From the Internet of Computers to the Internet of Things: RFID as an Enabler of the IOT

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Abstract- Today, as sensing, actuation, communication, and control become ever more sophisticated and ubiquitous, there is significant overlap in these communities, sometimes from slightly different perspectives. This paper discusses the vision, the challenges, possible usage scenarios and technological building blocks of the "Internet of Things". In particular, we consider RFID and other important technological developments such as IP stacks and web servers for smart everyday objects. The paper concludes with a discussion of social and governance issues that are likely to arise as the vision of the Internet of Things becomes a reality.

Keywords: Internet of Things, RFID, smart objects, wireless sensor networks.

INTRODUCTION

The Internet of Things represents a vision in which the Internet extends into the real world embracing everyday objects. Physical items are no longer disconnected from the virtual world, but can be controlled remotely and can act as physical access points to Internet services. An Internet of Things makes computing truly ubiquitous –a concept initially put forward byMarkWeiserintheearly1990s.Thisdevelopmentisopeninguphugeopportunities for both the economy and individuals. However, it also involves risks and undoubtedly represents an immense technical and social challenge. The Internet of Things vision is grounded in the belief that the steady advances in microelectronics, communications and information technology we have witnessed in recent years will continue into the foreseeable future. In fact due to their diminishing size, constantly falling price and declining energy consumption – processors, communications modules and other electronic components are being increasingly integrated into everyday objects today.

I. VISION

"Smart" objects play a key role in the Internet of Things vision, since embedded communication and information technology would have the potential to revolutionize the utility of these objects. Using sensors, they are able to perceive their context, and via built-in networking capabilities they would be able to communicate with each other, access Internet services and interact with people."Digitally upgrading" conventional object in this way enhances their physical function by adding the capabilities of digital objects, thus generating substantial added value. Forerunners of this development are already apparent today–more and more devices such as sewing machines, exercise bikes, electric tooth brushes, washing machines, electricity meters and photo- copiers are being" computerized "and equipped with network interfaces.

The use of the word "Internet" in the catchy term "Internet of Things" which stands for the vision outlined above can be seen as either simply a metaphor In the same way that people use the Web today, things will soon also communicate with each other ,use services, provide data and thus generate added value or it can be interpreted in a Stricter technical sense, postulating that an IP protocol stack will be used by smart things.

The term "Internet of Things" was popularized by the work of the Auto-ID Centre at the Massachusetts Institute of Technology (MIT), which in 1999 started to design and propagate across-company RFID infrastructure. In2002, its co-founder and former head Kevin Ashton was quoted in Forbes Magazine as saying, "We need an internet for things, a standardized way for computers to understand the real world".

This article was entitled "The Internet of Things", and was the first documented use of the terminal literal sense. However, already in 1999 essentially the same notion was used by Neil Gershenfeld from the MIT Media Lab in his popular book "When Things Start to Think" when he wrote "in retrospect it looks like the rapid growth of the World Wide Web may have been just the trigger charge that is now setting off there a explosion, as things start to use the Net."

II. BASICS

From a technical point of view, the Internet of Things is not the result of a single novel technology; instead, several complementary technical developments provide capabilities that taken together help to bridge the gap between the virtual and physical world. These capabilities include:

COMMUNICATION AND COOPERATION:
Objects have the ability to network with Internet resources or even with each other, to make use of data and services and update their state. Wireless technologies such as GSM and UMTS, Wi-Fi, Bluetooth, ZigBee and various other wireless networking standards currently under development, particularly those relating to Wireless Personal Area Networks (WPANs),are of primary relevance here.

ADDRESSABILITY:
Within an Internet of Things, objects can be located and addressed via discovery, look-up or name services, and hence remotely interrogated or configured.

IDENTIFICATION:
Objects are uniquely identifiable. RFID, NFC and optically readable bar codes are examples of technologies with which even passive objects which do not have built-in energy resources can be identified. Identification enables objects To be linked to information associated with the particular object and that can be retrieved from a server, provided the mediator is connected to the network (seeFigure1).

