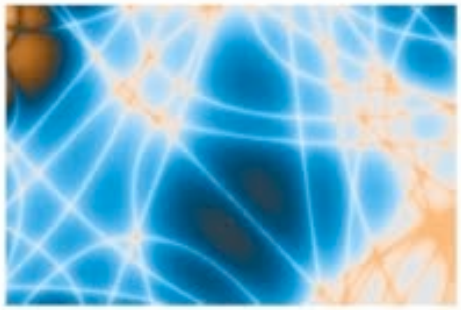
Inatel
Instituto Nacional de Telecomunicações



NovaGenesis

Internet of Things: Perspectives, Challenges and Opportunities

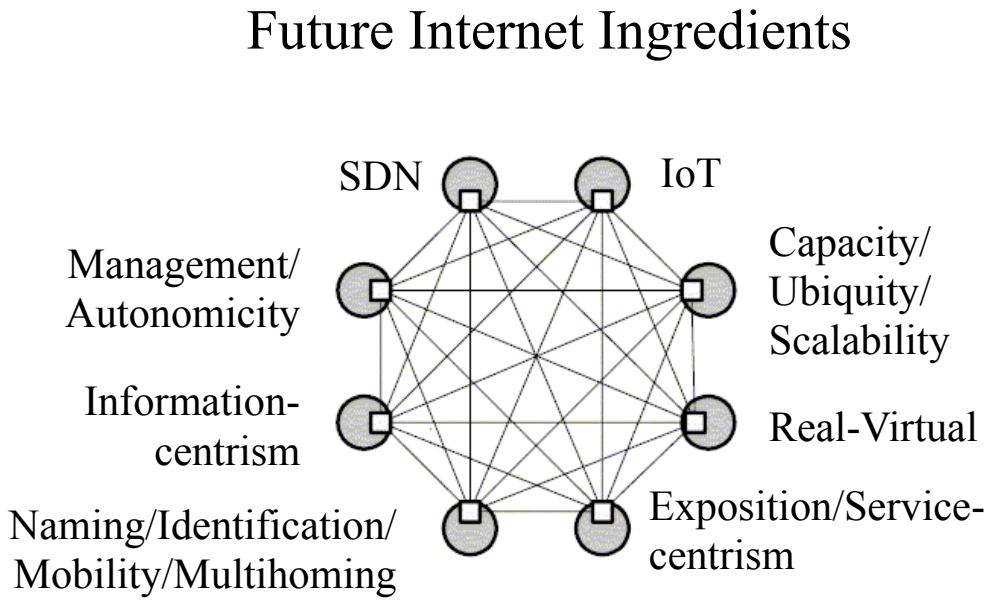
Antônio M. Alberti
Inatel, Santa Rita do Sapucaí, MG, Brazil.

alberti@inatel.br

Dhananjay Singh
Hankuk University of Foreign Studies, Yongin, South Korea.

