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INTERNET OF THINGS

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INTERNET OF THINGS

Small and lightweight components become more and more powerful, and at the same time cheaper. This enables the augmentation of physical objects with digital technology (e.g., information processing, communication). The interconnection of such 'intelligent' devices leads away from the classical internet of computers towards the 'Internet of Things'.
This development has a wide range of implications in the dimensions of technology, applications and society. A significant area of application areas will be influenced by the 'Internet of Things', from private households over mobility to research and industry.

In this seminar, various aspects of the Internet of Things were investigated. In the technological domain, the underlying communication technologies and hardware was discussed and an overview of interaction techniques with intelligent objects was gained. Furthermore, an overview of application domains was given and, based on selected examples, deeper investigated, such as the Internet of Vehicles. Last but not least, also economical implications and potential business models were investigated.

Each of the single chapters addresses a specific topic and presents fundamental research trends and developments. This report is targeted at electrical engineers, computer scientists and anyone interested in technology and realization of mobile services and corresponding new ways of interaction.

The seminar has been organized by the Institute for Media Technology and the Distributed Multimodal Information Processing Group at Technische Universität München.

This report contains the following scientific seminar theses:

1. Internet of Energy (IoE) *(Supervisor: Luis Roalter)*
2. Object Identification Techniques *(Supervisor: Andreas Möller)*
3. IoT and Related Business Models *(Supervisor: Stefan Diewald)*
4. IoT Technologies *(Supervisor: Luis Roalter)*
5. Application Domains of IoT *(Supervisor: Andreas Möller)*
6. Internet of Vehicles (IoV) *(Supervisor: Stefan Diewald)*

The website with the electronic version of the proceedings and additional material and resources can be found at `https://www.vmi.ei.tum.de/lehrveranstaltungen/hauptseminar-medientechnik.html`

We thank all students for the great work and their participation!

Munich, January 2013

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Internet of Energy

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January 15, 2013

Abstract

Over the last centuries we have seen a lot of new developments on the internet technologies transforming the energy area through the Information and Communication technologies (ICT), especially via the usage of networked embedded devices. The Internet of Energy can be described on its several kind of uses and impacts, explained here through the examples on the Smart Grid, Smart houses, Cooperation Objects and others implementations achievable with the development of new technologies concerning energy use, generation, distribution and transmission optimization.

1 Internet of Energy overview

The coupling of the physical and virtual world through the several interconnected devices we have nowadays create a new kind of interaction permitted by the sensors and actuators embedded in physical objects that communicate through wired and wireless networks. They become tools for understanding complexity and responding to it swiftly, even without human intervention. With that we could also generate fundamentally new insights for new activities and new forms of social relations. There are some important applications of these developments in waste management, urban planning, sustainable urban environment, continuous care, emergency response, intelligent shopping, smart product management, smart meters, home automation and day by day new opportunities of applications are being developed.

All of these appliances mainly that ones concerning the energy area should also be made carefully since we live in a world's economic regions dependent on each other and it is really necessary to ensure energy security and stable economic conditions. The main focus of the researches on energy nowadays are on spreading the intelligence of the internet distribution and controlling systems through many peripheral nodes, enabling more precise control and adaptation as well as more accurate monitoring of energy losses. Together with this challenges we expect to create a totally new infrastructure based on service oriented innovative applications that will have a lot of impacts on our everyday environment.

With these advances, highly distributed business processes will be create to help the deregulated energy market dealing with these new changes. Since there will be a growing number of providers and consumers interaction, the traditional static customer process with limited interventions will increasingly be superseded by a very dynamic, decentralized and market-oriented process.

We also need to get reliable IT applications that are widely supported and comprehensive. We should design the architecture of such distributed system landscapes and create some standards that will provide us the correct infrastructure to be closer to the era of the "Internet of things".

With this real-time two-way flow of information we could get many useful tools such as the so called cooperation objects to manage simple measurements from a large group of consumers in order to get most of the suppliers' efficiency. Another challenge is on how to apply all of these communications capabilities into others house's difficulties such as gas consumption since we could get an optimized fuel use.

Applying that on the Smart Grid as we imagine, it must support the large amounts of data that would be used and also be scalable and interoperable. Today internet deal with plenty of different ICT technologies (i.e., transceivers, protocols, services), and the expected result is to have only one common via with standard languages.

In the future we expect improvements on the energy efficiency by increasing the amount of renewable energy sources, originated by decentralized providers diversifying and stimulating a more competitive and free market for energy production and distribution. The Internet of Energy era and its several consequences is getting more powerful as the new technologies implementations are being made on important areas such as the power grids or our daily life pleasures.

1.1 Smart Grid

With the cities growth, the systems of energy in several voltages levels proliferate all over the world, so emerged the necessity of standardization of the voltages between them. The big interconnected energy systems were created inside countries as in Canada, US and Brazil and also between them as in Europe.
To interconnect all of these sources, it was necessary the creation of a system capable of: satisfy the continuous variation of the demand, supply electricity with low costs and the minimum environmental and ecological impacts and guarantee what we call power quality (constant voltage and frequency for example).
So, in the Internet of Energy (IoE) area, one of the most important developments is the implementation of technologies that permit us to have a more interactive grid called Smart Grid. According to the The Electric Power Research Institute - EPRI the definition of Smart Grid is: "...a power system that can incorporate millions of sensors all connected through an advanced communication and data acquisition system. This system will provide real-time analysis by a distributed computing system that will enable predictive rather than reactive responses to blink-of-the-eye disruptions". [1] For further clarification: Devices such as wind turbines, plug-in hybrid electric vehicles and solar arrays are not part of the Smart Grid. Rather, the Smart Grid encompasses the technology that enables us to integrate, interface with and intelligently control these innovations and others[2] .
Applying the use of the smart grids we see some common development points. It could be characterized as:

- Intensive and extensive use of technologies like Communication systems
- Real time monitoring (sensors + communication + processing)
- Information Technology
- Two way communication
- Distributed and renewable generation
- Electrical vehicles
- Smart meters
- Active customer participation
- PMUs (phasor measurement unit or synchrophasor) [3]
- FACTS (flexible alternating current transmission system) [4]
- New players (communication industry) and new services (home/business monitoring)
- Smart homes/smart appliances (from generators to refrigerators).

Beyond that, the share of decentralized power generation - by industrial or private producers - will increase and have a dominating effect on existing infrastructure, technologies and business practices as we can se on the Fig.1.
According to official documents for the U.S. Department of Energy, the ultimate success of the Smart Grid depends on the effectiveness of these devices in attracting and motivating large numbers of consumers. An intelligent or a smart grid integrates advanced sensing technologies, control methods and integrated communications into the current electricity grid, allowing the seamless integration of renewable sources like wind and solar, starting a new era of consumer choice. Explore the use of green building standards to help lighting the load, make large scales energy storage reality, enable nationwide use of plug-in hybrid electric vehicles, use of solar energy 24 hours a day are some of the others expected goals. [5]

[1] Electric Power Research Institute http://smartgrid.epri.com/
[2] U.S. Department of Energy http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf
[3] Also called Synchrophasors - are precise grid measurements of electrical waves to determine the health of the electricity distribution system. http://www.arbiter.com/solutions/phasor-measurement-unit-(pmu)-solutions.php
[4] Use of solid state devices to control bulk power flow in transmission systems, improving transmission capability; increasing the flexibility of power flow control http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1208&context=ecetr
[5] The Smart Grid: An introduction prepared for the U.S. Department of Energy by Litos Strategic Communication under contract No. DE-AC26-04NT41817, Subtask 560.01.04

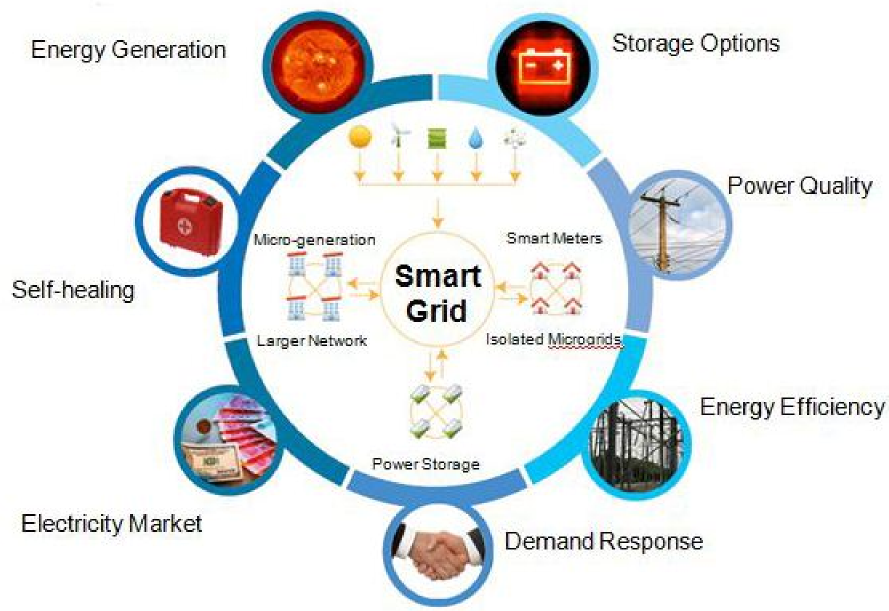

Figure 1: Smart Grid

2 Applications

2.1 Cooperation Objects

In order to achieve a more integrated grid towards more complete IoE systems, it is necessary a lot of communication and cooperation among the devices and systems involved. For these goals developments on the so called Cooperating Objects will increase the interaction with networked embedded systems that will be realizing its sensing and actuation functionality.

The domain of Cooperating Objects takes action between (networked) embedded systems, ubiquitous computing and (wireless) sensor networks. According to the European Commission co-funded project CONET (www.cooperating-objects.eu):"Cooperating Objects consist of embedded computing devices equipped with communication as well as sensing or actuation capabilities that are able to cooperate and organize themselves autonomously into networks to achieve a common task". [6]

In the context of IoE, many entities can be considered as Cooperating Objects. Typical examples are advanced smart meters, smart white label appliances, electric cars, various consumption/production devices, etc. Most of them are capable of providing their functionality (e.g. energy consumption, status, management, etc.) as a service alone or as part of more complex system. So as in any other electronic devices, some of them are limited by its resources. Sometimes there are external collaboration, and it uses the logic to understand semantics and build complex functional behaviors. It is also important avoid the security problems, incomplete information flow, slow responses and others difficulties that may emerge with the use of numerous protocols and even different technologies at hardware and communication layer since more gateways and (service) mediators IP-based will be used as Internet standards.

One of the opportunities created through the use of these devices is the price signals for example. If one energy provider (the monitoring or collaborator) with an on-line service shows that there are good opportunities for energy use or economization, the whole device can react generating commands and solutions in order to optimize the energy consumption. In this case both (the consumer and provider) involved have benefits.

Another important characteristic that can be evaluated on devices such as the smart meters are the fine measurements. For example during the discrete productions steps, during any logistic operations, during transportation etc., new dynamic energy-related information can be made available. Using these data we will be able to describe the whole

[6] The cooperative Internet of Things enabled Smart Grid, Stamatis Karnouskos SAP Research (www.sap.com) Vincenz-Priessnitz-Strasse 1,D-76131,Karlsruhe,Germany

lifecycle of a product evidencing its energy consumption. This way the customers will get a fair view of the energy impact it carries on. With enough information, reliable energy labels could contain precise numbers of the correct functions preventing that any significant deviation from the operational energy consumption may imply a malfunctioning device.
There are also side-effects of the use of these devices such as the unnecessary network utilization, therefore investments and researches are being made towards a model, where the necessary entities can subscribe and get only the interesting events for them exactly when it is needed. Notice that it is also important to guarantee that fine monitoring can be done and that the quality of monitoring services can be achieved. Once this data is evaluated either locally, on the network or on business systems, the actions on the enterprise level will be needed in order to close the loop of optimization.

2.2 Smart Houses

Also towards the implementation of IoE solutions in order to optimize energy consumptions or create new interaction opportunities it is evident the role of the future Smart homes. Heterogeneous devices will be able to measure, share their energy consumption, and actively participate in house-wide or building wide energy management systems (through Home automation, also called domotics[7]). It may include centralized control of lighting, Heating, Ventilation and air conditioning (HVAC [8]), appliances, and other systems, to provide improved convenience, comfort, energy efficiency and security. A Smart House is a home that uses ICT to control energy supply and demand. This creates a more pleasant living environment and enables residents to save energy and lower electricity bill payments.
Nowadays, with the whole connectivity of the smartphones and tablets, a lot of easy-to-use applications concerning home automation were created. The more affordable and assessable technologies of IoT could increase the smart houses selling and popularize some home automation solutions.
There are others IoE applications for the smart houses such as: Load shedding, demand response, real-time power usage and price reporting. All of them are considered Green Automation that use resources at either their lowest prices or highest availability, taking advantage, for instance, of high solar panel output in the middle of the day to automatically run washing machines. The thermostats used nowadays permit also that the use of gaseous, liquid fuels, or electricity in automation heating could be used in the most optimized way. Also control of domestic activities, such as home entertainment systems, houseplant, yard watering and pet feeding should be implemented.
Simple changes as motion sensors and detectors in terms of lightning control, integrated into a relatively simple home automation system can save hours of wasted energy in both residential and commercial applications. More sophisticated implementations such as Home Energy Management System (HEMS [9]) and residential energy storage systems play vital roles in a Smart House. This system automatically collects precise real-time data on power usage by room and presents it visually. This naturally heightens user awareness of energy saving and helps realize a reasonable, comfortable, eco-friendly lifestyle. In the case of the solar energy, it is possible to achieve the best efficiency if there is one energy storage system support.

3 Impacts

With some IoE solutions mainly on Smart Grids appliance we expect to solve problems such as poor reliability, integrating large scale generation and distributed generation (mainly renewable resources-based). It would also be easier to use integrated monitoring solutions and reduce grid losses by optimizing asset usage. Using the smart grid as we mean it would be accomplished the self-monitoring equipment remotely through Synchronized Measurement Technologies (for example PMUs) in a wide area using Wide Area Monitoring Protection and Control (WAMPAC [10]) . We could also get adaptive protection with Pervasive control system in order to achieve automated restoration, "self-healing".
We also see on the distribution and transmissions systems, main pain points such as:

- The manual restoration

[7] http://tinyurl.com/b3wfnbk
[8] HVAC systems control the temperature humidity and quality of air in buildings to a set of chosen conditions http://www.carbontrust.com/media/7403/ctv046_heating_ventilation_and_air_conditioning.pdf
[9] Helps monitoring the energy usage and advise on how to reduce both energy wastage and money on energy bills. http://www.theecoexperts.co.uk/home-energy-management-systems-a-comprehensive-guide
[10] Wide area control addresses automatic healing capabilities to some extent by proposing smart topology changes and control actions. http://pscc.ee.ethz.ch/uploads/tx_ethpublications/fp102.pdf

- The transmission system stress due to excessive load
- The inability to proactively diagnose problems.
- The manually equipment checking
- The local/limited protection
- The monitoring and control fails on the inability to isolate faults
- The electricity theft, the distribution losses
- The estimated reliability.

Applying smart grids solutions we could get:

- Real-time information about network to isolate faults
- Integrated monitoring solutions to avoid electricity theft
- Interconnected loss-reduction systems
- Predictive reliability
- Distributed generation.

In the end for the consumer use we check the influence of the smart grid on problems like, inability to exert direct control over electricity usage, lack of the consumers visibility into how they are consuming electricity (for usage reduction or optimization), inability to use distributed generation and storage systems. For these problems the provide solutions are: digital/microprocessor-based devices, advanced metering infrastructure, demand-response solutions with direct load control, home-energy-management solutions, solutions to integrate distribution, generation and storage systems assets and system automation which allows early detection or even prevention of problems. Summarizing others details on the Fig.1.

Characteristics	Today's Grid	Smart Grid
Enables active participation by consumers	Consumers are uniformed and non-participative with power system	Informed, involved, and active consumers- demand response and distributed energy resources.
Accommodates all generation and storage options	Dominated by central generation- many obstacles exist for distributed energy resources interconnection	Many distributed energy resources with plug-and-play convenience focus on renewables
Enables new products, services and markets	Limited wholesale markets, not well integrated- limited opportunities for consumers	Mature, well-integrated wholesale markets, growth of new electricity markets for consumers
Provides power quality for the digital economy	Focus on outages-slow response to power quality issues	Power quality is a priority with a variety of quality/price options- rapid resolution of issues
Optimizes assets & operates efficiently	Little integration of operational data with asset management-business process silos	Greatly expanded data acquisition of grid parameters- focus on prevention, minimizing impact to consumers
Anticipates and responds to system disturbances (self-heals)	Responds to prevent further damage- focus is on protecting assets following fault	Automatically detects and responds to problems – focus on prevention, minimizing impact to consumer
Operates resiliently against attack and natural disaster	Vulnerable to malicious acts of terror and natural disasters	Resilient to attack and natural disasters with rapid restoration capabilities

Table 1: U.S. Department of Energy http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf

Beyond all of these advantages it is clearly that the smart grid solutions would bring benefits for regulators with improvement of quality, balanced prices and reduction of $CO2$ emissions. For the GT&D[11] companies there will be increasing earnings and for the consumers, the lower prices.

[11] Generation, Transmission and Distribution

3.1 Security

Smart grids give clear advantages and benefits to the whole society, but their dependency on computer networks and applications, as well as on the Internet, make it more vulnerable to malicious cyber attacks with potentially devastating results. There are some critical points that need to be empowered:

- The network must be absolutely reliable
- Endpoints must be much lower cost in order to make it affordable
- Device hardware should not be upgraded often since it makes it more vulnerable during the changes.
- Cannot just ignore rural customers (must be more universal)
- The necessity of security all the time

Through Public-Private partnerships, knowledge sharing initiatives research collaboration or creation of standards, all of the companies and enterprises involved on the implementation of smart grids should work together in order to achieve a more secure network capable of supporting the goals expected. Today there are some opportunities making use of vulnerabilities of communication networks for financial or political motivation to shut off power to large areas or directing cyber-attacks against power generation plants. Beyond these examples, there are a lot of emerging difficulties creating more potential vulnerabilities and weaknesses that must be further analyzed. Besides, there are also well understood problems that need complex solutions such as the case of security issues concerning the data protection of end-consumers information. Hopefully there are some initiatives like Critical Infrastructure Protection (CIP[12]) and Critical Information Infrastructure Protection (CIIP[13]) in Europe that related directives and communications have already established a general regulatory framework for the protection of the critical infrastructures of the power (smart) grid.