SENSING: Objects collect information about their surroundings with sensors, record it, forward it or react directly it.

ACTUATION: Objects contain actuators to manipulate their environment. Such actuators can be used to remotely control real-world processes via the Internet.

EMBEDDED INFORMATION PROCESSING: Smart objects feature a processor or micro- controller, plus storage capacity. The sere sources can be used, for example, to process and interpret sensor information, or to give products a “memory” of how they have been used.

LOCALIZATION: Smart things are aware of their physical location, or can be located. GPS or the mobile phone network are suitable technologies to achieve this, as well as ultra sound time measurements, UWB (Ultra-Wide Band), radio be a constant optical technologies.

USER INTERFACES: Smart objects can communicate with people in an appropriate manner. Innovative interaction paradigms are relevant there, such as tangible user interfaces, flexible polymer-based displays and voice, image orgesturere cognition methods. Most specific applications only need a subset of these capabilities, particularly since implementing all of them is often expensive and requires significant technical effort. Logistics applications, for example, are currently concentrating on the approximate localization and relatively low-cost identification of objects using RFID or barcodes. Sensor data or embedded processors are limited to those logistics applications where such information is essential such as the temperature-controlled transport of vaccines. The smart phone a same diator between people, things and the Internet. But these days wireless communications modules are becoming smaller and cheaper, IPv6 is increasingly being used, the capacity of flash memory chips is growing, the per-instruction energy requirements of processors continues to fall and mobile phones have built-in barcode recognition, NFC and touch screens –and can take on the role of intermediaries between people, everyday items and the Internet (seeFigure1).All this contributes to the evolution of the Internet of Things paradigm: From the remote identification of objects and an Internet “with ”things ,we are moving towards a system where (more or less) smart objects actually communicate with users, Internet services and even among each other.

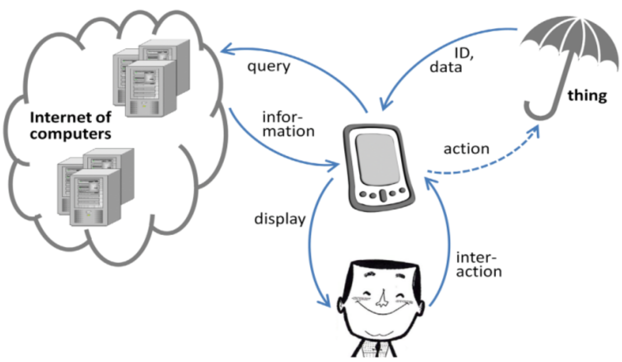

Figure1

III. DRIVERS AND EXPECTATIONS

What is driving the development of an Internet of Things? One important factor is the mere evolutionary progress of information and communications technology which is enabling continuous product improvements. Examples of this include navigation devices that receive remote road traffic messages, cameras that connect to a nearby net book to exchange photos, tire pressure sensors that's end their readings to the car's dashboard, and electronic photo frames that communicate with house hold electricity meters and display not only family photos but also illustrative graphs showing the power being generated by domestic solar panels.Another driver for the Internet of Things is the real-world awareness provided to information systems. By reacting promptly to relevant physical events, companies can optimize their processes, as typically illustrated by the use of RFID in logistics applications. Or to put it another way, by increasing the "visual acuity" of information systems, it is possible to manage processes better, typically increasing efficiency and reducing costs.

