Internet of Things

Position Paper on Research Priorities for FP8

European Research Cluster on the Internet of Things

16 December, 2010
Version 10.0

"Somewhere, something incredible is waiting to be known."

Carl Sagan

European Commission
Information Society and Media

Editors

Ovidiu Vermesan
Peter Friess
Patrick Guillemin
Sergio Gusmeroli
Harald Sundmaeker
Ignacio Soler

Contributing Projects and Initiatives

ASPIRE, BRIDGE, CASCADAS, CONFIDENCE, CuteLoop, DACAR, Ebbits, ETP EPoSS, EU-IFM, EURIDICE, GRIFS, HYDRA, IMS2020, Indisputable Key, iSURF, LEAPFROG, PEARS Feasibility, PrimeLife, RACE networkRFID, SMART, StoLPaN, SToP, TraSer, WALTER, IOT-A, IOT@Work, ELLIOT, SPRINT, NEFFICS, IOT-I, CASAGRAS2, eDiana

Additional Contributing Experts

Margaretha Mazura
Mark Harrison
Markus Eisenhauer
Claudio Pastrone
Maurizio A. Spirito
Peter Rosengren
Pat Doody

IERC Coordinators:
Ovidiu Vermesan, Coordinator IERC Cluster, Ovidiu.VERMESAN@sintef.no
Peter Friess, Coordinator IERC Cluster, European Commission, Peter.FRIESS@ec.europa.eu

www.internet-of-things-research.eu

Acknowledgements

The editors would like to thank the European Commission services for their support in the planning and preparation of this document. The recommendations and opinions expressed in this document are those of the editors and contributors, and do not necessarily represent those of the European Commission. The views expressed herein do not commit the European Commission in any way. The responsibility for any remaining errors remains with the editors.

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Executive summary

This position paper presents the European research Cluster on the Internet of Things research priorities in the Internet of Things (IoT) field, with a global view towards the structure and priorities of the EU's Eighth Research Framework Programme (FP8). It builds on the ideas put forward by the Cluster Strategic Research Agenda and extensive discussions among the Cluster projects on overall priorities for FP8. In addition, it presents global views on the challenges facing the research, development and deployment of IoT at the global level.

IoT together with the other emerging Internet developments such as Internet of Energy, Media, People, Services, Business/Enterprises are the backbone of the digital economy, the digital society and the foundation for the future knowledge based economy and innovation society. IoT developments show that we will have 16 billion connected devices by the year 2020[1], which will average out to six devices per person on earth and to many more per person in digital societies. Devices like smart phones and machine to machine or thing to thing communication will be the main drivers for further IoT development. The first direct consequence of the IoT is the generation of huge quantities of data, where every physical or virtual object may have a digital twin in the cloud, which could be generating regular updates. The IoT contribution is in the increased value of information created by the number of interconnections among things and the transformation of the processed information into knowledge for the benefit of mankind and society.

The IoT technology forms the "middleware" between the implementation of the "grand challenges" of climate change, energy efficiency, mobility, digital society, health at the European level and the enabling technologies such as nano-electronics, communications, sensors, smart phones, embedded systems, cloud computing and software technologies that will create new products, new services, new interfaces and new applications addressing the implementation of the "grand challenges" by creating smart environments and smart spaces.

Ensuring the implementation of the Grand Societal Challenges for Europe requires the recognition of enabling technologies such as IoT that will allow the sustainable implementation and application of dedicated resources of the European Union to this priority topic in FP8. The Internet of Things is an essential component of the Digital Agenda[2] and its presence should be strengthened within FP8. Therefore the Cluster makes the following specific recommendations:

- Set up coherent and interacting programmes with Internet of Things, Media, Energy, People, Services, Business/Enterprises as integral elements of the FP8.
- Define a dedicated IoT Research Development Innovation (R+D+I) initiative with a budget share that reflects the role of IoT to the Digital Agenda and Grand Societal Challenges for Europe implementation.
- Ensure the funding instruments for "Collaborative" research and partnership by focusing on three main elements: Excellence, Innovation and Market Deployment.
- Ensure better coordination among the national and European funding projects.
- Support relevant Research Collaboration and Innovation Partnerships at the global level in the Framework Programmes.
- Create new mechanisms such as Clusters that take the role of the Network of Excellence/Coordination action that adapt to new technological and societal challenges as well as to the market needs.
- Link to Policy development and supporting actions for societal changes in the scope of a wide adoption of the IoT and for the benefits of all citizens.