dsingh@hufs.ac.kr

Outline



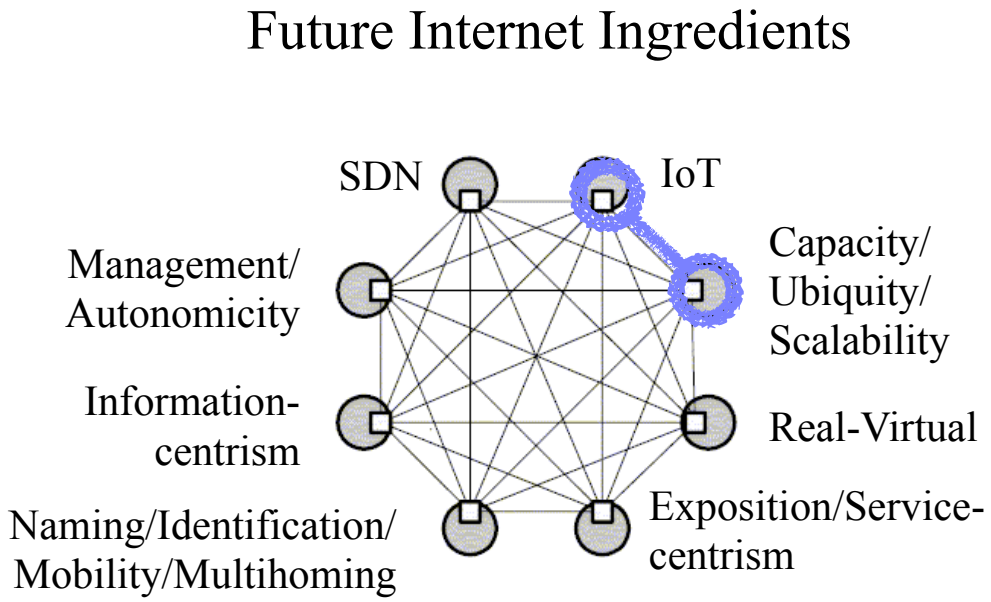
Introduction

- ✓ The Internet of Things (IoT) can be defined as to make the "things" belong to the Internet.
- ✓ Many wonder if the current Internet can support such a challenge, i.e. scalability, naming, identification, addressing for billions of nodes.
- ✓ For this and other reasons, hundreds of worldwide initiatives to redesign the Internet are underway - the so called Future Internet (FI) design.

Introduction

- ✓ This paper addresses two questions:
  - What are the perspectives, challenges and opportunities behind a future Internet that fully supports the “things”?
  - How the “things” can help in the design of a more synergistic future Internet?

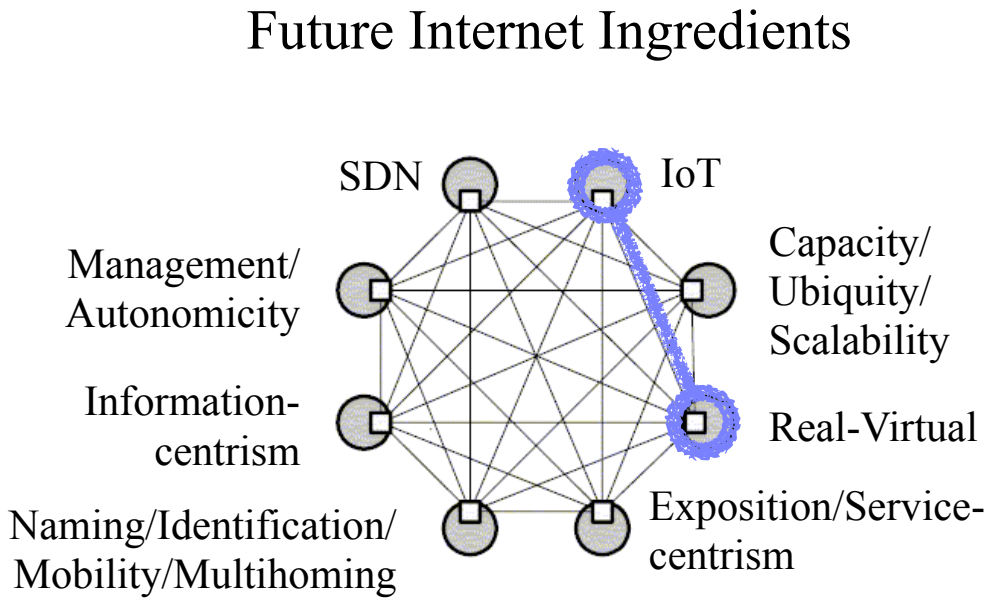
Capacity, Ubiquity, and Scalability



Capacity, Ubiquity, and Scalability

- ✓ The accelerated evolution of capacities allows the implementation of small devices capable of sensing the real world and transmitting the obtained data to services on the Internet.
- ✓ Those devices can also act over the real world.
- ✓ Sensing and actuating capabilities can become ubiquitous, allowing unprecedented scenarios of interaction between the real and the virtual worlds.
- ✓ This army of devices will push architectures' scalability requirements to new limits.

Real-Virtual Worlds Integration



Real-Virtual Worlds Integration

- ✓ New “smart” embedded devices are emerging and becoming connected to the Internet.
- ✓ This will create a flood of real world information, considerably enriching our applications, making them more aware of what happens in the real world, in real time, everywhere.
- ✓ To transform this huge amount of raw data on knowledge is one of the biggest challenges behind the IoT.

