Defining Internet of Things: A Survey

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Abstract

The Internet of Things (IoT) is a paradigm where a network of physical objects and infrastructure interact with each other, often autonomously. IoT connects people and things seamlessly forming a symbiotic relationship. In pervasive presence of IoT, services are provided as commodity. Since its inception, developments in Internet and Things in particular, added values to IoT and causing evolution. This evolution has forced us to reform the definition of IoT from time to time. This work is an attempt made to cognize relevant but varied definitions of IoT.

Keywords: *Internet of Things, IoT, Things, RFID, Ubiquitous Computing, Pervasive Computing*

1. Introduction

Kevin Ashton, in 1999, during his tenure with AutoId Center of Massachusetts Institute of Technology, used a term "Internet of Things" while presenting the idea of linking RFID in Procter & Gamble's supply chain to Internet. [1]. This term created ripples giving a life to new vision. The idea of connecting RFID to Internet to track the movement of goods is now transformed into a paradigm covering all areas of everyday life of individual, enterprises and society as a whole, making it more and more pervasive. Such pervasiveness requires the integration of various domains into single unified domain.

The IoT is not a single technology. Various information and communication technologies are converging together to fulfill the vision of IoT giving the potential to provide unlimited benefits and services to our society and is expected to create its own value. As services grow more widespread, IoT is evolving as a promising technology and creating high impact on several aspects of day to day life and behavior of potential users [2]. IoT has become a global network and service infrastructure. The applications of IoT are numerous and diverse. The implications of the technologies and their combination used in IoT are so profound that, IoT forms a base of fourth industrial revolution (Industry 4.0).

CERP IOT, in their 2014 report, mentioned the goal of IoT. Accordingly, the goal is to enable things to be connected anytime, anyplace, with anything and anyone ideally using any path / network and any service [3]. Several industrial, standardization and research bodies all over the world are involved in the development of IoT to achieve this goal. In this paper, attempt is made to gather various aspects that are considered during development of IoT. We have tried to gather varied IoT definitions and maintain the chronology so as to understand the evolution also.

2. IoT Evolution and Definition

In IoT, several numbers of things, that can be identified using technologies like wireless, forms a very dynamic network. These things can communicate with each other. Such network of heterogeneous devices, fuses the physical world with digital world to provide different services. To provide such services, different concepts and technical

components integrated together. Various applications, from diverse areas, are getting integrated into a single ecosystem with a shared user interface.

The phrase, "Internet of Things" is made up of two terms – Internet and Things. Development on the first term "Internet", which has its origin in ARPANET project, was started in 1969. The aim was to interconnect computers of U. S. Defense Department. Nowadays, Internet is not only a network of computers, but has evolved into a network of devices of all types and sizes, vehicles, smart phones, home appliances, toys, cameras, medical instruments, industrial systems (commonly referred as "Things") all connected and communicating, sharing information all the time. Today's Internet has become a global infrastructure [3].

"Things", the second term, can be as a real / physical or digital / virtual entity. Such objects exist and move in space and time. They are capable of being indentified [4]. Gubbi [4] observes that, as technology evolves, definition of "Things" also keeps on evolving. Depending on the domain in which things will be used, decides its perception and "Things" can be realized in a different way. Initially, only RFID, sensors, actuators, objects having intelligence were considered as "Things". But today's technology has made it possible to connect people, data, processes and things making it "Internet of Everything" (IoE). Incorporating nano-sensors in diverse objects through the nano networks forms an "Internet of Nano Things" (IoNE) [5].

Properties of IoT like interconnectivity, things related services, device heterogeneity, dynamic changes in state of devices, massive scale of interconnected devices have influenced technologies that enable things to acquire and process information and improve security, privacy (enabling technologies of IoT) [3]. These properties and enabling technologies have played influential role while defining of IoT.

There are several definitions of IoT derived from different perspectives. These definitions cover basic components of IoT – "Internet" and "Things". The development of Internet is also responsible to the evolution of IoT.

It all started from discovery of Radar by a Scottish physicist Sir Robert Alexander Watson-Watt in 1935. Radar works on principal of Radio Frequency Identification (RFID). Its use in detecting enemy planes in World War II, triggered the idea of using RFID Tags to identify the objects. Advances continued through 1950s, 1960s. Eventually first RFID Tag was patented in 1973 [6].

