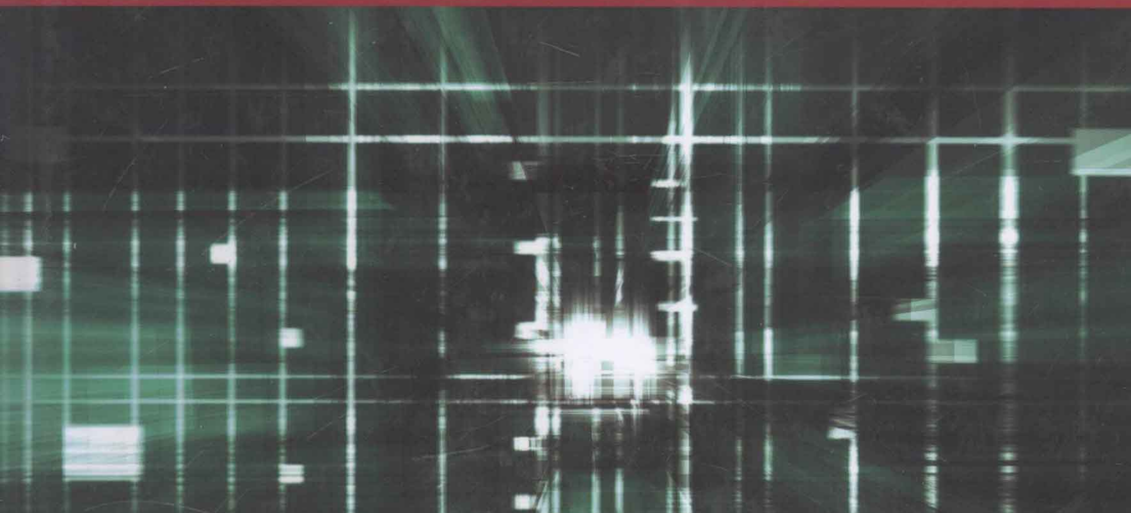
The Internet of Things

Connecting Objects to the Web

Edited by
Hakima Chaouchi



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Preface

Services designed over the Internet evolved depending on the needs identified from person-to-person interaction, such as email or phone services to meet other interactions, such as person-to-machine, machine-to-person and, lately, machine-to-machine where no human interaction is needed; thus building ubiquitous and pervasive computing. Such a computing system started a long time ago with the ambition of offering all-pervading computing to automate tasks and build a smart world. Introducing radio-frequency identification (RFID) technology in building new services over the network has pushed what is called the "Internet of Things" (IoT) as a meeting point between the real world and the virtual world, especially when combined with other technologies, such as sensor technology or mobile communication.

IoT appears to be one step further on the path to ubiquitous computing. This is possible with the introduction of RFID or sensor technologies, but also other technologies such as robotics, nanotechnology and others. These technologies make the Internet of things services an interdisciplinary field where most of the human senses are somehow reproduced and replaced in the virtual world.

So, what is meant by the Internet of things? From the economical point of view, it is about designing new services and generating new revenue streams in the communication value chain. This is not straightforward however, as lots of technical issues have been raised that need to be solved before an effective deployment of the new envisioned services. From the technical point of view, it is about connecting new devices, called objects or things, and investigating the issues related to connecting these objects with the network in order to develop exploitable applications. To tackle these issues, it is important to understand what the Internet and things mean in the IoT, knowing that, depending on the research community, the meaning and the related issues might be different.

A thing or an object in the IoT is described as any item from our daily life that is enhanced with some computing and/or communication capabilities. For instance, items or objects with RFID or sensor technologies will become connected objects. These objects, depending on the application, might range from a size as small as an atom or as large as a building; they might be fixed or mobile, such as a car; they might be inanimate or animate, such as animals or humans. These objects joining an IoT service will have an electronic identification, such as an RFID. Objects or things are also new electronic devices interacting with the real-world environment, such as sensors.

Conventional communicating devices, such as laptops, computers and phones might be considered to be objects. In our book, we exclude these classical devices from the object list since they do not directly enable interaction with the real-world environment. Other objects, such as consumer electronic products like a TV or a fridge have already been introduced in the communication chain via other technologies, such as power line communication technology. IoT will clearly have to allow the connectivity of a large number and different types of objects. This means that it has to face the heterogenity and scalability of the communication framework in order to build the envisioned applications. These applications will orchestrate the real environment-related new functionalities of identifying, locating, sensing and acting, thus building the task automation and environmental task monitoring expected by the IoT.

