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M2M Communications and Internet of Things for Smart Cities

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WHAT IS EURECOM

- **A graduate school & research centre in communication systems located in French Riviera**
- **A consortium with a private status (EIG) that brings together:**
  - **7 academic partners**
  - **8 industrial partners**
  - **1 institutional partner**
- **Three Departments**
  - Communication and Computer Security
  - Multimedia
  - Mobile Communications

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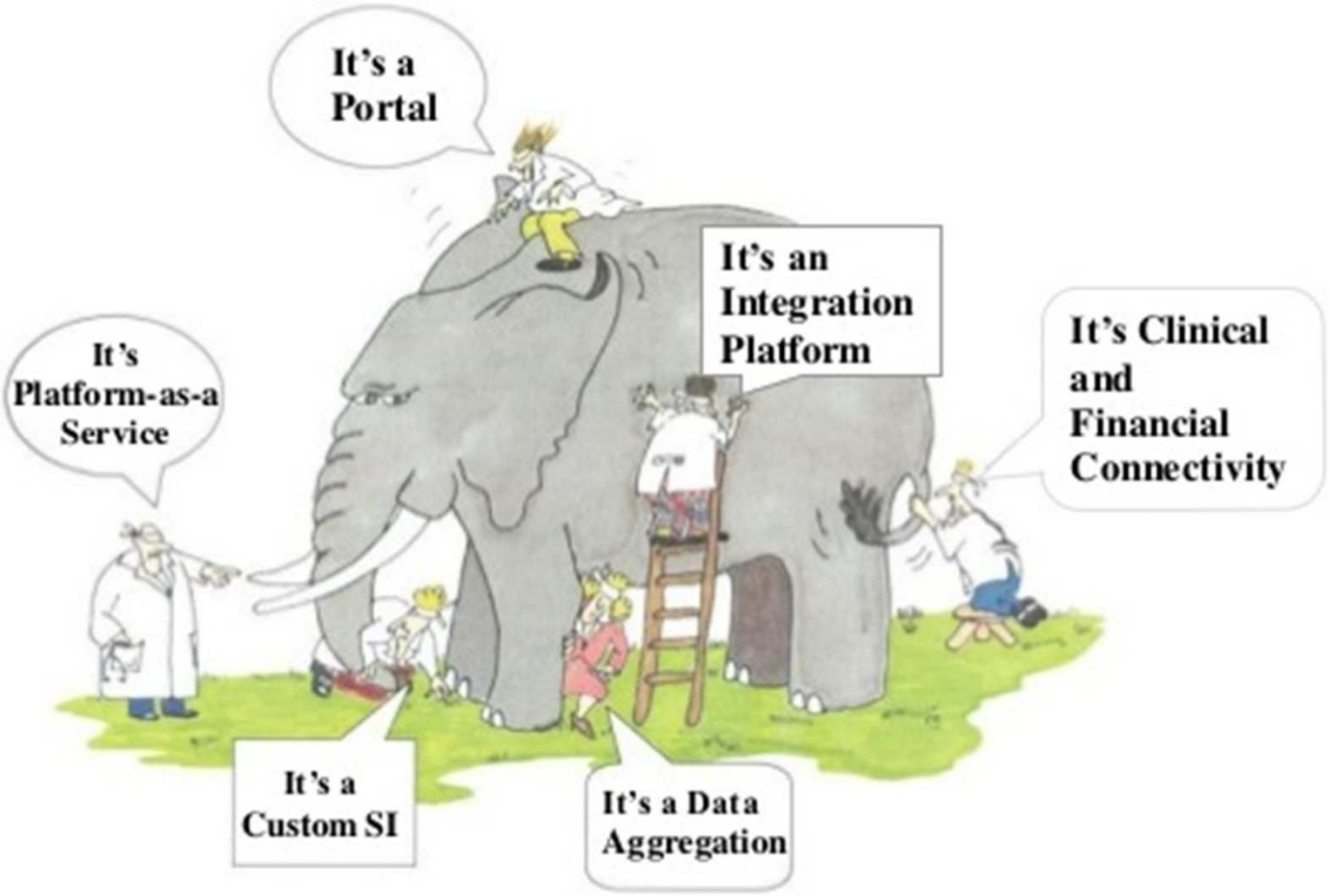
Roadmap

- Introduction to IoT & Smart City
- Three Fundamental Operations in IoT
- Uniform Data Exchange with Objects
- Managing Connected Objects
- M2M Data Processing for Smart City Applications
- Conclusion

