

Internet of Things: A New Paradigm

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Abstract- Like other milestones in technology, the Internet of Things enables us to measure what could not be measured before. Until today it remains difficult to come up with a clear definition of the Internet of Things. For companies this means additional information for high resolution management of industry and business processes. For citizens the possible implications are manifold, ranging from consumer empowerment to rethinking society. Different infrastructures and networks will compete and interact in the future Internet of Things. The Internet of Things is not synonymous with ubiquitous / pervasive computing, the Internet Protocol (IP), communication technology, embedded devices, the Internet of People or the Intranet / Extranet of Things, yet it combines aspects and technologies of all of these approaches. This paper elaborates the phrase Internet of things, discusses and analyses various definitions of IoT in use and try to distinguish it from other related technologies/concepts.

Index Terms- : IoT, RFID, Things, ubiquitous

I. INTRODUCTION (THE EVOLUTION OF IOT)

Communication between computers started with the EDI (Electronic Data Interchange) that made possible direct dialogue between two PCs. With the Internet, all the computers connected to the Internet can talk to each other and with the connection of mobile phones, the connection has become mobile. The evolution that we have been witnessing in the last few years is an extension of this Internet to all the things that surround us. Up until now the Internet has been the first place for uniting people by means of different types of social media (Email, Blog, Facebook, Twitter, Flickr etc), now it is being transformed into the tool that will allow all objects to interact and in certain cases to gain access to the collective knowledge that they will generate. The growth of the Internet is an ongoing process: only twenty-seven years ago it was connecting about a thousand hosts and has grown ever since to link billions people through computers and mobile devices. One major next step in this development is to progressively evolve from a network of interconnected computers to a network of interconnected objects, from books to cars, from electrical appliances to food, and thus create an 'Internet of things' (IoT) [1]. The concept of the Internet of Things first became popular through the Auto-ID center and related market analysts publications [2]. If all objects of daily life were equipped with radio tags, they could be identified and inventoried by computers [3][4]. However, unique identification of things may be achieved through other means such as barcodes or 2D-codes as well. With all objects in the world equipped with

minuscule identifying devices, daily life on Earth would undergo a transformation [5][6]. Companies would not run out of stock or waste products, as involved parties would know which products are required and consumed[6]. Misplaced and stolen items would be easily tracked and located, as would the people who use them. Our ability to interact with objects could be altered remotely based on your current status and existing user agreements [3]. These objects will sometimes have their own Internet Protocol addresses, be embedded in complex systems and use sensors to obtain information from their environment (e.g. food products that record the temperature along the supply chain) and/or use actuators to interact with it (e.g. air conditioning valves that react to the presence of people). The scope of IoT applications is expected to greatly contribute to addressing today's societal challenges: health monitoring systems will help meet the challenges of an ageing society [7]; connected trees will help fight deforestation [8]; connected cars will help reduce traffic congestion and improve their recyclability, thus reducing their carbon footprint. This interconnection of physical objects is expected to amplify the profound effects that large-scale networked communications are having on our society, gradually resulting in a genuine paradigm shift. To complement this overview, it is worth noting three points that highlight the complex nature of IoT. First, it should not be seen as a mere extension of today's Internet but rather as a number of new independent systems that operate with their own infrastructures (and partly rely on existing Internet infrastructures). Second, as detailed in a recent ISTAG report [9], IoT will be implemented in symbiosis with new services. Third, IoT covers different modes of communication: things-to-person communication and thing-to-thing communications, including Machine-to-Machine (M2M) communication that potentially concerns 50-70 billion 'machines', of which only 1 % are connected today[10]. These connections can be established in restricted areas ('intranet of things') or made publicly accessible ('Internet of things'). The advent of IoT is taking place in an ICT environment affected by several major trends [11]. 'Scale' is one of them: the number of connected devices is increasing, while their size is reduced below the threshold of visibility to the human eye. 'Mobility' is another: objects are ever more wirelessly connected, carried permanently by individuals and geo-localisable. 'Heterogeneity and complexity' is a third trend: IoT will be deployed in an environment already crowded with applications that generate a growing number of challenges in terms of interoperability.

II. VARIOUS TECHNOLOGY COMPONENTS IMPLEMENTING IoT

Services:

Systems integrators and services organizations provide integration and solution implementation services for IoT projects.

Software:

Middleware and application infrastructure vendors provide information for analytical engines regarding IoT endpoints and enable vertical market solutions.

Hardware:

GPS chips, RFID sensors, actuators, and embedded and external hardware devices capture location and status information.

Network:

Network access, satellite, and transport infrastructure vendors provide the network connectivity that underlies IoT solutions.