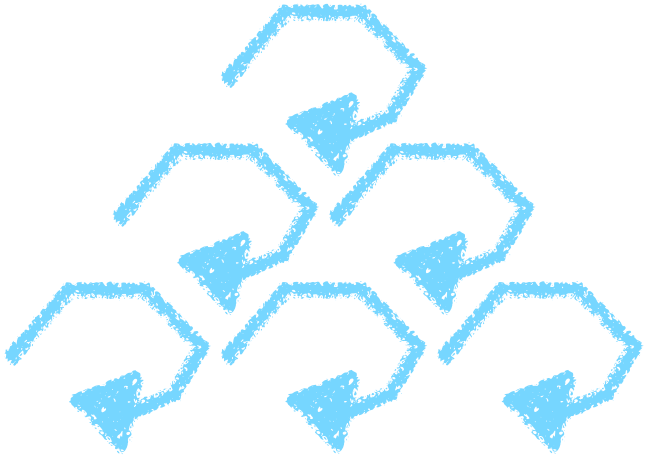
Data → Information → Knowledge → Wisdom

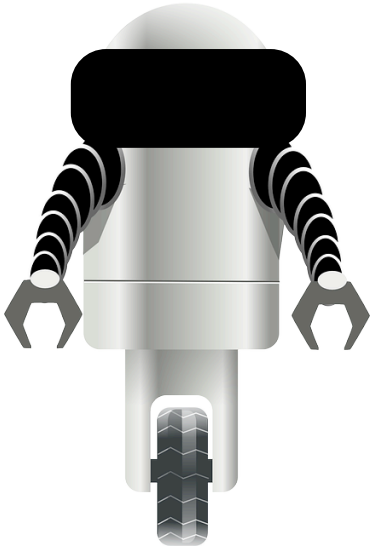
- ✓ There is an entire cycle of data processing up to the generation of cooperative knowledge networks.

Real-Virtual Worlds Integration

- ✓ These knowledge networks can feed complex hierarchical feedback control loops, since sensorial data is very important for decision making.

Some issues in this context are the stability, performance, and sensitivity of this control loops.

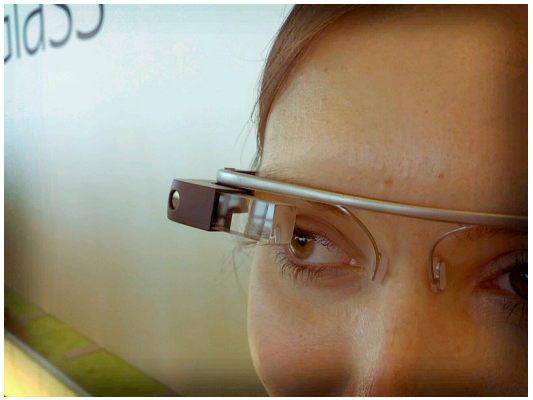




- ✓ Therefore, we do need to avoid blind autopilots.

Real-Virtual Worlds Integration

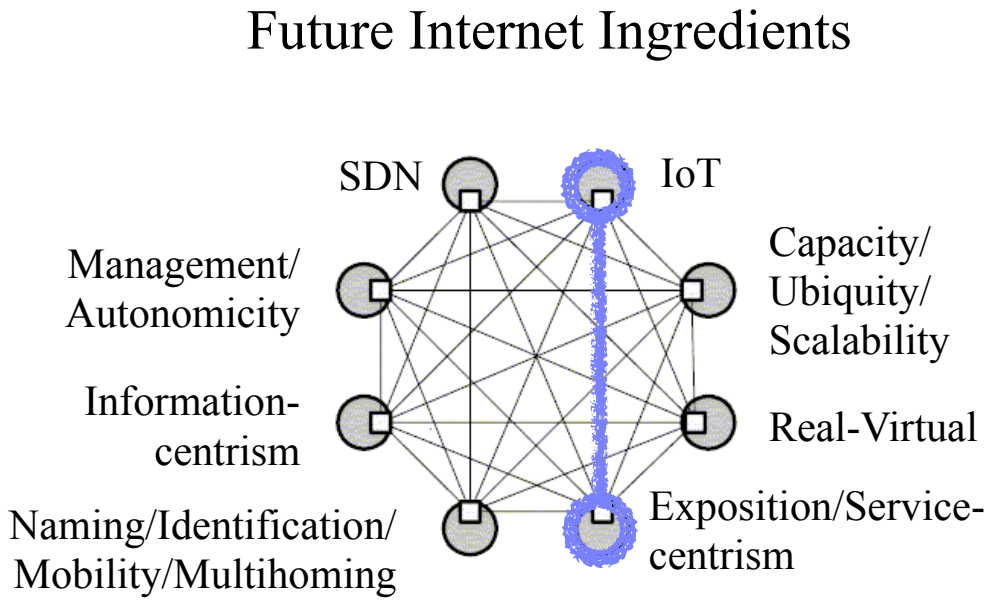
- ✓ New applications are emerging to take advantage of this situational information, e.g. like augment reality, ambient intelligence, social appliances, networked cars, etc.