What is Internet of Things (IoT)



Source: IDC Health Insights

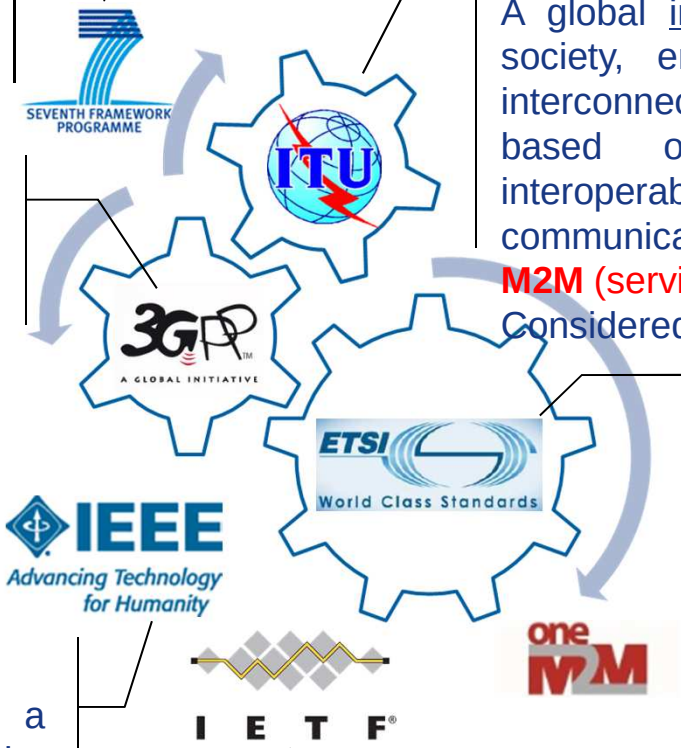
M2M/IoT Definitions

IoT

A global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities
[EU FP7 CASAGRAS]

MTC

A form of data communication which involves one or more entities that do not necessarily need human interaction



IoT

A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies [ITU-T Y.2060]

M2M (service layer)

Considered as a key enabler for IoT

M2M

Communication between two or more entities that do not necessarily need any direct human intervention

M2M

Information exchange between a Subscriber station and a Server in the core network (through a base station) or between Subscriber station, which may be carried out without any human interaction [IEEE 802.16p]

IoT

a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols [draft-lee-iot-problem-statement-05.txt]

