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The Internet of Things

In a Connected World of Smart Objects

- The «things» in the Internet of Things
- How intelligent are objects today?
- The three basic layers of the Internet of Things
- The impact of IoT in business and society

Accenture has worked with the **Bankinter** Foundation of Innovation on the production of this Future Trends Forum (FTF) study and also helps to disseminate the work of this leading independent voice in the field of prediction and innovation. The consultancy firm has placed all its knowledge at FTF's disposition, together with its extensive expertise in turning companies and institutions into high performance organisations.

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Many thanks.
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Executive Summary

What we mean by "thing" in the Internet of Things

The Internet of Things (IoT) consists of things that are connected to the Internet, anytime, anywhere. In its most technical sense, it consists of integrating sensors and devices into everyday objects that are connected to the Internet over fixed and wireless networks. The fact that the Internet is present at the same time everywhere makes mass adoption of this technology more feasible. Given their size and cost, the sensors can easily be integrated into homes, workplaces and public places. In this way, any object can be connected and can "manifest itself" over the Internet. Furthermore, in the IoT, any object can be a data source. This is beginning to transform the way we do business, the running of the public sector and the day-to-day life of millions of people.

Just how intelligent are things today? The current situation of a promising technology

The IoT applications that receive the most attention in the media tend to very consumer-oriented, but they are not easy to scale up to industrial level. The logical question is whether they can be rolled out to wider sectors and whether their processes can be redefined to create efficiency and lasting value. The first sectors to get fully involved in using IoT were logistics and transport, by adopting radio frequency identification tags. By 2010, nearly three billion labels were in circulation around the world. However, these are only the first steps towards wider adoption of the technology in other sectors. This publication will examine IoT's first incursions into sectors such as healthcare, agriculture, logistics and supplies, where it is allowing all types of machine to be connected and thus smartly monitored and controlled. It will also look at the way in which smartphones are becoming the "eyes and ears" of computer applications — motion and location sensors can tell us where we are, what we're looking at, and how fast we're moving in real time.

Understanding the three basic layers of the Internet of Things

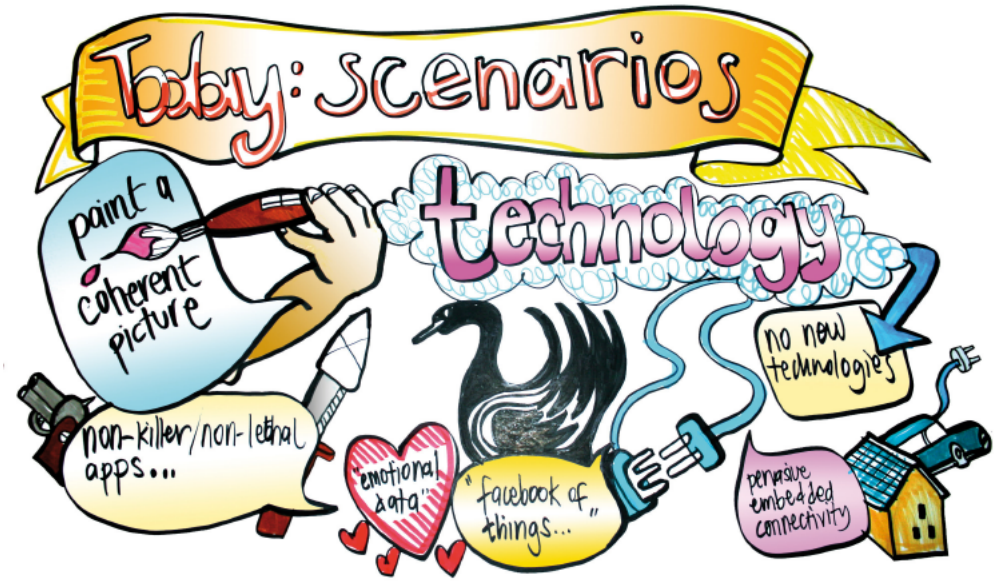
IoT has burst onto the stage, bringing life to everyday objects interconnected over the Internet, which constitute inexhaustible sources of information. The phenomenon has required a combination of three developments. First, miniaturisation, with computers components becoming smaller and smaller, enabling practically anything to be connected anywhere, anytime. Second, an overcoming of the limitations of the mobile telephony infrastructure. And thirdly, a proliferation in the applications and services that make use of the vast amount of information created via the IoT.

The impact of the Internet of Things on business and society

IoT is having a major impact on society and business. More than one billion users around the world use the Internet in their work and in their social life. Wireless technology has extended the possibilities of Internet interaction to "anywhere, anytime". As increasing numbers of people and quantities of information come online, the technology is acting as a tool for collaboration and decision making in a world in which the physical and the digital converge. A new generation of consumers is emerging, permanently connected and traceable, who take for granted a wireless connection and any other technical advance enabling mobility.

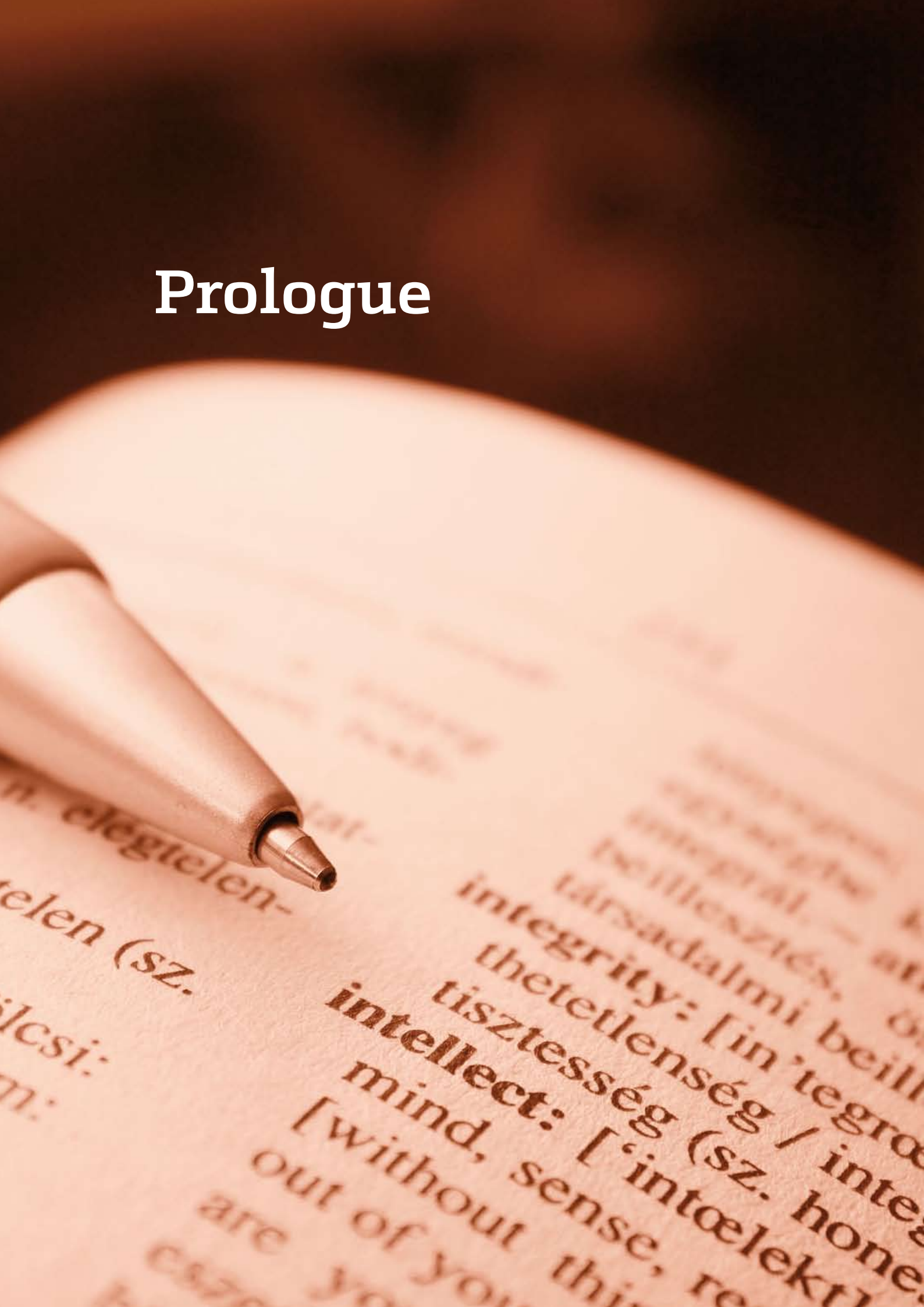
Decisive factors in the future of the Internet of Things

The Internet of Things conjures up the idea of a new "2.0 planet" with an emphasis on immediacy and automation. Yet like so many other science-fiction-type advances, this could be a truly earth-shattering development or just another soon-to-be-forgotten fad. We look at the factors that will encourage wider adoption and those that might slow the process. As well as success stories from America and Europe, we also see how emerging economies are gradually beginning to take off in this field. One representative case is China, which has announced that it intends positioning itself as the global leader in the next wave of technological innovation.



Source: Illustrations resuming Future Trends Forum's presentations.

Prologue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The Internet evolves to become the Internet of Things, which over time becomes the Internet of Everything and individuals, municipalities, and countries, are left with deep economic, social and even philosophical questions. How can you harness this evolution for societal benefit; what will the economic impact be; who will be the drivers, the winners and losers; and is this evolution inevitable or even desirable?

The Bankinter Foundation workshop on the Internet of Things touched on all of these fascinating and thorny issues. A biological analog between the Internet and human evolution is particularly apt because the Internet of Everything most certainly will include humankind. We already have Internet devices attached to our ears and some even have embedded devices connected to their doctors. Kevin Kelly in his fascinating new book entitled *What Technology Wants* describes the advancement of technology as an integral part of human evolution. The Internet of Everything is a natural step along the way, with the world of the "made" becoming more and more integrated with the world of the "born". And as this evolution proceeds, what is perhaps even more intriguing is that the Internet can actually be thought of as carrying atoms rather than just bits. We can capture the essence of a physical object in a design, transfer that design over the Internet and then construct the design with a three dimensional printer. While not quite the "transporter" on Star Trek, this embryonic concept nonetheless demands an entirely new way to look at the Internet, complete with new concepts in standards. What replaces TCP/IP when we need to standardize atom transport, and how will this new standard be established?

On a more immediate and less philosophical level, it is appropriate to ask about the economic implications of a world where more and more things attach online. Which industries will be most profoundly affected? Here I think it's easy to argue that healthcare will play a leadership role. The movement of healthcare out of the hospital and into the home will be greatly facilitated with remote sensing devices of all kinds connected to physicians and care givers. For example, today for a nominal price you can by a scale that in addition to your weight measures your hydration level and your body fat percentage. Add pulse rate meter, connect it to the Internet and you potentially have an excellent monitor of patients with heart failure who have the tendency to retain fluids. The examples are numerous and the potential for cost savings and improved care is staggering.

Another arena where connecting things to the network will be revolutionary is in energy. Smart grids require "use management" via connected devices which move non-essential workloads to off-peak hours when rates are low. Savings of over 20% are possible. Similarly, micro-grids require distributed "source management"; again being facilitated by devices online.

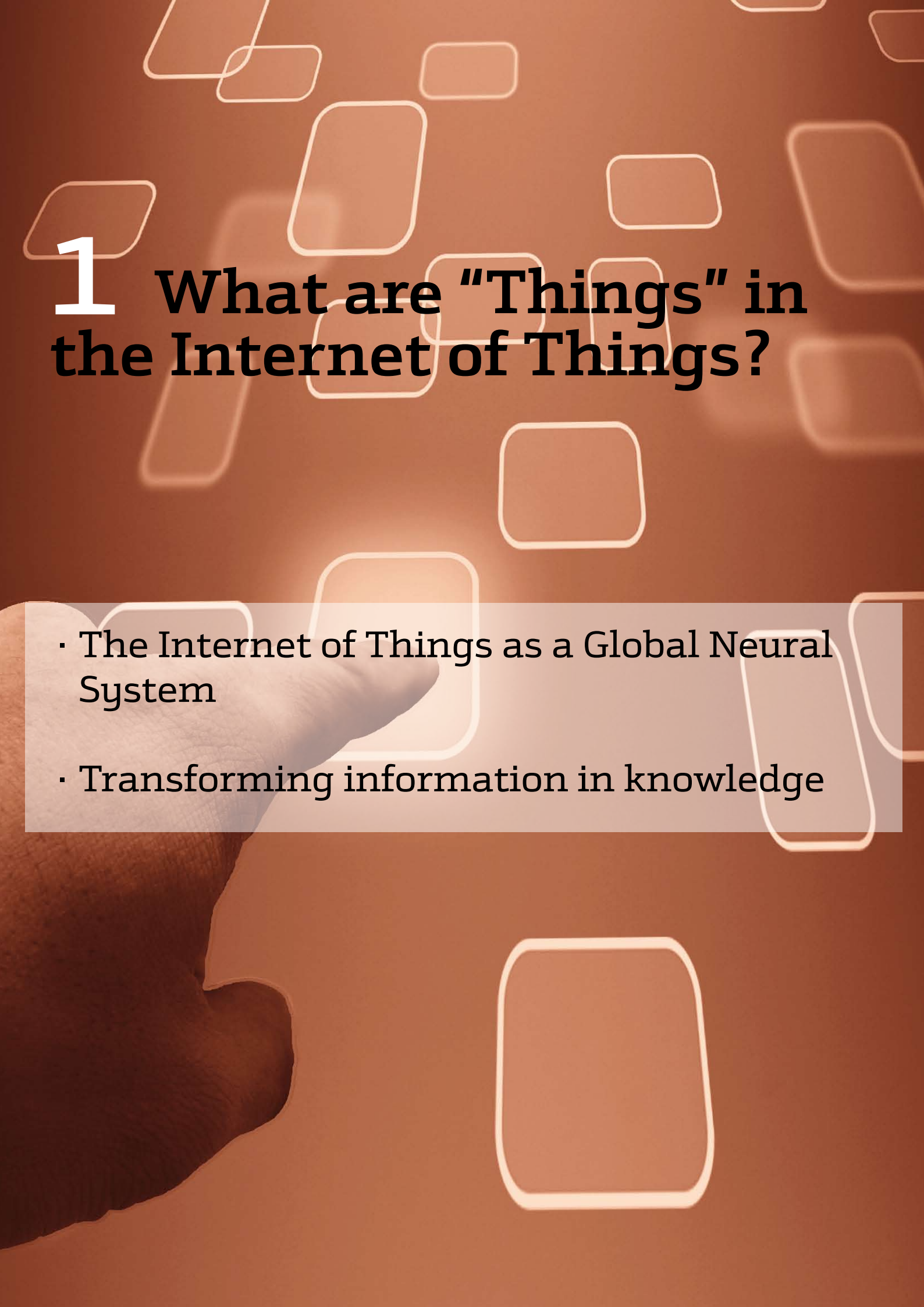
And of course there is electronics and home entertainment. Here we can hardly say the Internet of Things will be revolutionary, because in developed countries the revolution has already occurred complete with new business models with winners and losers. Streaming content is already a norm with micro- and other payment models commonplace.

The impact of the Internet of Things on the media industry gives us a clue into the types of jobs and the economic opportunities that will be created. Here the

We already have Internet devices attached to our ears and some even have embedded devices connected to their doctors

emerging business models have been heavily weighted toward services. In some cases the services are being provided by traditional device manufacturers, as with the Apple Ipod, and in some cases by traditional services providers, like for example the telcos. However, independent of the provider, there is no doubt that the opportunity has mostly been in the services sector. I anticipate that this general trend will prove true in other industries as well. The Internet of Things should greatly accelerate the movement toward services economies that is occurring around the world. In their book *The Profit Zone: How Strategic Business Design Will Lead You to Tomorrow's Profits,* Slywotzky, Morrison and Andelman write about the evolution of industries. When industries are young, member companies tend to be vertically integrated. Profits come from identifiable products and intellectual property. As industries mature, successful member companies become participants in industry value nets, with a higher proportion of the profits coming from services. The Internet of Things will accelerate this evolutionary trend, rapidly driving the growth of services companies. Countries and regions that embrace this trend will be the winners of a growing economy. Countries that focus on old style manufacturing will need to fight with others in a decreasing market segment.

Paul Horn
Distinguished Scientist in Residence and Senior Vice Provost for Research at NYU, and former IBM senior vice president.



1 What are "Things" in the Internet of Things?

- The Internet of Things as a Global Neural System
- Transforming information in knowledge

The Internet of Things (IoT) is the title of the 2010 Future Trends Forum organized by the *Fundación de la Innovación Bankinter*. But the chapter that follows makes it clear that the IoT is already here: miniaturisation and other technological advances already make it possible to instrument and connect virtually any object. In fact, FTF attendees heard about a wide variety of applications that already exist, from smart buildings that dramatically cut energy consumption, to pill bottles that remind patients to take their medication. Why then, would IoT be discussed as a "future trend?"

As the author eloquently describes, the speed of industrial and consumer adoption of the IoT will depend on several factors: from a social perspective, privacy and safety concerns are already being raised; from a technological perspective, the proliferation of connected devices requires a dramatic increase in our ability to store and process data. We are already seeing profound changes in the way some business create and manage data, such as the increasing reliance on RFID tags to track consumer items throughout the entire supply chains of large retailers. A more telling sign of things to come is the advent of entirely new business models for computation, from cloud computing to cities being built around data centers.

Will the Internet of EveryThing truly become ubiquitous? After you read this chapter you will see that, indeed, many "things" are now becoming connected, and that we have every reason to believe that, in this context, the future is upon us.

Paolo Gaudiano
President and CTO, Icosystem

We live in a connected world. Facebook, the social network, now has close to 600 million users[1]—and that particular milestone may well have been passed by the time this publication sees the light of day. Nearly two billion people connect to the Internet[2], share information and communicate over blogs, Wikis, social networks and a host of other media. Now, with the Internet of Everything, objects have joined in the billion-dollar conversation. By 2020, there will be fifty billion units connected[3] and, by 2015[4], it is estimated that there will be a further 15 billion objects online. This concept, known globally as the "Internet of Things" involves people and objects being able to connect to the Internet anytime from anywhere. It's as simple as that. However, the simplicity of this definition should not blind us to the complexity of its implications. What will happen when nearly everything is connected to the Internet? This publication seeks to answer that question.

Note the use of the future tense rather than the conditional in the question above. It's not a mistake; we're not talking about some hypothetical prediction. The Internet of Things is a very real and evolving scenario. Millions of devices are being interconnected over different communication networks. Small sensors make it possible to measure everything from the temperature of a room to a city's taxi traffic. Every day, CCTV cameras guard buildings, while panels at railway stations tell us how soon the next train is coming. Even the mechanism behind handing out traffic fines involves very little human intervention. Increasingly, objects are being fitted with sensors, which furnish them with communication capacity, blurring the boundaries between the real and virtual spheres. The world is becoming a field of global information and the amount of data circulating across the networks is growing exponentially[5]. Terms like *gigabyte* (one billion bytes) and *terabyte* (one [short-scale] trillion bytes) are already becoming outdated, as they are replaced by *petabytes* (one quadrillion bytes) and *exabytes* (one quintillion bytes) which better reflect the reality of global information—though they too may soon be obsolete.

The Internet of Things (IoT) is no new idea. In the early 1990s, Mark Weiser, scientific director at the Xerox Palo Alta Research Center, introduced the concept of "ubiquitous computing", a future in which computing would become invisible—in other words, it would be so integral to our daily lives that it would be transparent for us[6]. Weiser did not coin the term "the Internet of Things", a name attributed to the Auto-ID Center of the Massachusetts Institute of Technology (MIT) at the end of the 1990s[7]. However, the idea of the IoT has only become of practical relevance thanks to the rapid development of electronics over the last decade.