Analytics Solutions:

Business intelligence and analytical software solutions such as data mining and predictive analytics, video image analysis, pattern recognition, and artificial intelligence algorithms determine whether to act on or ignore a pattern.

III. THINGS IN IoT

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. [Internet of Things – Strategic Research Roadmap 2009]

Things are commonly identified either by assigned identification numbers, names and/or location addresses. In the future, ‘things’ as boring as household appliances could be networked to the Internet. Hypothetically speaking, a fridge could be aware of what is stored inside and order another litre of milk when it runs out or even make people aware that it is close to its expiry date. 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. The Internet of Things allows people and things to be connected anytime, anyplace, with anything and anyone, ideally using any path/network and any service. This implies addressing elements such as convergence, content, collections (repositories), computing, communication, and connectivity in the context where there is seamless interconnection between people and things and/or between things and things. The applications are endless. It's an exciting time for anyone involved with RFID and its associated technologies. The international move towards the development of an "Internet of Things" continues to raise the profile of RFID as a technology with enormous potential to revolutionise global markets, bringing both economic and societal benefits.

IV. DIFFERENT VIEWS AND CONCEPTS ON IoT DEFINITIONS

The term Internet of Things is not well defined and has been used and misused as a buzzword in scientific research as well as marketing and sales strategies. Until today it remains difficult to come up with a clear definition of the Internet of Things. Followings are some popular definitions.

(i) According to Cluster of European Research Projects on the Internet of Things (CERP-IoT 2009): “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.”

(ii) The Internet of Things is a concept in which the virtual world of information technology integrates seamlessly with the real world of things. The real world becomes more accessible through computers and networked devices in business as well as everyday scenarios. With access to fine-grained information, management can start to move freely from macro to micro levels and will be able to measure, plan and act accordingly. However, the Internet of Things is more than a business tool for managing business processes more efficiently and more effectively – it will also enable a more convenient way of life.

(iii) CASAGRAS project coordinator Ian G Smith said. The Internet of Things is “A world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes. Services are available to interact with these ‘smart objects’ over the Internet, query and change their state and any information associated with them, taking into account security and privacy issues.”

(iv) Another approach towards a definition of the Internet of Things can be derived from logistics where it is common to ask for the *right product* in the *right quantity* at the *right time* at the *right place* in the *right condition* and at the *right price*. In this analogy the *right product* relates to accurate and appropriate information about a uniquely identifiable physical object as well as its form, fit and function. This includes the usage of Auto-ID and appropriate sensor information or any other kind of linked information to the object that can be accessed through the Internet of Things. The *right quantity* can be achieved through high granularity of information combined with filtering and intelligent processing. The *right time* does not necessarily mean anytime, but more precisely ‘when needed’. It may be sufficient

to receive information about an object only once a day or only in the case of a status change. Consequently, right-time does not equal real-time, a term that is mentioned quite often in relation to the Internet of Things.

(v) The future Internet of Things links uniquely identifiable things to their virtual representations in the Internet containing or linking to additional information on their identity, status, location or any other business, social or privately relevant information at a financial or non-financial pay-off that exceeds the efforts of information provisioning and offers information access to non-predefined participants. The provided accurate and appropriate information may be accessed in the right quantity and condition, at the right time and place at the right price.

(vi) While there's been no single standard definition of IoT solutions since the possibilities of Internet of Things was first discussed, a variety of technologies are used in implementation (e.g., RFID tags, barcodes, and GPS technologies). These technologies are used to monitor and transfer the status of physical assets to remediate business problems like supply chain inefficiencies in industries such as manufacturing, healthcare, transportation, and retail, as well as to inspire innovation in organizations. For example, information embedded in RFID-tagged containers is collected by readers along the supply chain at the supplier's shipping department, throughout the transportation process, and during storage, collection, and installation along the assembly line. The availability of accurate, current data about supply chain events enables firms to deliver superior customer service while reducing inventory held as a buffer against uncertainty. Other IoT applications include food traceability, patient monitoring, and medical device and medicine tracking. A variety of forces are aligning to drive increased enterprise demand for IoT solutions, including declining device costs, widely deployed wireline and wireless IP networks, and regulatory mandates.

In the year 2012, various survey were conducted in Europe to understand: i) how well the term "Internet of Things" resonates with global enterprises; ii) what timelines corporations have for implementing IoT applications and solutions; iii) the benefits and challenges associated with IoT solution deployment; iv) and which third-party partners companies seek assistance from as they deploy IoT solutions. The study methodology included an online survey of hundreds of global enterprise IT decision-makers in specific industries including manufacturing; healthcare; oil, gas, and petroleum; retail and hospitality; transportation and logistics; and government. These decision-makers participated in or were aware of their corporate initiatives related to IoT solutions and applications.