3.2 Market Consequences

Energy systems are going to be self-managing, self-sustaining, and robust. It is also predictable that it will enable dynamic reorganization and coordination of services markets. The Internet-based infrastructure will be tightly coupled with the energy domain (IoE).
This way there will be many others mechanisms for trade based on supply and demand in the electricity market. Transaction platforms will provide services such as electronic marketplaces, facilitating the commercial activity associated with the buying and selling electricity and its derivatives.
For example one relevant aspect of the energy bill payments could be changed applying the real-time pricing method. It consists of energy prices defined for a time period on an advance or forward basis and which may change according to price changes in the market.
Consumers are not interested in changing drastically their energy consumption studying the best times to use the energy in order to reduce the costs. They want to easily adjust their own energy use. Equipped with rich, useful information helping manage load on-peak to save money and energy for themselves.

4 Conclusion

On the Internet of Energy field, the Smart Grid can be defined as an upgraded electricity network to which two-way digital communication between supplier and consumer, intelligent metering and monitoring systems have been added. We will see impacts on the efficiency since it is estimated that a lot of money will be saved thanks to demand-response programs that provide measurable, persistent savings with almost no human intervention. These advantages are clear since its autonomous working can provide faster solutions than human can respond. The grid itself will be capable of defining systems overloads and rerouting power to prevent or minimize a potential outage and will cooperatively work aligning the goals of utilities, consumers and regulators. The sensing and measurements technologies will be

[12] Improve physical and cybersecurity for the bulk power system of North America as it relates to reliability. http://www.dhs.gov/topic/critical-infrastructure-protection

[13] Aims to strengthen the security and resilience of vital Information and Communication Technology (ICT) infrastructures http://ec.europa.eu/information_society/policy/nis/strategy/activities/ciip/index_en.htm

improved to support faster and more accurate response such as remote monitoring, time-of-use pricing and demand-side management. Also the development of the advanced components, will apply the latest research in superconductivity, storage, power electronics and diagnostics to get better results. The dramatically reduced need to build more power plants and transmission lines will also help bringing a more reliable grid that anticipates detects and responds to critical problems in a fast way, reducing wide-area blackouts and loss of productivity. For everyone the affordability of the changes is one important point since energy prices will rise; but it should be controlled by the development of the technologies, tools, and techniques that will also provide customers many opportunities for managing their own electricity consumption and controlling their own bills. It is evident that the creation of new opportunities and markets by means of its ability to capitalize on plug-and-play innovation will generate large amounts of money that can be used in favor of the consumer delivering the power quality necessary-free of sags, spikes, disturbances and interruptions. Talking about security, the Smart Grid will be planned in order to avoid attacks and natural disasters. It will collaborate with the environmental trends using clean, renewable sources of energy like solar, wind, and geothermal integrated into the nation's grid reducing also the carbon footprint. The biggest challenges of the smart grid implementation are: A common definition of the smart grid concept; Cost reduction and fraud prevention; Cyber-security of the grid; Guaranteeing privacy of consumers; Consumer acceptance via awareness rising and education and Smart meter acceptance. In a few years probably most of this advances will become present on society daily life evidencing what we call Internet of Energy field.

5 References

Stamatis Karnouskos, The cooperative Internet of Things enabled Smart Grid, SAP Research (www.sap.com) Vincenz-Priessnitz-Strasse 1,D-76131,Karlsruhe,Germany http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6246751

Vinícius de Freitas Gomes Nogueira, Geracão Distribuida usando geradores síncronos trifásicos, Orientador: Prof. Dr. Ernesto Ruppert Filho

Nicola Bui,Angelo P. Castellani and Paolo Casari,Michele Zorzi, The Internet of Energy: A Web-Enabled Smart Grid System, University of Padova and Patavina Technologies , University of Padova , University of Padova and Patavina Technologies

Walmir Freitas, Smart Grids: a concept in Evolution. Seminário de redes inteligentes 26 e 27 de abril. Unioeste Parque Tecnólogico de Itaipu. Foz do IguaÃ§u-Paraná

Howard T. Liu Manager, Communication Architecture For SmartGrid, SmartGrid Communications Southern California Edison Feb. 2012

Larry Butts, Modeling the Smart Grid Communications Network DistribuTECH 2012 January 24, 2012, Southern Company Vaibhav Parmar, Accenture

Charles Newton, Global Outlook for Smart Grid and Supporting Communications Infrastructure: Trends and investments 2011-2015 , Newton-Evans Research Company

Asare, P.; Diez, T.; Galli, A.; O'Neill-Carillo, E.; Robertson, J.; and Zhao, R., "An Overview of Flexible AC Transmission Systems" (1994). ECE Technical Reports. Paper 205. http://docs.lib.purdue.edu/ecetr/205

Carbon Trust, Heating ventilating and air conditioning, UK: October 2011. CTV046 http://www.carbontrust.com/media/7403/ctv046_heating_ventilation_and_air_conditioning.pdf

Rene Avila-Rosales, Jay Giri, Wide-Area Monitoring and Control for Power System Grid Secutrity, AREVA T&D Inc. Bellevue, WA, USA. Session 9, Paper 3, Page 1 http://pscc.ee.ethz.ch/uploads/tx_ethpublications/fp102.pdf

European Network and Information Security Agency (ENISA) Smart Grid Security, also Anex I, II, III, IV and V http://www.enisa.europa.eu/activities/Resilience-and-CIIP/critical-infrastructure-and-services/smart-grids-and-smart-metering/smart-grid-security-related-initiatives/view

The Smart Grid: An introduction prepared for the U.S. Department of Energy by Litos Strategic Communication under contract No. DE-AC26-04NT41817, Subtask 560.01.04 http://energy.gov/oe/downloads/smart-grid-introduction-0

The European Strategic Energy technology plan SET-Plan towards a low-carbon future by European Comission http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm.

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Object Identification Techniques and the Application in IoT

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Abstract

Internet of Things (IoT) developed very rapidly in recent years. Object identification techniques is an important part to build IoT systems. This paper provides a overview of some typical object identification methods and compares these object identification techniques. To highlight the radio frequency identification (RFID) technique, the principle of RFID is explained; the application of RFID in building a IoT system is briefly introduced; in consideration of a problem with multiple objects identification with RFID tags, the anti-collision methods for RFID IoT system is simply discussed.

1 Introduction

The Internet of Things has become a hot topic in recent years. It is based on the Internet, using a lot of advanced techniques such as object identification techniques, wireless data communication techniques, following a certain protocol, to let different items connect with the Internet, in order to "talk" to each other and to exchange information. Through the Internet of things, we can realize an intelligent network of identification, locating, tracking, monitoring and management, and enable a more fine and dynamic way of living and production management. Through the implementation of the interaction between the physical world and the virtual world, new applications and services will be enabled.

From the application aspects, the construction of the IoT can be divided into three layers: First, the data acquisition at the front end; second, the data transmission within the network; third, data processing at the back end. With identification techniques and sensor technology, the front end can perceive and capture information data, which can describe and representative objects, at any time and anywhere. For instance, a visual sensor (e.g. camera) can capture images of objects, and with vision-based object recognition technique (such as local invariant feature-based methods, which are introduced in [1] in detail), the objects can be identified. The transmission part realizes the connection among objects, using different kinds of communication networks. The back end processing part could be a concentrated large data service, but also distributed cloud computing. There is a big mass of data and information to analyze and process, which have a high requirement to hardware and software. The most important task at the front end of the IoT system is the data acquisition which is realized by sensors and identification techniques.

There are many basic methods for object identification. In this paper there will be a few object identification methods briefly introduced in the second section, which contains different basic principles and technologies of identification. It includes the bar code technique, vision-based techniques and RFID. Then a comparison of these techniques will be presented. After that follows the detailed technique analysis of RFID, since it has been the most popular method for application in IoT. In consideration of a problem with multiple objects identification with RFID tags, there will be the section of anti-collision methods by RFID IoT systems.

2 Several Methods of Object Identification

The rapid development of object identification techniques provides a new effective method of fast, accurate data collection and input. It solves the problem of slow speed and high error rate while taking the keyboard for manual input. Hence, the object identification, as a kind of a high and new technology, was rapidly accepted by people. Bar code identification technology, vision-based object identification technology and RFID technology are three very important and typical object identification techniques at present.

2.1 Bar code Identification

Bar code is a graphic visible representation of information. Bar code technology has many advantages, such as a low error rate (generally below one over one million), quick input with a reader or scanner etc. Hence, it has been widely used. In many social service industries, like post transmission and product tracking and management, the bar code technology plays a very important role.

A bar code is composed of a set of bars and spaces, as well as the corresponding characters. When using a special bar code identification equipment (Bar code reader), such as a hand-held bar code scanner, to scan the bar code, the data information contained in the bar code will transfer the data, which can be identified by computers.

The Fig. 1 shows the reading principle of a bar code reader made by Keyence company. (1) The laser beams emitted from the laser diode hit the polygon mirror and scan a bar code. (2) The light-receiving element (photodiode) receives the light of diffuse reflection from the bar code. (3) The diffuse reflection looks like an analog waveform as illustrated. After that, (4) the bar code reader converts the waveform from analog to digital (A/D conversion) and (5) identifies the narrow/wide bars and narrow/wide spaces using digital signals. At last, (6) the bar code reader converts the signal combination of the bars and spaces into data according to the bar code rules (decoding). In the case of showing in the Figure, the outputs are "5" and "4".

The bar code is also called one-dimensional bar code. It represents data systematically by varying the widths and spaces of parallel lines. It is very simple and contains only dozens of data and characters. Examples are EAN code, UPC code, 39 code and 128 code. Later they evolved into rectangles, dots, hexagons and other geometric patterns in two dimensions (2D). The 2D code is more complicated. It stores information in the two-dimensional space, both horizontal and vertical direction. Nowadays, with the rapid development of image processing techniques, 2D code is more likely to be a vision-based identification technique. It can be identified not with a normal 1D laser scanner, but with a image reader (a camera). Examples are QR-Code (Quick Response Code), Data Matrix, Microsoft Tag and so on.

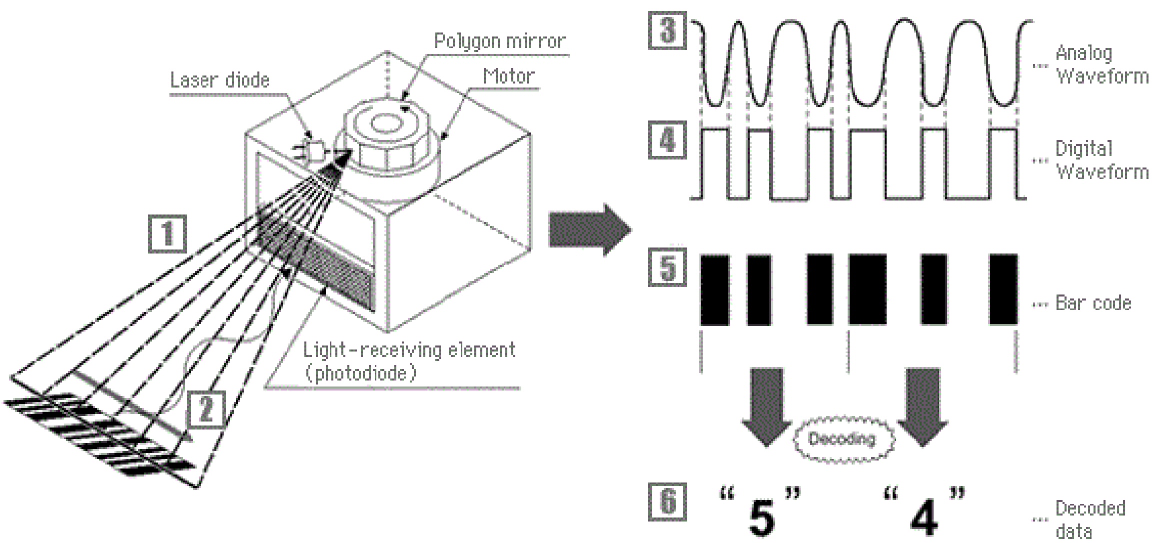

Figure 1: Reading principle of a laser bar code reader. Source: http://www.keyence.com/topics/barcode/

2.2 Vision-based Object Recognition

Vision-based object recognition is one important method, not only for IoT, but also in many other high-tech fields, such as computer vision [2], artificial intelligence [3], positioning and tracking system etc. There are many different methods to realize the vision-based object recognition. The basic principle of this technique is matching. Trough the matching of the features which chosen to detect and describe the objects, the target objects will be identified.

In general, one distinguishes between two different strategies, namely local and global approaches. Local approaches search for salient regions characterized by e.g. corners, edges, or entropy. In a deeper degree, these regions are characterized by a proper descriptor. For object recognition purposes, the through this strategy obtained local representations of test images will be compared to the representations of previously learned training images, namely the matching process. In contrast to that, global approaches model the information of a whole image. The reference [1] details the many widely used feature detectors and descriptors. Among them, Lowe presented scale-invariant feature transform (SIFT) for extracting distinctive invariant features from images that can be invariant to image scale and rotation. [4] Then it was widely used in recognition. Bay and Tuytelaars (2006) speeded up robust features and used integral images for image convolutions and fast-hessian detector. [5] Their experiments turned out that the speeded up robust feature (SURF) was faster and it works well.

There are also many other feature detection methods, e.g. the edge detection, corner detection and etc. Different method has its own advantages and disadvantages. Juan, L. and Gwun, O. implement several experiments, which focus on three robust feature detection methods: the SIFT, the SURF, and the Principal Component Analysis (PCA) SIFT. [6] They apply the three methods in recognition and compare the recognition results. It indicates that the SIFT presents its stability in most situations although it is slow. SURF is the fastest one with good performance as the same as SIFT. PCA-SIFT is not so fast but shows its advantages in rotation and illumination changes. As a conclusion, they argue that choose a suitable algorithm and giving improvement according to the application is very important by using the vision-based recognition to identify object.

2.3 Other Techniques

In the paper of Möller et *al*. [7], they have done an investigation and lab study, which classify the identification methods on smart phones in the view of different operation methods, such as text search, pointing, scanning, touching. Text searching is one method to identify an object which based on manual input. People enters the keyword about an object in the search engine and checks the results after text search, so as to identify the object. The principle of a pointing identification method on smart phones is vision-based recognition. As for scanning method, they use bar code and visual code identification in their study. The touching method suppose to be the technologies with wireless communication and high frequency transmission. Radio frequency identification (RFID) and near field communication (NFC) are the mentioned two techniques for scanning method. Objects are augmented with electronic tags based on radio communication.[8] NFC is widely used in smart phones. An NFC-enabled mobile phone can interact with a smart poster (NFC-tag), when they are in a distance of not more than ten centimeters. The study indicates that the identification with touching (NFC tags) is fast, precise and combined with good usability. The RFID can work in a very wide range of high radio frequency and even ultra high frequency. Hence, the transmission distance can reach a few meters. In the research of the application of object identification for IoT, the RFID is one of the most mature technologies. In the following section, we will concentrate on the RFID technique and its application in the IoT.

3 RFID Identification and its Application in IoT

3.1 A RFID System structure

A RFID system could consist of five components: transmitter, receiver, microprocessor, antenna and tags. Among them, transmitter, receiver and microprocessor are usually packaged together, and collectively referred to as reader, so that the RFID system can be divided into three parts: reader, antenna and tags. See Fig. 2.

1. Reader

   With three important components, the reader is the most complicated but also most significant part. On the one side, it can connect to the server computer with a normal WLAN interface, or with a RS232 serial port and USB interface. On the other side, it can communicate with the tags through the antenna. [9]

2. Antenna The antenna is linked together with the reader, and used to transfer radio frequency signal between reader and tag. Reader can be connected to one or more of the antenna, but normally only one antenna will be activated every time. The working frequency of RFID system is very wide, from low frequency to microwave, which makes matching between the antenna and the chips of tags very complicated. [10]

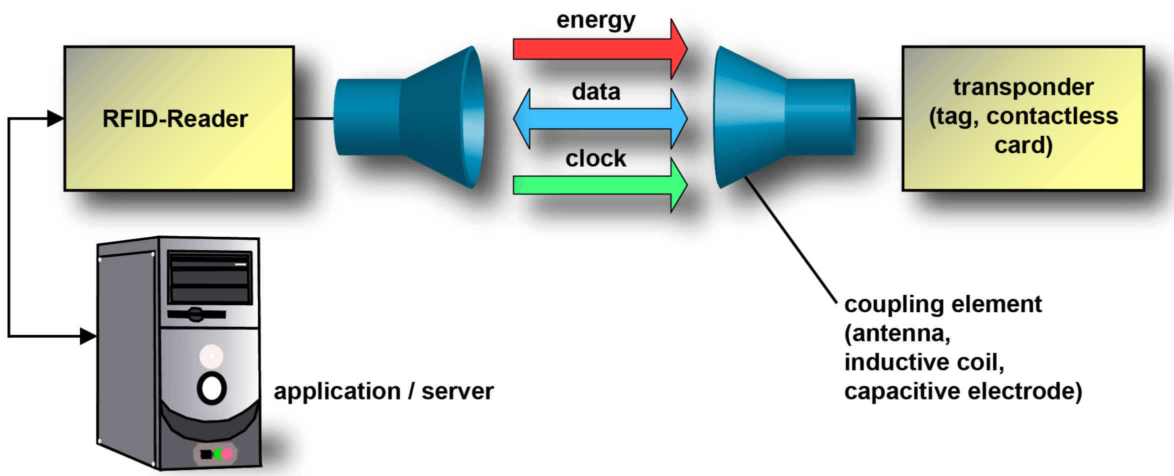

Figure 2: The system structure. The reader, the antennas and tags are the main components of every RFID system. Source: http://rfid-handbook.de/about-rfid.html

3. Tag

   The tag consists of a coupling element, a chip and a mini antenna. Each tag stores a unique electrical code, which attached to object and used to identify the object. When the tag is within the scanning field, it receives the RF signal from the reader. After that, a passive tag could send out the electrical code in the chip, since it has obtained energy thanks to the induction current. In contrast, an active tag will send the electrical code actively. [11]

3.2 Principle of Communication

Usually, the reader (antenna) can transmit energy in an area, which forms an electromagnetic field. The tag will detect the signal from the reader, when it turns out to be in this field. After that the tag will send out the stored data of the object. The reader will receive the radio frequency signal, decode and check the accuracy of the data, so as to achieve the purpose of recognition. However, this basic principle is only suitable for simple situation, which includes only one tag or one object. As for multiple objects identification, there are anti-collision algorithms should be implemented, which will be described in later sections.

Data communication between reader and tag is realized by some kind of coupling, which accomplish in the generated electromagnetic field. The antenna on the reader side transmits energy, which catched by the tag antenna, so that the radio frequency channel for information transmission can be constituted through coupling. There are two different kinds of couplings.(See Fig. 3.) The inductance coupling suits the lower frequency RFID system, which employs the electromagnetic induction, while the electromagnetic backscatter coupling has a higher or ultrahigh working frequency and uses the transmission (scattering) performance of the electromagnetic wave. So as to reach a high level of transmission distance when building IoT using RFID technique, the working frequency and the cooperated coupling method must be taken into consideration and well designed.