Although such telemetry applications are nothing new in principle, they have previously been restricted to special cases due to the costly technology involved (such as inductive loops in roads that transmit traffic conditions to a central computer in order to optimize these quenching of traffic lights).Due to diminishing cost and technical progress, many other application are a scan now benefit from an increased awareness of real-world processes. For example, it is now becoming worthwhile for suppliers of heat in goiloremotely check how full customers' oil tanks are, and for operators of drinks and cigarette machines to establish the estate of their vending machines via a wireless modem. In summary, the following expectations can be associated with the Internet of Things: from a *commercial point of view*, increased efficiency of business processes and reduced costs in warehouse logistics and in service industries (by automating and outsourcing to the customer), improved customer retention and more targeted selling, and new business models involving smart things and associated services. Of interest from a *social and political point of view* is a general increase in the quality of life due to consumers and citizens being able to obtain more comprehensive information, due to improved care for people in need of help thanks to smart assistance systems, and also due to increased safety, for example on roads. From a *personal point of view*, what matters above all are new services enabled by an Internet of Things which would make life more pleasant, entertaining, independent and also safer, for example by locating things that are lost, such as pet so revenother people.

IV. TECHNOLOGICAL CHALLENGES

While the possible applications and scenarios outlined above may be every interesting, the demands placed on the underlying technology are substantial. Progressing from the Internet of computers to the remote and somewhat fuzzy goal of an Internet of Things is something that must therefore be done one step at a time. In addition to the expectation that the technology must be available at low cost if a large number of objects are actually to be equipped, we are also faced with many other challenges, such as:

Scalability: An Internet of Things potentially has a larger over all scope than the conventional Internet of computers. But then again, things cooperate mainly with in a local environment. Basic functionality such as communication and service discovery therefore need to function equally efficiently in both small- scale and large-scale environments.

Arrive and operate: Smart everyday objects should not be perceived as computers that require their users to configure and adapt them to particular situations. Mobile things, which are often only sporadically used, need to establish connections spontaneously, and organize and configure themselves to suit their particular environment.

Interoperability: Since the world of physical things is extremely diverse, in an Internet of Things each type of smart object is likely to have different information, processing and communication capabilities. Different mart objects would also be subjected to very different conditions such as the energy available and the communications band width required.

Discovery: In dynamic environments, suitable services for things must be automatically identified, which requires appropriate semantic means of describing their functionality. Users will want to receive product-related information, and will want to use search engines that can find things or provide information about an object's state.

Software complexity: Although the software systems in smart objects will have to function with minimal resources, as in conventional embedded systems, a more extensive software infrastructure will be needed on the network and on backgroundserversinordertomanagethesmartobjectsandprovideservices to support them.

Data volumes: While some application scenarios will involve brief, infrequent communication, others, such as sensor networks, logistics and large-scale "real-world awareness" scenarios, will entail huge volumes of data on central network nodes or servers.

Data interpretation: To support the users of smart things, we would want to interpret the local context determined by sensors as accurately as possible. For service providers to profit from the disparate data that will be generated, we would need to be able to draw some generalizable conclusions from the interpreted sensor data. However, generating useful information from raw sensor data that can trigger further action is by no means at rivial undertaking.

SECURITY AND PERSONAL PRIVACY: In addition to the security and protection aspects of the Internet with which we are all familiar (such as communications confidentiality, the authenticity and trust worthiness of communication partners, and message integrity), other requirements would also be important in an Inter- net of Things. We might want to give things only selective access to certain services, or prevent them from communicating with other things at certain times or in an uncontrolled manner; and business transactions involving smart objects would need to be protected from competitors' prying yes.

Fault tolerance: The world of things is much more dynamic and mobile than the world of computers, with contexts changing rapidly and in unexpected ways. But we would still want to rely on things functioning properly. Structuring an Internet of Things in arobustand trust worthy manner would require red undancy on several levels and an ability to automatically adapt to changed conditions.

Power supply: Things typically move around and are not connected to a power supply, so their smartness needs to be powered from a self-sufficient energy source. Although passive RFID transponders do not need their own energy source, their functionality and communications range are very limited. In many scenarios, batteries and power packs are problematic due to their size and weight, and especially because of their maintenance requirements. Unfortunately, battery technology is making relatively slow progress, and "energy harvesting", i.e. generating electricity from is not yet powerful enough to meet the energy requirements of current electronic systems in many application scenarios.