This development has continued the pattern set by visionary Gordon Moore, co-founder of the microchip manufacturer Intel. Moore formulated his famous prediction, known worldwide as "Moore's Law", in 1965, refining it in 1975. Moore said that the number of transistors that can be placed on an integrated circuit doubles approximately every two years[8]. Whether Moore was really capable of predicting the future or simply because the chipset manufacturers made his forecast their long-term goal, his law has been fulfilled for the last forty years[9]. Functions which decades ago required a computer the size of a room are now easily possible with simple electronic devices the size of a drop of water. The size, cost and energy consumption of the hardware have been drastically reduced and it is now possible to make tiny electronic devices for a very low cost. These small

[1] http://www.socialbakers.com/blog/100-facebook-reaches-another-milestone-600-million-users/

[2] http://www.internetworldstats.com/stats.htm

[3] http://www.china.org.cn/business/2010-06/23/content_20325729.htm

[4] http://www.alcatel-lucent.com/new-thinking/market-growth/Internet-of-Things.pdf.

[5] http://www.youtube.com/watch?v=sfEbMV295Kk.

[6] Weiser, M.: The Computer for the 21st Century. Scientific American 265(9):66–75 (1991).

[7] http://www.rfidjournal.com/article/print/4986.

[8] http://www.intel.com/pressroom/kits/bios/moore.htm?iid=tech_mooreslaw+body_bio.

[9] http://www.intel.com/technology/mooreslaw/.

devices, together with the expansion of communication networks have enabled intelligence and connectivity to be incorporated into real-world objects, transforming what was formerly a global network of people into a global network of "everything".

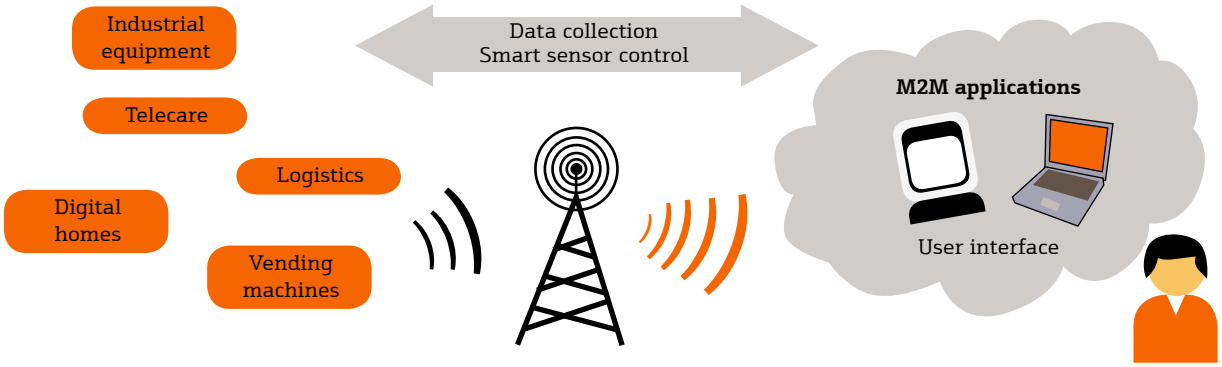
In this report, we shall try to explain how the Internet of Things (IoT) technology allows the objects around us to be instrumentalized. If it is widely adopted, it has the potential to radically change the way we live and work. We shall also look at the growing quantity of information being produced and the ways in which individuals and companies can gain a competitive edge by transforming the new information sources into real economic value.

1.1. Instrumentalizing the Planet: the Internet of Things as a Global Neural System

Paul Horn, Distinguished Scientist in Residence and Senior Vice Provost for Research at NYU, former IBM senior vice president and Future Trends Forum expert, says that the world is being instrumentalized and interconnected, and at the same time becoming smarter. The objects that form part of our everyday life have always produced a large amount of information, but that information was not available to us. With the IoT, small sensors are being integrated into real-world objects, acting as instruments that offer information about practically everything that can be measured. It means that we are now ever more interconnected and people and objects can interact in a completely different way. Today there are one billion Internet users, four billion people with mobile phones and an endless list of objects (cars, domestic appliances, cameras, etc.) that are connected to the Internet in one way or another[10]. Around them, "smart" environments are being created, capable of analyzing, diagnosing and performing functions, eliminating possible human error, etc... for better or for worse. For example, a "smart" power grid can detect voltage surges and reroute the electricity to minimize black-outs. The big question is whether we are ready to delegate this type of operation to entirely automatic procedures.

Any object can be connected and can "manifest itself" on the Net. RFID (radio frequency identification) tags are small sticker-like devices that can be attached to a product, person or animal to store relevant dynamic information. Using radio frequency, the information is transmitted to a computer or mobile device with Internet access. This information can then be received by a user for interpreting. Alternatively, at the other end of the line there may be another machine that interprets the data and acts according to pre-established parameters (see Illustration 1).

[10] Presentation by Paul Horn to the FTF.



Smart sensors
Physical components of the solution (RFID-tag reader, GPS unit, wireless GPRS module) integrated with any device

Communications
Data is transferred to a centralised platform through mobile or fixed connection

M2M applications
M2M solutions which translate information in order to send alerts or reports to computers or smartphones

Illustration 1. M2M: When Machines become SMART.
Source: Accenture (April 2009).

The company Violet has a portfolio of RFID readers and tags evidencing the different applications of RFID in our daily life. Nabaztag is a rabbit-shaped device that can connect to the Internet to read email, download traffic reports and act out a range of situations with lights and movements of its ears. Version two incorporates an RFID-tag reader capable of identifying objects with these labels and performing a number of programmed actions. So for example, you could attach an RFID sticker to a cup of coffee so that, when it came into contact with the reader and the computer, it would open a web-page. Sending a postcard will never be the same again; now you can attach an RFID sticker to the postcard with photos and videos of your holiday.

Yet however innovative these products may be, they are still targeted mainly at consumers and are difficult to scale up to an industrial level. The most obvious question is whether the Internet of Things is applicable to wider sectors and whether it is capable of redefining their processes to create lasting efficiency and value. The logistics and transport sectors have been the first to get deeply involved in the IoT concept, using radio frequency identification labeling. In 2010 nearly three billion RFID tags were in circulation around the world[11]. Logistics firms can optimize their supply chains by knowing exactly where all their goods are and vehicles can avoid having to stop at motorway toll stations. However, although these devices have revolutionized both industries (see Illustration 2) these are just the first steps in the IoT.

[11] Presentation by Paul Horn to the FTF.

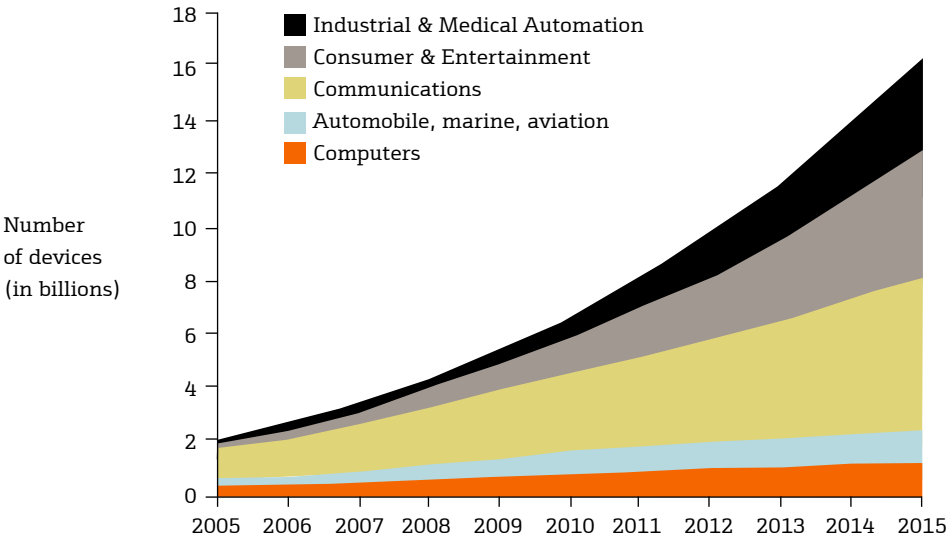


Illustration 2. Devices that communicate over a global network.
Source: *Rise of the Embedded Internet,* White Paper Intel® Embedded Processors, 2009.

A survey of Future Trends Forum experts shows a similar conclusion (see Illustration 3). Sixty-nine percent of those surveyed thought that the Internet of Things would take off in under five years in the retail and logistics sectors. At the other end of the scale, the experts believe that the aerospace, automotive and aviation industries will take longer than eight years to adopt the technology.

Don't know where to start exploring the world of IoT? We recommend visiting the Pachube website, often referred to as the "Facebook for Sensors". It consists of a platform that offers real time information on individuals, organizations and companies interacting in the global Internet of Things. The infrastructure allows the public at large to build IoT products and services and to check for information on sensors integrated into objects and buildings across the world. From monitoring air quality in a city to checking your domestic appliances while you're away on holidays, it's all at your fingertips.

Will the Internet of Things end up being a generally-used technology, capable of affecting the global economy as electricity and the automobile did in their time? The IoT may develop very quickly in certain areas such as industrial automation, health and security, but may fail to take off in everyday life, business and government. The possibility of terrorist attacks and breaches of privacy may make some people feel that the disadvantages of the technology outweigh its advantages.

At the same time, IoT may take a bit longer to be widely adopted, giving business and government time to assimilate its implications and implement the measures needed to minimize the associated risks to security and privacy. The sensors will cover all areas, from homes to the workplace and public areas, marking a breakthrough in our current way of life. Neil Gershenfeld, Director of the Center for Bits and Atoms at the MIT and Future Trends Forum expert, believes that it is important to "differentiate between the long term future and some of the

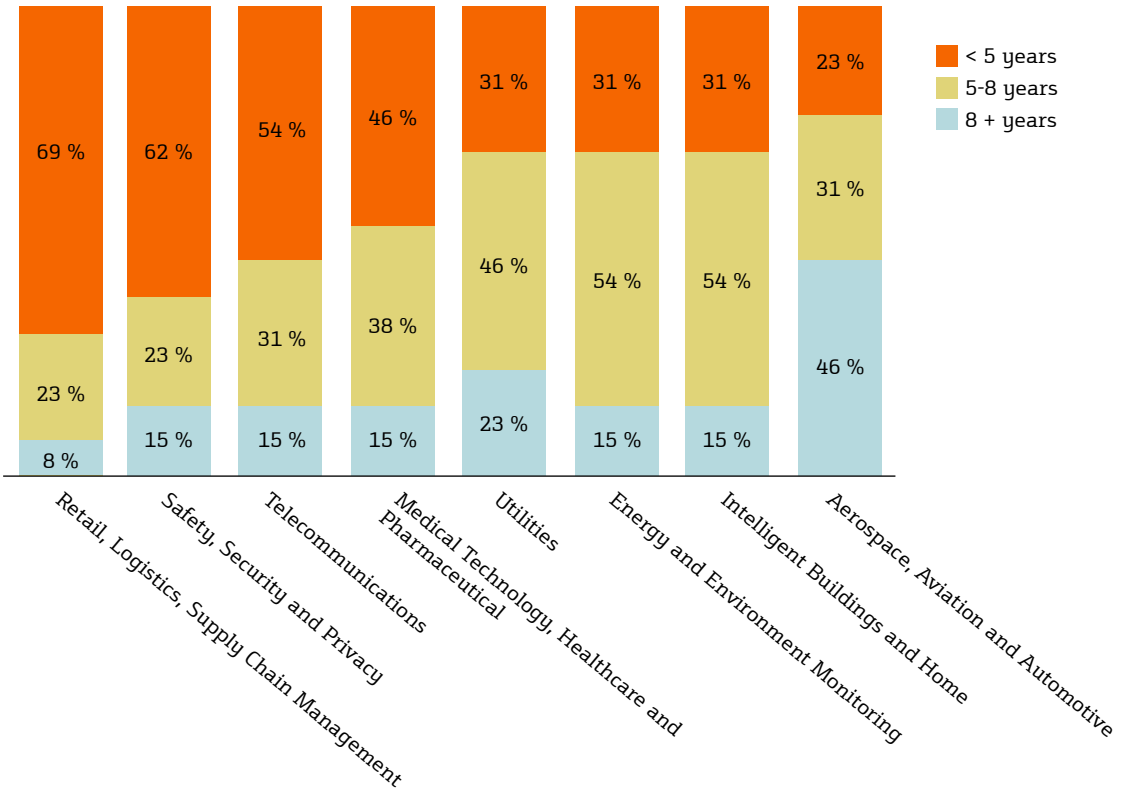


Illustration 3. Speed of adoption of the "Internet of Things" in different industries.
Source: authors.

surprising steps being taken in the short term. Understanding the long term will allow us to understand what the digital revolution will involve"[12].

1.2. A Global Data Field: When Data Becomes Knowledge

Albert Einstein once said: "Information is not knowledge". While it is true that we have more information at our fingertips than he could ever have imagined, Einstein was right; separating the wheat from the chaff has become an ever more difficult task. Only 5% of the information created is "structured", i.e., is in a standard format of words or numbers that can be interpreted by computers. The rest comes in the form of photos and phone calls, making it more difficult to recover and use, in theory at least. This situation is changing with the tagging of photos and face- and voice-recognition, which allow people and words to be identified online[13]. The question is, how much information is there out there?

Last year the digital universe came to 800,000 petabytes (remember that one petabyte equals one million gigabytes). This year it will hit 1.2 million petabytes or 1.2 zettabytes. At this rate by 2020 the digital universe will be forty-four times bigger than in 2009 (see Illustration 4)[14].

This disproportionate amount of information is beginning to transform the way we do business, the running of the public sector and the day-to-day life of millions of people. For example, the American company Walmart handles over a million transactions... *every hour!* The Internet of Things means that any object can be a

[12] "El reto del Internet de las cosas". http://www.elpais.com/articulo/portada/reto/Internet/cosas/elpeputecib/20070517elpcibpor_1/Tes.

[13] "All too much", The Economist (February 2010).

[14] *2010 Digital Universe Study*, IDC, May 2010, http://gigaom.files.wordpress.com/2010/05/2010-digital-universe-iview_5-4-10.pdf.

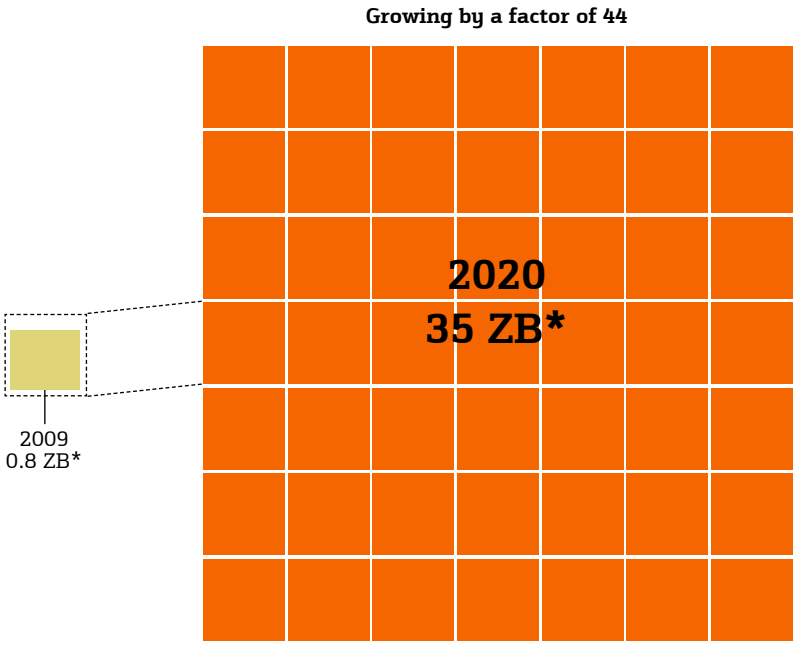


Illustration 4. The digital universe 2009-2020
Source: *IDC Digital Universe Study*, EMC, May 2010.
* Zettabyte = 1 trillion gigabytes.

source of data, and that its "behavior" can be monitored in time and space. As a result, the world is going to be full of new and available information. Faced with this growing quantity of information, it is hardly surprising that companies and entrepreneurs are in a race to innovate data storage, speed, access and analysis methods. Just as in an agricultural economy, the factors of production were land and labor, and in an industrial economy they were capital and labor, information has become the production factor of the twenty-first century.

The challenge of meeting this growing need to manage information is palpable in many business initiatives. One of them involves responding to the miniaturisation of technology, i.e., the trend towards developing smaller and smaller systems and devices because the physical space is running out. Defying Moore's Law, Hewlett Packard has announced the creation of a device called a *memristor* (memory resistor) which takes the size of a chip down to atomic scale without requiring any electric current[15].

Storing any information flow on the Internet is also big business. The Future Trends Forum experts agree that the business of datacenters as "hotels" for computers on the Internet is growing exponentially. It is "high season" for information. Google is said to have more than 30 datacenters, the equivalent of over a million servers. In order to catch up with Google's global roll-out, Microsoft is investing billions of dollars and putting up to 20,000 new servers on-line a month[16]. A range of factors, such as the immense heat given off and the energy consumption the processing requires, have made it necessary to situate these datacenters in some of the world's more remote locations. By 2020, the combined power consumption of these centers is expected to exceed that of Germany, Canada and Brazil put together[17].

[15] H.P. Sees a Revolution in Memory Chip, NYTimes.com (April 2010) http://www.nytimes.com/2010/04/08/science/08chips.html?_r=1.

[16] Down on the server farm, The Economist (May 2008).

[17] The Age of Exabytes, Audrey Watters, sponsored by HP (June 2010).

Information has become the production factor of the twenty-first century

Many companies have benefited from Google's storage service. Virtualization or cloud computing[18] allows these companies to make use of the greater space and processing capacity the datacenters can offer. In this way, they do not have to invest in the fixed costs of implementing and maintaining their own technical infrastructures, but instead pay a monthly fee—just as they would for any other supply. Later on, we shall see how the availability of bandwidth and IP addresses in a network that is beginning to be saturated is starting to become a major priority.

Another very fashionable trend at the moment is metadata—literally "data on data" or "information about information". Think of a can of food: you don't have to open it to know what it contains; you just have to read the label on the outside. This is a good way of explaining how search engines index websites. In general, any service that can filter or sort a very large quantity of information is of interest in the current climate, where decisions are made in a matter of seconds, and companies are prepared to pay high prices for this possibility. The market for data analysis programs is expected to grow by over 30% in under four years, to $3.4 billion[19].

Experts are also working hard on the algorithms to cope with a ubiquitous world. Programming objects in such a way as to allow them to "communicate" is a complicated task, especially since they will have to interact with increasingly diverse and autonomous systems. Much of the economic value will centre on algorithms that allow machine-to-machine communication and the development of software services. UbiComp Grand Challenge is an initiative created by the universities of Nottingham, Oxford and Cambridge, among others, to encourage collaboration and to respond to the challenge of ubiquitous computing. If a central gearbox can be built that allows a heterogeneous federation of "Internet of Things" technologies, it will aid interoperability and avoid the barriers to large-scale acceptance[20].

Given the importance of processing all the information, storage and search speed are not the only challenges. The capacity to analyze a large amount of information in real time is essential for organizations, and represents a major market opportunity for companies capable of offering such a service. Companies such as ThinkAnalytics or Praxis Softek have seen the importance of decision-making in sectors such as the retail trade. Ultimately, speed and efficiency in information are competitive advantages for customers. So data can mean wisdom. In technical circles, people speak of the DIKW hierarchy (data, information, knowledge, wisdom). The most basic tier is "data". By contextualizing a data set, you get "information". This information will only be "knowledge" if you know how to use it. And finally, "wisdom" explains why you are using it.

Business is clearly starting to invest in "smart" services as well as the more common items of information technology. Increasingly, companies are turning to external providers who can offer powerful solutions based on shared service centers that allow their clients to get on with their core business, leaving these providers to act as "aggregators" of applications and infrastructures.