3.3 Comparison RFID with other Identification Techniques

Comparing with bar code, visual code, vision-based recognition and other techniques, RFID has irreplaceable advantages in many aspects, such as transmission distance, reading and writing performance, anti-interference ability, service life etc. Although the manufacturing cost of RFID is relative higher than than bar code and visual code, it turned out to be a good method to building IoT.

In the table below, we compare the before mentioned identification techniques. (See Tab. 1) From the table we can also see that the RFID is a relative suitable technique in the application of building IoT, since it has a good performance almost in all of the compare items.

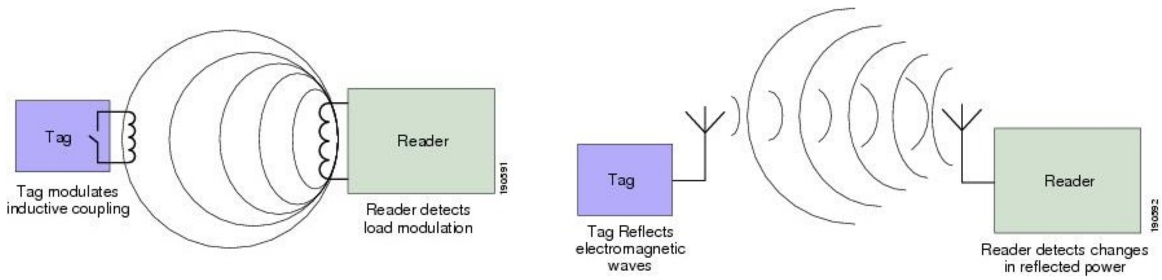

Figure 3: Different coupling methods. Left: inductance coupling; right: backscatter coupling. Source: http://www.cisco.com/en/US/docs/solutions/Enterprise/Mobility/wifich6.html

Identification methods	Information carrier	Information capacity	Read and write	Data acquisition	Confidential-ity	Lifetime	Cost
Bar code	label made by paper or plastic	little	only readable	photoelectric sensor, laser scanner	not good	short	lowest
Visual code	label made by paper or plastic	large	only readable	CCD or COMOS camera scan	normal	relative short	low
Vision-based	target object	large	only readable	CCD or COMOS camera, image	good	relative long	highest
RFID	EEPROM	large	read or write	wireless radio communica-tion	good	long	relative higher than bar code

Table 1: Comparison RFID with other Identification techniques

3.4 Building IoT with RFID

Since IoT mainly consists of smart objects, including all forms of sensors, actuators, small devices, and they connect together normally using radio technologies. In the paper of Rob van Kranenburg et *al*. [12], they discuss the situation and development of IoT with many paradigms, which also implicates, what a role RFID plays in the IoT.

In their view of this point, "IoT applications will be used in a wide range of innovative areas like industrial automation, smart grids, smart cities, home and building automation to name a few. However, in order to be uniquely addressable, all smart objects will have some form of electro-magnetic identification, and RFID technologies will be likely used to tag every sort of manufactured item."

A simple RFID-based IoT should include RFID tags which attached to objects, reader to acquisition signal and data from the tags, middleware with application programs to realize different operation about objects and end-user server which is directly contacted with humans. See Fig. 4.

The purpose of the IoT is to achieve a connection between objects and an interaction between objects and humans. An advanced example of building IoT with RFID takes place at the university of Washington, Evan Weibourne, Leilani Battle and their colleges a built an Internet of Things using RFID in their computer science and engineering building, which called a RFID ecosystem. [13] Using this system, the students in the building can manage their own objects very easily and also learn about the situation of their friends through the searching of their objects. Evan Weibourne, Leilani Battle et *al*. also developed a suite of web-based, user-level tools and applications, which were the middlewares in this system, to make the system more user friendly and very acceptable. After a four-week study of the using circumstances of the RFID ecosystem, they found that more and more participants joint the using of this ecosystem and the recorded operation of the users also increased. However, they also concluded that building application with RFID data in the IoT would be challenged to create a safe control of privacy, since the metadata associated with tags, antennas, and

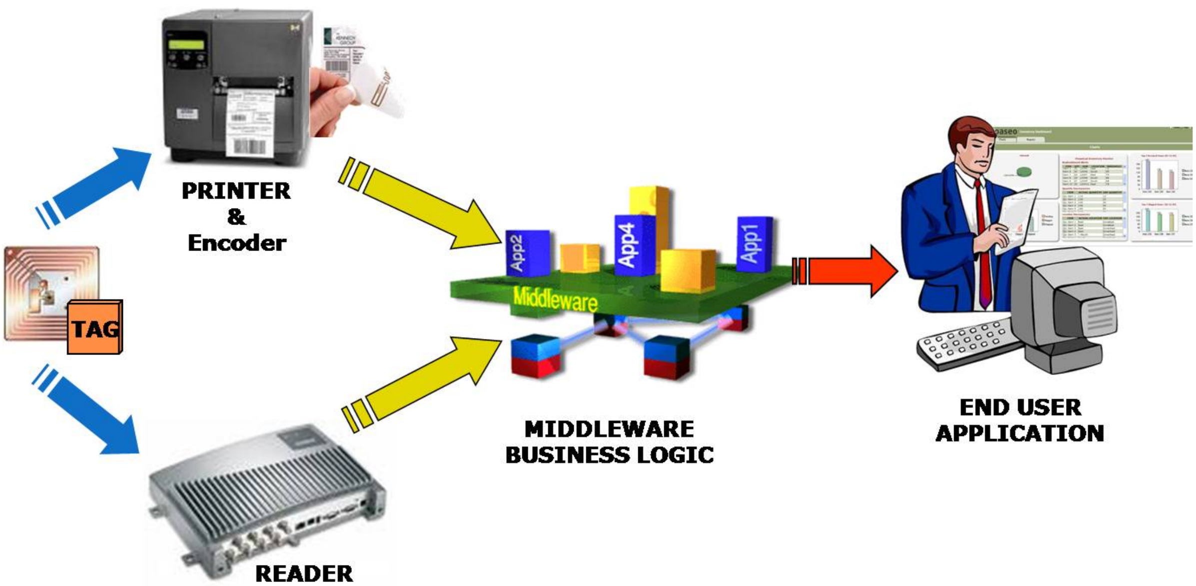

Figure 4: Basic construction of IoT with RFID Source: http://www.dolphinrfid.in/knowledge.htm

events must be personalized. Nevertheless, they state that the RFID-based personal objects tracking are feasible and have given us a good practice model of building IoT with RFID.

3.5 Anti-collision

The main application of passive RFID systems so far is the identification of objects where items are presented to the antenna one at a time, or where the identification of a single tag (out of many tags attached to the same object) is sufficient to identify an item. A different problem is the identification of multiple tags where each tag determines the identity of one object. In this case, it is not sufficient to identify a small subset of tags, but all tags should be identified robustly. As examples, consider a warehouse or a supermarket checkout. Hence, we need to research the applicability of passive RFID systems to the simultaneous identification of multiple objects. Advanced RFID systems support this capability by providing anti-collision techniques that address the problem of tag messages cancelling each other out. [14]

The existing anti-collision schemes can be classified into two big categories: Tree-based schemes and Aloha-based schemes. Typical Tree-based schemes include memory-less algorithms, such as Query-Tree scheme [15] and also algorithms with memory. Typical Aloha-based schemes include Bit Slot scheme [16], Grouping scheme, and ID Slot scheme. In this paper, we focus on the anti-collision issue which is specified for passive RFID system. In this case, we only take "Slotted Aloha" schemes as an example to discuss.

In a slotted aloha algorithm, time is divided into equal size of slots. Each slot is equal to the transmission time of every data packet in tags. When the reader broadcasts a request, each tag in the field receives the request and choose a random slot beginning to send its data packet. Once a tag has successfully sent its message, it will not resend it, and the other tags are woken up one after another. If two or more different tags choose the same slot for sending their answer, a collision occurs and all data is lost. See Fig. 5, nodes 1, 2 and 3 are three tags on different objects, which collide in the first slot. Node 2 finally succeeds in the fourth slot, node 1 in the eighth slot, and node 3 in the ninth slot. The notation C, E and S represent "collision slot", "empty slot" and "successful slot", respectively.

Framed slotted aloha is a modified method of slotted aloha. It suppose to divide the time into several frames, each with a same quantity of slots. Whenever a collision has occurred, another frame of slots is provided, and hopefully the tags will choose different slots this time, such that no collision occurs.

Since each tag choose slot randomly and independently, collision happens inevitablely. However, we can minimize collision rate and improve the identification efficiency. It is proved that if the frame size is equal to the number of tags in the read area, the system efficiency will reach the maximum value [17]. So the problem of anti-collision is

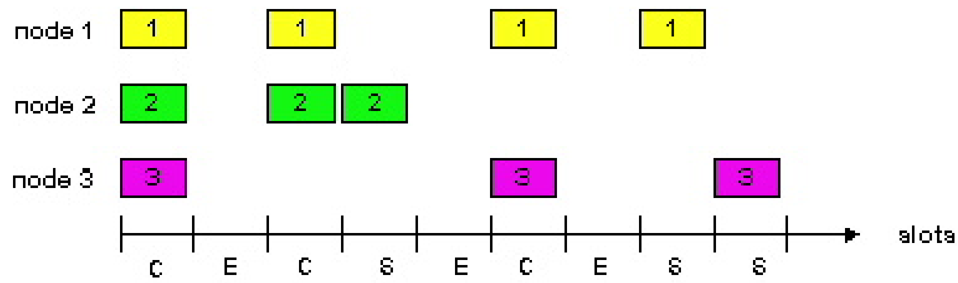

Figure 5: Slotted aloha working scheme Source: http://jpkc.ncwu.edu.cn/jsjwl/nrxx.asp?id=81

transformed into the problem of estimating the number of tags in the electromagnetic area. Nowadays, most anti-collision algorithms are designed to resolve this problem, so that the RFID technique can keeps in development.

4 Summary

The whole paper begins with a brief introduction of IoT, leads to the key technology in the realization of IoT - object identification. It gives a overview of different object identification techniques, such as bar code, visual code, vision-based recognition and RFID technique. After the comparison of both advantages and disadvantages of different techniques, the paper focuses on the RFID and gives a detailed discuss of this technique, include the analysis of the communication principle between tags and antennas, the anti-collision algorithm. For instance, an example of building IoT with passive RFID has been introduced.

Since the it own the advantages of long transmission distance, low error rate, quick and convenient and so on, the RFID has a very application in many situation especially for object identification in IoT. Meanwhile, it put forward a challenge because of the problem of privacy and system security when employing the RFID for IoT.

References

[1] Tuytelaars, T., Mikolajczyk, K.: Local invariant feature detectors: a survey. Foundations and Trends® in Computer Graphics and Vision **3**(3) (2008) 177–280 1, 2.2

[2] Medioni, G., Kang, S.: Emerging topics in computer vision. Prentice Hall PTR (2004) 2.2

[3] Rubin, C.: Artificial intelligence and human nature. The New Atlantis **1** (2003) 88–100 2.2

[4] Lowe, D.: Object recognition from local scale-invariant features. In: Computer Vision, 1999. The Proceedings of the Seventh IEEE International Conference on. Volume 2., Ieee (1999) 1150–1157 2.2

[5] Bay, H., Tuytelaars, T., Van Gool, L.: Surf: Speeded up robust features. Computer Vision–ECCV 2006 (2006) 404–417 2.2

[6] Juan, L., Gwun, O.: A comparison of sift, pca-sift and surf. International Journal of Image Processing (IJIP) **3**(4) (2009) 143–152 2.2

[7] Möller, A., Diewald, S., Roalter, L., Kranz, M.: MobiMed: Comparing Object Identification Techniques on Smartphones. In: Proceedings of the 7th Nordic Conference on Human-Computer Interaction (NordiCHI 2012), Copenhagen, Denmark, ACM (October 2012) 31–40 2.3

[8] Want, R., Fishkin, K., Gujar, A., Harrison, B.: Bridging physical and virtual worlds with electronic tags. In: Conference on Human Factors in Computing Systems: Proceedings of the SIGCHI conference on Human factors in computing systems: the CHI is the limit. Volume 15. (1999) 370–377 2.3

[9] Ahson, S., Ilyas, M.: RFID handbook: applications, technology, security, and privacy. CRC (2008) 1

[10] Ranasinghe, D., Cole, P.: Far-field tag antenna design methodology. Technology, Security, and Privacy/Syed Ahson and Mohammad Ilyas (eds.) (2008) 65–92 2

[11] Dontharaju, S., Tung, S., Hoare, R., Cain, J., Mickle, M., Jones, A.: Design automation for rfid tags and systems. RFID Handbook: Applications, Technology, Security, and Privacy, ed. S. Ahson and M. Ilyas (2008) 35–64 3

[12] Van Kranenburg, R., Anzelmo, E., Bassi, A., Caprio, D., Dodson, S., Ratto, M.: The internet of things. A critique of ambient technology and the all-seeing network of RFID, Network Notebooks **2** (2008) 3.4

[13] Welbourne, E., Battle, L., Cole, G., Gould, K., Rector, K., Raymer, S., Balazinska, M., Borriello, G.: Building the internet of things using rfid: the rfid ecosystem experience. Internet Computing, IEEE **13**(3) (2009) 48–55 3.4

[14] Vogt, H.: Efficient object identification with passive rfid tags. Pervasive Computing (2002) 98–113 3.5

[15] Law, C., Lee, K., Siu, K.: Efficient memoryless protocol for tag identification. In: Proceedings of the 4th international workshop on Discrete algorithms and methods for mobile computing and communications, ACM (2000) 75–84 3.5

[16] Kim, C., Park, K., Kim, H., Kim, S.: An efficient stochastic anti-collision algorithm using bit-slot mechanism. In: Proc. of Int. Conf. on Parallel and Distributed Processing Techniques and Applications. (2004) 3.5

[17] Quan, C., Hong, W., Kim, H.: Performance analysis of tag anti-collision algorithms for rfid systems. Emerging directions in embedded and ubiquitous computing (2006) 382–391 3.5

Internet of Things and Related Business Models

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Abstract

The Internet of Things (IoT) is a new paradigm or vision projected taking as base the existing technologies and the extreme speed with which these technologies are incresing their functionality and reducing their size. IoT as we know it today is closely related to RFID (Radio Frequency Identification), WSN (Wireless Sensor Network), UBICOMP (Ubiquitous Computing) and M2M (Machine to Machine Communications). IoT may have several applications in transportation, logistics, healthcare, smart environments, personal living and social domain. This article describes the new tendencies towards the Internet of Things, the related technologies, its main characteristics, its evolvement, and focuses on an analysis of the main models of revenue or business models that could be based on its development.

1 Introduction

On a world that is continuously evolving, technology has played an important role in providing tools to cope with such constant and rapid progress. This is evident in all aspects of human life, since technology has helped us to adapt to our environmental context, and also has given us comfort and stability. Communication and Information Technologies are nowadays a big part of this situation, making the factor of distance close to irrelevant and the processing of data almost instantaneous. This has opened new possibilities with every discovery and development. The aim of this paper is to give insight over one of these recent developments, the Internet of Things, also see how it relates to the technological trends and analyze how it may interact with some economical and business models.

After the emersion of the Internet, a big stream of developments has come attached to it. This can be evidenced on every aspect of our society, everything from educational schemes to business and corporate processes evolved with the use of the Internet. Now the vision is to take things one step further, which means that Internet will not only be a service used by humans on will by operating some network node or device, but artifacts around us will have access and make use of the Internet to perform the task for which they were designed. This may occur even when humans are not completely aware of it in the moment and just implicitly enjoy its benefits (Reference 1). This concept is called the Internet of Things (IoT).

The concept of Internet of Things first appeared in 2001 in an AutoID Center paper by David Brock about the Electronic Product Code and it is undeniable the special attention and emphasis that it has gotten ever since [1]. There is a growing number of researchers and professionals sharing and working on the vision of what this new concept could represent and how it can be achieved, as can be inferred from the large number of books, articles and conferences about the topic that can be listed just by typing Internet of Things on any scientific search engine. The topic has become to form a very important part of the vision of The Internet of the Future, as we will see in the following chapters.

2 The Future Internet and the Internet of Things

Current Internet is based on an architecture with protocols, addresses, and a domain name scheme that all together represent core principles that restrict its ability to adapt to enhanced performance and requirements of reliability. In the future, considering the amount of devices that will have access to it and their mobility, the Internet will have lowered the mentioned obstacles and devices will be able to connect directly into the Internet, eliminating barriers, such as local networks, local network routers, and domain name servers [2]. This vision challenges the traditional understanding of a network topology as a sum of networks working in parallel one next to another, and instead proposes the Future Internet as a single unified network in which devices and components interact in a more unhindered manner [3].

The previous definition gives a wide range of possibilities for the benefits that the Future Internet has to offer, but also allows to infer the prematurity of the current state of the technology and its market [4]. It also states the importance of the Internet of Things, increasing the role of almost every object around us by giving them an enhanced mission of assisting directly or indirectly human life by the use of Internet.

In that way, the Internet of Things can be defined inside the context of the Future Internet and the benefits that it brings to business processes and everyday living:

```
 A world where physical objects are seamlessly integrated into the
information network and where the physical objects can become active
participants in business processes and everyday living.  Services are
available to interact with these smart objects over the Internet, query their
state and any information associated with them, taking into account security
and privacy issues [5].
```

2.1 Evolution

Fig. 1 shows the evolution phases that have led to the concept of the Internet of Things as described in previous segments. When an organizations private computer network uses Internet Protocol Technology and allows a device in the network to be aware of the information and states of other devices in the network, follows under the category of an Intranet of Things. If this same information and states of devices inside an intranet is reachable by a network node outside the intranet following the determined authentication and security protocols, the concept evolves to Extranet of Things. Internet of Things takes it some steps further by making this interaction between devices a multiple and constant real-time activity, and by bringing the serviceability to people under everyday basis.

