



# Sensor networks and applications

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Smart Santander – Smart City project

# **Smart Santander (EU FP7)**

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# Santander

- Mid-size seaside town in North of Spain
  - 180.000 inhabitants, 35 km<sup>2</sup>
  - Slightly smaller than District XI in Budapest





# Smart Santander

- EU FP7 (Framework Program 7) interational research project
  - September 2010 – November 2013
  - 8,67 MEUR budget, out of 6 MEUR funding from EU.



Telefonica I+D	Spain	Partnerek
Alcatel-Lucent Italy s.p.a.	Italy	
Alcatel-Lucent Spain S.A.	Spain	
Ericsson d.o.o.	Serbia	
TTI Norte	Spain	
Universidad de Cantabria	Spain	
University of Surrey	United Kingdom	
Universität zu Lübeck	Germany	
Lancaster University	United Kingdom	
Commissariat à l'Energie Atomique	France	
Computer Technology Institute	Greece	
Alexandra Instituttet A/S	Denmark	
Santander Council	Spain	
Sociedad para el Desarrollo de Cantabria	Spain	
University of Melbourne	Australia	





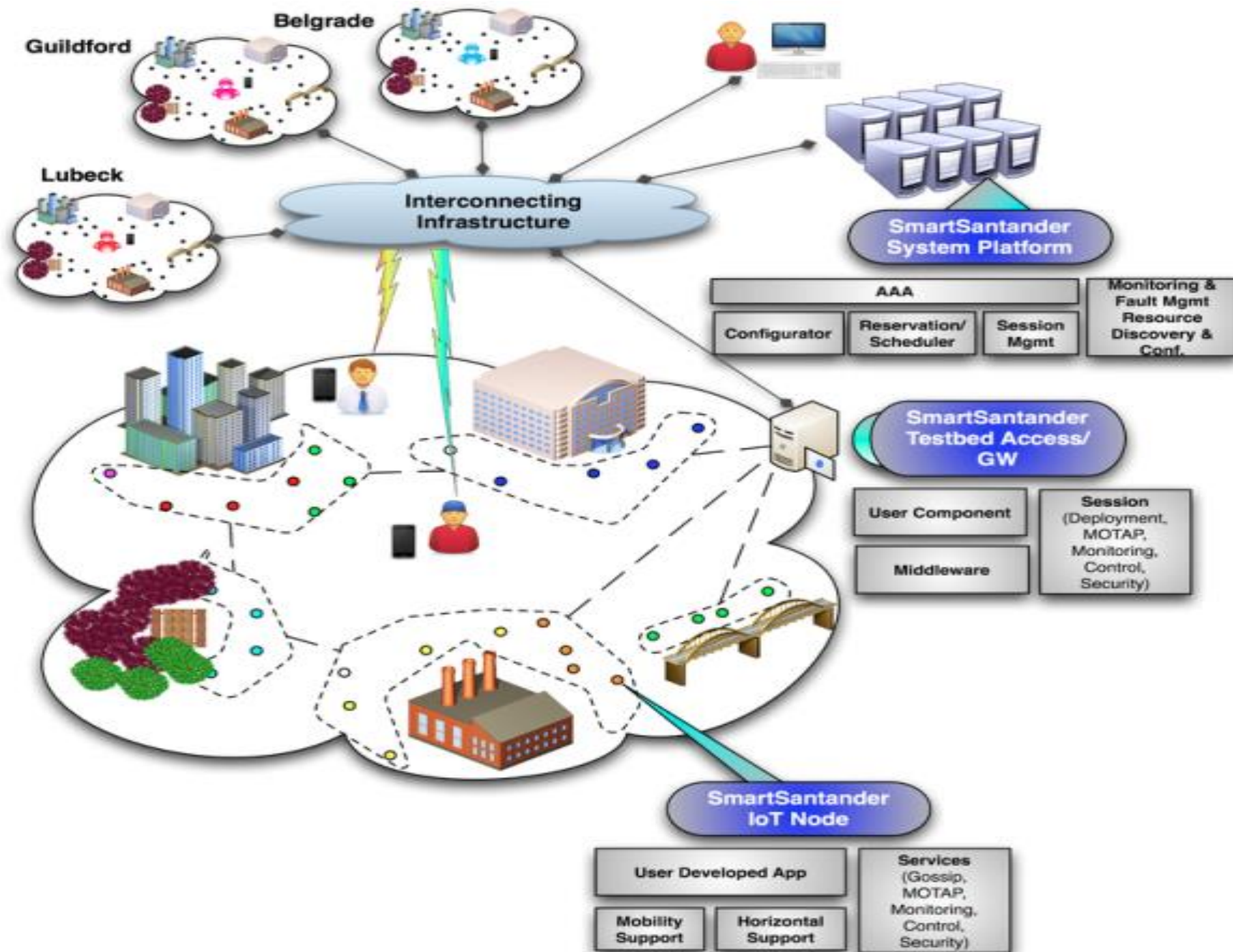
# Goal of project

- Large size smart city testbed
- Total of 20.000 deployed sensors
  - 12.000 in Santander
- 4 smart cities (Santander, Lübeck, Beograd, Guildford)





# The project



# 3-layer architecture

- **IoT nodes (sensors)**
  - Temperature, air pollution, noise, light, parking
  - Sensors on batteries
  - Some integrated into repeaters
- **Repeater**
  - High above the surface, on lamp posts, traffic lights, information panels
  - Power supply is available
- **Gateway nodes**
  - Sensor nodes send all information to the gateway node
  - The GW stores the data, or transmits it via one of its interfaces (WiFi, GPRS/UMTS, Ethernet)

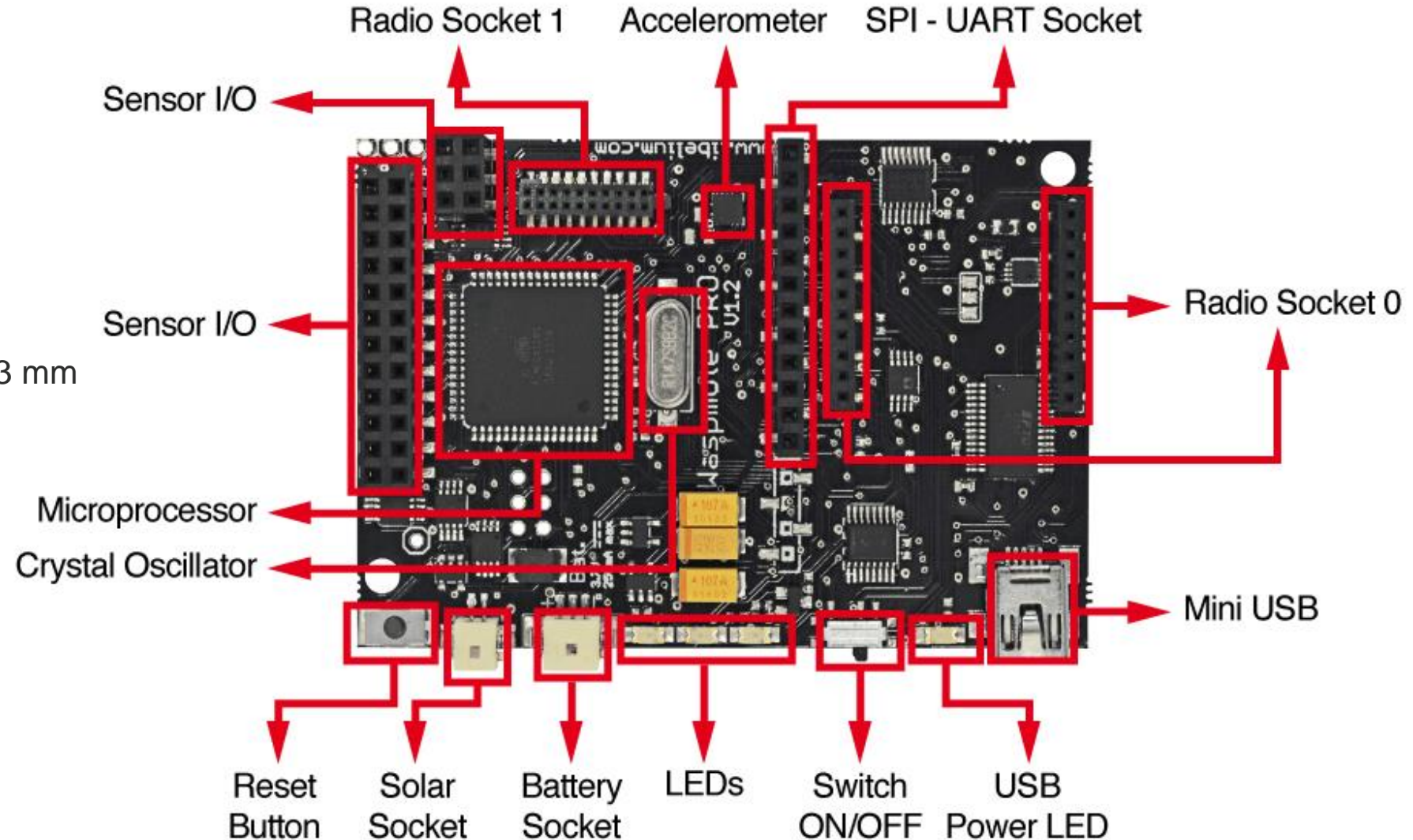


# Libelium Wasp mote

- Microcontroller: ATmega1281
- Frequency: 14MHz
- SRAM: 8KB
- EEPROM: 4KB
- FLASH: 128KB
- SD kártya: 2GB
- Weight: 20gr
- Dimensions: 73.5 x 51 x 13 mm