Interaction and short-range communications*:* Wireless communication over distances of a few centimetres will suffice, for example, if an object is touched by another object or a user holds their mobile against it. Where such short distances are involved, very little power is required, addressing is simplified and there is typically no risk of being over heard by others. Active NFC units are small enough to be used in mobile phones; passive units are similar to RFID transponders and are significantly smaller, cheaper and do not need their own power source.

Wireless communications*:* From an energy point of view, established wireless technologies such as GSM, UMTS, Wi-Fi and Blue tooth are far less suitable; more recent WPAN standards such as ZigBee and others still under development may have an arrowed band width, but they douse significantly less power.

V. RFID AND THE EPC NETWORK

RFID (Radio Frequency Identification) is primarily used to identify objects from a distance of a few meters, with a stationary reader typically communicating wirelessly with small battery-free transponders (tags) attached to objects. As well as providing two important basic functions for an Internet of Things–identification and communication–RFID can also be used to determine the approximate location of objects provided the position of the reader is known.

The development of RFID over recent years is reflected not only in technical progress but also in cost reductions and standardization. For example, the power consumption of the latest generation of transponders is less than30μW, with reading distances of up to ten meters possible under favourable conditions.
Increasing miniaturization has also led to a unit price of close to five cents for bulk orders of simple RFID transponders. Major progress has also been made in the field of standardization, with the ISO18000-6CRFID protocol–also referred to as EPC globalGen2 being supported by several manufacturers, dominating the market and guaranteeing interoperability.

High cost pressure and the absence of batteries in transponders means that RFID communications protocols cannot be based on established Internet protocols due to a Scarcity of resources. For example, a typical RFID microchip merely consists of a few hundred thousand transistors, contains no microcontroller and has minimal storage capacity–usually just a few bytes. Instead of using a battery, passive RFID microchips are supplied with power remotely from a reading device. Since the power supply can frequently be interrupted due to "field nulls", the transmission of large data packets is avoided–at128 bits, these are typically much shorter than IP packets. Everyday objects that are to be addressed in an Internet of Things using RFID technology will therefore not behave in exactly the same way as Internet nodes. Instead, it is likely that a highly optimized wireless protocol will be used over the last few meters due to scarce resources and the adverse conditions encountered in the physical world. The RFID reader would act as a gateway between the two different protocols. TCP and HTTP-based protocols have been developed for use in RFID environments, where they are used to configure readers and distribute the data captured via the Internet.

One key application area for RFID is logistics. Where as previously information systems had to be "handfed" with data via a keyboard or barcode reader, data relating.

To logistics units cannot be captured automatically, without delay and at a fraction of the cost using RFID technology. The systematic development of RFID technology now means it is used not only in the commercial supply chain, but also in numerous other application areas. For example, RFID is used to manage books and media in libraries, to locate tools and other portable inventory items in factories, and even in the apparel industry, where RFID systems ensure that here tail store shelves are regularly replenished with the appropriate clothing items.

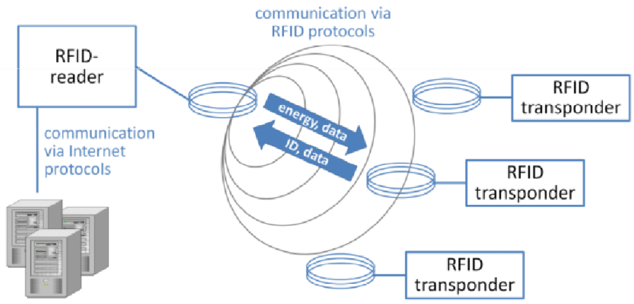

Figure2.RFIDcommunication.