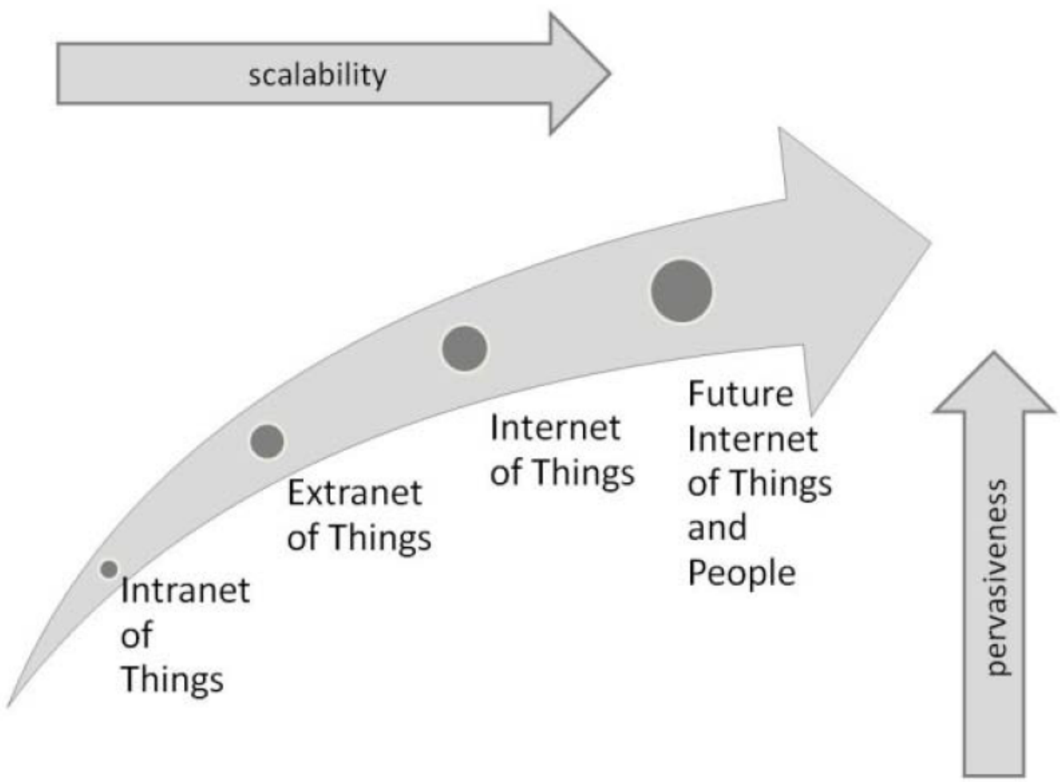

Figure 1: A Phased Approach from the Intranet of Things to a Future Vision on the Internet of Things [1]

While pervasiveness can increase with every step on this phased evolution through applications and wider adoption, scalability and infrastructure requirements also increase and have to be met.

2.2 Web Based Service Economy

Future economy is estimated to be driven by services managed through Internet applications (Internet of Services). These services will answer to needs that may have been consciously stated by a person, or seamlessly sensed, processed and communicated by an artifact, as stated on the basic definition of the Future Internet and the Internet of Things.

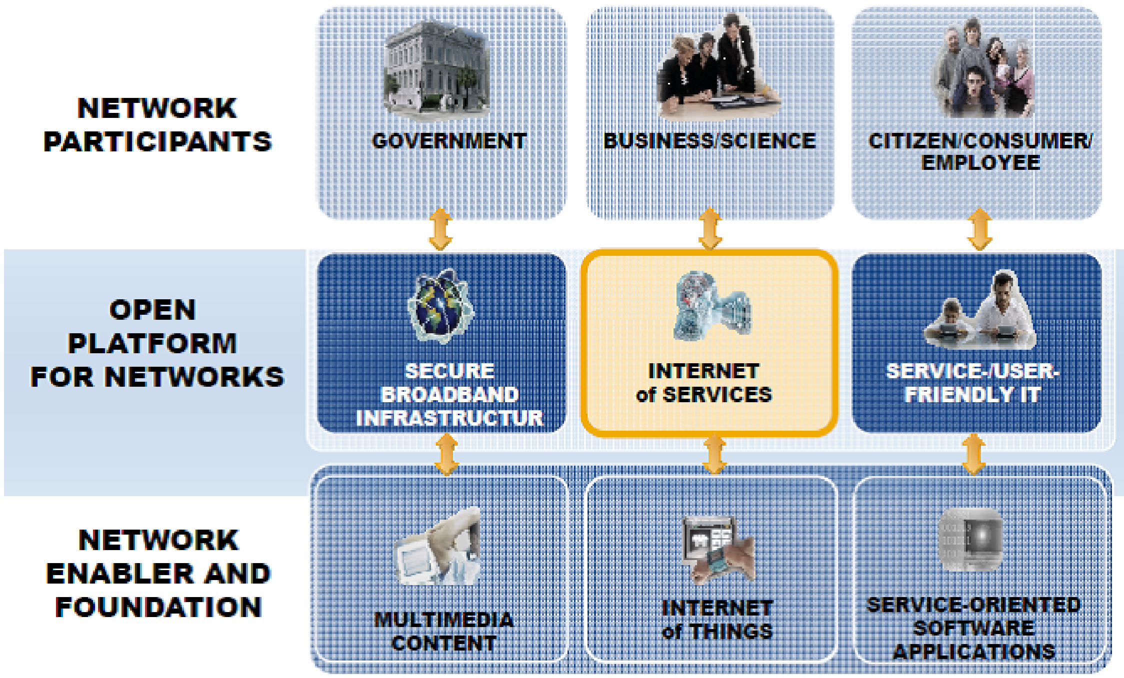

Figure 2: Vision of a Web-Based Service Economy and its different components [6]

In Fig. 2 the different components of a Web-Based Service Economy are shown, together with the interrelations between them. It presents how the final users or participants obtain the desired service through different types of platforms by the use of diverse technologies and concepts. In other words, government, industry and the people in general, enabled by an infrastructure and technologies will be allowed a fluent use of the Internet to assist people and their artifacts in their jobs, recreation and everyday living [6].

3 Current Challenges

3.1 Technical

3.1.1 Reliability

Many research programs established extensive ubiquitous systems pushing technical limitations to new heights. This is evidenced on current research being done by universities and Research and Development departments around the world focusing on RFID or NFC (Radio Frequency Identification - Near field Communication). Nevertheless, all these experiments occur under laboratory conditions. Not only the people using the systems are analyzed and supervised but the systems themselves. The state of the art systems are not thought of for domestic use as of the current state, but they are used for research purpose only. Systems often break or deliver inaccurate measurements leading to fatal decisions of an autonomously working environment [3].

3.1.2 Limited Interoperability

Due to economic constrains users establish their systems over time with the financial means they have available. Different brands, operating systems and platforms on a broader perspective and simply updates and altered versions on a company scale foster a difficult interoperability. More over, the highly variable subsystems are supposed to connect with the ubiquitous environment (invisible to user) and partially change locations (human movements). This induces ad-hoc connections with little to zero human interaction, which is currently hardly achieved as no standards exist. Furthermore, those connections often cause major problems. Systems connections that should not work together and users would have to debug everything [2].

3.1.3 Complexity and System Administrator

Researchers are technology-affine people who like to operate with and be connected to high-tech. Further they have the knowledge to oversee their technology enhanced environment. Home users on the other hand often lack the ability to operate the systems. Moreover they do not like to be bothered by such systems and are missing the interest for it. The technology has to be developed in such a way that the environments are working with the maximum of capabilities but requiring the least knowledge or preparation for controlling it or regulating it, at least on everyday basis [7].

3.1.4 Ambiguity

Systems consist of subsystems. Subsystems are further established by a broad set of sensors. All the gathered information must be interpreted and an adequate action has to be undertaken. The question arises: How does the system react if contradictory data is gathered? Users still have to understand the pragmatics of sensors, interpretations and actions to predict the outcome. The more subsystems are in use the higher the degree of automation but the more complex and harder to understand it gets. Besides the complexity of system parts, the number of users increases the ambiguity [7]. For example, a home environment that only serves one person can optimize its conditions to this specific user. Handling many users in an environment demands an optimization of functions underlying many more considerations and algorithms. Mostly no sufficiently good results have been achieved.

3.2 Political - Legal

3.2.1 Privacy and Security

The systems not only have to work but must provide meaning full results. They have to be linked to peoples daily routines and lives. Enough information has to be gathered to implement the supervision and assistance without neglecting users privacy. Intensive legal regulations have to be developed to handle the privacy of the now extremely volatile data [7].

3.3 Economical

3.3.1 Investment

After all this technical drawbacks were exposed, it is clear that there is still the need for a considerable amount of investment in Research and Development so that the Internet of things is an everyday reality. Also the Political factors have to be coped with in order to be implemented. So, appealing business models have to be developed in order to make the idea attractive and generate the motivation of overcoming the current challenges so that the investment in time and resources is made with the certainty of worthy revenue.

4 Business Models

4.1 Push-Pull Approaches

In logistics and supply chain management, Push Manufacturing is a strategy in which the production quantities follow internal parameters of a company, it usually means Make to Stock and has no relation with the demand curve of a specific market. On the other side, Pull Manufacturing is the opposite strategy in which the production quantities follow strictly the demand curve of the market. It generally means Make to Order and only the items that already have been sold are manufactured.

Following the same analogy, a Push Approach for business models related to the Internet of Things categorizes all those economical activities that generate income from making the IoT technology available, but that do not depend on it. The Pull Strategy, on the other hand, is related to those models that use the IoT Technology to generate an additional product or perform an additional service. Totally depends on IoT Technology to generate additional value.

In simple words, all those enterprises that invest resources to develop and make possible the IoT technology, follow a Push Approach. Meanwhile, those enterprises that make use of the existent IoT technology to maximize their capabilities, make more efficient their processes or offer an additional product or service, follow a Pull Approach. So, while pull approaches depend on the IoT technology and IoT technology depends on the push approaches, it is safe to infer that the PUSHERS will probably act as suppliers or service providers for the PULLERS.

4.1.1 Business Value

While the business value of push models is easily reduced to offering products and services that make possible the use of the Internet of Things, the business value of pull models is somewhat more complex and allows a wide margin of possibilities. These possibilities can be resumed in the following two big paradigms:

- Real World Visibility: by using automated systems for data collection and identification by applying IoT technologies like RFID, it will be possible to achieve a High-Resolution Management allowing a company to be aware in real-time what actually is happening in its real world. This means to have immediate feedback on location and status of assets and products and also information on how the companys operations are performing [5]. The deeper insight obtained and its correlation with time leads to a better understanding of business processes allowing its optimization and better control.
- Business Process Decomposition: this concept takes things one step further, by decomposing processes into subprocesses and having smart items making decisions by applying some business logic. This approach allows the decomposition and decentralization of existing business processes which increases the performance and opens possibilities for escalating the business [8]. The main idea is easily understood after analyzing Fig. 3.

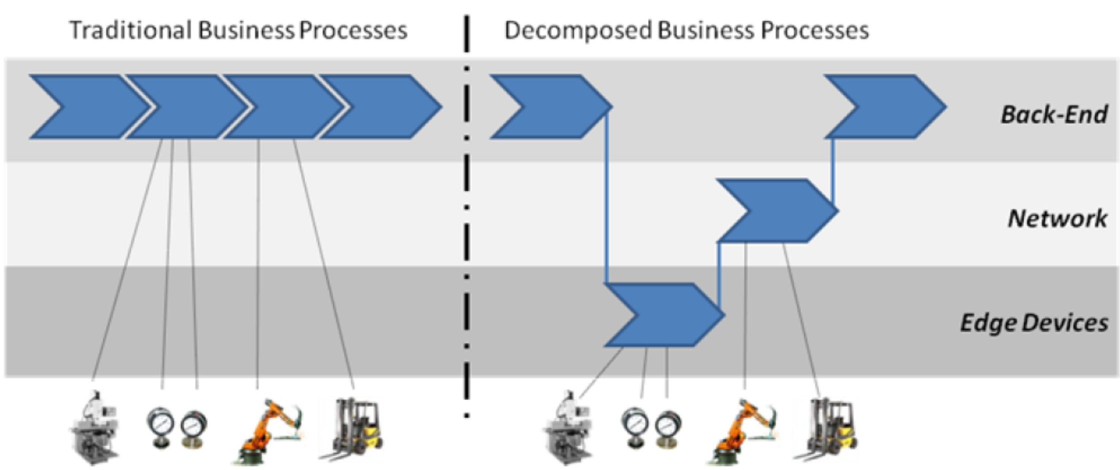

Figure 3: Traditional vs. decomposed and distributed business processes [5]

4.2 Main Application Areas

Here are some of the application areas that stand to profit most from the possibilities offered by the Internet of Things. Only some of the most general categories are analyzed and discussed, since from these main ones many others will be deployed. In general all businesses will transform their internal way of working, and will evolve from the traditional back-office, report-oriented platform, into a real- time analytic and data intensive approach bringing business operations to the IoT Era [9]. In addition to the ones described below, some other areas that can be greatly impacted by the Internet of things are Energy, Automotive and Insurance industries.

4.2.1 Manufacturing

Manufacturing and production processes can highly benefit from IoT technologies [10]. By the use of distributed sensors, smart devices, actuators and machine-to-machine communication production processes can be greatly optimized [11]. By having real- time/real-world visibility, a deeper insight is obtained on the different aspects of the manufacturing processes. It will be possible to have immediate tracking of machinery performance, material management, improved quality control which would lead to increased productivity [5].

Also new possibilities arise. For example a company could offer a service of custom manufacturing, by which clients could remotely operate machinery through an Internet based application, and fabricate their own products and prototypes. This will offer a series of advantages to small companies with not enough capital or volume demands as for investing in expensive production machinery [12]. These benefits are stated clearly in the following quote:

> All the devices would offer their functionality as a web service. Device integration thus means service integration, focusing on the functionality a device offers and not on the particular device technology. This not only creates a new paradigm on the shop floor, but it also would encourage the development of new devices in the automation industry that offer embedded web services [5].

4.2.2 Supply Chain

The current problems in supply chain management are mainly due to the inability to make completely assertive decisions due to the lack of real-time information of different parameters on the supply chain. This brings problems such as lags in demand forecast, price fluctuation and Limited supply [13]. All this can be basically attributed to the traditional information transmission model. With the new possibilities brought by the Internet of Things, the traditional vertical information transmission model is broken, and these information transmission lags can begin to be solved [14]. Fig. 4 shows a possible configuration of an IoT system applied to supply chain management.

Aditionally, IoT technologies support the integrity and control of products by allowing tracking of the location and the state of assets throughout the full product life-cycle. Complete integrity of assets in the supply chain includes the following aspects as described in [5]:

- Physical integrity of the product itself. Sensors can be used to ensure that the product was never exposed to potentially damaging environmental conditions.
- Transportation routes, checking that the product never was in an area where it was not supposed to be. Analysis of logistics, production processes.
- Integrity of product regarding means of production.

4.2.3 Health

In the health sector, IoT technologies can provide benefits from two main perspectives. The first perspective is aiding processes and tracking medicines and equipment as in the previous examples. For this RFID tags are an important technological enabler. This is being done already by some hospitals like the Jena University hospital in Germany, which to improves logistics processes while provides better care by tracking equipment, patients and medications [5].

The second perspective is by health monitoring and assisted living, which can also be done in places outside hospitals by the use of smart data gathering devices in ubiquitous environments [16]. Constant communication connectivity enabled by the Internet of Things in Assisted Living Environments allows a real time evaluation of the health parameters of patients, as a sort of quantified-self tracking of vital signs information and determined characteristics given the conditions and requirements of specific patients. It also offers benefits as it acts as a step towards prevention health treatment rather than solution health measures [17].

4.2.4 Architecture - Construction Process

Construction process may benefit from the use of IoT Technologies from the following perspectives, synergically oriented in the same direction as current trends in construction industry.

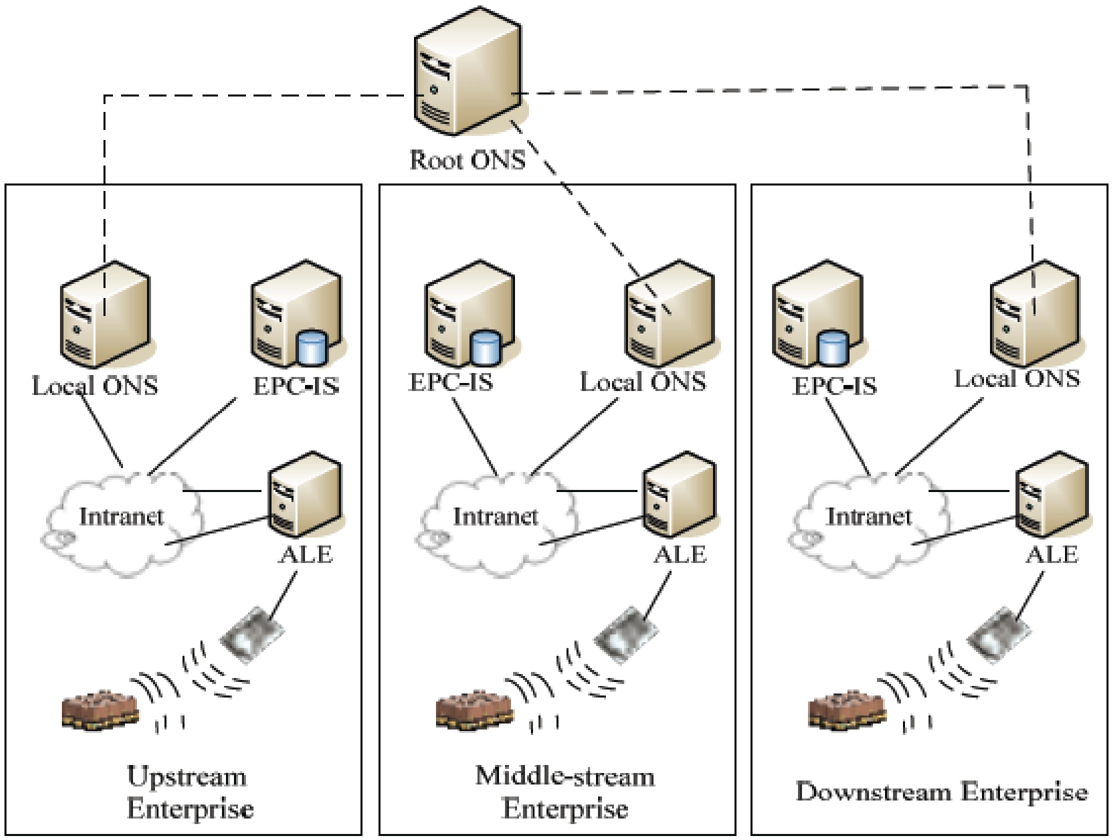

Figure 4: Structure of Internet of Things system in supply chain context [15]

- Building Information Modeling: Building Information Models can greatly benefit from the use of the Internet of Things. On an industry characterized for being static and not easily embracing changes, Internet of Things could allow components detailed on a construction model to be analyzed and tracked, allowing machinery and operators to get information about position, location, orientation linked to a schedule and a budget. Would be a significant development towards robotics and automation in Construction.
- Prefabrication in construction: by the use of the prefabrication strategy in junction with concepts as standardization of constructive elements, a great potential in the increase of productivity and average quality of buildings can be achieved. The analysis for both manufacturing and supply chain categories also apply in prefabrication for construction, as it is a step towards industrialization of a traditionally craftwork industry. Internet of Things and Machine to Machine Communications applied in prefabrication is also a big step towards automation in construction.

4.2.5 Architecture - Building Technology

This category refers mainly to the Internet of things applied to architecture after it is completely constructed. How can IoT Systems and devices aid architecture in the lifecycle of a building.

