Value of the Internet of Things for the Industry – An Overview

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Abstract. The Internet of Things (IoT) is a concept according to which uniquely identifiable things can indirectly or directly collect, process or exchange data via Wide Area Network – the Internet. Recently this concept has become a hot topic in science and resulted in multiple new technology developments. There is however also a lot of ambiguity surrounding the topic, which leads to questions if the IoT is a fad or a profound phenomenon. This article aims at answering the question about the value of the IoT idea for the industry. Academic definition of the concept is presented, global standardization initiatives reviewed, and a short survey of key technologies made. Then several existing and prospective applications involving the Internet of Things technologies are analyzed to determine values of this phenomenon from the point of view of the Industry understood as production of goods and services. Business models enabled or supported by the Internet of Things are also briefly described. It is concluded that there is substance in the IoT idea and the Industry can benefit from its adoption.

Keywords: Internet of Things, industry, standards, protocols.

1 Introduction

The term *Internet of Things* (IoT) was coined by Procter & Gamble employee Kevin Ashton in 1999 in the context of supply chain management [1]. It conveys a quite simple to understand idea that *Things* (that is arbitrary objects existing in the world) become connected to *The Internet* (that is the worldwide network used by billions of people every day) and start to exchange data between each other.

Realization of this idea seems to be underway and soon we may witness proliferation of smart cities, where every street lamp, water hydrant, traffic lights, bridges and other elements of urban infrastructure will be connected to the Internet.

On the other hand the idea of connecting devices into a network is nothing new in the industrial automation domain, so is it really necessary to push the Internet-related technologies there where many solutions exist today with proprietary technologies and they function well?

Maybe the biggest winner of the *Internet of Things* will be the ICT companies that offer Internet-related solutions to the Machine-to-Machine market?

In 2010 European Telecommunications Standards Institute (ETSI) published annual report, in which it estimated that out of 50 billion machines only 50 million were

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connected, that is roughly 1 %, with potential 99 % market gap [2]. Major ICT market players already coined their own terms to call the concepts closely related to the *Internet of Things* like *Industrial Internet* (GE) [3], *Internet of Everything*, *Smart+Connected Manufacturing* (both Cisco) [4], *Smarter Planet* (IBM) [5].

Is there a real value for various industries in the concept of IoT, or it is more a buzzword which does not have much substance?

In the attempt to find the answer, first an academic definition of the Internet of Things concept is given, related activities of major standardization bodies are reviewed, a brief survey of available technologies is presented, and finally several industry-related existing and prospective applications are analyzed to determine value of the IoT for the industry.

2 Definition

It is possible to find in the literature many definitions associated with the term *Internet of Things* [6]. Authors of the present work decided to use the definition proposed by the IERC-European Research Cluster on the Internet of Things [7]:

"A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual *things* have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network."

The above definition seems comprehensive and has been already adopted by some Authors [8].

3 Standardization Support for the Internet of Things

Development of the Internet of Things has become an important area of standardization activities undertaken by major institutions both at national and international levels (Tab. 1).

In 2012 seven of the world leading standard development organizations for information and communications technology established a new global organization – oneM2M – with aim to *create technical specifications to ensure that Machine-to-Machine communications can effectively operate on a worldwide scale* [9]. IEEE maintains a Web Portal for topics related to the Internet of Things [10], and a separate webpage where IEEE standards connected with this concept can be found [11].

Important activities are also carried out at the international level. IETF has four active working groups concerned with problems of adaptation of the protocols to the needs of low power (or constrained) devices [12]: (1) Constrained RESTful Environments, (2) IPv6 over Networks of Resource-constrained Nodes, (3) Routing Over Low power and Lossy networks and (4) Authentication and Authorization for Constrained Environments. The World Wide Web Consortium is involved in the Ubiquitous Web Applications activity, with working groups on developing standard application programming interfaces (APIs) to enable more secure device geolocation, easier use of Near-Field Communications technology or real-time communication between web browsers [13]. The Global Standards Initiative on Internet of Things (IoT-GSI) aims to act as an umbrella for IoT standards development worldwide. Apart from that, recommendations developed under the IoT-GSI in collaboration with other standards developing organizations will enable worldwide service providers to offer the wide range of services expected by this technology [14]. Finally, there is a special working group 5 of the joint technical committee of ISO and IEC devoted to the Internet of Things which aims at consolidation of works of internal agendas and external bodies rather than at publishing standards [15, 16].

