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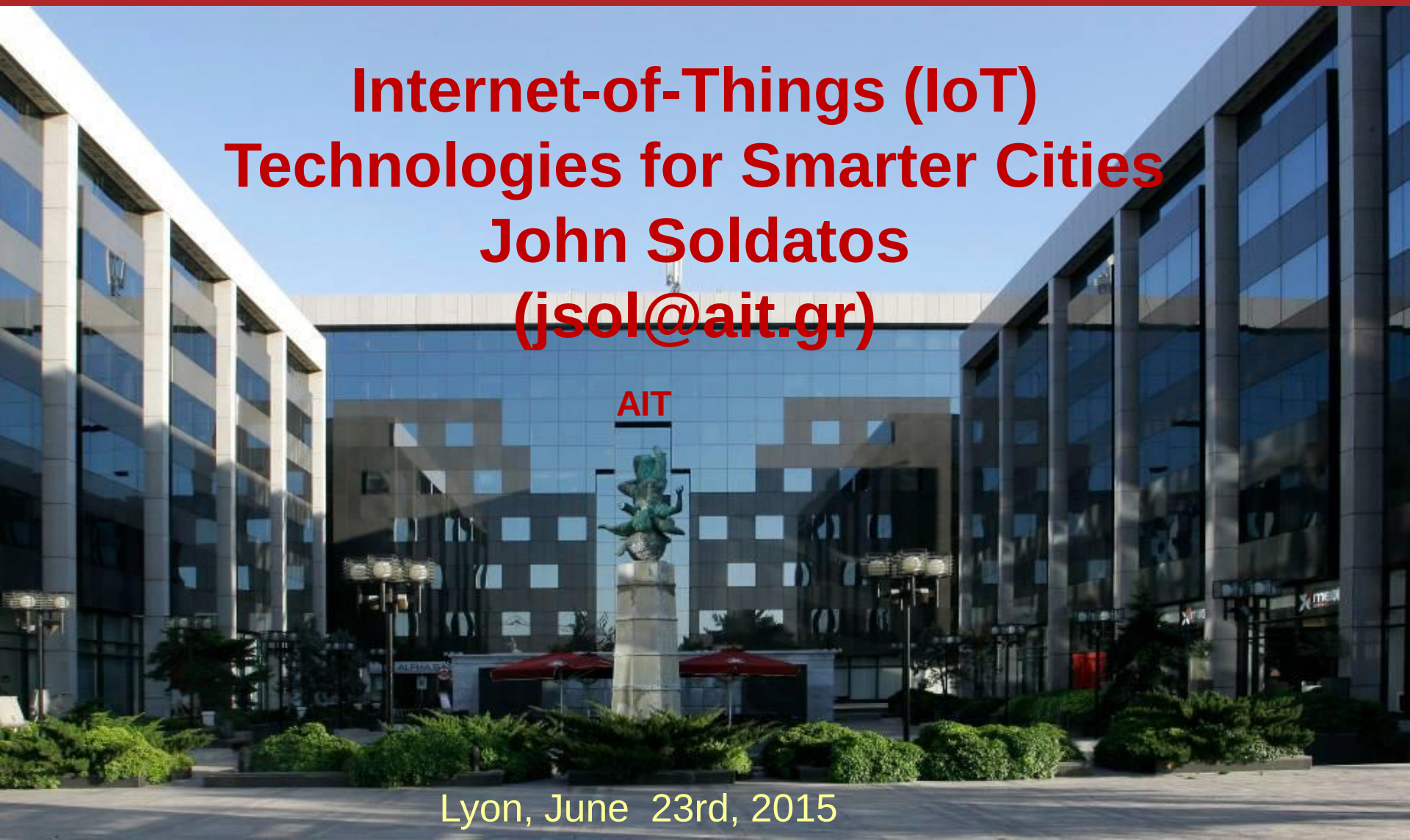
# RESCOM Summer School



# Internet-of-Things (IoT) Technologies for Smarter Cities

John Soldatos
(jsol@ait.gr)

AIT

Lyon, June 23rd, 2015

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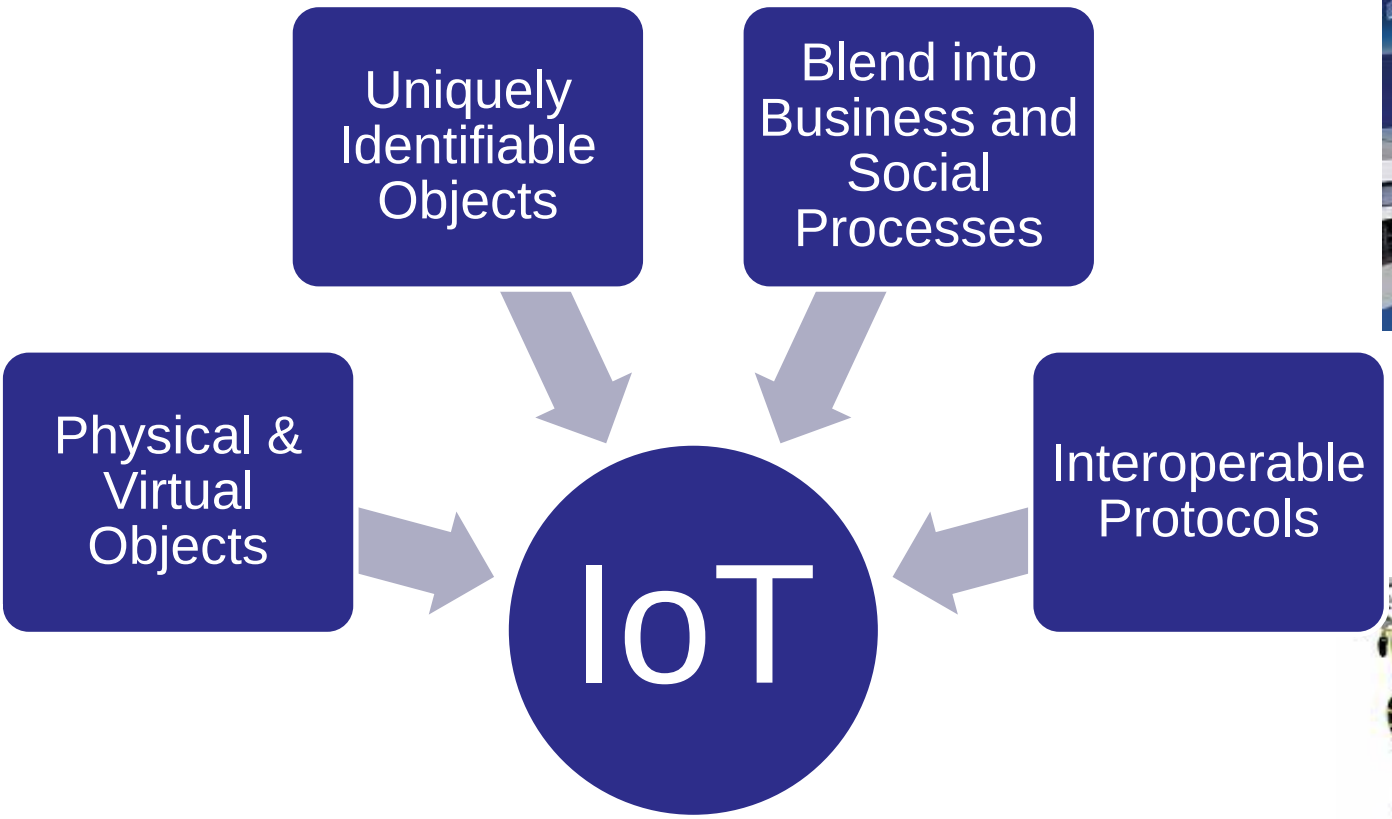
# Internet-of-Things

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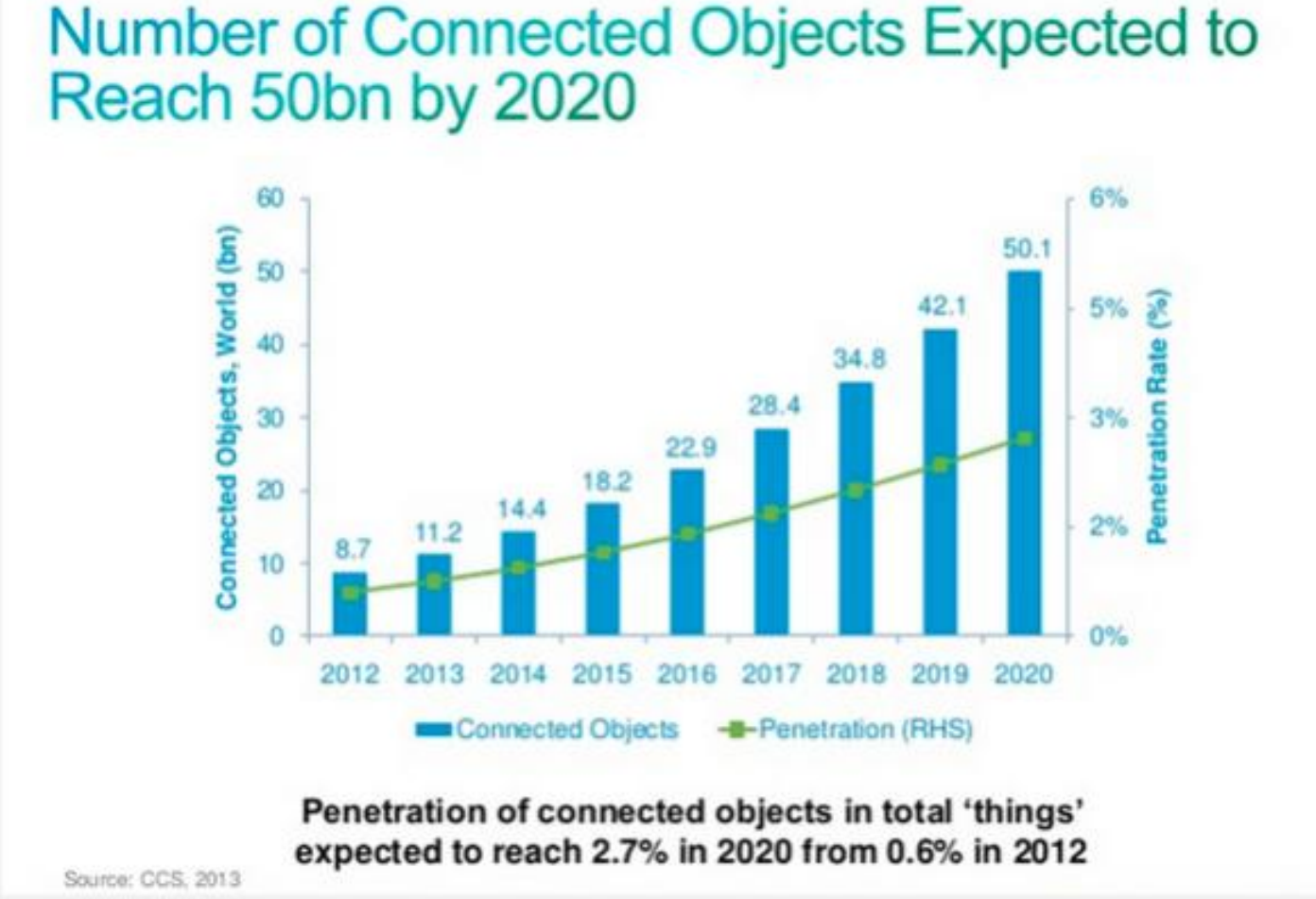
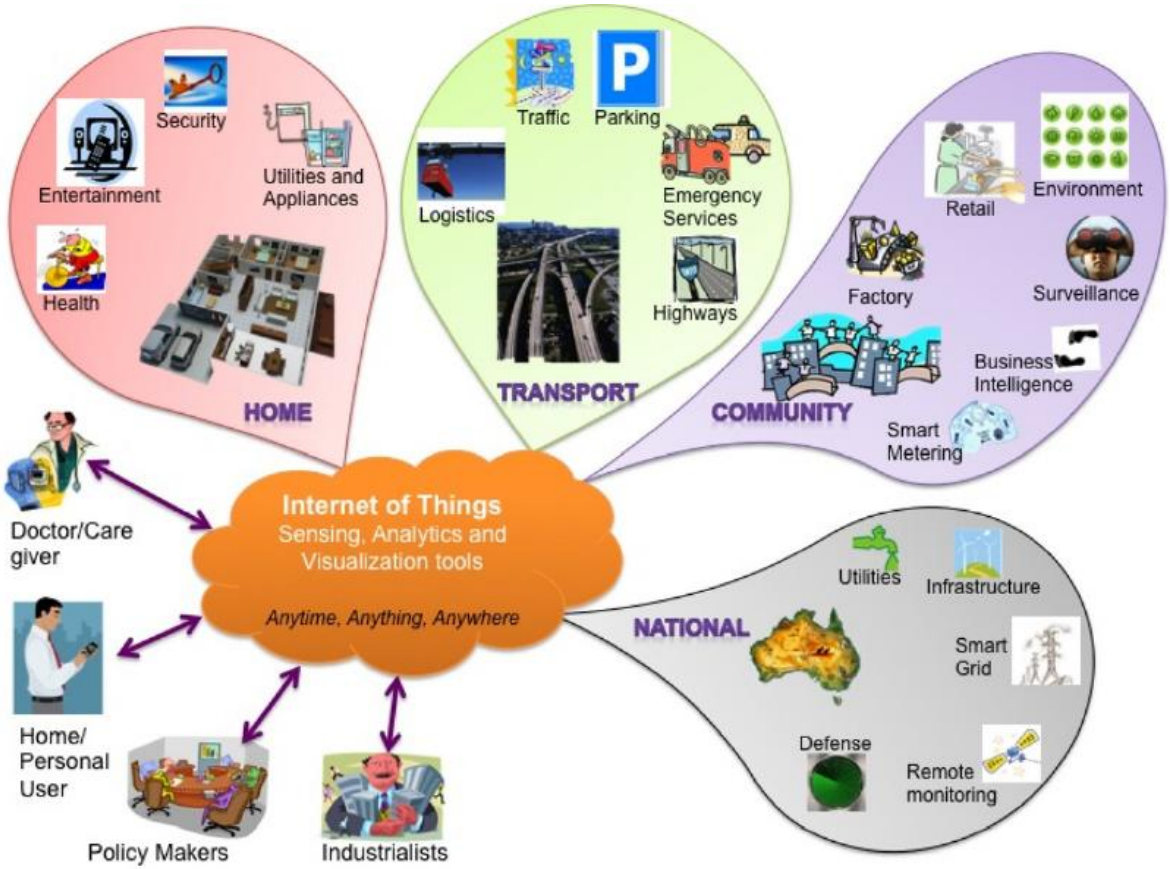
# Number of Internet Connected Objects