[1] Internet 3.0: the Internet of Things. © Analysys Mason Limited 2010.
[2] A Digital Agenda for Europe, COM(2010) 245, chapter 2.5.3. Industry-led initiatives for open innovation, pp.24.

IoT Definition and Research Needs

"Internet of Things" as discussed in this position paper is based on the definition provided by the Cluster in the Strategic Research Agenda published in the Cluster Book in March 2010[3].

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.

The major application fields for IoT are the creation of smart environments/spaces and self-aware things (for example. smart transport, products, cities, buildings, rural areas, energy, health, living, etc.) for climate, food, energy, mobility, digital society and health applications. These will enable the development of the novel technology needed to address the emerging challenges of public health, aging population, environmental protection and climate change, the conservation of energy and scarce materials, enhancements to safety and security and the continuation and growth of economic prosperity by:

- Providing reliable, intelligent, self managed, context aware and adaptable network technology, network discovery and network management.
- Refining the interaction between hardware, software, algorithms as well as the development of smart interfaces among things (smart machine to machine, things to things interfaces) and smart human-machine/things interfaces, thus enabling smart & mobile software.
- Embedding smart functionality by further developments in the area of nano-electronics, sensors, actuators, antennas, storage, energy sources, embedded systems and sensor networks.
- Developments across disciplines to address the multi functional, multi-domain communications, information and signal processing technology, identification technology, and discovery and search engine technologies,
- Developing novel techniques and concepts to improve the existing security, privacy and business safety technologies in order to adapt to new technological and societal challenges.
- Enhancing standardisation, interoperability, validation and modularisation of the IoT technologies and solutions.
- Defining new governance principles that address the technology developments and allow for business development and free circulation of knowledge in line with global needs while maintaining respect for privacy, security and safety.

[3] Vision and Challenges for Realising the Internet of Things, European Union 2010, ISBN 9789279150883, p.43.

The challenge for IoT research

Wider technological trends

It is possible to identify, for the years to come, a number of distinct macro-trends that will shape the future of ICT.

- **First**, the explosion in the volumes of data collected, exchanged and stored by IoT interconnected objects will require novel methods and mechanisms to find, fetch, and transmit data. This will not happen unless the energy required to operate these devices is dramatically decreased or we discover novel energy harvesting techniques. Today, many data centres have already reached their maximum level of energy consumption, and the acquisition of new devices can only follow the replacement of old ones, as it is not possible to increase energy consumption.
- **Second**, research is looking for ultra low power autonomic devices and systems from the tiniest smart dust to the huge data centres that will self-harvest the energy they need.
- **Third**, miniaturisation of devices is also taking place at a lightning speed, and the objective of a single-electron transistor, which seems to be (depending on new discoveries in physics) the ultimate limit, is getting closer.
- **Fourth,** the trend is towards the autonomous and responsible behaviour of resources. The ever growing complexity of systems will be unmanageable, and will hamper the creation of new services and applications, unless the systems will show "self-*" properties, such as self-management, self-healing and self-configuration.

The key to addressing these macro-trends by IoT is research and development, which drives the innovation cycle by exploiting the results to bring beneficial new technologies to the market and therefore into industrial applications.

IoT research and development is becoming more complex, due to the already highly advanced level of technology, the global, inter-sectorial and interdisciplinary collaboration needed and the ever increasing demands of society and the economic global marketplace. Development of certain enabling technologies such as nano-electronics, communications, sensors, smart phones, embedded systems, cloud computing and software technologies will be essential to support important future IoT product innovations affecting the different industrial sectors. In addition, systems and network infrastructure (Future Internet) are becoming critical due to the fast growth and advanced nature of communication services as well as the integration with the Energy Efficient Buildings (E2B), and the Green Car initiatives.

The focus of IoT research and development projects is on producing concrete results for several industries, which can then be further developed or exploited directly in creating smart environments/spaces and self-aware products/processes for the benefit of society. This is an essential element of the success of EU projects in driving the three main elements of **excellence**, **innovation** and **market deployment** in order that Europe maintains its leading position in global IoT. Moreover, this is one of the reasons European stakeholders use their own resources to co-fund these research and development activities. This focus on achieving collaborative research and development results needs to continue in FP8.

Enablers

Energy

Energy issues, such as harvesting and ultra low power chipsets, are central to the development of the IoT. There is a need to research and develop solutions in this area (nano-electronics, semiconductor, sensor technology, micro systems integration) having as an objective ultra low power devices, as current devices seem inadequate considering the processing power and energy limitations of the future. The "More Than Moore's Law" movement will address these challenges by focusing on system integration – this will lead to increased functional electronics that form an essential enabler for IoT technology.