- Smart Home Automation: Ubiquitous Computing is a model that describes a system that is composed by multiple embedded and partially invisible computer systems that perform as subcomponents of the main Ubiquitous system. These systems are aware of their surroundings and provide interactive or proactive support to the users of a determined ubiquitous environment. When this awareness is exploited it can assist inhabitants of a house or building on daily activities by tracking tendencies and anticipating needs. These benefits can be easily appreciated when imagining a lighting system that graduates automatically depending on natural light context or activities of the inhabitants. Also a good example might be the regulation of artificial temperature in accordance to external condition and weather forecasts. Highly functional subcomponents already exist but the connection and integration of these systems is not yet fully exploited. It is still restricted, costly and unstable, as previously described on the technical limitations to overcome. Compared to the early days of the automobile industry, the smart home automation is still the car for which there are still no roads, and its usefulness is questioned. Now, it is evident that people spend most of their life at home, or general buildings for that matter, and a big portion of the capital is bounded in buildings. This fact, combined to the current trend of spending in convenience and comfort make visible that a huge opportunity for a rising market exists, and that it just waits to be exploited as soon as the industry overcomes the existing challenges on the research and development stage.

- Ambient Assisted Daily Living: Elderly members of society struggle finding their place in their community trying to prove themselves useful in a world that is leaving them behind. Many of the activities that they used to perform regularly, are now a great challenge due to their diminishing vitality and strength. New concepts and ideas are continuously emerging from different disciplines to counter attack this problem and to help transforming most elderlys feelings of futility and unreliability into independence, autonomy and vitality. Assisted Daily Living (ADL) is one of the approaches in which technology, specifically Internet of Things and Ubiquitous Computing, can play an important role regarding this matter. By the inclusion of smart assisting devices into their environment, elderly can get to perform tasks that they could not otherwise imagine, given their advanced age. Additionally, Ambient Assisted Daily Living is closely related to the home health tracking vision discussed in the health applications of the Internet of Things. When applied on a ubiquitous home environment, it can greatly assist in the tracking and control of vital signs and other parameters.

References

[1] Uckelmann, D., Harrison, M., Michahelles, F.: An Architectural Approach Towards the Future Internet of Things. In Uckelmann, D., Harrison, M., Michahelles, F., eds.: Architecting the Internet of Things. Springer Berlin Heidelberg (2011) 1–24 1, 1

[2] Schneidewind, N.: Proposed future internet. Innovations in Systems and Software Engineering **8** (2012) 125–173 10.1007/s11334-011-0158-z. 2, 3.1.2

[3] Zahariadis, T., Papadimitriou, D., Tschofenig, H., Haller, S., Daras, P., Stamoulis, G., Hauswirth, M.: Towards a future internet architecture. In Domingue, J., Galis, A., Gavras, A., Zahariadis, T., Lambert, D., Cleary, F., Daras, P., Krco, S., MÃ$\frac{1}{4}$ller, H., Li, M.S., Schaffers, H., Lotz, V., Alvarez, F., Stiller, B., Karnouskos, S., Avessta, S., Nilsson, M., eds.: The Future Internet. Volume 6656 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2011) 7–18 2, 3.1.1

[4] Mazhelis, O., Luoma, E., Warma, H.: Defining an internet-of-things ecosystem. In Andreev, S., Balandin, S., Koucheryavy, Y., eds.: Internet of Things, Smart Spaces, and Next Generation Networking. Volume 7469 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2012) 1–14 2

[5] Haller, S., Karnouskos, S., Schroth, C.: The internet of things in an enterprise context. In Domingue, J., Fensel, D., Traverso, P., eds.: Future Internet FIS 2008. Volume 5468 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2009) 2, 4.1.1, 3, 4.2.1, 4.2.2, 4.2.3

[6] Heuser, L.: The future web-based service economy. (2008) 2, 2.2

[7] Mattern, F., Floerkemeier, C.: From the internet of computers to the internet of things. In Sachs, K., Petrov, I., Guerrero, P., eds.: From Active Data Management to Event-Based Systems and More. Volume 6462 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2010) 242–259 3.1.3, 3.1.4, 3.2.1

[8] Leminen, S., Westerlund, M., Rajahonka, M., Siuruainen, R.: Towards iot ecosystems and business models. In Andreev, S., Balandin, S., Koucheryavy, Y., eds.: Internet of Things, Smart Spaces, and Next Generation Networking. Volume 7469 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2012) 15–26 4.1.1

[9] Castellanos, M., Dayal, U., Hsu, M.: Live business intelligence for the real-time enterprise. In Sachs, K., Petrov, I., Guerrero, P., eds.: From Active Data Management to Event-Based Systems and More. Volume 6462 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2010) 325–336 4.2

[10] Renton, P., Bender, P., Veldhuis, S., Renton, D., Elbestawi, A., Teltz, R., Bailey, T.: Internet-based manufacturing process optimization and monitoring system. In: Robotics and Automation, 2002. Proceedings. ICRA '02. IEEE International Conference on. Volume 2. (2002) 1113 –1118 4.2.1

[11] Wu, G., Talwar, S., Johnsson, K., Himayat, N., Johnson, K.: M2m: From mobile to embedded internet. Communications Magazine, IEEE **49**(4) (april 2011) 36 –43 4.2.1

[12] Ngiam, K., Tan, K., Tay, F., Kwong, K., Tan, T., Toh, E., Goh, E., Khanal, Y.: Internet manufacturing (iman). In: Internet Workshop, 1999. IWS 99. (1999) 69 –74 4.2.1

[13] Yunxiao, W., Xuecheng, Z., Haitao, W.: Study of the internet-based supply chain management application. In: Computer Application and System Modeling (ICCASM), 2010 International Conference on. Volume 8. (oct. 2010) V8–76 –V8–79 4.2.2

[14] Ping, L., Quan, L., Zude, Z., Wang, H.: Agile supply chain management over the internet of things. In: Management and Service Science (MASS), 2011 International Conference on. (aug. 2011) 1 –4 4.2.2

[15] Yan, B., Huang, G.: Supply chain information transmission based on rfid and internet of things. In: Computing, Communication, Control, and Management, 2009. CCCM 2009. ISECS International Colloquium on. Volume 4. (aug. 2009) 166 –169 4

[16] Istepanian, R.S.H., Sungoor, A., Faisal, A., Philip, N.: Internet of m-health things. In: Assisted Living 2011, IET Seminar on. (april 2011) 1 –3 4.2.3

[17] Davie, B., Florance, V., Friede, A., Sheehan, J., Sisk, J.: Bringing health-care applications to the internet. Internet Computing, IEEE **5**(3) (may/jun 2001) 42 –48 4.2.3

IoT technologies

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Abstract

This paper gives an overview of the state-of-art technologies used for various deployments of the Internet of Things concept. It discusses the hardware and middleware platforms for IoT, as well as the communication technologies. The paper focuses on the IEEE standards for IoT communication and on other important protocol stacks used in IoT, for instance, ZigBee and 6loWPAN. The common usage cases for different technologies are described and compared.

1 Introduction

Internet of Things (IoT) is an emerging concept of an ubiquitous automation. It gains more and more importance due to the rapid technology development and the rising interest from the industry. The key idea is to integrate a high amount of technical objects (e.g. sensors, tags or actuators) for collecting the information and for performing actions into the casual environment, ensure the communication between these objects and interaction with the user [1].

The general term "Internet of Thing" comprises a huge range of possible applications. On the one hand, there are different industry applications, such as medical, logistic or healthcare [2]; on the other hand, the concept could be deployed in the field of home and office automation [3], [4]. The diversity of applications causes the high range of different technologies involved. Since most of the standards for IoT are still in development, there are a lot of generally accepted and used protocols and different concept implementations, even in the same application field.

This paper aims to give an overview about the enabling technologies of IoT. We do not want to restrict the topic to the particular field of application, but, however, it is hardly possible to describe all possible solutions in one document. Therefore, the primary thread of the paper will cover the featured IoT technologies, that is, the technologies and their peculiarities, which are distinct from the conventional ones. The paper comprises such topics as communication, hardware and software platforms, presenting them in the context of resent problems, which they tend to solve.

2 Hardware Technologies in IoT

The IoT environment in the typical sense consists either of the everyday objects with embedded modules for enabling their communication, or of the dedicated networks of devices, serving for the special purposes, such as sensing or controlling; however, the border between these two application groups is fuzzy. The example for the first type could the wireless personal area networks and smart environments and for the second type - wireless sensor networks. These objects, embedded or detached, will be called IoT nodes throughout this paper.

The application range for IoT concept varies significantly, and therefore the technologies used are diversified. Nevertheless, there exist some common open, as well as proprietary, platforms widely used in IoT implementations. The most common requirements for such platforms are the following: support of the IoT communication technologies, low power consumption, wide range of possible applications, low costs and complexity. The focus of this section is the examples of open hardware platforms, satisfying the above requirements.

2.1 TelosB

TelosB is a good example of an open source platform. It was originally developed by the UC Berkeley research community, and aims to provide a simple and efficient hardware for the modern projects. It based on the MSP430 microcontroller (8 MHz, 10 Kbytes RAM) and is adjusted to the TinyOS operating system family. Also, the included radio module and support of extension sensor boards, along with the integrated humidity and temperature sensors, makes the platform very well suited for wireless sensor networks [5].

2.2 Btnode

Btnode is another example of an academic platform. It was developed in Swiss Federal Institute of Technology. Compared to TelosB, it has some additional features. First, it has two radios: the primary interface is Bluetooth, and the secondary is low-power radio operating in the 433-915 MHz band. Second, Btnode uses the specially developed C-based operating system, BTnut, with an plane C programming interface (compared to TinyOS, where the specific language nesC is used) [6].

The dual-radio modules allow the hardware to be used in a wider range of applications and make it compatible with other platforms, e.g. Mica2. However, the absence of 802.15.4-supporting radio shortens the use cases for the device, since it is one of the most important data transmission standard in IoT communication.

2.3 Other

There are some other platforms, used for prototyping and experimenting in the IoT-related projects. Essential to mention are the open-source platform Arduino, used in a broad spectrum of applications due to its flexibility and simplicity, and the "miniPC" RaspberryPI, which is also well suited for fast prototyping, for it being inexpensive and versatile.

The important constituent of the IoT network, along with the special devices like sensors or actuators, are the devices, which are already present in our everyday life. In this respect, the modern devices like smartphones are gaining more importance. Normally, they already possess the low-power communication interfaces (e.g. Bluetooth), and the ability to run arbitrary applications (apps) on top of the operating system (Android, iOS or Windows Phone), what makes them appropriate for interacting with the local objects, e.g. RFID tags or sensors, whereby providing a plenty of deployment opportunities [7].

3 Communication technologies in IoT

The typically high number of nodes in the network and their location distribution in the IoT environment are the reasons for communication between these nodes being an essential feature. IoT comprises a lot of different technologies, covering all the layer of the respective OSI communication model. The following sections give an overview of enabling protocols, from physical (PHY) and media access control (MAC) layer (3.1) to the network (NWK) and higher layers (3.2).

3.1 Communication standards

Generally, all communication technologies used in IoT are based on the IEEE 802 standard family, which defines the group of standards for local and metropolitan area networks. The most important technologies from this standard family, with respect to IoT purposes, are:

- 802.3 Ethernet, defining the physical and data-link layers of the wired local area network [8].
- 802.11 Wireless Local Area Network [9].
- 802.15 Wireless Private Area Network, including the Low-Rate (802.15.4), High-Rate (802.15.3) and Bluetooth (802.15.1) specifications [10].

The standard defines both wired and wireless communication. Although some IoT solutions use wired technologies as well (e.g. for various IoT Gateways [11]), they will not be covered in this paper. The reason for it is that wired technology provides less flexibility and contradicts with the main IoT idea of the ubiquitous automation deployment, and therefore could be considered only as a complementary technology. Wired communication cannot be applied in some cases, and even if it can, wiring significantly increases the costs, e.g. for some sensors wiring constitutes 80% of the total installation costs [12].

The wireless networks were developed long time ago, e.g. 802.11 WLAN standard, which had been introduced back in 1985 [8]. However, the appearance of IoT brought some new challenges to wireless networking hardware and, thereby the challenges for the standardization authorities, since the hardware characteristics are determined by the functionality it is deploying. The specific design requirements are:

1. Low power consumption; the IoT nodes are required to have as small power consumption as possible. This consequently follows from the fact that they are integrated into objects we interact with and, in most of the cases, don't have any external power supply.

2. Low costs and complexity; due to the potentially very high number of nodes, the expenses for one node should remain on a very low level.

Depending on the application, there surely could arise some requirements or restrictions on the range, data transmission rate and frequency usage. But for the most deployment scenarios, these factors remain in the background, therefore this fact makes the major difference to the conventional wireless networking, where power consumption and costs are at least of the same or even of less importance than high throughput and large transmission distance.

3.1.1 WLAN 802.11

This standard was originally developed for local area networks, but it can be adapted for usage in the IoT scenario too, especially if we recall the fact that IoT node could be every object, even the regular laptop or desktop PC. Its main advantages are:

- High data transmission rates (up to 600 Mbps)
- High range of transmission
- Widely deployed, i.e. there are plenty of devices already using this standard, including user devices (e.g. laptops and smartphones), therefore, the interoperability problem is solved.

WLAN could be used in case of widely distributed networks, and with low density networks. However, there is no power consumption optimization and the nodes would most likely need an external power supply for proper functioning. The expenses arising while using WLAN are also very high compared to other standards.

3.1.2 Low-Rate 802.15.4

The Low-Rate WPAN standard is designed to meet the demands of the comparatively small areas, where the nodes density is very high. It assumes a short range of transmission and low data rate requirements. This scenario is often found in the wireless sensor networks. The standard defines a physical and media access control layers of the system, thus allowing to use different higher-level protocols on top of it, such as ZigBee or 6loWPAN (See Fig. 2).

The physical layer. The major functions of this layer are the transceiver control, channel selection and energy control. It supports three operational frequency ranges: 868.0-868.6 MHz (1 channel), 902-928 MHz (10 channels), 2400-2483.5 MHz (16 channels). The modulation schemes are Offset Quadrature Phase Shift Keying (O-QPSK) for 2,4 GHz operating band and Binary Phase Shift Keying (BPSK) for 868/902 MHz bands.

The media access layer. The MAC layer specification defines two different types of nodes: the Reduced Function Devices (RFDs) and Full Function Devices (FFDs). The latter ones have full MAC layer capabilities and are designed for functioning as network coordinators and network end-devices. Network coordinators are capable of sending beacons to other nodes, for providing synchronization. The RFDs, on the contrary, are equipped with a limited number of MAC-layer functions and are only able to act as end-devices. They can only interact with one FFD, and are pre-designed for information gathering mostly. Such limitations in RFD's functionality serve for optimizing the average power consumption in the network [12].

Due to its current characteristics, the 802.15.4 appears to be the best suited standard for the short-range IoT communication nowadays. The limitations in range and data rate do not contradict to the requirements of the most common IoT applications, and, on the other hand, the essential specifications, such as low complexity and power consumption, are met.

3.1.3 High-Rate wireless PAN 802.15.3

High-Rate WPAN (HR-WPAN), similar to 802.15.4, specifies the PHY and MAC layers for wireless private area networks. The difference from the previous set, as follows from its name, is the rate of data transmission: the HR-WPAN specification assumes the data rates 11 Mbit/s and higher. Evidently, increasing data rates lead to the increasing complexity and costs, yet making the standard suitable for multimedia and interactive data transmission.

The HR-WPAN is based on the concept of piconet, which represents a communication system comprising ad-hoc devices (DEVs). A piconet, similarly to WPAN, is defined as a small area (10m) network, build around a person or object . As the network coordinator in 802.15.4, one of the devices serves as a piconet coordinator (PNC). Its functionality is to provide a beaconing, managing the QoS in the network and access control (see Fig. 1) [13].

The design goals of Media Access Layer (MAC) were the following:

- Ad-Hoc networking
- Dynamic joining/leaving the network
- QoS support
- Security

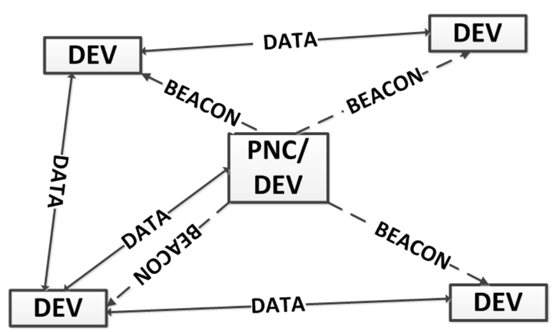


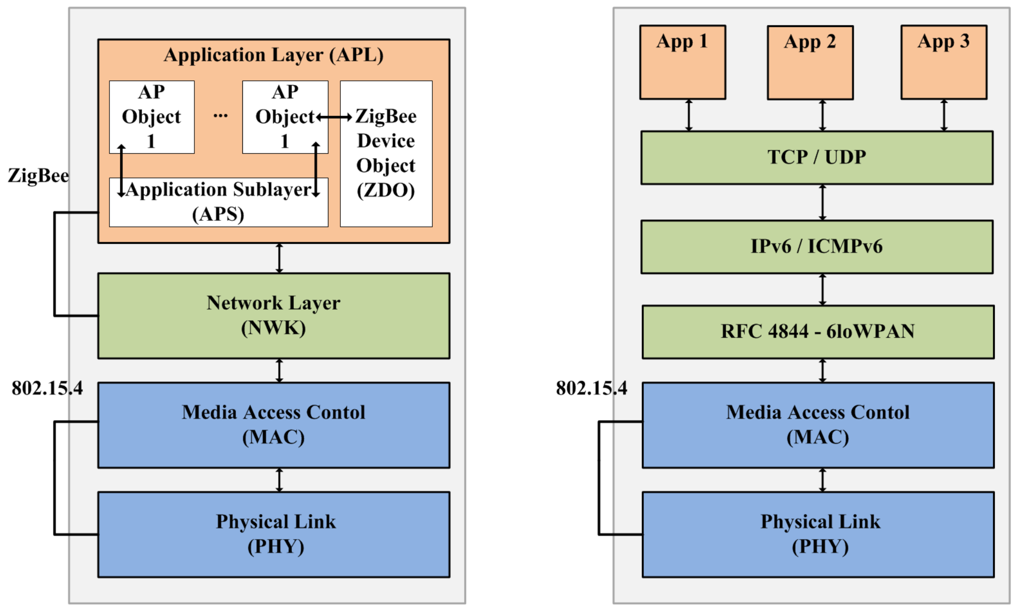
Figure 1: The piconet example. DEV - is a regular 802.15.3 device, and PNC/DEV is a device with network coordination capabilities.

The physical layer of 802.15.3 (PHY) has the following characteristics:

- The operating frequency is in the 2.4-2.4835 GHz band.
- 4 channels or 3 channels are stipulated for use.
- 5 data rates: 11, 22, 33, 44, and 55 Mb/s, there the basic unencoded rate is 22 Mb/s, whereas other rates are trellis coded.