Google Glass™

- ✓ In addition, decisions made on the virtual side can be reflected on the real environment. This will help us to save energy, to better use our resources.

Resources Exposition and Service-Centrism



Resources Exposition and Service-Centrism

- ✓ IoT and FI resources need be exposed to software orchestration frameworks, allowing the dynamic and integrated composition of real and virtual existences.

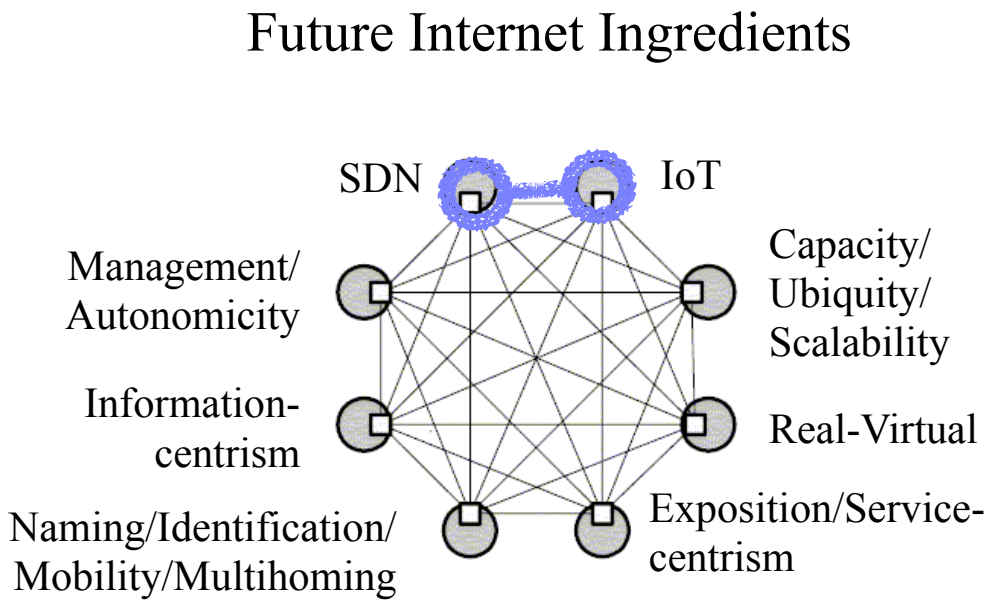
Resources Exposition and Service-Centrism

- ✓ Entire services' life-cycles can be orchestrated involving such exposed resources.
- ✓ The life cycle can include devices description, search, selection, negotiation, admission, installation, monitoring, failure handling, and all the other management functionalities.
- ✓ In short, IoT capabilities can be seen as a service (IoT-as-a-service).
- ✓ This view approximates the IoT to the so-called Internet of Services (IoS).

Resources Exposition and Service-Centrism

- ✓ Some open challenges on IoT + IoS are:
  - How to design a service-oriented IoT?
  - How to enable the joint orchestration of non-IoT and IoT substrate resources and services?
  - How small sensors and actuators will expose their capabilities, or establish dynamic contracts?
  - How to share IoT resources among several orchestration frameworks?
  - How to describe the device capabilities?
  - How to format the contracts?
  - How to provide the adequate search mechanisms?
  - Which circumstances can cause a contract revocation?
  - How to provide energy-awareness?

