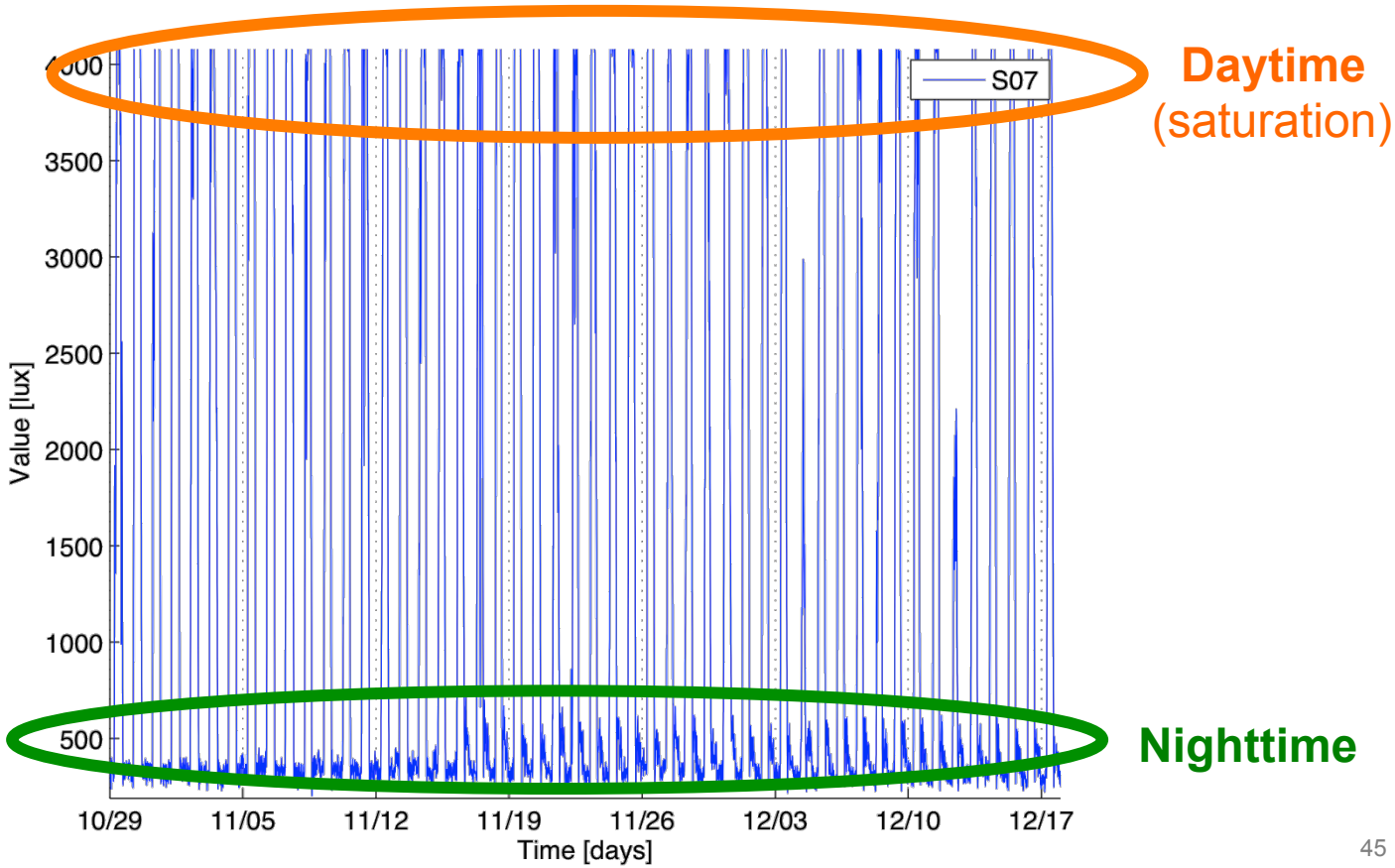
Nodes placement

Sensor node protected by transparent plastic shield that permits air circulation

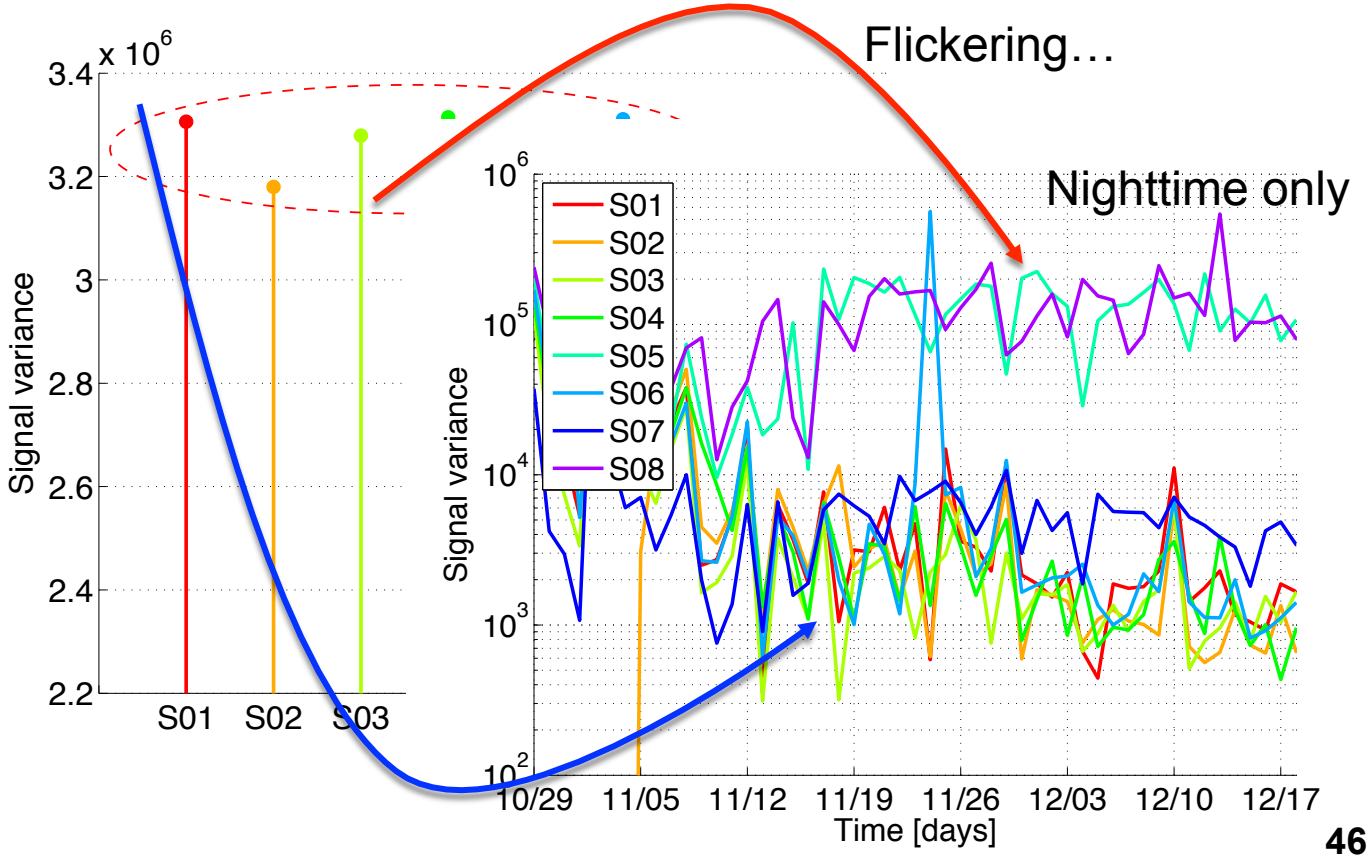
Nodes' location on the map



Example of light readings

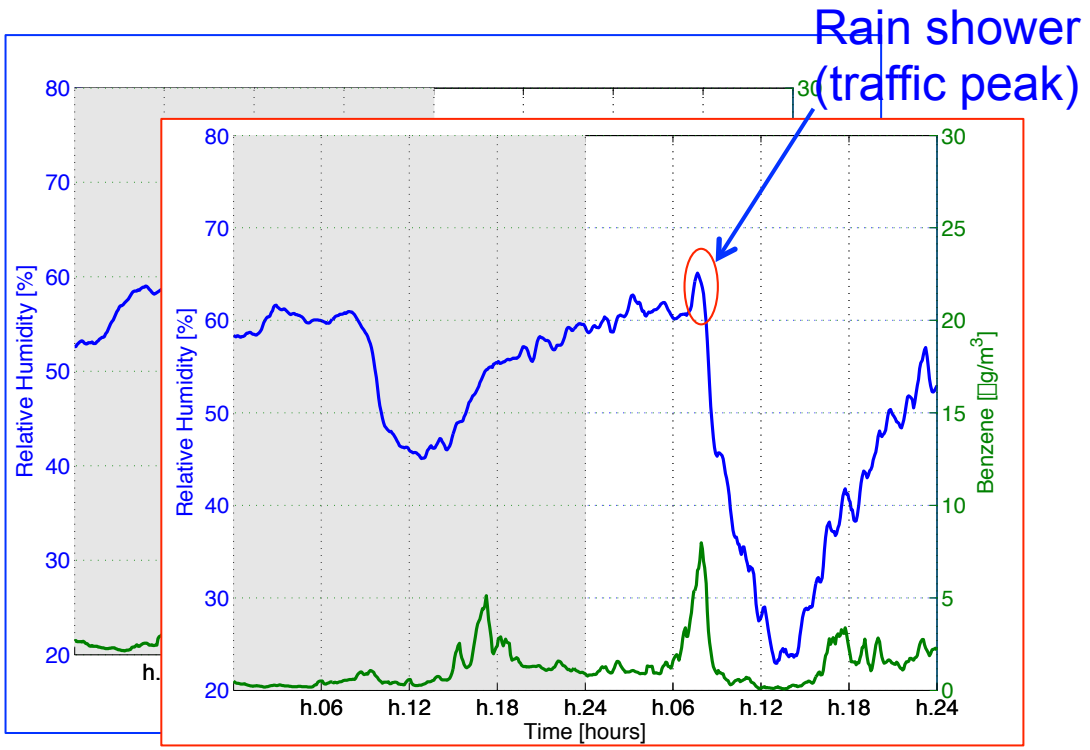