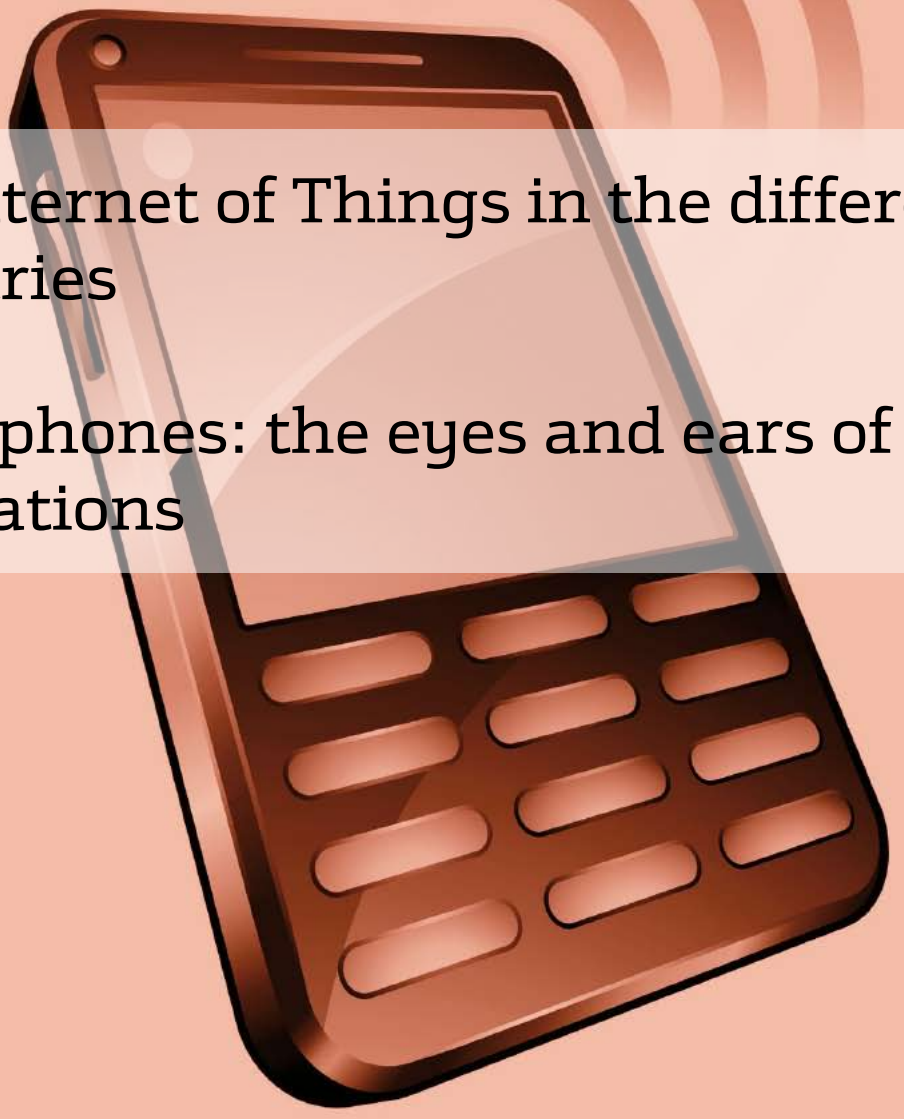
Having set out the bases of the Internet of Things and explained the workings of a ubiquitous world in which people, objects and machines can interact by transcending the barriers of time and space, we will now go on to explore the current state of the technology.

[18] See XIII Publication of the Future Trends Forum, "Cloud Computing: The Third Wave of Information Technology" http://www.fundacionbankinter.org/es/publications/cloud-computing.

[19] The IT paydirt, The Economist (November 2010) http://www.economist.com/node/17388298.

[20] www.smart-systems-integration.com.

2 Just How Intelligent are Things Today? The Current Situation of a Promising Technology



- The Internet of Things in the different industries
- Smartphones: the eyes and ears of applications

The Internet of Things has a futuristic ring to it, but in fact the utilization of the Internet for machine to machine communication is alive, well and growing. Numerous industry segments are appreciating the power of capturing sensor-derived information, sharing it via the Internet and automating a response. The common theme is one of efficiency facilitated by self-correcting systems. Examples abound and include every industry from energy (smart buildings) to automotive (engine diagnostics interacting with central facilities via satellite networks) to health care, where vital sign inputs are enabling software-derived customized disease management and wellness programs. This exciting revolution brings the power of the Internet to a new level and this chapter gives an in depth view of related developments.

Joseph C. Kvedar
Founder and director of the Center for Connected Health

Machine-to-machine (M2M) communications technology has been with us for over a decade in the form of fleet management, sensor networks, and other industrial applications, but its progress has been slow and reported on mainly in trade publications. Indications are that M2M is now poised to enter the mainstream and become the defining component of many next-generation consumer-focused products and services.

Now that wireless networks are robust and accessible almost everywhere in the world, we find that entrepreneurs from many different industries are actively engaged in applying wireless technology to their own products and services. This new role for M2M is being fueled by a storm of factors that include the need for wireless operators to expand beyond voice communications, sharp reductions in the cost of wireless chipsets and connectivity, government regulations focused on energy savings and public safety, and an unprecedented consumer demand for everything mobile, as indicated by their rapid uptake of the smartphone and wireless tablet.

Two of the most important new applications for M2M are energy management and the "connected car". Both of these initiatives are, in part, driven by government regulations. Smart Grids that connect Smart Meters are being installed by utilities around the world to improve energy efficiency, and emergency call systems (such as eCall in Europe) are being mandated to speed emergency response in the event of an accident and to provide other public safety benefits. However, Accenture research predicts that these large government projects will soon be eclipsed by a much larger consumer-driven market opportunity. The Smart Meter is only the first step toward home automation that will eventually encompass nearly all appliances, entertainment devices and other household items. Similarly, the connected car will evolve to support a host of new information and entertainment functions. And completely new markets, such as "connected healthcare" (or mHealth) are in their early stages of development.

In short, many different organizations in many industries are recognizing the relevance of M2M to their own businesses. But, as we see in our research, the addition of connectivity to a traditional product is a significant complication from both technical and business perspectives. The development of an effective M2M solution requires expertise in communications technology, hardware, software applications, integration and implementation, and typically involves working with multiple parties for specialized capabilities. A top down business process review is required as the addition of connectivity often provokes a transition from product focus to a persistent services business model that generates ongoing revenues through subscriptions or add-on sales.

The complexity of M2M solutions makes aligning with the right partner a critical decision. Accenture Mobility Operated Services are at the forefront of the M2M ecosystem in addressing both generic and industry-specific mobility needs and in providing a highly robust Managed Service Delivery platform that reduces upfront development costs, speeds time-to-market and delivers an end to end service offering.

I hope that you will enjoy this chapter on How Smart are things today.

Paul Lalancette
International sales director, M2M, Accenture

Just as the nineteenth century was the stage for the Industrial Revolution, the twentieth century witnessed the Information Revolution. With the emergence of TCP/IP, html and wireless technology, we learned to "surf" the Net and use website content. Later we saw the birth of *e-commerce* and witnessed the explosion of crowdsourcing and the "2.0" concept. The popularizations of the Internet and advances in telecommunications have clearly been essential in connecting everything up. But what's next?

As if in anticipation of a new age in which anything is possible, the next great step has been dubbed the Internet of Everything. Rather than imagining what is possible, we now wonder what *isn't* possible. Sensors and devices fitted to all types of objects and connected to the Internet over fixed and wireless networks are becoming ever smaller and ever cheaper. Networks can now extract huge volumes of data which can be analyzed by computer. In a new twist, objects can now not only talk to *us*; they're even smart enough to talk to each other. Welcome to the ubiquitous society, where you can be in several places at the same time.

Just how smart are these devices? As the technology develops, the information compiled will be subject to more exhaustive analysis, more accurate decision-making and, if necessary, the launch of a more optimized automatic process. The result will be a gradual minimization of the human intervention. By 2012, over sixty million devices in Western Europe are expected to be linked up and sharing information using M2M (machine-to-machine) systems[21]. To get a better idea of how an object can become "smarter", take a look at Accenture's pyramid of the evolution of a smarter object[22]. Let's start at the base of the pyramid. At this level, the object takes on a unique identity, for example using an RFID tag. In the second tier, technology (GPS) is used to track the object's current position or path. One tier up, the object gains status, i.e., it is capable of communicating its current state and properties. Finally at the apex of the pyramid, the object has context so that it is "aware" of its environment (see Illustration 5).

For the most typical example of all, you don't even have to look to the Internet of Things; it's already there in most homes. Thermostats are used to regulate room temperature based on their readings. However, connecting the sensors to the Internet will make them even more sophisticated. For example, it will be possible to stitch sensors into garments to measure how much the wearer weighs and give him slimming tips; or fit them in refrigerators to check supplies and order food automatically.

In this chapter we're going to explore the uses of sensors and devices in the logistics, healthcare, environment and consumer sectors. We will also look at one of the devices that is going to do most to encourage the widespread use of the IoT: the mobile phone.

2.1. First Steps: Adoption of IoT in Industry

Try to imagine the city of the future: a "smart" city in which mobile phones open doors, sensors detect leaks in water pipes and publicity billboards change to match the consumer profile of passers-by. As we shall see in the next chapter, the IoT has been applied to all types of sectors, such as healthcare, agriculture, logistics and supplies, making it possible to link in all types of machines to monitor and control

[21] IDATE estimation of active modules in Western Europe.

[22] Sensor Telemetry, Accenture 2005.

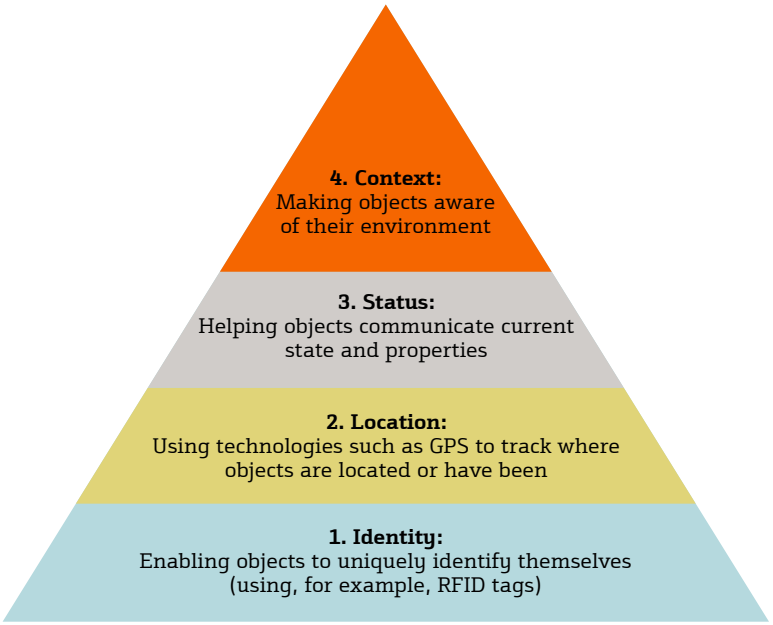


Illustration 5. The Evolution of a Smarter Object.
Source: Sensor Telemetry, Accenture 2005.

them intelligently. The extent to which these industries have evolved in IoT terms varies, so they now stand at different points in Accenture's smarter object pyramid (see above). Nonetheless, they all share the common aim of increasing efficiency, reducing costs, improving decision making, saving energy and protecting the environment.

The Internet of Logistics

In 2008 a batch of baby milk from China adulterated with melamine went on sale. 300,000 babies were affected, of whom six died and another 860 were hospitalized. Cases are still being reported which, though isolated, are nonetheless a source of social concern. Could distribution of the product on the Chinese market have been avoided? Thanks to the Internet of Things and RFID tagging, the milk could probably have been recalled faster, as it would have been easier to track the location of the contaminated units.

Actually, any company can use RFID labels in its supply chain. Combine this technology with a mobile phone application that enables you to view all the aggregated information on all the products in the chain at any time and you have a way of reducing the time and resources spent on tracking company operations. The number of orders currently underway, stock levels and retained faulty products... all this information and much more can be displayed in easy-to-read text or graphic format. There are a large number of companies on the market implementing these comprehensive systems. For example, all the technical solutions at Softeon are fully integrated into the Internet. This means that traditional tools such as warehouse management and distribution orders can be accessed using smartphone applications.

Traditional tools such as warehouse management and distribution orders can be accessed using smartphone applications

It is also possible to monitor the temperature of certain production processes remotely via sensors. In the paper-making industry, for example, the temperature in the lime kilns has to be adjusted manually at frequent intervals. Using the data from integrated temperature sensors, the shape and intensity of the flame can be adjusted, increasing production and improving product quality without human intervention[23].

As we have seen in the example of the contaminated milk, by using RFID tags it is possible to communicate with the objects even when they have left the company's warehouse. This can be especially useful in helping companies to improve their products or diversify variety to appeal to consumers. This means gaining valuable information all the way from the shop shelf to the purchaser's home, to turn these commoditized products into services.

At the end of June 2010, the Danish transportation firm Container Centralen undertook to use sensor technology to enable horticultural agents to track the progress of shipments through the supply chain, from producers to wholesalers and retailers, across forty countries in Europe. When transporting flowers and pot plants, which are very sensitive to the environment, it is important to monitor conditions and climate throughout the journey[24]. In essence, logistics managers can use up-to-the-minute information on weather and traffic conditions to plan the routes of their trucks and planes. This increases business efficiency by cutting costs and avoiding constant scheduling changes.

The Internet of Things is also going to space. NASA plans to use over five hundred sensors on jet engines to gather information on almost every aspect of their flights. Project engineers say it will show how the engines work in real conditions and will be used to create individualized models that will prevent failures in the future[25].

The Internet of Health

People normally only go to the doctor when they're feeling ill or when they have to get a compulsory annual check-up. But what if there were a way of constantly monitoring your body and warning you of any anomaly? Of course, you could say: "my body already has an early-warning system: it's called symptoms"; but what about ailments that have no apparent symptoms or ones that require biochemical analysis for a certain diagnosis? Early diagnosis is often the solution to potentially fatal conditions. It would be like having a thermostat in your body: the moment it detected a problem, it would trigger a message—or in certain cases, release a dose of medication.

With IoT sensors, this is possible. One example might be a sticker on your chest to prevent heart attacks. It would monitor activity and fluid levels in your chest. You'd only have to replace the sticker once a week to ensure continuous monitoring over a wireless connection.

More examples... The Telcare company wants to launch the world's first mobile glucometer which would transmit the results of an analysis to a medical center for immediate on-line assistance. The device has a data display with a wireless connection and a slot into which the patient inserts a strip of paper with a drop of blood. The system will avoid unnecessary trips to the doctor, saturation at medical

[23] Internet of Things, *The McKinsey Quarterly,* March, 2010, http://www.mckinseyquarterly.com/The_Internet_of_Things_2538.

[24] Sensor Telemetry, Accenture 2005, http://www.readwriteweb.com/archives/top_5_web_trends_of_2009_internet_of_things_1.php.

[25] «Sensor Telemetry», Accenture 2005, http://www.accenture.com/SiteCollectionDocuments/PDF/sensortelemetry.pdf.

centers and the high associated costs. In the US there are 20 million diabetics and Telcare estimates that the market for their device is worth around 8 billion dollars[26]. Unfortunately, it has not yet been approved for sale by the American Food and Drug Administration (FDA).

STAR Analytical Services is developing an application that will analyze a patient's cough over their mobile phone. From the specific noise of the cough, the system can help doctors remotely diagnose anything from a common cold to pneumonia, by matching the sound to a database of 1,000 profiles[27]. Another way of avoiding several trips to the doctor is by using applications such as ARUP Consult and Care360, which sends the results of the analysis to the doctor's mobile phone. If doctors spot any abnormal values, they can contact the patient by e-mail with instructions[28].

Thanks to Quantified Self, a web community with a shared interest in self-knowledge using self-monitoring tools such as the Telcare glucometer, there are many case studies available on IoT applications in medicine. Using nanotechnology, it is possible to monitor different parts of your body and send the data over the Internet for diagnosis. Spectacles that check your eyes and give advice on changes in prescription, shirt collars that analyze your sweat and helmets that measure your brain activity... it's all possible in the Internet of Health (see Illustration 6).

[26] http://www.telcare.com/.

[27] Cough Into Your Cell Phone, Get Diagnosis http://news.discovery.com/tech/cough-cell-phone-diagnosis.html.

[28] *How Smartphones are Changing Health Care for Consumers and Providers*, California Healthcare Foundation, April 2010.

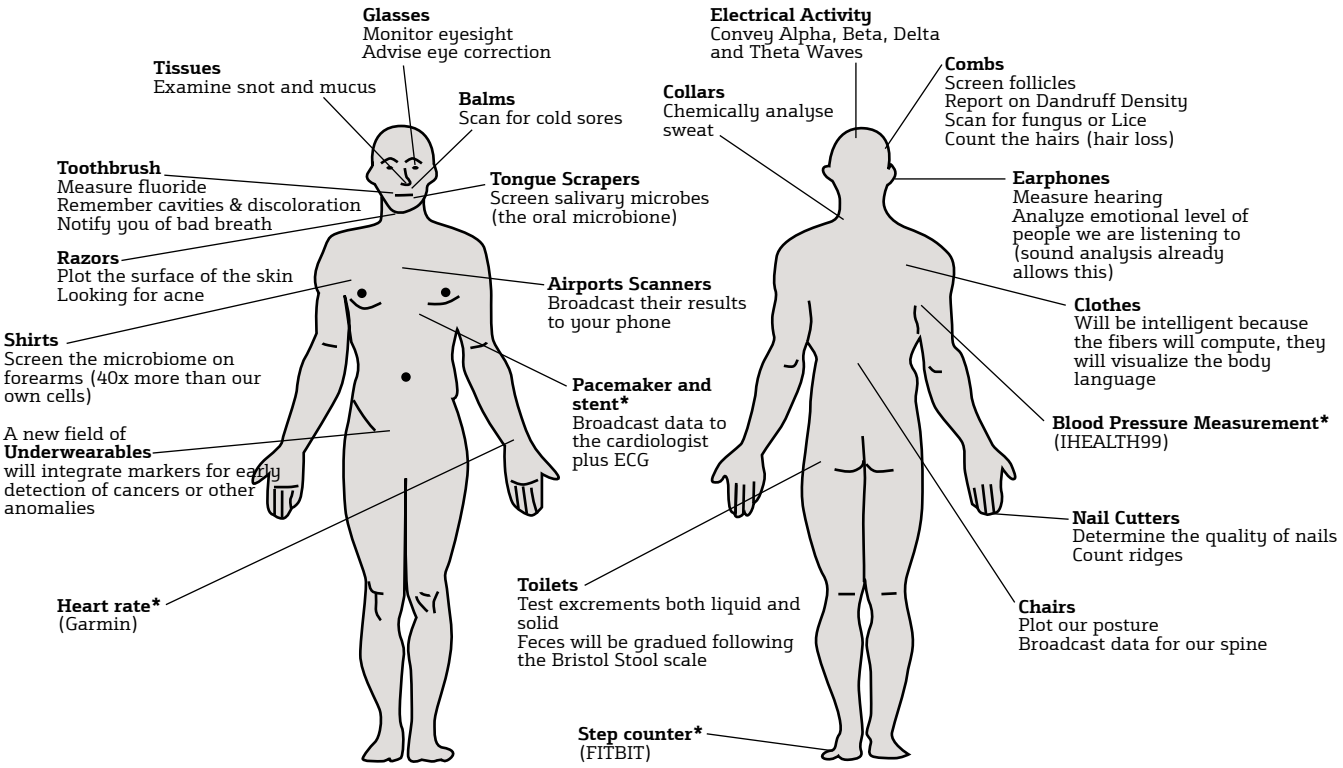


Illustration 6. The Internet of Health.
Source: http://quantifiedself.com/.

The initiatives are not restricted to tending to patients. In the medical field, constant advances require doctors to keep up to speed with new treatments and improved techniques. Applications such as Epocrates Mobile CME offer physicians a means of continuous training over their mobile phones with on-line clinical case studies.

Finally, it is worth mentioning the robot developed by Swisslog, a global supplier of integrated logistics solutions, which is capable of retrieving the daily doses of multiple patients and registering them using RFID before the health worker gives them to the patient. This helps prevent errors and ensures strict control of drug supplies in hospitals.