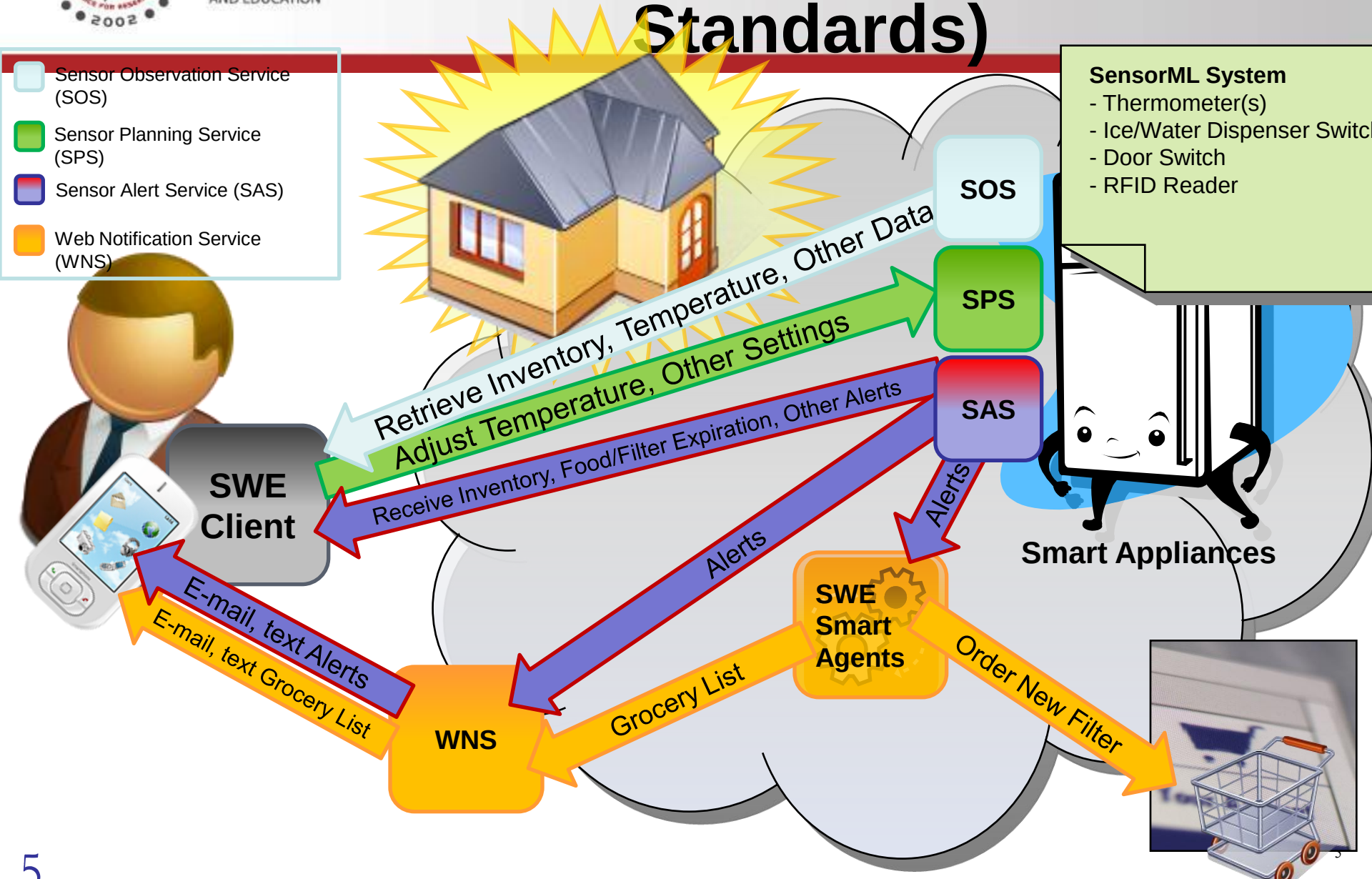

Source: Cisco

# IoT Application Areas

*Source: J. Gubbi et al. / Future Generation Computer Systems 29 (2013) 1645–1660*



# Sample IoT Application (OGC Standards)



# Smart Cities

**Invest in**
- Human Capital
- Intellectual & Social Capital
- Infrastructure (incl. ICT)

**towards**
- Sustainable Development
- Economy Growth
- Quality of Life

**Based on**
- Participatory Governance
- Improved Management of Natural Resources

# Smart Cities Market

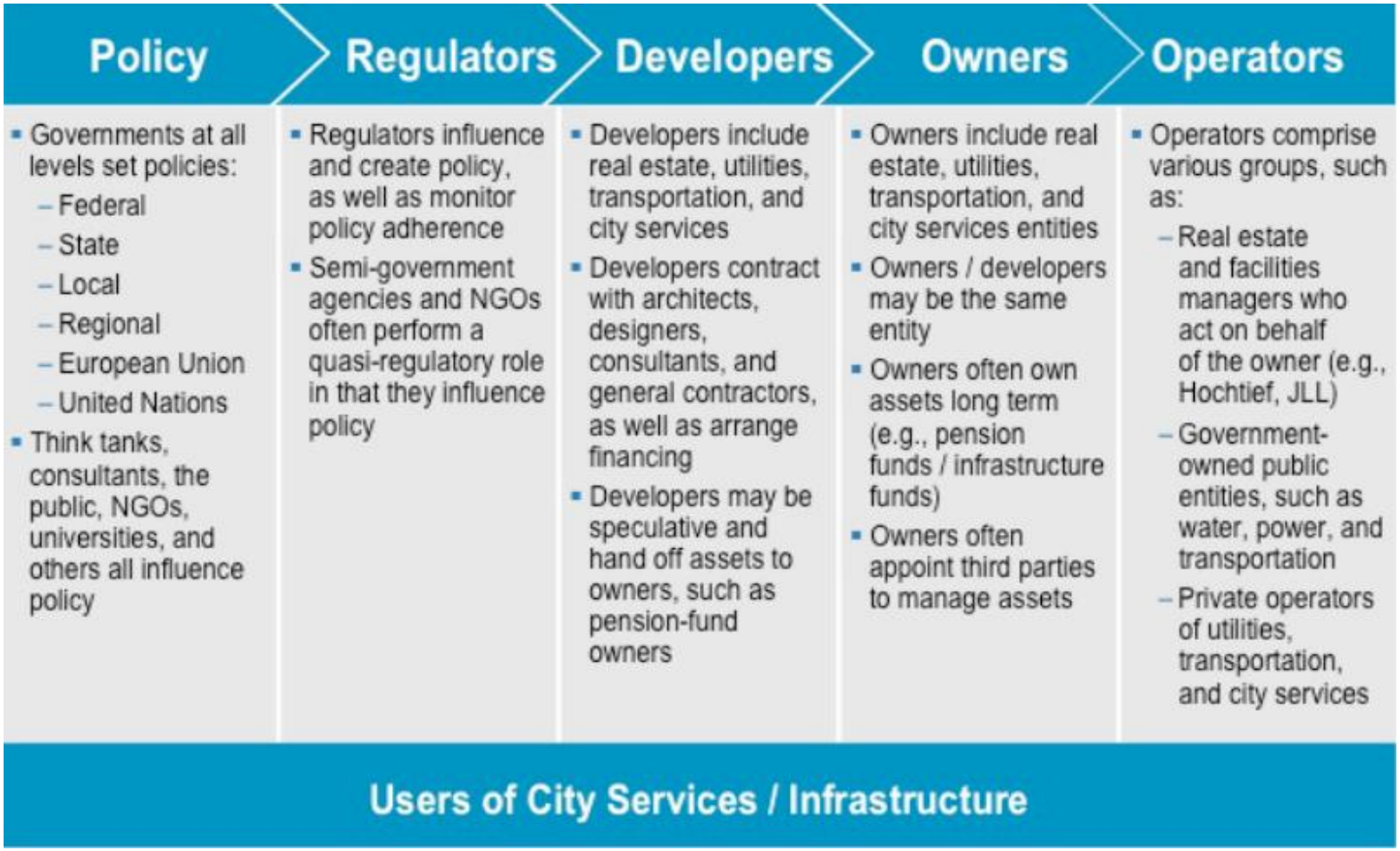
*Source: Frost & Sullivan "Global Smart City Market – A $1.5 Trillion Market Opportunity by 2020", Market Report, September 2013.*


Expected market growth: From $6.1 billion annually in 2012 to $20.2 billion in 2020 (i.e. 16.2% CAGR)

Dominant Areas: Energy, transportation, government

# Smart Cities Stakeholders & Roles

*Source: Smart City Framework, Cisco, 2012*



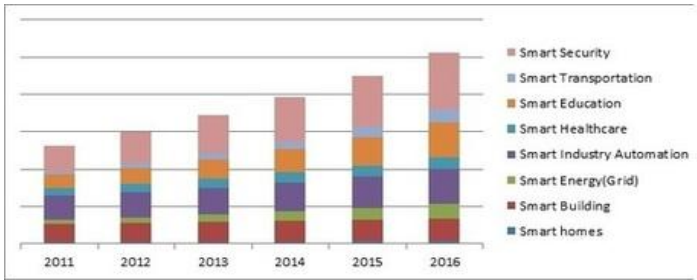
# Smart Cities and Internet of Things

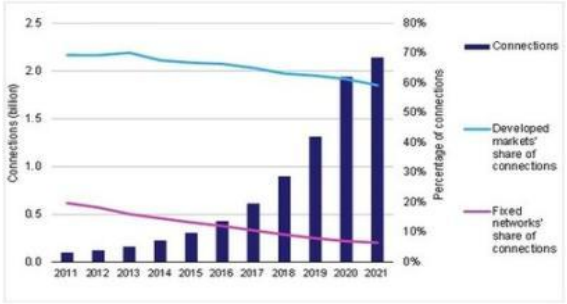
Smart Cities are based on broadband and IoT infrastructures (e.g., sensors)

Smart City Applications Handle Data Streams (from different information), and deal with multiple events

Smart Applications (Smart Home, Smart Transport, Smart Buildings, Smart Police Activiies,...)

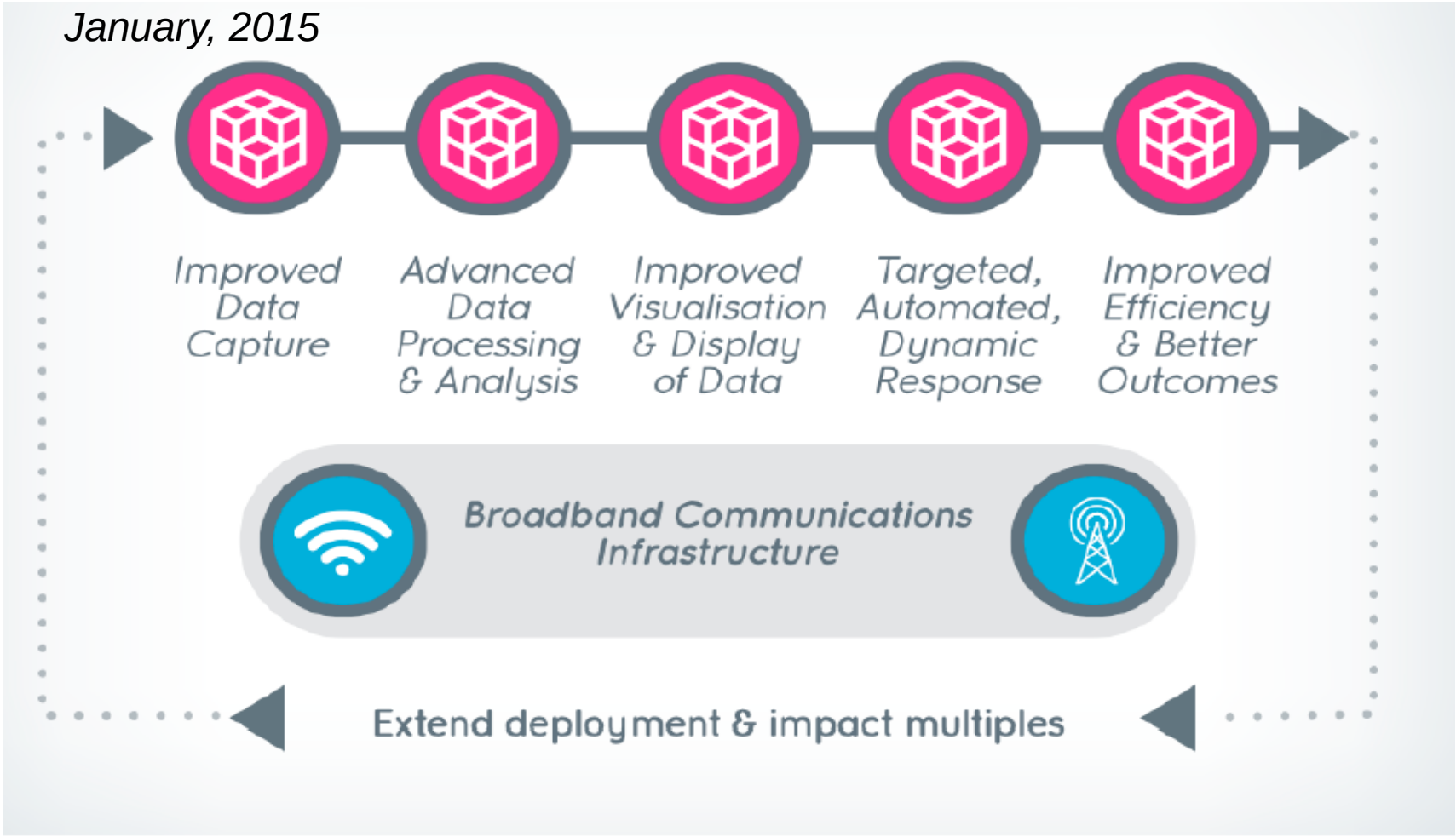
Environment for Integrated Surveillance (leverage sensors from municipalities, city authorities, community sensors...)



# Smart Cities - Data Processing & Analytics

*Source: JScottish Cities Alliance, "Smart Cities Maturity Model and Self-*
*--Assessment Tool", Guidance Note for completion of Self--Assessment Tool*
*January, 2015*



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# Maturity Models

## Phase 1 – Digital Infrastructure

- Broadband Networks Sensor Networks, (Public Open Data)
- Certification & Validation of Infrastructures
- Digital City

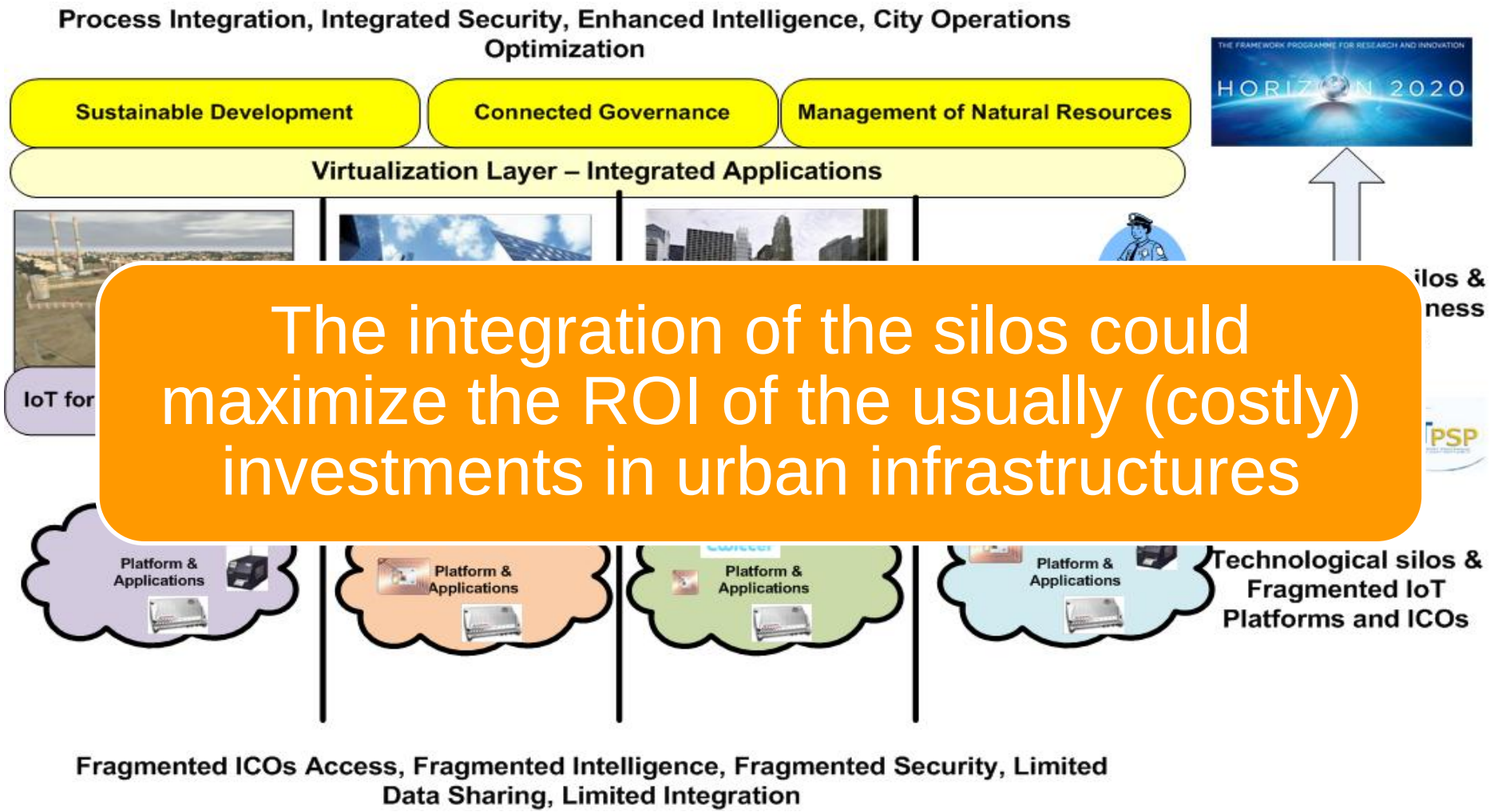
## Phase 2 – Services Development

- Smart Energy, Smart Transport, Urban Mobility
- Stakeholders' Involvement
- "Smart City"