Table 1. Initiatives of major national and international standardization institutions to support development of a worldwide network of connected devices

Region	Name of the Institution	Initiative
Europe	ETSI European Telecommunications Standards Institute	oneM2M
Japan	TTC Telecommunication Technology Committee	
Japan	ARIB Association of Radio Industries and Businesses	
Korea	TTA Telecommunication Technology Association	
China	CCSA China Communications Standards Association	
USA	ATIS Alliance for Telecommunications Industry Solutions	
USA	TIA Telecommunications Industry Associations	
USA	IEEE Institute of Electrical and Electronics Engineers	IoT Web Portal
Int'l	IETF Internet Engineering Task Force	4 Working Groups
Int'l	W3C World Wide Web Consortium	Ubiquitous Web Applications Activity
Int'l	ITU International Telecommunication Union	Internet of Things Global Standards Initiative
Int'l	ISO International Organization for Standardization	ISO/IEC JTC 1/SWG 5 Internet of Things (IoT)
Int'l	IEC International Electrotechnical Commission	

4 Technology Overview

4.1 General Architecture

A general architecture of the contemporary Internet of Things (IoT) is presented in Fig. 1. A *Thing* symbolizes any object equipped with a communication module allowing it to access the Internet. Depending on the type of communication module and power capabilities of the object, connection with the Wide Area Network may be possible directly or via the IoT Gateway. The IoT Gateway differs from ordinary gateways in capability to handle different short-range communication standards (e.g. Bluetooth, ZigBee, Wi-Fi, etc.). A particular type of devices that can be connected to the Internet are sensors, usually deployed as a wireless sensor network (WSN) including a large number of sensors characterized by the very low transmitter power and extremely low energy consumption. Data from those sensors is usually routed to final destination by the special node of greater capabilities.

The important components of the system are Service Providers that handle tasks associated with effective realization of variety of applications, e.g. provide data storage, expose sensors to top-level applications, facilitate negotiation of agreements between and users and devices owners, etc.

Some applications can be realized autonomously, but in many cases human supervision is needed or a human is the end user who receives demanded data or performs whatever actions he needs. In those cases a smartphone of the user can be the device of choice to provide the human-machine interface to the IoT application.

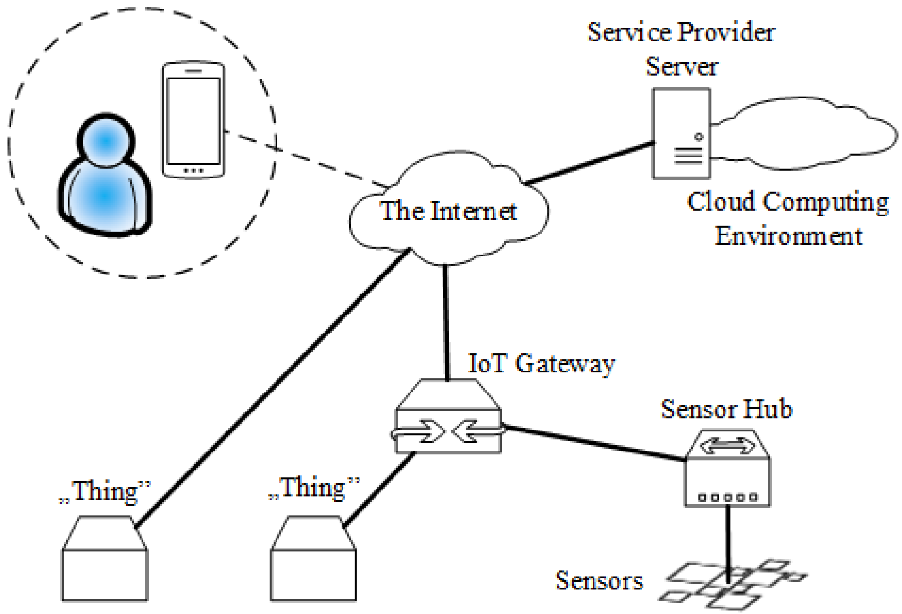

Fig. 1. The Internet of Things high-level architecture schematic

4.2 Key Technologies

Below a number of ICT technologies which enable the Internet of Things applications are briefly discussed. This review is not meant to be exhaustive, but it highlights which technologies are necessary and some available commercial solutions are also mentioned.

Hardware. The hardware layer comprises: edge devices (*Things*), optional gateways, access networks, backbone networks, equipment necessary to establish the cloud computing environment, and optional end user terminals.

Edge devices. The edge devices can be anything on condition that they have a communication module which allows direct or indirect connection to the Internet. The communication module must have appropriate size and energy consumption requirements to be easily incorporated into existing designs of *Things*. One possible solution is the Electric IMP [17] which has the size of an SD Card and provides Wi-Fi connectivity.

Gateways. Gateways are not the mandatory component, but in many scenarios they will be a part of the system as is the case with ordinary Internet solutions, because they offer enhanced protection of the local network and reduce cost and size of communication modules installed on the edge devices. Gateways for the Internet of Things should be capable of connecting devices using multiple short range communication protocols like Bluetooth Low Energy, ZigBee, Wi-Fi, etc. One of the commercial solutions is the Freescale IoT Gateway [18] which is to be introduced to the market by the end of 2014.

