THE INTERNET OF THINGS PROGRAM: THE FINNISH PERSPECTIVE

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INTRODUCTION

Recent advances in radio, network, mobile, and cloud technologies have supported the development of the first generation Internet of Things (IoT) services and products. IoT promises to connect various physical and digital objects to the Internet and thus enable a plethora of new innovative applications that enhance society and quality of life [1–3]. IoT and ubiquitous computing [4] extend the current mobile computing revolution by reaching beyond the current four billion mobile phones, connecting the phones, sensors, and other devices with the Internet. The resulting communications network is exponentially larger and more complex than the current Internet with potentially trillions of identifiers and communicating endpoints. This IoT revolution creates both technological and societal challenges that need to be addressed.

IoT as a concept is not new as it was proposed over 10 years ago in the MIT Auto-ID Center. The concept has since gained momentum and importance, and now it is considered in Europe, the United States, and Asia, not only on the implementation and deployment level, but also on the societal level. From the telecommunications point of view, IoT pertains to the interconnection of physical objects in so called global machine-to-machine (M2M) communications. Previous telecommunications paradigm shifts have first involved the interconnection of physical locations, and then of people.

The key challenges in IoT are in the fragmented nature of the solutions and its integration with everyday life. At the moment, traditional industrial IoT solutions are ossified and based on closed proprietary technologies, making it difficult to integrate them across application domains. New standards and enablers are needed to bridge these vertical silos. With the advent of mobile and IoT solutions, we are surrounded by a cloud of myriad devices that monitor us, control the environment, and interact with us in sectors such as healthcare, smart home, industry automation, and services. Thus, it is increasingly important to guarantee the correct operation of the IoT solutions, and ensure the required levels of security and privacy.

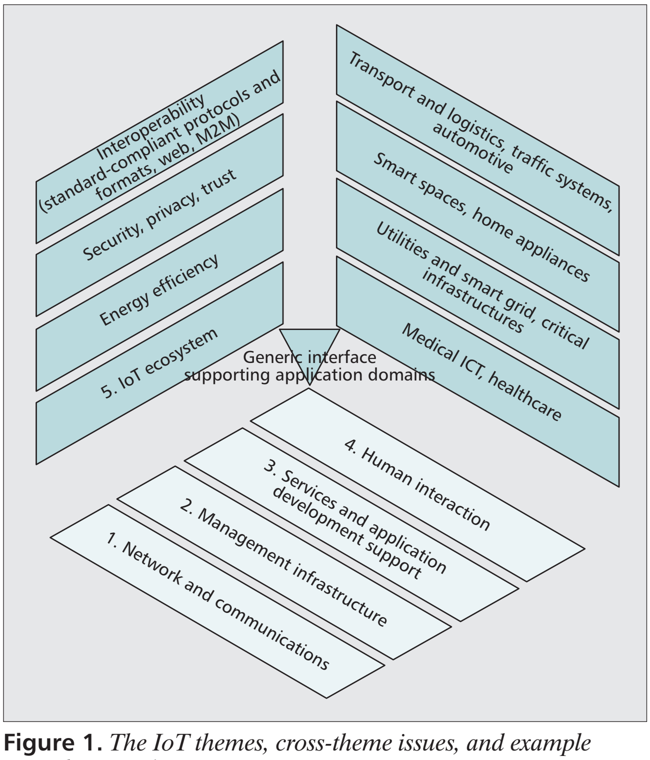

Figure 1. *The IoT themes, cross-theme issues, and example application domains.*

IOT PROGRAM OVERVIEW

The IoT research program managed by TIVIT[1] aims to address these key challenges, and create and support IoT ecosystems, in which consumers, companies, and the government build their IoT solutions on top of an interoperable IoT framework. The four-year program started in early 2012, and consists of 16 Finnish companies and eight universities and research organizations. Wilhelm Rauss from Ericsson leads the program, and the University of Helsinki is coordinating academic activities. The expected total project volume is on the order of €50–60 million for the four years.

The IoT program will provide a set of solutions at different levels and instances where things (e.g., everyday objects, locations, vehicles, meters) are extended with sensors, radio frequency identifiers (RFIDs), actuators, or processors, made discoverable and enabled to communicate with, and closely integrated with future Internet infrastructure and services. Research themes under the IoT program were described in detail in the Strategic Research Agenda [1].

Thus, one of the key challenges for IoT research and development is to realize the backbone that supports the different deployment scenarios (verticals) and meet the functional and non-functional requirements. The nature of the IoT environment calls for protocols, network designs, and service architectures that can cope with billions of IoT entities, and connect the suppliers of the data with the consumers.

Therefore, the IoT needs to support a large number of diversified objects, based on different types of radio interfaces with very different requirements in terms of available resources. Such diversity of connected moving objects would create a hoard of information for Internet users, resulting in new applications and services. It is clear that such a heterogeneous system should evolve into a more structured set of solutions.

IOT TECHNICAL DESCRIPTION

The program aims to create and sustain IoT ecosystems based on interoperable technological enablers. This section briefly considers the five crucial research themes that are investigated in the program. Figure 1 illustrates the research themes. The first four themes are depicted by the lower part of the diagram. They support the requirements and various application domains as well as connect data across domains. The research themes target generic interfaces and enablers that support various application domains as well as the formation of sustainable IoT ecosystems.