## Phase 3 – Services Integration & Citizens Participation

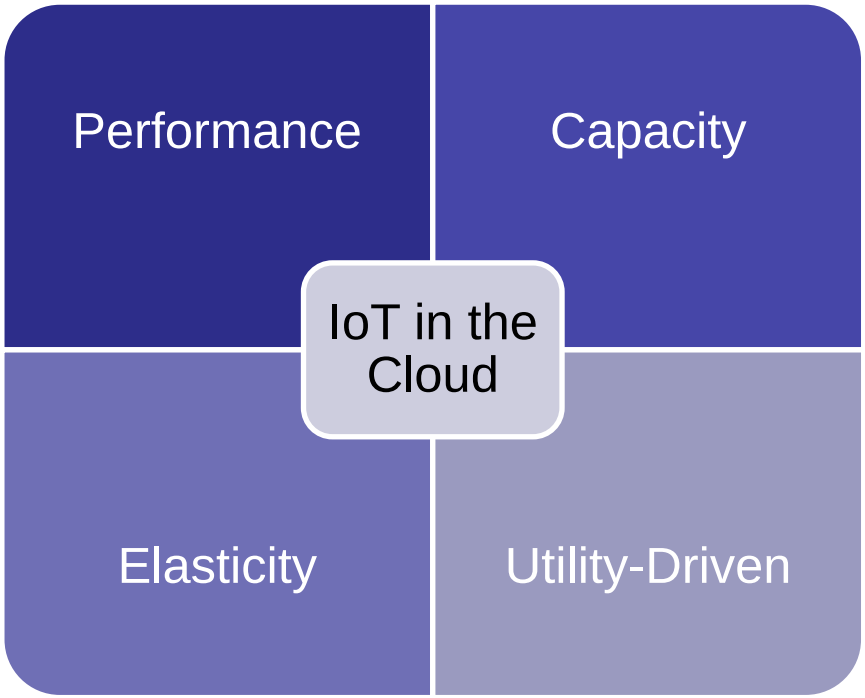
- Integration and Reusability of Data & Services
- Citizens' Engagement
- Integrated Smart City

# Challenge: Smart Cities Silos Integration



# IoT / Cloud Convergence

- Convergence IoT Between IoT and Cloud Computing
  - Allow IoT applications to leverage the benefits of the Cloud
- Challenge
  - Conflicting properties of IoT (e.g., WSN) and Cloud




| IoT/Sensors | Cloud Computing |
|---|---|
| • Location specific<br>• Resource constrained,<br>• Expensive (development/ deployment cost)<br>• Generally inflexible (resource access and availability) | • Location independent<br>• Wealth of inexpensive resources<br>• Rapid elasticity<br>• Flexibility |

# Sensor Clouds and IoT Clouds

- Streaming of Sensor / WSN data in a cloud infrastructure (2005-2009) (Mainly Research Efforts)
- Advent of Public IoT Clouds (2007+ including commercial efforts) e.g.,:
  - Xively (xively.com)
  - ThingsWorx (www.thingworx.com)
  - ThingsSpeak (thingspeak.com)
  - Sensor-Cloud (www.sensor-cloud.com)
  - Realtime.io (https://realtime.io/)
  - ... And many more

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# Lack of Semantic Interoperability

- Most Sensor Clouds focus on the integration of data streams within the cloud
  - Including  a syntactic harmonization of the data streams
  - Use of CSV, XML, JSON format
  - Suitable for Intra-Enterprise Applications
- Lack of semantic interoperability
  - Foundation for Inter-Enterprise Applications in global IoT
  - Common  Semantics – Uniform / Global Discovery of IoT Resources
  - Foundation for Integrated Smart City Applications that bridge existing silos

# Ontologies for IoT Semantic Interoperability

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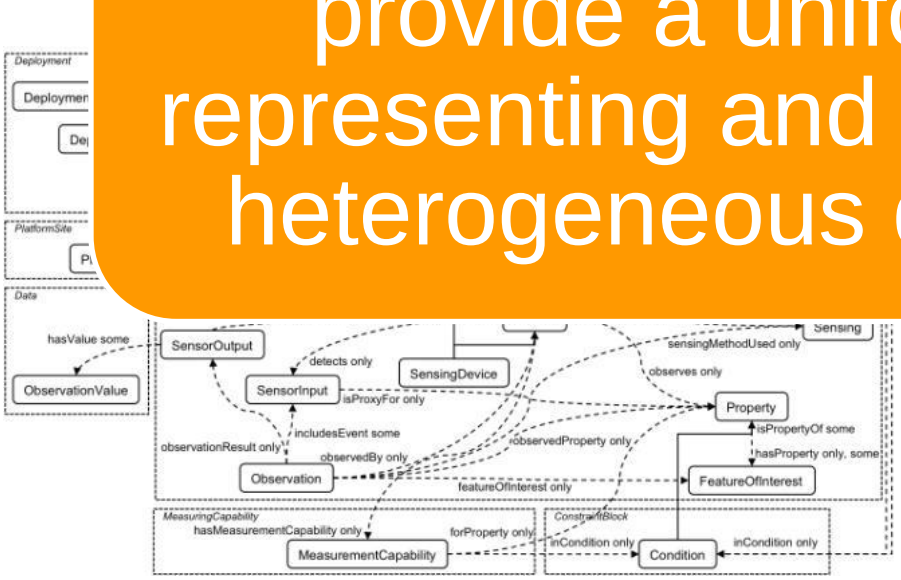
| Semantic Interoperability | Reasoning Algorithms |
|---|---|
| • Distributed and Heterogeneous Data Sources<br>• Diverse Data Streams<br>• Cor<br>• Sc<br>Or | • Intelligent Selection & Filtering of Sensors<br>• Intelligent Selection & Filtering of Sensor Data<br>nked |

Semantic Standards for sensors provide a uniform way for representing and reasoning over heterogeneous data streams




# OpenIoT Project (openiot.eu)

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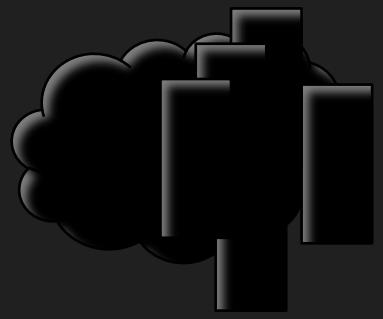
Contract No.: 287305
Objective: ICT-2011.1.3 Internet-connected Objects

EC Contribution: €2,455,000.00

Project Start Date: 1/12/2011
Duration: 36 months

Cloud Computing



Management

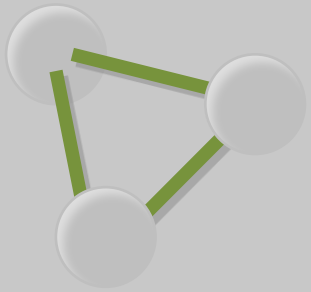
Data Privacy and Security

Sensor Mobility


Internet of Things

Open Source

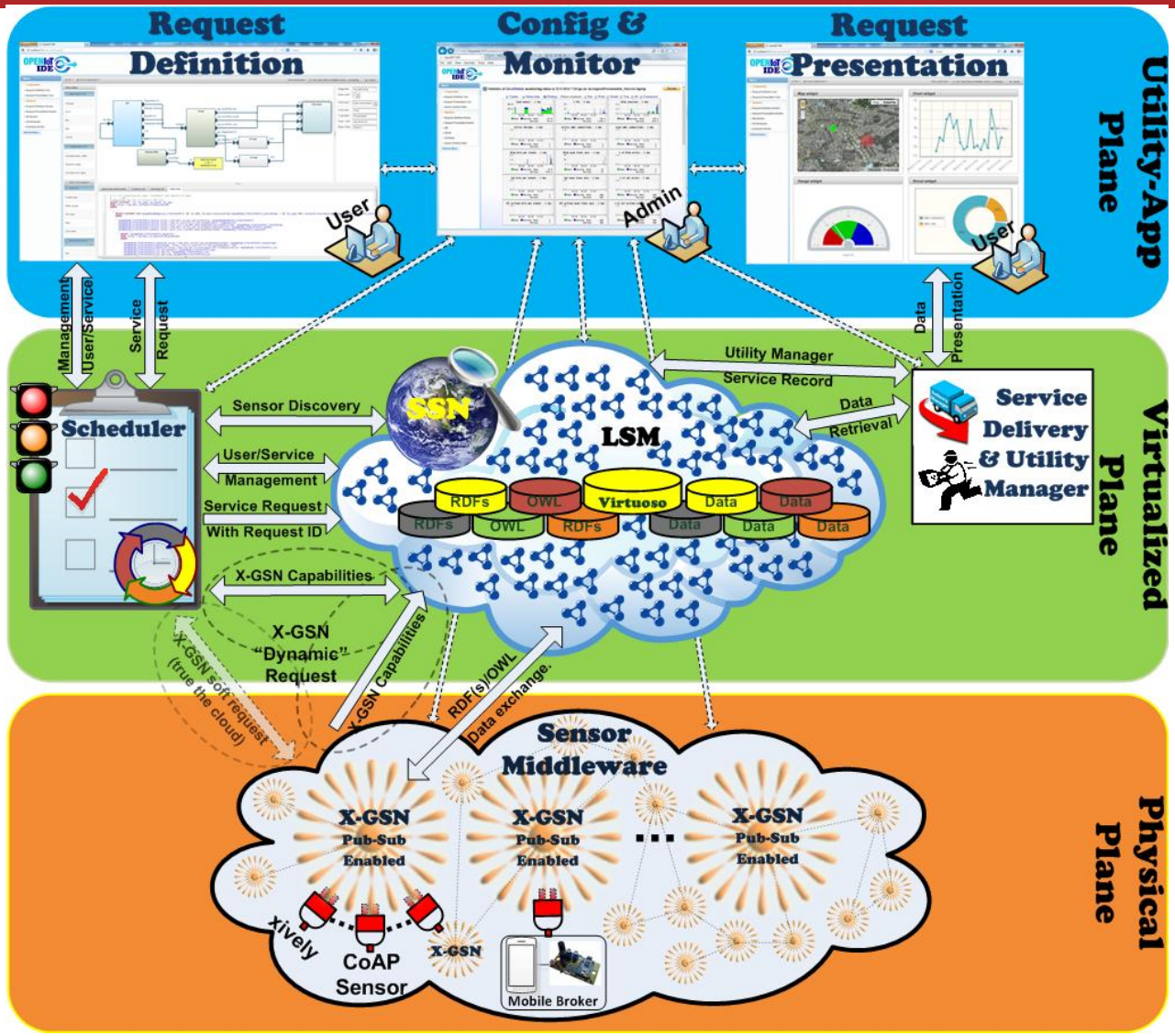
Linked Data



**Open Source Cloud Solution for the Internet of Thing**

DERI NUI Galway OÉ Gaillimh · ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE · Fraunhofer IOSB · AIT CENTER OF EXCELLENCE FOR RESEARCH AND EDUCATION · Perceptum ex Optimus · across limits · μSens@p systems · CSIRO

# OpenIoT Architecture



# OpenIoT Interoperability Architecture

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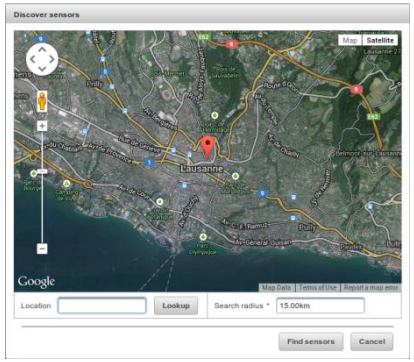
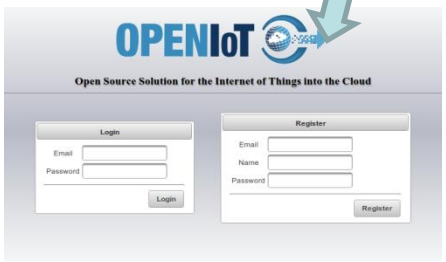
Present