In addition to defining EPCIS events, the EPCIS standard also defines an interface that can be used to search for such events in repositories. If the repositories that hold information on a particular RFID transponder are known, one can follow the "trail" of the object to which it is attached. In practice, however, there are numerous problems associated with this type of global information scenario. For example, one would not normally know all of their positories that held data relating to a given object, and a global search of all repositories would be unrealistic as their numbers grow. In many cases, the data would be commercially confidential and not generally accessible even the fact that a company possesses information relating to a particular object may itself be confidential. These difficulties show that there are still many challenges relating to applicability, scalability and security that need to be overcome before we can achieve an Internet of Things that supports such global queries.

VI. IP FOR THINGS

If, in a future Internet of Things, everyday objects are to be addressed and controlled via the Internet, then we should ideally not be resorting to special communications protocols as is currently the case with RFID. Instead, things should be have just like normal Internet nodes. In other words, they should have an IP address and use the Internet Protocol(IP) for communicating with other smart objects and network nodes. And due to the large number of addresses required, they should use the new IPv6 version with 128-bit addresses. The benefits of having IP-enabled things are obvious, even if the objects in question are not going to be made globally accessible but instead used in a controlled intranet environment. This approach enables us to build directly on existing functionality such as global interoperability, network wide data packet delivery (forwarding and routing),data transport across different physical media, naming services (URL, DNS) and network management. The use of IP enables smart objects to use existing Internet services and applications and, conversely, these smart objects can be addressed from anywhere since they are proper Internet participants. Last but not least, it will be easy to use important application layer protocols such as HTTP. IPv6 also provides the interesting capability of automatic address configuration, enabling smart objects to assign their own addresses.

The opportunities that this open sups have recently led to companies and standards committees adopting various measures. At the end of 2008,Atmel, Cisco, Intel, SAP, Sun Microsystems and other companies founded the "IP for Smart Objects"(IPSO) corporate alliance to promote the implementation and use of IP for low powered devices such as radio sensors, consumption meters and other smart objects. More specifically, the "IPv6 over Low Power Wireless Area Networks" (6LoWPAN) working group set up by the Internet Engineering Task Force (IETF)is addressing the problem of supporting IPv6 using the 802.15.4 wireless communication standard. This is a technical challenge because the maximum length of 802.15.4 data frames is only127 bytes due to lower data rate, higher susceptibility to failure and bit error rate of wireless communications. The IPv6 packet header alone is 40bytes long (primarily due to the source and target addresses each being 16 bytes long), and Unregimented IPv6 packets can be up to 1280 bytes long.

To make IPv6 communications function efficiently in wireless networks, a protocol modification layer has been defined that essentially deals with four issues embedding IPv6packets in 802.15.4 frames, fragmenting long packets to fit these frames, stateless compressing packet headers(typically to just 6bytes),and forwarding IPv6 packets via multi hop wireless routes. It is possible to compress the IPv6 header so drastically because 802.15.4 nodes communicate mainly with in their own wireless network, and therefore most of the information can be reconstructed from the general context or the surrounding 802.15.4 frames and considerably shorter local addresses can be used. The working group's proposal has now been published as proposed Internet standard RFC4944, and an implementation based on this is described in. In 2009, the ZigBee Alliance announced it would be in cooperating this "native IP support" into future ZigBee specifications, "allowing seamless integration of Internet connectivity into each product".

VII. THE WEB OF THINGS

One logical development of the Internet of Things is to leverage the World Wide Web and its many technologies as an infrastructure for smart objects. Several years ago, Kindbergetal.

Put forward the idea of marking physical objects with URLs that could, for example, be read using an infrared interface and cross-reference Web pages containing information and services on the objects in question. Another fundamental way of using the Web is to incorporate mart objects into a standardized Web service architecture (using standards such SOAP and WSDL), although in practice this might be too expensive and complex for simple objects.

