Conclusions

The digital era revolutionized human society during the last century. In fact, information digitization processes have led to the design of computers, phones and other machines offering a plethora of applications running on standalone computing machines. Then digitized information transport developed. This has introduced digital communication and networking where machines are connected to form very large networks and offer remote applications. These machines connected to these networks created the opportunity to deploy different services, either in voice communication, data transfer or entertainment, such as TV, and has led to this digital society.

Our society is now totally dependent on the biggest ever network, the Internet; one of the major and most astonishing of human inventions. In this network, most of the information traffic is created and generated by people through email, the web and other user services.

Now, after information digitization, transport and communication, ubiquitous computing is emerging. It relies on digitized information coming from the real-world environment, and allows us to build more task automation to better interact with the real-world environment. Ubiquitous computing, pervasive computing and ambient intelligence have recently appeared to be the most challenging and ultimate goals of the digitization process. Automatic processes are expected to be all around us to build the so-called "smart world", where the real and

The Internet of Things: Connecting Objects to the Web Edited by Hakima Chaouchi

virtual worlds co-exist together. Here it is not just people who are communicating through the network but any connected object or thing involved in a certain process, with and without human intervention, will be communicating and generating traffic in the network. Ubiquitous computing is becoming embedded everywhere and is programmed to act automatically with no manual trigger; it is just omnipresent.

Internet of Things (IoT) is somehow a leading path to the smart world with ubiquitous computing and networking to ease different tasks around users and provide other tasks, such as easy monitoring of different phenomena surrounding us. In the IoT, environmental and items from daily life, termed "things", "objects", or "machines" are enhanced with computing and communication technologies. They join the communication framework, meeting a variety of services based on person-to-person, person-to-machine, machine-to-person and machine-to-machine interactions using wired and wireless communication. These connected machines or objects/things will be the new Internet or network users and will generate data traffic of the emerging IoT. They will perform new services to be carried out by the current or future Internet.

New functionalities, inspired mostly by human senses, will be introduced in the network, such as identifying, locating, sensing, deciding, actuating and acting, building more task automation and shaping the virtual world around the real world. This will be possible with the introduction of technologies such as RFID or sensors but also other technologies, such as robotics, nanotechnology and others. These technologies make IoT services an interdisciplinary field where most of the human senses are somehow reproduced and replaced in this virtual world.

Plenty of technical, research, economic and societal issues are correlated to the IoT. In this book *The Internet of Things* we have taken a more "network related view", to bring together current knowledge associated with what a connected object means; what the Internet means in the IoT; the issue of standardization and the governance of the IoT is described; what the enabling technologies of IoT are (the closest to the market are described in detail, mainly RFID for identifying and tracking objects, sensors for sensing the environment and actuating). RFID and sensor technologies both use wireless connectivity.

We also have described the power line communication technology used for home networking, where the idea of building smart homes by connecting smart objects at home, such as the smart fridge, smart TV, etc. emerged before we started to use the IoT terminology. Services developed in home networking are also part of the IoT services, but do not have the same connectivity issues as RFID or sensors, that are tiny devices with limited resources (memory, processor and, most importantly, battery). We are not ignoring the other issues related to IoT, such as the need for high-performance computing, the need for even faster processing and the limits of component physics in increasing the speed of processors, etc. to face the billions of objects expected to be connected and generating traffic in the network. Other research disciplines will have to work and interact with the networking community to build ubiquitous computing and design IoT services and networking.

It was important to clarify at this stage what the object and what the Internet are in the IoT, as different views exist in the community (see Chapter 1). In fact, an object or a thing in the so-called IoT has different interpretations, but mainly it means any product or item enhanced with communicating technologies, such as RFID or sensors, or any other emerging communicating technology. It can also refer to classical devices, such as computers or phones.

In this book, however, we use the object or thing terminology excluding this category, since these devices have enough computing resources and are already running the Internet as communication model for different services not automatically including information from the real world. An object, as described in this book, can range from a very small size, such as an atom, to as big as a building; it can be also animate and mobile, such as an animal, or inanimate, such as any object in daily life (a table, a book a pen, a tree, etc.). Services offered vary depending on an object's size, whether it is static or mobile, animate or inanimate. It is enhanced with connectivity and/or some intelligence capability and joins the network communication enabling real-world environment information to be processed by IoT services.