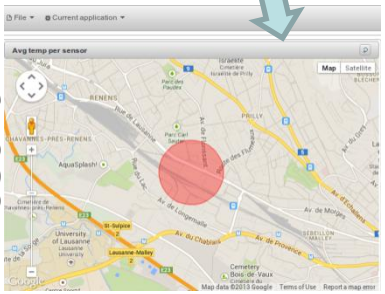

Discover



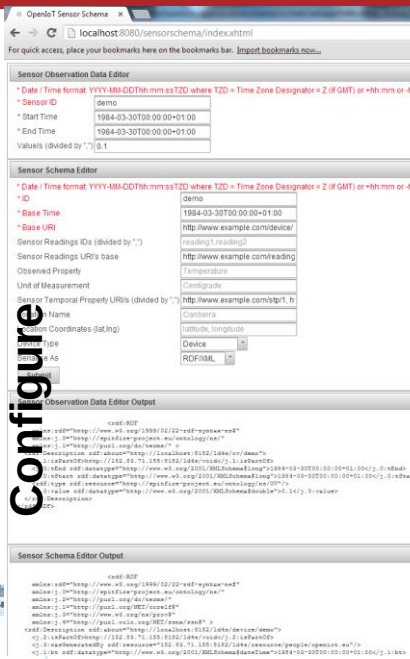

Authenticate



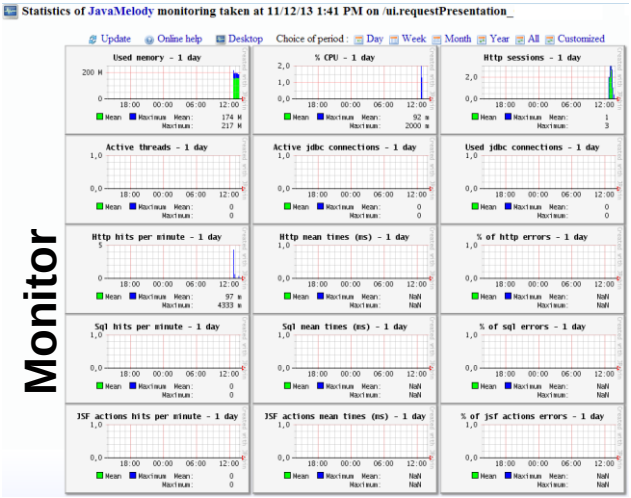

Present



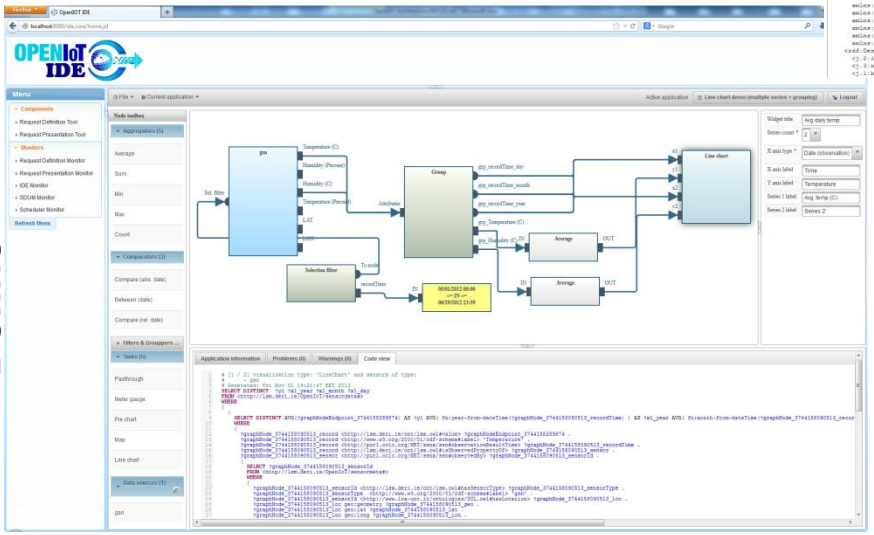

Configure



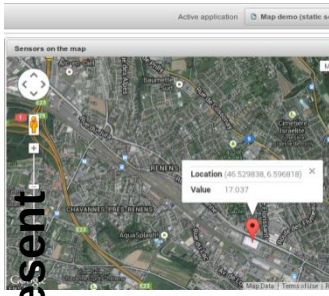

Monitor




Define



Present



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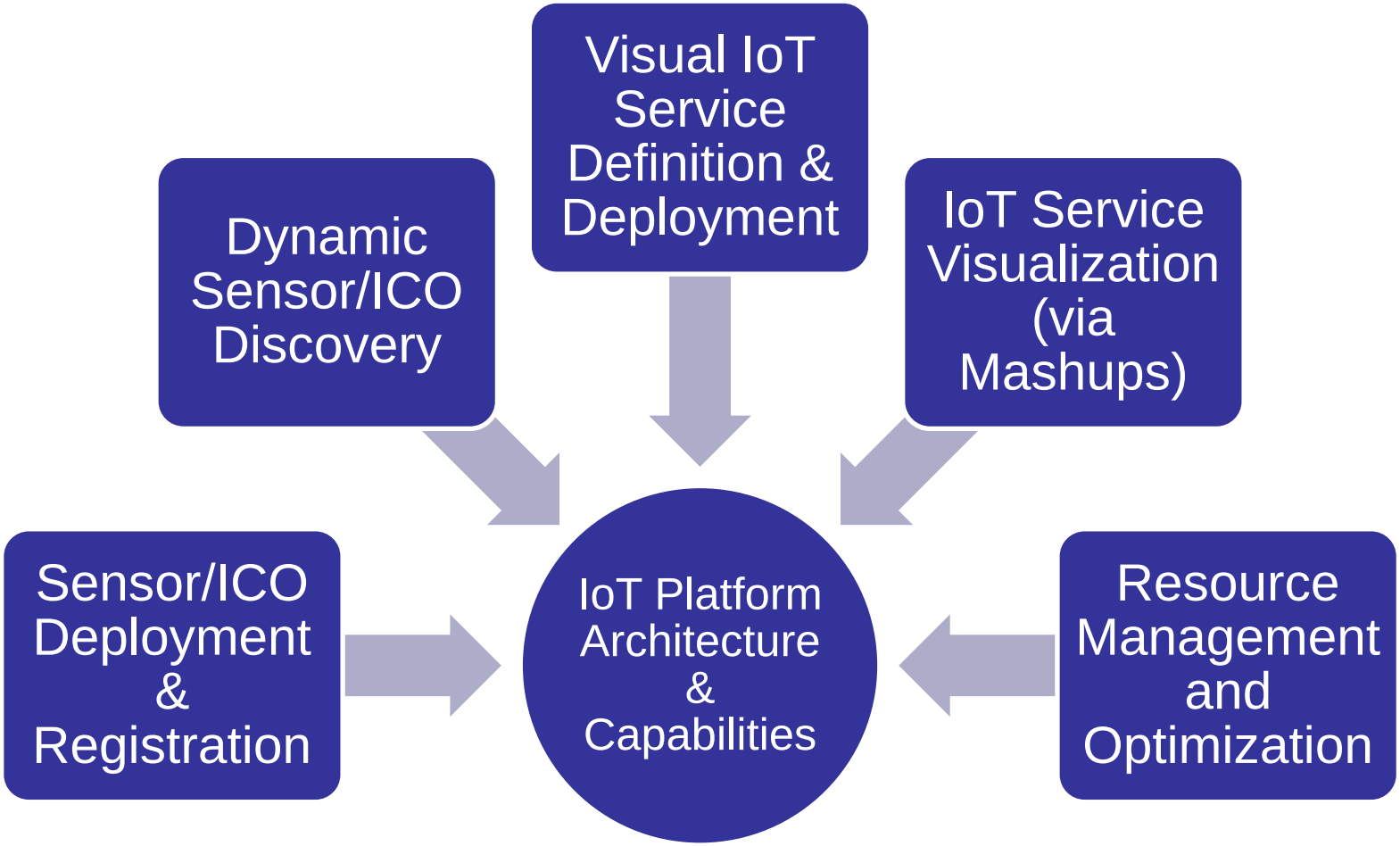
# What can I do with OpenIoT?



# Sensor & ICO Registration

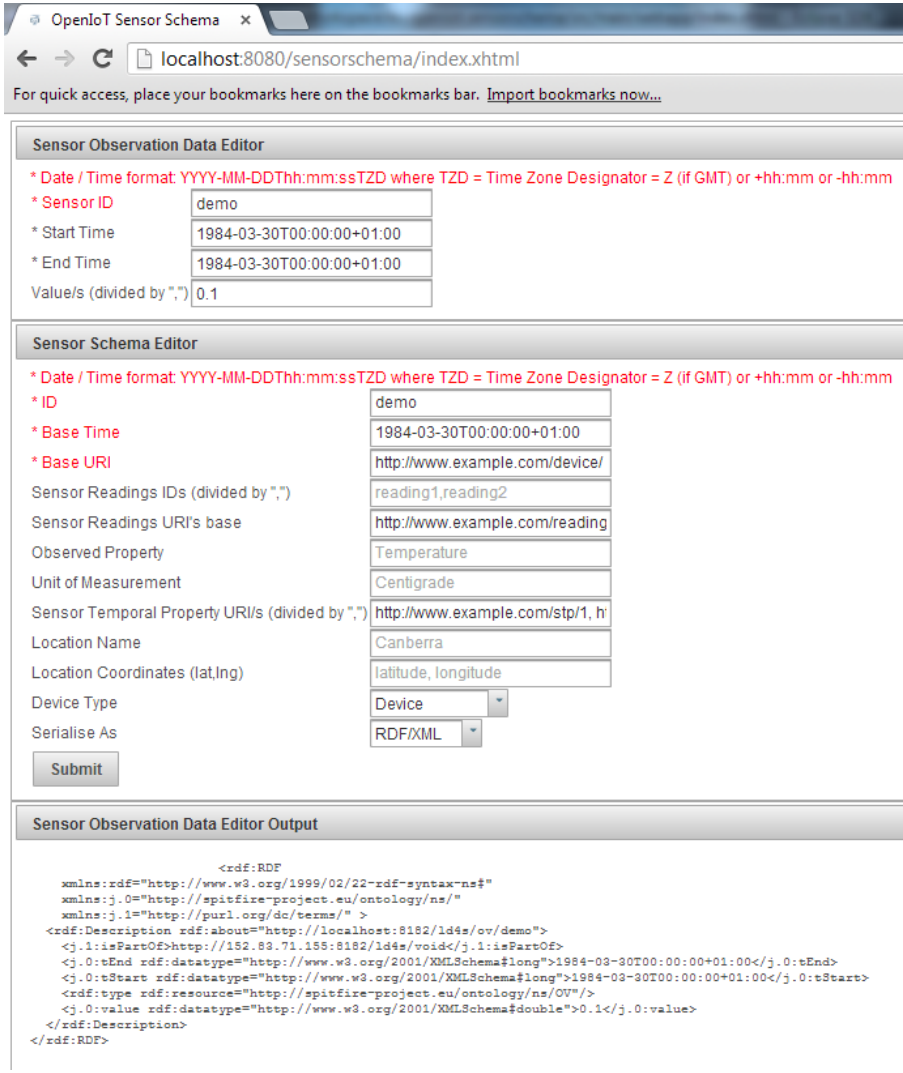
OpenIoT can integrated virtually any ICO through X-GSN

Support for both physical sensors (e.g., cameras, microphones, temp etc.) and virtual sensors (e.g., algorithm, twitter streams)

If a low level is available the process involves editing a simple metadata file

Impelementation of drivers for not supported sensors is a matter of 1-2 man days effort

Deployed ICOs publish their data according to OpenIoT (W3 SSN) ontology via LSM



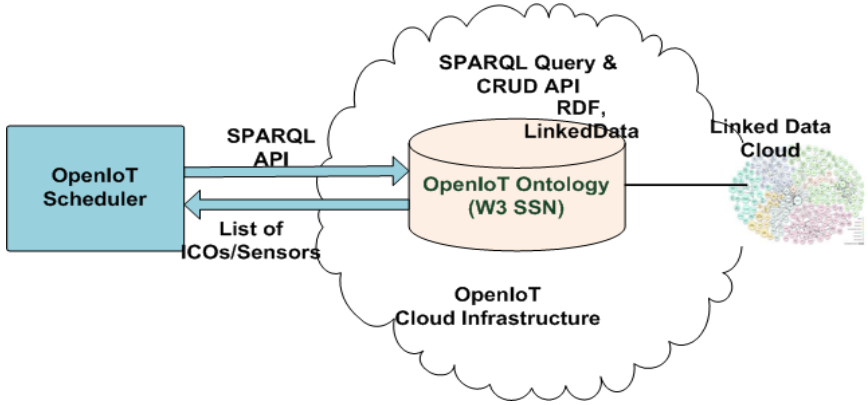
# Dynamic Sensor & ICOs Discovery

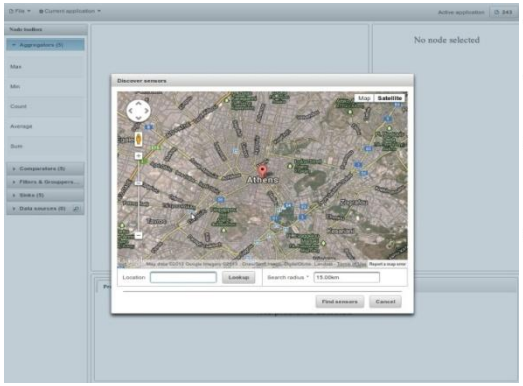
Dynamic ICOs and Sensors Look-up Takes place through the Scheduler

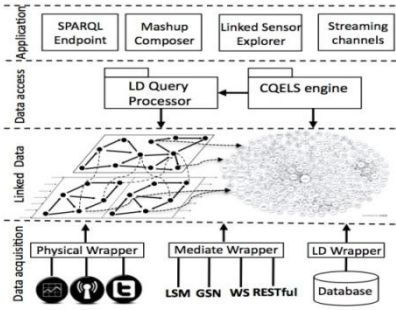
Discovery Citeria including ICO/sensor type and location

The Discoverer component (LSM) is deployed in the cloud

SPARQL is used for accessing both sensor data and meta-data (dynamically)



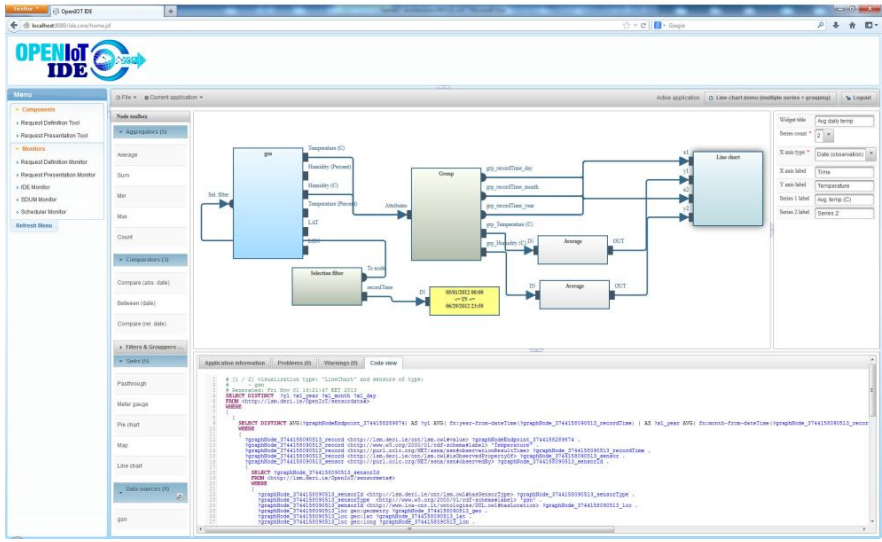


# Visual IoT Service Definition & Development

OpenIoT provides the means for dynamically selecting sensors/ICOs and synthesizing their data into services

The «Request Presentation» visual tool (part of OpenIoT IDE) provides a zero-programming interfaces

The tool enables validation and deployment of the service




Select Sensors/ICOs → Filter & Combine Sensors/ICOs → Select Sinks for Visualization/Presentation → Validate & Deploy on OpenIoT middleware

# OpenIoT is an Open Source Project

**Open Source**

- http://github.com/openiot/OpenIoT
- Open Source Release of OpenIoT software (3rd Quarter 2013)

**License**

- OpenIoT reseleased under LGPL v3.0 (Business Friendly)
- Ensures compatibility with background libraries/projects

**Governance**

- Master-governed planning
- Masters (OpenIoT partners) defined for major subprojects

# OpenIoT at github

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As of **22/01/2014** OpenIoT had:

- 960 commits
- 13 contributors
- mostly written in Java
- first commit in April, 2013
- COCOMO model: estimated 28 man-years of effort

| Version | Blank Lines | Comment Lines | Code Lines | Total Lines |
|---|---|---|---|---|
| OpenIoT v1.0 total Lines (**22/01/2014**) | **23,491** | **34,081** | **109,517** | **177,621** |
| OpenIoT new total Lines | **8,314** | **10,652** | **37,997** | **58,044** |
| Other non-OpenIoT total Lines (XGSN + CUPUS) | 15,177 | 23,428 | 71,520 | 110,125 |
| Other non-OpenIoT new Lines | **1,021** | **3,327** | **5,114** | **9,452** |

| | | | | | | |
|---|---|---|---|---|---|---|
| JavaScript | 18,938 | 4,283 | 18.4% | 3,174 | 26,395 | 15.8% |
| CSS | 9,049 | 186 | 2.0% | 1,457 | 10,692 | 6.4% |
| XML | 7,548 | 1,597 | 17.5% | 1,152 | 10,297 | 6.2% |
| HTML | 632 | 55 | 8.0% | 78 | 765 | 0.5% |
| XML Schema | 435 | 95 | 17.9% | 85 | 615 | 0.4% |
| SQL | 239 | 134 | 35.9% | 89 | 462 | 0.3% |
| XSL Transformation | 139 | 2 | 1.4% | 11 | 152 | 0.1% |
| shell script | 23 | 3 | 11.5% | 9 | 35 | 0.0% |
| DOS batch script | 10 | 0 | 0.0% | 1 | 11 | 0.0% |
| Totals | 109,517 | 34,081 | | 23,491 | 167,089 | |

# OpenIoT awarded Open Source Rookie by Black Duck

OpenIoT project receiver of the "Black Duck Rookie of the Year 3"

OPEN IoT

www.openiot.eu

EU FP7-ICT-2011-7

STREP 287305

2013 Winner

OpenIoT Architecture

An Open Source Cloud Solution for the Internet of Things

http://www.blackducksoftware.com/news/releases/

OPEN SOURCE ROOKIE OF THE YEAR

https://github.com/OpenIotOrg/openiot

# FP7 VITAL Project (www.vital-iot.eu)

The **VITAL** project (EU FP7 - 608682) is financially supported by the European Union Seventh Framework Programme (FP7 2007-2013).