Intelligence

Capabilities such as self-awareness, context awareness and inter-machine communication are considered a high priority for the IoT. Integration of memory and processing power, the ability to withstand harsh environments are also a high priority, as are the best possible security techniques. The "More Than Moore's Law" movement will address these challenges by focusing on transistor density. This will lead to more “intelligent” electronics with increased on chip processing and memory capabilities. Novel cognitive approaches that leverage opportunistically on the time-dependent available heterogeneous network resources can be adopted to support seamless continuous access to the information network as well as handle intermittent network connectivity in harsh and/or mobile environments. “Intelligent” approaches to knowledge discovery and device control will also be important research challenges.

Communication

New smart antennas, integrated on chip and made of new materials are the communication means that will enable new advanced communications systems on chip which when combined with new protocols optimized across the Physical (PHY), Media Access Control (MAC) and the Network (NWK) layers will enable the development of different Application Programming Interfaces (APIs) to be used for different applications. Modulation schemes, transmission rates, and transmission speed are also important issues to be tackled.

Integration

Integration of wireless identification technologies (like Radio Frequency Identification) into packaging, or, preferably, into products themselves will allow for significant cost savings, increased eco-friendliness of products and enable a new dimension of product self-awareness for the benefit of consumers. Integration requires addressing the need for heterogeneous systems that have sensing, acting, communication, cognitive, processing and adaptability features and includes sensors, actuators, nano-electronics circuits, embedded systems, algorithms, software embedded in things and objects.

Dependability

Dependability of IoT systems is of paramount importance; therefore the IoT network infrastructure must ensure security and privacy by supporting individual authentication of billions of heterogeneous devices using heterogeneous communication technologies across different administrative domains. Reliable energy-efficient communication protocols must also be designed to ensure dependability.

Semantic Technologies and IoT

IoT requires devices and applications that can easily connect and exchange information in an ad-hoc fashion with other systems. This will require devices and services to express needs and capabilities in formalised ways. To facilitate the interoperability in the IoT further research into semantic technologies is needed. Examples of challenges are large-scale distributed ontologies, new approaches to semantic web services, rule engines and approaches for hybrid reasoning over large heterogeneous data and fact bases, semantic-based discovery of devices and semantically driven code generation for device interfaces.

Resource-constrained scenarios for business based IoT

IoT implies that even the smallest device or sensor could be connected to the network. Research in wireless sensor networks has already resulted in promising solutions, tools and operating systems that can run on very small and resource-constrained devices. These solutions need to be evaluated in real large-scale industrial applications in order to illustrate business-based scenarios for IoT.

Modelling and Design

The design of large-scale IoT systems is challenging due the large number of heterogeneous components involved and due to the complex iterations among devices introduced by cooperative and distributed approaches. To cope with this issue, innovative models and design frameworks need to be devised; for example, inspired by co-simulation methods for large systems of systems and hardware-in-the-loop approaches.

Validation and Interoperability

Standardisation is a must but it is not enough. It is a known fact that, even if following the same standard, two different devices might not be interoperable. This is a major showstopper for wide adoption of IoT technologies. Due to the complex and diverse nature of IoT technologies an interoperability solution may not be possible and integration is therefore required. Future tags and devices must integrate different communication schemes, allow different architectures, centralised or distributed, and be able to communicate with other networks. Interoperability of IoT technologies will always be a complex topic which requires research effort to address the new challenges raised. This for instance might be achieved by increased embedded intelligence and different radio access technologies sometimes even with cognitive capabilities. All these new emerging features together with the necessary intercommunication between different technologies will raise even more complexity in testing and validation and therefore common methodologies and approaches are necessary to validate and ensure interoperability in a coherent and cost effective way. The efforts necessary in achieving success in this area must not be underestimated as the results will serve to really exploit IoT research results by successful worldwide interoperable deployments.

Standards

Clearly, open standards are key enablers for the success of wireless identification technologies (like RFID), and, in general, for any kind of Machine-t0-Machine communication (M2M). Without global recognised standards (such as, the TCP/IP protocol suite) the expansion of RFID and M2M solutions to the Internet of Things cannot reach a global scale. The need for "faster setting of interoperable standards" has been recognised by the Commission Communication on the Innovation Union that predicts "If not able to adapt, the European standardisation system risks becoming irrelevant with companies turning instead to other instruments [...] or worse could start to work as a brake on innovation"[4].