Currently RFID technology and sensor technology are promising, very close-to-market applications, since they offer the new functionalities of identifying and sensing, respectively. Sensor technology and sensor networks for phenomenon monitoring have interested the telecommunication research community earlier than RFID technology, which evolved in the retail product chain for product tracking and only recently joined the telecommunication value chain. Some recent examples show the development of RFID-based systems to help vision-impaired people to be guided on buses and enhance museum visits with smart phones and RFID. Combining RFID, sensor, and mobile communications appears to be very promising and will enable more applications to contribute in building the IoT. Although already used, these technologies need to be improved from security, privacy, performance and scalability points of view.

On the other hand, the Internet in the IoT might also have different interpretations. The obvious interpretation, which is more direct, refers to the current Internet adapted to these new objects' connectivity needs. Current Internet is that of connected nodes using a TCP/IP (the internet protocol suite) protocol stack with IP addressing and routing capabilities. Usually, the Internet model runs a TCP/IP stack in the connected device or offers the possibility of designing corresponding gateways to specific nodes or networks.

Connecting objects to the current Internet involves adapting the TCP/IP stack to the resources of the objects. This is what is proposed by the Internet Engineering Task Force with the 6LoWPLAN protocol stack for sensor networks. It also means designing gateways connecting the objects to the Internet, as might be done with connecting RFID objects to the Internet via gateways.

Another view of the IoT involves designing a new communication model, different from TCP/IP. This would be a new Internet, also called future Internet, where it is possible to adapt the communication model to the context, traffic constraints, resource limitations and so on. Note that designing the network of the future (or future Internet) is one of the major research goals of the current networking research community, where better network adaptation than the current Internet is expected.

In the long run, the IoT appears to be one of the leading paths to this goal since it challenges the current Internet model with new needs of object connectivity: such as identification, naming and addressing, scalability, heterogenity, resource limitation, new traffic modeling, etc.

While waiting for the future Internet, the current Internet operators show a great interest in the concretization of unlimited IoT services. They are welcoming any new and attractive internet services generating new traffic to be transported by the Internet or all-IP network that already offers one network model for multiservice support, such as voice, data and multimedia services.

Designing services involving real-world things' and objects' interaction and communication through the Internet is therefore highly encouraged under the condition of solving all the related issues of security and privacy and of connecting billions of objects to the Internet directly or through gateways. These gateways can be simple or intelligent gateways, capable of interpreting the traffic needs at the entrance of the network.

The current objects' resources such as memory, processing and battery in tiny objects are very limited and cannot run the current Internet communication model which means that these objects will use an adapted version of the Internet model, a proprietary communication system that will be seen as a heterogenous one from the Internet, and thus needs a gateway to benefit from the forwarding of traffic.

Of course, the traffic that will be generated by these object-based applications will have different expectations from the network. In fact, until now voice was considered the most difficult object to transport since it was used over a circuit-switched forwarding system designed to match its expectation. Now the traffic generated by these specific IoT applications will have to be modeled and need to be satisfied, probably partially by the current Internet and totally by the future Internet. For instance, if an "*actuate*" is ordered remotely via the network, the traffic priority should match the emergency of this action. Also the packet size should be adapted to this new type of information. Similarly to the voice application, with the IoT-generated traffic, the packet design and priority of the packets will have to be specified to match the traffic requirement.

It is clear that plenty of technical, research, economic and societal issues are correlated with the IoT. In this book *The Internet of Things*, we have tried to bring together the up-to-date knowledge associated with what a connected object means, what Internet means in the IoT, and what the technical challenges (see Chapter 1) are with a more network-related view.

The book, also describes what the enabling technologies of the IoT are; the closest to the market are described in detail. These are mainly RFID (Chapter 2) for identifying and tracking the objects, and sensors (Chapter 3) for sensing the environment and actuating. Both RFID and sensor technologies use wireless connectivity.

This book additionally describes power line communication technology (Chapter 4) used for home networking. This applies the idea of building smart homes by connecting smart objects at home, such as a fridge and TV. This idea emerged before we started to use the IoT terminology, which was pushed more with RFID-connecting objects. Services developed in home networking are also part of the IoT services, but do not have the same connectivity issues as RFID or sensors, which are tiny devices with limited resources, mainly battery power.

This book, discusses the applications and research issues related to RFID (Chapter 5). It also proposes to look at other RFID technology usage in improving some network-related functionalities, such as location and mobility (Chapter 6). Finally, setting the standards and the governance of the IoT is discussed in Chapters 7 and 8.