- Project Number: 608682
- Project Acronym/Title: VITAL
- Call (part) Identifier: FP7-SMARTCITIES-2013
- Duration in months: 36
- Starting date: 01.09.2013
- Total Project Costs: 4,190,359.00 €
- Requested EU contribution: 2,695,000.00 €
- Project website: http://vital-iot.eu

# Integration for Smart City Silos

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Technical Silos

Organizational Silos

Application Silos

Information Silos & Fragmentation

Process Integration, Integrated Security, Enhanced Intelligence, City Operations Optimization

Sustainable Development | Connected Governance | Management of Natural Resources

VITAL Virtualization Layer – Integrated Development

IoT for Smart Industries

IoT for Smart Buildings

IoT for Urban Transport

IoT for Law Enforcement

Platform & Applications

Platform & Applications

twitter

Platform & Applications

Platform & Applications

Organizational silos & Fragmented Business Applications

Technological silos & Fragmented IoT Platforms and ICOs

Fragmented ICOs Access, Fragmented Intelligence, Fragmented Security, Limited Data Sharing, Limited Integration

# VITAL Goals

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Integrate Diverse IoT Silos (technical & organizational)

Alleviate Fragmentation (common platform and tools, interoperability)

Enable larger scale and holistic applications

Enable innovative applications spanning multiple administrative domains and business contexts

IoT Deployments operated by different organizations / departments

Multiple IoT Deployments in Smart Cities

Diverse IoT architectures and Platforms

IoT Smart City Applications Fragmentation

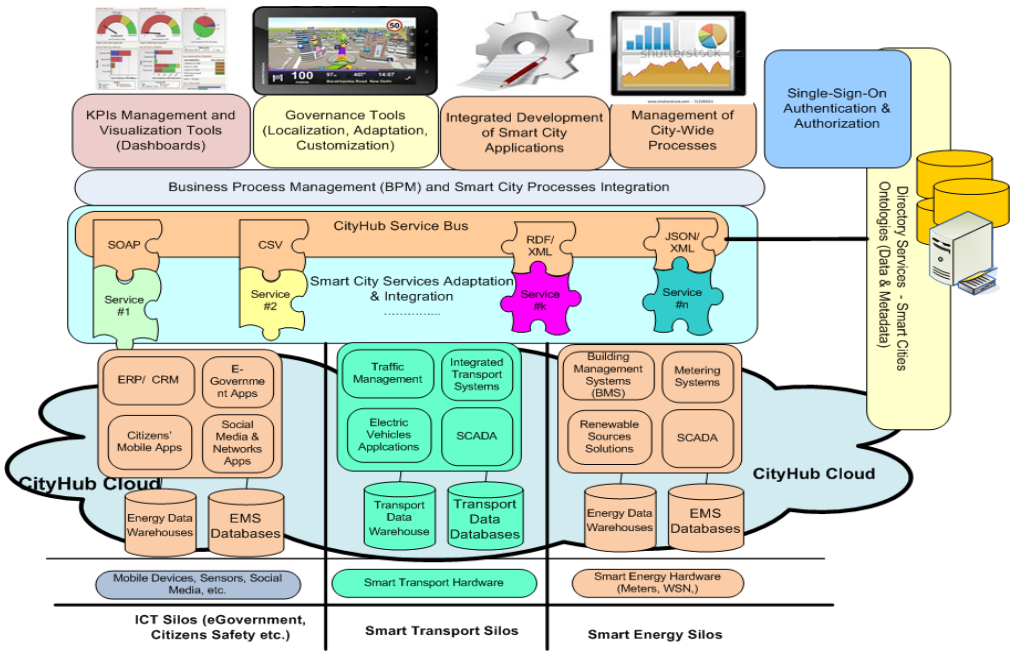
# Smart City Operating Center

Control Center integrating all systems and projects in the smart city

Control Center = Software Middleware and Processes

Example #1: Integrated Performance Management – Calculate CO2 saving across all different energy projects

Example #2: Repurposing and reusing smart city infrastructures across multiple applications



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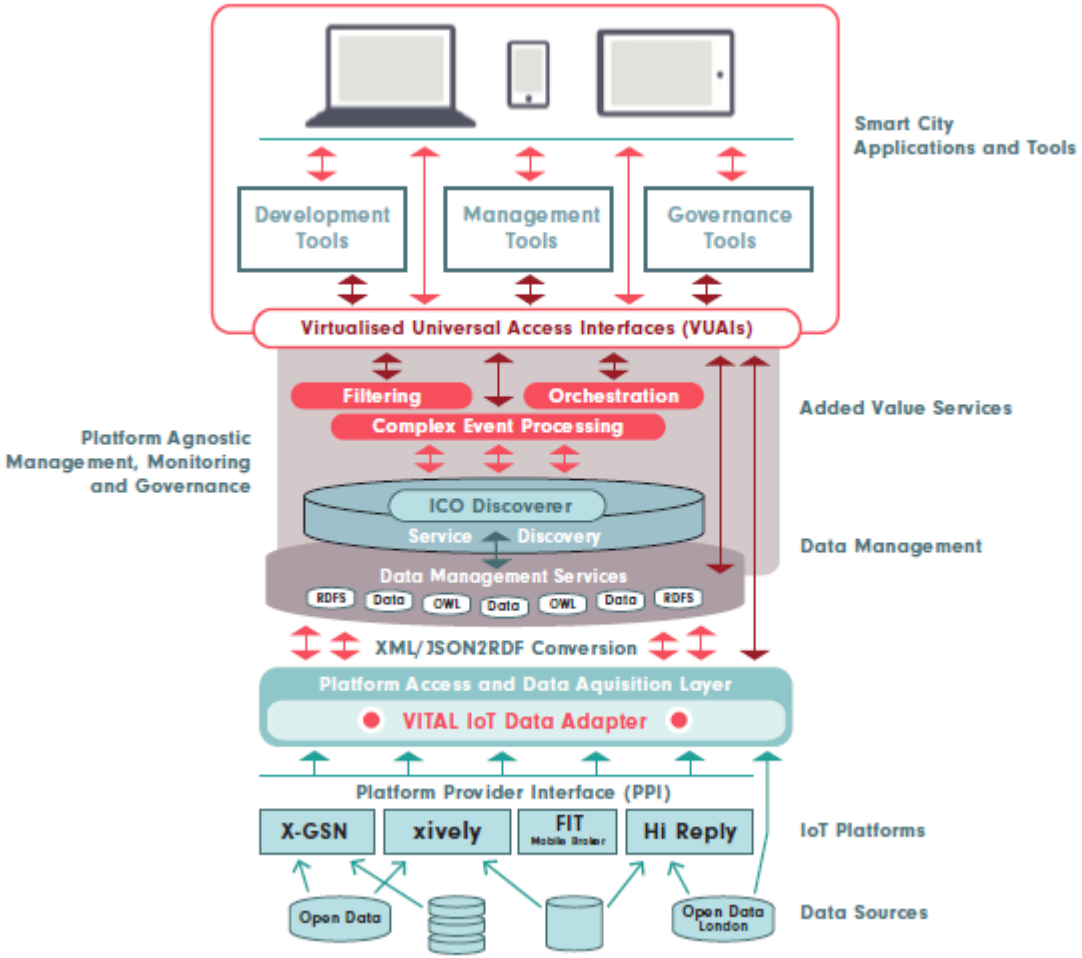
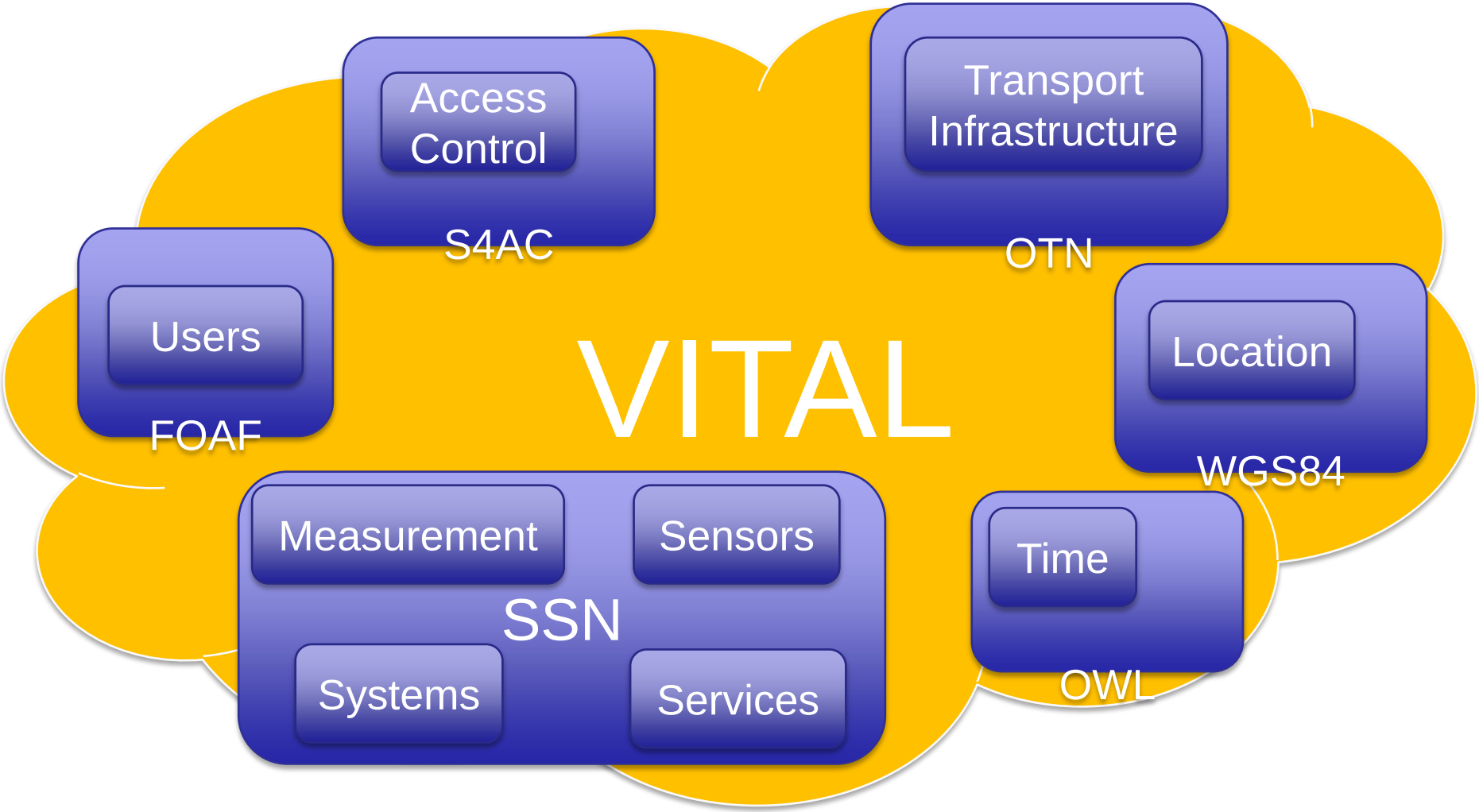
# VITAL Architecture



# VITAL Ontologies



# Sample PPI Primitives

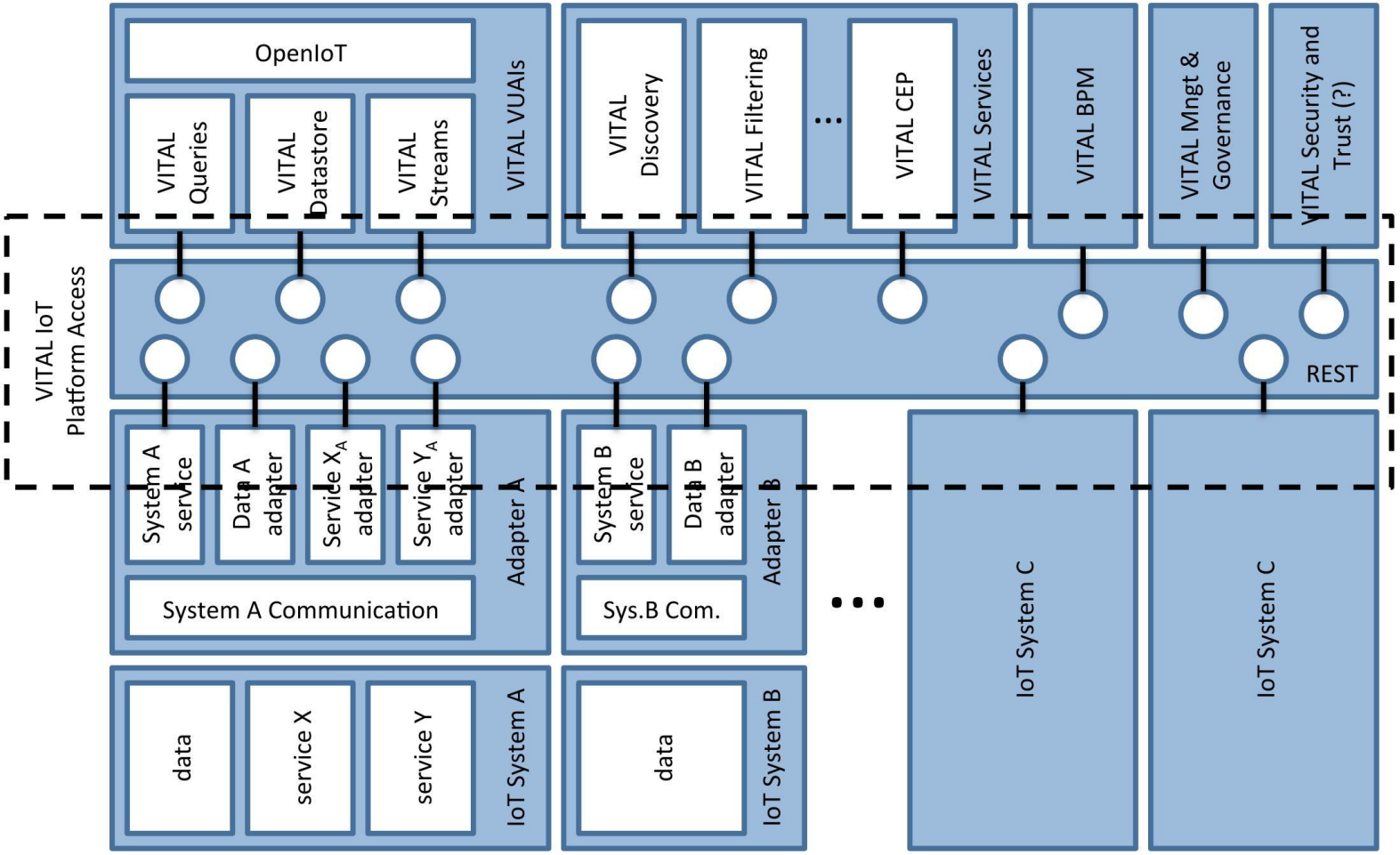
| | | |
|---|---|---|
| | **Get IoT system metadata** | |
| **Description** | VITAL pulls from an IoT system its metadata. | |
| **URL** | `BASE_URL/external/metadata` | |
| **Method** | `POST` | |
| **Request headers** | `Content-Type` | `application/ld+json` or `application/json` |
| **Request body** | **Example**<br>`{`<br>`  "@context": "http://vital-iot.org/contexts/query.jsonld",`<br>`  "type": "vital:iotSystem"`<br>`}` | |
| **Response headers** | `Content-Type` | `application/ld+json` or `application/json` |

