

**ISTITUTO SUPERIORE  
MARIO BOELLA**



# INTRODUCTION TO THE INTERNET OF THINGS

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Workshop on Scientific Applications  
for the Internet of Things (IoT)  
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Pervasive Technologies

# ABOUT ME



- 2000 – Telecommunication Engineering Master Degree at Politecnico di Torino
- 2003 – Communication Engineering PhD Degree at Politecnico di Torino
- 2004 – Research Grant on Wireless Networks at Politecnico di Torino
- [2005 - Today] – Researcher @ ISMB in the Pervasive Technologies (PerT) Area, mainly working on low-power wireless networks
- ISMB PerT Area
  - IoT Objects and Platforms
  - Pervasive Secure Networks
  - IoT Service Management

# OUTLINE

- IoT – Concept and Definition
- IoT – Roots and Evolution
- IoT – Data Networks Historical Evolution
- IoT – Different Visions
- IoT – An Example of White Paper

- The **Internet of Things (IoT)** is the **interconnection** of **uniquely identifiable embedded computing devices** within the **existing Internet** infrastructure. (→ *Wikipedia definition*)
  - '**Interconnection**' refers to (wireless) networking
  - '**Uniquely identifiable**' reminds (IPv6) addressing
  - '**Embedded**' reminds reduced size and full integration of components
  - '**Computing**' reminds processing capabilities
  - '**Existing Internet**' reminds IoT as the next evolution of the current Internet
  - (+) It grabs the essential: the IoT is seen as the Internet of the Future, characterized by a very large population mainly composed of objects
  - (-) It is partial: says much but not all

# IOT: ROOTS AND EVOLUTION

- The **origin** of the term 'IoT'
  - Coined in 1999 by the founders of **MIT Auto-ID Center**
  - Born in the **field of identification technologies, RFID** in particular
  - Strictly associated with the **EPC network**, open infrastructure allowing computers to automatically identify man-made objects and track them while flowing from the plant to the distribution center
- The **evolution** of the term 'IoT' and the current meaning
  - A **heterogeneous** network connecting computers to objects
    - **affordable hardware** (not just RFID tags and readers)
    - network **software and protocols**
    - **languages** for **describing objects** in ways computers can understand

# DATA NETWORKS HISTORICAL EVOLUTION

- ARPANET
  - 1969 – first RFC on Host Software
  - 1971 – 15 nodes and 23 hosts; e-mail application
  - 1973 – first release of FTP application, first release of TCP
- Other Data Networks
  - 1976 – Ethernet, X.25
  - 1982 – Token Ring IBM
  - 1985 – FDDI

**'Intelligent' hosts in packet switching networks**

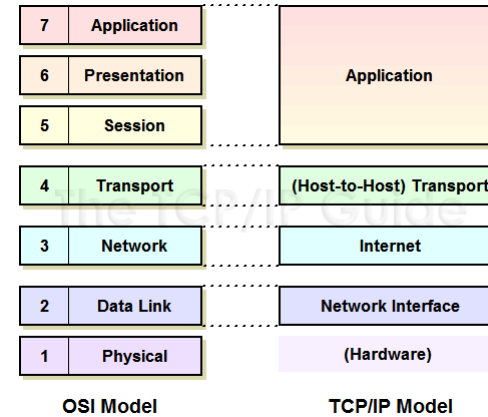
**Different techniques for accessing the shared medium**

**Companies as IBM and standardization institutes as ITU, ISO**

**Basic applications (FTP, mail) as primary engine**

# DATA NETWORKS HISTORICAL EVOLUTION

- Layering Models
  - 1980 – ISO/OSI Software
  - 1983 – TCP and IP operative as reference Internet stack protocols
- Information Content Management
  - 1990 – World Wide Web protocol by Berners-Lee at CERN
- Killer Applications from the 90s
  - www, just 1% of Internet traffic in 1993
  - P2P applications for file sharing
  - VoIP applications



Standardization of layers allowed to turn attention on apps

Bandwidth increase pushed apps development

- Relevant aspects about data networks evolution in 2000's
  - From wired to **wireless**: explosion of wireless communication technologies
  - **Mobile**/nomadic and intermittent hosts behavior
  - New technologies for **accessing the Internet** (WiFi, Cellular, Satellite, ...)
  - Continuous **available bandwidth increase**
  - **Exponential increase** of **storage resources** at **decreasing cost** ( $10^{-9}$  \$/byte)
  - Widespread diffusion of **low-cost powerful-computing embedded devices**
  - **Multiradio** interface devices