Manufacturing

Last but certainly not least, manufacturing challenges must be convincingly solved. Costs must be lowered to less than one cent per passive RFID tag, and production must reach extremely high volumes, while the whole production process must have a very limited impact on the environment, be based on strategies for reuse and recycling considering the overall life-cycle of digital devices and other products that might be tagged or sensor-enabled.

[4] Europe 2020 Flagship Initiative Innovation Union, COM(2010)546 final, p.16.

Societal demands and research

Excellence, innovation and market deployment

The focus of IoT research and development is based on societal demands and needs to be interlinked with the main pillars for the research strategy: **excellence**, **innovation** and **market deployment,** in order that **Europe** maintains its **leading position** in **global IoT**.

Excellence

European excellence in the area of IoT

A digitally enabled and effective European economy is founded on a digitally enabled and effective society and requires improving the capacity to innovate using digital technologies, building a world class digital infrastructure, growing the information and communications technology industry and other enabling technologies needed to implement IoT. Scientific and technological excellence must be the final criterion for choosing projects in all areas of the IoT research and development, therefore strengthening the competitiveness of science and industry in Europe in order to maintain its leading position at the global level. The cooperation at the global level can mobilise a critical mass, based on international "Excellence Clusters" from different parts of the world and the financing of joint projects/ programmes in the area of IoT. There is need to develop excellence by making better use of the synergy and compatibility with research and innovation at national level (i.e. French Pôle de compétitivité, etc.) and by integrating these research activities rather than duplicating them.

Innovation

Internet of Things Innovation Implementation

An innovation-oriented, industry-driven approach will be needed for IoT activities as an integral part of FP8 where the involvement of SMEs as drivers of innovation should be ensured. This will ensure dissemination of the IoT knowledge and technology transfer including applications that address social and societal challenges.

IoT research and innovation activities should be interlinked and integrated across FP8. These innovation activities must address important IoT advancements such as infrastructure development, standardisation, education programmes and measures to support important industrial sectors or innovation-conducive environments such as smart cities or regions.

European Technology Platforms (for example; ARTEMIS, ENIAC, EPoSS, eMobility, etc.) also need to cover innovation strategies for the development of enabling technologies (nano-electronics, embedded systems, communication technologies, software and cloud computing, etc.) required for IoT applications.

Further synergies within the knowledge triangle and with the EUREKA and EUROSTARS programmes should be explored and integrated into FP8.

Market deployment

Research transfer

Rapid transfer of IoT research and development results into applications is a critical element when it comes to stimulating economic growth and dynamics. It is imperative to concentrate funds on the development of IoT technologies and applications that address and propose solutions to solve social challenges such as climate protection, energy efficiency, health and ageing, nutrition, and safe food mobility, communication, security, governance, etc. These global challenges need global solutions where IoT that is intrinsically global can bring important contributions. IoT technology transfer and exploitation must be ensured in particular in thematic funding with relevance to application within the framework of sustainable implementation plans which are updated during project implementation. From research and development to innovation the time to market is the key for the success of the IoT technologies, to enable the industry to improve the performance and the productivity of their processes, making them cleaner, more efficient and more autonomous.

Global cooperation

Global vision

In October 2009, the Expert Group Report on "*The Role of Community Research Policy in the Knowledge-Based Economy*[5]" for DG Research **advocates for international cooperation. In its recommendation No.5, it states: "**Improve ***international cooperation***, particularly for challenges of a global nature; build this cooperation on a clearer assessment of European strengths and ambitions".

In the IoT area, the EU started early on to collaborate internationally (in the framework of RFID) and DG INFSO Unit D.4 fostered international consortia from the early days. The IERC Cluster project gives an unequivocal testimony of the advantages of acting at a global level.

The ICT "bible" for the coming decade is doubtlessly the ***Digital Agenda***[6]**.** This Commission Communication is one of the seven flagship initiatives of the Europe 2020 Strategy[7]. The Digital Agenda addresses the International Dimension, underlining that "The seven pillars in the Digital Agenda all have international dimensions. The Digital Single Market in particular needs an external face because progress on many of the policy issues can only be made on an international level.[...] Thus an international dimension of the Digital Agenda in order to complete the actions above is crucial, in particular given the strategic importance of the internet. Europe must continue to play a leading role."[8] The IERC Cluster endorses this approach. However, the international strategic objectives of the European Research Area still appear rather vague. "Technology transfer and marketing partners from third country markets should be brought into projects from the outset to ensure a smooth transition between research, development and marketing[9]". Such an approach would not only strengthen Europe's position in the global research arena but would open up new markets for European IoT products and services.