Variance analysis



46

Pollution and weekdays…



Lesson learned

- Multihop works… but it is critical
- Over-the-air software updating is essential!
- Environmental data can reveal useful information regarding air conditions, traffic management, citizens habits… particularly useful if combined with other data
  - Bike/car sharing, traffic monitoring, city events calendar, pollution monitoring stations,…

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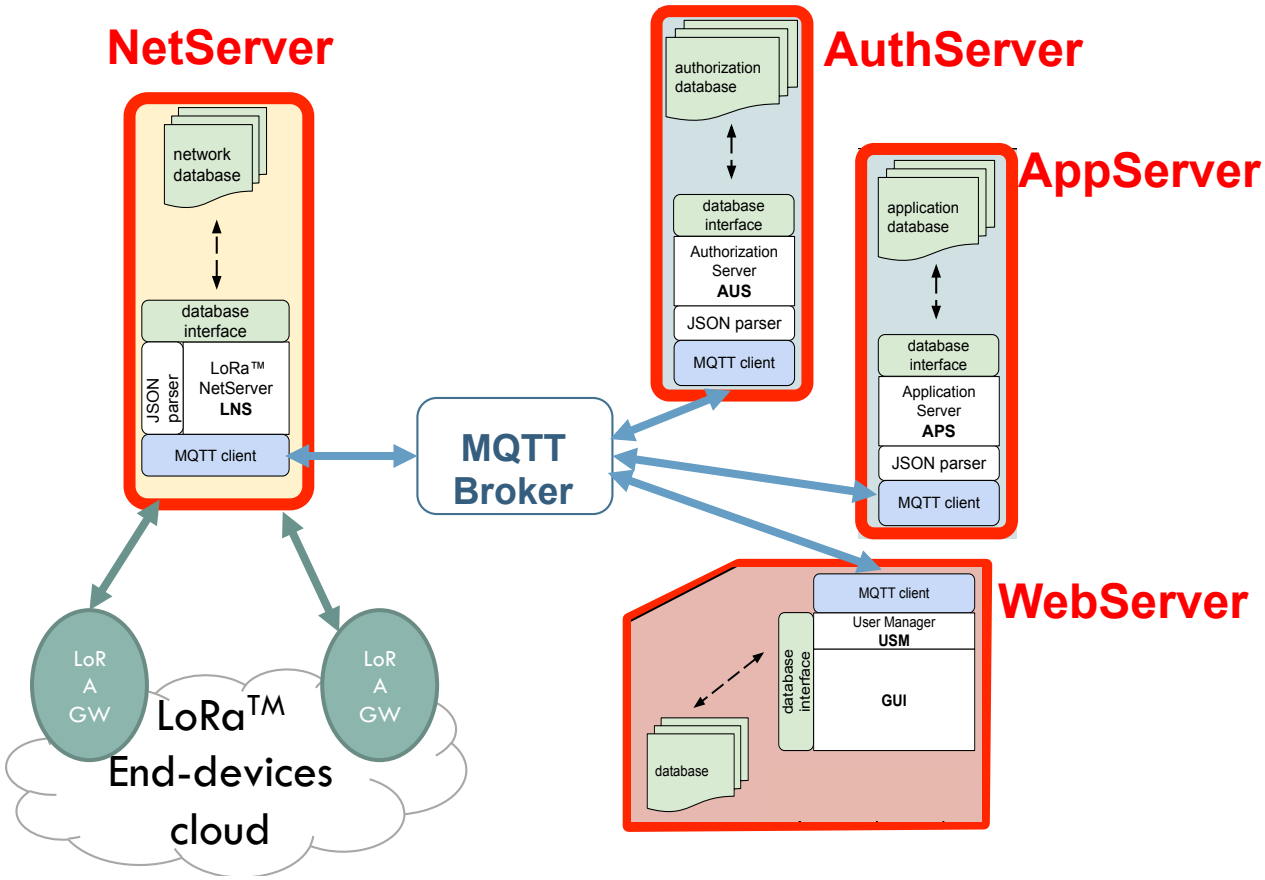
PT ThingSpeak Project