# Sample PPI Primitives

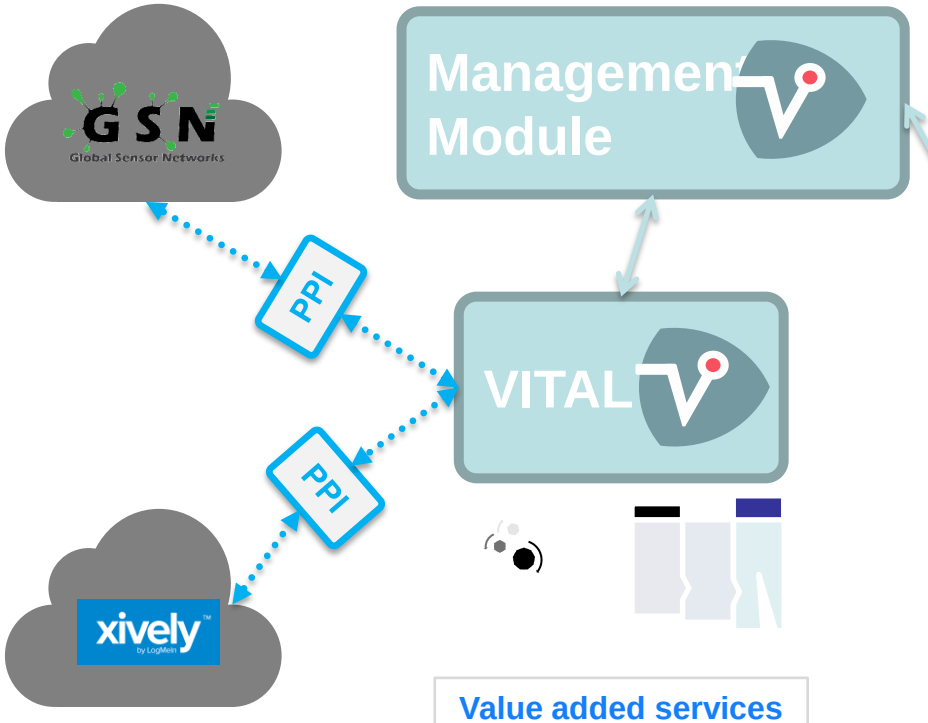
| Response body` | Example |
|---|---|

```
{
  "@context": "http://vital-iot.org/contexts/system.jsonld",
  "uri": "http://www.example.com",
  "name": "Sample IoT system",
  "description": "This is a VITAL compliant IoT system.",
  "operator": "http://www.example.com",
  "serviceArea": "http://dbpedia.org/page/Camden_Town",
  "status": "vital:Running",
  "providesService":
  [
    {
      "@context":
        "http://vital-iot.org/contexts/service.jsonld",
      "type": "ICOManager",
      "msm:hasOperation":
      [
        {
          "type": "GetMetadata",
          "hrest:hasAddress": "http://www.example.com/ico/metadata",
          "hrest:hasMethod": "hrest:POST"
        }
      ]
    },
    {
      "@context":
        "http://vital-iot.org/contexts/service.jsonld",
      "type": "ObservationManager",
      "msm:hasOperation":
      [
        {
          "type": "GetObservations",
          "hrest:hasAddress":
            "http://www.example.com/observation",
          "hrest:hasMethod": "hrest:POST"
        }
      ]
    }
  ]
}
```

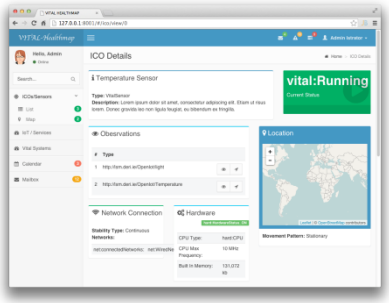
# IoT Platform Access & Platform Providers Interfaces



# VITAL Management Module

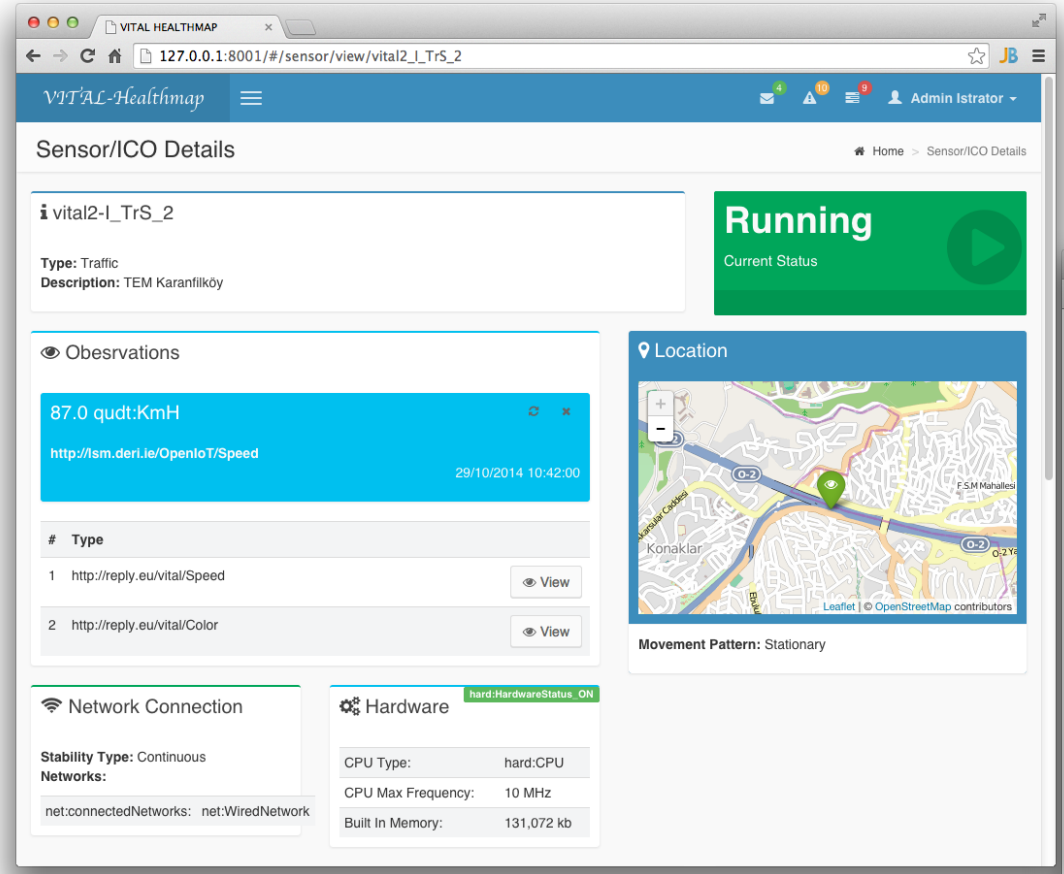


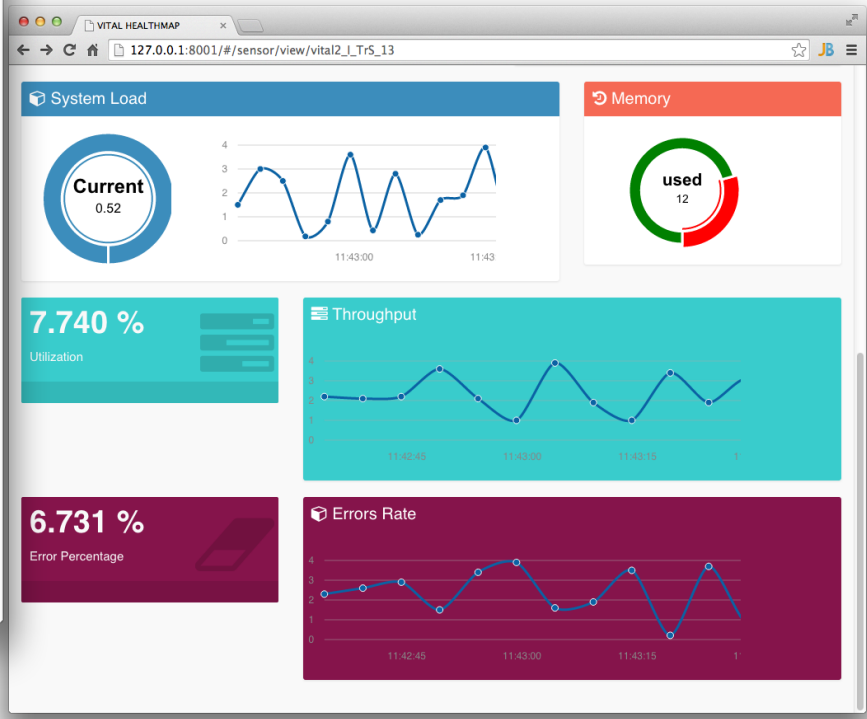

The Management & Governance Web UI provides a unified view of the health and operational status of systems, services, sensors, VITAL modules, etc…




**Value added services**
(CEP, Semantic Reasoning, Configuration, Security,…)

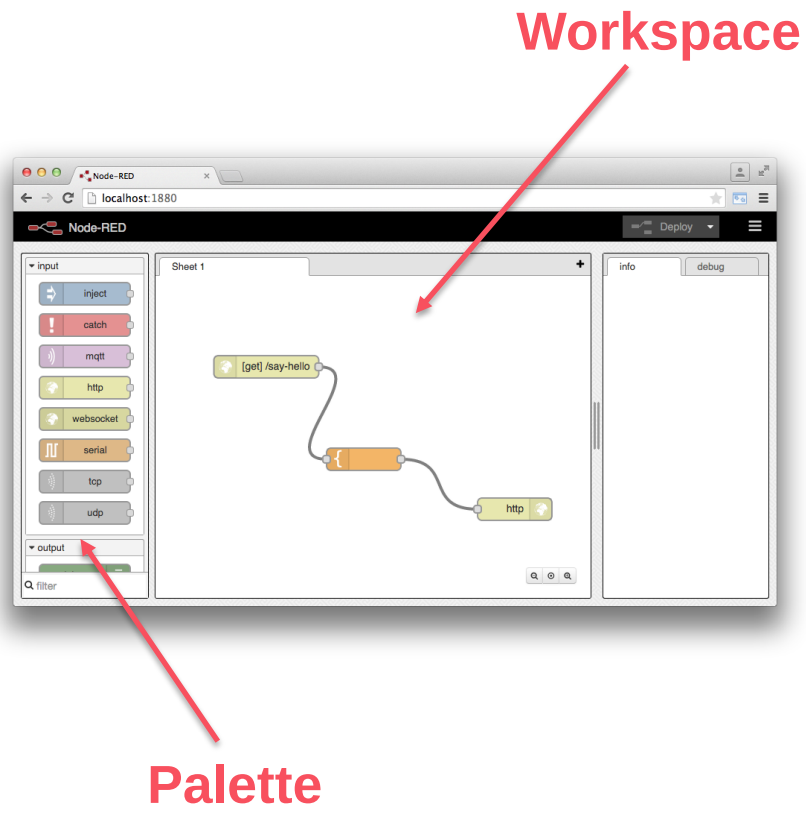
# VITAL Management Modules UI



# Node-RED Editor (nodered.org)

- Browser-based tool for **designing** flows
- **Drag** nodes from the **palette** and **drop** them into the **workspace**
- **Wire** the nodes together to create **flows**
- Flows are represented and stored using **JSON**



# Node Examples

- **http request**:
  - Makes HTTP requests
- **function**:
  - Represents a function block written in JavaScript
- **mqtt out**:
  - Connects to an MQTT broker, and publishes a message to a topic
- **twitter in**:
  - Searches either the public or a user's stream for tweets containing a specific term, or all tweets by specific users, or direct messages received by a user

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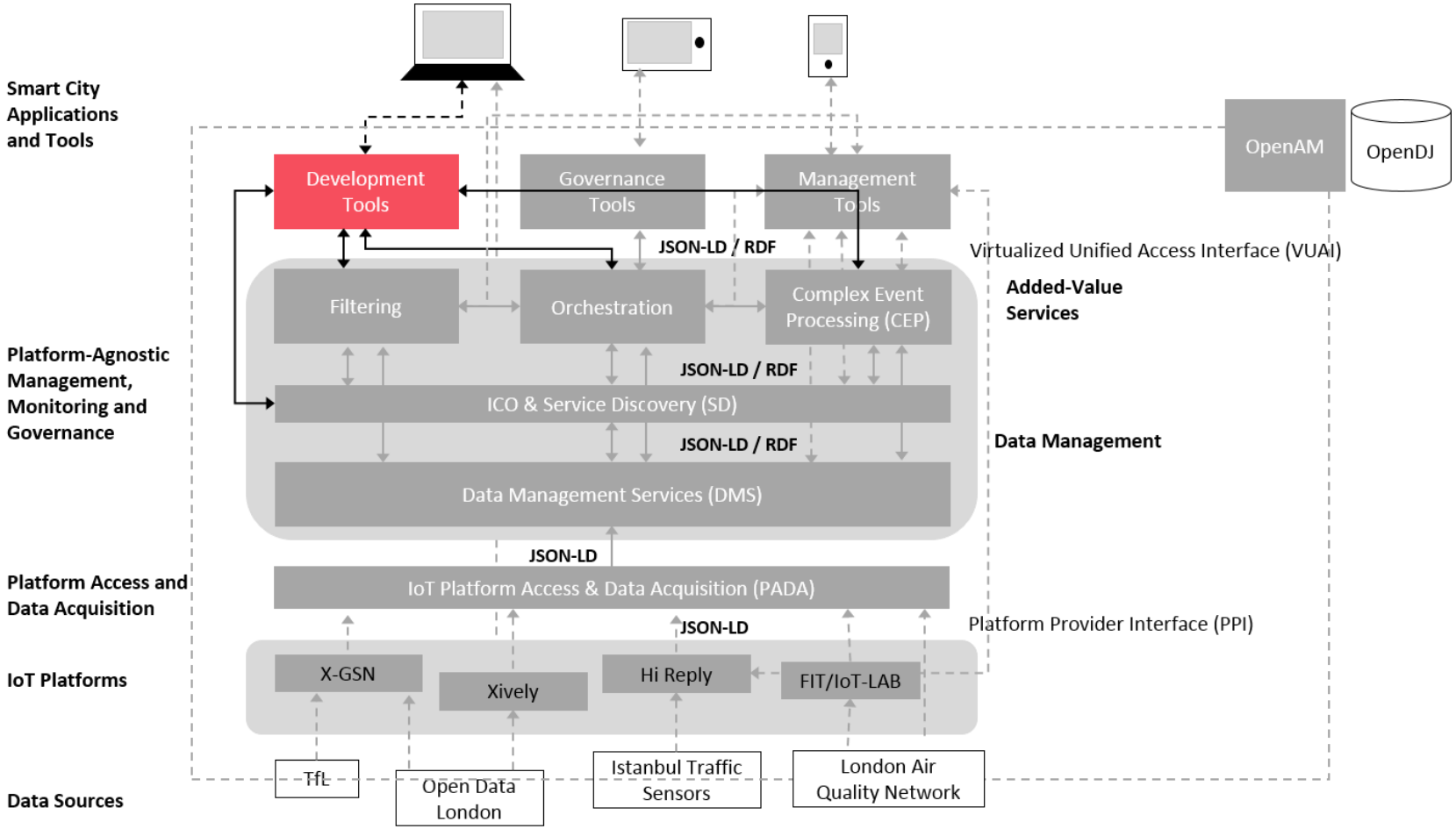
# Node-RED Runtime & Extensions

- **An environment for executing flows (built on Node.js)**
  - Creates, starts and stops nodes
- **During its lifetime, a node may:**
  - Receive messages from up-stream nodes
  - Do some work
  - Send messages to down-stream nodes
- **The node palette is extensible**
  - Search for new nodes in the Node-RED Library and the npm (node package manager) repository, or write (and even package and publish) your own nodes
- **Each node comprises two files**
  - a JavaScript file that defines its runtime behaviour
  - an HTML file that defines how the node appears in the editor