Key results from this online study include:

- *Enterprise decision-makers have a positive perception of IoT solutions.* 64% of survey respondents were familiar with the term "Internet of Things." More than 70% of the respondents who were familiar with the term have a positive perception of it. In addition, 85% of the respondents who were familiar with the term strongly or completely agree with the following definition of "Internet of Things solutions".

"Smart interconnected devices that businesses use to get more visibility into the identification, location, and condition of products, assets, transactions, or people to drive more effective

and timely business decisions or to improve customer interactions."

- *Barcodes and RFID devices are valuable components of IoT solution implementations.* Firms consider many different devices valuable to implementing IoT solutions. Specifically, 72% of enterprises state that barcodes are valuable to enable IoT solutions; 71% say the same thing about real-time location tracking technologies like active RFID and 58% of firms consider passive RFID devices as valuable IoT solution technologies.

- *Many firms are planning to deploy IoT solutions and applications in the future.* Companies are in the early stages of deploying IoT solutions, as only 15% of surveyed enterprises already have an IoT solution in place. However, future momentum for these solutions appears strong: 53% of surveyed enterprises are planning to implement IoT solutions within the next 24 months.

V. ANALYSIS OF DEFINITIONS

While these definitions list the possible technical components of the Internet of Things, they still have some major shortcomings. *Firstly*, they list components that have been mentioned before in relation to other visions such as pervasive or ubiquitous computing and therefore it is difficult to distinguish IOT from these concepts. *Secondly*, it misses wider consideration of current developments and user interactions in the Internet commonly referred to as Web 2.0/Web 4.0. Similar to the relationship between the World Wide Web (WWW) and the Internet, the addition of Web x.0 functionality may be seen as a user-centric extension to the Internet of Things rather than an integral part of it. However, whereas the development of the Internet began more than thirty years before the realisation of the WWW in the early 1990s, the Internet of Things is already being influenced by Web 2.0 functionality right from the beginning. Both technology developments have been happening in parallel rather than consecutively. *Thirdly*, they do not provide a reason why or how the Internet of Things will be a self-sustainable and successful concept for the future. Self-sustainability encompasses viability, including a dynamic global network infrastructure with self-configuring capabilities based on standards and interoperable communication protocols as well as openness for future extensions, ideas, and technologies. Economic success may never have been a part of a definition for the Internet or other technical network infrastructures. Nevertheless, we consider it a valid consideration within a holistic definition approach as economic success and adoption is just as important as technical sustainability in a forward-looking statement.

For the purposes of differentiation it may be best to consider what the Internet of Things is not – or at least not exclusively. A corresponding blog discussion has been started by Tomas Sánchez López (Sánchez López 2010). He considers that the Internet of Things is not only:

- *ubiquitous / pervasive computing*, which does not imply the usage of objects nor does it require a global Internet infrastructure
- the *Internet Protocol (IP)*, as many objects in the Internet of Things will not be able to run an Internet Protocol

- a *communication technology*, as this represents only a partial functional requirement in the Internet of Things similar to the role of communication technology in the Internet
- an *embedded device*, as RFID tags or Wireless Sensor Networks (WSN) may be part of the Internet of Things, but stand-alone they miss the back-end information infrastructures and in the case of WSN the standards to relate to ‘things’
- the *application*, just as Google or Facebook could not be used in the early 90’s to describe the possibilities offered by Internet or WWW

[13] D. Uckelmann et al. (eds.), *Architecting the Internet of Things*, 1 DOI 10.1007/978-3-642-19157-2_1, © Springer-Verlag Berlin Heidelberg 2011

With these negations in mind it is easier to differentiate the Internet of Things. However, all fields of research that has been mentioned above overlap partially with IoT.

VI. CONCLUSION AND OUTLOOK

Internet of things can help to improve citizens’ quality of life, delivering new and better jobs for workers, business opportunities and growth for the industry. The Internet of Things will make it possible for objects to get information about their position in the world, to interact with other objects and to have access to comparative information for data gathered in their vicinity. Future developments in the Internet of Things will optimise the information flow in industrial and social scenarios and revolutionise business and private communication. Thanks to the recent advances of miniaturisation and the falling costs for RFID, sensor networks, NFC, wireless communication, technologies and applications, the Internet of Things suddenly became relevant for industry and end-users. Detection of the physical status of things through sensors, together with collection and processing of detailed data, allows immediate response to changes in the real world. This fully interactive and responsive network yields immense potential for citizens, consumers and business.

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