However, commercialization of these initiatives is being slowed down by lack of FDA approval. An ageing population is putting a strain on healthcare resources, with not enough specialists to go round. The promise of a less saturated system may drive the necessary rationalization of the healthcare system, with distinctions being drawn between necessary personal visits and possible self-diagnosis (though only in specific cases, without completely replacing the doctor's professional opinion).

The Internet of the Environment

The Future Trends Forum expert Paul Horn gives hard figures to illustrate the need for progress in environmental care: 170 billion kilowatt hours are wasted each year by consumers due to a lack of information on energy use. He talks about 3.7 billion work hours lost and 8.7 billion liters of petrol squandered – in the US alone – because people are not efficient in their working and commuting habits respectively. He also says that 100 million people around the world are being pushed across the poverty line by personal health care expenditure.

For all of these reasons, Horn sees the Internet of Things as a solution to some of our current environmental problems. IBM's Smart Planet initiative offers successful case studies: a 10% saving in energy costs when Pacific Northwest National Laboratory allowed its subscribers to monitor their domestic appliances over the Internet and switch them on and off remotely. And a 20% cut in traffic, a 12% reduction in emissions and 40,000 extra public transport users in Stockholm thanks to the establishment of traffic monitoring initiatives, such as a city center congestion charge, among others.

"Smart" buildings are the best example of the way the Internet can be used for environmental purposes. In the US, buildings consume 70% of all electricity, of which 50% is wasted. 50% of all water consumed is also squandered. To remedy this type of situation, many blocks are being fitted with a smart grid, a network that can optimize energy generation and consumption using a series of smart meters that choose the best time slots from amongst different power utilities and discriminate between consumption times. The result is more sensible and economic power consumption.

The imperative need for efficient consumption has led to the creation of "green" office spaces in the GreenSpaces complex in Delhi (India)[29] and the launch of the Smart IPv6 Building project with a pilot programme in Geneva (Switzerland). We also have the example of Dubuque in Iowa, which is intended to be the first integrated smart city in America. In 2010 they installed monitoring systems to

[29] "Constructing a Smarter Planet, one building at a time", IBM Smarter Planet http://www.ibm.com/smarterplanet/global/files/us__en_us__buildings__green_buildings.pdf.

"Smart" buildings are the best example of the way the Internet can be used for environmental purposes

analyze the interaction between water and electricity supplies and transport. More than three hundred volunteers agreed to have smart meters fitted that would analyze their consumption and send the results by wireless every fifteen minutes, so that users could check them on-line. The aim of the Dubuque 2.0 program is to reproduce the experience in other American cities. Nonetheless, as we shall see in Chapter 5, IoT knows no borders between developed and emerging countries, with a range of initiatives springing up across the globe.

Finally, one could point to the Ambient Devices' Energy Orb, a device that changes color to display information on the status of the smart grid. Consumers can see the most expensive times for domestic supplies and turn their homes into "smart buildings". This is not the only way consumers can connect up to interact with the Internet of Things. We'll now look at some more examples in which consumers play a lead role.

The Internet of Consumers

Clearly the Internet of Things benefits the consumer thanks to more transparent pricing of the services they consume. It may not be cheaper (Bakersfield is a good case in point (see Chapter 5)), but it does encourage users to be more conscious of their consumption. This is because the sensors allow any activity to be registered continuously. This means that decisions can be based on the results; for example, by monitoring spending on power or water. In some cases, however, it does translate into economic benefit for certain sectors of consumers. Some automobile insurers in Europe and the United States are installing sensors in their customers' vehicles to charge them on the basis of their driving behavior rather than by demographic criteria[30].

And there are other applications for cars. Zipcar marks a real revolution in passenger transport. Sign up on-line and you can use a car whenever you like—for a few hours or the whole day. So what makes this system different to regular car rental? First of all, the pick-up and return points are located at strategic points around the city, unlike car hire agencies, which tend to have only a few, not necessarily central, offices. Secondly, you save time and money. Hiring a vehicle tends to involve bothersome paperwork; with Zipcar, once you've signed up, you just hold your membership card against the car window to use it at any time of day. As for the cost, renting a car can cost up to $807 a month. In contrast, with Zipcar $340 gets you several trips a week, plus a weekend excursion[31]. As well as cutting the fixed costs involved in owning a vehicle, Zipcar is good for the environment, because it is a way of sharing cars already in circulation. Each Zipcar replaces between fifteen and twenty automobiles[32].

The Internet of Things can also throw light on some consumer patterns, which are extremely valuable for brands and stores. A survey by marketing professors at the Wharton School shows the shopping activities of supermarket customers. Using an RFID tag attached to the shopping trolley, they could monitor and add data on speed of purchase and the physical route round a supermarket[33]. The company that designed the technology, called PathTracker®, claims that only between 20% and 30% of a buyer's time is spent actually buying products[34]. These results offer valuable information on consumer behavior, which companies can use, for example, to decide how to get the most from the remaining 70% of the time. As well as improving the layout of the store and identifying the most profitable areas,

[30] Clouds, big data, and smart assets: Ten tech-enabled business trends to watch", *The Economist,* September, 2010, http://www.mckinsey.com/mgi/mginews/ten_of_the_best.asp.

[31] Calculation based on a medium-sized car in the state of California, including proportional cost of car payment, finance charges, insurance, petrol, taxes, maintenance, parking, http://www.zipcar.com/losangeles/rates/savings-compare-own.

[32] http://www.zipcar.com/is-it/greenbenefits.

[33] An Exploratory Look at In-Store Supermarket Shopping Paths, Jeffrey S. Larson, Eric T. Bradlow, Peter S. Fader (University of Wharton, April 2005) http://knowledge.wharton.upenn.edu/papers/1293.pdf.

[34] "The 'Traveling Salesman' Goes Shopping: The Efficiency of Purchasing Patterns in the Grocery Store", *Knowledge@Wharton,* January, 2007. http://www.knowledgeatwharton.com.cn/index.cfm?fa=viewArticle&articleID=1546&languageid=1.

knowing how customers shop creates a new dimension in marketing in which companies can try to influence the routes taken with electronic media.

To sum up, one might consider that the US Department of Agriculture is going a bit too far when in wanting to allocate an identification number to every cow in the country, so that it can use RFID technology to locate the source farm of a disease outbreak. However, there can be no doubt that in the next few years we are going to see the Internet of Things taking form in different initiatives and applications that seek to bring greater instantaneity to our everyday life. Indeed, much of the dissemination in IoT is thanks to the mobile phone, through which people become their own sensors.

2.2. The Internet of Everyone: the Mobile Phone as a Dissemination Sensor

You're bound to have seen it: people tapping away at their phone keypads non-stop on buses, clicking to see how to get somewhere or uploading a photo to a social network in the middle of the street. Smartphones are all the rage. Anyone who thinks that their mobile phone is only useful for phone calls, text messages and perhaps to wake them up in the morning is about to discover that they can offer far, far more. "Smartphone" is the commercial term for a mobile phone whose functioning centers on an Internet connection and the use of a keyboard similar to that of a computer. Sometimes they come in the form of a touch screen and, in all cases they have menus and short-cuts as part of an operating system to make them easier to use. As well as sending and receiving e-mails, smartphones allow applications to be installed that perform a specific function for the user, such as word processors, databases, graphic editors and chat applications. The best-known brands in Spain are Blackberry and iPhone, although models using the Android operating system are also beginning to take off. The latest IDC report indicates that there were 302.6 million smartphones in existence around the world in 2010, 74.4% up on 2009[35].

But what do smartphones have to do with the Internet of Things? Very simple: "Our phones and cameras are being turned into eyes and ears for applications; motion and location sensors tell where we are, what we're looking at, and how fast we're moving. Data are being collected, presented, and acted upon in real time. The scale of participation has increased by orders of magnitude"[36]. Smartphones contain a multitude of sensors of sound, light and acceleration that gather information and upload it to the Internet. As more users form part of the platform and more data are generated, more applications will be developed to tap into the gold mine. Some of them are just pure entertainment, others are effective solutions to real problems. Some of the most unusual uses? An application that blows out candles, another that solves Rubik cubes or Sudoku, Trapster, which allows users to share information on speed traps with other members, or WideNoise which measures noise pollution.

At the other end of the scale, there are smartphone applications that will revolutionize logistics and healthcare, as we saw in the previous section. Indeed, in February 2010, Apple's on-line app store had 5,805 applications in its health and fitness section. Although only 27% were targeted at professionals (and the rest at patients and end users)[37], the applications are increasingly seeking to address shortfalls in our saturated health systems in areas that can be delegated to devices—such as monitoring chronic illness. Nonetheless, it is important to

[35] http://www.celularis.com/smartphones/smartphones-2010.php.

[36] Tim O'Reilly and John Battelle, "Web Squared: Web 2.0 Five Years On", Web 2.0 Summit, 2009.

[37] "How Smartphones Are Changing Health Care for Consumers and Providers", California Healthcare Foundation, April, 2010.

remember that downloading an application does not make you a qualified physician—and of course finding precisely the application you need from among the 5,805 on offer can be an impossible task.

Smartphones are called that for a good reason. Although most users have yet to discover all the possibilities of these latest-generation mobiles, manufacturers are well aware of the importance of keeping ahead of the market. Experts believe that success in this field depends to a great extent on satisfactory consumer experience—which means user-friendly systems and optimum network coverage. Let's now look at some of the business initiatives that are being launched to speed up the convergence of the real and virtual worlds, including a form of identification for accessing restricted areas, the provision of location-specific information, a form of payment and a means of "sensorial participation".

Open Sesame!

Assa Abloy and OpenWays have launched a system for opening your hotel room door using your smartphone as a remote control[38]. By means of a phone confirmation at the hotel, guests can go straight to their rooms without stopping at the reception desk.

Smartphones can also be used for boarding flights. Companies like British Airways, KLM, Iberia and Spanair allow passengers to use their phones as a digital boarding card which is reproduced on their mobile and can be scanned before they get on the plane[39].

Also worth a mention are the BiDi codes that open the doors to a whole world of content. These small squares look somewhat like bar codes and contain coded information. First launched in Japan, they are now starting to appear in magazines and posters in Spain. Movistar was the first to offer the service here. It is a highly interactive means of advertising, encouraging the user to photograph the code to access additional brand content on-line. Also very popular are those that allow users to download video games while they're hanging around waiting for a bus.

Functionality on the Hoof

Many people are no longer content just to update their Facebook status. They now find it essential to keep their network friends informed of exactly where they are at any time. They can do this by "signing on" at the location, for example "xxx is in the Starbucks on Calle Serrano in Madrid". The commercial response has been quick to follow: ShopKick is an application that offers appetizing walk-in discounts and bonuses to users who sign in to a shop using their smartphones.

The application Layar can open up a whole universe of information to users who just have to point their smartphone cameras at the street they're standing in. The program is capable of superimposing relevant data on a photograph, from local shops to information on properties for sale[40]. OpenStreetMap is an initiative that seeks to offer free geographical data, such as street plans. Not everyone knows that many existing maps have legal restrictions on usage, which, according to the initiative, "prevents people using them in creative, productive or unexpected ways"[41]. SeeClickFix is a community that gives information on incidents that affect residents in a specific neighbourhood: a

[38] "Cinco usos de su smartphone que todavía no conocía", *Expansión.com* (December 2010) http://www.expansion.com/2010/12/10/empresas/digitech/1291985701.html.

[39] "Cinco usos de su smartphone que todavía no conocía", *Expansión.com* (December 2010) http://www.expansion.com/2010/12/10/empresas/digitech/1291985701.html.

[40] "It's a smart world", *Economist.com*, http://www.economist.com/node/17388368.

[41] http://www.openstreetmap.es/.

The latest IDC report indicates that there were 302.6 million smartphones around the world in 2010

pothole in the road, a broken traffic light or a deficient refuse collection service, for example.

In the area of shopping, online queries to compare prices or find product reviews are becoming more and more common. Indeed, Emily Green, president of Yankee Group Research and Future Trends Forum expert says that the number of people making these queries has increased eight percentage points to 43% in just three months[42].

Farewell to Plastic

One particularly important area is phone payment. Mobipay was a mobile phone payment service launched in Spain in 2001[43]. It allowed people to confirm their purchases via a message received on their mobiles, giving information on the shop and the amount of the transaction. Despite the fact that users had to enter a PIN number to make the payment, thus guaranteeing security, the initiative was not well received among Spanish consumers. Perhaps it was ahead of its time, because ten years later efforts are being made to re-launch the service (though it is running into considerable teething troubles). The fact that the service depends on the interaction between two companies (the credit card firm and the mobile phone operator) is not helpful. Equally discouraging is the threat of theft or hacking, mischarging and possible mail bombing as a result of data being made available on customers' consumption habits.

Two factors will be decisive in making this method of payment universally acceptable. On the one hand, shops will need to see that it is easier and cheaper to use. It will also have to win over credit card owners (in America alone there are around one billion cards in circulation[44]) with the promise of unmatched customer service. Interestingly, in emerging countries this method of payment is helping plug a growing gap in the field of micro payments (well covered by credit cards in developed countries). The possibility of making transactions in remote spots and in places with low technology penetration facilitates the creation of small rural businesses.

Sensorial Participation

You're standing on the street in a city you don't know very well. You're hungry, so you whip out your smartphone, press a key and say "pizza". Immediately the location of the nearest pizza parlor flashes up. Using the Google Mobile App search engine for iPhone, the application can detect the movement of the phone towards your ear and automatically activate voice recognition. Using a voice recognition database, triangulation of your location and sophisticated algorithms, it can respond with information on the requested restaurants[45].

Any everyday activity is capable of allowing interaction over a smartphone. "Sensorial participation" is the order of the day, with smartphones turning people into human sensors. What' s Invasive is an application that the employees of natural parks and hikers can download to their smartphone to show on an on-line map the locations of invasive species of plants and animals (e.g. weeds that endanger the natural ecosystem of an area). Against the backdrop of climate change and the existence of other destabilizing agents, there are plenty of people who are concerned about caring for their environment.

[42] Presentation by Emily Green at the Future Trends Forum.

[43] http://www.expansion.com/2010/12/10/empresas/digitech/1291985701.html.

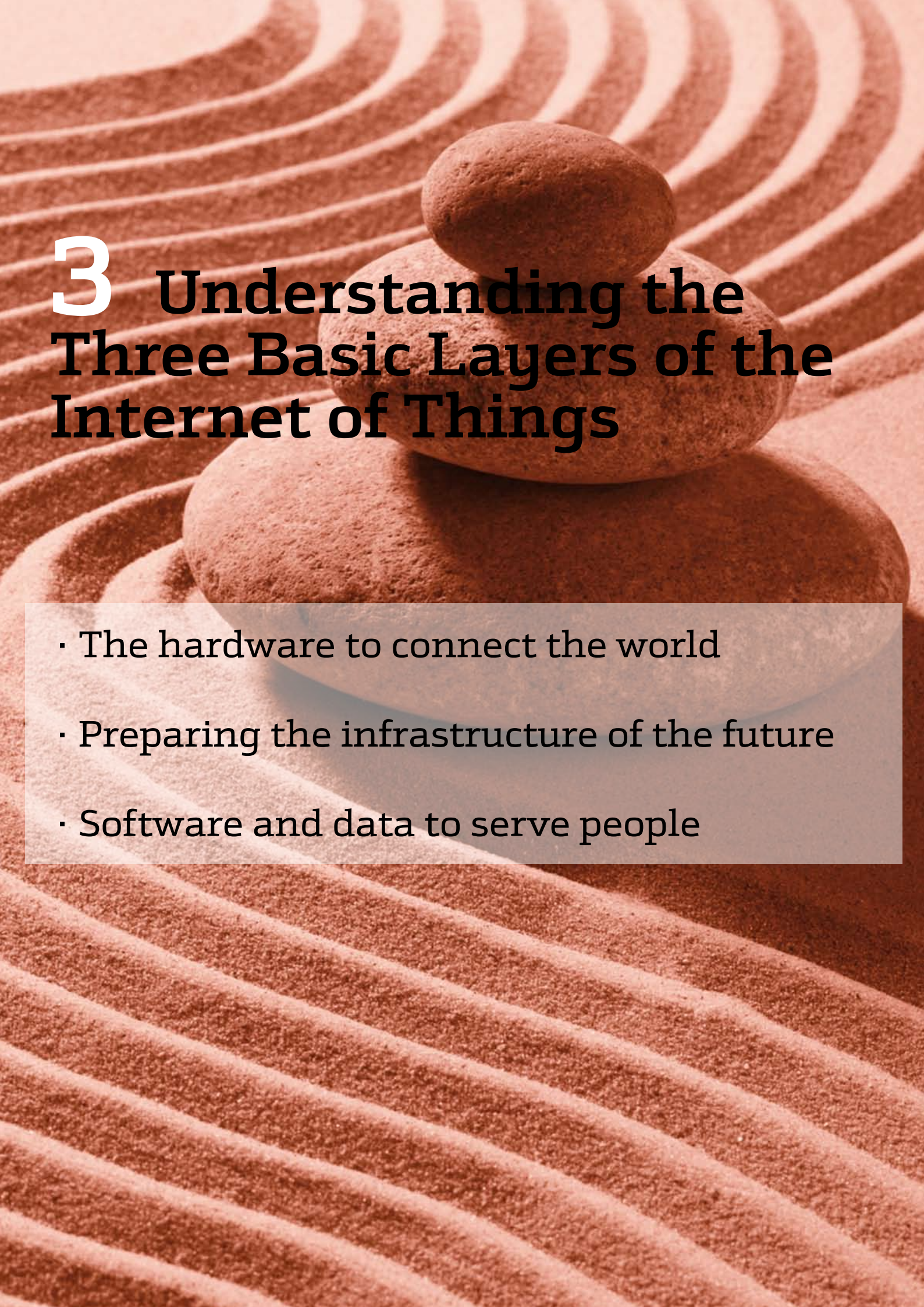
[44] http://www.slideshare.net/ReportLinker/credit-bureaus-rating-agencies-in-the-us-industry-market-research-report

[45] Tim O'Reilly and John Battelle, "Web Squared: Web 2.0 Five Years On", *Web 2.0 Summit*, 2009.

Share your biking experiences with other cyclists who might be interested in your route and any difficulties you experienced. Bikenet is an initiative that allows people to share information on biking routes. The information is automatically uploaded on-line by way of an application comprising a GPS and a speedometer which records the itinerary, average speed and time spent at intersections with traffic.

In short, smartphones are the new paradigm for users to interact with large quantities of information. In Spain, two out of every ten people have a smartphone and the mobile phone industry is very keen to increase this proportion. This explains why the price of smartphones is getting closer and closer to that of a conventional mobile phone. The operators can make back an important part of the full cost of the terminal by way of minimum-term contracts, given that the real money is to be had from monthly voice and data charges[46]. As long as market penetration continues to increase, the way in which the information generated is used to create business value through new applications and services will also increase.

[46] "Hacia el smartphone de 36 euros", *elmundo.com*, http://www.elmundo.es/blogs/elmundo/el-gadgetoblog/2011/02/21/hacia-el-smartphone-de-36-euros.html.



3 Understanding the Three Basic Layers of the Internet of Things

- The hardware to connect the world
- Preparing the infrastructure of the future
- Software and data to serve people

The miniaturisation revolution began many decades ago, but the latest manifestations (at the nano-level and at the molecular-level) are both quantitatively and qualitatively different from what's come before. The large-scale industrialization of sensor technologies and other "hardware" makes IoT possible. But equally important is the software that enables all of the parts to talk to the whole. Increasingly, the hardware and the software will be linked in ways that make them potential indistinguishable from one another.

Alongside the question being considered here ("Is the infrastructure ready?"), there are two other questions that concern network providers, and we must consider their point of view:

- who will pay for the installation of the expensive services and solutions that will allow IoT to flourish?
- which business models will work best?

Mining of the data is one place where the value of the data can be developed and discovered. But there are other roles for software in a world which is increasingly integrating the IoT into our working lives — enabling us to live, work, play and learning in some entirely new and better ways.

