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'Things' in the Internet of Things: Towards a Definition

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Abstract This work is an attempt to provide a definition of the word 'Things' in the context of the Internet of Things (IoT). It does this partly by reviewing the existing descriptions of, and variations to, the IoT phrase as well as the alternative terms that have so far been used to replace the word 'Things' in the phrase. This review was done to draw from these different terms and descriptions a sense of the wide breadth of the examples of ways that 'Things' in the IoT can manifest. An attempt is made to relate all the relevant but varied definitions and descriptions in order to draw up a definitive definition which can serve as a reference for stakeholders who are keen to understand the IoT concept as it exists presently as well as in the future.

Keywords Internet of Things, Things, Definition

1. Introduction

Ever since the phrase 'Internet of Things (IoT)' was coined in 1999 [1], it has been attributed a variety of descriptions; it has been described as a network [2], a paradigm [3, 4], a concept [5], an Internet application [6] and a global network infrastructure [7], to mention a few. In addition, the word 'Things' in the IoT phrase has been replaced with several alternative terms giving rise to several 'Internets of α' including the Internet of Everything (IoE) [8, 9], Internet of Anything [10], Internet of People [11, 12], and the Internet of Signs [13, 14] among other examples.

The first word in the IoT phrase, 'Internet', has already been researched extensively and various widely-accepted definitions and descriptions of the Internet have been put forward. In general terms, the Internet describes an inter-network, spread over a wide geographical area (essentially and increasingly, the entire globe). This inter-network is enabled and managed by any of a number of well-known protocols, connectors and devices including http, https, routers, switches, computers, Ethernet and fibre cabling, Wi-Fi technology, Bluetooth, Personal Computers, smart phones, and tablets.

The second word, 'of', is a preposition that connects the first and third words of the phrase together. The Oxford dictionary defines it as "*indicating an association between two entities, typically one of belonging, in which the first is the head of the phrase and the second is something associated with it*". This makes it evident that the IoT is *an* internet which is composed of *things*. (This internet, it must be noted, is not necessarily limited to the Internet previously described).

Next is the word *Things* and deriving a unified description for this word forms the bulk of the discussion in this paper. Gubbi explains that "the definition of 'Things' has changed as technology evolved" [2]. Stakeholders within the IoT context have created - or are creating - their own understanding of what 'Things' are and what the word can represent. What this paper proposes is a definition of 'Things' so that anyone approaching the subject of the IoT can quickly grasp what it means and what it can mean for various stakeholders going forward. The aim of defining 'Things' in this paper is not to restrict the concept of the IoT to mean the interconnection of only a select type of media. Realistically, promoting such a restrictive view is, hopefully, no longer even possible especially when one takes into consideration the proliferation of projects that are experimenting with interconnecting disparate technologies. The aim is instead to be as non-restrictive as possible. The unified description obtained may be a single definition or a set of characteristics or criteria. 'Things' in the IoT currently include nodes ranging from smart devices to animals [15, 16] with each introduction of a new third word an obvious effort to understand and attune the notion of the IoT to identified requirements. These interconnected nodes can be of any size from miniature to large, and the networks they form currently span areas from a single individual's personal space (in the form of Body or Personal Area Networks (BAN/PAN) [17-20]) to networks that stretch across the globe. However, knowing what distinguishes the IoT from other networks does not necessarily provide an answer to the question of what a Thing is.

In order to simplify a definition of 'Things', this paper takes the position that the IoT is the same thing as the IoE and that all other 'Internets of α' are subsets of or variations

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on the IoT. This paper refuses to apply a distinction between the IoT and the IoE because it takes the position that the phrase *Internet of Things* represents the possibility of an interconnection of *every necessary thing* possible.

Section 2 introduces some of the different Internets of Things; Section 3 provides various acronyms for the '*α'* in the 'Internets of *α'*; Section 4 introduces the definition of 'Things' in the IoT context; Section 5 concludes.

2. Previous work

The IoT is an internetwork composed of Things where 'Things' include any physical or logical object/objects or element identified as being necessary by the agents requiring the network OR as dependent and specified by the agent requiring the interconnection. This section discusses existing IoT alternative forms.

2.1. Various Internets of Things

'Things' in the IoT can be physical and logical, where logical includes virtual representations and/or outputs of physical objects (Table 1).

Table 1. Different states of 'Things'

Internet of Things	
Physical	Logical
Sensors	Services
People	Processes
Animals	Data and Databases

'Things' can also be living or non-living entities; M2M technologies, sensors, embedded technologies, nano-technology devices, RFID-tags, other sensing, communicating technology nodes or end points with either in-built/embedded intelligence (e.g. humans) or with attached intelligence all fall into the group of 'Things'. The wide range of possibilities is demonstrated by the different Io*α*'s that have been proposed some of which are discussed next.