**The above concurrent conditions are the enabling factors for the IoT**



- A given fact
  - **Multiple IoT visions** with **substantial differences**
- The reason
  - Stakeholders, business alliances, research and standardization bodies **differently approach** the issue, **depending on** their **specific interests**, **finalities** and **backgrounds**
- 'Internet of Things' is syntactically composed of two terms:
  - **Internet** -> pushes towards a **network oriented vision** of IoT -> **1<sup>st</sup> vision**
  - **Things** -> moves the focus on **generic objects to be integrated** into a common framework -> **2<sup>nd</sup> vision**

# IOT DIFFERENT VISIONS

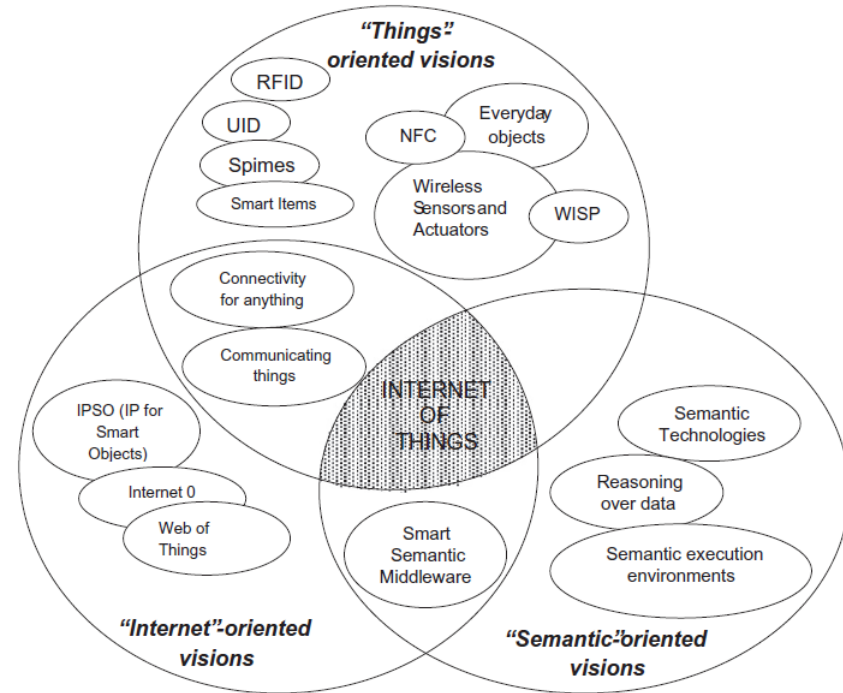
- 'Internet of Things' semantically means '*a **world-wide network of interconnected objects uniquely addressable, based on standard communication protocols***'
  - Source: '*Internet of Things in 2020, Roadmap for the Future*', May 2008
  - Strictly reminding Wikipedia definition
- Third main IoT vision: **semantic oriented** perspective of IoT
  - Representation and storing of exchanged information is the most challenging issue -> **3<sup>rd</sup> vision**

# IOT DIFFERENT VISIONS

- **Heterogeneous interpretations of IoT → 'naming confusion'**
  - Internet of Things (IoT)
  - Internet of Objects (IoO)
  - Internet of Everything (IoE)
  - Internet of Data (IoD)
  - Machine to Machine (M2M)
  - Cyber-Physical Systems (CPS)
  - Intelligent Systems
  - Industrial Internet
  - Connected Devices
  - ...