The project in a nutshell

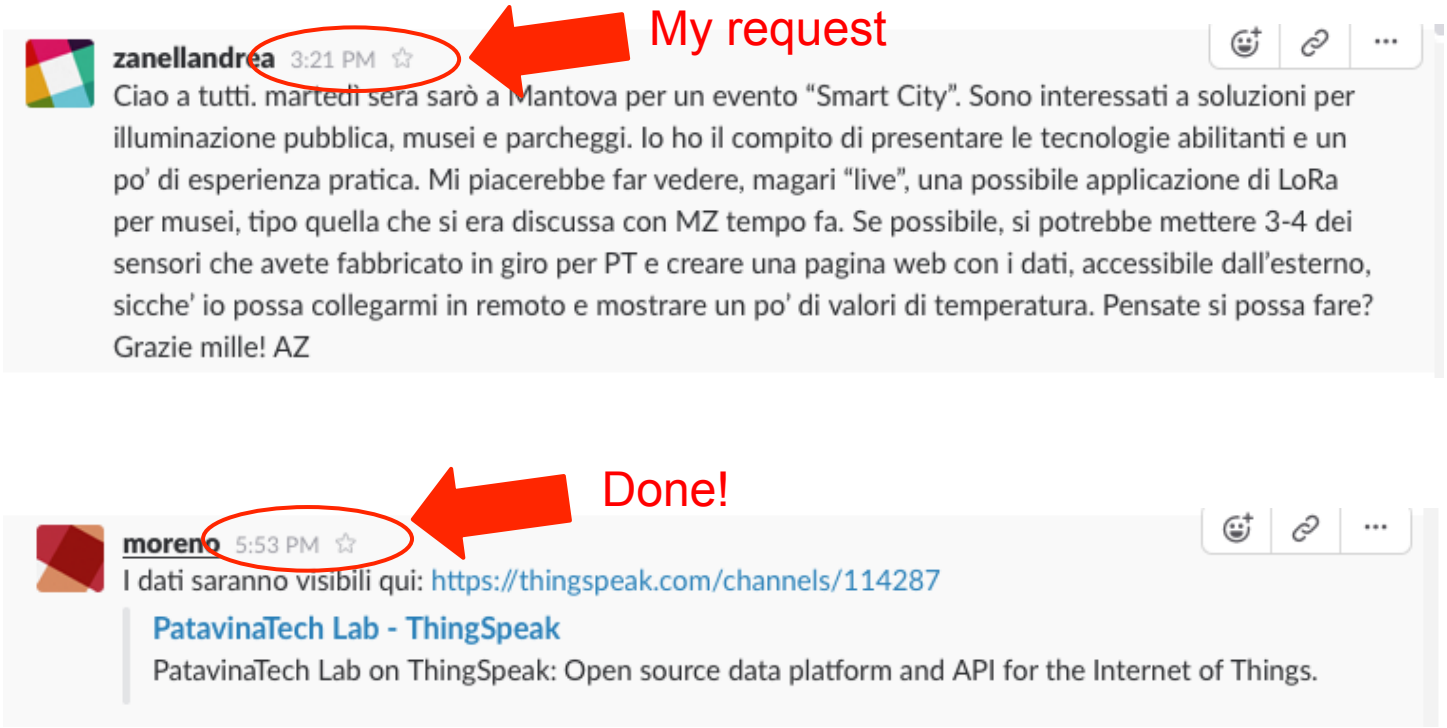
- **What:** collect environmental measurements from a building