## Energy consumption

- ON: 15mA
  - Sleep: 55uA
  - Deep Sleep: 55uA
  - Hibernate: 0.7uA
- 
- Akku voltage: 3.3V - 4.2V
  - USB charge: 5V - 100mA
  - Solar charging: 6-12V - 280mA





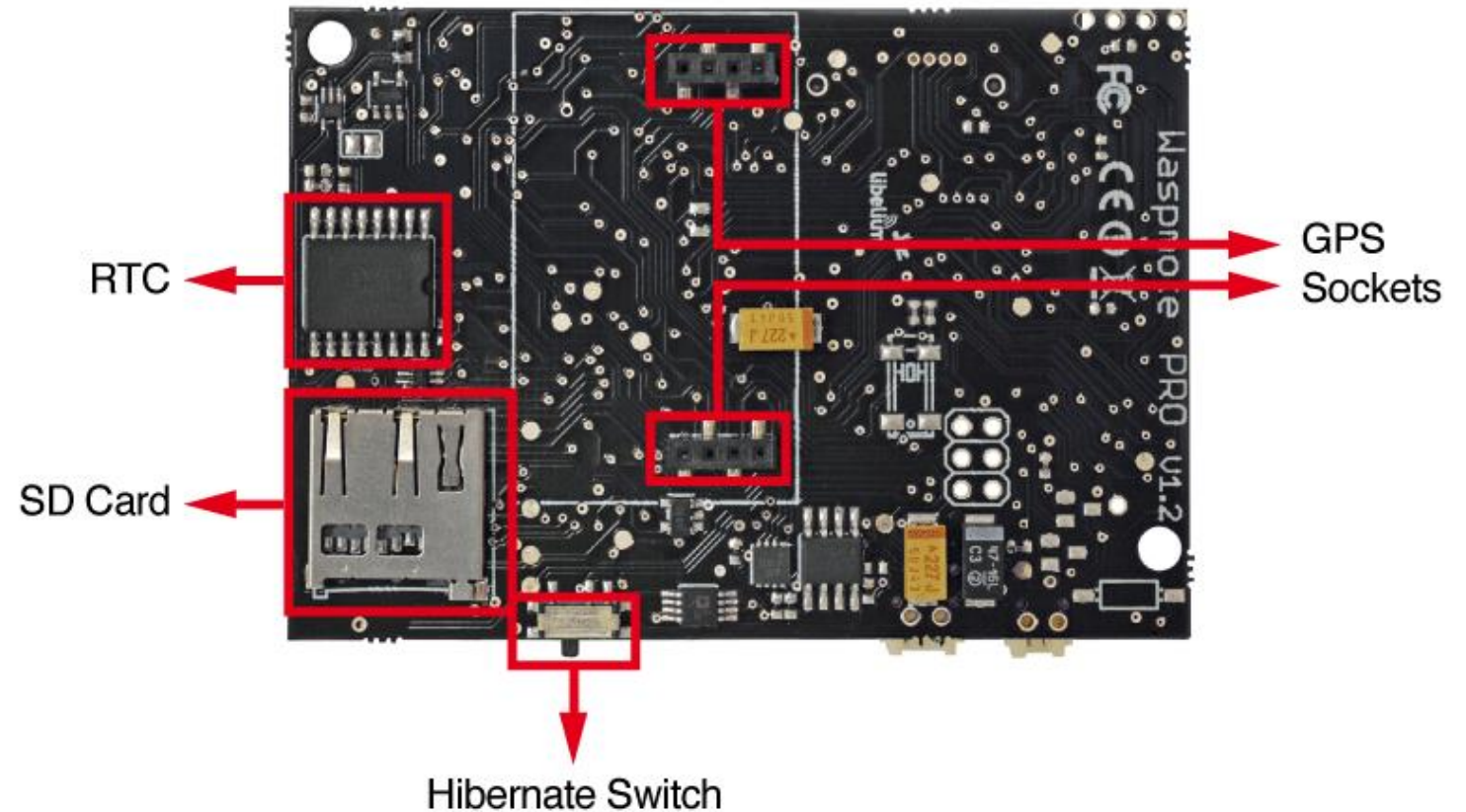
# Libelium Wasp mote

## Input / Output

- 7 analog input, 8 digital I/O, 2 UART, 1 I2C, 1 SPI, 1 USB

## Integrated sensors

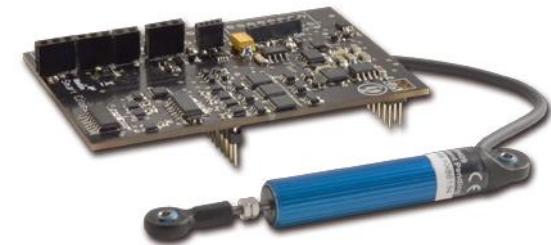
- Temperature: (+/-): -40°C , +85°C. Accuracy: 0.25°C.
- Accelerometer:  $\pm 2g/\pm 4g/\pm 8g$
- Light meter



# External sensors

## Gas Sensor Board

- Carbon-monoxide – CO
- CO<sub>2</sub>, O<sub>2</sub>, CH<sub>4</sub>, H<sub>2</sub>, NH<sub>3</sub>, C<sub>4</sub>H<sub>10</sub>, CH<sub>3</sub>CH<sub>2</sub>OH, C<sub>6</sub>H<sub>5</sub>CH<sub>3</sub>, H<sub>2</sub>S, NO<sub>2</sub>, O<sub>3</sub>, VOC
- Temperature, humidity, air pressure



## Smart City Board

- Noise ensor(omni-directional microphone, 20Hz – 20 KHz)
- Ultrasonic distance measurement



## Parking Sensor Board

- Senses changes in magnetic field to detect parking cars



## Agriculture Board

- Soil humidity

# Wasmote radio

- **Libelium Wasmote Expansion Radio Board**

- Two XBee radio units, both at 2.4 GHz
  - First one with IEEE 802.15.4 protocol, for testing
    - Anyone can write and run test applications, will not disturb network operation
  - Second one with DigiMesh for sensor data gathering, and signalling
    - Modified 802.15.4, with a simple routing algorithm
    - Motes can be programmed via this interface (OTAP), MOTAP)
- The city is divided into 22 areas, each using different frequencies