# IOT DIFFERENT VISIONS

- **Network-oriented** vision
- **Things-oriented** vision
- **Semantic-oriented** vision



Source: *The Internet of Things: A survey*

- **Network-oriented** vision
  - **Unified architecture** for **objects** and traditional users **connectivity**
  - **IPSO** -> The IP stack is a light protocol that
    - already connects a huge amount of communicating devices
    - runs on tiny and battery operated embedded devices
  - **Internet Ø** -> similar approach, reducing the complexity of the IP stack to achieve a protocol designed to route '**IP over anything**'
  - Example: incorporation of **IEEE 802.15.4** into **IP** architecture with **6LoWPAN**
  - ITU and EC -> From 'anytime, anyplace connectivity for anyone' to 'anytime, anyplace connectivity for anything'
  - Mainly **communication community**

- **Things-oriented** vision
  - The **very first one**, originated by RFID research world
  - Remember Auto-ID group!
  - **Object** visibility: **traceability**, status awareness, current location
  - **Extended to NFC and WSN** objects, *the atomic components that will link the real world with the digital world*
  - **Extended concept:** IoT primarily focused on the 'Things' but full deployment through the **augmentation in the Things' intelligence**, not just mere traceability
  - Smart Items: required capabilities as autonomous and **proactive behavior**, **context awareness**, collaborative communications and elaboration
  - Mainly **hardware community**

- **Semantic-oriented** vision
  - Basic reasoning
    - **Extremely high number of items** involved in the Future Internet
    - Challenging issues: how to **represent, store, interconnect, search**, and **organize information** generated by the IoT
    - Key role: **semantic technologies**
  - Keywords
    - **Middleware** -> the semantic engine, a distributed software tool/system
    - **Data processing** (raw data → information → experience → wisdom)
    - **Virtualization** -> **physical (real)** and **virtual** objects
    - **Context awareness, reasoning** -> artificial intelligence
  - Mainly **computer/software community**