3.2 Communication protocols

The network and higher layer protocols used in the conventional networking are also not always applicable in the IoT scenario. The fundamental reason is the fact that they were designed to support the multitude of features, most of which are irrelevant or overabundant for IoT applications (e.g. the various features of TCP/IP protocol stack). Therefore, they do not optimally use the limited hardware resources of the typical IoT device. There were several approaches used to address this lack of the proper protocols for IoT. On the one hand, completely new protocols had been developed, on the other hand, there had been some attempts to adjust the existing protocols. This section illustrates both approaches by describing the most important examples, namely ZigBee and 6loWPAN.



(a) ZigBee **(b) 6loWPAN**

Figure 2: ZigBee (a) and 6loWPAN (b) in the layer model representing the communication instance.

3.2.1 ZigBee

ZigBee is one most promising protocols for IoT wireless communication. It is maintained, supported and promoted by the group of companies called ZigBee Alliance, including Phillips, Emerson or Texas Instruments. ZigBee stack defines upper OSI layers build upon the IEEE 802.15.4 standard. In general, it comprises two layers: network layer (NWK) and application layer (APL) (see Fig. 2a).

The network layer supports multihop routing, route discovery and 16-bit addressing scheme. It provides the following basic functionality:

Network organization. Based on the two types of devices from IEEE 802.15.4, FFD and RFD, ZigBee defines tree other types: end-device, which corresponds to RFD, router and network coordinator, both corresponding to FFD. With these three device types, ZigBee network is capable of building such topologies as star, tree and meshed variations (see Fig. 3).

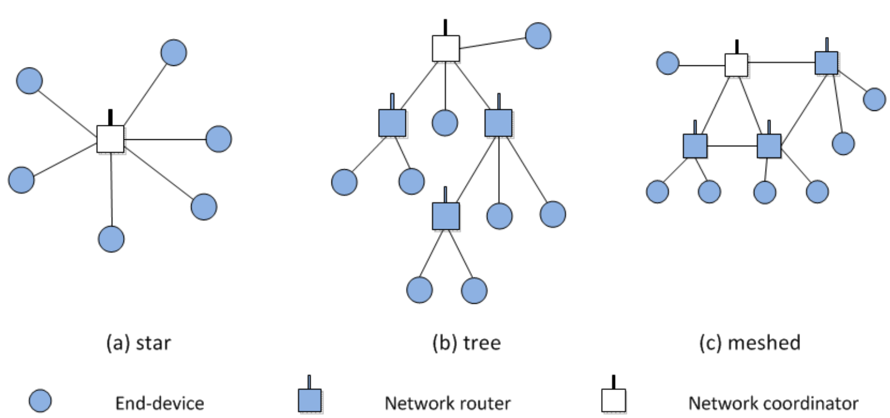


Figure 3: Example network topologies, supported by ZigBee. a - star topology, b - tree topology, c - meshed topology

Address distribution. Joining a network is realized via network discovery procedure. Since several ZigBee-networks can overlap in one area, the end-device should be capable to decide which to choose. After choosing a network to join, the parent node is selected. A router or a network coordinator directly could act as a parent node. The parent node is responsible for the address assignment: if the newly joined node is an end-device, it obtains its address; if it is a router, it obtains a set of addresses for future distribution. The size of the set (A(d)) is calculated according to the following formula:

$$A(d) = 1 + D_m + R_m \text{ if } d = L_m - 1$$

$$A(d) = 1 + D_m + R_m A(d+1) \text{ if } 0 \leq d < L_m - 1$$

where R_m - the maximum number of routers in network, D_m - maximum number of end-devices, d - depth of the routers' tree, L_m - maximum depth of the tree.

Routing. The algorithm for determining a route in the network depends on the topology used.
In the tree topology the simplified algorithm is deployed. Since the whole communication is performed along parent-child links, the routers keep only their addresses, as well as their child's and parent's addresses. The procedure to determine the destination path for a packet is very simple due to the deployed addressing scheme described above.
On the other hand, the meshed topology demands more sophisticated algorithm, because the addressing does not provide all the necessary information for the path choice. The routers and network coordinator serve for maintaining routing as well as route discovery tables. ZigBee makes use of the distance vector routing algorithm, based on the Ad Hoc On Demand Distance Vector (AODV).

Additional functionality is provided by the ZigBee application layer. APL is based on the application objects (APO) and ZigBee Device Objects (ZDO) model (See Fig. 2a).

APO represents software that is in charge for a particular hardware (e.g. switch or lamp). APOs of the ZigBee device are numbered uniquely within a device, and this number can be used in addition to the device's address to access the required functionality.

ZDO is an object type for providing functionality to the APOs, e.g. communication and network services. The data transfer for APOs and ZDO is carried out via the Application Sublayer (APS) [12]. All the possible application objects, as well as the interaction with them, are standardized by the ZigBee alliance. It allows, on the one hand, the third-party developers to implement a desired functionality, and, on the other hand, to maintain interoperability of the objects.

3.2.2 6loWPAN

The major motivation for 6loWPAN (IPv6 over Low-Rate WPAN) development was the idea of using an existing reliable protocol in the new scenario. IPv6, as the most prospective protocol for the Internet communication, was chosen to be deployed in the IoT networks. Main challenge, arising from such a decision, was to adapt IPv6 in such a way that it will be interoperable with the existing 802.15.4 specification for data-link and physical layers (see Fig. 2)) [14]. In order to do that, 6loWPAN address the following issues:

Address resolution: IPv6 operates with 128-bit addresses, whereas 802.15.4 uses only 64-bit, or the short 16-bit addresses, therefore, 6loWPAN utilizes an address resolution scheme, capable of mapping 16-bit short address to IPv6.

Packet size adaptation: The 6loWPAN, similarly to ZigBee, assumes IEEE 802.15.4 as the default MAC-PHY layers specification. But, the data payload in 802.15.4 is 127 Bytes large, and the standard IPv6 header is 40 Bytes. Hence, usage of pure IPv6 over LR-WPAN would lead to an intolerable overhead during the data transmission. For that reason, the header compression mechanism had been developed (HC1) and deployed in 6loWPAN.

Parameter optimization: The original IPv6 was tailored to attaining a high speed and usage with link layer protocols like Ethernet. On the contrary, 802.15.4 has other focuses, namely low power consumption along with the low data rates.

Routing protocol adaptation: 6loWPAN utilizes the same basic routing protocol as ZigBee, namely the Ad Hoc On Demand Distance Vector (AODV). However, it uses the simplied version of AODV - 6LoWPAN Ad Hoc On-Demand Distance Vector Routing (LOAD). The main operations of LOAD are route discovery, data structures management and maintaining the local connections. The features of LOAD, compared to other routing protocols (e.g. RIP or OSPF), are:

- LOAD operates on the adaptation layer, not on the transport layer. Therefore, it doesn't make use of IPv6 and is completely transparent for IPv6.
- LOAD relies on the two addressing schemes: either EUI-64 address or the 16 bit shot 6loWPAN address.
- It makes use of two tables: the routing (storing destination, next hop and route status) and the route request table (for the provisional route information, obtained during the route discovery process) [citing the RFC]

There are several available 6loWPAN stacks nowadays, open or proprietary, e.g. US Berkeley's b6loWPAN and blip, or the commercial implementation of Sencinode Ltd. They all are very tailored to a particular operation system, and dependent on their functionality. [15].

4 Conclusions

In the paper we have described the different hardware and communication solutions, applicable in the typical Internet of Things scenario. Evidently, different technologies have different niches for their deployment. In this summarizing section we want to compare the IoT communication technologies with respect to the distinctive IoT requirements.

Standard comparison. Some of the technologies, described in the communication standards section, had been developed even before the emergence of IoT. Their applications in IoT are, therefore, very limited. The comparison summary is presented in the tab. 1.

Thus, WLAN 802.11 is mostly applicable for communication between the gateways for special purpose IoT devices (e.g. sensors, actuators, RFID tags) and traditional devices, present in the environment, such as laptops or tablets. WLAN features a high data rates and the wide range of transmission, but requires an external power supply.

The WPAN standard family, on the contrary, is suited for the small embedded devices with a short radius of action. The extremely low power consumption makes the usage of the internal battery sufficient for a tolerably long functioning time. The standards are appropriate for different applications: HR-WPAN allows the multimedia data transmission, thereas LR-WPAN is a proper protocol for irregular sensor data transmission.

Bluetooth (802.15.1), as being the part of WPAN standards, could be considered mainly as an protocol for integration the devices into an existing environment. It features the comparatively low power consumption along with the high transmission rates, and is already present in the contemporary devices, e.g. smartphones or laptops.

	WLAN 802.11g	Bluetooth 802.15.1	Low-Rate WPAN 802.15.4
Range	100m	10m	10m
Data Rate	up to 54 Mbit/s	up to 3 Mbit/s	up to 250 kbit/s
Power Consumption	Medium	Low	Ultra Low
Size	Large	Small	Smallest
Costs/Complexity	High	Medium	Very Low

Table 1: Standard comparison with respect to major requirements

Protocol comparison. The high-layers communication protocols, described in the paper, tried to address the new requirements of IoT, and maintain as many features of traditional networking as possible. The developers of ZigBee had taken the more straightforward way, namely the development of the new protocols. It brought the advantages, as, for instance, the fact that ZigBee is highly tailored to the IoT needs, thus allowing to achieve the best power consumption and hardware performance. Also, the application layer specifications ensures the interoperability and common interface of different IoT devices.

However, it also has some cons. First, ZigBee is not an open standard, in the full sense, since it is maintained by the commercial organizations. Second, the gateway is more complicated compared to the 6loWPAN case, since the addressing and networking in general for ZigBee are not interoperable with other networks.

As compared to ZigBee, the 6loWPAN represent an adjustment layer for the existing IPv6 protocol. It bring such advantages as the possibility to use existing protocols, e.g. TCP/UDP or higher layers, on top of 6loWPAN, or the involvement in the global addressing scheme. Each 6loWPAN node has a globally (if needed) available address from IPv6 space, therefore there is no need for address translation.

Summarizing, we have shown the different IoT technologies with respect to their appropriate usage scenarios. As it could have been observed, there are two basic threads of IoT technologies development: first, is the integration of existing ones (e.g. WLAN, Bluetooth or 6loWPAN), and second is the development of the tailored standard and protocols (LR-WPAN, HR-WPAN and ZigBee). However, the border between these two ways is not strict and depends on the applications, therefore, there is still a need for technological integration and more strict standardization.

References

[1] Atzori, L., Iera, A., Morabito, G.: The internet of things: A survey. Computer Networks **54**(15) (2010) 2787–2805 1

[2] Fleisch, E.: What is the internet of things? When Things Add Value. Auto-ID Labs White Paper WP-BIZAPP-053, Auto-ID Lab St. Gallen, Switzerland (2010) 1

[3] Kranz, M., Roalter, L., Michahelles, F.: Things That Twitter: Social Networks and the Internet of Things. In: What can the Internet of Things do for the Citizen (CIoT) Workshop at The Eighth International Conference on Pervasive Computing (Pervasive 2010). (May 2010) 1

[4] Kranz, M., Schmidt, A., Rusu, R., Maldonado, A., Beetz, M., Hornler, B., Rigoll, G.: Sensing technologies and the player-middleware for context-awareness in kitchen environments. In: Networked Sensing Systems, 2007. INSS '07. Fourth International Conference on. (June 2007) 179–186 1

[5] Polastre, J., Szewczyk, R., Culler, D.: Telos: enabling ultra-low power wireless research. In: Information Processing in Sensor Networks, 2005. IPSN 2005. Fourth International Symposium on. (april 2005) 364 – 369 2.1

[6] Beute, J.: Fast-prototyping using the btnode platform. In: Design, Automation and Test in Europe, 2006. DATE '06. Proceedings. Volume 1. (march 2006) 1 –6 2.2

[7] Kranz, M., Schmidt, A., Holleis, P.: Embedded interaction: Interacting with the internet of things. IEEE Internet Computing **14**(2) (March-April 2010) 46 – 53 2.3

[8] IEEE: IEEE Std 802.3 - 2005 Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications - Section Five. Technical report (2005) 3.1

[9] IEEE: IEEE Standard for Information technology–Telecommunications and information exchange between systems Local and metropolitan area networks–Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications. IEEE P802.11-REVmb/D12, November 2011 (Revision of IEEE Std 802.11-2007, as amended by IEEEs 802.11k-2008, 802.11r-2008, 802.11y-2008, 802.11w-2009, 802.11n-2009, 802.11p-2010, 802.11z-2010, 802.11v-2011, 802.11u-2011, and 802.11s-2011) (29 2012) 1 – 2910 3.1

[10] IEEE: Approved Amendment to Standard for Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks Specific Requirements - Part 15.3: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPAN): Amendment to MAC Sublayer (Amendment to IEEE Std 802.15.3-2003) Replaced by IEEE 802.15.3b-2005. IEEE Std P802.15.3b/D04 (2005) 3.1

[11] Zhu, Q., Wang, R., Chen, Q., Liu, Y., Qin, W.: Iot gateway: Bridgingwireless sensor networks into internet of things. In: Embedded and Ubiquitous Computing (EUC), 2010 IEEE/IFIP 8th International Conference on. (dec. 2010) 347 –352 3.1

[12] Paolo Baronti, Prashant Pillai, V.W.C.S.C.A.G.Y.F.H.: Wireless sensor networks: A survey on the state of the art and the 802.15.4 and zigbee standards. Computer Communications **30** (2007) 1655–1695 3.1, 3.1.2, 3.2.1

[13] IEEE: Approved Draft Amendment to IEEE Standard for Information technology-Telecommunications and information exchange between systems-PART 15.4:Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs): Amendment to add alternate PHY (Amendment of IEEE Std 802.15.4). IEEE Approved Std P802.15.4a/D7, Jan 2007 (2007) 3.1.3

[14] Mulligan, G.: The 6lowpan architecture. In: Proceedings of the 4th workshop on Embedded networked sensors. EmNets '07, New York, NY, USA, ACM (2007) 78–82 3.2.2

[15] Yibo, C., mean Hou, K., Zhou, H., ling Shi, H., Liu, X., Diao, X., Ding, H., Li, J.J., de Vaulx, C.: 6lowpan stacks: A survey. In: Wireless Communications, Networking and Mobile Computing (WiCOM), 2011 7th International Conference on. (sept. 2011) 1 –4 3.2.2

The Internet of Things: Application Domains

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Abstract

This paper addresses the application opportunities regarding the Internet of Things. Given the contribution and collaboration of different technologies and innovations, the Internet of Things is quickly becoming an interesting and possible factor to future developments in countless areas and fields. Throughout this paper, we will analyze more in depth how the Internet of Things is affecting and revolutionizing the fields of smart environments and in the health department as example domains.

1 Introduction

The Internet of Things (IoT) term was first used in 1999, but it was until the use of radiofrequency identification (RFID) became popular that the IoT became a feasible idea and therefore boomed in the research institutes. RFID and other similar sensors are crucial for the Internet of Things since one of its main goals is to achieve everything in a pervasive way.

Given the ongoing development that IoT has, it is unquestionable that its impact will reach every aspect of our daily lives; the more the technology develops, in areas such as communications, sensors and networking, the more the Internet of Things will be capable of reaching us in every way we can imagine. Given the broad aspects the IoT can cover, business opportunities will be and are arising just as they did when the Internet became available for the public.

Throughout this paper, the reader can find in Section 2 more information about Internet of Things and its development. After this analysis we will focus on the application domains of this developing idea, Section 3 talk about in the intelligent environment and health field. Section 4, containing the conclusions, will bring a proper closure to the paper.

2 Internet of Things: From concept to reality

2.1 Definition

As it tends to happen when a new concept arises, especially in technology, it is linked to what is currently happening in your surroundings. It is said that the first idea of 'Internet of Things' came up in 1999 at the Massachusetts Institute of Technology (MIT) Auto-ID Labs. This center, having an international presence, consists of a research network focused on RFID and sensing technology, and thus the concept was born based on what the RFID technology could provide. IoT at that time referred to the possibility in which all physical objects where given a GUID called the Electronic Product Code (EPC) and tagged with a RFID.

As technology evolved, so did the concept. "After the World Wide Web (the 1990's) and the mobile Internet (the 2000's), we are now heading to the third and potentially most 'disruptive' phase of the Internet revolution - the 'Internet of Things'. The Internet of Things links the objects of the real world with the virtual world, thus enabling anytime, anyplace connectivity for anything and not only for anyone. It refers to a world where physical objects and beings, as well as virtual data and environments, all interact with each other in the same space and time." [1]

On the other hand, Haller defined it as "a world where physical objects are seamlessly integrated into the information network, and where the physical object can become active participants in business processes. Services are available to interact with these 'smart objects' over the Internet, query their state and any information associated with them, taking into account security and privacy issues" [3]. As we can see from this definition the concept Internet of Things now covers not only the technology aspect and its relationship or interaction with the user and the environment, but it also addresses its ramifications in future business opportunities and states the importance of privacy and security.

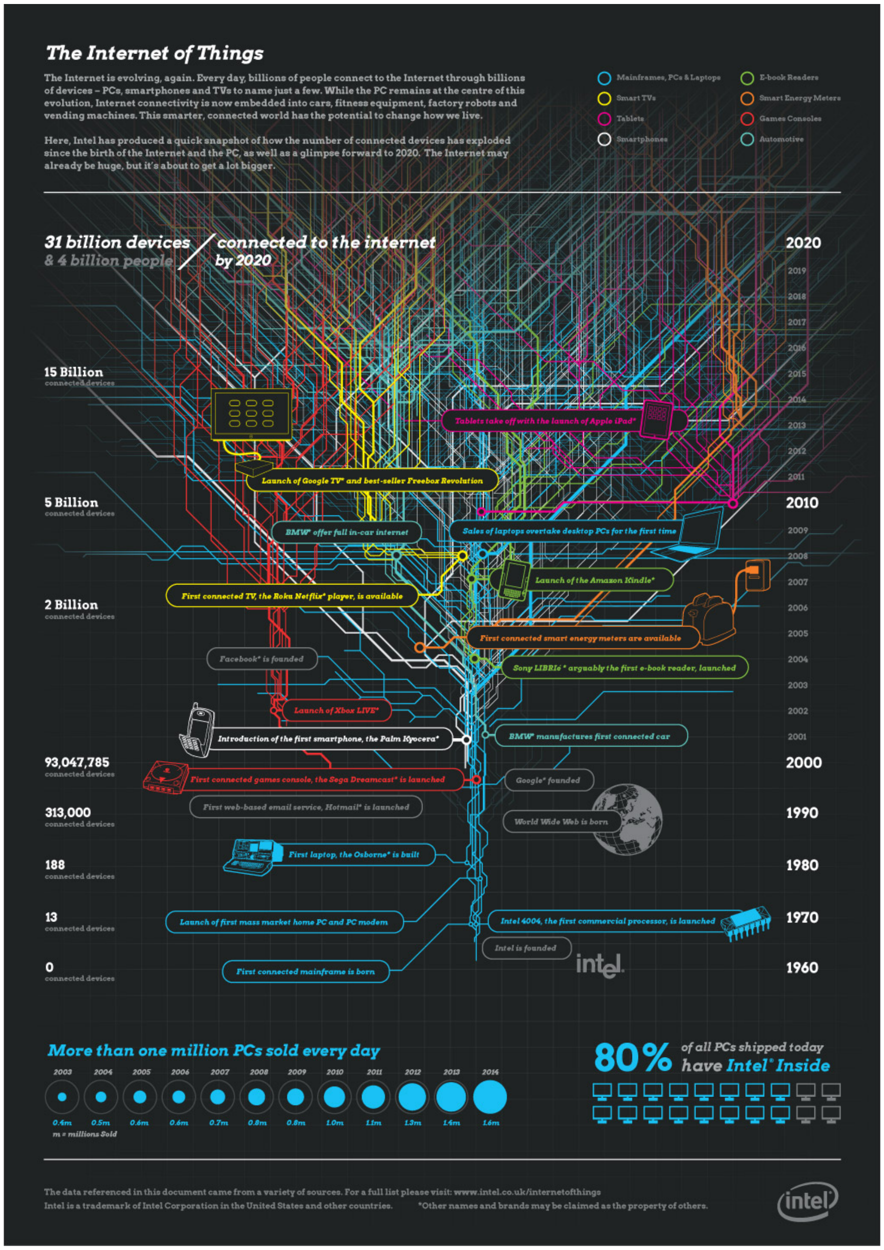


Figure 1: Internet of Things: Intel's Vision [2]

As Atzori mentions in his article The Internet of Things: A survey "Differences, sometimes substantial, in the IoT visions raise from the fact that stakeholders, business alliances, research and standardization bodies start approaching the issue from either an "Internet oriented" or a "Things oriented" perspective, depending on their specific interests, finalities and backgrounds." [4]

2.2 From the Internet to the Internet of Things

Thanks to the Electronic Data Interchange (EDI), a communication between two computers became possible in 1996. Afterwards LAN and DSL made a communication between two fixed devices possible through a fixed connection to the Internet. After finding a way to make this technology wireless and therefore mobile, communication between different computers and cellphones was possible. Given the outburst of mobile technology, social media became part of "the next best thing" providing us a way to communicate between us instantly; thus bringing the possibility and idea of establishing communication between things, taking us to a smarter (technology related) environment.