- Internet of People/Humans: These are created when humans are the nodes at the end of the communication and computing networks. The IoP can be formed by families, hospitals, online social networks, school children, etc. One simple example of the Internet of People is the social network group formed by Facebook. Human beings are the nodes in these types of networks.
- Internet of Signs: This concept is introduced and explained in [14]. According to the authors, "the relationships between things generate signs". Their interest is therefore in the generation of knowledge or useful information from the signs created by related 'Things' e.g. from blogs and other online forums. The can be information about sentiment, behaviours, reputations and even happenings. They posit that *signs* can be generated from a wide range of 'Things' where things can include databases, including from blogs and wikis
- Internet of Animals: In this case, communication with and between animals (i.e. lower class animals, not humans) is established through the use of sensor technology. This network can be used by farmers and herders to keep track of their flock. Another potential application of the Internet of Animals was discussed by [16] where they suggest that town dwellers and others who, for some reason are not able to maintain farm animals but who have an interest in doing so will be able to maintain them remotely whilst having the actual animals being maintained physically by someone else in a sort of collective for remotely-owned animals. This Internet of Animals system can be made possible through the use of remote care and security systems.
- Internet of Relating to Things: According to Bari et al., this is a more appropriate description of the IoT. They posit that in this IoRT, 'Things' are "information about things (meta data)" [21].
- Internet of Services: According to [22] an increasing number of ICT services can be offered online through an Internet of Service. These services can be anything from selling things online through websites such as EBay or providing online courses through Massive Open Online Courses (MOOCs). They however contend that the IoS has not yet reached full-scale development and identified a number of potential barriers to the development of the "web-based service economy" including "security, reliability, extendibility, and flexibility of infrastructures, both of enterprises and the Internet".
- Internet of Everything (IoE): As posited earlier in this work, the IoE encompasses the entirety of the IoT and is thus another way of expressing the IoT. The IoE implies that the IoT *can* expand to become an Internet of Everything although this is not necessarily any kind of end goal for the IoT since the 'Things' that are being interconnected in the IoT are connected by choice and not by any stipulation that everything that exists is meant to eventually be interconnected. The IoE is a projected vision of what is possible as the IoT grows to accommodate a growing number of 'Things'.
- Internet of Processes [23]: The linkage of different processes, for instance, in an industrial context. This can be a link between the manufacturing process to the testing to the delivery and repair process. Connecting up processes in this way can make it easier to trace causes of defects in manufactured products by enabling a quicker identification of when these were introduced during the entire chain.
- Internet of Data: This was proposed by Fan et al., and they describe a network of the data entities available from the IoT. This harnessed data can then be utilized for different purposes including for data identification and data tracing. This data, they describe, can be embedded with "Virtual tags" comparable to the

physical RFID tags that physical objects that IoT devices will carry. This data can be documents, music and video [24].

- Your Internet of Everything (YIofE) [25]: In this case the suggestion is that within the IoT/IoE, individuals will end up with their own personal network of interconnected things called 'YIofE'.

2.2. Synonyms for 'Things' in the IoT phrase

This section discusses some terms that have been used to describe the 'Things' keyword in the IoT phrase.

- Spimes [26]: This is formed by a combination of the two words '*SP*'ace and t'*IME*'. This word was coined by Bruce Sterling and represent objects that can be tracked and are traceable.
- Blogjects [27]: Objects that are able to communicate their status by blogging.
- Objects [28]
- Smart things [29]/smart objects [30]/Smart devices [31]
- Atypical devices [32]: From a purely digital forensics perspective, this term is used to describe all new and unfamiliar technology that incident responders and forensic investigators may encounter during their investigations in the near future.
- IoT-ware: This is a generic term for all the above items. It simply describes any entity that is part of the IoT network. IoT-ware can be tangible and intangible and is anything and everything that can communicate and operate either autonomously (e.g. human beings), semi-autonomously or non-autonomously.

The term 'Things' can therefore be seen as a generic term which can be replaced by alternative terms depending on the stakeholders and/or scenario.

3. Thing Groupings

It has been established that 'Things' are not of a particular type. This section presents the groupings of things in the IoT.

Things as physical, tangible entities

This first group of things is the type that most often referred to when the IoT is spoken about i.e. physical, tangible elements make up the IoT. This is a major expectation of Things because they are expected to have the capability to meet the requirements of computing - i.e. to receive data, and to perform operations on the data and produce results. An example of such things is sensors that are deployed over wide areas with difficult terrains in order for them to sense environmental factors such as temperature and wind direction. These sensors can be set up to transmit the acquired data to a central sensor node or other form of receiving station for further operations and utilization. This is an essential feature of Things and so a Thing can be defined as a computing device in one sense. According to oxforddictionaries.com, a physical object is one that has an element of tangibility about it. It is as something that is perceivable "through senses as opposed to the mind". Alternatively, a physical object can be described as one that is discernible or perceptible by touch. This means that within the IoT domain, Things can be expected to have an element of physicality about them. A good example of these has already been provided earlier in this section. As a subsection of this section, Things are described as computing elements.