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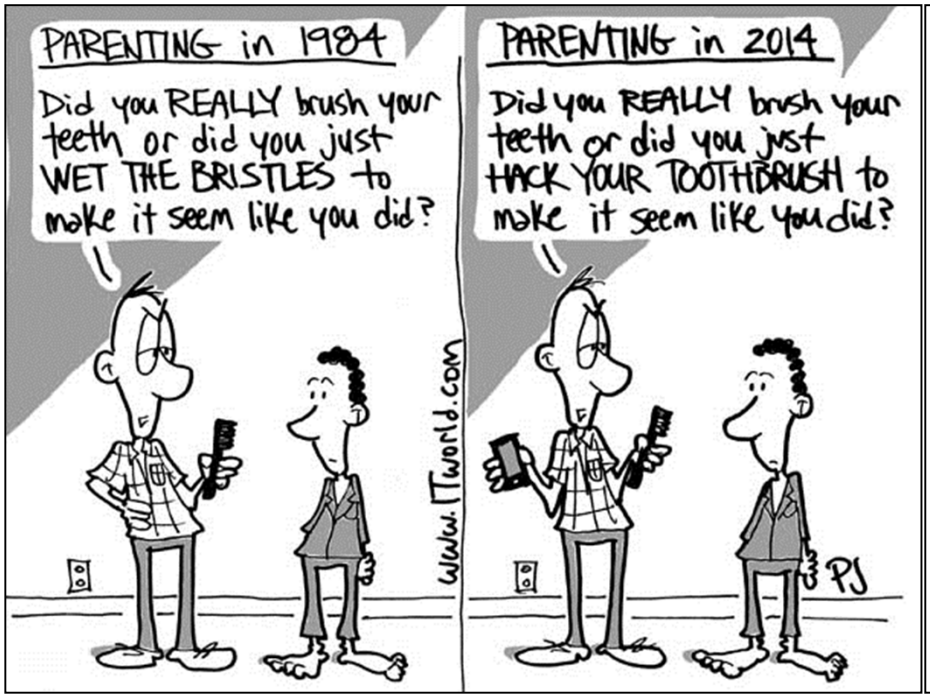
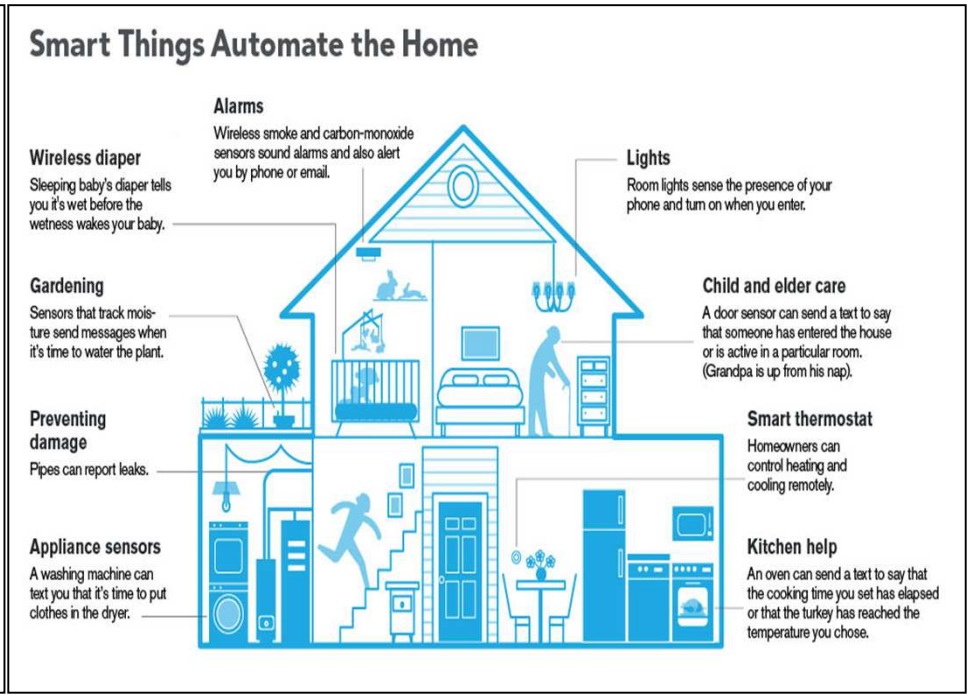
IoT ecosystem

- **To achieve the IoT ecosystem**
  - Things (sensors, actuators, RFID tags) need to be connected to **software**
  - Things need to be made available to be used together as a **system**
- **M2M architecture and protocols address the first item**
- **Second item is a challenge**
- **IoT applications**
  - Home automation
  - E-Health
  - Intelligent transportation system

How IoT is changing our surroundings





Source: http://www.itworld.com/

Source: market-intel.info

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Smart City Initiatives: Motivations

- Urban population is expected to grow by an estimated 2.3 billion in the next 40 years, having almost 70% of the world population living in cities by 2050. [1]
- This poses diverse challenges
  - public safety, transportation management, waste disposal, noise, air and water pollution and more
- Smart City – a promising solution
  - To provide advanced services to the citizens
  - Enabled by Information and Communication Technologies (ICT).
  - Drives competitiveness, sustainability and improves quality of life.