Software-Defined Networking



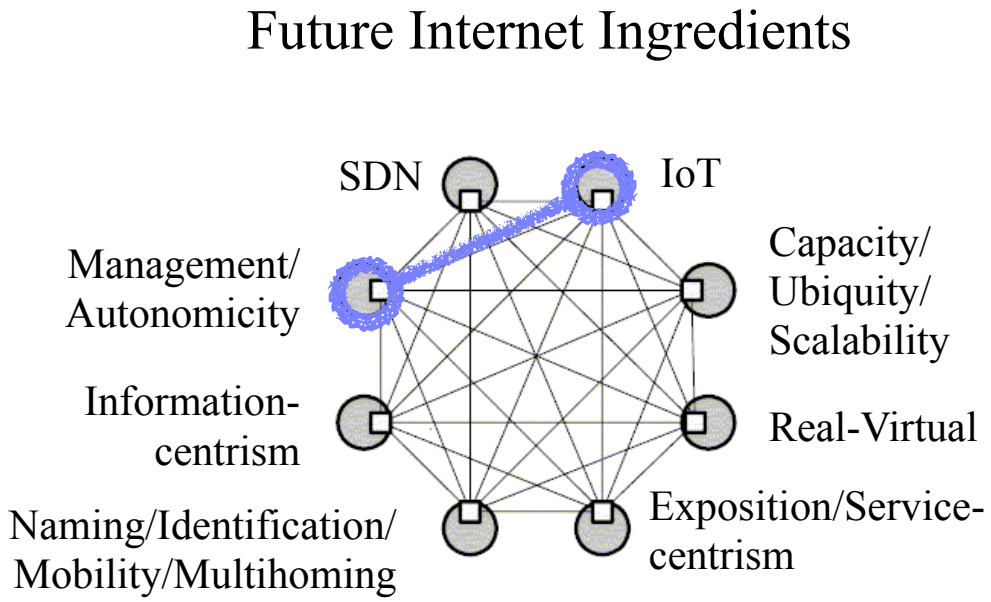
Software-Defined Networking

- ✓ The SDN paradigm could be applied to the IoT devices:
  - T. Luo, H. Tan; T.Q.S. Quek, Sensor OpenFlow: Enabling Software-Defined Wireless Sensor Networks, IEEE Communications Letters, vol.16, no.11, pp.1896,1899, (2012).

- ✓ IoT can be used to collect real-world information that is relevant for networking control, as well as to reflect software decisions on network hardware.

- ✓ Some open issues are:
  - How the well-known limitations of WSANs will shape the application of the SDN paradigm on this networks?
  - How to design networking control and management systems that take advantage of the IoT?

Management and Autonomicity



Management and Autonomicity

- ✓ IoT will manage itself or at least reduce considerably the degree of the human intervention required.

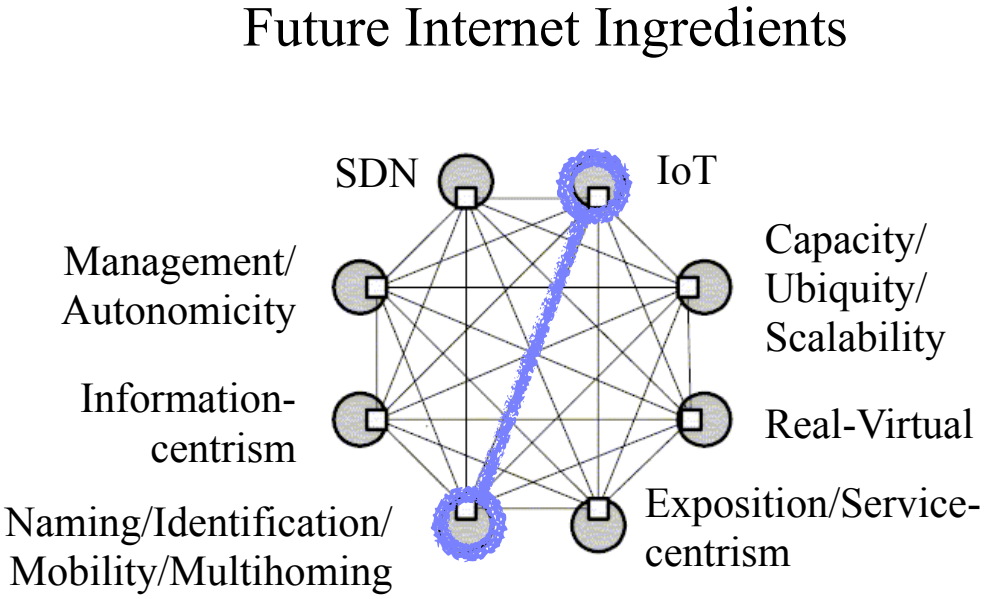
We have self-driven cars.
Why not to have a self-driven FI?

- ✓ We cannot expect that the IoT will be managed in the same way as the telecom operator's networks today.

Management and Autonomicity

- ✓ Among the proposals to reduce human interference on ICT, there is the so-called autonomic technology, or self-*.
- ✓ Many of the IoT roles overlap with the functionalities advocated by the autonomic cycle, e.g. monitoring, analysis, acting.
- ✓ Thus, the autonomic technology appears to be a natural candidate for the IoT management.
- ✓ However, the IoT provides the information necessary to feed the autonomic cycle of other FI architectural components.
- ✓ Thus, IoT appears to be a natural candidate to implement some of the phases of the autonomic cycle for FI components.

