Introduction to the Internet of Things

Chapter · September 2013

DOI: 10.1007/978-3-642-40403-0_1

3 authors, including:

Thorsten Kramp
IBM
34 PUBLICATIONS 551 CITATIONS

Rob van Kranenburg
Resonance Design
37 PUBLICATIONS 540 CITATIONS

Chapter 1
Introduction to the Internet of Things

Thorsten Kramp, Rob van Kranenburg, and Sebastian Lange

The expression "Internet of Things" (IoT), coined back in 1999 by Kevin Ashton, the British technology pioneer who cofounded the Auto-ID Center at the Massachusetts Institute of Technology, is becoming more and more mainstream. In opening the IoT Week 2013[1] with a pre-recorded video message,[2] Ashton insisted on the realization that IoT is here *now*; it is not the *future* but the *present*. While Gartner identifies IoT as one of the top ten strategic technology trends,[3] Cisco forecasts 50 billion devices connected by 2020,[4] a potential market in excess of $14 trillion,[5] and also claims that IoT is actually already here.[6] Similarly, it is not only companies with a technological focus, such as Ericsson, Bosch or Siemens that use IoT to advertise their cutting edge technologies – media companies such as the BBC are conducting research activities and have plans for IoT deployment. In short, we are currently on the verge of witnessing the emergence of a "mega-market", where markets such as home and building automation, electricity generation and

[1] http://www.iot-week.eu

[2] http://kevinjashton.com/2013/06/17/pre-recorded-opening-talk-for-internet-of-things-week-helsinki-june-17-2013/

[3] http://www.gartner.com/newsroom/id/2209615

[4] http://share.cisco.com/internet-of-things.html

[5] http://iotevent.eu/cisco-sees-14-trillion-opportunity-in-iot/

[6] http://newsroom.cisco.com/press-release-content?type=webcontent&articleId=1158640

T. Kramp (✉)
IBM Research, Säumerstraße 4, 8803 Rüschlikon, Switzerland
e-mail: thk@zurich.ibm.com; www.zurich.ibm.com

R. van Kranenburg
Internet of People Ltd., Suite 3, 32-38 Scrutton Street, London EC2A 4RQ, UK
e-mail: kranenbu@xs4all.nl; www.theinternetofpeople.eu

S. Lange
Deloitte & Touche GmbH, Kurfürstendamm 23, 10719 Berlin, Germany
e-mail: sebastian.lange@web.de

A. Bassi et al. (eds.), *Enabling Things to Talk*, DOI 10.1007/978-3-642-40403-0_1,

distribution, logistics, automotive, as well as telecommunications and information technology will steadily converge. As yet, we do not know the consequences of connecting all of these smart objects (smart meter, e-vehicle, cargo container, fridge etc.) to the Internet.[7]

At the same time, the Internet of Things (IoT) is not something you will experience as such itself. What you will see is that more and more objects become connected. If you are selling products, you will be negotiating with providers of connectivity. If you are building, selling or inventing models or tools for providing services or applications, you will notice that the convergence of IoT, big data and energy efficiency, combined with cheap hardware, software, data storage and analytics, favours open standards, innovation and interoperability. Daily activities that were distinct become interwoven in new formats and business models.

Thus, in effect, the Internet of Things is a combination of a technological *push* and a human *pull* for more and ever-increasing connectivity with anything happening in the immediate and wider environment – a logical extension of the computing power in a single machine to the environment: *the environment as an interface*. This push-pull combination makes it very strong, unstoppable, fast and extremely disruptive.

Mireille Hildebrandt, a Dutch professor working on the implications of emerging technologies and the rule of law, states that “we may need to develop an *Ambient Law* that is embodied in the algorithms and human machine interfaces that support Ambient Intelligence and for this we will have to break through our paralysis, ready to become literate in terms of a new script.”[8] In a speech to the Pittsburgh Technology Council in 2009, Eric Schmidt, an American software engineer and executive chairman of Google, focused on the negative effects of (what he called) institutional fragmentation on innovation and integration. He wondered whether governments – and the very process of policy and policymaking itself – could benefit from the iterative cycles of measuring success and failure that characterize the engineering and design prototyping cycles. With this amount of real-time tracking and aggregated data and information rather than heuristics, the act of governing itself could benefit. Specific laws could take effect for 3 months and be evaluated and adjusted and then, based on real data rather than estimates, be adjusted again. It is this process that can lead to combinatorial and system innovation.