Things as intangible entities

This group of 'Things' includes processes, services, signs and data. Internet accessible IoT nodes have virtual representations of themselves which can be accessed remotely. The data output from interconnected physical nodes can be analysed for information in order to improve services provided by the physical nodes. Home security systems can make improvements on clients' overall home security based on the input of home owners and patterns learned by the installed security systems over a period of time.

Things as living or animate entities

The largest examples in this group are humans and animals. Plants can also be communicated with; there are already water pots which can report their status and provide gardeners with an idea of whether the plants they hold require nutrients.

Things as non-living or inanimate entities

Examples of these are smart devices.

Further characteristics of 'Things' as suggested in [14] are that 'Things' can be autonomous, semi-autonomous, or not autonomous.

4. Characteristics and Criteria for Things

According to The Free Dictionary (http://www.thefreedictionary.com) a definition is the "specification of the essential properties of something, or of the criteria which uniquely identify it". For the purpose of this work, it has been deemed necessary to consider and discuss a set of non-binding, preliminary (and not necessarily comprehensive) criteria as a basis for identifying what a 'Thing' is. Definitions play an important role in language allowing us to communicate fact and information with the same or at least similar meanings and implications in mind. It is essential to have a definition of the word or the concept of a 'Thing' because it will give stakeholders within the IoT domain the ability to discern and manage 'Things' according to what they are and not just as ordinary everyday items. IoT-enabled things, smart objects, IoT-ware, whatever they are called, should be seen as having properties that differentiate them from non-IoT items. For instance, a smart driverless car should be discernible from a non-smart car and owners of smart cars should be aware that the laws that apply to owners of non-smart cars also apply to them with, possibly,

additional laws. This awareness will be especially useful in situations where disputes arise in relation to the independent decisions taken by smart things e.g. driverless cars caught driving above stated legal speed limits.

Huang et al. describe 'Things' as the non-tangible aspect, the actual information held and made available by the physical objects. They explain that "the real meaning of the word 'Things' in IoT is the information about things" [6]. Conversely, [10] present the following as one of the tenets of the IoT: "Things should be physical…software shouldn't be considered a *thing*". This work takes a contrary position to these two arguments. Based on the explanation in [14], 'Things' can be, essentially, *any*thing, tangible or intangible. Also, according to the Oxford Dictionaries (http://www.oxforddictionaries.com/definition/english/thing) the word t*hing* is defined as "an object that one need not, cannot, or does not wish to give a specific name to". This work agrees with these viewpoints and argues that it is best that the exact and precise nature of a 'Thing' be allowed to be as broadly-defined and non-restricted as possible thus allowing for a greater chance for research development and thus greater potential for hitherto un-envisioned benefits.

The dictionary definition of the word 'Thing' above implies that for the IoT concept to be re-defined to meet its actual purpose, it is the Internet of *any*-thing that is relevant to the agent in question, with all restrictions set aside.

For anything to be classed as a 'Thing' in the IoT sense of the word, the following criteria are suggested:

- It serves a purpose;
- It can be interconnected though it might not always be. All 'Things' possess the facility for interconnection either using technology (e.g. 802.11 or Ethernet connectivity) or via a natural method e.g. verbal or physical human communication;
- It either has form or is a set of structures for applying something that has form;
- Traceable physically or via a defined mechanism e.g. by sight or GPS location tags;
- It can be communicated with or it can communicate or both;
- It can be interfaced or communicated with
- It can have a physical or logical form;
- It can be living or non-living;
- It can be identified;
- It has capacity for autonomous operation;
- It is tangible or intangible;
- It can be naturally autonomous (e.g. humans), enabled to be autonomous or even non-autonomous.

5. Conclusions

This work investigated the term 'Thing' in the IoT phrase. The aim was to identify the key characteristics of 'Things' within the IoT discourse and to provide a framework or definition for the term 'Thing'. The derived definition was drawn up after a detailed investigation of existing acronyms and descriptions of the IoT as well as 'Things' in the IoT. However, it must be pointed out that whilst it is useful for terms to be defined for clarity and information purposes, the term 'Thing' in the IoT phrase does not lend itself to an easy definition. It encompasses a host of other terms, processes and functions as was evidenced by the different Io*α* examples presented in this work. Therefore, the definition provided in this paper is only meant to serve as a guide to using the term and not as an absolute definition of what the term actually means. The description proposed in this work can be built upon as part of future research and development towards giving the term an even clearer meaning. In the meantime, its definition as '*anything at all, depending on requirements'* suffices.

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