As for objects or things, Internet in the IoT currently has different interpretations. We can think of the current Internet network as the network supporting remote transport of traffic generated by connected objects or the network of objects from IoT services via special gateways. We can also see it as the IP communication model adapted to handle communication between objects in the network of objects, as in sensor networks. An example of IP adaptation to networks with different needs is IPv6, which is adapted to tiny devices with resource limitations, particularly energy limitations, as described in Chapter 3.

We can also see the IoT as a subset of some functionality developed by the Internet community, such as the naming resolution service; domain name server) that can serve to resolve the correspondence of an object identifier (e.g. radio-frequency identification) to a certain addresses in the network that might trigger a certain application or service. We can see it as just a buzz word, referring to the connectivity of objects but not to the IP model or the current internet network. In this case IoT could be named a network of objects as the connectivity could follow any existing or forthcoming communication model. Other interpretations may exist, but it is important to avoid calling any application orchestrating new technologies, such as RFID, sensor, robotics, etc. IoT without any support from the current or future Internet working functionalities, such as scalable addressing or routing between connected nodes.

It is also important to remind ourselves that initially the vision of IoT emerged in the process of bringing greater automation in the product market chain using RFID, and that other communities became interested in this technology, such as the telecommunication community. In fact, RFID technology (see Chapter 2), which was introduced to replace the bar code, has a very promising market forecast, as shown in Figure C.1.

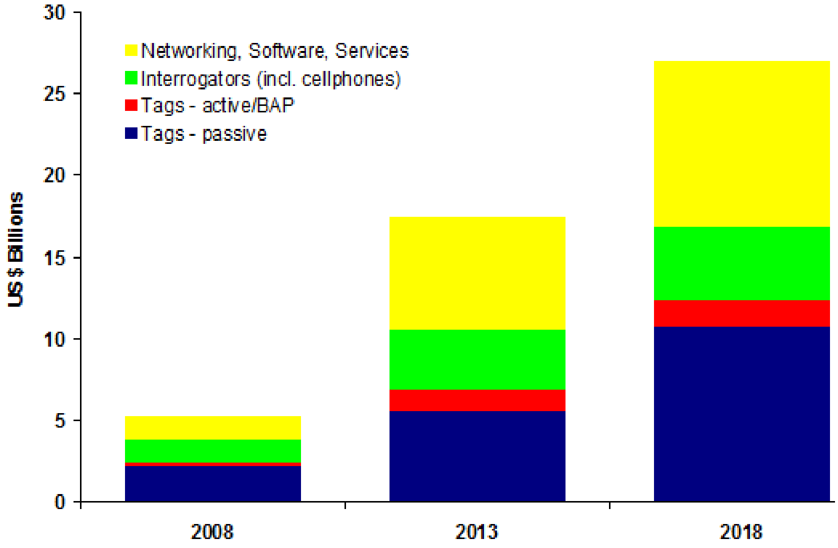


Figure C.1. *RFID market forecast (source: http://www.IDtech.com)*

Based on the promising RFID market forecast network operators, both fixed and mobile, we have foreseen the interest in using such technology in the communication chain by introducing new connected objects that can interact with existing, ones such as mobile phones. This will enable the development of new services; thus generating new revenue streams with the traffic transported by these networks.

The technical issues related to integrating this technology in the existing network (e.g. the Internet), such as addressing, identifying, routing, securing, etc. have been left to the research community. At this point few applications can emerge as touch-a-tag with an RFID reader-enabled mobile phone and trigger. Some things, such as the current Internet, are keeping the network model unchanged, and so we are not yet facing the scalability and heterogenity problems of connecting billions of different objects as expected by the IoT.

In fact, in the expected IoT, there will be more objects connected than people, and the traffic generated by the IoT services will need to be handled following a certain business model. The telecommunications value chain will have to evolve to include new participants, such as the identification, sensing and process automation. Among them, manufacturers of RFID, sensors, robotics and nanotech items are listed as the major enabling technologies in the IoT and will join the value chain. Once again, the market forecast for these technologies is very promising, as shown in Figure C.1 for RFID, Figure C.2 for sensors and Figure C.3 for nanotechnology and robotics. Nanotechnology and robotics are not presented in this book as we have chosen to describe IoT-related technologies that are the closest to the market, such as RFID and sensors.

