

Internet of Things Strategic Research Roadmap

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... The meaning of things
lies not in the things
themselves, but in our
attitude towards them.

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Executive Summary

As a part of future trends and developments the coming Internet of Things will shape the world and the society – yet sound research work and applicable recommendations are necessary to guide Europe on its way and to make it beneficial for all citizens.

In order to reply to this challenge the Cluster of European Research Projects on the Internet of Things (CERP-IoT) developed in 2009 its Strategic Research Agenda (SRA), taking into account its experiences and the results from the ongoing exchange among European and international experts.

The present document proposes a list of research fields and a roadmap on future R&D until 2010, before 2015 and beyond 2020.

This initial CERP-IoT SRA version is part of a continuous IoT community dialogue initiated by the European Commission (EC) DG INFSO-D4 Unit for the European and international IoT stakeholders. The result is a lively one and will be updated with expert feedback from ongoing and next calls for proposals within the FP7 Framework Program on Research and Development in Europe.

The SRA for the Internet of Things is the result of a four-step collaboration between the members of the cluster research projects:

1. Elaboration of an IoT common definition about the meaning of "Things" and IoT visions, introducing the IoT concept and presenting the underlying vision
2. Identification of IoT Application Domains exploring the application domains for the future IoT
3. Identification of Technologies that will drive the IoT development and supporting the IoT vision
4. Formulation of an IoT Research Agenda, presenting the research challenges and priorities, the standardization issues and the security and privacy concerns that have to be addressed and solved over the next decade

As a result the main outcomes could be summarized as follows:

- The Internet of Things is an integrated part of Future Internet and could be defined as a dynamic global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have

identities, physical attributes, virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.

- The vision of Future Internet based on standard communication protocols considers the merging of computer networks, Internet of Media (IoM), Internet of Services (IoS), and Internet of Things (IoT) into a common global IT platform of seamless networks and networked "things". This future network of networks will be laid out as public/private infrastructures and dynamically extended and improved by terminals created by the "things" connecting to one another.
- We envisage that the Internet of Things will allow people and things to be connected Anytime, Anyplace, with Anything and Anyone, ideally using Any path/network and Any service.
- The concept of Internet of Things can be regarded as an extension of the existing interaction between humans and applications through the new dimension of "Things" communication and integration.
- The main identified IoT application domains are:
 - Aerospace and aviation,
 - Automotive,
 - Telecommunications,
 - Intelligent Buildings,
 - Medical Technology, Healthcare,
 - Independent Living,
 - Pharmaceutical,
 - Retail, Logistics, Supply Chain Management,
 - Manufacturing, Product Lifecycle Management,
 - Oil and Gas
 - Safety, Security and Privacy,
 - Environment Monitoring,
 - People and Goods Transportation,
 - Food traceability,
 - Agriculture and Breeding,
 - Media, entertainment and Ticketing,
 - Insurance,
 - Recycling

The main IoT technologies presented allow identifying the research and development challenges and outlining a roadmap for future research activities to provide practical and reliable solutions.

This roadmap forms the basis for the research priorities presented and these IoT enabling technologies are:

- Identification Technology,
- Internet of Things Architecture Technology,

- Communication Technology,
- Network Technology,
- Network Discovery,
- Software and algorithms,
- Hardware,
- Data and Signal Processing Technology,
- Discovery and Search Engine Technologies,
- Relationship Network Management Technologies,
- Power and Energy Storage Technologies,
- Security and Privacy Technologies,
- Standardisation

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The authors would appreciate any sharing of thoughts from the interested reader and constructive feedback on the IoT Strategic Research Agenda.

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Chapter 1

Internet of Things Vision

1.1 Internet of Things Common Definition

The meaning of “things”

Defining things and recognizing what a particular thing is and represents in the context of Future Internet requires a careful analysis of what philosophers like Aristotle and Philoponus had to say and how their philosophical thoughts can transcend into the future.

Aristotle, in his work “The Categories” gives a strikingly general and exhaustive account of the things that are (ta onta) - beings. According to this opinion, beings can be divided into ten distinct categories. They include substance, quality, quantity, and relation, among others. Of these categories of beings, it is the first, substance (ousia), to which Aristotle gives a privileged position.

Aristotle is distinguishing things that are by nature from those that are from other causes. Philoponus, commenting on this distinction, first divides things that are by nature into those that have soul and those that do not.

The proper nature of “besouled” things (i.e., plants and animals) is their form, which, Philoponus says is properly identified with soul, their intrinsic mover.

From the “philosophical definition” of “things” one can conclude that the word is not restricted to material things but can apply to virtual things and the events that are connected to “things”.

In the context of “Internet of Things” a “thing” could be defined as a real/physical or digital/virtual entity that exists and move in space and time and is capable of being identified. Things are commonly identified either by assigned identification numbers, names and/or location addresses.

Internet of Things

Internet of Things (IoT) is an integrated part of Future Internet and could be defined as a dynamic global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual “things” have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.

In the IoT, “things” are expected to become active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information “sensed” about the environment, while reacting autonomously to the “real/physical world” events and influencing it by running processes that trigger actions and create services with or without direct human intervention.

Interfaces in the form of services facilitate interactions with these “smart things” over the Internet, query and change their state and any information associated with them, taking into account security and privacy issues.