- **How:** battery-powered sensors + LoRa + WebApp

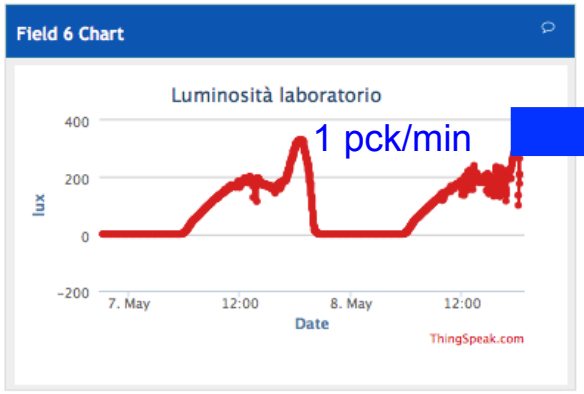
PT' LoRa™ system architecture

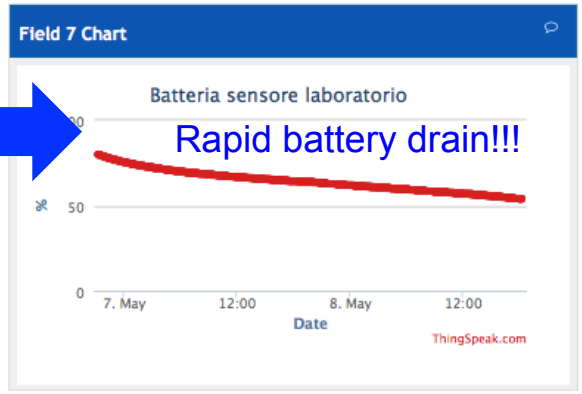


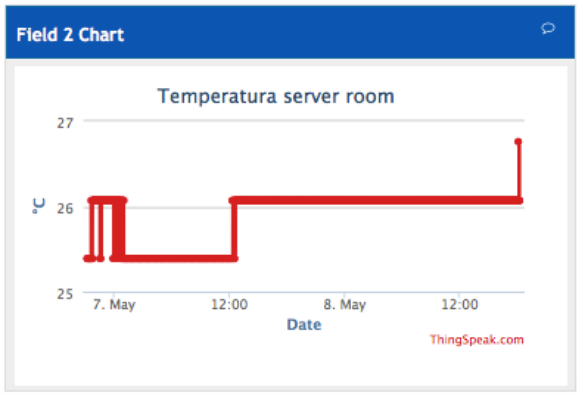
Snapshot of deployment time

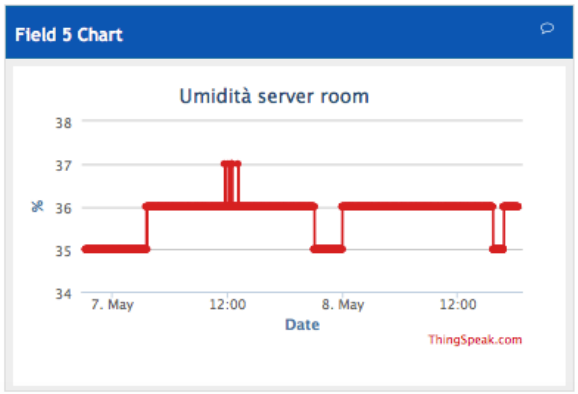


Snapshot of results

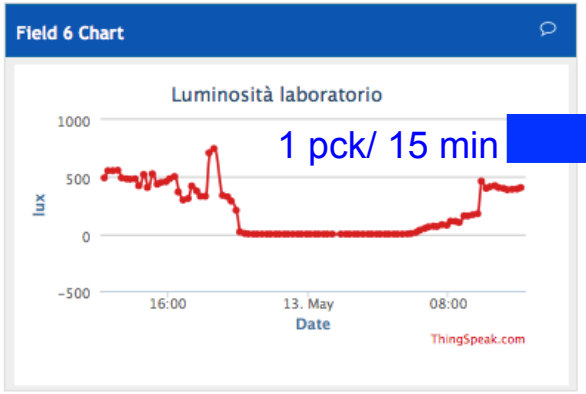




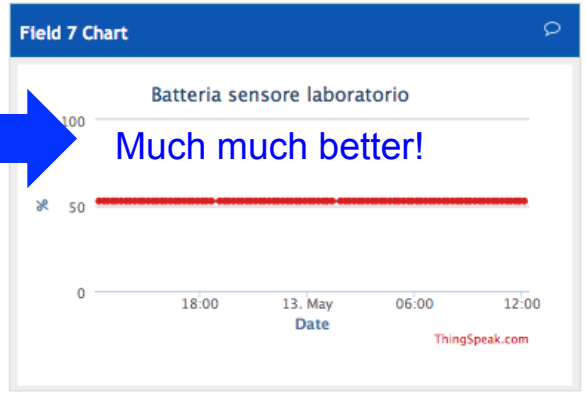




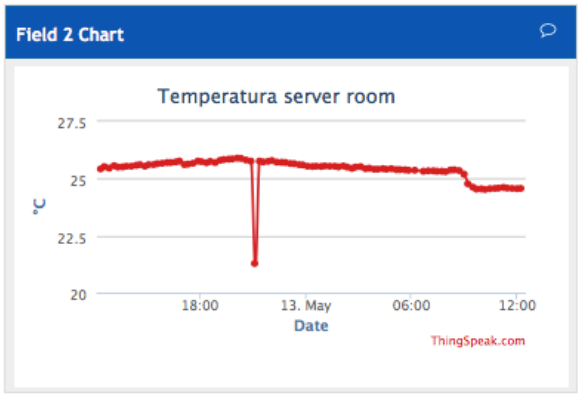
Adjusting the parameters…

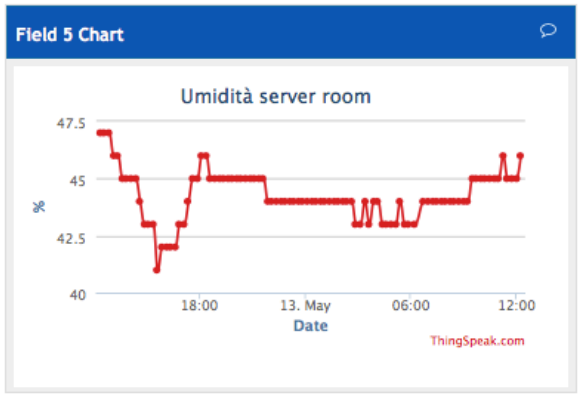