Gordon Feller
Director-IBSG, Cisco Systems

Expand the digital territory!

Thanks to the high speed mobile infrastructure, Internet is everywhere now. Ubiquitous environment enables us to be connected all the time as a human being. It made us to create a huge economy so called Internet economy within a decade. On top of the network, we are able to create more valuable solutions utilizing Internet of Things from now on. We can change everything as a product into an intelligent products through the Internet of everything concept. Instead of just a legacy car as a product, we can insert a soul into a car which recognizes his owner or others through the various sensors interconnected via mobile Internet. We can imagine spoon of sensing the degree of the density of salt and warning to the user. Like that, we can insert souls into the every products with sensors eventually connected to the Internet to the cloud computing intelligent management centers.

That means we can expand the territory of the horizon of the Internet and it's utilizations through the Internet of everything for the second generation of Internet economy which could be "Internet economy 2".

Jong Lok Yoon
Bell Labs

Thus far, we have seen how the Internet of Things phenomenon has burst onto the scene, bringing everyday objects to life by connecting them to each other over the Internet and creating inexhaustible sources of information. In order to look at the Internet of Things from a more technical perspective we need to understand the three tiers into which it is currently divided.

The first layer is the hardware. More than half a century on from the days of mainframe computers that took up whole rooms, components are becoming smaller and smaller, enabling faster and more powerful computers to be developed. This physical layer occupies less space, making it easier to connect practically anything, anywhere, anytime. What we are seeing is the phenomenon of miniaturisation. The second tier is infrastructure—or more importantly, its limitations. How will today's technology cope when billions of new devices connect to the IoT? Is the Internet spectrum going to become the fuel of the twenty-first century? Spectrum needs to be dealt with as a limited resource. The third and last tier consists of the applications and services that use the vast quantity of information created by the IoT. This is where the greatest potential for value creation lies. These applications involve creating new business models and very interesting business initiatives in terms of innovation.

These three tiers – hardware miniaturisation, infrastructure needs and the development of innovative software – are essential for understanding the expansion of the Internet of Things into the field of information and communication technology.

3.1. Miniaturisation: the 'Hardware' that Makes IoT Possible

At the beginning of this publication, we talked about sensors as essential enablers of the Internet of Things. Ultimately, they allow everyday objects to interact with computers over the Internet and harvest valuable information on their surroundings. In the not-too-distant future, more information will probably be being generated from these sensors than from computer keyboards. The reason is simple: sensors are getting smaller and smaller, which means that they can more easily be integrated into any object, under any circumstance.

We can identify three different trends that are making this possible: device miniaturisation (a widespread trend at present), the development of new forms of computing (such as DNA computers and quantum computers) and the creation of smart networks of simple elements.

The first trend –miniaturisation– involves technological processes which have allowed electronic devices, including sensors, to be built smaller. Together with nanotechnology, miniaturisation has made it possible to minimize the size of elements such as microprocessors (something akin to the computer's brain) without affecting the speeds at which they operate.

So it seems that Moore's prediction wasn't that far off after all. Remember that in 1975 he postulated that the number of transistors in a printed circuit would double every two years[47], enabling a proliferation of technology around the world. More transistors mean higher computing speeds. Moore also suggested that there would be a reduction in costs, since the performance of silicon-based components used in

[47] http://www.intel.com/pressroom/kits/bios/moore.htm?iid=tech_mooreslaw+body_bio.

Components are becoming smaller and smaller, enabling faster and more powerful computers to be developed

computers would improve as they became more economic to produce and more common in our daily life. Combined with Metcalfe's Law, which states that the value of a telecommunications network is proportional to the square of the number of connected users of the system, "it is clear that all economic and technological drivers point to ubiquitous computing"[48].

However, this reduction in size is not infinite; we shall soon reach the physical limits of silicon-based components. Some experts have sought to overcome this problem by centering their research on "DNA computers" (which use organic molecules to store the basic information and resolve mathematical problems through chemical reactions) and "quantum computers" (which use elements of quantum mechanics to code and process information). The components used in quantum computers will be smaller, and at the same time it will be possible to make vast calculations in a much shorter time[49].

Another area of research in the field of computing follows a different path. Instead of increasing the capacity of a central processor, the idea is to divide processing up between different elements of hardware with "limited intelligence", capable of great things when they act together. Each element will communicate with the others around it using a very basic language. And the experts have a very useful exemplar in nature: ants. These insects look for the shortest route between a source of food and their colony. To do so, they simply follow the pheromone trail left by other ants searching for food. The more ants that follow the same path, the stronger the trail becomes, making the ants more effective as a whole. By means of simple patterns of conduct, the ants are capable of building tremendously complex colonies and filling them with food[50]. Following the example of the ants, scientists are trying to design hardware which, by using simple interactions with other surrounding elements, can build the Internet of Thing's equivalent of complex anthills.

What are these Sensors Capable of Doing?

As the miniaturisation of electronic components progresses, their applications are multiplying. Tiny sensors are increasingly being integrated into the elements around us, connecting the physical and digital worlds. What are the sensors around us capable of doing? In broad terms, these sensors have three major applications.

First, they allow information to be harvested on the host object and its environment for subsequent analysis. For example, insurance firms can use sensor systems to recover information on their clients' driving habits.

Secondly, sensors can trigger an action, allowing certain functions to be automated. This might include setting off an alarm when an unauthorized person is detected in an area or automatically halting a car before it collides with another vehicle.

Finally, sensors will increasingly be traceable at all times, which will expand the range of applications. For example, the location of packages in logistics management systems allows them to be precisely tracked and enables communication with different conveyor belts to determine the destination of the goods. But the applications do not end there. IoT will allow the consumer's habits or the contracting company's decisions to be factored into the process, allowing changes on the hoof to minimize costs, avoid delays or simply, adapt to

[48] http://blogs.orange-business.com/realtimes/technology/future-technologies/building-the-internet-of-things.php.

[49] http://www.muyinteresante.es/icomo-seran-los-ordenadores-cuando-se-llegue-al-limite-de-miniaturizacion.

[50] "Riders on a swarm", *The Economist* (August 2010).

fluctuations in product supply and demand. Independently of the large-scale applications of the sensors, there are two major challenges to developing them: energy consumption and the interoperability of their components.

Sensors consume energy. The smaller they are, the more this consumption becomes a limiting factor. As the size of the sensor diminishes, so too does the size of its power source and consequently its operating time. It is hoped that new components will be capable of generating their own energy. In this way, the sensors will be able to remain autonomously connected to the Internet for longer periods of time. Moreover, "in environments where there will be no fixed access point offering efficient communication for the things, they will form extensive ad-hoc networks routing information towards the infrastructure or their destination node in the formed network. This allows sensors to be placed everywhere, even when the infrastructure is weak or absent, and even if the sensors are mobile" [51].

However, the big challenge to promoting IoT acceptance will not be energy consumption, but the flexibility and modularity of the components to ensure easy integration. If no move is made to promote interoperability between components, large scale acceptance of IoT will face serious obstacles. We shall come back to these and other issues later on.

Internet Zero: the Advantages of Low Speed

As we have seen, advances in technology have allowed the size of the components to be reduced without affecting their speed. However, a low-speed Internet connection isn't necessarily a disadvantage. To understand why this is the case, we need to turn to the concept of "Internet Zero". According to Neil Gershenfeld, director of the Center for Bits and Atoms at the MIT and Future Trends Forum expert, many alternative IoT standards are currently competing to provide everyday objects with the capacity to connect to the Net. This situation is very similar to that seen in the early years of the Internet, when a number of incompatible computers and networks were being created. Internet 0 (Internet Zero) is a system that allows objects to connect to the Internet at low speeds, but at a vastly cheaper rate.

Internet 0 was originally intended to network buildings, improve efficiency, and gather data through the control of HVAC systems (heating, ventilation, and air conditioning). A cheap, low capacity Internet server can be integrated into many devices to allow data to be recovered and monitored over the Internet[52]. The aim is to provide a system that will facilitate wide access to the Net at slow speeds, but without incurring high costs and remaining highly compatible with all types of systems. In this way, it will be possible to build the capacity to connect over the Internet into vast numbers of objects. Gershenfeld says that if home automatics has not progressed as much as anticipated, it is because the construction industry has not realized that as well as an electrical department they also need an IT section. "The cost is not in the devices but in the network, if it has to be rebuilt"[53].

3.2. Is the Infrastructure Ready for IoT? The Point of View of the Operators

According to Paul Jacobs, chairman and CEO of Qualcomm, by 2014, 70% of all electronic consumer devices will be connected to the Internet[54].

[51] Internet of Things in 2020: Roadmap for the Future (September 2008).

[52] http://en.wikipedia.org/wiki/Internet_0.

[53] "El reto del Internet de las Cosas", *El Pais.com* (May 2007), http://www.elpais.com/articulo/portada/reto/Internet/cosas/elpepisupcib/20070517elpcibpor_1/Tes?print=1.

[54] http://www.readwriteweb.com/mobile/2011/02/mobile-phones-will-serve-as-hubs-to-internet-of-things.php.

The capacity of mobile phone infrastructures is limited and the proliferation of smartphones is saturating network capacity. With millions of new devices connected to the Internet, 3-G or LTE[55] technology won't be able to cope, and the combined use of mobile phones, wireless connections and optic fiber will be vitally important in resolving oversaturation of mobile infrastructures. Although the 3-G business is growing, the capacity of the mobile networks is acting as a bottleneck. In this situation, the IoT is finding it hard to cope. A number of measures have therefore been considered to help resolve the issue.

Governments are beginning to call for spectrum-sharing. One trend at the moment is for "WiFi hotspots". These are public areas—in cafes, airports and libraries—where people can, for free or for a small fee, connect their computers, mobile phones and other devices to the Internet. The Chinese government proposes to turn public phone boxes into hotspots and thus turn the country into one giant WiFi network. With a population of 1.3 billion[56], it will be creating a connection platform for an emerging economy that has all the potential to become the new big target of on-line activity.

American president Barack Obama is also aware of the problem of the spectrum and the obstacle it poses for growth in the mobile Internet. He has released 500 megahertz of frequencies formerly reserved to the administration for voice and data transmission because "Spectrum is the oxygen of wireless... Broadband is about investment, innovation, jobs and opportunity, and spectrum is vital infrastructure for broadband".

Why does it represent an opportunity? Spectrum Interactive, the leading supplier of Internet access and wireless services to the catering, travel and media industries, offers a clear example of the opportunities Obama was talking about. As well as offering reliable wireless connection solutions from any location and from Internet booths, the company has also developed a portfolio of very diverse services related to the Internet of Things: IP television, remote tools for monitoring weather conditions (e.g. sea area forecasts) and digital advertising formats that can promote the right product at the right time and place.

To take advantage of these opportunities, the networks of sensors must be open to the wider public. This will mean that many microsuppliers will be able to develop business models based on locally managed networks that capitalize on assets that can be connected to the IoT and meet the needs of millions of consumers. A fragmented market will be created of billions of nodes of sensors integrating the physical world with the digital. This is where the real innovation will come from. And it is important to remember the point we have been stressing throughout this publication on the use of the highly valuable information generated in the process.

3.3. Extracting Value from the Data: the Role of 'Software' in the Internet of Things

In the seventeenth century, the mathematician and engineer Muhammad ibn Muses al-Khwarizmi invented the algorithm, i.e., an ordered and finite set of steps that allows a task to be performed or a problem solved. We have already talked about the vast amount of data that is being generated in the Internet of Things, where any object is capable of transmitting information. New IoT algorithms and

[55] With download speeds of up to 60 Mbps and data deliveries of up to 40 Mbps, LTE technology could become the new standard for high-speed wireless networks and could be added to existing networks without requiring additional infrastructure.

[56] http://geography.about.com/od/populationgeography/a/chinapopulation.htm.

To take advantage of these opportunities, the networks of sensors must be open to the wider public

software need to be developed to allow us to discover and interpret the *totum revolutum* of data around us.

The algorithms have very valuable applications. Used in software applications, they can offer rapid responses to physical phenomena, based on the information collected or patterns in the behavior of certain objects or people. New opportunities are being created to meet business requirements, perform new real-time services, gain insights into complex processes and relationships, handle incidents, address environmental degradation, monitor human activities, improve infrastructure integrity and address energy efficiency issues[57].

The real business value will come from these applications and services using the new information being generated in the Internet of Things. New smart methods for analyzing information will emerge and manual tasks will be replaced by automated systems operating on the basis of this information, making human intervention unnecessary. The development of the best software for this type of task will have to keep pace with the growth in opportunities. Entrepreneurs and existing companies will develop new applications to exploit new information sources and radically change business models.

For example, KIVA Systems is a company that uses automation technology for distribution centers, helping companies to simplify their operations, cut costs and increase flexibility. Their clients include Gap, Staples and Office Depot, which benefit from machines that remove "human error" and use massive data sets, sophisticated sensors and clever algorithms to master logistic tasks[58].

We can also see algorithms being used in the construction of a car-free city at Masdar in Abu Dhabi (United Arab Emirates). The city has a PRT (*personal rapid transit*) monorail of small driverless electric vehicles. The PRT is based on automated inventory systems currently used in large warehouses. Passengers key in their destination and, using algorithms and a magnetic running system, the vehicle takes them there[59]. Imagine the sort of world that would be possible if these algorithms were combined with traffic forecasts and incidents, for example, to manage road lanes.

The Applications Gold Mine

However, data analysis is not the only IoT-related business opportunity the experts see. There is also a real gold mine out there for anyone who develops software capable of collecting, storing, organizing and integrating the information with other data sources or of sending alerts to other programs or humans. Thanks to IoT, the objects themselves, fitted with sensors and actuators, become components of the information systems, capable of capturing and communicating data on a large scale. In some cases, they can automatically adapt to changes in their surroundings. These "smart" assets can make the processes more efficient and provide the products with new capacities. "Only with appropriate software will it be possible that the Internet of Things comes to life as imagined, as an integral part of the Future Internet. It is through software that novel applications and interactions are realized, and that the network with all its resources, devices and distributed services becomes manageable" [60].

One example is crop irrigation using a system made up of buried sensors and control software. Backed by a weather forecast query, the system takes intelligent

[57] *Internet of Things: Strategic Research Roadmap* (September 2009), http://www.internet-of-things-research.eu/pdf/IoT_Cluster_Strategic_Research_Agenda_2009.pdf.

[58] Steven Levy, "The AI Revolution is On" (January 2011) http://m.wired.com/magazine/2010/12/ff_ai_essay_airevolution/.

[59] *The Internet of Things: Vehicles as networked objects,* The Hammersmith Group, 2009, http://www.thehammersmithgroup.com/images/reports/networked_vehicles.pdf.

[60] *Internet of Things: Strategic Research Roadmap* (September 2009), http://www.internet-of-things-research.eu/pdf/IoT_Cluster_Strategic_Research_Agenda_2009.pdf.

decisions based on the level of moisture in the soil and the likelihood of rainfall. This technology is more common in arable farming, but applications already exist for residential and commercial gardening[61].

IoT software is also being used to manage shops. For some years, Wal-Mart has been working with Auto-ID Center, a non-profit research organization with head offices at the MIT, to develop RFID technology that allows companies to monitor their products and see how many units there are on each shelf unit. The RFID readers check the inventory, reporting on needs throughout the whole distribution chain—even to the store manager—via in-shop software.

[61] http://www.scribd.com/doc/13744808/Disruptive-Technologies-Global-Trends-2025-The-Internet-of-Things.

4 The Impact of the Internet of Things on Business and Society

- Ubiquitous services for connected consumers
- Open source and collaborative business models
- The optimisation of things: towards a truly sustainable development

With the Internet of Everything, it will possible for everybody and everything to be connected at all times, receiving and processing information in real time. The result will be new ways of making decisions, backed by the availability of information. The option of being online and traceable at all times has also led to the emergence of a new generation of consumers, who demand new products and services based on ubiquity and interconnection. These shifts in production and consumption patterns are changing the relations between all the agents in the system. There is a whole host of new opportunities to design and offer new products and services and make more efficient use of existing assets, creating a fertile ground for entrepreneurs.

The dynamic of change of the technologies involved in the Internet of Everything is particularly interesting. In many fields, successful new solutions will turn their backs on traditional models of evolution, based on standards set out by large corporations or supranational bodies. Instead, they will consist of "cheap hacks" promoted by entrepreneurs who are capable of identifying efficient problem-solving alternatives and distributing them efficiently thanks to permanent and ubiquitous connectivity, enabling collaboration and interaction between the different agents across the network. Initiatives don't have to involve an economic incentive. Often, a mere willingness to share combined with a feeling that technical discovery should be a public domain value are enabling developments to be introduced at previously unheard-of speeds. Once again, entrepreneurs have an essential role in accelerating the process of change.

In all their debates, the *Future Trends Forum* experts pay particular attention to the social dimension of the technologies they are analysing. As consumers become aware of the opportunities provided by the Internet of Everything their service expectations will change, their shopping criteria will evolve and they will have ever more power in their relations with providers of goods and services. IoT will also allow people to play a more active role as agents of production, enabling businesses to develop by sharing existing resources. This will further blur the distinction between producers and consumers. The Internet of Everything offers us all the opportunity to be entrepreneurs.

Juan José González
CSO, Indra

Internet has become an essential figure in the global economy. More than one billion users around the world use it for working and socialising. Wireless technology has taken everything one step further, making it possible to interact with the Internet anywhere, any time. This has meant opening up a platform of new ubiquity-based products and services, with a high degree of innovation. Some experts, however, feel that the Internet of Things is predominantly an academic concept rather than a real response to an unsatisfied market need. Nonetheless, they also accept that it marks a breakthrough, with strong potential to have a major impact on society and business[62].

It is worthwhile looking at the way the Internet of Things is changing the terrain of business models. In all their debates, FTF experts try to take a business angle on the trends they are discussing. In a process as revolutionary as IoT, they see the intervention of all groups in society as being crucial, particularly value creation by entrepreneurs. While it is true that the foundations of the technological infrastructure tend to be laid by large companies, it is entrepreneurs who are the transforming agents in our society, promoting and driving the most innovating trends. They are capable of translating costs into value creation.

As we shall see, however, a new group of agents has emerged as the promoters of IoT initiatives. Their collaboration and interaction through the Internet is another key piece in understanding the importance being assumed by IoT. Peer-to-peer information and social networks are examples of how individual effort has the potential to become a platform that is open to billions of people. New initiatives no longer require an economic incentive to take off. Just the fact that people want to share technical discoveries and see them as a public-domain value means that the IoT will take on social dimensions rarely seen before — though increasingly frequent.

In this chapter we are going to examine three aspects of IoT that are worth highlighting from a social and economic perspective: its direct impact on people, the trend towards increasingly open and collaborative business models, and the profound change it can bring in the way scarce resources are utilised.

4.1. Connected Consumers: IoT's Impact on People

Throughout this publication we have used the term "ubiquitous" to refer to situations in which previous limitations of time and space are overcome and the digital and real worlds become blurred, allowing computing to be integrated into the individual's surroundings. Future Trends Forum expert Emily Green prefers the term *Anywhere* (also the title of her book on the subject). It is the "future in which not just all of us, but the things we care about, will be connected through a fabric of global networks that we expect to be as fluid, far-reaching and safe as we need it to be".

As a result, a sort of contradiction emerges whereby our location is both irrelevant and essential at the same time. It is irrelevant because to remain connected it matters less and less where we are. Neil Gershenfeld's answer when asked "Where are you located?" is "Yes": what is important is not the exact location of a person or object, but whether or not they can be located. All thanks to the ubiquity of the Internet. And it is essential, because our location is a factor that contributes

[62] "What is the Real Business Case for the "Internet of Things"", http://www.itsc.org.sg/pdf/synthesis08/Five_Internet.pdf.

The possibility of checking product characteristics, performance and ratings gives consumers unprecedented power

greater value to the information we are generating around objects in our everyday life. And once again, it's all thanks to the ubiquity of the Internet.