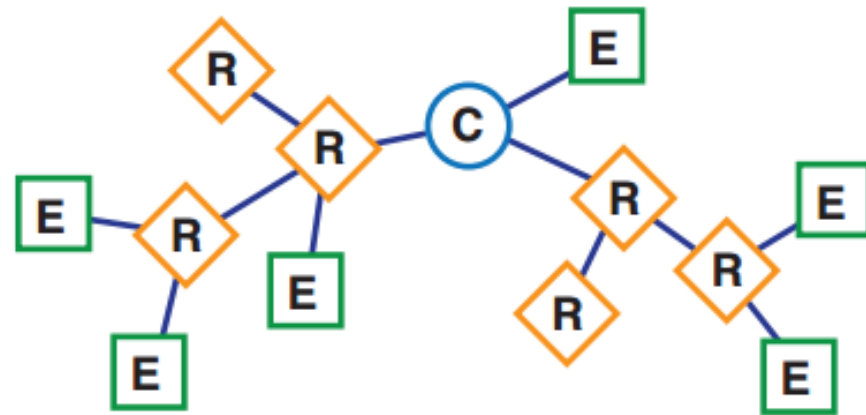
# Zigbee vs. DigiMesh

- Zigbee

**C** Coordinator

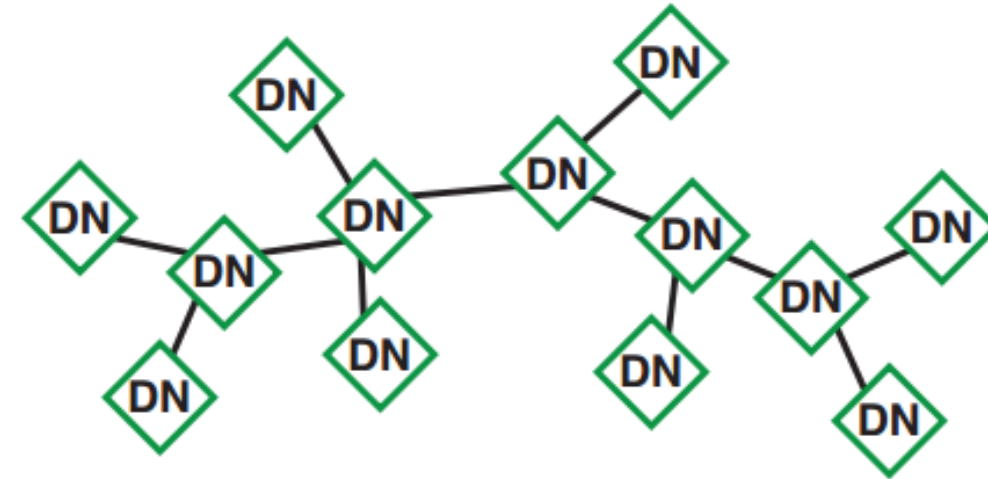
**R** Router

**E** End Device



- DigiMesh

**DN** Digi Mesh Nodes

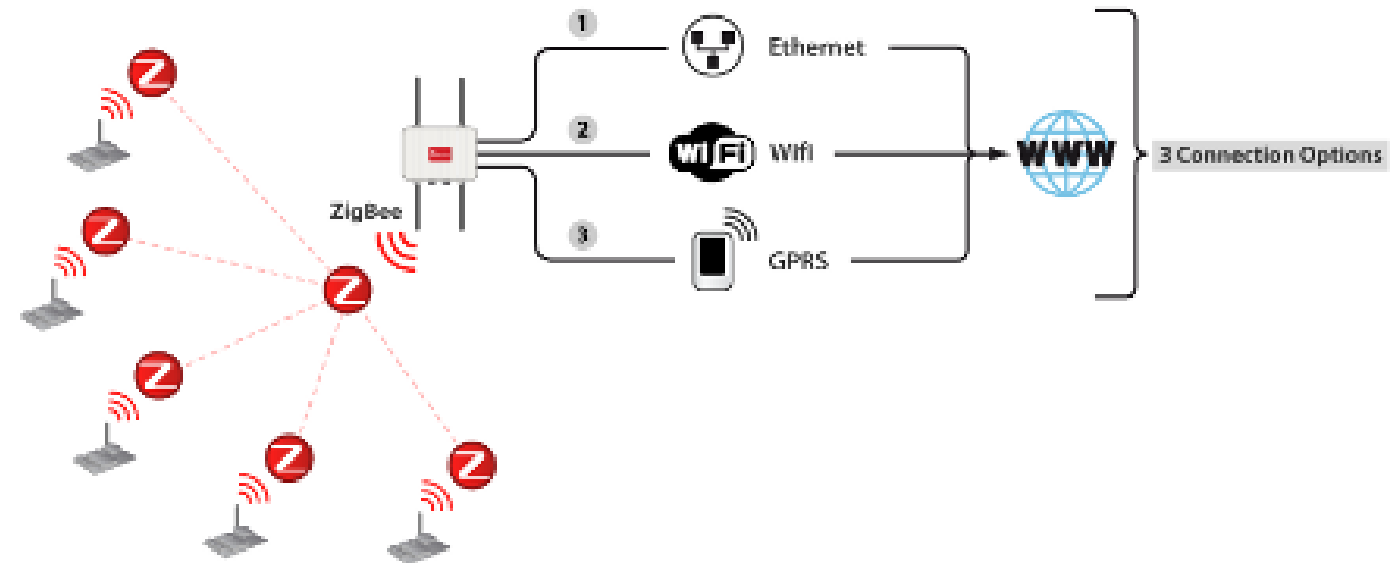


# Repeaters



# Meshlium gateway

- Processor: 500MHz (x86)
- RAM: 256 MB (DDR)
- Disk: 8 GB
- Energy: 5W (18V), Power over Ethernet
- Box: aluminium, 210x175x50mm, 1,2 Kg
- OS: Linux Debian
- Network: WiFi, Xbee, Bluetooth, 3G





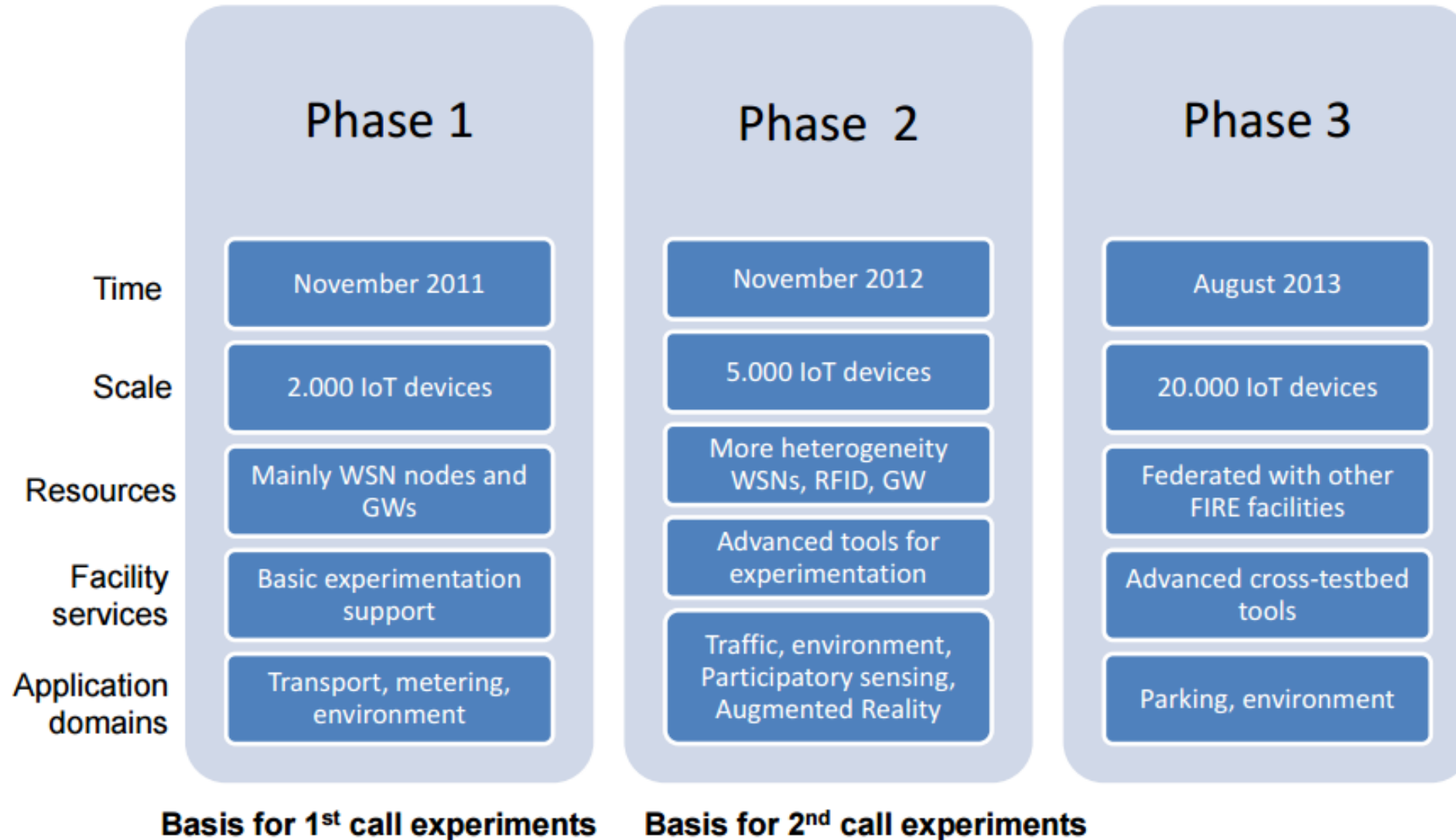
# Santander testbed clusters

- Sensor and repeaters that belong to the same gateway form a **cluster**.



# Smart Santander deployment

- Deployment in 3 phases, followed by a call for test applications



# Phase 1

- Two use cases: **environmental monitoring** and **outdoor parking area management**
  - It is not possible to run test application on parking sensors to save battery

Node Type		Amount	Sensors	Radio I/F
Gateway		23	N/A	IEEE 802.15.4, IEEE 802.11, Digimesh, GPRS/UMTS
Repeater	Temperature	74	Temperature, Acceleration	IEEE 802.15.4, Digimesh
	Light	553	Light, Temperature, Acceleration	
	Noise	58	Noise, Acceleration	
	Gases	13	Temperature, CO, Acceleration	
Parking Sensor		373	Occupancy	Digimesh
<b>Total:</b>		<b>23 GW 1,071 Nodes</b>	<b>2,322 sensors</b>	





# Phase 2

- 6 new use cases
  - **Traffic intensity monitoring** (sensors built into the surface)
  - **Mobile environmental monitoring**
    - On buses – IEEE 802.15.4, GPRS
    - On taxis and police cars – only GPRS
      - Not possible to run test algorithms on them
  - **Parks and gardens irrigation**
  - **Guidance to free parking lots**
  - **Augmented reality**
    - NFC tags everywhere in the city
    - Presence monitoring and meta-data
  - **Participatory sensing**