Two dominant characteristics unite these different perspectives: firstly, a sense that Internet connectivity is becoming increasingly ubiquitous and pervasive; and secondly, the idea that eventually everything – including mundane physical artefacts – will be connected.

[7] On the LinkedIn Group “Internet of Things” strueker@iig.uni-freiburg.de.

[8] Hildebrandt, Mireille and Koops, Bert-Jan, The Challenges of Ambient Law and Legal Protection in the Profiling Era, Modern Law Review, Vol. 73, Issue 3, pp. 428-460, May 2010.

IoT Application Example 1: Transport/Logistics

In transport logistics, IoT improves not only material flow systems but also the global positioning and automatic identification of freight. It also increases energy efficiency and thus decreases energy consumption.

In conclusion, IoT is expected to bring profound changes to the global supply chain via intelligent cargo movement. This will be achieved by means of continuous synchronisation of supply chain information and seamless real-time tracking and tracing of objects. It will make the supply chain transparent, visible and controllable, enabling intelligent communication between people and cargo/goods.

IoT Application Example 2: The Smart Home

Future smart homes will be conscious about what happens inside a building, mainly impacting three aspects: resource usage (water conservation and energy consumption), security and comfort. The goal is to achieve better levels of comfort while cutting overall expenditure.

Moreover, smart homes also address security issues by means of complex security systems for detecting theft, fire or unauthorized entry. The stakeholders involved in this scenario constitute a very heterogeneous group.

Different actors will cooperate in the user's home, such as Internet companies, device manufacturers, telecommunications operators, media service providers, security companies, electricity utility companies, etc.

IoT Application Example 3: Smart Cities

While the term smart city is still a fuzzy concept, there is general agreement that it is an urban area which creates sustainable development and high quality of life. Giffinger et al.'s model elucidates the characteristics of a smart city, encompassing economy, people, governance, mobility, environment and living.[9] Outperforming in these key areas can be achieved through strong human or social capital and/or ICT infrastructure. For the latter, an initial business analysis concludes that several sectors/industries will benefit from more digitalised and intelligent cities (examples for a city of one million people):[10]

(continued)

[9] http://www.smart-cities.eu/download/smart_cities_final_report.pdf

[10] http://de.slideshare.net/rlnicholson2/smart-cities-proving-ground-for-the-intelligent-economy

(continued)

(a) Smart metering, 600,000 m, $120 million opportunity
(b) Infrastructure for charging electric vehicles, 45,000 electric vehicles, $225 million opportunity
(c) Remote patient monitoring (diabetes), 70,000 people, $14 million opportunity
(d) Smart retail, 4,000 stores, $200 million opportunity
(e) Smart bank branches, 3,200 PTMs, $160 million opportunity

IoT Application Example 4: Smart Factory

In a global supply chain, companies will be able to track all of their products by means of radio frequency identification (RFID) tags. As a consequence, companies will reduce their operating expenses (OPEX) and improve their productivity due to tighter integration with enterprise resource planning (ERP) and other systems. Also, maintenance of machinery will be facilitated by connected sensors, allowing for real-time monitoring of the health and performance of the factory equipment.

Generally, IoT will provide automatic procedures that imply a drastic reduction in the number of employees needed. Workers will be replaced by bar code scanners, readers, sensors and actuators, and in the end by complex robots as efficient as a human being.

Without any doubt, these technologies will bring opportunities for white-collar workers and a large number of technicians will be required to program and repair these machines. This is synonymous to a transfer to maintenance jobs, but it also constitutes a new challenge for providing all blue-collar workers with an opportunity to move toward these types of jobs and to avoid unemployment.

As the developments got closer to the market and the everyday lives of citizens, the need for non-technical research in the area of machine to machine (M2M) communication and the Internet of Things was acknowledged in the 1996 EU Call for Proposals of i^3: Intelligent Information Interfaces, an Esprit Long-Term Research initiative. The aim of i^3 (pronounced "eye-cubed") was to develop new, human-centred interfaces for interacting with information, aimed at the future broad population. This approach was also the starting point and rationale for the EU-funded proactive initiative "*The Disappearing Computer*", a cluster of 17 projects conducted by interdisciplinary research groups. Its mission was "to see how information technology can be diffused into everyday objects and settings, and to see how this can lead to new ways of supporting and enhancing people's lives that go above and beyond what is possible with the computer today."[11] The third research iteration of this approach was Convivio (2003–2005), a thematic network of researchers and practitioners developing a broad discipline of human-centred design of digital systems for everyday life. The coordinator of Convivio stated that human-centred design "still has little influence either on governmental and super-national policies or on industrial strategies. As a result, it also has little impact on the quality of ICT in public and private life."[12]