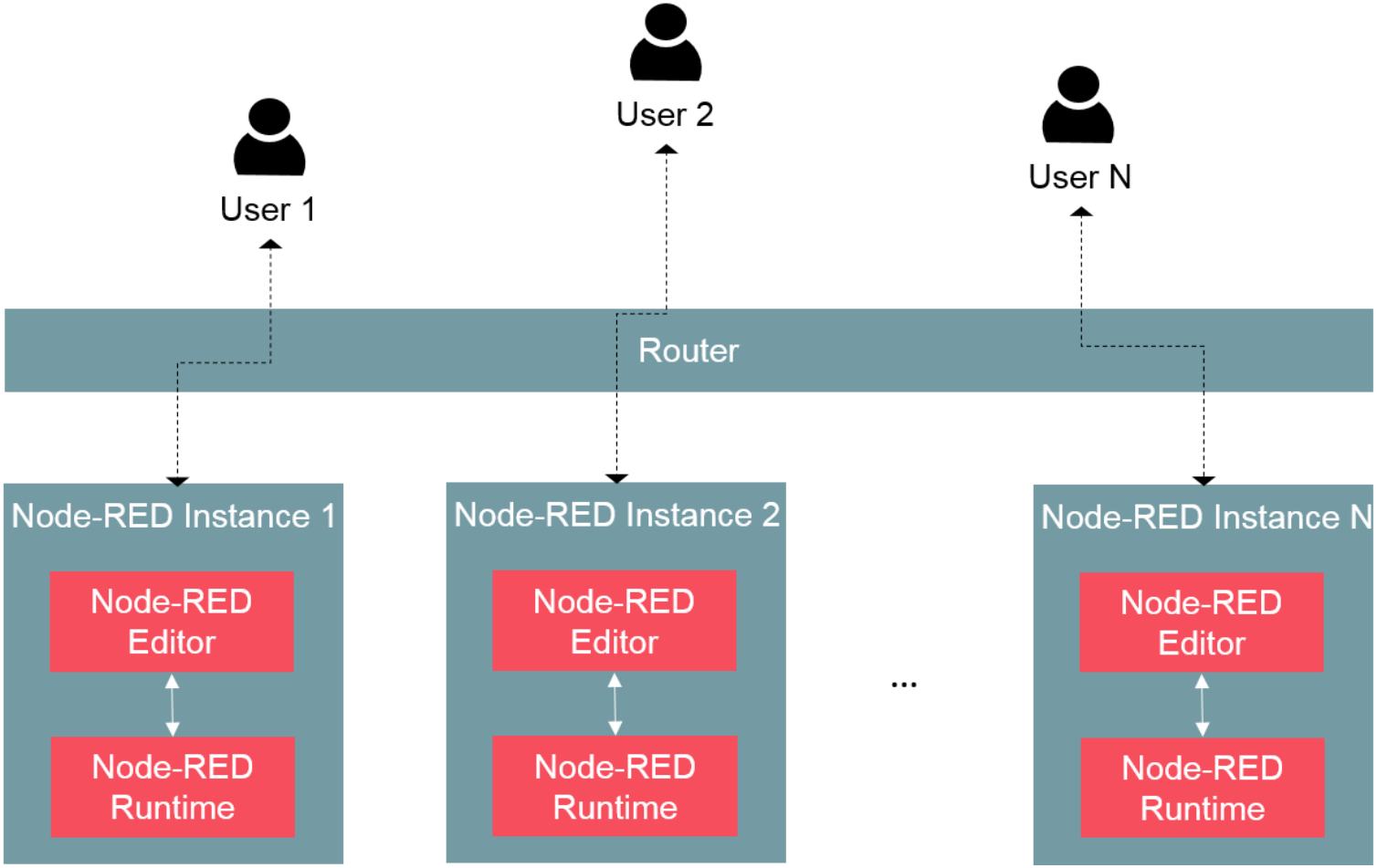
# VITAL Development & Deployment Environment



# Node-RED Customization to VITAL Needs

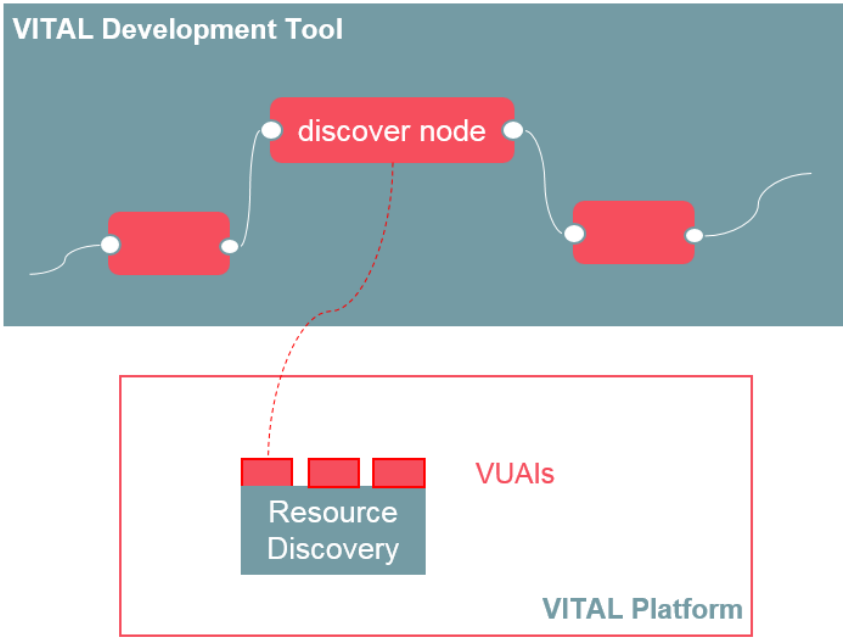
- Based on **Node-RED**
- Enhanced with **R**
- Overcomes the **user-less** nature of Node-RED by creating and deploying a **dedicated Node-RED instance** for each VITAL user
- An extra component takes care of the **mapping** between users and Node-RED instances (the **router**)

# Node-RED Architecture for VITAL



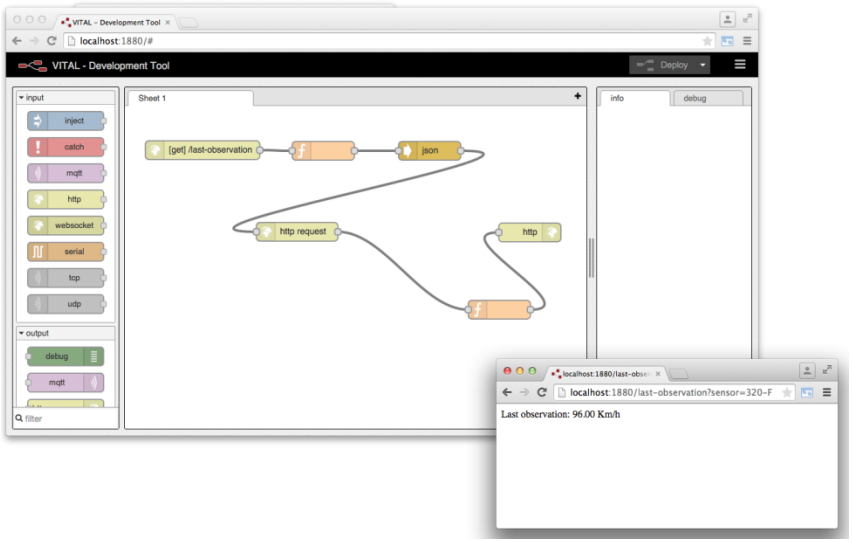
# Implementation of Nodes for VITAL Components

- **VITAL toolbox** = a set of VITAL-related nodes
- One **node** for each piece of functionality exposed by a VITAL component
- Hide **implementation** and **formatting** details from developers



# Example: Sample Workflow

A **web service** that accepts HTTP **GET** requests, which contain the **ID** of a **traffic sensor** in the query string, and responds with the **last observation** made by that sensor.




**Traffic Management in Istanbul**


# TRAFFIC PREDICTION

## Current State

- Traffic prediction up to an hour based on 15min intervals
- Current traffic measurement data & latest 4-week traffic data are used.
- Not very sensitive and adaptive to changes in traffic speeds. Prone to make errors when it starts to get congested or when it tends to get free flow.
- Weather conditions are not taken into consideration.

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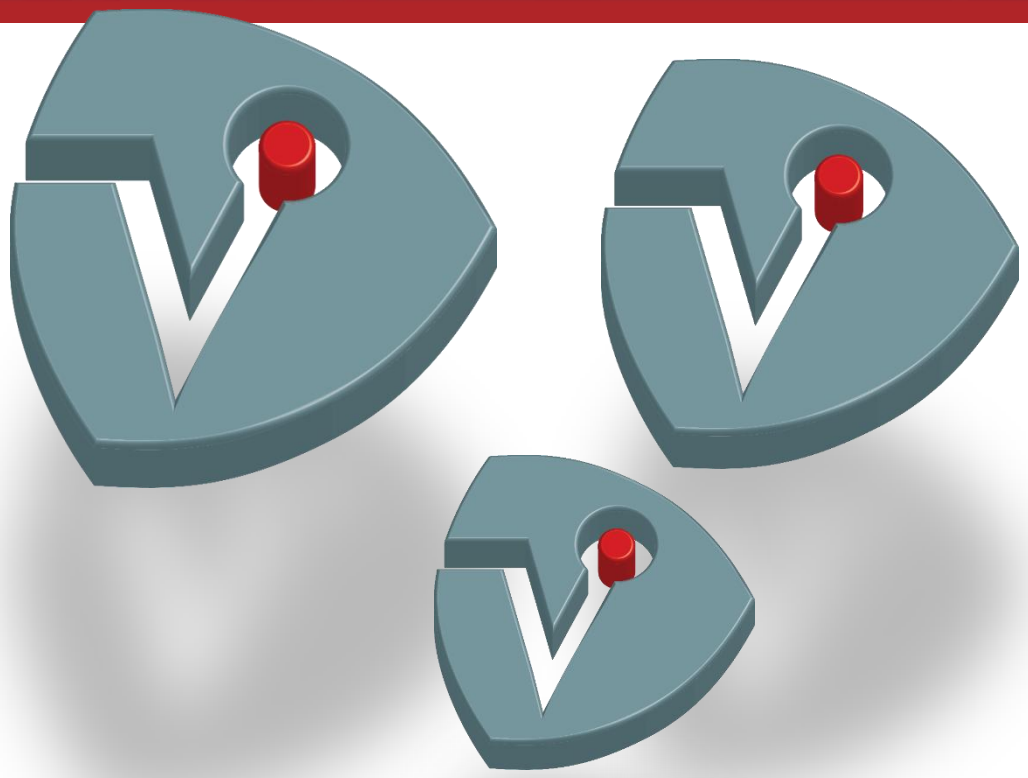
# Traffic Prediction

**VITAL** platform helps Istanbul to make more consistent and accurate traffic predictions by taking both traffic measurement data, weather observation data & local events data into consideration.



**VITAL helps improve the quality of traffic services provided by Istanbul Metropolitan Municipality**


ISTANBUL METROPOLITAN MUNICIPALITY
TRAFFIC
DENSITY MAP
TRAFFIC PREDICTION
DATE INTERVAL
11.06.2015
16.06.2015
00:00
14:45
23:59
11 June2015
Thursday
Mo Tu We Th Fr Sa Su
25 26 27 28 29 30 31
1 2 3 4 5 6 7
8 9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28
29 30 1 2 3 4 5
TRAFFIC PREDIC
By UTILIZING VITAL F
By applying Data M
Techniques on IMM
weather data
Trafffic prediction up to a week or mo
Traffic sensor data, weather obser
management data, mobile applicat
be taken into consideration to make
consistent & scientific predictions.
Esenler
Gaziosmanpaşa
Başakşehir
Bağcılar
Bayrampaşa
Şişli
Küçükçekmece
Avcılar
Güngören
Bahçelievler
Küçükçekmece Gölü
Bakırköy
Kadıköy
Ataşehir
Maltepe
Marmara Denizi
Congested
Free

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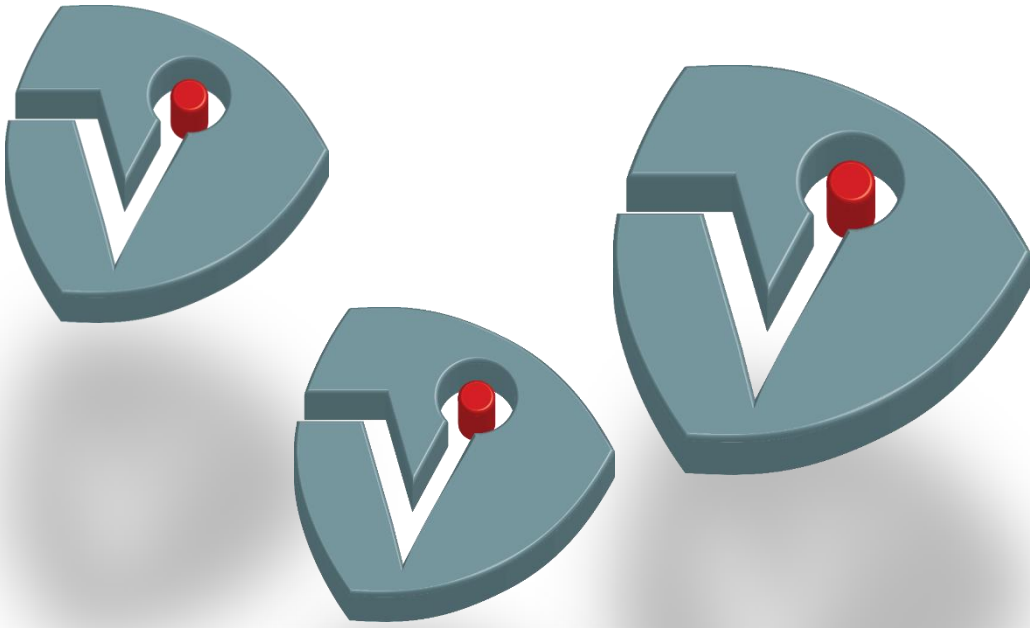
# Incident Detection

**VITAL** platform will ease the task of identifying incidents which adversely affect traffic in Istanbul.

Traditional way of observing traffic cameras & identifying events will be automated.



Traffic operators will take advantage of being notified about incidents.