5 http://ec.europa.eu/research/era/pdf/community_research_policy_role.pdf.
6 A digital Agenda for Europe, COM(2010) 245, 19 May 2010.
7 EUROPE 2020 - A strategy for smart, sustainable and inclusive growth - COM(2010) 2020.
8 A Digital Agenda for Europe, op.cit., p.35.
9 EMF Position paper on a Digital Agenda for Europe, p.5, www.emfs.eu/EMF_position_paper_on_digital_agenda.

Funding and instruments

Funding mechanisms

EU financing

It is important to ensure flexibility combined with a minimum of administrative effort and harmonisation of the financial rules among the countries participating in FP8. Definition of a minimal unambiguously set of regulations, procedures and processes of FP8 so that coherent application can be ensured at all levels, from the European Commission to the project participants and to the auditors. Common accounting procedures should be one of the basic principles of European research funding.

Joint EU national projects

Coordination with national programmes addressing the IoT and joint calls that facilitate the formation of trans-national research collaborations on the basis of national funding programmes need to be supported in FP8. Coordination with the Joint Technology Initiatives (JTIs) and links made by the thematic Clusters with the national projects addressing IoT technology and applications are recommended to be strongly supported in FP8.

Joint EU global partners projects

In the area of IoT it is imperative to support initiatives to develop new and strengthen existing research infrastructures under the FP8. A dialogue between science and society at international level, involving joint projects experts from different countries around the world would create a platform for creating thematic initiatives addressing the global challenges of IoT technology. Results can be fed into common Science and Technology research agendas that define bilateral priorities. As an example, ICT research priorities between the EU and Latin America mention "future networks, efficient water resource management, energy efficiency and governance"[10] among the top issues, all of them touching upon IoT. It is therefore imperative to tap all sources and gain access to all possible information to satisfy these obvious needs of collaboration in European Projects.

Instruments

Programme type projects

Introduce large industrial and applied research driven ancillary instruments to FP8 in line with JTI or similar (for example Public Private Partnerships). Refine the JTI by FP8's starting date, in order to make the JTI regulation easier and the project funding faster and more effective and to allow effective competition with the large programmes that are financed in countries like US, Japan, China, Korea, India, Latin/South America (Brazil), Russia, Australia and Africa. These large programmes grouped around the JTI need to provide the innovation strategies for the development of enabling technologies for IoT which take into account all relevant factors for successful innovations (knowledge, technology transfer, standardization, etc.) across the entire value-chains.

Collaborative projects

Collaborative project instruments consisting of a consortium of a limited number of industrial companies, universities and research institutions, provides a valuable, efficient and effective way of cooperative research that is recommended to be continued in the FP8. In order to be more efficient and provide a rapid exploitation it is recommended that the projects are connected to the other projects and to large programmes addressing the IoT or the enabling technologies through the Cluster of

[10] http://www.pro-ideal.eu/sites/default/files/PI+%20Report%20on%20ICT%20Research%20Priorities%20in%20LA-Survey%20results-September2010.pdf.

Excellence and Competence. Focus should be on useable and transferable results instead of mere academic reports.

Cluster projects

FP8 needs to introduce new mechanisms that allow funding of an IoT cluster and Clusters in other areas (in the context of financing, areas of knowledge, competence centres) in order to contribute to setting up joint activities which facilitate better network competences in the triangle of knowledge to meet changing European and global challenges. The Clusters can replace the existing Networks of Excellence.

The research and innovation driven Clusters could consist of projects financed by the FP8 and public and private institutions with the aim of pooling and using joint research resources, coordination of research and innovation activities, staff exchanges and knowledge transfer as well as the joint implementation of application oriented projects or competence centres.

CSA

The coordination and support instrument should be used for supporting dissemination activities, promoting the implementation of innovation policies and supporting SMEs to participate in joint initiatives. It should also be used to collect SME's opinions related to future technology needs and developments and create links between IoT research and standardisation in Europe. As such, CSA can become the instruments to help remedy Europe's failure "*to convert intellectual advantage of research into the competitive advantage of market-based innovations*[11]" and implement one of the actions identified by the "Innovation Union" Communication[12]:

[11] Commissioner Neelie Kroes' statement of 4 May 2010 as quoted in EMF Position Paper op.cit.
[12] Europe 2020 Flagship Initiative Innovation Union, op.cit. p. 11.