However, in 2013, some 50 % of respondents[13] to a European Commission Public Consultation fell into the "interested citizen" category rather than belonging to a particular industrial, academic or other sector.[14]

Andreas Kirsch in the IoT Expert Group commented that the main point that emerged from the work of the subgroup on privacy was that everyone will be affected by IoT but many people will not realise it. It is vital that this realization is handled well. By default, the Internet of Things may involve function creep or have unintended consequences: "It was noted that most people use the same concepts when discussing IoT as when discussing the Internet in general. There is a significant difference, however. IoT involves objects talking to each other without user consent, with possibly un-envisaged functionalities. Cameras, for example, might take on functions that are different from their overt primary functions. These possibilities, once perceived, may cause user anxieties to rise. Moreover, what is the role of user consent if objects may be able to talk to each other spontaneously? It will be very difficult to backtrack after the deployment of million of chips employing a passive approach to connectivity."

Privacy, security and ideas in society about data storage and tracking could stall adoption when, for example, by combining the analysis of supply and demand, energy enterprises are able to supply more efficient demand shaping. They will not just give incentives to consumers; they will actually turn off devices that are not needed (e.g. turn off the freezer for 20 min). Furthermore, these actions must take place automatically. In IoT we always face a heterogeneous scenario involving diverse stakeholders. The main actors are of course energy utility companies, but public entities will also be important players. These services need to be coupled with educational programs that explain what is happening in reality.

[11] The Disappearing Computer II (DC) Proactive Initiative http://cordis.europa.eu/ist/fet/dc2-in.htm

[12] Letter to the Convivio community, Giorgio De Michelis, Convivio network coordinator, http://daisy.cti.gr/webzine/Issues/Issue%201/Letters/index.html

[13] Additional responses have been received since the last report, with the total number rising from 500 to more than 600. These additional responses did not affect the statistics for the exercise as a whole.

[14] Tenth Meeting of the Internet of Things Expert Group, Brussels, 14 November 2012. Tom Wachtel, rapporteur.

IoT Application Example 5: Retail
IoT realises both customer needs and business needs: price comparison of a product; looking for other products of the same quality at lower prices; with shop promotions, giving information not only to customers but also to shops and businesses. Having this information in real time helps enterprises to improve their business and to satisfy customer needs.

Obviously, big retail chains will take advantage of their dominant position to enforce the future IoT retail market, as was the case with RFID adoption, which was enforced by Walmart in 2004 (Wu et al. 2006). In particular, companies with controlling positions, such as Carrefour, Metro, Migros, Walmart, etc. will be able to push the adoption of IoT technology due to their sizable market shares.

IoT Application Example 6: E-Health
Control and prevention are two of the main goals of future health care. Already today, people have the option of being tracked and monitored by specialists even if the patient and specialist are not in the same place. Tracing peoples' health history is another aspect that makes IoT-assisted e-health very versatile. Business applications could offer the possibility of medical services not only to patients but also to specialists, who need information to proceed in their medical evaluation. In this domain, IoT makes human interaction much more efficient because it permits not only localization, but also tracking and monitoring of patients. Providing information about the state of a patient makes the whole process more efficient, and also makes people much more satisfied.

The most important stakeholders in this scenario will be public and private hospitals and institutes such as the Institute of Applied eHealth at Edinburgh Napier University, which participated in the first stakeholder session of IoT-A. It is worth mentioning that telecommunications operators are quite active in e-health (for instance, O2 UK).