ISTANBUL METROPOLITAN MUNICIPALITY

# TRAFFIC DENSITY MAP

85 km/h

10 km/h

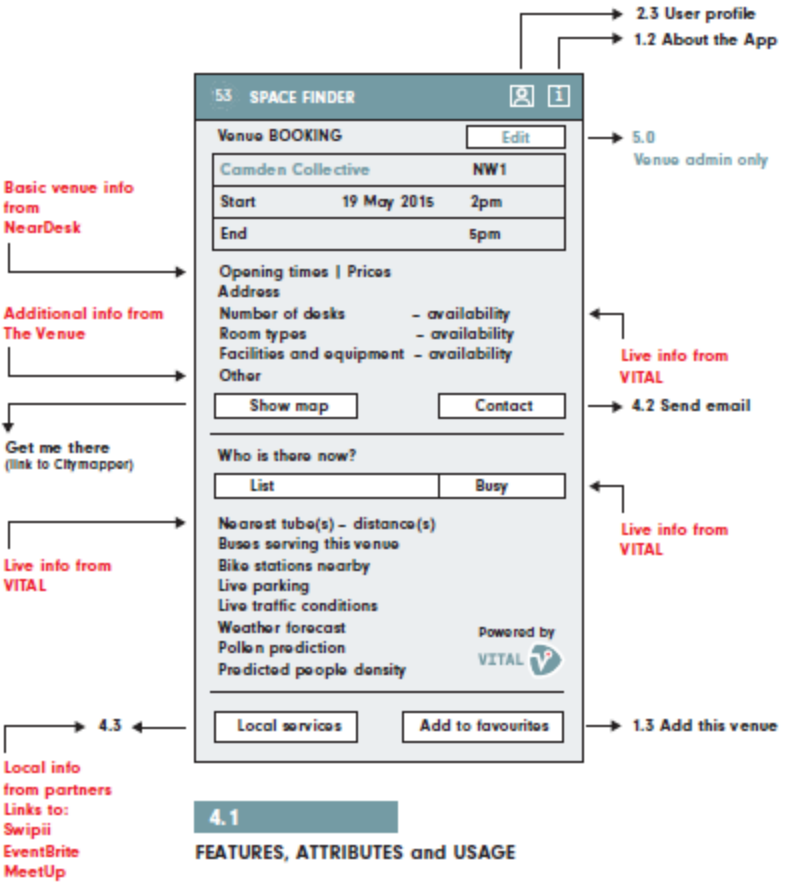
Celaliye

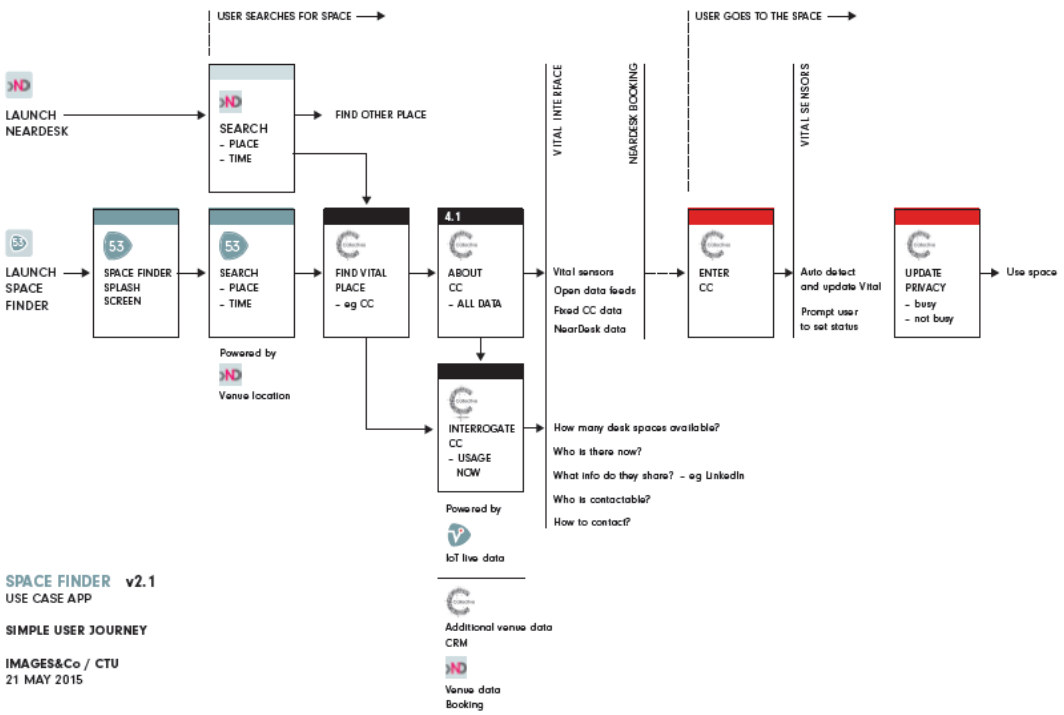
Sensor data says it's free flow

Vehicle data says it's congested


Congested Free

# Smart Working (Camden Borough of London)



# VITAL Project Web Site & Social Media

VITAL Web Site: **http://www.vital-iot.com**

- All our (public) deliverables and publications are accessible there!
- Subscribe our newsletter!
- Stay tuned for VITAL “Smart Cities” Hackathon, 3rd Quarter 2015

Follow us on Twitter: @VITALfp7

Join our “VITAL” discussion group on LinkedIn!

Like our “VITAL Project” Page on Facebook!

# Smart Cities and Social Media

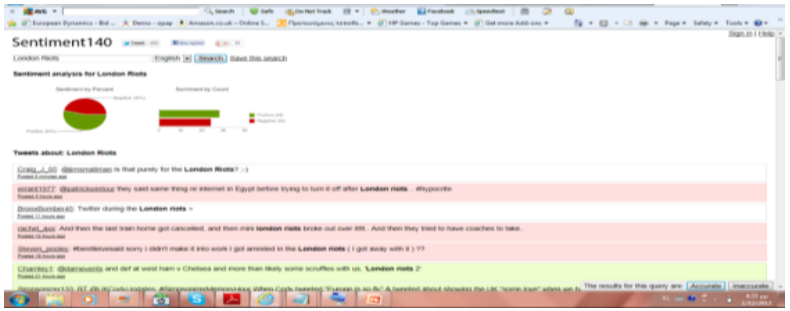
Social Media provide millions of insights on human activity and behaviour during emergencies and security incidents

Examples: London Riots (Twitter), Egypt (Twitter/Facebook), but also «Sandy» Storm (20M Tweets, 10 Instagram photos / sec)

Relevant Technologies: Sentiment Analysis, Community Tracking, Rumour Spreading Detection,...) - Used in several industries (marketing, branding, finance...)

IoT architectures and technologies support «Social» Sensors (as Virtual Sensor)

***Twitter Sentiment Analysis On-line: http://www.sentiment140.com/***




facebook

twitter

Instagram

# IoT & «Social» Sensors

Social Media provide millions of insights on human activity and behaviour during emergencies and security incidents

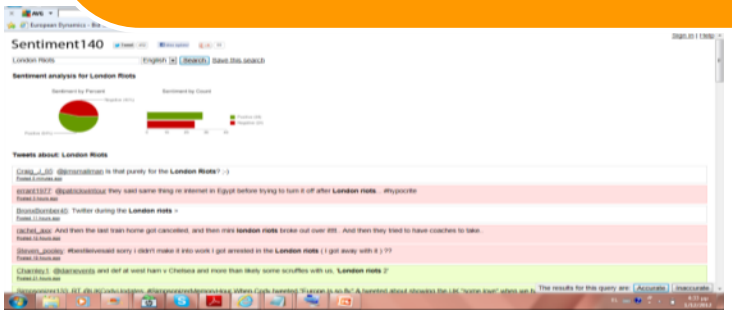
Examples: London Riots (Twitter), Egypt (Twitter/Facebook), but also «Sandy» Storm (20M Tweets

Relevant T ading Detection,

IoT archite

***Twitter***
***http://w***

**IoT architectures deal with the proliferating «Social» Sensors**




facebook

Instagram

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# Smart Cities and Citizen Engagement

- Citizens Engagement is a key to personalizing smart city services
  - Turning a smart city to a social, personalized and more effecive city
- Multiple Forms of Citizen Engagement Exist
  - Supported by IoT and Social Media

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# Citizens-as-Sensors

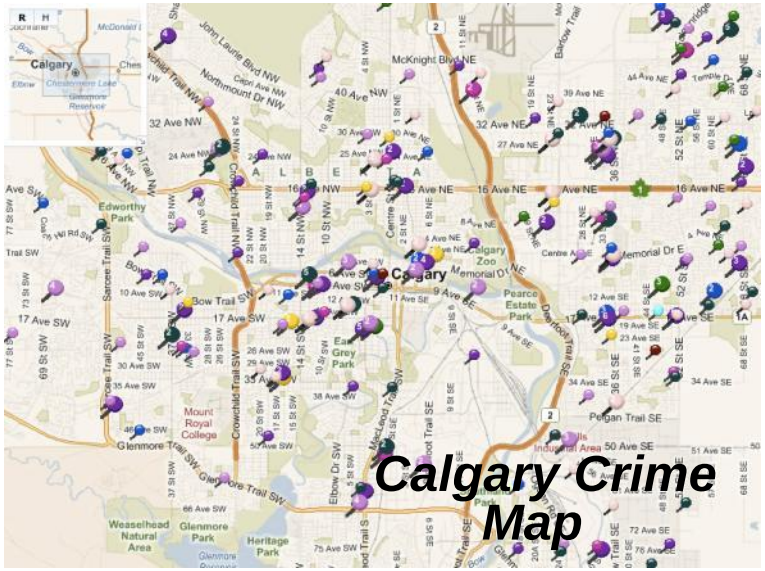
***Citizens can act as sensors to connect with governments and help the latter understand their wishes and needs***

| Technologies | Typical Use Cases | Use of Social Media |
| --- | --- | --- |
| GIS Applications | Incident Reporting | Tweet to government accounts @gov |
| Web and Mobile Apps | Suggestions & Comments | Access/post in Facebook pages etc. |

# Community Consolidated Community Feedback

## *Connect/Consolidate Citizens Data in Given Geographical Areas – Aggregate Citizen Generated Mapping*

| Sample Applications | Technologies | Using Social Media |
|---|---|---|
| • Crime Mapping<br>• Reporting of Location specific problems | • GIS & Location Services<br>• Mobile Phones / Mobile Apps<br>• Social Media Processing (e.g., Twitter Sentiment, Topic Tracking) | • Tracking of Topic-based Community (e.g., based on Twitter)<br>• Tracking of Location based Comunities |



# Citizen Centric Apps

***Enable Personalized Citizen-Centric Services using Location Information and based on Processing of Smart City Data***

**Data Availability**

- Collected from Smart City Apps
- May Include OpenData

**Innovative Ideas**

- Open Innovation
- Creative Developers (notably SMEs)

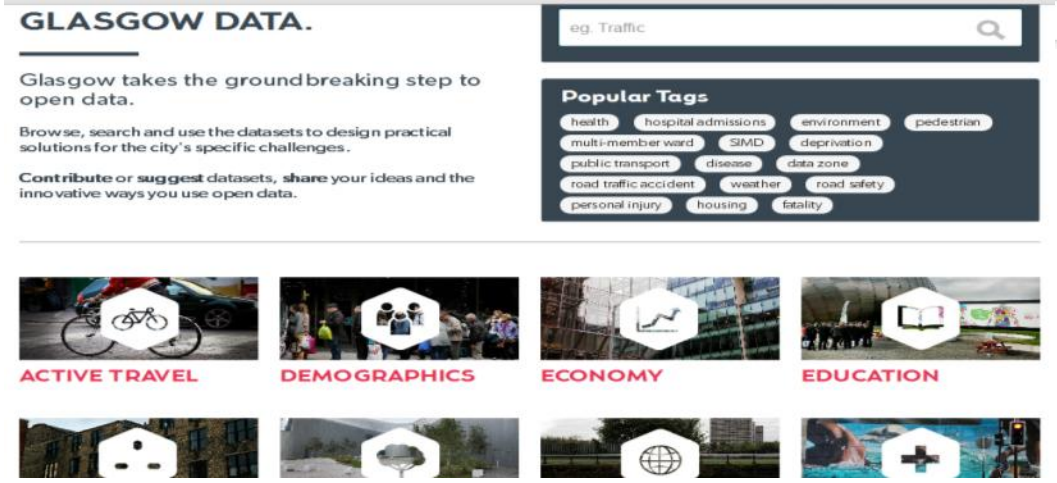
**Citizens Cenric Applications**

- Blend with GIS system and Back-office systems
- Avoid Citizen Data Silos

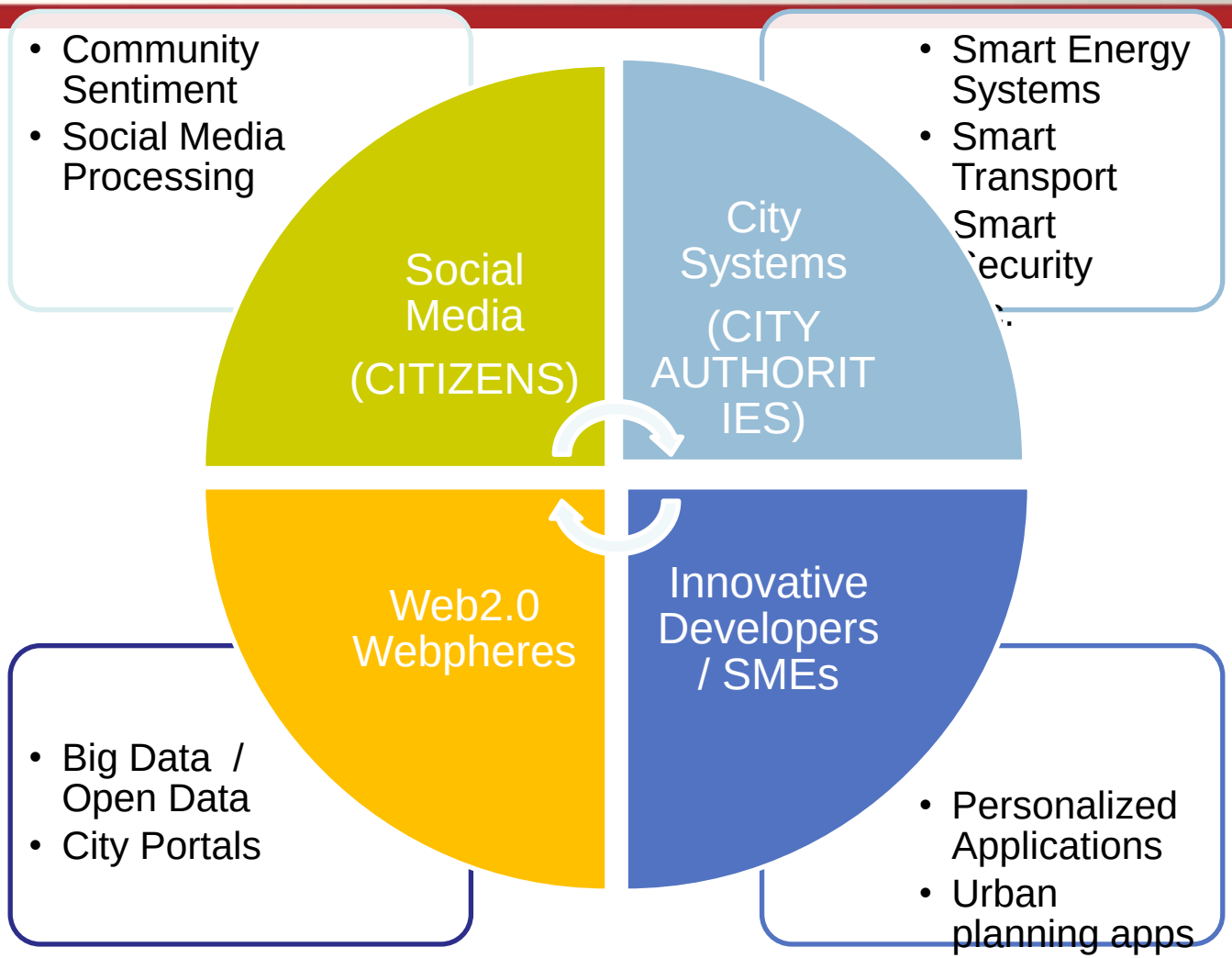
# Open Data & Innovation

- ***Open Data Sets == Key enab***
  ***for open innovation / novel a***
- ***Examples: London Data Sto***
  ***Glasgow Data***





# Using IoT & Social Media to Connect Citizens with Stakeholders



# Social View of Citizens Engagement

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## Consulting and Involving Citizens in Urban Planning and Smart Cities Design

## Privacy – Security - Ethics

## Trasparency and Engagement

- Including Open Data

## Usability key to acceptance

- User Interfaces and Apps

## Public Policy and Regulation

- Keeping up with technological development is essential

## Training Citizens

- Key success factor, especially for younger generations.

# Acknowledgements

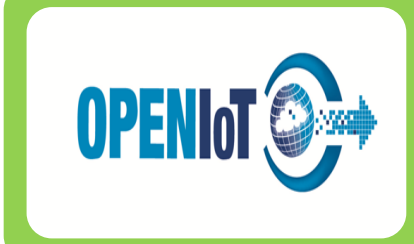


## Research Cluster on the Internet of Things

- Develops EU approach to IoT technologies

## FP7 VITAL Project

- VIRTUALIZED PROGRAMMABLE INTER-FACES FOR INNOVATIVE COST-EFFECTIVE IOT DEPLOYMENTS IN SMART CITIES




## FP7 OpenIoT Project

- Open Source Internet-of-Things

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# Thank You!

# Questions