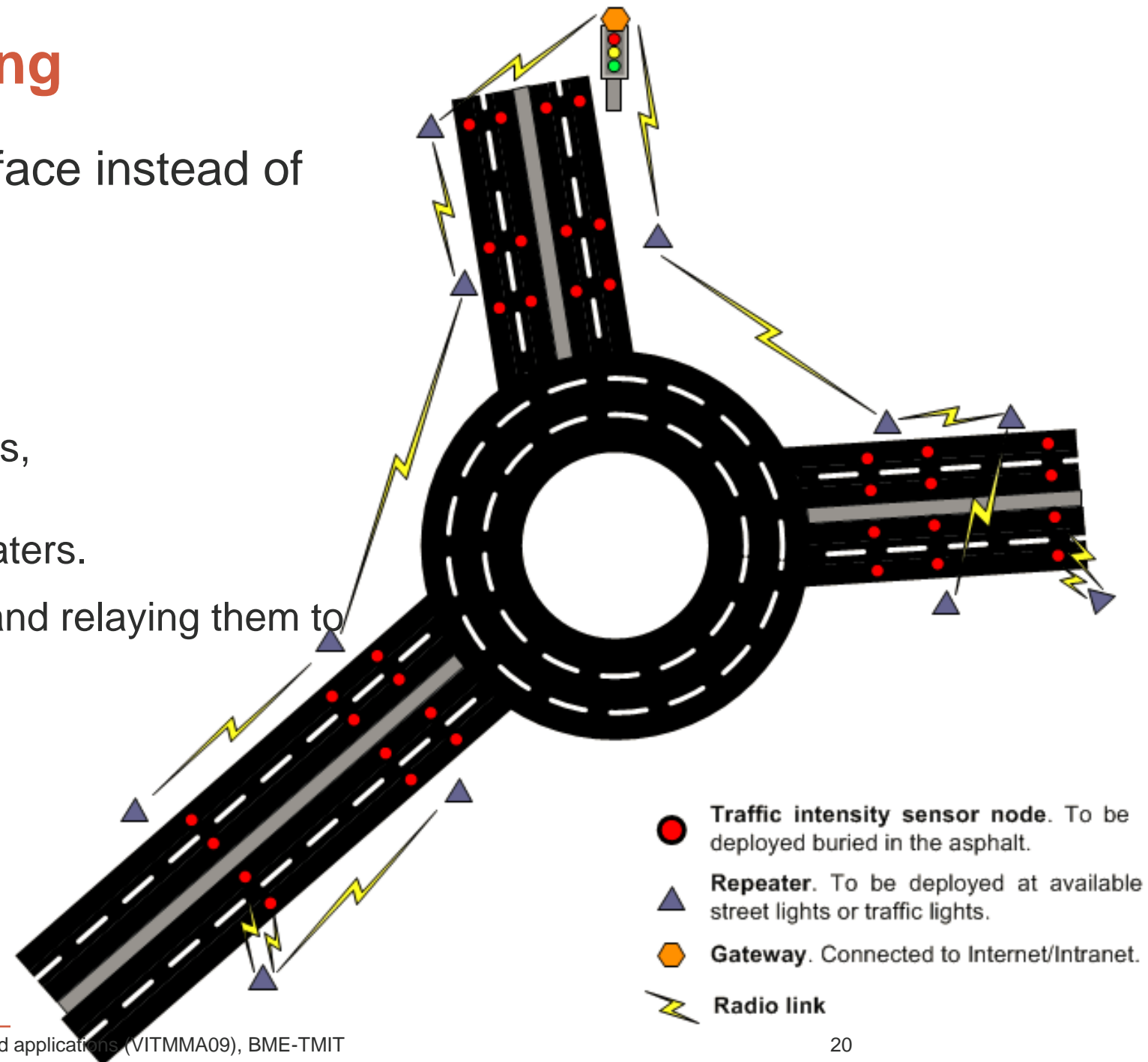


# Phase 2

Node Type		Amount	Sensors	Radio I/F
Gateway	Irrigation	3	N/A	IEEE 802.15.4, IEEE 802.11, Digimesh, GPRS/UMTS
	Traffic	2		IEEE 802.15.4, GPRS/UMTS
Repeater	Traffic	9	N/A	IEEE 802.15.4
	Weather	3	Temperature, Relative Humidity, Soil Moisture, Solar Radiation, Rainfall, Windspeed, Atmospheric Pressure, Acceleration	IEEE 802.15.4, Digimesh
	Irrigation	23	Temperature, Relative Humidity, Soil Moisture, Soil Temperature, Acceleration	IEEE 802.15.4, Digimesh
	Water Flow	2	Water Flow, Acceleration	IEEE 802.15.4, Digimesh
	Agriculture	19	Temperature, Relative Humidity, Acceleration	IEEE 802.15.4, Digimesh
Mobile node	Bus (w. CAN-BUS)	2	CO, Particles, NO <sub>2</sub> , Ozone, Temperature, Relative Humidity, Speed, Course, Odometer, Location, CAN	IEEE 802.15.4, GPRS
	Bus	68	CO, Particles, NO <sub>2</sub> , Ozone, Temperature, Relative Humidity, Speed, Course, Odometer, Location	IEEE 802.15.4, GPRS
	Car	80	CO, Particles, NO <sub>2</sub> , Ozone, Temperature, Relative Humidity, Speed, Course, Odometer, Location	GPRS
Traffic Sensor		59	Road Occupancy, Vehicle Count, Vehicle Speed	IEEE 802.15.4
Augmented Reality Tag		2,500	Presence (+ metadata)	NFC
Participatory Sensing Smartphone		6,500	Multiple	IEEE 802.11, GPRS/UMTS
Augmented Reality Smartphone		~14,000	Presence (+ metadata)	IEEE 802.11, GPRS/UMTS
<b>Total:</b>		<b>5 GW 115 Fixed Nodes 150 Mobile Nodes 2,500 Tags 10,000+ Smartphones</b>	<b>377 fixed sensors 1,500+ mobile sensors 20,000+ smartphone sensors</b>	

# Traffic intensity monitoring

- Sensors built into the road surface instead of inductive loops.
- Architecture:
  - Traffic sensors
    - Traffic intensity, speed of vehicles, waiting queue length
    - 802.15.4 interface towards repeaters.
  - Repeater: Receiving sensor data and relaying them to the access point.
  - Access point: Access + storage (GPRS/UMTS, Ethernet)





# Traffic intensity monitoring (hardware)

- traffic sensor



repeater



access point



# Mobile environmental monitoring

- Mobile units: Public transport buses: Buszokon, police cars and taxis.
  - On buses: sensor boards, CAN bus module, IoT units (waspote) and LPU.
  - On police cars and taxis: only sensor board and LPU (no testing!)
- Architectural elements:
  - Waspote board
    - 802.15.4 rádiós interfész (antenna: 5dBi), soros kommunikáció (RJ45) a waspote és az LPU között.
  - Sensor board (temperature, humidity, CO, NO2, O3)
    - Basic RISC microcontroller on 8MH. Data receive/transmit: RJ45 connector.
  - CAN bus module
  - LPU (local processor unit): sensor data gathering network management, OTAP
    - 32-bit RISC processor 60 MIPS ARM7 70 MHz, Linux op, 8 MB Flash, 16MB RAM. Interfaces: RS232/485 and CAN bus, 7 digital and 2 analog inputs, 5 digital outputs. GPRS radio.
  - GW (gateway): connection to the SmartSantander backbone