As part of this possibility of being permanently connected and traceable (who has never said, "I don't know how I used to manage without a mobile"?), a new generation of consumers is emerging, in close association with the emergence of mobile broadband. This segment expects —and indeed demands— that the Internet should facilitate everything they want to do and they should be connected wherever they are. They almost take a wireless connection for granted (and any other technical advance that facilitates mobility). In other words, the Internet of Things covers everything that can satisfy their needs.

In many cases, all the manufacturers have to do is reinvent existing objects to make them more useful through Internet connectivity. For example, a box of pills is an everyday object which, if fitted with an Internet connection, can tell the user, their family or their doctors when it's been opened or closed and thus monitor the patient's doses. It is particularly useful for monitoring chronic diseases, such as diabetes and high blood pressure. When launching this product on the market, the inventor did the right thing by partnering with the pharmaceutical companies — who obviously have a strong incentive to ensure that patients take their medication regularly.

Another device now on the market is the Chumby, which is something along the lines of a 2.0 bedside clock. It consists of a touch screen with a wireless Internet connection for accessing a whole host of applications including weather forecasts, social networks, chats, on-line shopping, videos, etc. The secret? It is totally customised to each user's interests and hobbies. All of this is creating new paths to consumers. The way the Internet is applied to everyday objects will be very similar to the time around a century ago when the first electrical versions of many household objects began to appear — such as the washing machine, coffee maker, liquidiser, etc.— all of which had previously existed in hand-operated versions.

Paradoxically, surveys by the Yankee Group[63] show that while consumers don't have a clear idea which home devices can be connected to the Internet, they do think it is very important for the items they plan to buy in the future to be connectable. In a way, you could say that consumers can already see how important connectivity will be, and are not prepared to do without it.

There are also profound changes in the way consumers behave when it comes to using technology for shopping. In just three months in 2010, the proportion of consumers using their smartphones to compare prices and check product reviews on-line before buying rose by eight percentage points[64]. What's more, the majority took some form of purchase decision based on the information — either going to another shop where the item was cheaper, asking the shop assistant to match another offer or simply deciding not to buy the product.

However they go about it, the possibility of checking product characteristics, performance and ratings gives consumers unprecedented power. Market comparisons help lower prices and, above all, make consumers better informed and more active. It has become commonplace for consumers to generate content and interact with other buyers on-line to share their impressions of different products. Forums are a good starting point for people wanting information about their purchases. They look for information on a new neighbourhood when buying

[63] http://www.fundacionbankinter.org/es/videos/what-is-anywhere.

[64] http://www.fundacionbankinter.org/es/videos/what-is-anywhere.

a house, on the way electronic devices work and on the restaurants with the best service. Aggregate figures based on first-hand experiences —the information most highly valued by consumers— can be accessed at the click of a mouse.

In short, the development of the Internet of Things is making consumers more and more demanding. Being more connected and more traceable allows greater personalization of the services and objects around us, as well as greater access to information when it comes to making decisions.

4.2. Towards a New, More Collaborative Business Model

In terms of business models, the emergence of permanently-connected objects is helping create open, collaborative models in the physical world, similar to the open source models to be seen in the software world.

Google and Microsoft are two of the market leaders in developing software: Google is world-famous for its search engine and Microsoft has made Windows the most popular operating system in the world. So if each of them has been so successful in its own way, why is Microsoft afraid of Google? The answer is simple: whereas Microsoft limits itself to selling software and applications (i.e., products), Google has focused on selling services. Indeed, Google offers all its products free of charge, a model that is more popular among users who don't want to have to pay to use applications for short periods of time. These applications rapidly become obsolete or are improved on by the users themselves. The open-source movement is based on the premise that by openly sharing program source codes, the improvements contributed by third-party users create an infinitely better program. With backing from companies such as Sun, open-source is helping introduce more open and collaborative business models.

This happens because there are things in a business that don't change very often. Petrol stations sell petrol, restaurants sell food from a menu and dentists sell teeth-cleaning[65]. That's not going to change. These are the core functions on which the business bases its activity, the *raison d'être* of the company. However, there is another set of factors that can change frequently: prices, tax rates, new products, marketing campaigns and business units. Businesses have to be capable of changing quickly to adapt, without adversely affecting the core business functions. Software developers are well aware of this and know how to distinguish between elements that change frequently and those that remain the same. When this practice is applied to a company's information management, it is called "service-oriented architecture" (SOA). In other words, SOA consists of isolating core business functions in independent services that don't change frequently.

Many companies are jumping on the 2.0 and social network bandwagons. Their aim is clear: to get closer to consumers and discover new lines of business. However, smart business means taking network interaction to its logical conclusion. In other words, a business with no formal hierarchy run by motivated people working together. The best example is *Wikipedia*, which shows that companies can tap into specialist knowledge by handing over control of the product's content to contributors and participants (providers, customers, intermediaries, etc.).

ABB, a global leader in electro-technical and automation technologies, is exploring the idea of creating communities of collaborating devices by connecting smart

[65] http://blog.objectmentor.com/articles/2007/04/11/what-is-soa-really.

devices to a social network. These devices will be capable of personifying a piece of equipment or system, thus enabling it to interact with end users and technical experts, and generate contents of value to a community. The traditional approach to troubleshooting separates the interaction between technical support and the end user from the diagnostics performed by the service engineer. Using the connectivity already established for remote services, this device allows problems to be solved quickly and accurately. In addition, diagnostic approaches are captured and readily available for reuse[66].

This trend towards increasingly open and collaborative approaches proves beyond doubt that new business models are not always driven by economic incentives. Collaborative innovation has the potential to go beyond new products and services to discover, design and develop ubiquitous systems in which innovation comes above all else.

4.3. The Optimisation of Things

There is growing concern today about sustainable development, motivated by a shortage of resources. This situation has been made worse by climate change, an increase in the percentage of the population living in urban areas and the fact that developing countries are progressively adopting the production and consumption patterns of developed nations[67]. In this context, the challenge for the twenty-first century is to develop advances that will halt unchecked consumption of natural resources and energy.

It is no coincidence that the optimisation of resource consumption is one of the most promising fields for the Internet of Things. Sensors and automatic control systems integrated into the objects around us enable us to measure different variables that can lead to a change in usage patterns of scarce resources. For example, Pacific Gas and Electric (PG&E) is introducing "smart" meters providing real-time information on gas and electricity consumption and their associated costs in American homes. Consumers can see that the cost of producing energy does not remain constant throughout the day, and can alter their consumption habits to cut their bills. PG&E also has industrial customers who can plan their energy-intensive processes for times with lower rates.

There is a paradoxical vicious circle here: while the application of IoT in smart networks allows more sensible energy consumption, the information and communication technology (ICT) industry itself is a growing energy consumer. The Technical University of Dresden calculates that 3% of global power consumption currently goes on server farms and telecommunications infrastructures. By 2030 world electricity consumption is expected to have doubled, partly as a result of the exponential increase in ICT consumption.

As well as smart power grids, other applications based around more responsible consumption are emerging in water management, smart transport and traffic control, waste and recycling management, building design, etc. It should come as no surprise that Hewlett Packard has developed a platform, called CeNSE (Central Nervous System for the Earth), which seeks to create a global network of billions of sensors measuring objects and people. The aim is to harvest information on variables such as location, temperature, pressure, sound, light, humidity and many others. Part of the challenge is to make the sensors not only small and resistant, but also as cheap as possible.

[66] The Internet of Things Meets The Internet of People, Harbor Research (2010) http://www.scribd.com/doc/35371822/Harbor-Research-Internet-of-Things-Meets-Internet-of-People.

[67] See the eleventh report of the Fundación de la Innovación Bankinter, *Competing in Challenging Times: New Rules and the Role of Innovation*, http://www.fundacionbankinter.org/es/publications/competing-in-challenging-times.

The challenge for the twenty-first century is to develop advances that will halt unchecked consumption of natural resources and energy

As we said, all this information is essential for allowing people to make better consumption choices. RFID tags make an important contribution in this respect, enabling buyers to have all the information they need literally at their fingertips. Imagine a supermarket product with an RFID tag that could tell you when it was produced, when it was packaged, how long it took to get to the supermarket, whether the temperature during the journey was optimal, historical prices of the product, etc.[68] Another example is Zipcar, where vehicles are shared by a group of customers who see a clear benefit in not having to buy and maintain their own car, instead using them for specific hours or days. This is what Robin Chase, co-founder of Zipcar and Future Trends Forum expert calls "collaborative consumption". It consists of an infrastructure built on the basis of individual demands, i.e., a business model that explores consumers' needs through economies of scale because on their own they are powerless, but in collaboration with others they have huge potential.

Similarly, but as a non-profit organisation, Couch Surfing is an international network that connects travellers who need a place to sleep to people living in over 240 countries around the world. The system functions thanks to the hospitality and donations of its participants, who get an opportunity to meet people from around the world and share experiences with them. You couldn't be blamed for being doubtful about the system - but what if we told you that part of the collaboration consists of sharing information about the participants and making recommendations about them? Would that change your mind? The participants are the people most interested in creating a safe network. Still don't trust it? What if we told you there are over 1.2 million beds and 4.8 million positively-rated experiences[69]? The most important thing is that in seven years in existence, this initiative has achieved what hotel groups have taken decades to develop. In this case they're optimising the use of what Robin Chase calls "excess capacity ", in other words, the sort of unused assets we all have (e.g. a spare bed), to create new business models that soon triumph on the market.

Finally, it's worth mentioning Sourcemap, a social network and free tool that can be used to get information on the origin of everyday objects in order to make sustainable consumption choices. Did you know that the components of a laptop computer include copper, tin, lithium, rhodium and indium? Some of them are processed by hand by families in developing countries; others are thought to be likely to run out in under ten years. The founders of Sourcemap stress the importance of knowing where things come from — and laptops are just a case in point. This is one way we can avoid disproportionate consumption of essential and endangered materials.

You might well think that suitable alternatives will be found before the necessary materials run out, for laptops, for example. But just think of the other end of the life cycle, when they are decommissioned and broken up. Laptops tend to end up in countries with lax environmental controls, where they are cannibalised for materials that are then used to make new objects. The problem arises when these new objects are, for example, toys. We've already seen market recalls of toys that contained hazardous substances because they were being manufactured in countries that didn't have the necessary checks. Once again, not knowing where things come from can have serious consequences.

Hence the Sourcemap initiative, which aims to bring back transparency throughout the supply chain. Volunteers from around the world investigate the

[68] http://www.readwriteweb.com/archives/top_5_web_trends_of_2009_internet_of_things.php.

[69] http://www.couchsurfing.org/index.html.

origin of things because the companies themselves are often not entirely aware of where the things they sell come from. From Ikea furniture to paper coffee cups by way of pork products, all the examples have been researched by consumers interested in tracing the route from point of manufacture to the consumer's shopping trolley across the globe.

In short, global collaboration by consumers helps spread information that can improve quality of life and reduce the environmental impact of our habits. The Internet of Things is just the technology that allows valuable information to be monitored and compiled about objects with smart sensors and devices. It's another example of the way in which technological innovation is being used to help offset the adverse effects of our way of life on the environment.

Illustration 7: Origin of an Ikea bed.
Source: Sourcemap.com.

5 Key Factors in the Future of the Internet of Things

- Chief obstacles to the Internet of Things
- The players and their commitment with the future

The Internet of Things will be the most complex structure mankind has ever created. In a generation, there will likely be a trillion nodes measuring anything on Earth that can be measured, and with the insights culled from that data, we'll control every aspect of our built world.

The idea that we can plan a lot of this up front –getting the standards, rules and applications right before we get too far into it– is an opportunity for an enormous case of the computer architect's version of writers block. Or, it's hubris. Or, it's both.

And yet we have a lot of experience with how complex and messy structures get designed and built. So what can we learn from what's come before and how might that guide us?

1. **Who architects all this?** Much of the conversation at our Foundation meeting was over IoT design: would it be top down (orderly, integrated, as befits a giant corporation or China) or bottoms up (messy, innovative, the work of brilliant hacks, but how could it all work as a system?) Many at the meeting fell into one or another camp. Is such tension warranted?

   History tells us that some of our most complex and workable structures are not large integrated networks but actually many heterogeneous networks, which adapt and learn. Planning is more a systematic application of what's learned than an act of preordination. Cities and the Internet are both examples of this and also two of mankind's greatest achievements. And with today's global innovation communities and crowdsourcing it's a good bet that some of the most valuable and enduring ideas will come as an unplanned surprise.

2. **The Internet of Things is political.** This is sorcerer's apprentice stuff that will affect all our lives –with vast social, economic and privacy implications. So it had better be built inclusively or its benefits might be outweighed by fear.

   America's founding fathers didn't proscribe how the country should be run for the next 200 years; they designed mechanisms for participation and voicing competing interests. With the IoT there is a similar opportunity for flexible governance. Here's an early example cited in this chapter: SmartMeter energy monitoring technology deployed by a California utility was resisted by customers who saw it as a lack of control and act of surveillance. Yet similar technology which lets customers discover how to save energy individually and as a community, even as a form of game, is not seen as intrusive. Likewise, the Open Data movement in cities engages community groups, journalists and hackers with sensors and data – building support and new ideas for urban solutions.

3. **No one knows what the IoT's killer app will be.** We're first going to instrument the obvious things (the same things we measured in the 20th Century): energy, transportation and industrial processes. Yet the most profound applications of the Intent of Things don't exist today and probably wouldn't make a lot of sense to us if they did.

   The first time I heard MIT put sensors on pieces of trash to see where they went, I thought, "That's silly. They instrumented garbage. Why would they do that? Maybe it's an art project". In fact, TrashTrack revealed nuances of the reverse supply chain that no one had seen before, and commanded the attention of government and industry.

So as you hear about IoT apps that seem goofy, annoying or trivial, pay attention. Someone is seeing something new! And in that nugget may lay a pointer to the future

Peter Peter Hirshberg
CEO of The Reimagine Group and former president of Technorati

There are estimated to be 50 billion operating machines worldwide and the number of M2M lines is expected to top 186 million in 2012[70]. In other words, given that there are six billion people in the world with communication needs, the possibility of using connections between machines capable of talking to each other is particularly appealing. It is clear that there are more and more machine-controlled applications that go unnoticed but which are helping cut costs and optimise systems.

As these figures start to increase exponentially, one can imagine an automated world with no calculation errors, in which all incidents are solved in seconds. In the event of a two-car traffic accident, for example, the surveillance cameras would detect the incident and while the medical service protocol was being implemented, the traffic lights would be set to reroute traffic. Add to this scenario the omnipresence of the Internet and the constant circulation of information (a text message would be automatically sent to the insurance company to file an accident report), and you begin to see a future in which functionality and immediacy will be at a premium.

So what could possibly go wrong in this ideal world? Is this just another of those trends that might end up transforming our way of life forever... or end up in the rubbish bin? In this chapter we will examine the factors that will shape IoT, including those that will determine whether it is universally adopted and some aspects that may slow up the process.

5.1. The Internet of 'What'? Chief Obstacles to the Internet of Things

The two main obstacles to the adoption of the Internet of Things are similar to those encountered in the past by other technological developments affecting people's day-to-day life: issues surrounding the privacy and security of the new solutions, and the problem of achieving globally accepted standards. Other concerns that threaten to halt take-off are the limitations of the current infrastructure; a lack of interoperability between different systems; the size of the investment required in the equipment and psychological barriers. The Future Trends Forum experts consider that the great majority of the factors identified as challenges to the adoption of the Internet of Things are significant, rating them at over 3 on a scale of 1 to 5. The list was headed by privacy and security issues, with a score of 4 (See Illustration 8).

We shall now look at these and other obstacles to large-scale acceptance of the Internet of Things.

Nightmare in Bakersfield

The city of Bakersfield, in northern Los Angeles, witnessed one of the most negative sides to IoT when Pacific Gas & Electric rolled out a massive smart grid for homes in the area. As part of the project, the homes were fitted with "smart" meters. Unlike traditional devices, these could be read remotely, doing away with the estimated meter readings and bills that so irritate users. And in the event of a power cut, the utility could even reconnect the power faster, remotely.

[70] Silicom.com: "Mobile M2M connections on the up" (May 2008) http://networks.silicon.com/mobile/0,39024665,39213366,00.htm.

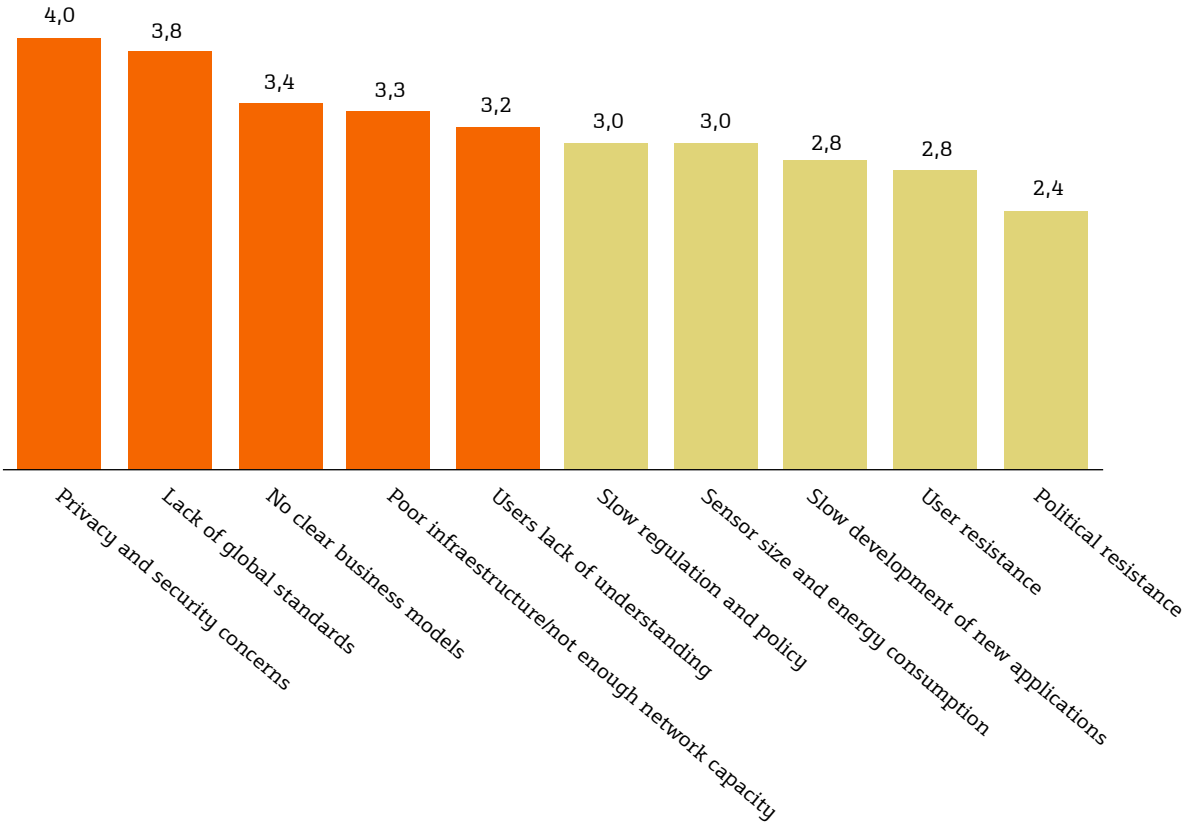


Illustration 8: Assessment of factors on a scale of 1 to 5 (1= insignificant; 5= very important) as challenges to the adoption of the Internet of Things.
Source: Authors.

The residents of Bakersfield soon received their first bills... and a high-profile protest campaign began. For some, costs had nearly trebled. The company claimed that the disproportionate increase was due to a heat wave and the fact that consumers had made no effort to adapt their consumption to times with lower rates (e.g. at night)[71]. Whatever the reason, the incident has put a damper on the initial excitement of signing up to the smart grid and may represent an obstacle in the mind of other consumers when it comes to adopting IoT-related technologies.