1 pck/ 15 min



Much much better!





Lesson learned

- Simple architecture → rapid deployment!

- Data reporting frequency is critical for energy consumption
  - No more than few pcks per hours to preserve battery charge
  - Online parameters adjustment is fundamental

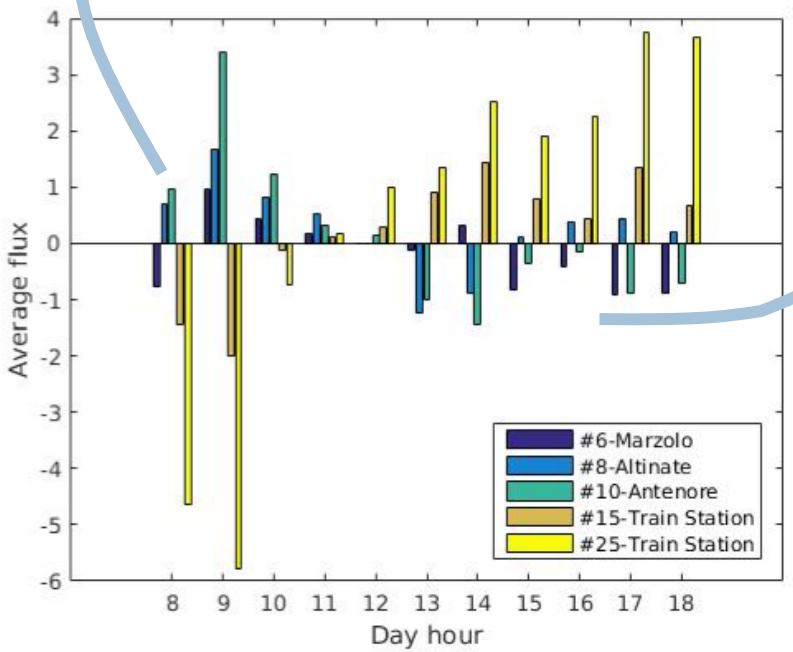
- Environmental data can reveal human behaviors
  - Privacy issues should always be considered when designing IoT applications

Smart Bike

The rebalancing problem

Morning:

- many departures from near the station
- many arrivals in the university area

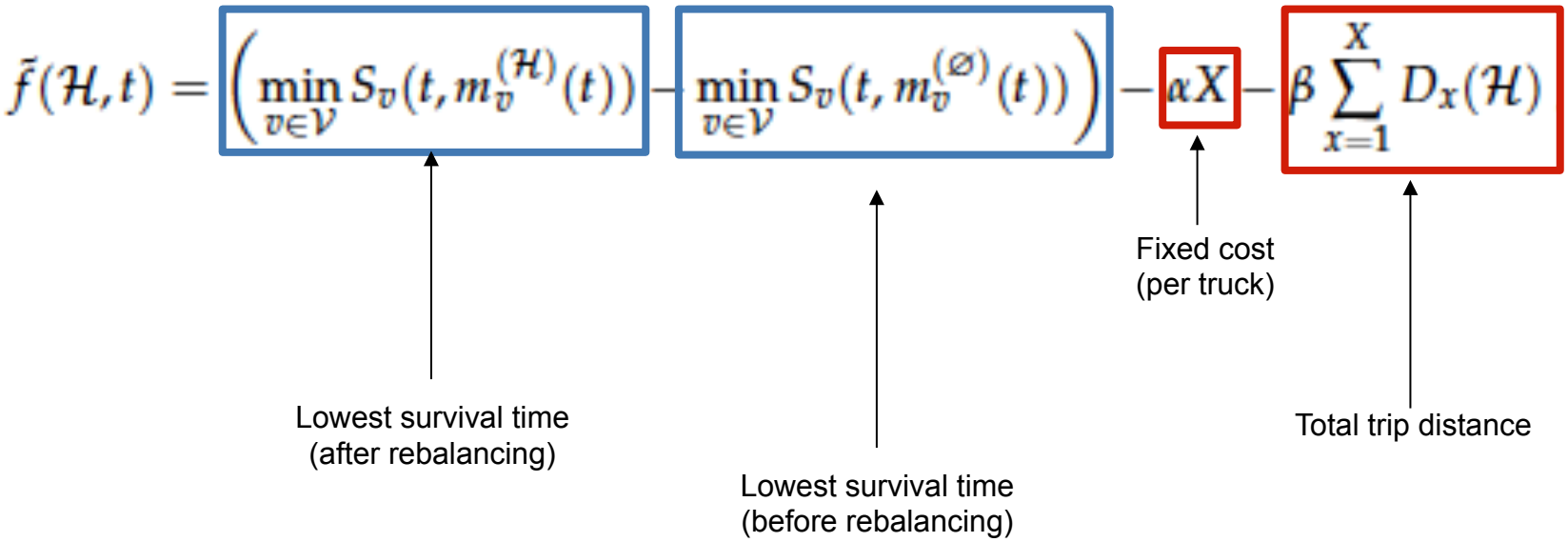


Afternoon:

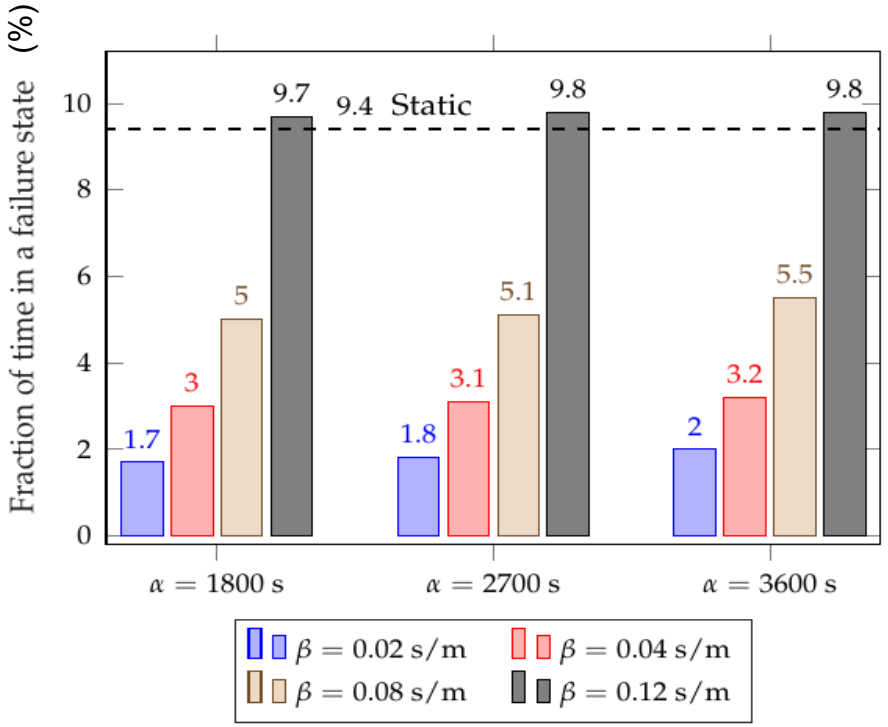
- many arrivals at the station
- many departures from the university area