[1] *The Strategic Centre for Science, Technology and Innovation in the Field of ICT. Web link: www.tivit.fi*

NETWORKING AND COMMUNICATIONS

This research theme focuses on the networking and communication solutions needed to enable global connectivity among hundreds of billions of physical objects. Basic solutions are already available, such as Long Term Evolution (LTE), wireless personal area networking (WPAN), and WLAN, and Bluetooth Low Energy radio technologies as well as IPv6 and 6LoWPAN for networking, and the Internet Engineering Task Force's (IETF's) Constrained Access Protocol (CoAP) for resource access; however, efficient integration of existing and new solutions with IoT requires research and standardization. LTE wireless technologies will become a key player in M2M services, and both the European Telecommunications Standards Institute (ETSI) and Third Generation Partnership Project (3GPP) already have several work items defined for M2M communications.

The amount of connected things, their varying capabilities, and the amount of data generated create new challenges for the networks. While the current Internet has been able to scale to some billions of connected devices, IoT will push the scalability requirements several orders of magnitude higher.

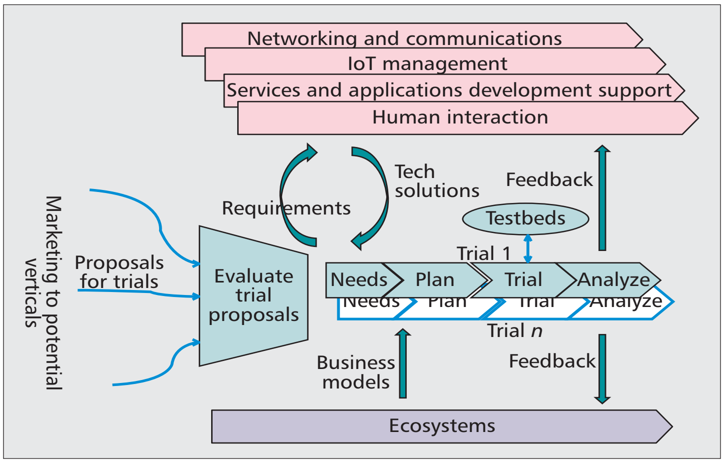

Figure 2. *Trials and demos link R&D to innovation.*

MANAGEMENT INFRASTRUCTURE

The management of IoT devices and entities is much more complex than the management of the Internet or its other precursors (e.g., current M2M cellular systems). Much of this complexity is due to the expected great size of IoT, its continuous growth, the heterogeneity of the system, and the limited availability of resources. The IoT program focuses on the management challenges. From the viewpoint of physical IoT devices, energy management is the most critical issue.

SERVICES AND APPLICATION DEVELOPMENT

This research theme focuses on solutions enabling and facilitating service and application development in IoT. Middleware aspects and application programming interfaces (APIs) are addressed to support easy application development, debugging, and deployment. The focus areas include integration with the web, service enablement platforms and APIs, data processing infrastructure, and interoperability.

HUMAN INTERACTION

This research theme focuses on end-user aspects. IoT enables tangible and ubiquitous interaction between people, objects, locations, and services. The focus is transferring from graphical user interfaces to direct interaction with the real physical environment and its everyday objects. This kind of interaction has significant potential in enabling easy-to-use services that intertwine into our everyday life. To fully exploit this potential, we need to study the implications of IoT for user activities. Understanding user needs and behavior and the factors affecting user experience is a prerequisite for successful business as well.

ECOSYSTEMS AND TRIALS

This research theme focuses on the ecosystem and business model creation of IoT. There is clearly indicated business potential in the area of IoT. The challenge of enhancing an IoT ecosystem depends on numerous vertical businesses. The development of a business area will create economies of scale and also a critical mass in the markets, allowing consumers free choice of providers, and leading to a virtual cycle of adoption ofthe IoT ecosystem.

The purpose of trials and demos is to link IoT technology research and the business domains needing and utilizing IoT (i.e., linking research and development to innovation). Trials and demos are the means to achieve this. In the trials we extract requirements from real-life IoT application domains so that the requirements can be used in technical work to find the common denominators and needs, and thus guide the planning; when the technical work produces solutions, they are experimented and tested in trials to give further feedback for research and development and verify or falsify the assumptions made. The interplay between technical research, ecosystem, and business model creation and trials is depicted in Fig. 2.

The demos are first to showcase results and potential of IoT technology for business professionals and citizens at large, and second to verify the feasibility of concepts and ideas developed in the program. Demos also play a role in proofing and justifying the results for stakeholders in the community.

THE IMPACT

The expected impact of the research program has many facets: the standardization and development of key technology enablers, scientific advances, and formation of IoT ecosystems. The program is active in 3GPP, IEEE, IETF, and W3C IoT related standardization efforts, and one of the goals will be an energy-efficient variant of LTE for IoT. Academic impact is expected in the five theme areas. Energy efficiency and security are current focus areas of the academic research that span across the themes. The technological enablers and scientific advances are tested and examined through the experimental trials. Indeed, significant impact is expected from the real-life trials in the form of experimental results and, ultimately, product field trials.

CONCLUSION

The future potential for IoT is enormous. A large number of innovative services and applications are enabled by the interconnection of large numbers of devices. However, the potential can only be realized if the cost for deploying various solutions is low enough, and various devices are interoperable with each other. An interoperable mass deployment of devices or connected things requires extensive use of open standardized interfaces, protocols, and APIs. The IoT program focuses on these as well as on various non-functional requirements, such as energy awareness and scalability, in order to advance toward the set goals.

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