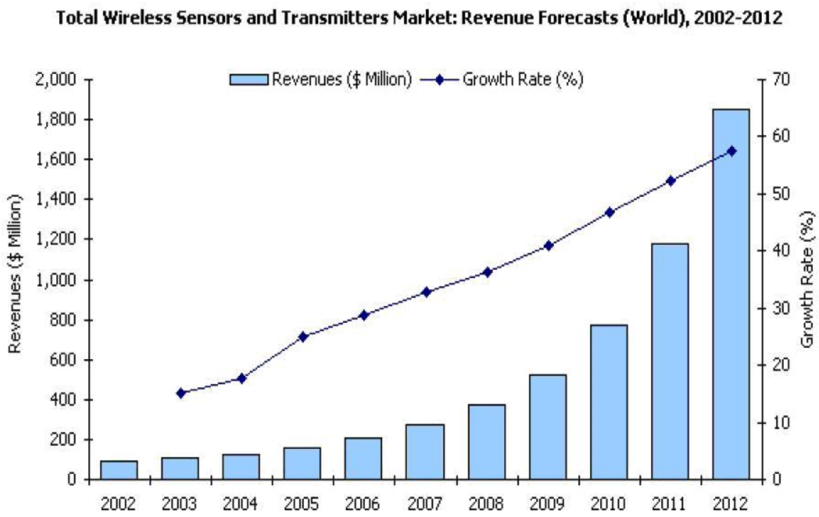
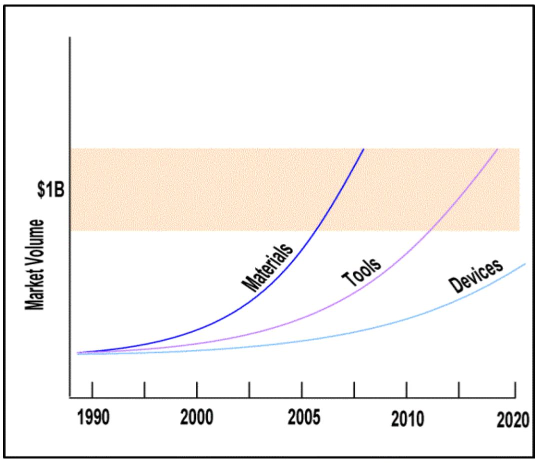
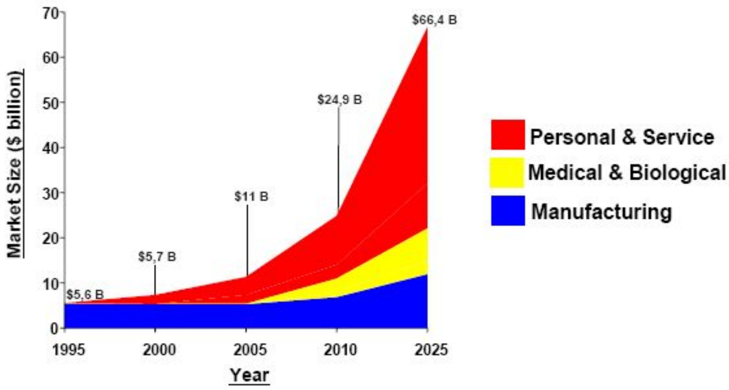


Figure C.2. *Sensors market forecast (source: http://www.IDtech.com)*

Based on these market forecasts, it has been established that integrating these technologies to build IoT services is economically viable. This is why different telecommunication companies, such as mobile phone designers, are interested in participating in the integration of different technologies, such as RFID and sensors, to provide services to enable the access to new IoT services.