[1] http://www.alcatel-lucent.com/eco/low-carbon/travel_less.html

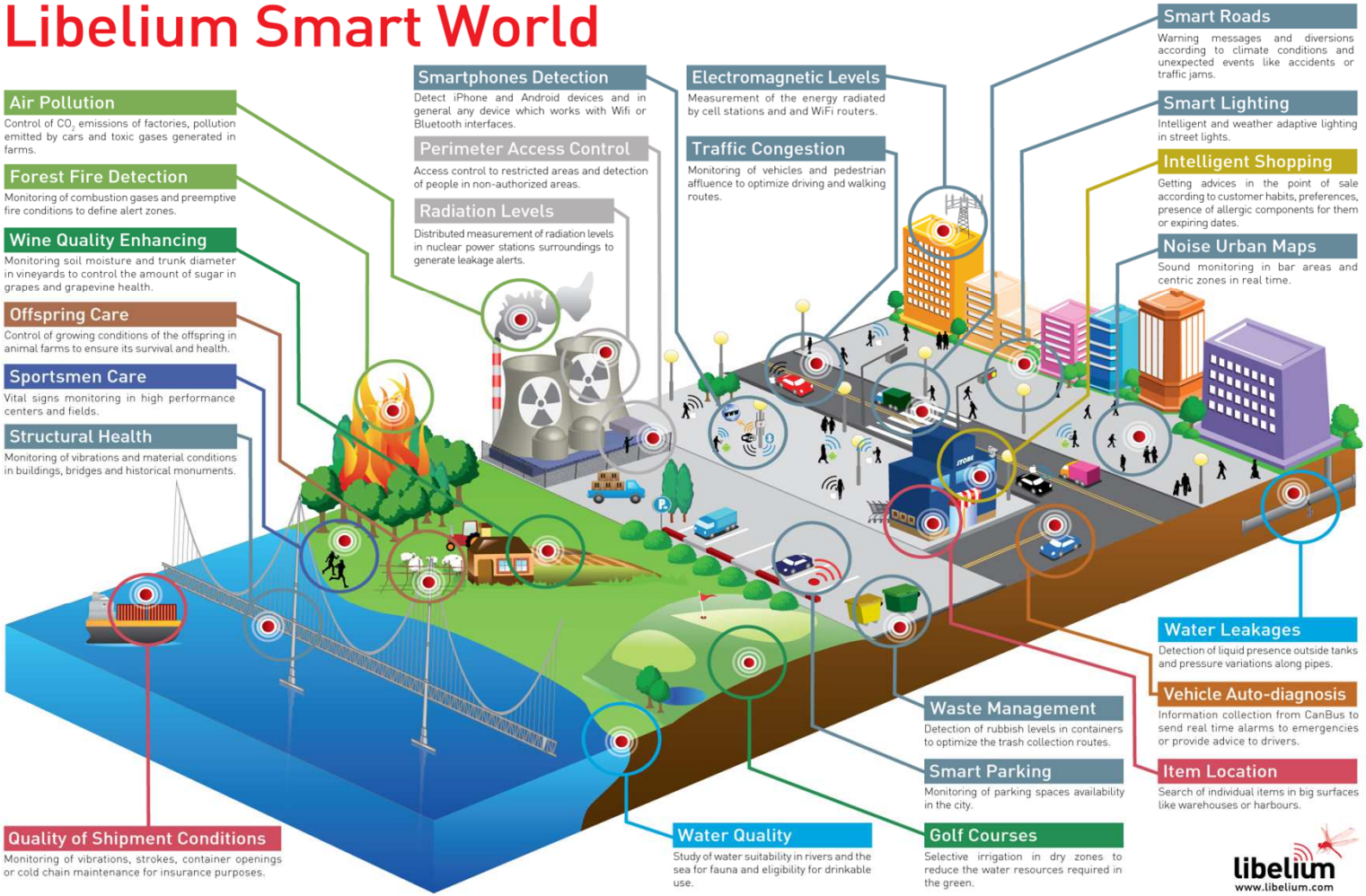
Smart Cities

- Smart city mainly focuses on applying the next-generation information technology to all walks of life, embedding sensors and actuators to [2]
  - Smart homes
  - Heath-care centres
  - Smart power grids
  - Roads & transportation systems
  - Water systems
  - Oil and gas pipelines
- Internet of Things (IoT) and Machine-to-Machine (M2M) communication are seen as the enablers of such initiatives.
- IBM Smarter Planet Initiative [3]

[2] Yongmin Zhang, Interpretation of Smart Planet and Smart City [J]. CHINA INFORMATION TIMES, 2010(10):38-41.

[3] http://www.ibm.com/smarterplanet/us/en/?ca=v_smarterplanet

Libelium Smart World Infographic



http://www.libelium.com/libelium-smart-world-infographic-smart-cities-internet-of-things/

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Three Fundamental Operations

- **Collection of data**
  - Sensor oriented collection
- **Processing the data**
  - Semantic reasoning
- **Control**
  - Sensing based actuation
  - E.g. switching on fog lamp when fog is detected

Wait, it is not so simple

- **Heterogeneity**
  - Sensors belong to different domains
  - Sensors use various technologies to communicate
  - What about actuators?
- **Management of connected objects**
  - Concerns due to high mobility
  - Naming and addressing billions of objects
  - Discovery of objects
- **Processing**
  - Utilizing semantic web technologies?
  - Cloud computing vs. Mobile edge computing vs. M2M gateway

Uniform Data Exchange with Objects

- **Sensor Markup Language (SenML)**
  - Uniform way to exchange sensor “metadata”
    - Sensor measurement, name, id, unit, timestamp etc.
- **SenML extensions**
  - Uniform way to exchange actuator “metadata” [4]
  - Used to send commands to actuators
    - Switch on/off a light, reduce the speed of motor etc.
- **Advantage**
  - **Uniform mechanism to interact with both sensors and actuators**