We are not ignoring other issues related to the IoT, such as the need for high-performance computing to face scalability, the need for even faster processing and the limits of component physics in increasing the speed of processors, to face the expected billion connected objects generating traffic in the network. Moreover, research disciplines will have to work and interact with the networking community to build ubiquitous computing and design the IoT services and networking.

Hakima CHAOUCHI

April 2010

Table of Contents

Chapter 1

Introduction to the Internet of Things

1.1. Introduction

The Internet of Things (IoT) is somehow a leading path to a smart world with ubiquitous computing and networking. It aims to make different tasks easier for users and provide other tasks, such as easy monitoring of different phenomena surrounding us. With ubiquitous computing, computing will be embedded everywhere and programmed to act automatically with no manual triggering; it will be omnipresent.

In the IoT, environmental and daily life items, also named "things", "objects", or "machines" are enhanced with computing and communication technology and join the communication framework. In this framework, wireless and wired technologies already provide the communication capabilities and interactions, meeting a variety of services based on person-to-person, person-to-machine, machine-to-person, machine-to-machine interactions and so on. These connected machines or objects/things will be new Internet or network users and will generate data traffic in the current or emerging Internet.

Chapter written by Hakima CHAOUCHI.

Connecting objects might be wireless, as with the radio frequency identification (RFID), or sensor radio technologies that offers, respectively, identification of items and sensing of the environment. Connection may be wired, as with power line communication (PLC). PLC offers data transport over electrical media and has pioneered the in-home networking connectivity of electronic consumer devices that we also name "objects" such as smart fridges, smart TVs, smart heaters, etc.

IoT-based services will provide more automation of various tasks around people and connected objects in order to build a smart world not only in manufacturing industries but also in the office, at home and everywhere. Most of these services will also rely on the easy location and tracking of connected objects. Other services – object-to-object-oriented services – will emerge for instance in the context of the green planet goal. This is where specific applications will monitor the environment and automatically react, for example, to minimize energy wastage or avoid natural disasters.

In the IoT, identifying, sensing and automatically deciding and actuating will be the main new functionalities that will enable ubiquitous computing and networking. Therefore, sensor and RFID, among other technologies, will be increasingly deployed and will thus allow integration of the real world environment in the networked services. In fact, billions of RFID tags and sensors are expected to connect billions of items/objects/things to the network in the coming years. Scalable identification, naming and addressing space and structure, scalable name resolution, scalable and secure data transfer are all of major concern. Other enabling technologies for this real-world networked service include nanotechnology, automatic processing and robotics, and probably newly-emerging technologies enabling the envisioned smart world to become real.

IoT will connect heterogenous devices and will be very dense, connecting billions of objects. An Internet-, IP- (Internet protocol) or TCP/IP (transport control protocol/Internet protocol) -based model stands at the centre of the IoT. It is one possible INTERNETworking solution to hide the ever-increasing heterogenity of networking technologies and communication systems in the ubiquitous environment envisioned. IP might not, however, support the resource limitation and scalability of the network.

IP or the Internet will certainly support the close-to-market IoT applications, but IoT research development will hopefully also come with a new INTERNETworking communication model and architecture. These will better support the new requirement of the heterogenity of objects, scalability (of billions of objects expected), limited resources of connecting objects and requirements related to new services and applications to be designed over this connected real world. It falls exactly under the post-IP or future Internet era [EUR 08, GEN 10, FIN 10], where several research projects are building a new communication model and architecture that is more adaptive to the requirements of a given network.

IoT is one network with new requirements related to the introduction of these nodes/objects with new technologies in the network. The existing TCP/IP model might be compatible with the emerging post-IP or future Internet model. While seeking the design of the IoT network and services, a rethinking of the basic concepts will emerge related to addressing, routing, scaling, guaranteeing quality of service, security, mobility, etc. These research projects are currently supported by the all-IP network, where the packet-switching TCP/IP model has taken over the classical telecom circuit-switching model. Thanks to convergent efforts, the Internet is already the generalized model in telecommunications to offer different services.

1.2. History of IoT

IoT was originally introduced by the Auto-ID research center at the MIT (Massachusetts Institute) [AUT] where an important effort was made to uniquely identify products. The result was termed EPC (electronic product code), which was then commercialized by EPCglobal. EPCglobal was created to follow the AutoID objectives in the industry, with the EAN.UCC (European Article Numbering – Uniform Code Council), now called GS1, as a partner to commercialize Auto-ID research, mainly the EPC.