# Mobile environmental monitoring



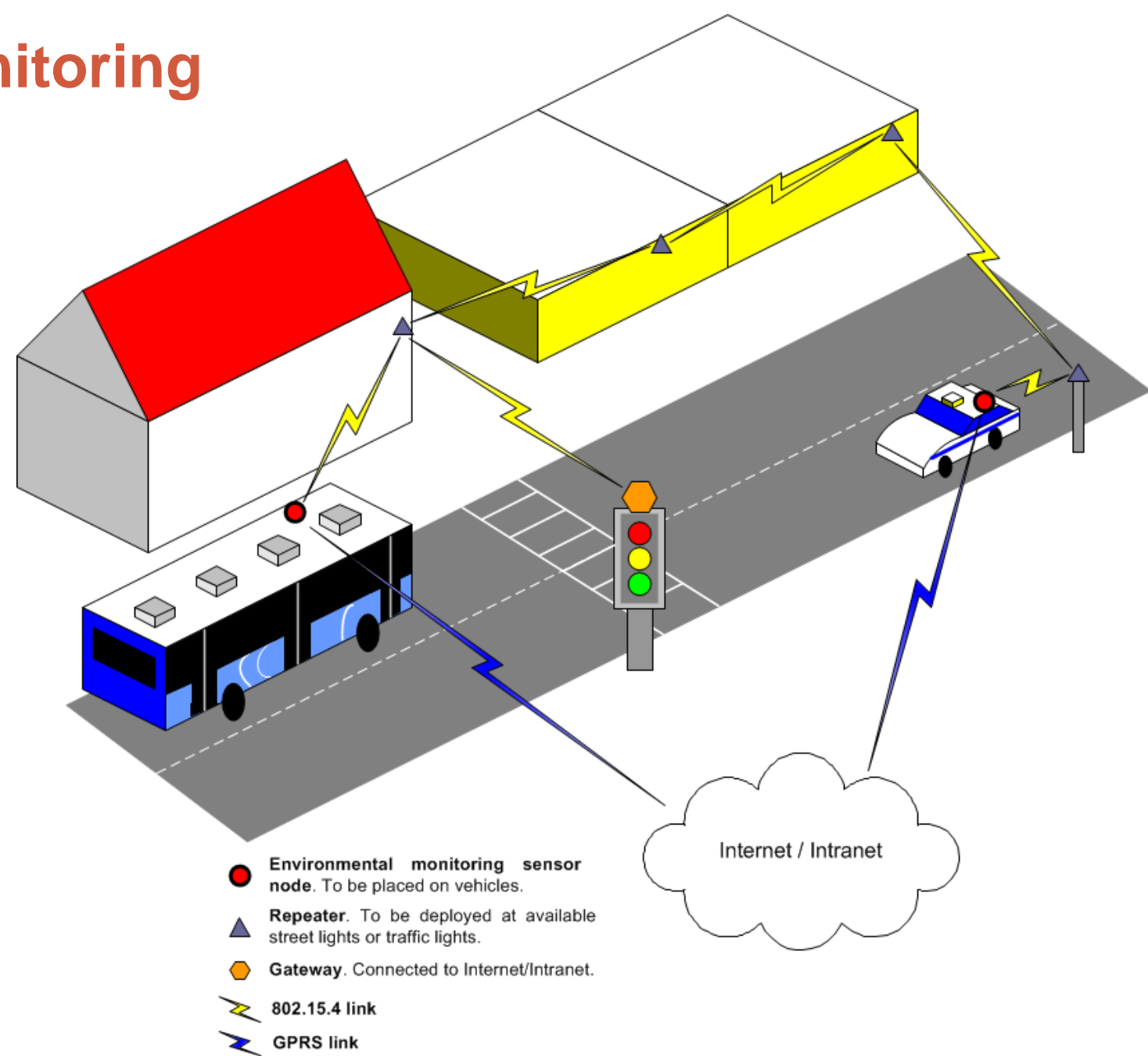
LPU



sensors



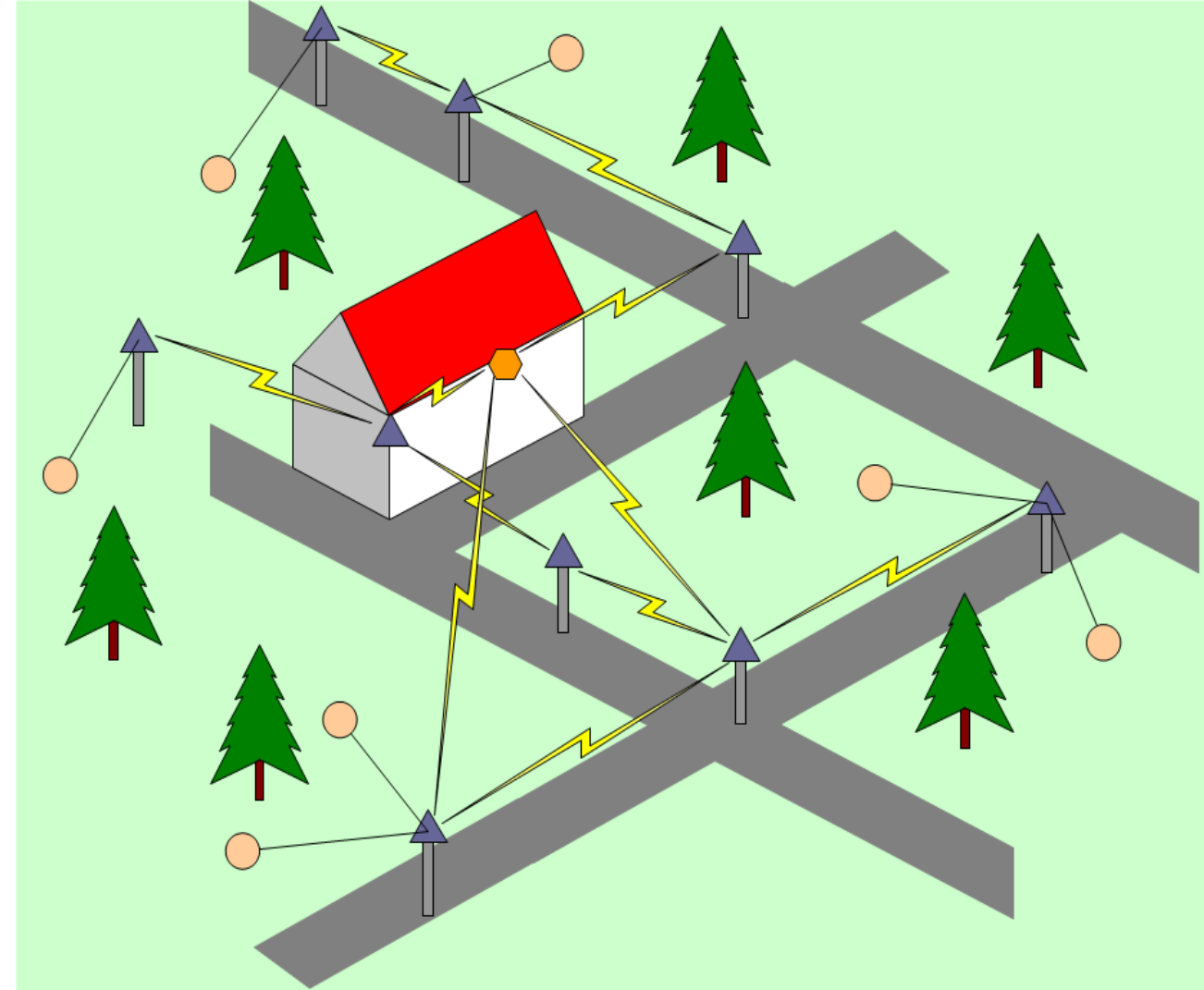
Wasp mote





# Park irrigation

- Sensors:
  - Weather station: Anemometer, pluviometer.
  - Atmospheric pressure, solar radiation, air humidity and temperature sensors.
  - Soil temperature and humidity sensors.
  - Evaluation of water consumption sensor.



- **Park irrigation monitoring sensor.** To be deployed buried in the ground.
- ▲ **Repeater.** To be deployed at available street lights or traffic lights.
- ⬡ **Gateway.** Connected to Internet/Intranet.