(a)



(b)

Figure C.3. *Other emerging technologies market forecasts: (a) nanotechnology; and (b) robotics (source: http://www.IDtech.com)*

Note that, even if several research issues related to the introduction of these technologies in the network, such as object addressing, performance and scalability, security, privacy, governance and standardization, the first generation of IoT services is very close to the market. These services are mainly based on RFID technology and a touch-and-trigger application. These types of applications are mainly supported by cell phone operators where phones are RFID integrators and can be used for different applications. An example of such an application is automatic payment on cell phones. With touch-a-tag, different applications can be developed that increase automation in our daily life, making things easier for users.

Combining networking facilities, such as mobile network communication with connected objects to offer certain services, shows that the current and future Internet will serve as a transport network for these new services. New services, such as IoT services, will be added to the existing ones (voice, data and video). To add IoT service traffic in this network, the traffic properties have to be identified and then satisfied by the communication model, such as the Internet or IP model. There is therefore clearly a need for IoT traffic modeling in addition to how connected objects carry out identifying and addressing, and the scalability and complexity of the model, as presented in the introduction of this book.

Since one of the goals of the convergence in telecommunication to all IP is to minimize operators' charges and maximize revenues; the service-oriented approach, such as in IMS (IP multimedia subsystem), is interesting for developing new opportunities, such as IoT services. By adopting a service-oriented approach, the service will be accessible by the user or object via any access technology. It is a service abstraction layer that gives more flexibility to the user. In the case of IoT, as shown in Figure C.4, we need to include the new functionalities in the service abstraction layer and benefit from any transport network in the current Internet or any network that can transport the traffic generated.

Finally, the path to this convergence will start by considering IP or an adapted version of IP to handle the first generation of IoT services that are still user-centric. The massive deployment in the short- and medium-term of these IoT services will be enabled by society's acceptance of the new technologies, such as RFID (which is one of the enabling technologies for most attracting IoT services) with privacy issues and with promising new revenues in the user-centric value chain.

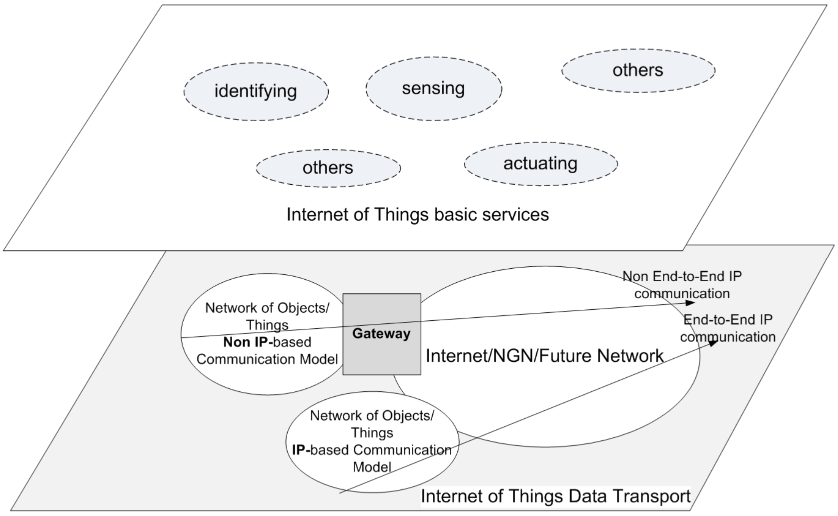


Figure C.4. *IoT service-oriented approach*

In the long term, a new communication model will probably emerge following the post-IP and future Internet/network developments. The next generation of IoT services will then naturally be deployed, being user-centric but mostly object-centric where network scalability needs will increase. It is expected that more than a billion objects will be connected and orchestrated by IoT applications, focusing on adding increasing task automation and monitoring the real-world environment to improve human life.

We conclude this book by saying that after the identification of the main IoT-enabling technologies, issues and challenges, the next step is the design of the network architecture and framework to efficiently support the future IoT applications. This will shape the future networking concepts and functionalities of the future Internet. Only the future will show how successful IoT services will be! Meanwhile, society is not very welcoming of certain IoT services, especially those proposing to use RFID technology for automatic tasks without a clear view of how to protect the person's privacy, protect them from being tracked, and management any other privacy-related information. These issues need to be tackled before such services become used in every-day situations. Other IoT services are very close to the market, however, such as touch-a-tag applications and sensor-based monitoring services or home networking.