The lesson is that in order to avoid situations like Bakersfield, it is important to manage customer expectations on IoT applications. In this case, consumers should have been made aware that the change would also require an effort on their part. The ideal thing would have been to complement the grid roll-out with the installation of home control panels providing real-time information on consumption and costs. Opower, an American start-up has already turned to "social engineering" to achieve customer engagement by offering consumers data on their own consumption and also their neighbours' (anonymised) to encourage energy saving[72]. Its analytical tool is capable of extracting and comparing the habits of a community, processing millions of power consumption readings every hour. The domestic appliance manufacturers General Electric and Whirlpool have also come under pressure to develop smart versions that monitor customer consumption in this way.

[71] PG&E smart meter problem a PR nightmare (November 2009) http://www.smartmeters.com/the-news/690-pgae-smart-meter-problem-a-pr-nightmare.html

[72] Sensors and Sensibilities (November 2010) http://www.economist.com/node/17388338

It is important to manage customer expectations on IoT applications

Big Brother 2.0

Who would want to get on a plane piloted only by a machine, with no human intervention whatsoever? We don't feel secure about artificial intelligence, finding it difficult to hand over control to automatic processes. There is still a long way to go before a computer can pass the Turing test — in other words, before it is capable of demonstrating its intelligence scientifically. In the Turing test, using a series of written questions, a judge in one room has to determine whether the intelligence on the other side of the wall belongs to a person or a machine. Turing's thesis is that if both players are sufficiently intelligent the judge will not be able to distinguish between the two. To date, no machine has been capable of passing the test.

In October 2008, European ministers responsible for the area of Information Technology, conscious of this psychological barrier and the need to guarantee maximum security, discussed the challenges to privacy and security involved in the move to IoT[73]. Vast quantities of information will be transferred and made available to many people. Unauthorised personnel will be able to access data and extract information on user profiles for commercial or even criminal purposes. Did you know that Google is developing FBI-type facial recognition technology[74]? All you'll have to do is upload a photo of a person on the street and match it with information available on the Internet, such as a Facebook account.

Moreover, technological developments make it possible for objects —and therefore their owners— to be located. Some Japanese parents, concerned for the safety of their children, have had no hesitation about planting RFID tags in their school bags to receive text messages on their whereabouts. At the other extreme, almost 250,000 users in Germany have already asked Google Street View (a map service with real photographs of streets and buildings) to blur the image of their houses under draft legislation that will toughen up privacy regulations[75]. Innovation or violation of privacy... Has Orwell's dystopia come true?

Communication Breakdown

Contrary to what you might think, the sensors commonly used to make our cities "smarter" often operate on fragmented and incompatible systems, hindering interaction. If they don't operate on the same infrastructure, it is difficult for them to share data and launch automated processes. Take for example the electronic devices in a car, ranging from the low wheel pressure light on the dashboard to the rain-activated windscreen wipers. Because the makers' market is so fragmented, there is no industry standard and as a result, companies reprogram the way these devices operate every time a new car is designed — even when it is made by the same firm. Incompatibility is also a feature of the electric car market. With no consensus, each manufacturer is designing their own charging system — and they don't "talk" to each other.

Everything appears to indicate that the great competition of the twenty-first century will be to design the operating system that controls all mechanisms — just like the battle between Microsoft and Apple to create the definitive operating system for personal computers. According to the FTF experts, in order to reduce fragmentation, it will be necessary to start by identifying "winners" and ensuring that a majority accept the *de facto* standard solution. They feel it would be counterproductive to try to pre-establish a standard, given that it is practically

[73] http://www.euractiv.com/en/infosociety/internet-things-prompts-eu-push-privacy-rights/article-176075.

[74] http://www.dailymail.co.uk/sciencetech/article-1280145/Google-facial-recognition-debate-goggles-privacy-controversy.html.

[75] Sensors and Sensibilities (November 2010) http://www.economist.com/node/17388338.

impossible to commercialise an innovative product from scratch without requiring adaptations. They cite the example of mobile communications, where it takes about seven years for an idea to go from conception to consumer acceptance of the standard — a considerable length of time.

Until the standard is decided upon, a temporary solution has been found to the problem of interoperability. Under the open source concept, the source code of a program is made readily available to everyone, as a more collaborative method of developing applications[76]. However, an open and ubiquitous operating system is not a permanent solution. Some applications, for example, may have weapons-related applications: Talon robots, for instance, were designed to defuse explosives in war situations. If their source code were programmed through collaboration, it would be extremely vulnerable to hacking. Just ask the nuclear power stations, power facilities and oil pipelines attacked in September 2010 by the Stuxnet worm which threatened to take control of their processes.

Catch-22

As we saw in Chapter 2, sensors can be fitted in everyday objects to measure values such as temperature and motion and send this information over the Internet. Although the sensors themselves are certainly getting cheaper and cheaper, many of the complementary tools and equipment required to use them involves large investment. Unless there is an industrial application, such devices are not particularly profitable at a personal or residential level.

The same is true of RFID tags. Manufacturers of consumer goods that could benefit from these tags are waiting for there to be sufficient RFID readers on the market. And vice-versa: reader manufacturers don't want to increase output until a critical mass of products is reached with integrated tags[77]. This Catch-22 situation influences the acceptance of standards. Deciding on the rules too early in the game can hinder innovation, but an absence of any rules discourages investors from putting their money into the technology for fear of possible changes in regulations.

Nonetheless, some Future Trends Forum experts say that standards are urgently needed to make up for the absence of legislation with regard to the vast amount of information that is about to start being accumulated. Aspects such as data retention and data security have already become an industry in themselves; in 2009, it was worth around $4.6 billion — but is that enough given the growth in IoT?[78].

Bottleneck

Computers and other pieces of equipment connect to each other over the Internet using their respective IP addresses. Under the IPv4 version currently in use, there is only room for around 4.3 billion addresses. With almost a third of the world's population (two billion people) now online, there is not much room left to continue connecting all the objects in the Internet of Things. This bottleneck in our infrastructures will be solved in the latest iteration of the protocol (Ipv6), which will allow around 340 *trillion trillion trillion* IP addresses — "more than enough for everything on the planet and the rest of the solar system as well[79]". However, it will all depend on how quickly IPv6 is adopted. On June 8th, 2011, Google, Facebook and Yahoo, among others, will run a 24-hour simulation, offering their content in IPv6.

[76] Cloud Computing: the Third Wave of Information Technology, *Future Trends Forum* de la Fundación de la Innovación Bankinter.

[77] The Difference Engine: Chattering objects, The Economist (August 2010) http://www.economist.com/node/21009505.

[78] The Digital Universe Decade – Are You Ready? IDC (May 2010) http://www.ifap.ru/pr/2010/n100507a.pdf

[79] The Difference Engine: Chattering objects, The Economist (August 2010) http://www.economist.com/node/21009505.

The other side of the coin is not free from problems either. As capacity issues are overcome, an increasingly interconnected system will be built up, in which any fault could have a domino effect. Are we ready to entrust machines with tasks related to our health and the general running of our homes, with all the risk of system failure, cyber attack or natural disaster? And of course there are still places where Internet connectivity is still very deficient or even non-existent. Some Future Trends Forum experts believe that with the Internet of Things we are trying to run before we can walk.

Another problem that needs to be addressed is information overload. As we mentioned at the beginning of this publication, integration of sensors into everyday objects means that the amount of information available around the world is becoming increasingly difficult to handle. How will we find the information we need, when we need it? There is still a potential gold mine out there for businesses offering Internet data structuring and management. Proof of this is the proliferation in the number of websites selling more refined and exclusive content, thus avoiding a flood of Google hits.

Unnecessary Solutions for Simple Problems?

Stop for a moment to consider. Umbrellas with handles that change colour depending on the weather forecast? Smartphones that tell you the ratio of women to men in a bar? Devices that warn you when a baby's nappy needs changing? All scientific marvels which –fortunately– also have a much simpler solution. A lot of developments involve simply redefining existing objects, and the technology seems to be driven more by a large supply than by demand. The umbrella that flashes when it's going to rain thanks to a wireless connection with a meteorological portal costs around €100. Is it really worth it just to avoid having to put your hand out the window?

Some experts consider that fields such as healthcare can benefit from IoT. A device with a glucose sensor that releases insulin could save diabetics having to visit overstretched medical centres. However, many IoT applications are targeted at older people – who are precisely the age group most resistant to technology. And growing automation of services is bad for employment in the one industry that sustains most of the world's developed economies. Customer care is the keystone of societies like America. Do we really want to reduce human contact even further? After all, it's already annoying enough to be answered by an automatic voice system with an infinite loop of questions.

Some experts wondered whether our homes would be a future battlefield for the big corporations. Adrian Wooldridge, Future Trends Forum expert, explained that "people long for simplicity: they want a single bill, a single supplier, a single integrated solution". He thinks that companies that can provide a wide variety of Internet services have the chance to take control of everything we need to run our homes, from the grid connection to our heating and watering our gardens.

5.2. Who, Where and How Will Win the Game?

This new world of possibilities raises a host of questions about the future. There may be great potential, but there are many unknowns too. We shall focus on three essential and closely-related, themes.

Information overload is another problem that needs to be addressed

Firstly, there is the doubt as to who will lead the process of change. Will it be government? Big business? Entrepreneurs? Or will it be the consumers? They all have the credentials to lead change.

Secondly, we consider what regions we should be looking at. America and Europe have traditionally been seen as the driving forces, but China and, in certain sectors, other regions of the world, are coming up strong.

And finally, there is a discussion underway at to the best way of promoting the Internet of Things. The FTF experts argued that there are two ways innovation will be promoted in the private sector: a top-down initiative led by large corporations and a bottom-up drive by entrepreneurs and consumers. In the public sphere, the big issue is the most suitable approach: open and collaborative systems, or directed systems?

The Agents of Change

What is the fastest-growing democracy in the world? The answer is Facebook, with its 600 million users voting each day on their likes and dislikes. A few decades ago, many experts predicted that multinationals would wrest power from states as organs of government. Just as that idea now belongs more to the realm of science fiction, social networks seem unlikely to become constituent assemblies. Nonetheless, most of the Future Trends Forum experts agree that governments are not in a position to undertake all the regulations needed to run the new ecosystem of the Internet of Things. Quick turnover among political leaders prevents any long-term consideration of a country's development, while bureaucracy tends to get in the way of any agreement on standards.

Government continues to have a key part to play in innovation, but its role will be more one of leadership than control. The state can direct the establishment of common standards which, from a technical perspective, guarantee aspects such as the interoperability of the systems and the individual rights of the participants. Some experts argue that standards such as Apple and Microsoft were not the fruit of government imposition, but of radically new models that ended up becoming the market standard because they were widely adopted as such. The FTF experts talk about the need to focus on "what the consumer wants". And that is precisely what makes Apple different to other smartphone manufacturers: it has made a business out of understanding what the consumer wants. Indeed, the experts think that the second most important group in promoting the Internet of Things —after entrepreneurs, of course— are the industry's primary consumers (see Illustration 9).

Nonetheless, there are many companies other than Apple, especially in the supplies area, with smart-grid initiatives, who are finding it difficult to align their profit-maximisation targets with a reduction in consumption in the context of smarter and more efficient cities. What incentive do companies have to promote energy saving other than complying with a government regulation? And what chances do governments have of establishing such regulations given all the stakeholders involved?

Many companies prefer to see the state not so much as a market regulator, but more as a client for RFID applications in national identity cards and passports or vehicles run by alternative energy. The use of new technologies will revolutionise

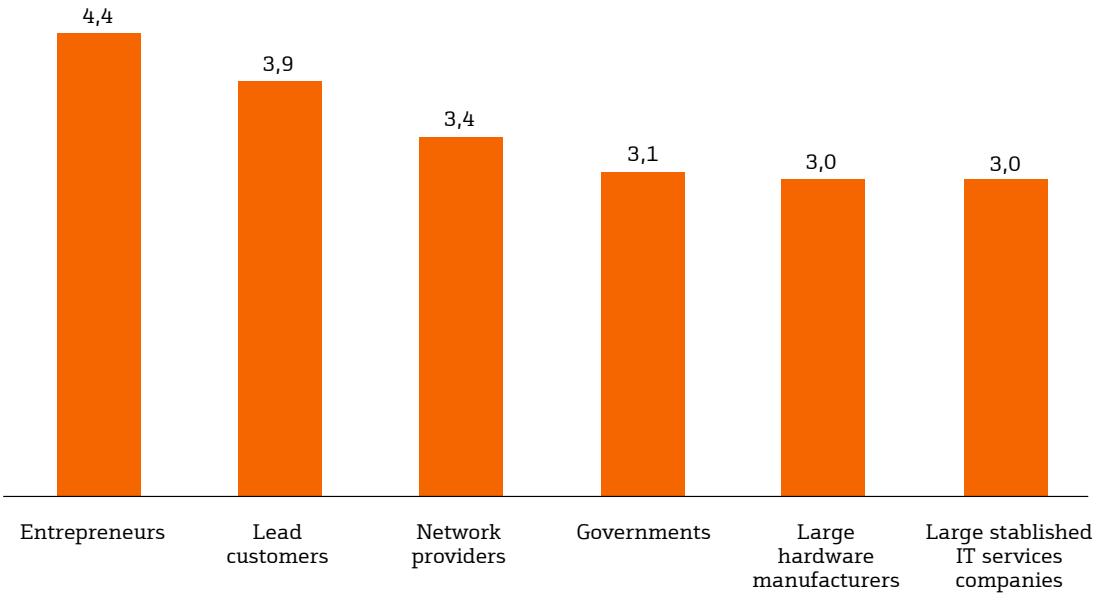


Illustration 9: Rating of agents on a scale of 1 to 5 (1= insignificant; 5= very important) as drivers of adoption of the "Internet of Things".
Source: Authors.

the way public services are run. "Instead of being a collection of departmental silos, they could come to resemble computing platforms. Most services, from payment systems to traffic information, would be provided in only one version and used by all departments—or by private firms that want to offer their own urban applications"[80].

For companies to be able to do this, all the information compiled and accumulated by governments will have to be placed in the public domain. This would include statistics on the workings of the public service, crime figures and maps that could be used by companies and individuals to offer new services — some information that might cause red faces among certain politicians. By business intelligence we mean the set of strategies and tools geared towards the administration and creation of knowledge through the analysis of data in an organisation or company. Pioneering cities in this regard, such as London, San Francisco and Washington have made this content public.

A more horizontal system, characterised by openness of information and collaboration between agents, would allow innovative ways of managing data. However, the idea of sharing that large quantity of information for indexing has not taken off. The greatest concerns revolve around data privacy. There may be some reluctance on the part of American associations such as the FDA and conflicts with laws such as the Health Information Protection Act, or HIPA, which relates to regulations on hard and soft copies of private healthcare information. Contradictorily, many of the fields of development for IoT (energy, health and environment), seem to continue to need strong leadership from the state in leading the achievement of scalable models. Some experts feel that once certain efficiencies have been established, it will be possible to tap into innovation coming from the base of the system, i.e. from users inventing *killer apps*[81].

[80] Sensors and Sensibilities (November 2010) http://www.economist.com/node/17388338.

[81] A "killer app" is a definitive computer program i.e. one whose implementation leads to definitive user acceptance. The classic example is e-mail, which has replaced traditional mail.

When the Future Trends Forum experts were asked which regions would head the field in the Internet of Things in different sectors, the clear leaders were the USA, followed by Europe and China. However, they also mentioned the presence of other regions in specific industries: Africa in "smart building", "medical, health and pharmaceutical technology" and "logistics" and South America in "energy and the environment" (see Illustration 6).

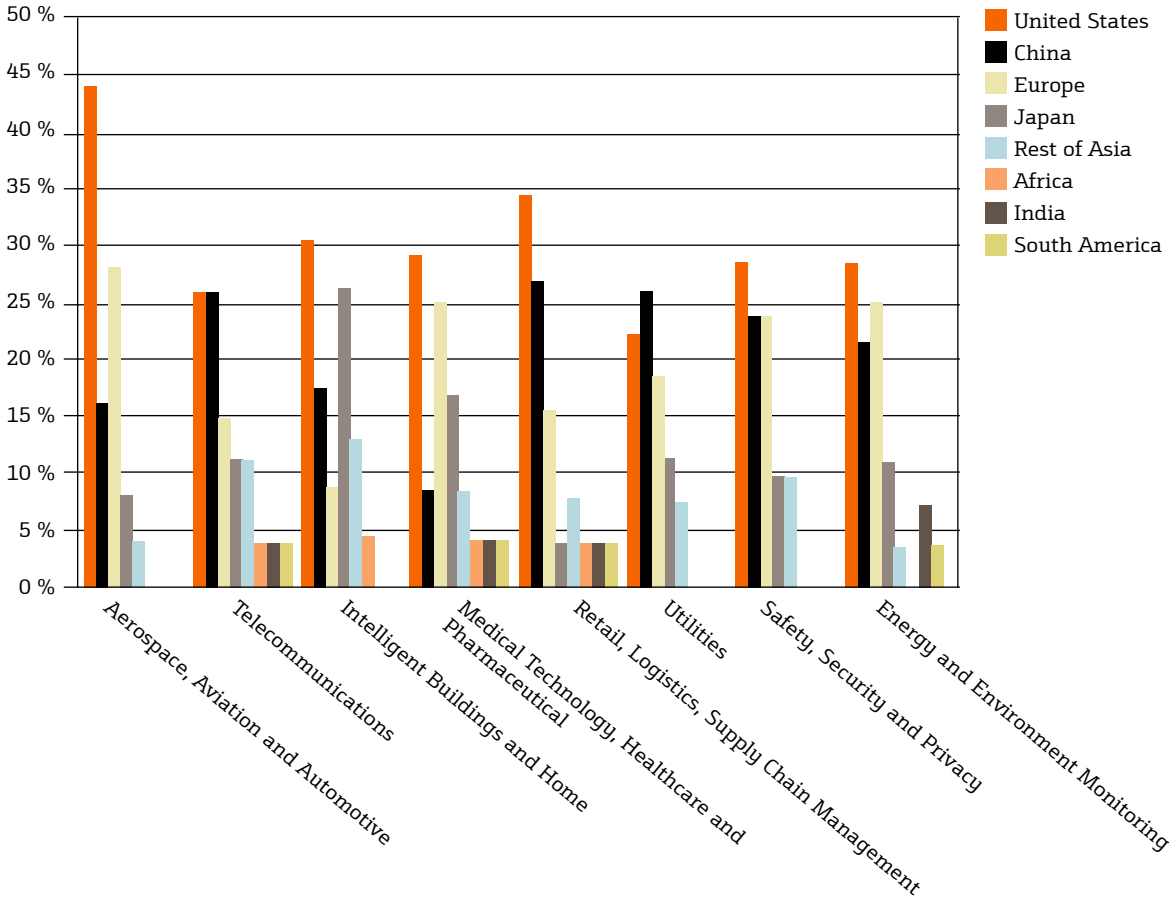


Illustration 10: Pioneering regions in the Internet of Things in different sectors.
Source: Authors.

This reflects a process now underway in which the world's power bases are shifting. Countries from developed economies are losing ground and emerging economies are beginning to take off in areas such as innovation, heretofore the domain of more advanced nations. The IoT field is no exception. With globalisation and the free movement of goods, people and information, there is no longer any reason to think that one specific group of countries that will be more liable to generate innovation within the framework of IoT.

Some Success Stories

One of the greatest success stories in wireless technology in Europe is GSM. The ability of European institutions and industries to work together to create a

Most public services, from payment systems to traffic information, would be provided in only one version

common standard meant that it was universally accepted and adopted. This was no easy task, given the innumerable different idiosyncrasies in the European Union[82]. For the time being, the same does not appear to be happening with the Internet of Things. Initiatives in developed countries are disjointed and there has been no apparent attempt to reach a common standard to be used by all countries on the road to IoT innovation.

Two projects deserve a mention for setting a long-term goal and trying to involve the general public in the process. Amsterdam Innovation Motor (AIM) was set up to try to turn the Dutch capital into a "smart city". AIM was a public-private joint venture placed in charge of coming up with projects and mediating between the parties involved[83]. We have already discussed about the importance of involving consumers in this type of initiative and managing their expectations. Rather than just installing smart metering technology and expecting consumers to pay for it without being informed, AIM has tried to appeal to "co-creation" of the project and ask for suggestions from users on ways of saving energy and monitoring consumption.