The IoT Expert Group claims that, "As IoT will introduce new difficulties for contextual integrity, the principle whereby information supplied for use in one context (e.g. a meeting with one's doctor) is not expected by the owner of the data to be used in a different context (e.g. the doctor applying for a mortgage). There will be a social contract between people and objects, and the ethical ramifications of a contract of this kind must be considered".[15]

[15] Internet of Things Expert Group (E02514), Commission Decision of 10 August 2010 setting up the Expert Group on the Internet of Things. OJ C 217, 11.8.2010, p. 10–11, http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=2514

All current computing and IoT paradigms position connectivity and content-centric networking centrally as an ecology of devices, protocols, services and networks, such as RFID, active sensors, biometrically-related smart camera data, 2D and 3D bar codes and 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks) or ZigBee. At the core of this ecology there is a seamless flow between:

- The **BAN** (body area network): e.g. the ambient hearing aide, the smart T-shirts
- The **LAN** (local area network): e.g. the smart meter as a home interface
- The **WAN** (wide area network): the bike, car, train, bus
- The **VWAN** (very wide area network): the smart city as e-government services everywhere; no longer tied to physical locations

Traceability, sustainability and security linking the gateways of these different area networks cannot be ensured without interoperability at architectural, domain-specific and application level. (see also the box on page 9 – The hierarchy of networks)

It is also highly likely that monitoring mechanisms will be built into devices themselves: for example, "if a guest is charging their electric car at a friend's house, we should consider applications that will understand that the charge should appear on the guest's electric bill and not that of the friend."[16] But there is a clear deadlock: clients do not know what they can expect, nor do they know what they could ask.

M2M vendors cannot interface their sensor capabilities beyond an optimizing function. No one is *asking* for an Internet of Things. People have no idea about what they can expect and why they should hand over their washing machines to a local grid to ensure energy efficiency, for example. Is a positive outcome feasible?

A successful IoT means the best possible feedback on our physical and mental health, the best possible deals based on real-time monitoring for resource allocation, the best possible decision-making based on real-time data and information from open sources, and the best possible alignments of our local providers with the global potential of wider communities.

Now that we have introduced the basic ideas of the Internet of Things concept and pointed out some aspects of the current discussion taking place in the Internet of Things community, you can see that the whole field is very much "in motion". New ideas, concepts and new technologies are appearing constantly, whereas others are disappearing, being ruled out as incompatible or not feasible. In the IoT concept, which is itself disruptive, other potential "disruptive" technologies (e.g. Google Glass etc.) strongly influence the direction of technological development as well as the related societal and political discussion.

Despite the high-level discourse that is necessary to assess the socio-economic impact of IoT in general, in this book we will focus on the underlying technological concepts, network architecture approaches and connectivity and interoperability requirements that are required to provide and realise the fundamental connectivity that will ultimately allow for the emergence of the Internet of Things to the benefit of mankind in general.

---

[16] http://tools.ietf.org/id/draft-roychowdhury-6lowappsip-00.txt

With a strong focus on network architectures, architecture models and guidelines for building a truly interoperable Internet of Things, this book summarises the results of the IoT-A[17] project, funded by the European Union and conducted between 2010 and 2013. More than 50 scientists and researchers contributed to the development of an "Architectural Reference Model" (ARM) for the Internet of Things.

This book is in two parts (I and II). Part I (Chaps. 2, 3, 4) introduces, on a more general level, the concepts developed over the course of the IoT-A project. It is targeted at a general audience including end users who want to employ IoT technologies, managers interested in understanding the opportunities generated by the new technologies, and system architects who are interested in an overview of the models developed. In Chap. 2 we explain the history behind and origin of the IoT-A project. In Chap. 3 we introduce the ARM as enabler, its terminology and methods for employing it. Chapter 4 then highlights use cases that exemplify how the ARM has been used in real life scenarios.

Part II (Chaps. 5, 6, 7, 8, 9, 10, 11, 12) contains Chap. 5, which provides an overview on guidance to the ARM, followed by Chap. 6 with very detailed and elaborate description of a process to generate concrete architectures. In Chap. 7 the IoT Reference Model is aiming at establishing a common grounding. Based on this, in Chap. 8 the IoT Reference Architecture is presented. Chapter 9 provides reference manuals with guidelines how to use the various Models and Perspectives presented in creating a concrete architecture. In Chap. 10 an interaction analysis on some selected scenarios is given to provide a general understanding on the interactions to be considered. The best practices and guidelines relating to how system engineers or other end users can use the ARM to develop specific IoT architectures for dedicated IoT solutions and how users can apply the concepts presented to develop a dedicated IoT architecture for a specific application case are illustrated in Chap. 11 and exemplified in reverse mapping exercises of existing standards and platforms to the IoT ARM up to a business case evaluation in Chap. 12.

In contrast to Part I, Part II addresses the topic on a very scientific and technical level and is targeted at the knowledgeable scientific or technical reader.