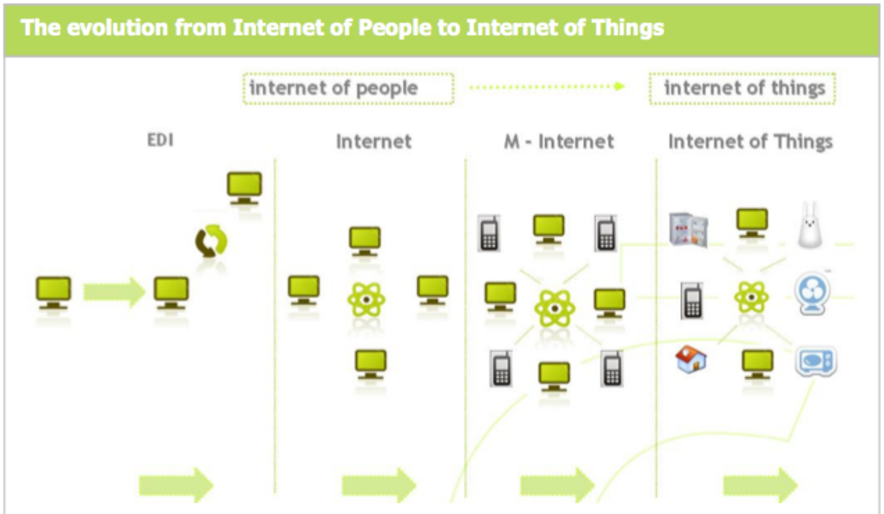


Figure 2: From the Internet to the Internet of Things [5]

2.3 Thing, Internet, Semantic-Oriented Vision

Depending on how much the concept Internet of Things covers, different approaches can be possible. Atzori mentions how you can approach IoT from a Thing-Oriented Vision, an Internet-Oriented Vision and a Semantic Oriented Vision.

In an Internet-Oriented Vision, the concept is an established sphere of networked information. Examples of this approach are `www.ipso-allience.org` and `www.webofthings.com`. In a Thing-Oriented Vision you have "atomic" components (like RFID) to link the world. "The object unique addressing and the representation and storing of the exchanged information become the most challenging issues, bringing directly to a third, "Semantic oriented", perspective of IoT" says Atzori. Figure 3 below shows a graphical representation of the three different visions and how they should or can interrelate to create the Internet of Things.

3 Application Domains

3.1 Industry, Environment and Society Domains

Before entering into specific Application Domains, we need to briefly analize the three mayor domains in which the Internet of Things can be applied. First we have the Industry, in which activities involving financial or commercial transactions between entities are involved. For this domain applications involving manufacturing, logistics, banking, etc. can be developed. For the protection, monitoring and development of natural resources we have the Environment Domain. Some examples are: agriculture and breeding, recycling, energy management, etc. Finally the Society domain, in which activities regarding the development and inclusion of societies, cities and people is considered. A great field of opportunity in this domain is the governmental services towards citizens and other society structures. [6]

3.2 Smart Environments

Roalter et *al*. [7] describe a Smart or Intelligent Environment as heterogeneous distributed sensor-actuator systems including multimedia presentation services, building automation and control components, intelligent physical objects, wireless sensor network nodes, nomadic personal or shared devices, and many other systems and entities. This complex setup demands for leveraged support on each of the following tasks: prototyping and development, system state visualization and environmental simulation of all potential components, along with their physical and digital properties.

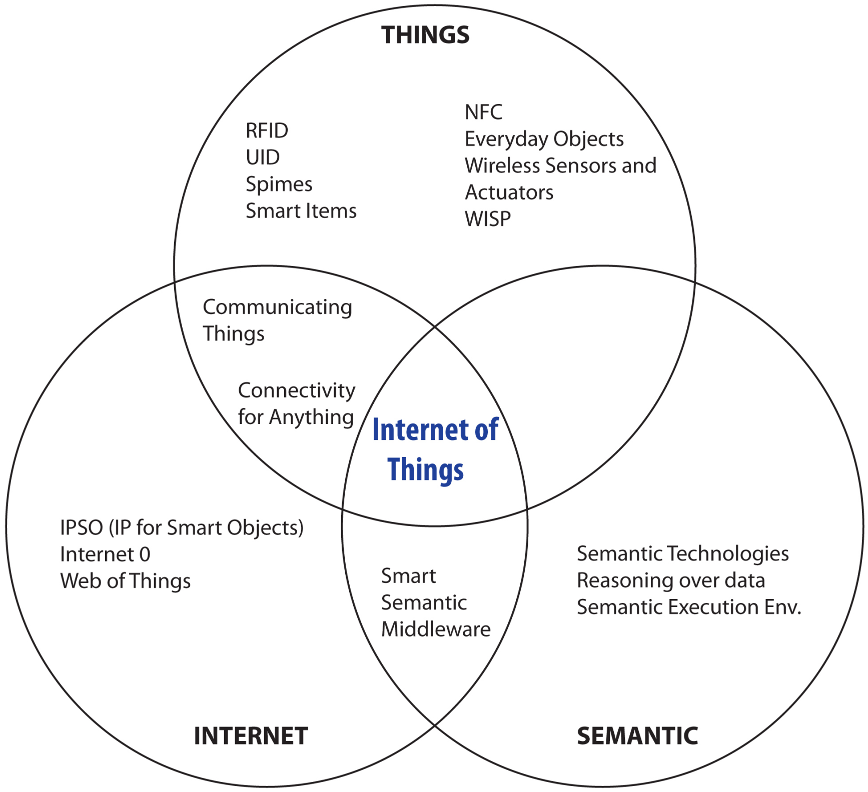


Figure 3: Thing, Internet, Semantic-Oriented Vision [6]

Eventhough Smart Environments implementations represent several obstacles or challenges specially in indoor communication, still some prototypes and ideas for different implementations have arised. For the development of Smart or Intelligent environments the use of sensors for temperature, humidity, lighting, human activity, etc. are utilized and communicate wirelessly forming an ubiquitous sensor network.

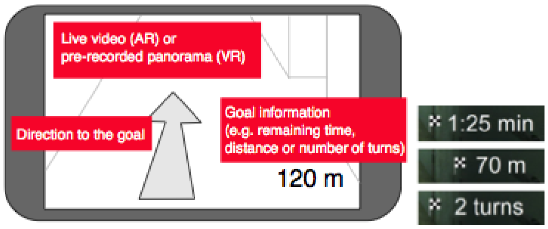
3.2.1 Indoor Navigation System Interfaced Adapted to Vision-Based Localization

Möller et *al*. [8] propose an augmented reality or virtual reality visualization for the user through its smartphone in order for him to interact with its environment. The augmented reality option shows guidance as it overlays on real-time video, while the virtual reality uses a pre-recorded panorama view.

The user interface proposed consists of a perspectively displayed navigation arrow which is included in a prerendered panorama of the environment (virtual reality) or imposed over the live video (augmented reality). Additional information, such as the remaining time, distance, etc. can be displayed

3.2.2 Factory Monitoring

Monitoring the environment in an industrial plant, automation can be improved. By adding RFID tags to parts in the production line, events can be generated to inform about the presence of it to start the production and it can store usefull information like serial number or any other necessary data during the process. At the same time, you have some sensors monitoring the correct function of the machines in the factory; if a malfunction presents istself then the production process immediatly stops ensuring the quality control of the product. [4]



(a) Mockup of application

(b) Augmented Reality Example

Figure 4: Proposal Prototype. [8]

3.2.3 The PEIS-Home

The PEIS-Home was developed using the PEIS-Ecology Concept, which consists of intelligent environments built around the notion of PEIS (Physically Embedded Intelligent Systems).[9] In this approach, the environment and the computerized system are seen as part of the same system and work in a symbiotic relationship.

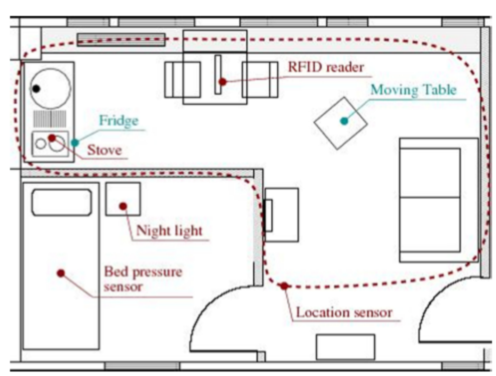
Developed by the Orebro University Mobile Robotics Lab in Sweden, the PEIS Home, consists of a kitchen, living room and bedroom, in which sensors and actuators are integrated. Since the concept is not based on sophisticated robots performing the tasks, a simple cooperative way of achieving the goal is implemented.

The example provided is that of wanting a glass of water when the user is on the couch. The use of the moving table (See Figure 5) goes to the fridge, where a robotic arm pours the glass of water and puts it on the moving table, which returns to the user that's sitting on the couch.

3.2.4 The Social Web of Things: Ericsson

Alendal describes a social network for our devices, in which you can be connected to more or about 50 billion devices that can and will interact among themselves. "This will introduce a stage of 'networkedness' rather than single connections on a one-to-one basis. Such networkedness unleashes the true power of a web with 50B connected devices. The devices become social, just as we are. You have a social network, and your devices will have a social network: the social web of things." [10]

(a) PEIS Model Apartment



(b) PEIS Sensor Diagram

Figure 5: PEIS Home. [9]

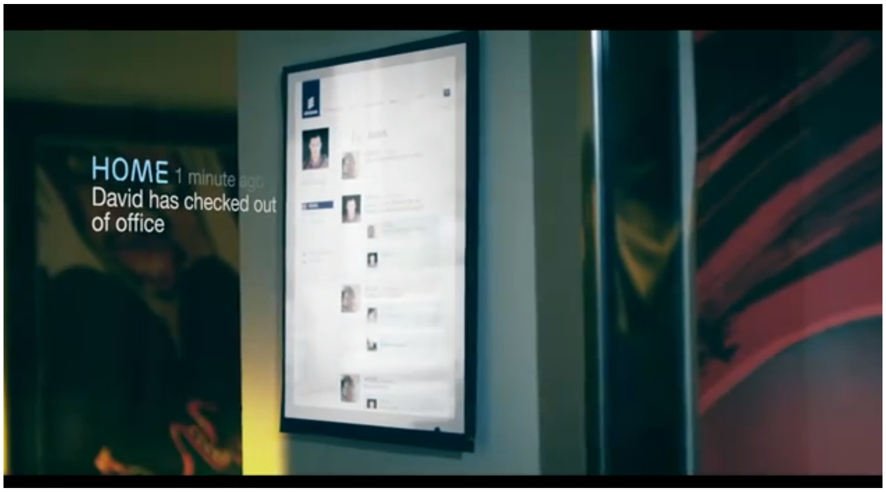


Figure 6: The Social Web of Things. Source: http://www.youtube.com/watch?v=i5AuzQXBsG4

3.3 Health Environment

Just as in the smart environment, the health department has multiple applications in which the Internet of Things can be applied. Given the growth of the elderly generation and it's desire of a still active independent life, the Ambient Assisted Living (AAL) field of development continues to grow. Here are some examples in which the Internet of Things is applied in the Health department

3.3.1 Independent Living: Wellness, mobility monitoring of an aging population

"IoT applications and services will have an enormous impact on independent living and as support for an aging population by detecting the activities of daily living using wearable and ambient sensors, monitoring social interactions using wearable and ambient sensors, monitoring chronic disease using wearable vital signs sensors, and in body sensors." [6]

The Technical University of Munich, in their department of Building and Robotic Implementation, developed a project called LISA in which its main focus was the Ambient Assisted Living, by providing a platform for elderly people, in which aspects of daily life can be controled or monitored

"Daily living becomes an important quality factor especially in the ageing society. Elderly people are facing limitations in most of their daily living activities. Novel approaches need to be followed when trying to service ageing society needs. Various research fields deal with Activities of Daily Living (ADLs), fusing different technologies, to enable mechanisms that could efficiently assist, enhancing the everyday living quality in the ageing society. In LISA, the implementation of a novel Robotic Service Wall supporting those ADLs was the main objective. The proposed system followed a modular approach, whereas all system elements provide "plug and play" characteristics. Such an approach enables an efficient system, which can be arranged and rearranged into various configurations, and can be easily installed in any residence without requiring specific space dimensions." [11]

Figure 7 shows a mockup of this implementation. As we can see, every component is modular to help with transportation and installation. The same way, only plug-and-play technology was used to help with its development.

3.3.2 Medical Technology Healthcare

By using cell phones with RFID-sensor capabilities or any other Near Field Communication (NFC) Technology, the user can monitor medical parameters and drug delivery. [6] This technology, in companion with, Bluetooth, ZigBee, WiFi and many others can make possible an improvement in measuring and monitoring vital functions, thus giving preventive medicine a better possibility or even early diagnosis of a present disease.

3.3.3 Pharmaceutical

For pharmaceutical products, security and safety is of utmost importance to prevent compromising the health of patients. [6] If RFID or similar technology is attached as a smart label to the drugs, quality controlling can be done during

Figure 7: LISA - Mockup at the Technical University of Munich. [11]

the supply chain process, making sure the right temperature is maintained. In the same way, the technology can be used to pevent counterfeiting.

As for the use of it, after the sale of the medicine has been done, the user can be informed of the dosage, expiration date, available quantity and even remind him to take it on time.

3.3.4 GymSkill: A Personal Trainer for Physical Exercise

GymSkill is a personal trainer developed at the Technical University of Munich, in which a smartphone-based personal trainer is used for monitoring the excercise done by the user. "The system utilizes the embedded sensing capabilities of a phone placed on the balance board (accelerometer and gyroscope) to record the exercises. The quality of recorded data is automatically analyzed, i.e., the skill of the trainee is assessed. The system provides basic situated (auditive and visual) feedback during exercising and, moreover, performs retrospective automatic assessments of the quality of the performed exercises. It provides a global quantitative judgment of physical exercises in the form of an aggregated skill metric, which is the basis for competitive evaluations of physical exercises. It is, thus, ideal for tracking individual progress over the course of a long-term training program." [12]

3.3.5 MobiMed: Comparing Object Identification Techniques on Smartphones

Although physical mobile interactions can be applied in may fields, in this case Möller et *al* present an application for the Health Environment. MobiMed can identify drug packages using different interaction methods.

"We conceived MobiMed, a medication package identifier implementing four interaction paradigms: pointing, scanning, touching and text search." [13]

By identifying the medicine, the user could get additional information about it, check side effects, and even consult his physician if that medicine is appropriate for him.

(a) Overview of the GymSkill System (b) GymSkill Example

Figure 8: GymSkill. [12]

(a) Overview of the MobiMed System (b) MobiMed Example

Figure 9: MobiMed. [13]

4 Conclusions

"And men got dreaming. Shouldn't there be a network that made all my devices collaborate at all times, converse spontaneously among themselves and with the rest of the world, and all together make up a kind of single virtual computer - the sum of their respective intelligence, knowledge and know how?" Rafi Haladjian

We have shown in this paper, that the Applications Domains regarding the Internet of Things, is constantly growing and improving, thus presenting everyday a new opportunity of implementation. As technology grows, it becomes possible to achieve interactions we could not before, specially when this breakthroughs are in the area of communication, networking and sensors. The two-multi way communication is what is going to make the Internet of Things grow hopefully exponentially, as those the technology.

In this paper, we only cover two major Domains, the Smart or Intelligent Environments and the Health Environment, and as we could see, these two link together and even some examples can be considered part of either one of the categories, or just change its focus. Imagine using the technology of MobiMed to identify movie posters and be able to read the reviews or see the trailer; we could also have the LISA technology implemented at a Gym and not only for an elderly person. Or even combine the LISA project with the PEIS Home and create an intelligent apartment.

This just comes to show how the technology can be applied differently and cover different needs according to the parameters we set as important; and as technology continues to improve, we would be able to do anything we once dream of.