⚡ **Radio link**  
— **Wired link**



# Park irrigation

Soil Moisture Tension



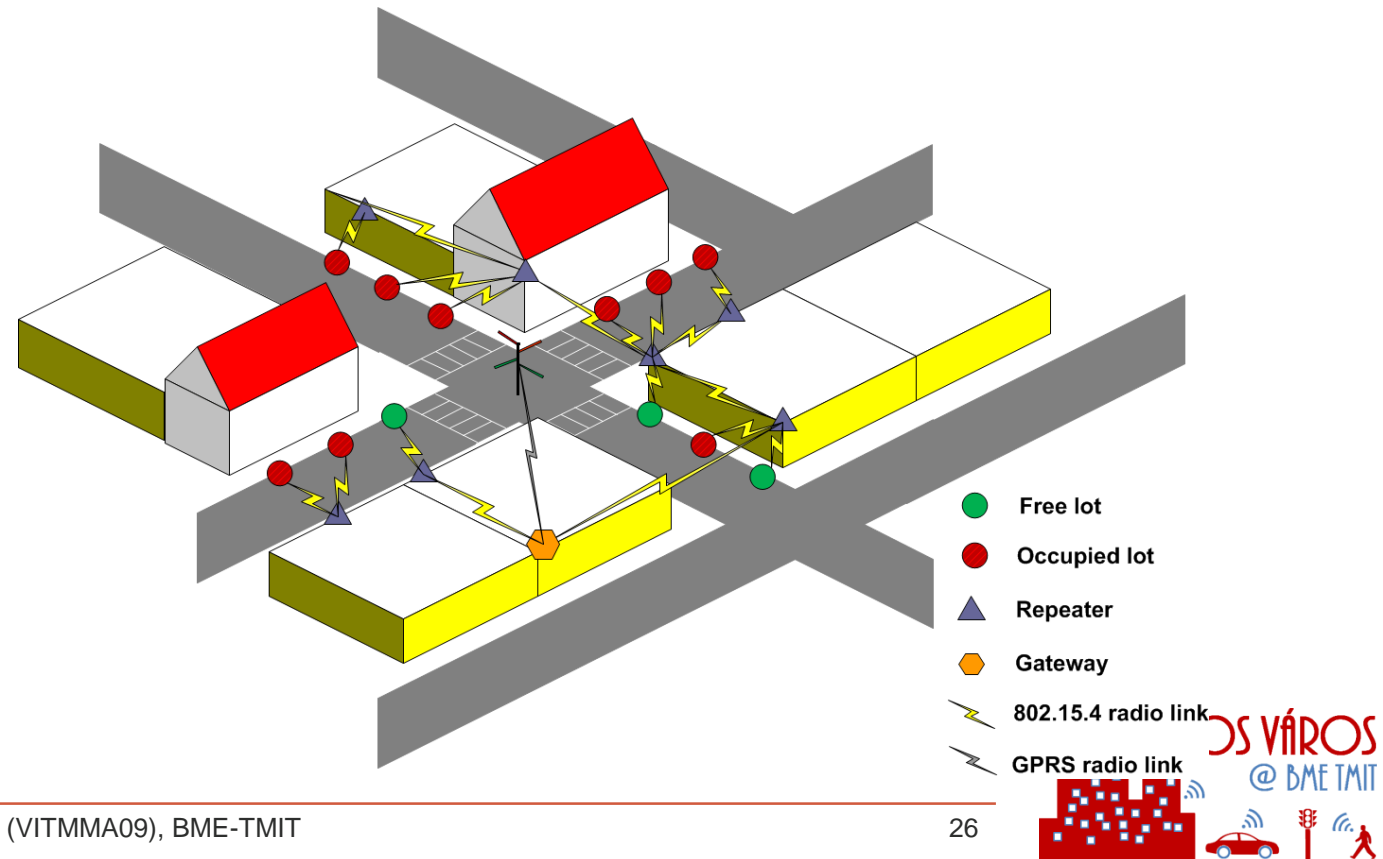
Soil Moisture Temperature





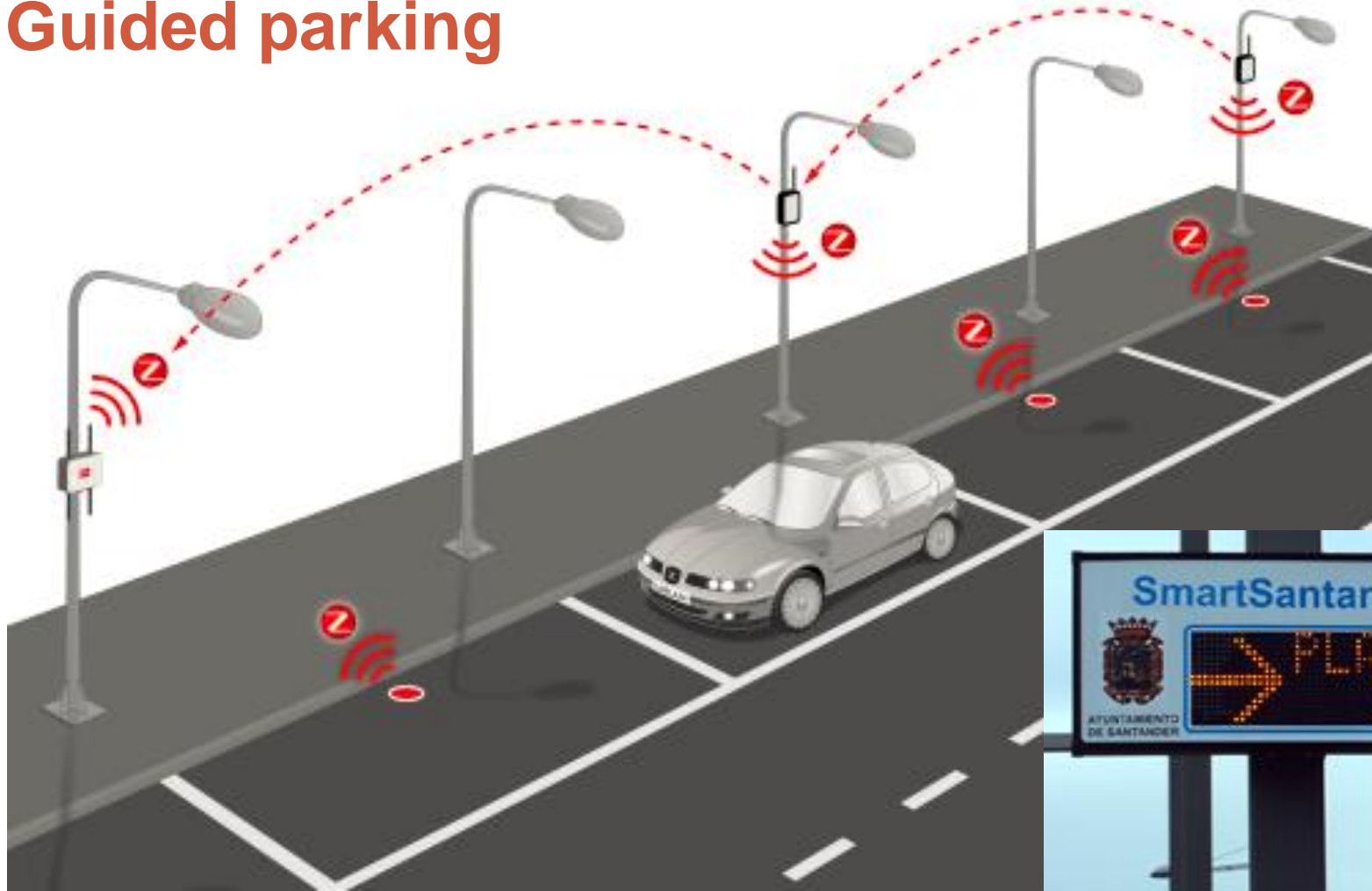
# Guidance to free parking lots

- 400 parking places within a parking zone.
- Sensors monitor occupancy (free/occupied)
- Guide the drivers towards available free lots through the use of several panels, mainly placed at the streets' intersections.
- Architecture
  - **Panel:** shows the number of places available in a determined parking zone.
  - **Central Station:** It receives, from the Portal Server, all data retrieved by the sensors.