[4] Datta, Soumya Kanti; Bonnet, Christian; Nikaein, Navid, "CCT: Connect and Control Things: A novel mobile application to manage M2M devices and endpoints," *Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), 2014 IEEE Ninth International Conference on* , pp.1,6, 21-24 April 2014

Managing Connected Objects

- **Ensuring flexibility, scalability and dynamicity**
- **Deploying millions of connected objects**
- **We have developed**
  - **CoRE Link based configuration for connected objects [5]**
  - **Lightweight and can be stored in home gateways**
  - **OMA Lightweight M2M Technical Specifications based API for connected object management**
- **Work on progress**
  - **Naming and addressing schemes**
  - **Automatic discovery of M2M devices and services**
    - **Offline map for smart tourism**

[5] Datta, Soumya Kanti; Bonnet, Christian, “Smart M2M Gateway Based Architecture for M2M Device and Endpoint Management," IEEE International Conference on Internet of Things 2014, Taipei, Taiwan, 1-3 September 2014.

Interacting with Legacy Objects

- **Legacy objects can not be replaced overnight**
- **Including them into IoT based systems require [6]**
  - An intermediate gateway or
  - A proxy of the legacy object
- **This is to make the overall system aware of the intelligence of objects**

[6] Datta, S.K.; Bonnet, C.; Nikaein, N., "An IoT gateway centric architecture to provide novel M2M services," *Internet of Things (WF-IoT), 2014 IEEE World Forum on* , vol., no., pp.514,519, 6-8 March 2014

- **We deploy objects, interact in a standardized manner**
- **We get data**
- **But what can we do with the data**
  - How to get meaning out of data
  - Understand the context

Data Processing for Smart City Applications

- **Same sensor can be used in**
  - Different contexts
  - Across different domains
  - E.g. – Accelerometer in smartphones can be used to judge road conditions as well as determining earthquakes
- **Smart city comprises of several domains**
  - There are rules associated with the knowledge of the each domain
- **What if you want to build applications combining several domains**

Semantic Reasoning

- **Use of semantic reasoning to enrich M2M data**
  - First step – SenML to add some side information
  - Second step – decorate the M2M data with additional semantic reasoning
- **Link the data with the meaning**
  - From the point of view of different domains

M3 Approach

- **The M3 (Machine to Machine Measurement) approach**
  - Enrich M2M data with semantic web technologies [7]
  - The M3 ontology: A hub for cross-domain ontologies and datasets
    - e-Health: weather, recipe, health
    - Smart city: weather, home automation, transport, vacation
    - STAC (security): sensor, cellular, web, mobile phone
  - LOR (Linked Open Rules): share and reuse domain rules
- **M3 integrated in a semantic-based M2M architecture**
- **Prototype: http://sensormeasurement.appspot.com/**

[7] Gyrard, A.; Bonnet, C.; Boudaoud, K., "Enrich machine-to-machine data with semantic web technologies for cross-domain applications," *Internet of Things (WF-IoT), 2014 IEEE World Forum on*, pp.559,564, 6-8 March 2014

Limitations in Current Standards

- **Existing standards (ETSI M2M, W3C SSN Ontology) lack [8]**
  - A common format or syntax to describe sensors, measurements, units and domains.
  - Interoperable and standardized domain knowledge (ontologies, datasets and rules).
  - Semantics components are not explicitly described in M2M architectures.
  - Uniform methods to interpret high level abstraction from M2M data.

[8] Gyrard, A.; Datta, SK.; Bonnet, C.; Boudaoud, K., “Standardizing Generic Cross-Domain Applications in Internet of Things," *3rd IEEE Workshop on Telecommunication Standards: From Research to Standards, Part of IEEE Globecom 2014*, 8 December 2014.

Vision to Standardize the M3 Approach

- **Describe sensor measurements in a uniform way**
  - Utilize Sensor Markup Language and **our proposed extensions**.
- **Standardize common domain ontologies for IoT domains**
  - Tackles the interoperability issues related to combining cross domain knowledge.
- **Already proposed to oneM2M MAS group.**

Conclusion

- **Shading lights on some fundamental and specific points of IoT and Smart City initiatives**
  - Uniform way to exchange information
  - Managing billions of connected objects
  - Semantic reasoning to develop cross domain applications
  - Ability to react and control using actuators
  - Vision to improve standardization

Thank you!

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