References

[1] Santucci, G.: The internet of things: Between the revolution of the internet and the metamorphosis of objects. 23 2.1

[2] Intel: The internet of things (2012) 1

[3] Haller, S., Karnouskos, S., Schroth, C.: The internet of things in an enterprise context. Future Internet–FIS 2008 (2009) 14–28 2.1

[4] Atzori, L., Iera, A., Morabito, G.: The internet of things: A survey. Computer Networks **54**(15) (2010) 2787–2805 2.1, 3.2.2

[5] Associati, C.: The evolution of internet of things. (February 2011) 16 2

[6] Sundmaeker, H., Guillemin, P., Friess, P., Woelfflé, S.: Vision and challenges for realising the internet of things. CERP-IoT, European Commission, Luxembourg (2010) 3.1, 3, 3.3.1, 3.3.2, 3.3.3

[7] Roalter, L., Möller, A., Diewald, S., Kranz, M.: Developing Intelligent Environments: A Development Tool Chain for Creation, Testing and Simulation of Smart and Intelligent Environments. In: Proceedings of the 7th International Conference on Intelligent Environments (IE). (july 2011) 214–221 3.2

[8] Möller, A., Kranz, M., Huitl, R., Diewald, S., Roalter, L.: A mobile indoor navigation system interface adapted to vision-based localization. In: Proceedings of the 11th International Conference on Mobile and Ubiquitous Multimedia. MUM '12, New York, NY, USA, ACM (2012) 4:1–4:10 3.2.1, 4

[9] Cirillo, M.: Proactive assistance in ecologies of physically embedded intelligent systems: A constraint-based approach. (2011) 534–538 3.2.3, 5

[10] Alendal, M.: The social web of things - a social network for your devices 3.2.4

[11] Bock, T.: Lisa smart walls 3.3.1, 7

[12] Möller, A., Scherr, J., Roalter, L., Diewald, S., Hammerla, N., Plötz, T., Olivier, P., Kranz, M.: Gymskill: Mobile exercise skill assessment to support personal health and fitness. In: Ninth International Conference on Pervasive Computing (Pervasive 2011), Video Proceedings, San Francisco, CA, USA (June 2011) 3.3.4, 8

[13] Möller, A., Diewald, S., Roalter, L., Kranz, M.: Mobimed: comparing object identification techniques on smartphones. In: Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design. NordiCHI '12, New York, NY, USA, ACM (2012) 31–40 3.3.5, 9

Internet of Vehicles

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January 15, 2013

Abstract

Internet of vehicles will be discussed in this paper. It could be some cars talk to each other or the driver obtains information from a road-side infrastructure. It can increase the safety level, improve the drive efficiency, save fuel, cut down carbon dioxide emission, pay bill electronically[1] etc. The architecture of a Vehicle to X communication system will be explained and the IEEE 802.11p protocol is especially given to car wireless communication protocol to suit the complex car to car communication.

1 Introduction and Motivation

Building a highly efficient car is recently a trend worldwide for automobile industry, since cars are familiars to everyone and people are not only satisfied with the basic function of car, namely the movement, they are looking for the most comfortable way to drive a car and even the car can drive themselves. They focus on the comfortability and on cheap travelling, on the meanwhile they do not want to abandon the trip with a car. Due to these reasons a new and modern car product with communication ability is under consideration.

It can be imaged, when cars interact with the infrastructure, they can receive the current traffic light's phases and use the GPS location to determine the distance to the next traffic light. Combined with the remaining time, in which the light will change its color, the computer in the car can calculate with which speed the car should go through the intersection without needing to stop. With this method people can on the one hand save gas, on the other hand have not to provoke anxiety at waiting for the red light and waste time.

Safety problem is always to be solved in the automobile area. People hope the car assistance system can do their best to reduce the probability of a car accident.

Once the car is capable to communicate with the infrastructure such as a parking device, then it is easy to park your car and you do not need to roll down the window and take the park ticket, which can cause an accident if your car is stopped far from the ticket device. Everything is controlled between the park system in the park place and the intelligent payment system in the car, which is coupled to your credit card[2].

2 Overview

Dimitrakopoulos [1] believes, that Information and Communication Technology should be used to increase the traffic efficiency and avoid most of traffic accidents, once the cars talk to each other and the infrastructure.

Arief et *al*. [2] focus on how an intelligent smartdust can cooperate with other transport sensors under different conditions on the road. At which range, accuracy, direction and speed could these smartdusts communicate with each other.

Car communication is exposed in public [3, 4], some security and privacy things from the individual car should be protected. So some trust management methods and secure interaction will be set up.

Reduction of fuel consumption is an important advantage of the Car-to-X communication [5]. As people can smooth drive through the intersection without any red light, that is not only a comfortable feel but also save the fuel and protect the environment.

[1] Audi Travolution Project: http://www.audiusanews.com
[2] Audi Travolution Project: http://www.audiusanews.com

Natural user interfaces are recommended [6, 7] for great UI experience in Vehicles. From technology aspects to user experience it is worth for automobile manufacture to think about it.

The American intelligent transport deployment [8] wants to figure out how to deploy their intelligent infrastructure on the road and if there are any barriers on the technological side and how does their market react. In this background they can develop several applications, which can be interesting.

Gerla and Kleinrock [9] explain the Vehicle connected with others comprehensively from a network aspect especially under P2P technology. The authors think the content in the vehicle net can be shared, so everything can be spread widely.

3 The concept of Vehicle-to-x (V2X) communication

As we all know vehicle to other things communication means that one car interacts with another thing and do something about safety and efficiency for the driver. One car can talk to another car, the traffic light or road-side infrastructure. Following will be introduced the architecture of this system and their typical applications.

3.1 Architecture of Vehicle-to-x communication

The car to car communication system consists of 4 parts: in-vehicle domain, ad hoc domain, infrastructure domain and the last protocol [10].

In-vehicle domain includes on-board unit (OBU) and application unit (AU). OBU is a communication module, it talks to AU and transfer the information to others. AU is a controller. It decide what to do and distribute orders through OBU.

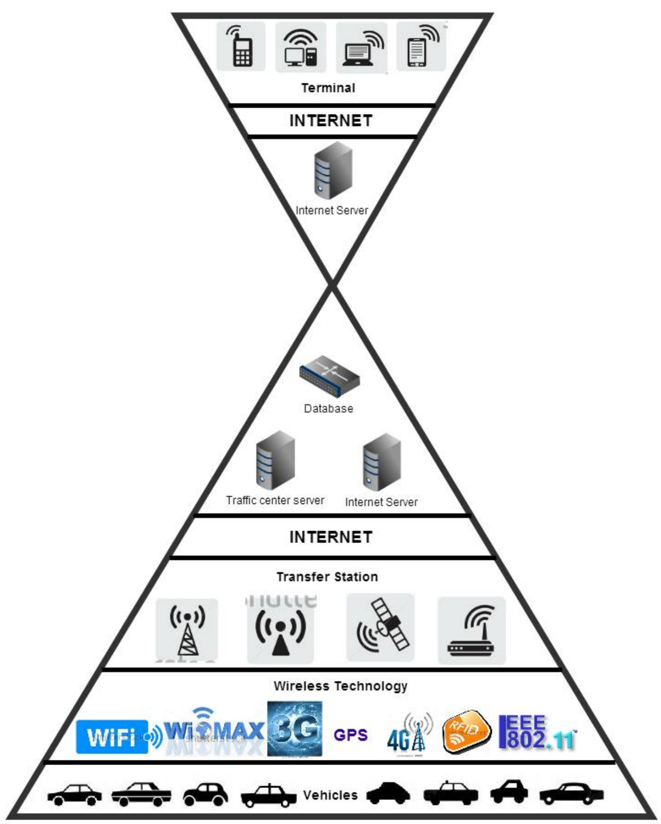

Figure 1: Architecture of Car-to-X communication.

In the car wireless communication technology, cars not only talks to each other through OBU, but also talk to road-side unit (RSU). Considering the dynamic characteristic of cars, the two ways of communication both use ad hoc communication network (Vehicular ad-hoc network). Ad hoc network has no wired infrastructure supported mobile network, the nodes in the network are composed of mobile units (cars or road-side units). When two mobile units in the ad hoc domain, they can directly talk. If two units are not in the same ad hoc area, the message should be transferred from another unit, that stay between the two units. So in the ad hoc network, a unit is also a router, which is responsible for searching route and transferring messages.

Infrastructure domain includes RSU and WIFI. That means cars can talk to some connected RSU or WIFI, which can help the units to access Internet. Furthermore the OBU can be intergrated with other communication functions, such as GSM, GPRS, UMTS, HSDPA, WiMax, 4G [9], which are connected to mobile station.

In the future, people could even observe and control their cars just at home or in faraway as the triangle in Figure 1 showed above.

3.2 Vehicle -to-traffic light communication for comfortable drive

What can greatly support the internet-to-traffic light communication is a database of traffic light center controller, which is stored all of the real-time traffic light data in the city, 3G/LTE or wireless communication technology for rapid information communication with the center-server, which can be used wherever you are and whatever real-time traffic data you want, when you are closed to an intersection. A GPS direction is a necessary device, which cannot be ignored in the whole system. With this system the driver drives comfortably through the intersection instead of waiting for the red light. Thanks the real-time traffic light information the driver always knows how much time left the red light in the next intersection will be changed, so that driver can adjust the speed on a suitable level, so that he do not need to stop to wait for a red light.

The following system uses a flexible 3G/4G or traditional GSM communication with the traffic center server to obtain the real-time traffic light situation. All the driver needs is a mobile station. The advantage is that the road-side infrastructure is not needed.

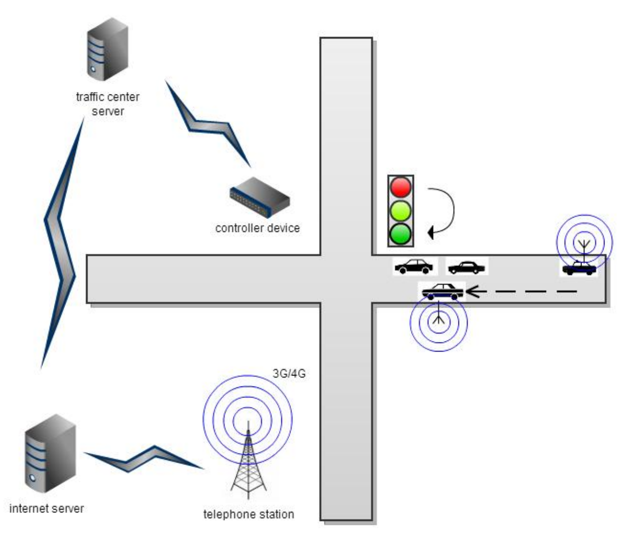

Figure 2: Vehicle-to-traffic-light solution with mobile station

Another solution is, when a car come into the ad hoc domain, it can obtain the traffic light information. This solution will not be restricted to the mobile station and it is free for drivers. And this method is faster to capture a intersection information. But the installation of infrastructure will be spent a lot.

These two methods are the most efficient ways to set up a car to traffic light communication system, which is more efficient for drivers from one destination to another. Meanwhile it helps drivers to save fuel and reduce the CO_2 emission.

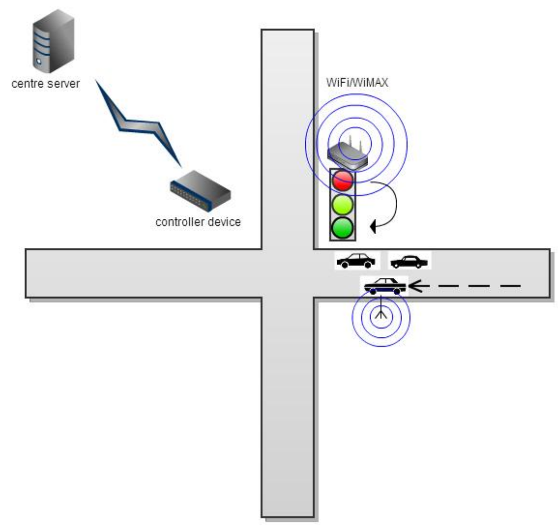

Figure 3: Vehicle-to-traffic-light solution with ad-hoc wireless communication

3.3 Vehicle -to-infrastructure communication to assistant

Audi has tested its parking system using a car-to-infrastructure communication system[3]. With this system the driver does not need to roll down the window to take a parking ticket, instead of taking anything they need only to operate on the car central screen to take a virtual ticket and when they come out they can electronically pay the bill just on the seat.

With the car to infrastructure technology rising, a new commercial advertisement could be used to attract customer to the local restaurant or shop to have a look. The information from the infrastructure is a good resource to spread to drivers, if the driver now is just looking for a hotel or restaurant [8].

The road-side infrastructure can also collect traffic follow information, so the server behind the system can calculate the real-time pavement situation, which could be advisable to other drivers to choose a path to the destination, which is not in traffic jam.

3.4 Internet-to-car functions

Figure 4: Car-to-car communication with safety assistance [10]

[3]Audi Travolution Project: http://www.audiusanews.com

The car to car communication system plays a great roll in the car safety assistant system, because people can only see straightly from the car window. If there is any thing blocks our sight view, that could be very dangerous, when we drive a car at a very high speed. So now the car communication means a lot to driver to know if there are other cars or Vehicles beside the driver.

It is easy to understand with the following picture. The motor driver cannot see the car behind the van, because the van blocks his view on the right side. So it is dangerous to drive across the intersection without braking. If the motor driver knows, that the car on the right comes near, he will slow down the speed and let the car go first.

Other inter-car functions will be developed to meet the human demands, such as sharing music and pavement situation.

4 Technology Aspect

OBUs between cars is based on the protocol IEEE 802.11p, furthermore OBU can be appended with IEEE802.11a/b/g/n and even GSM. Here IEEE 802.11 is an IEEE defined wireless network communication[4]. The protocols include suffix in IEEE802.11a/b/g/n have been supplemented on the physics layer against the original version, which increase the data transfer ability. IEEE 802.11p is especially supported to car wireless communication, which is an expansion of IEEE 802.11, that is suitable to intelligent transportation systems (ITS). So IEEE 802.11p is also called Wireless Access in the Vehicular Enviroment (Wave) or dedicated short range communications (DSRC)[5].

According to the “open system interconnection reference model, OSI” the OBU communication module should be divided into five layers: application, car to car transport, car to car network, MAC/LLC layer, physics layer.

Car-to communication is based on 3 wireless technologies: vehicular IEEE 802.11P, traditional IEEE 802.11a/b/g/n and other mobile wireless technology. IEEE 802.11p has a higher safety level between the vehicular communication against others. Safety application as a core application uses the IEEE 802.11p protocol. The other application, which requires a lower safety level, can use the TCP, UDP communication protocol to talk to other cars or road-side infrastructure. They can also be transmitted through wireless communication technology IEEE 802.11a/b/g/n.

Car-to-car protocol transport layer help OBU to encrypt, decrypt data, point to point transport and transfer messages as required [10]. Transport layer can integrate and encapsulate messages and transfer it to the next node. It can order OBU to act as one of the transfer nodes, to choose the route reasonably according to the destination to transfer the messages. Transfer layer consists of unicast, broadcast and geocast, three data communication methods.

5 Audi Travolution Project

In Ingolstadt the traffic lights are connected together so that they can share information with each one. The car once come to the intersection with green, then it should be sure that the next intersection is also green when the car is driven with a certain speed between the two intersections, so that the car can avoid a stop. But how can the single traffic lights know the moment traffic flow on the street? The system of Travolution is an adaptive traffic light, which can be suitable for the above mentioned situation. The adaptive traffic light is connected with an induction loop under the street, so that it can measure the traffic flow. A controller device near the intersection sends the traffic flow information to the center server, which determine an optimal solution with the message from the single traffic light and send it back to the controller device beside the intersection. And the controller device controls the traffic lights in this intersection as the central server has calculated.

Additionally the controller device is connected with a small computer. In this housing the vehicle communications is realized. Through a WLAN network the traffic lights send their information to the environment. The traffic light assistant conveys the information to tell them at which speed he should drive until to the next intersection and how long it takes until the next traffic light changes to green.

The traffic signals transfer data that are processed into graphic form and shown on the car’s driver information display screen. The signals tell the driver what speed to keep so that the next traffic light changes to green before the driver touches it. With the adaptive cruise control (ACC) from Audi the driver can feels very comfortable and smooth to pass through an intersection.

[4] IEEE 802.11p http://standards.ieee.org/findstds/standard/802.11p-2010.html
[5] IEEE 802.11p http://standards.ieee.org/findstds/standard/802.11p-2010.html

However the car cannot always be driven with green traffic light, when there is no optimal speed for the car to close up to the next intersection. But the display screen will give out the last of second number of the red light to warn the driver when he can start and the driver can utilize the Start/Stop function to save the gas as he wishes.

According to the Audi Impress, when a car is driven under this network, the driver can save the amount of time spent on the way and cut fuel consumption by 0.02 liter[6] for every traffic light stop and avoid a high frequent and uncomfortable acceleration phase. Meanwhile through this technology a large amount of CO2 emissions can be reduced, which meets the demands of environmental conservation.

6 Conclusion

It is always the rule, that the safety of a car is the most important. Then people think about efficiency and entertainment.

So the car-to-x communication system is worth to be mentioned. Under its function the car talk to each other and they can interact well on the road, because they already know each other well before an accident may occur. With a traffic light assistant system a car can move avoiding many red lights. Entertainment and commercial opportunities obviously will not be ignored if the whole system is maturely built up [5].

References

[1] Dimitrakopoulos, G.: Intelligent transportation systems based on internet-connected vehicles: Fundamental research areas and challenges. In: 11th International Conference on ITS Telecommunications (ITST). (August 2011) 145–151 2

[2] Arief, B., Blythe, P., Fairchild, R., Selvarajah, K., A, T.: Integrating smartdust into intelligent transportation systems. Report 1062, School of Computing Science, University of Newcastle upon Tyne (dec 2007) 2

[3] Ellison, G., Lacy, J., Maher, D., Nagao, Y., Poonegar, A., Shamoon, T.: The car as an Internet-enabled device, or how to make trusted networked cars. In: Electric Vehicle Conference (IEVC), 2012 IEEE International. (March 2012) 1–8 2

[4] Diewald, S., Leinmüller, T., Atanassow, B., Breyer, L.P., Kranz, M.: Mobile Device Integration and Interaction with V2X Communication. In: 19th World Congress on Intelligent Transport Systems (ITS). (October 2012) 2

[5] Tielert, T., Killat, M., Hartenstein, H., Luz, R., Hausberger, S., Benz, T.: The impact of traffic-light-to-vehicle communication on fuel consumption and emissions. In: Internet of Things (IOT). (December 2010) 1–8 2, 6

[6] Diewald, S., Möller, A., Roalter, L., Kranz, M.: Mobile Device Integration and Interaction in the Automotive Domain. In: AutoNUI: Automotive Natural User Interfaces Workshop at the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2011). (November–December 2011) 2

[7] Diewald, S., Möller, A., Roalter, L., Kranz, M.: DriveAssist - A V2X-Based Driver Assistance System for Android. In Reiterer, H., Deussen, O., eds.: Mensch & Computer Workshopband, Oldenbourg Verlag (2012) 373–380 2

[8] Hill, C., Garrett, J.: AASHTO Connected Vehicle Infrastructure Deployment Analysis. Technical report (2011) 2, 3.3

[9] Gerla, M., Kleinrock, L.: Vehicular networks and the future of the mobile internet. Computer Networks **55**(2) (2011) 457–469 2, 3.1

[10] Baldessari, R., Bödekker, B., Deegener, M., Festag, A., Franz, W., Kellum, C., Kosch, T., Kovacs, A., Lenardi, M., Menig, C., et al.: Car-2-car communication consortium-manifesto. DLR Electronic Library [http://elib. dlr. de/perl/oai2](Germany) (2007) 3.1, 4, 4

[6] Audi Travolution Project: http://www.audiusanews.com