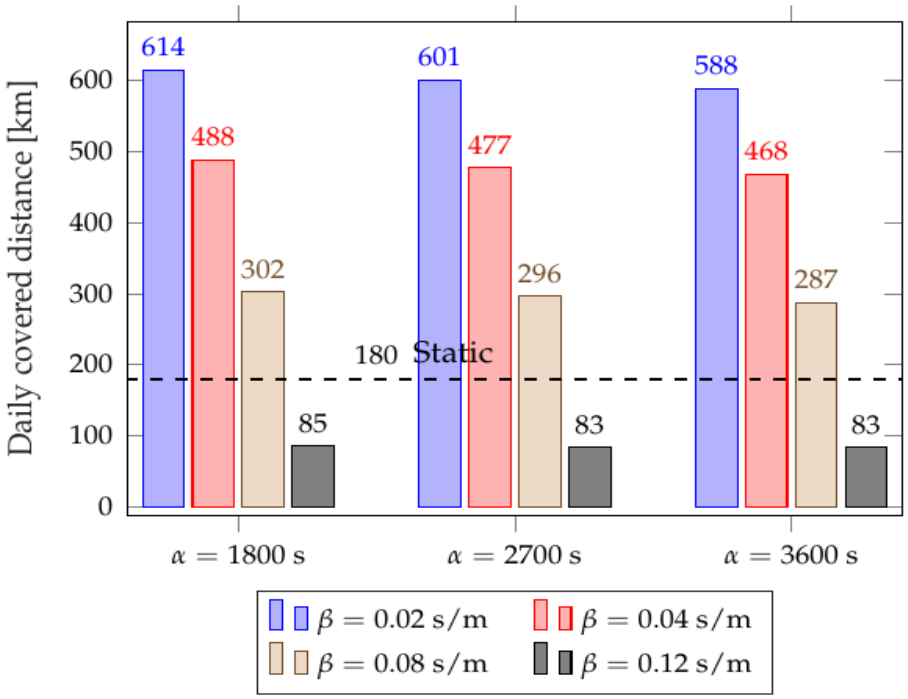
Stations where users want to deposit their bikes may be ***full***, stations where users want to pick a bike may be ***empty***

When to rebalance



Service quality





Lesson learned

- Engineers can help shaping and improving Smart City services
  - Strong theoretical background, together with clear understanding of practical problems can help designing better services, saving costs

- By making data publicly available, new solutions can be proposed!
  - New York bikesharing data → new rebalacing strategies
  - London Traffic data → better planning of wireless system
  - Milano's mobile telecom data → accurate mapping of people flows

Wrap up

- Smart City
  - a nice promise… but still to come!
- Why?
  - Many enabling technologies… not yet a clear winner
  - Many data… not clear what can be done with them
  - Many players… not clear who leads the play

Wrap up

- New challenges
  - Integration of multiple technologies
  - New security issues
  - New business models
  - Social aspects
    - Involvement of citizens
    - Change of social habits

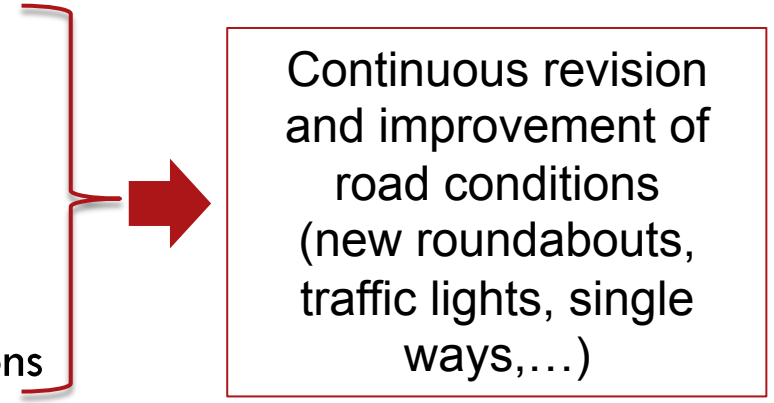
The power of the diversity!

- Currently, Smart City services are a "+" version of legacy services
  - Lack of a common framework/architecture → not easily replicable in other scenarios → not capable to trigger scale economy
- The full potential of the smart city can be disclosed only crossing the boundary of isolated services and **merging multiple services and technologies together**

Example of advantage of horizontal integration

- In a few regions in Italy, one single agency is in charge to manage the information technology aspects for all public agencies

- Road accidents database
  - Time, date, and location of the accident
  - Involved vehicles and people
  - Reasons of the accidents
- Medical reports of people
  - Injuries, fatalities, pre-existing health conditions



A symbiotic perspective

- ICT can support data collection and smart city services
- But smart city services can help improving communication systems…

SYMBIOCITY

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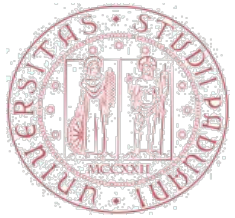

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Research Center

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SIGNAL PROCCESING
AND NETWORKING Lab

Smart Cities: potential & challenges

Andrea Zanella

zanella@dei.unipd.it

International Congress of Systems Engineering

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Contacts

Andrea Zanella – zanella@dei.unipd.it