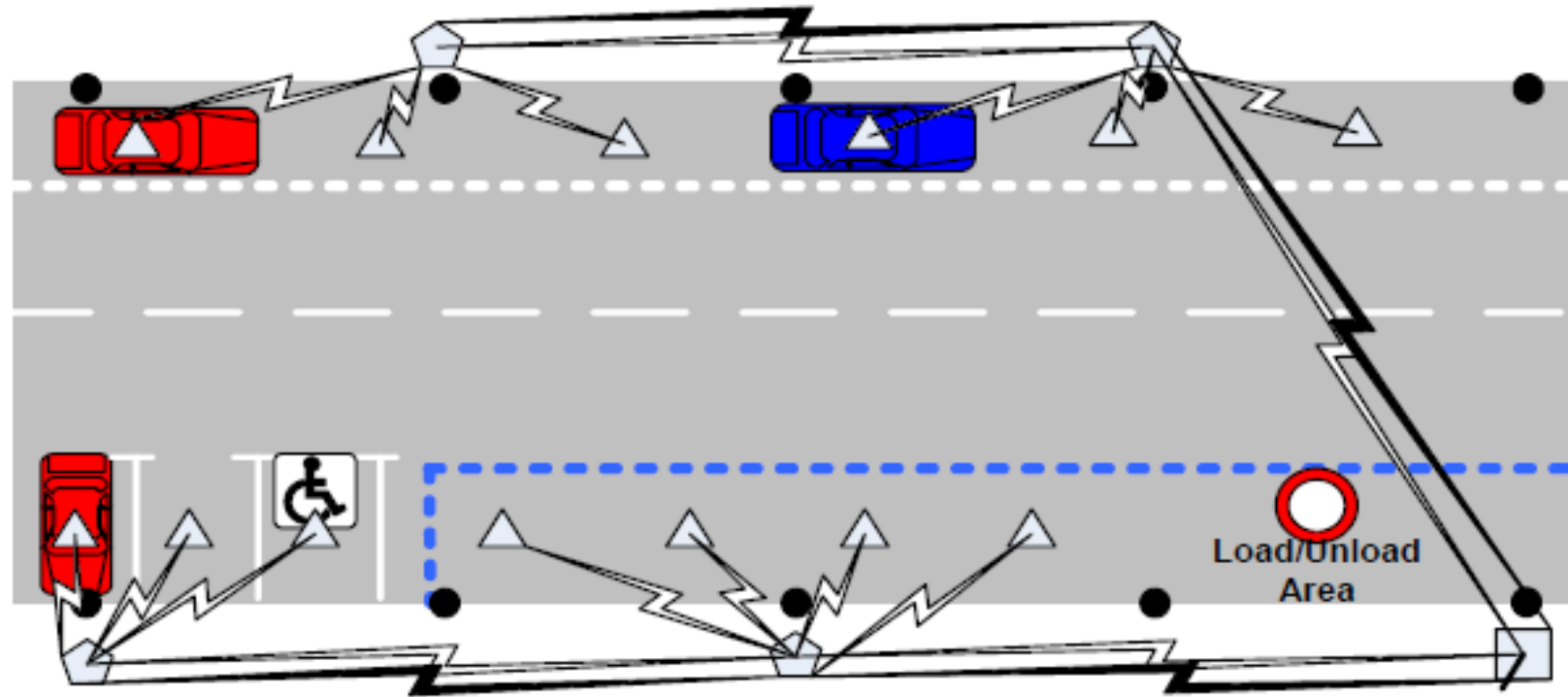




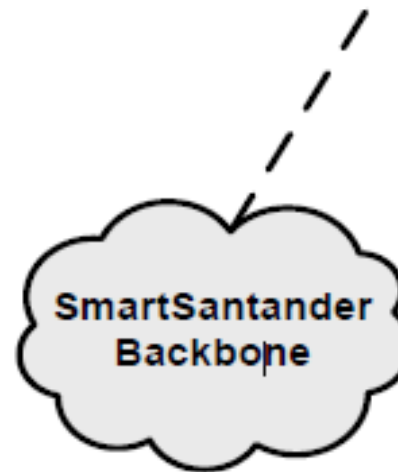
# Guided parking



# Parking example

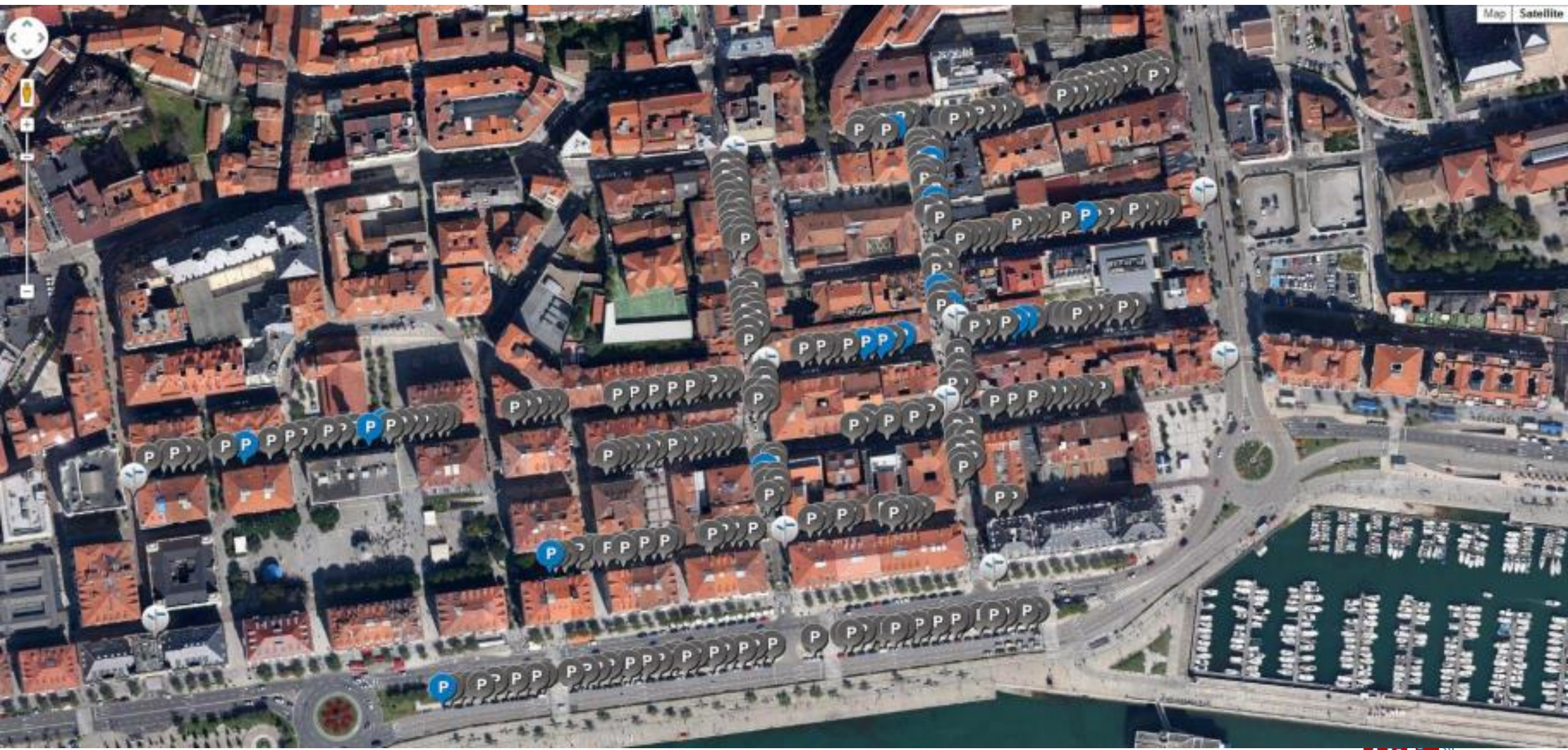


- Streetlight
- ▲ Parking sensor: Sensor node with one transceiver (Digimesh)
- ◑ Repeater: Sensor node with two transceivers (Digimesh and 802.15.4)
- ◻ Gateway: Node with communication with sensor networks (Digimesh and 802.15.4) and communication with external networks (WiFi, GPRS, ethernet)
- ⚡ Digimesh Link
- ⚡ 802.15.4 Link
- - - WiFi/GPRS, ethernet Link





# Parking example





# Augmented reality

- 2000 RFID tags/QR codes deployed
- Mark POI-s (point-of-interest)
- Location-based services

SmartSantander 

ACCEDA A OFERTAS EXCLUSIVAS E INFORMACIÓN DE ESTE COMERCIO  
Access to exclusive offers and information on this trade

AYUNTAMIENTO DE SANTANDER 

O ESCANEE ESTE CÓDIGO  
Or scan this code

APROXIME SU MÓVIL NFC AQUÍ  
Tap your phone here



  
comerciosantander.com

The advertisement features a blue background with a sunburst pattern. At the top, the 'SmartSantander' logo is displayed. Below it, a green banner contains the text 'ACCEDA A OFERTAS EXCLUSIVAS E INFORMACIÓN DE ESTE COMERCIO' and its English translation. The central focus is a large blue smartphone graphic. The phone screen shows the 'AYUNTAMIENTO DE SANTANDER' logo at the top, followed by a large 'N' logo with a speech bubble pointing to it. Below the 'N' logo, the text 'APROXIME SU MÓVIL NFC AQUÍ' and 'Tap your phone here' is displayed. At the bottom of the phone screen is the 'comerciosantander.com' logo. To the right of the phone, a QR code is shown with the text 'O ESCANEE ESTE CÓDIGO' and 'Or scan this code' above it. The bottom right corner of the advertisement features a stylized cityscape logo for 'OKOS VÁROS @ BME TMIT'.



# Participatory sensing

- Users and their smartphones (and all sensors within the smartphone!):
  - GPS coordinate, compass
  - Environmental parameters: noise, temperature
- „The pace of the city” – users can subscribe to services
  - Events, alerts



# Phase 3

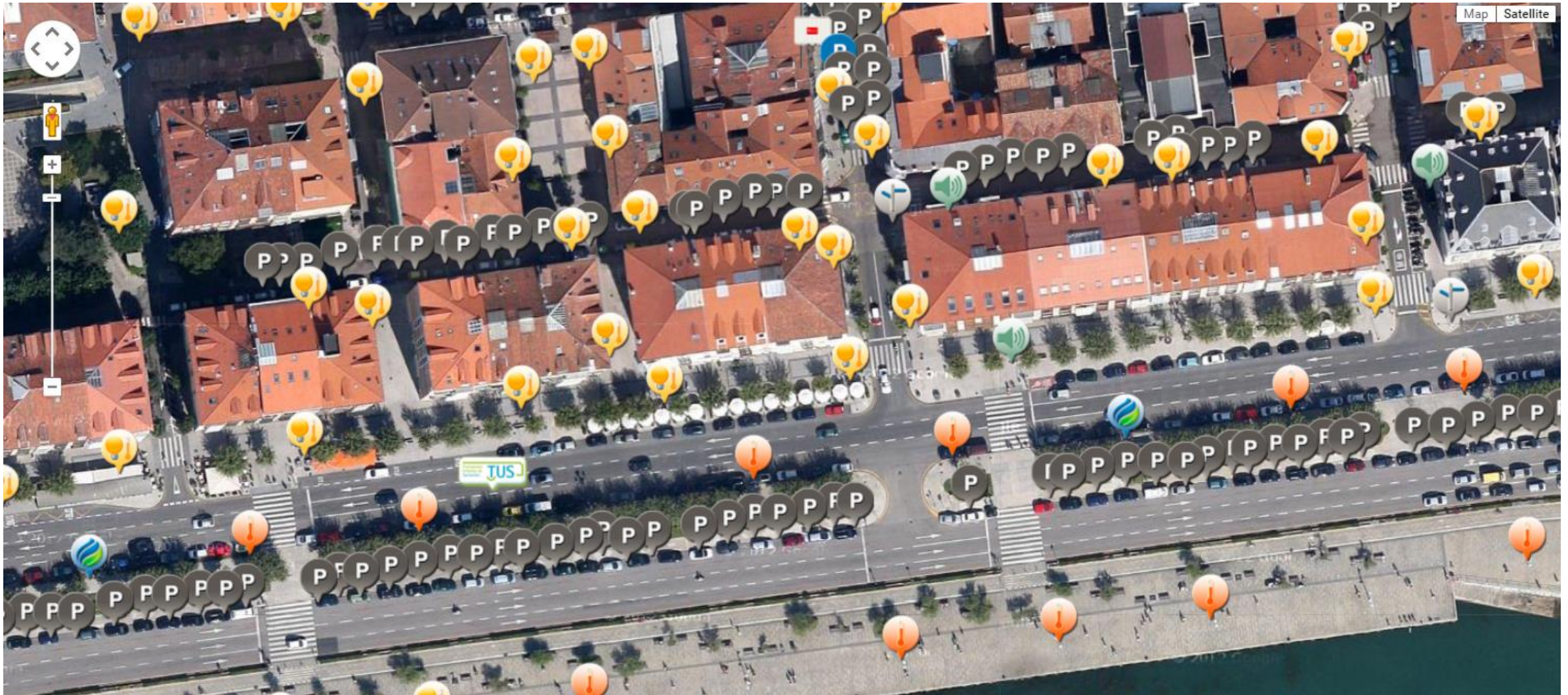
- Mobile environmental monitoring and outdoor guided parking

Node Type		Amount	Sensors	Radio I/F
Gateway		3	N/A	Proprietary, GPRS/UMTS
Repeater		37	N/A	Proprietary
Mobile node	Bus (w. CAN-BUS)	10	CO, Particles, NO <sub>2</sub> , Ozone, Temperature, Relative Humidity, Speed, Course, Odometer, Location, CAN	IEEE 802.11, GPRS
	Bus	15	CO, Particles, NO <sub>2</sub> , Ozone, Temperature, Relative Humidity, Speed, Course, Odometer, Location	IEEE 802.15.4, GPRS, IEEE 802.11
Parking Sensor		330	Occupancy	Proprietary
Parking Tag		30	Authorization	Proprietary
<b>Total:</b>		<b>3 GW 330 Fixed Nodes 25 Mobile Nodes 30 Tags</b>	<b>330 fixed sensors 250+ mobile sensors</b>	