Another initiative is i-Japan Strategy 2015, which aims to build a vibrant digital society, promoted by citizens applying IoT in the running of government, healthcare and education. After starting the largest smart-metering project to date in 2000, Italy now has over 27 million consumers and Britain has plans to fit around 29 million homes with this technology by 2020[84]. Stockholm successfully implemented a toll system capable of recording the registration numbers of vehicles passing control points and sending a bill for the amount to the driver's address or charging it directly to their bank account on-line. As well as being a representative case of IoT, it gives the government greater control over traffic and thus over carbon emissions.

The IoT Giant: China

In mid-2010, China announced with great hype that it was planning to begin a National IoT Plan under the slogan, " Internet+ Internet of Things = Wisdom of the Earth ". Some of the FTF experts who recently visited the country confirmed that it plans to take the lead not only in designing the architecture of the technology, but also the architecture of the business, i.e. ways of doing businesses with IoT. This shows how serious the Chinese proposal is; the country is keenly prepared to invest in costs and risk in order to position itself as the leader in the next wave of technological innovation. Indeed, universities such as Jiangnan University already have an IoT engineering school with an extensive associated curriculum[85].

What will be the key factors of the People's Republic of China's success in this area? Firstly, there are incentives in two directions. On the one hand, the government is bringing top-down influence to bear by setting up funds and a related regulatory framework. Clearly, with a one-party system, the majority joins the initiative; there is much less opposition and things can advance faster[86]. The municipality of Chongqing and the telecommunications company China Unicom last year announced a partnership worth billions of dollars in investment and tax cuts to potentially generate 7 billion dollars in IoT-related income per year within five years[87]. At the same time, the motivation also comes from the bottom up, from university students impatient to get ahead and set a global precedent.

[82] Internet of Things in 2020 Roadmap for the future (September 2008).

[83] Sensors and Sensibilities (November 2010) http://www.economist.com/node/17388338.

[84] Sentec MD: Time for UK to take the smart meter plunge, Greenbang.com (June 2010) http://www.greenbang.com/sentec-md-time-for-uk-to-take-the-smart-meter-plunge_14520.html.

[85] http://english.jiangnan.edu.cn/schools/IoT.html.

[86] El Gobierno chino impulsa el Internet de las cosas con un Plan Nacional, El Mundo (July 2010) http://www.elmundo.es/elmundo/2010/07/12/navegante/1278933382.html.

[87] China quiere dominar el Internet de las cosas, El Mundo (August 2010) http://www.elmundo.es/elmundo/2010/08/13/navegante/1281705095.html.

Secondly, China has a very clear advantage when it comes to infrastructures. Because they began to develop late, they could take advantage of the latest technologies in building them. In more developed countries, the supposed benefit of being the first has been clouded by not being able to continue advancing because they have to get a return on the costly initial investment. China, however, is promoting a super smart grid to increase the proportion of renewable energy to 15% by 2020[88].

Finally, China aims to become the world's leading IoT manufacturer, but at the same time it is the country with most potential customers on the verge of entering the consumer market. So the market is being driven by both supply and demand. Far from restricting itself to just building the infrastructure, the Chinese industry wants to move up the value chain and reach the end consumer with Internet-fitted consumer products, supplying its own population and countries around the world. It also wants to be a reference point for global standards.

Is it possible that emerging countries might overtake developed countries in the area of IoT? They have the advantage that they can leap-frog certain phases to achieve technological maturity faster and more sustainably. Everything seems to suggest that they will: the most connected building in the world is the Cisco East in Bangalore. Countries such as South Korea and Singapore are working hard to adapt their infrastructure to the Internet[89]. Singapore will be one of the first nations to combine all its smart systems in one, thanks to collaboration between ministries and agencies in establishing a common roadmap[90].

David and Goliath?

The FTF experts consider that the development of the Internet of Things in sectors such as home automatics, logistics and environmental and energy control, will come primarily from what they call *cheap hacks*, made possible to a great extent by the existence of open source software. In contrast to technological standards, *cheap hacks* are developments that arise as small modifications to programs or systems, created using resources not provided by the original manufacturer or programmer. The people who design them are not necessarily professionals, but technical whiz kids who improve the way the program operates creatively or come up with an unconventional solution to a problem.

Nonetheless, the experts feel that there are a series of sectors that will continue to evolve through technological standards, perhaps because by their nature they require more formal procedures for accepting innovations. This is the case of the aerospace, aeronautics and automotive industries, medical supplies and pharmaceuticals.

The Adaptive Infrastructure

From the point of view of governments, what is the most appropriate IoT model? Will the western approach of innovation built out of an open and collaborative system triumph? Or will it be a model like the Chinese government's, which acts as an agent capable of financing initiatives on a large scale and establishing a starting point in interoperability standards? It is certainly ironic that a country often accused of violating Internet freedom of speech should have deployed a system like that used at the 2008 Olympic Games, with cameras, taxis and security systems all connected via IPv6[91]. IoT will certainly be appealing from the

[88] China está lista para construir red inteligente para aprovechar energía renovable (March 2010) http://spanish.china.org.cn/specials/lianghui2010/2010-03/14/content_19604894.htm.

[89] The Internet of Hype, The Economist (December 2010) http://www.economist.com/blogs/schumpeter/2010/12/internet_things

[90] Sensors and Sensibilities (November 2010) http://www.economist.com/node/17388338.

[91] Sensors and Sensibilities (November 2010) http://www.economist.com/node/17388338.

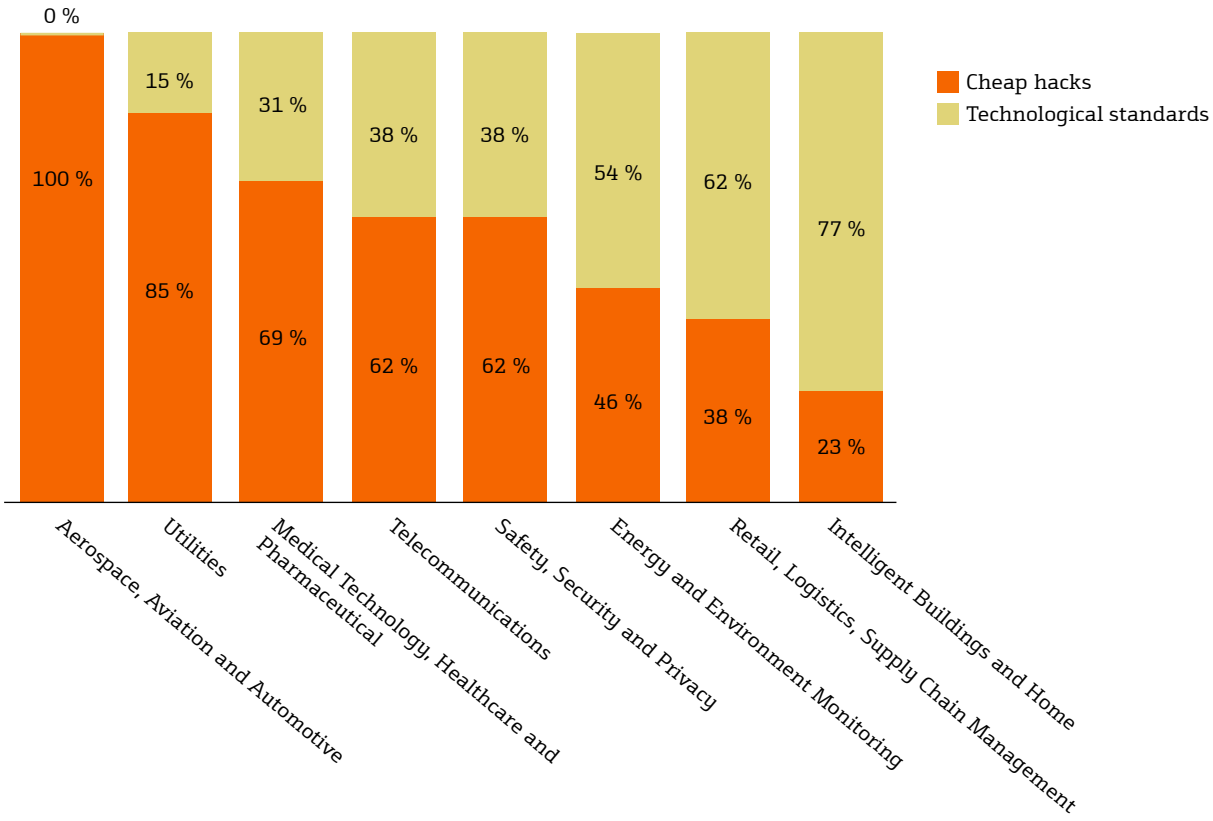


Illustration 11: Technological standard or cheap hack: what will determine the development of the "Internet of Things" in the following sectors?
Source: Authors.

controlling perspective of a centralised government, but the results are clear: China's State Grid Corporation targets 2020 as the year when it will complete roll-out of its smart grid. One might suspect, however, that the appeal of the IoT for centralised governments such as China's lies in control, using it almost as a "weapon of industrial policy" as The Economist calls it.

Time will tell. The Future Trends Forum experts argue that the real challenge lies in developing adaptive infrastructure that combines the grounds for economic development and the possibility of changing over time to enable new innovations to be inserted into the model. For the moment, in Spain there are already over two million machine-associated mobile phone lines and national e-government services are among the best in the world[92].

[92] http://blogs.20minutos.es/masquemedios/2011/01/13/la-sociedad-de-la-informacion-avanza-a-buen-ritmo-en-espana/.

6 Conclusion

If one were to ask a few people at random on the street what the Internet of Things is, the chances are nobody would have the slightest idea. Ironically, one of the most self-explanatory terms in all of information and communication technology seems destined to remain a modish term, used only by experts.

They may not know the name, but many people use the IoT every day. Some of them may even need IoT detox sessions soon! Apparatuses that used to be used for making phone calls or at most, for sending and receiving text messages, have now become "weapons of mass connection". These are "smartphones", part of the advance guard of IoT, which have helped make the "wherever, whenever" dream come true.

Nonetheless, as we have seen in this publication, IoT is much more than just ubiquity. To start with, it is a way of instrumentalising the planet. As everyday objects take life thanks to sensors and RFID tags, the world is becoming more interconnected. These different objects, as well as machines and people, are communicating in a radically new way. With objects now able to communicate, information has begun to be generated in incalculable quantities, opening up a whole seam of gold for businesses working in areas of data mining, interpretation and analysis.

For the time being, the Internet of Things is the state of the art of a promising technology. Any object you can imagine can be connected to the Net, leading to massive advances throughout different industries. Although IoT can be applied to all areas, the FTF experts advise caution, saying that the impact will not be the same in all sectors. They consider that home automatics, retail, logistics, medicine and the pharmaceutical industry will be the main areas in which IoT will have the most impact. Interestingly, the experts ranked the impact on one of the most highly publicised industries, smart grids, as being among the lowest. They may well have taken into account the negative impression left by the first bills sent out when smart meters were first fitted in certain supply systems.

Like the residents of the pilot test in Bakersfield, consumers can to some extent imagine what the Internet of Things is. However, until they understand the technical foundations of the IoT, they will not comprehend its implications. As we have seen, three different phenomena had to come together to make IoT possible at a consumer level: component-miniaturisation that did not adversely affect operating speeds; alternatives such as hotspots allowing the scarce spectrum to be shared and prevent saturation of mobile infrastructures; and the appearance of applications and services that create value from IoT-generated information. Without these three conditions, the current expansion of the IoT would have been well-nigh impossible.

The Internet of Things will have a major impact on society and business. As information and people become increasingly more connected, technology will be used as a tool of collaboration and decision-making in a world in which the physical and digital converge. With figures just a click away, the IoT is empowering consumers. New business models are emerging that seek to maximise the potential of an open system that can be modified by anyone. The idea that a company has to be an organisation with economic goals is history. Motivations as diverse as the optimisation of resources with a clear environmental

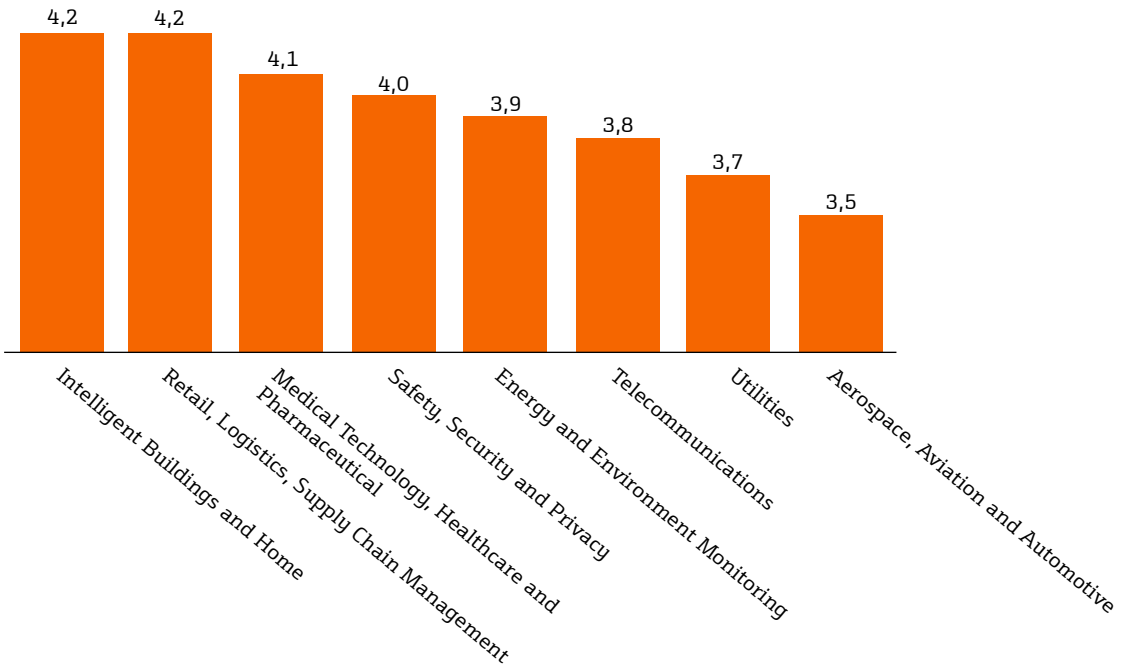


Illustration 12: On a scale of 1 to 5, rank the impact of the Internet of Things on the following industries.
Source: Authors.

base, the provision of individual excess capacity and a collective demand to identify the source of products have all served as bases for an innovating business concept under the IoT umbrella.

And speaking of umbrellas, does the Internet of Things really usher in innovations or does it simply mean redefining everyday objects in a new and more expensive way? There are numerous obstacles: insufficient IP addresses, cascading computer collapses, information overload, lack of interoperability and security and privacy shortfalls, to mention but a few. However, this has not stopped countries such as the Netherlands, Japan and China in their mission to lead the field as representatives of the IoT industry. Spain is not far behind: there are already over two million mobile lines associated with machines, mostly meters and inspection devices[93].

In short, the Internet of Things is one of the major technological trends of the twenty-first century, but the challenges outlined above must be addressed if it is to be rolled out on a more global scale. The most crucial issues will unquestionably be to bring Internet connections to the many places that still lack one. Let's not put the cart before the horse.

[93] http://blogs.20minutos.es/masquemedios/tag/internet-de-las-cosas/

Appendix

- Glossary
- Members of the Future Trends Forum

Glossary

A

Algorithm
A prescribed set of well-defined, ordered and finite instructions or rules that allow an activity to be performed by means of successive steps leaving no doubt as to how it is to be conducted.

C

Cheap hack
A development comprising a small modification to a program or system, devised using means not provided by the original manufacturer or programmer.

Cloud computing
A new paradigm, based on the idea that anything that can be done on a computer can be transferred to the cloud — in other words, to the Internet. This model involves using computer resources like any other supply, such as electricity or telephony. These resources are offered by cloud providers, which manage them in large remote data centres, providing a service to large numbers of customers who can access them over any Internet-connected device.

D

Data center
An installation used to host computer systems and their associated components. The facility contains all or some of the resources needed for processing an organisation's information. They generally have redundant or backup power supplies, redundant data connections, backup copies, cooling systems and special security devices. The computer resources are accessed over data connections or the Internet. In the case of cloud providers, these data centers also concentrate the customer's processing needs.

I

Internet of Things (IoT)
A new concept that develops on advances in communications and IT by applying them to objects, enabling improved interaction. The IoT comprises a network of everyday objects interconnected over the Internet.

IPv6
Version 6 of the Internet Protocol (IP). It has been designed to replace IPv4, currently implemented in the great majority of devices accessing the Internet, whose limited number of network addresses is beginning to restrict the growth and use of the Internet, especially in China, India, and other densely-populated countries in Asia. The new standard will improve the service as a whole; for example, it will provide future phone cells and mobile devices with their own permanent addresses.

M

Machine-to-machine (M2M)
Technologies that allow both wireless and cable systems to communicate with other devices with the same capacity. M2M uses a device (such as a sensor or meter) to capture an event (temperatures, stock levels, etc.), which is then retransmitted over a network to an application (software), which translates the captured event into meaningful information.

Memristor
Formed from the words *memory* and *resistor*. After the condenser, the resistor and the inductor, it forms the fourth element in passive circuits.

Miniaturisation
Technological process by which the size of electronic devices is reduced. The clearest example of miniaturisation at this time is nanotechnology.

Moore's Law
States that roughly every eighteen months the number of transistors in an integrated circuit will double. This is an empirical law, formulated by the co-founder of Intel, Gordon E. Moore on 19 April of 1965. To date it has been approximately fulfilled.

O

Open Source
Production and development practices that promote access to the source material of the final product. The term was first widely used with the coming of the Internet and involves a pragmatic methodology for developing software that enables access to the source code of the programs distributed.

P

Peer-to-peer
The interaction or relationship between different agents to exchange information and form a large social network capable of offering large-scale services. This is made possible by way of technology that allows different machines to exchange files over the Internet with little server interaction and without the participants needing to know each other.

R

RFID tag
Small sticker-like devices that can be attached to or implanted in a product, animal or person. They contain aerials that enable them to receive and respond to radiofrequency requests from an RFID transmitter-receiver.

RFID (Radio Frequency Identification)
Consists of a remote data storage and recovery system using devices called RFID labels, cards, transponders and tags. The basic purpose of RFID technology is to transmit an object's identity via radio waves.

S

Sensor
A device capable of detecting physical or chemical values and instrument readings and turning them into electrical variables.

Smart grid
A network that uses IT to optimise power production and distribution in order to balance the supply and demand between producers and consumers better.

Smart metering
A measuring process which instantly quantifies and transmits information on the amount of energy consumed or produced to allow better grid management.

Software as a Service (SaaS)
Method that provides access to software and its functions as a web-based service, on a pay-for-use basis. SaaS allows organisations to access business functions at a lower cost, without having to invest in major technological developments. Because the software is housed remotely, users do not have to invest in additional hardware for the new application. SaaS eliminates the need for installation, commissioning, conservation and maintenance.

T

Turing Test
A test proposed by Alan Turing as a way of checking for intelligence in a machine. It was first proposed in 1950 in an article entitled "Computing machinery and intelligence" for *Mind* magazine and for defenders of AI, it continues to be one of the best methods devised. It is based on the positivist notion that if a machine behaves in all ways as if it were intelligent, then it must be intelligent.

U

Ubiquity
Quality or capacity of being in several different places at the same time.

V

Virtualization
A way of splitting a physical server up into a large number of "virtual" ones, giving each one the appearance and capacity to function on its own dedicated machine. Each virtual server operates as a fully-operative server and may be rebooted independently. This makes it possible to spread the physical resources among virtual servers, depending on demand.

W

Wifi hotspots
Wireless coverage areas in public places, such as airports, libraries, convention centres, cafes, hotels, etc. This service can be used free of charge or for a fee, depending on the provider.

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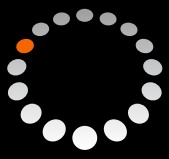

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