Naming, Identification, Mobility, and Multihoming



Naming, Identification, Mobility, and Multihoming

- ✓ People like to attribute natural language names to devices, networks, services, and even for information.
- ✓ Additionally, some FI initiatives are adopting self-certifying names (SCNs), which are the result of hash functions over the binary pattern of entities or their unique attributes.
- ✓ Names can be identifiers if they are unique in some scope.
- ✓ As a data moves it changes its address and location, but its identifier remains the same within the same scope.
- ✓ The same occurs to a node that moves in some network.

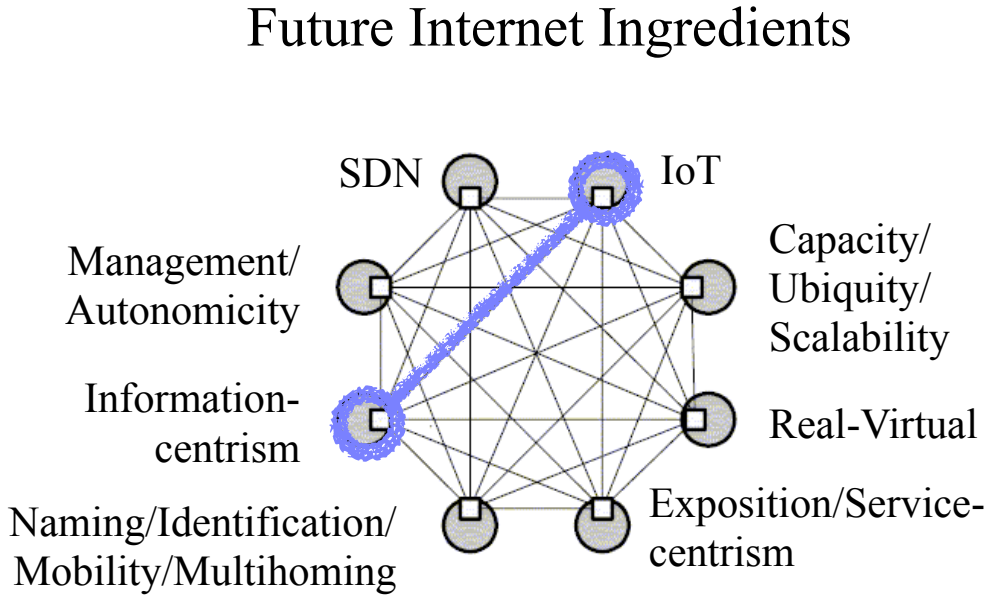
Naming, Identification, Mobility, and Multihoming

- ✓ Therefore, the separation of identifiers and locators in the IoT is very desirable.
- ✓ New architectures need to support simultaneous connectivity and multipath routing, fully enabling multihoming.
- ✓ The ubiquitous connectivity needs to be explored in design, as well as new routing approaches.

Naming, Identification, Mobility, and Multihoming

- ✓ Some open challenges are:
  - How to ensure that there is no collision? Or at least, how to minimize collisions probability?
  - How to check the veracity and uniqueness of a given identifier?
  - How to map an identifier to a locator in a large population of IoT devices?
  - Is it possible to use the IDs as addresses to forward or route information?
  - Or more generally, how to design an ID-based IoT?

Information-centrism



Information-centrism

- ✓ Node-centrism is perhaps the most common approach for designing WSANs.
- ✓ IoT can take great advantage of the precepts behind the Internet of Information (IoI).
- ✓ SCNs can be used to name data in a persistent and verifiable way.
- ✓ The integrity, provenance, and non-repudiation of sensing and actuating data can be checked based on such names.

Information-centrism

- ✓ Name-based search and discovery of network-enabled devices and information helps on IoT services' life-cycle.

- ✓ Information is secured per se – it do not depend anymore only on secured connections.

Final Remarks

- ✓ The IoT is a fundamental ingredient of the FI, since it provides the sensorial and actuating capabilities required to greatly enhance the interaction between the real and virtual worlds.
- ✓ Internet-enabled devices will become ubiquitous, allowing the FI to achieve increasing levels of real-world-awareness, as well as making our environment more intelligent and sustainable.
- ✓ The synergies between FI ingredients and the IoT needs to be better explored, eliminating unnecessary overlappings and cohesively integrating ingredients towards a new Internet.

Thank you!