In the Web of Things, smart objects and their services are typically addressed via URL sand controlled via a simple interface using a few well-defined HTTP operations such as GET and PUT. The data that objects transmit to the Web usually takes the form of a structured XML document or a JSON object hat is machine-readable. These formats can be understood not only by machines but also by people, provided meaningful mark-up elements and variable names are used. They can also be supplemented with semantic information using micro formats. In this way, smart objects cannot only communicate on the Web but also create a user-friendly representation of them, making it possible to interact with them via normal Web browsers and explore the world of smart things with its many relationships.

Dynamically generated real-world data on smart objects can be displayed on such "representative" Web pages and can then be processed using the extensive functionality of widely available Web2.0 tools. For example things could, via their digital representations, be indexed like Web pages, users could "Google" their properties, or they could be passed on as references. The physical objects themselves could become active and keep blogs or update each other using social networking tools like Twitter. Although this may sound like anode humanizing of in animate objects, it is of practical significance. The Web and its services are being used a ubiquitous middleware facilitating the implementation of new functionality and innovative applications for smart things.So if, for example, your washing machine is in the basement and you want to monitor its progress, you could subscribe to it stomped on Web client and get information on major state changes, or follow its tweets on Twitter.
In a more generalized way, amash up editor can be used to link event and data streams from physical objects with each other (and with Web services). Here is an example to illustrate this: most planes are equipped with radio beacons ("ADS-B") that transmit a short data packet once or twice per second at1090MHz, which can be received within a range of a few hundred kilometres. In addition to the plane's identifier, this packet contains its current position, height, speed and rate of climb ordescent. At http://radar.zhaw.chone can find amash up that uses Google maps to display the real-time flight paths of planes around Zurichin Switzerland (see Figure3;the size of the shadow and its proximity to the plane symbol indicates altitude).This mashup is enriched with additional datafromvarioussourcessuchaswww.flightstats.com. Clicking on the plane symbol now also results in a display of details such as the airline, departure and destination airports, expected arrival time, etc.

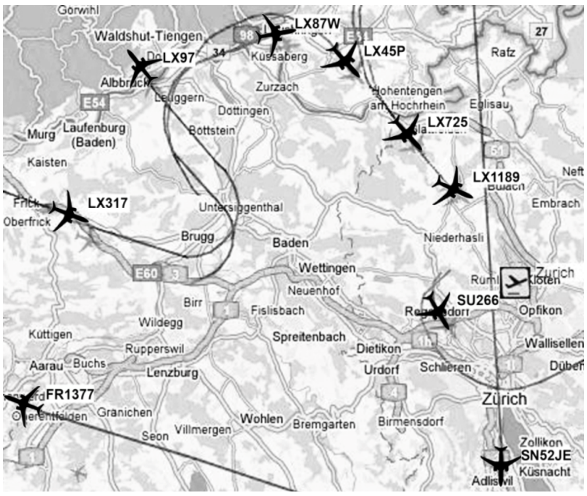

Figure3. Amash up displaying flight paths around Zurich[18].

Since it is cheap, standardized and widely available, Web and Internet technology could be the answer here. Such an approach would allow for the use of tried-and-tested network concepts (such as auto-configuration and network management tools), and remote maintenance would be possible using standard Web browsers and interfaces. With smart household devices ("Web2.0-ready"), WLAN- enabled electricity meters and other wirelessly communicating and self integrating gadgets; it might then be possible to gradually realize the old dream of the "smart home".

VIII. SOCIAL AND POLITICAL ISSUES

The Internet has long since changed from being a purely informational system to one that is socio-technological and has a social, creative and political dimension. But the importance of its non-technological aspects is becoming even more apparent in the development of an Internet of Things, since it adds a entirely new quality to these non-technological aspects.

So in addition to the positive expectations mentioned above, several critical questions need to be asked with regard to possible consequences. Irrespective of the data protection issues, there is also the question of who would own the masses of automatically captured And interpreted real-world data, which could be of significant commercial or social value, and who would be entitled to use it and with in what ethical and legal framework.

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