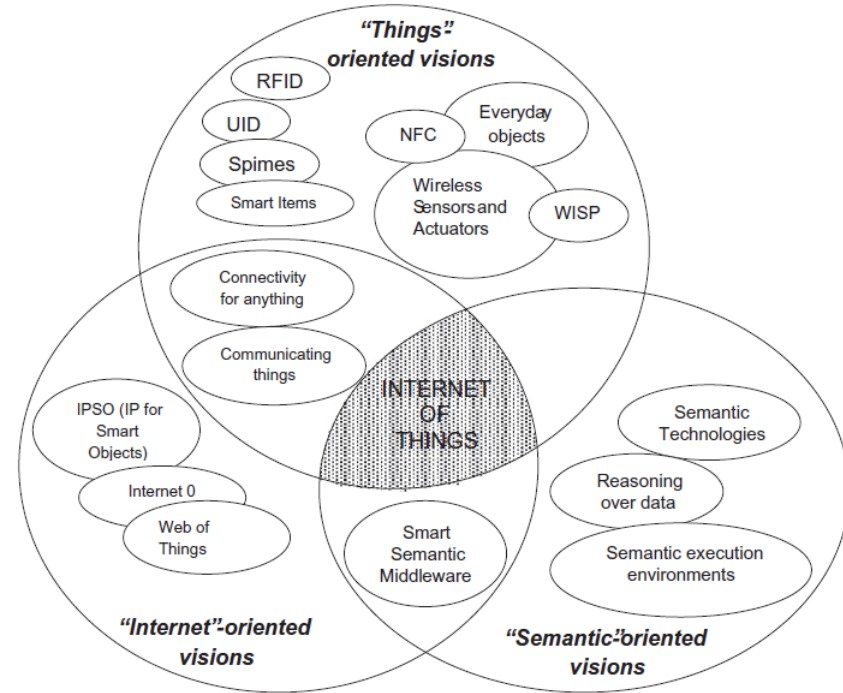
# IOT DIFFERENT VISIONS

**Correct IoT vision**



**CONVERGENCE**

**among the three sectorial visions**



Source: *The Internet of Things: A survey*

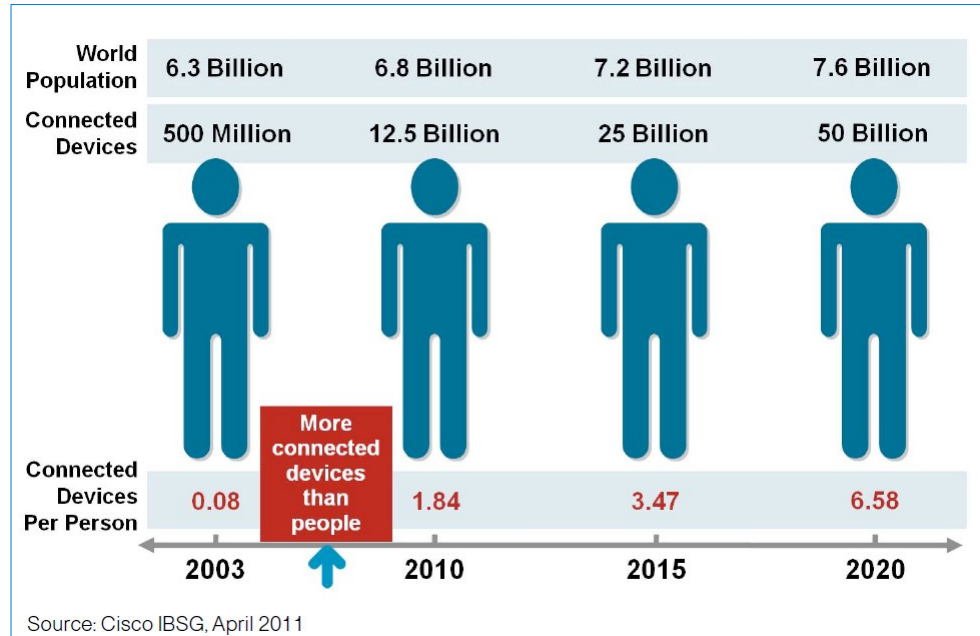


- Contributions to the advance of the IoT necessarily result of **synergetic activities** conducted in **different fields of knowledge**
  - Telecommunications
  - Informatics
  - Electronics
  - Nanotechnology
  - Energy engineers
  - Laws experts
  - Social science
  - ...

# IOT – AN EXAMPLE OF WHITE PAPER

IoT is *simply the point in time when more “things or objects” were connected to the Internet than people.* (Cisco IBSG, IoT White Paper, 2011)

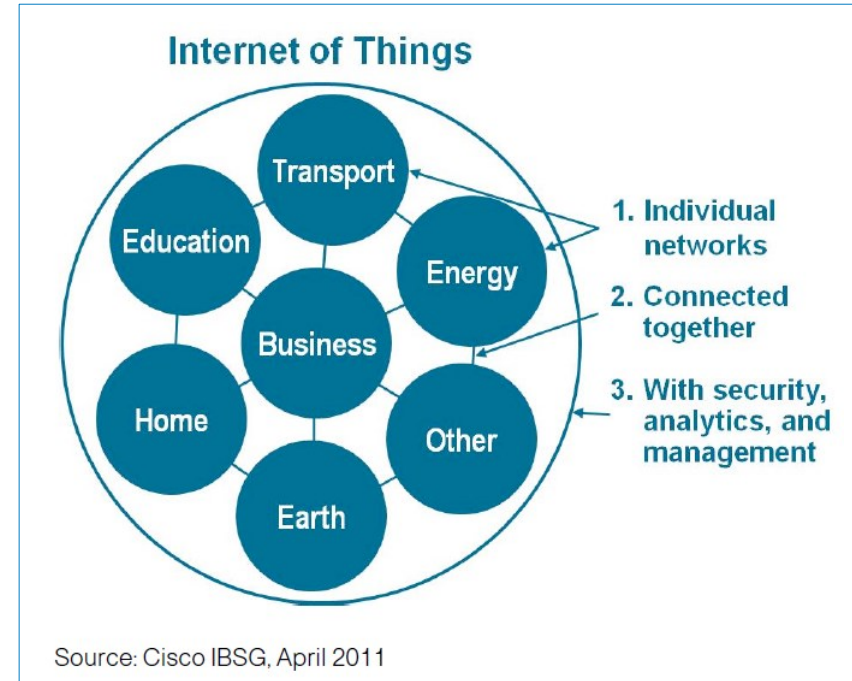
- Measurements for 2003-2010, forecast for 2015-2020
- 2010: 6.8 billion world's human population but just 2 billion actually connected
- Forecast ignores potential to add millions/billions of sensors to the IoT



# IOT – AN EXAMPLE OF WHITE PAPER

IoT as ***a network of networks***. (Cisco IBSG, IoT White Paper, 2011)

- Cars – multiple networks to control engine function, safety features, communications systems, ...
- Buildings – various control systems for HVAC, telephone service, security, and lighting
- Similar to multi-protocol routing to bring disparate networks together (leading to IP as the common networking standard).



# THANKS FOR YOUR ATTENTION !

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