Mark Weiser who was working at Xerox Palo Alto Research Center (PARC), put forth the idea of Ubiquitous Computing (ubicomp). In ubicomp, profound technologies weave themselves into fabric of everyday life until they are indistinguishable from it, thus making technology disappear. According to him, in smart environment, the physical world is invisibly interwoven with sensors, actuators, displays, and computational elements and connected through a continuous network and embedded seamlessly in the everyday objects of our lives. Researchers at Xerox tried to create human-to-human interface using technology in the late 1980s resulted in ubiquities computing. This was one of the first successful attempts to connect objects to Internet [7].

Since its discovery RFID has gone through various developments. Use of RFID tags was very common. In 1999, The Auto-ID Center was established at the Massachusetts Institute of Technology (MIT) to find and indentify a broad class of technologies required to automate, reduce errors, and increase efficiency in industrial environment. Technologies like smart cards, bar codes, various sensors, voice recognition tools, and biometrics were included. In the same year, The Auto-ID Center received funding from Uniform Code Council, EAN International, Procter & Gamble and Gillette. Two eminent professors at Auto-ID Center, David Brock and Sanjay Sarma, were busy in research work of RFID. Their main interest was to track all supply chain products using RFID technologies, for e.g. like low-cost RFID

tags with a serial number. The serial number would hold a data related to item. This data then would be stored in a database and Internet would be used to access such data. This research by Sarma and Brock changed the thinking about using RFID in the supply chain [8].

In the same year, one of the members of Auto-ID Center of MIT, Kevin Ashton, coined the term "Internet of Things" to refer to a network where RFID tags connected to Internet. In 2003, members of Auto-ID Center of MIT developed Electronic Product Code (EPC) to provide an universal identifiers for any specific item. The aim was to support the spread use of RFID in worldwide modern trading networks and to create industry driven global standards [8].

RFID was most sought after technology used to connect and identify an object connected to Internet. IoT was not defined formally. Technological advances made it possible to provide "always on" services that provided relevant content and information to users, wherever they may be located [6]. In 2003-2004, the emergence of projects such as Cooltown, Internet 0, and the Disappearing Computer initiative started serving the IoT idea. IoT started to appear in book titles for the first time. US Department of Defense deployed RFID on a massive scale.

In 2005, IoT achieve a new level when International Telecommunication Union (ITU) published a report on Internet of Things. ITU suggested to connect the objects all over the world, in both – sensory and intelligent manner. Depending on which technology will be used, ITU classified things as, *"tagging things"* where identification technology will be used, *"feeling things"* where sensors and wireless sensor network will be used, *'thinking things"* where embedded systems will be used and *"shrinking things"* where nanotechnology will be used [9].

In 2008, The IPSO Alliance, an alliance of 53 companies as Bosch, Cisco, Intel, Ericsson, SAP, started promoting the use of Internet protocol (IP) in network of smart objects [9].

In year 2009, Cluster of European Research Project (CERP) envision IoT as a paradigm that will bind physical and digital world by bringing together different concepts and technical components of pervasive computing, ubiquitous computing and ambient intelligence. As per the ITU and Internet of Things – European Research Cluster (IERC) IoT can be defined as :

"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". [3]

Coordination and Support Action for Global RFID-related Activities and Standardization, (CASAGRAS) an 18-month E.U.-funded project was carried out by an international group of companies and organizations working on RFID and other standards. In 2009 they published a report regarding Internet of Things saying that IoT should not be developed exclusively around radio frequency identification, but other automatic identification and data capture technologies must also be used, and new sensor and communication technologies and networks must also be incorporated. According to CASAGRAS IoT is a:

"*A global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object identification, sensor, connection capability as the basis for the development of independent cooperative services and applications. These will be characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability".* [10]

During tracking the evolution of Internet of Things concept across various application domains, Ibarra-Esquer J. E. et. al., noted that, definition of IoT proposed by CERP, and CASAGRA are the two most referred definitions adopted by researchers [11].

Advancement in sensor technologies and improvement in device capabilities made it possible to execute business logic at the edges of network. This helped in making business processes decentralize and benefitted in performance, scalability and local decision, making. Considering these improvements, as mentioned in [12], CERP further extended idea of IoT by including 6 As and 6 Cs to allow:

*"people and things to be connected **A**nytime, **A**nyplace, with **A**nything and **A**nyone, ideally using **A**ny path / network and **A**ny service implying addressing elements as **C**onvergence, **C**ontent, **C**ollections (Repositories), **C**omputing, **C**ommunication and **C**onnectivity" so that people and things will be seamlessly interconnected and will have symbiotic relationship".* [12].