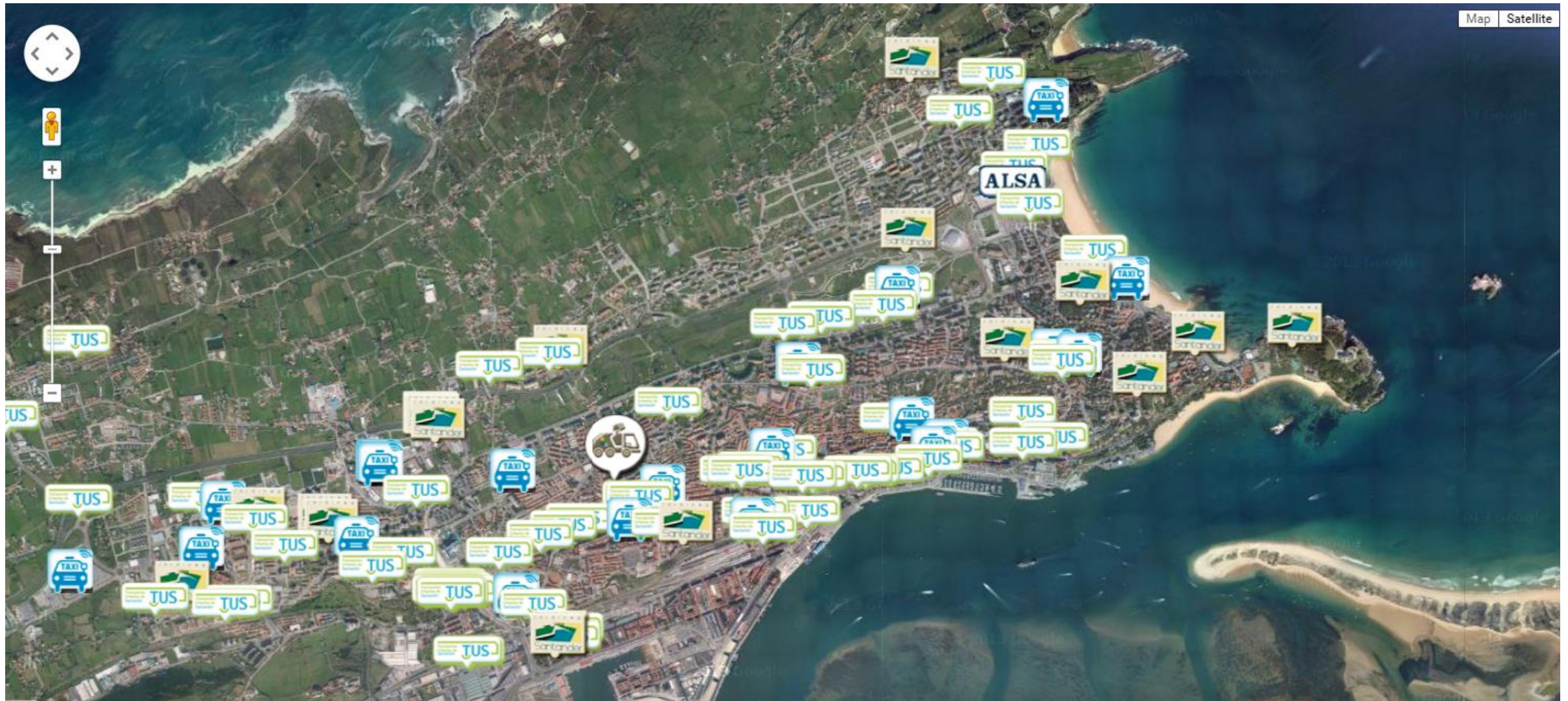


# Smart Santander – IoT map





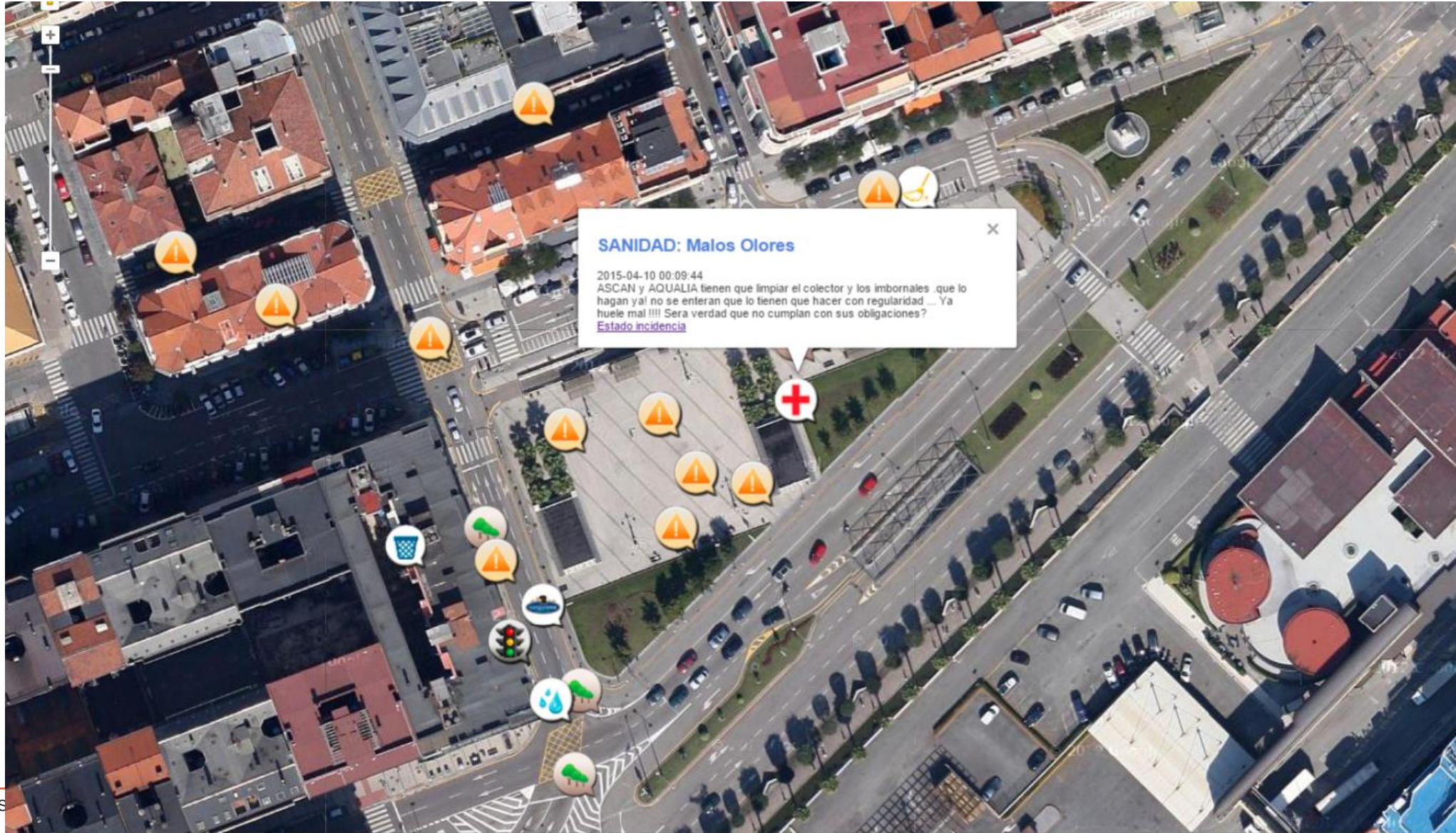
# Smart Santander – Mobile sensor map





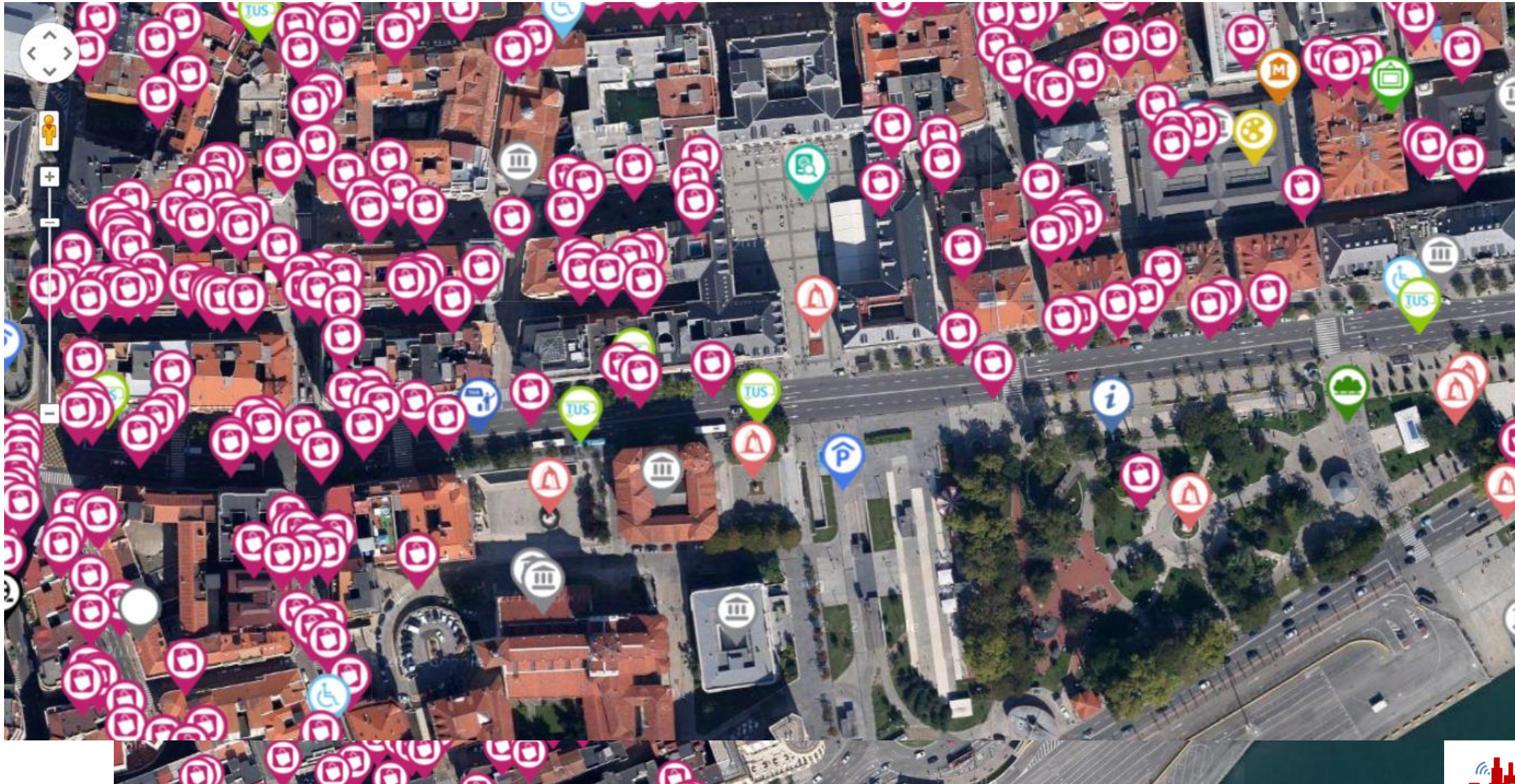
# Pace of the City

- User posts on problems in the city, together with responses from the authority





# Augmented reality





# The team

## Project meeting (2013)

## Kick-off meeting (2010 September)



# Smart Santander @ EuroNews



<https://www.youtube.com/watch?v=E6mqiSc-8ls>