IoT Application Example 7: Smart Energy/Smart Grid

This field has many overlaps with other scenarios, such as smart home and smart city. The key issue in these scenarios is to detect ways to save energy. We are basically referring to what is known as a smart grid. In this application area, initiatives that imply a more distributed energy production must be highlighted, as many houses today have a solar panel, for example. As a vital constituent, smart metering is considered a prerequisite for enabling intelligent monitoring, control and communication in grid applications. The use of IoT platforms in smart metering will provide the following benefits:

(continued)

[17] www.iot-a.eu

(continued)

a. An efficient network of smart meters allows for faster outage detection and restoration of service. Such capabilities abound to the benefit of customers.
b. Customers will have greater control over their energy or water consumption, providing them with more choices for managing their bills.
c. IoT deployment of smart meters is expected to reduce the need for building power plants. Building power plants that are necessary only for occasional peak demand is very expensive: a more economical approach is to enable customers to reduce their demand through time-based rates or other incentive programs, or to use automatic recording of consumption to temporarily turn off devices which are not in use.

Finally, by combining the analysis of supply and demand, energy enterprises will able to supply more efficient demand shaping. They will not just give incentives to consumers, but will actually turn off devices that are not needed (e.g. turn off the freezer for 20 min). Furthermore, these actions must take place automatically. Here, we again face a heterogeneous scenario involving diverse stakeholders. The main actors are of course energy utility companies, but public entities will also be important players.

The Hierarchy of Networks: BAN (Body Area Network): The Ambient Hearing Aide, the Smart T-shirts

Control and prevention are two of the main goals of future health care. Already today, people have the option of being tracked and monitored by specialists even if patient and specialist are not in the same place. Tracing peoples' health history is another aspect that makes IoT-assisted e-health very versatile. Business applications could offer the possibility of medical services not only to patients but also to specialists, who need information to proceed in their medical evaluation. In this domain, IoT makes human interaction much more efficient because it permits not only localization, but also tracking and monitoring of patients. Providing information about the state of a patient makes the whole process more efficient, and also makes people much more satisfied. Trust is a key issue in this relationship. Patient to patient networks become more empowered as well.

LAN (local area network): the smart meter as a home interface

Future smart homes will be conscious about what happens inside a building, mainly impacting three aspects: resource usage (water conservation and energy consumption), security and comfort. The goal is to achieve better levels of comfort while cutting overall expenditure. Moreover, smart homes

(continued)

(continued)

also address security issues by means of complex security systems to detect theft, fire or unauthorized entry. The stakeholders involved in this scenario constitute a very heterogeneous group. Different actors will cooperate in the user's home, such as Internet companies, device manufacturers, telecommunications operators, media service providers, security companies, electricity utility companies, etc.

WAN (wide area network): the bike, car, train, bus, ...

In transport logistics, IoT improves not only material flow systems but also global positioning and automatic identification of freight. It also increases energy efficiency and thus decreases energy consumption.

Prof. Dr. Michael ten Hompel, Managing Director at Fraunhofer-Institut for "Materialfluss und Logistik", describes the consequences for something as "solid" as logistics: "The logical consequence of the Internet of Things is not just a new philosophy of how we can control our production and logistics. It completely changes the paradigms of conventional supply chain management. Within the Internet of Things the supply chain will be created in real time: *Entities*, consisting of objects and a piece of (agent based) software, generates the resulting supply chain 'on the move.' Therefore the sequences of operations are not predicted. This leads to a new understanding of how to handle our logistic management which won't be a supply chain (!) anymore."

IoT is thus expected to bring profound changes to the global supply chain via intelligent cargo movement. This will be achieved by means of continuous synchronisation of supply chain information and seamless real-time tracking and tracing of objects. It will make the supply chain transparent, visible and controllable, enabling intelligent communication between people and cargo.

VWAN (very wide area network): the smart city as e-government services *everywhere;* no longer tied to physical locations

While the term smart city is still a fuzzy concept, there is general agreement that it is an urban area which creates sustainable development and high quality of life. Giffinger et al.'s model elucidates the characteristics of a smart city, encompassing economy, people, governance, mobility, environment and living (Giffinger 2007). Outperforming in these key areas can be achieved through strong human or social capital and/or ICT infrastructure. There are a number of critics who question whether the smart city as it is conceived now can be inclusive and educational.