IEEE observed the diversity of research on IoT, and fuzziness caused by its definition. To address these issues, and for the better understanding of the subject, IEEE IoT Initiative published a report on its web portal in 2015. This report included an all-inclusive definition of IoT. Depending on size and complexity of systems, IEEE IoT Initiative, proposed two distinct definitions, one for small localized systems and other for a large global system.

As proposed in [8], in small environment system, where "things" can be identified uniquely and be connected to Internet, complexity will be low. In such scenario, proposed definition of IoT is:

"*IoT is a network that connects uniquely identifiable "Thing" to the Internet. The "things" have sensing / actuation and potential programmabilities. Through the exploitation of unique identification and sensing, information about the "thing" can be collected and the state of the "thing" can be changed from anywhere, anytime, by anything"* [8].

In large environment scenario, complex services need to be delivered. System needs to support execution of complex processes. This achieve this functionality, huge number of things needs to interconnected, thereby increasing system complexity. As specified in [8], IoT, cab be defined as:

"Internet of Things envisions a self-configuring, adaptive, complex network that interconnects 'things' to the Internet through the use of standard communication protocols. The interconnected things have physical or virtual representation in the digital world, sensing/actuation capability, a programmability feature and are uniquely identifiable. The representation contains information including the thing's identity, status, location or any other business, social or privately relevant information. The things offer services, with or without human intervention, through the exploitation of unique identification, data capture and communication, and actuation capability. The service is exploited through the use of intelligent interfaces and is made available anywhere, anytime, and for anything taking security into consideration." [8]

In their research on study of IoT on various trends and future directions from the social science perspective [13], Lee et. al. divided several definitions suggested in variety of fields into four categories.

i) IoT as Intelligent objects: Things have intelligence are most prominent feature of IoT. These things have their own identities and thinking making them smart objects. These concepts are related to "Ambient Intelligence", where technology identifies and performs necessary tasks without human instructions.

ii) IoT as an extension of Internet: IoT is understood as an evolution of a Web. This IoT provides Web based environment for networked devices. The Web includes real world objects, each embedded with sensors, and are connected to Internet.

iii) IoT as a global network infrastructure: The further extension of Internet becomes global infrastructure, where physical world ultimately integrated into virtual world providing a "Pervasive Computing" environment, synonymous to "Ubiquitous Computing". At the core of which, lies the ideology that vanishes technologies in the background making them indistinguishable, disappear from user, weaving IoT into everyday life activities.

iv) IoT as an interaction of information: IoT can viewed as connection of "things information" or "product information", rather than only connection of things themselves. Thus IoT can be seen as "Semantic Web" with regards to both, the semantic meaning and its practical properties.

All definitions of IoT are trying to address central issues as interoperability of interconnected devices, higher degree of smartness of devices enabling their adaption and autonomous behavior, and at the same time guaranteeing trust, privacy, and security [4].

IoT has been defined in various ways. Most of the definitions proposed by various institutions, researchers tried to cover all aspects of "Internet" and "Things" as desired in "Internet of Things" paradigm and its expansion into Internet of Everything (IoE), leading to Internet of Anything (IoA or Io<*>).

Lack of common or unified definition of IoT can be observed. The technology itself is on a maturing stage or it is interpreted according to specific needs, interests, or technical bias. The meaning of the term continuously evolves because technology and the ideas behind it change themselves over time [11].

Today, technology is progressing at exponential rate. This trend may remain same in future also. We are witnessing the evolution of Internet of Things (IoT) from merely connecting RFID tags in the field of supply chain management with Internet, to a more comprehensive paradigm where various technologies are conversing for extending the reach of Internet encompassing every object across the globe. IoT has made it possible to provide services as commodity.

3. Conclusion

In IoT, "Things" from very diverse areas, smart objects, devices, product, processes, and living beings etc. are getting involved. Using computation and communication capabilities of such things, IoT is used to provide application services in different domains. Sometimes services are provided in single domain, or a set of domains or across various domains. Various groups, scientific communities, industries, government agencies etc. are involved in process of defining IoT and proposing various definitions.

We conclude that, presently varied definitions of IoT proposed by various groups, describes IoT rather than defining IoT. At the same time enabling technologies of IoT are constantly under development. These rapid changes are churning the complete scenario and making IoT more dynamic. This dynamic nature of IoT is creating fuzziness. Moreover, IoT also is being defined and used according to the phrase - beauty lies in the eyes of beholder - everybody has a different view and opinion about IoT. These factors keep IoT evolving and are compelling the reformation of IoT definition.

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