Access networks. Either the edge device itself or the gateway must be connected to the backbone (core) Internet via the access network with wired or wireless connection possible. Here the existing technologies used with the ordinary Internet can be used. Besides well known wired and mobile technologies (e.g. Fiber and LTE), the satellite technologies may be of greater use with the Internet of Things. They can be deployed in the areas with poor terrestial network infrastructure, which is particularly attractive for environment monitoring applications. Satellite technologies are usually viewed as expensive and having large latency. The o3b project aims at changing this stereotype, by deploying a constellation of satellites at the orbital height of about 8000 km [19] (as compared to geostationary satellites at 35 000 km orbital heights).

Backbone (core) networks. The backbone networks for the Internet of Things are likely to share the hardware technology with the ordinary Internet.

Cloud computing. Hardware technologies to provide cloud services for the Internet of Things can be the same as for the classic Internet. Bare metal servers (dedicated hardware) or virtual servers (shared hardware) completely configurable according to customer demand are offered, e.g. by SoftLayer (an IBM company) [20]. With time, growing number of connected devices and increase in amount of generated data associated with development of IoT may set new requirements for the cloud infrastructure.

End user terminals. End user terminals in many cases can be based on existing solutions, i.e. industrial panel PCs, desktop personal computers, and many kinds of mobile devices including tablets and smartphones.

Software. The software layer for the Internet of Things devices can be presented by reference to the ETSI M2M functional architecture described in [21] and discussed in [22]. This architecture is probably the most advanced proposal for the global standard for connected devices interoperability today.

The ETSI M2M functional architecture design is based on Service Capabilities that various devices connected to the network may have and conforms to the Representational State Transfer (REST) style [23]. With this architecture services offered by devices and their resources are uniquely identified by Uniform Resource Identifiers (URIs). Resources can be registered or discovered and used by applications running on devices connected to the network.

This approach allows an application to access the network resources without explicitly referring to specific protocols used by different devices.

Recently there has been a number of efforts to adapt existing protocols to the constraints of energy and computing power at small connected devices like Bluetooth Low Energy (BLE) [24], ZigBee Smart Energy Profile 2 [25]. Another important effort by IETF to bring IPv6 support in constrained devices resulted in 6LoWPAN specification [26].

For running applications on a low power connected device open source operating systems like Contiki-OS are already available. The Contiki-OS features full IP network stack and supports the recent protocols like 6LoWPAN, RPL and CoAP, and also implements mechanisms for power saving [27].

Cloud Services. There already exist providers of cloud services *specifically built for the Internet of Things* like Xively [28]. Xively offers a public cloud with searchable directory of devices, data storage for time-series archiving and API to build user applications.

As it can be seen, it is clear that from the technological point of view the Internet of Things is already possible. One of the main concerns is establishment of global standards to create good conditions for its development. International and national level initiatives towards this goal are underway and were briefly discussed in the previous section.

5 Applications

5.1 Methodology

In order to determine values for the Industry associated with the Internet of Things, the analysis of existing and possible applications was carried out.

Analyzed applications were taken from the oneM2M collection of Use Cases [9]. Out of 33 Use Cases, 9 pertaining to the Industry were selected (the Industry is understood as a business that focuses on production of goods and services).

The selected applications were classified according to their application patterns. There is a variety of applications possible across different market sectors, but it is possible to qualify those applications into several categories, according to the underlying idea of an application. This division brings clarity to the description.

Analysis of applications from the point of view of values for the Industry was conducted with the Value Reference Model [29] in mind. It is possible to group the values into those which stem from *any* connectivity of machines (things) and those which emerge only when this connectivity is realized according to the *Internet of Things* concept and with cooperation of multiple stakeholders.

Basic business models that are possible with the Internet of Things are also presented.

5.2 Application Patterns

In Table 2 selected applications from the oneM2M collection of Use Cases [9] are summarized. Names of the applications are in most cases self-explanatory and no extensive description of each application will be given here. Interested reader may find necessary details in document [9] – the symbol of the Use Case from that document is given in the column *Use Case*.

Table 2. Selected applications from oneM2M collection of Use Cases [9]

Sector	Application Name	Use Case	Application Pattern
Energy	Smart Meter Reading	5.3	SN
Transportation	Remote Maintenance Services	10.2	Data Deployment
Energy	Measurement & Control System for Advanced Transmission and Distribution Automation	5.1	SCADA
Energy	Environmental Monitoring of Remote Locations to Determine Hydropower	5.4	SCADA
Energy	Oil and Gas Pipeline Cellular/Satellite Gateway	5.5	SCADA
Transportation	Fleet Management Service using Digital Tachograph (DTG)	10.4	SCADA
Transportation	Devices, Virtual Devices and Things	8.2	Intelligent Device
Residential	Plug-in Electrical Charging Vehicles and Power Feed in Home Scenario	9.3	Intelligent Device
Residential	Semantic Device Plug and Play	9.7	Intelligent Device

Each of those specific applications can be viewed as developed around one of four application patterns: (1) Sensor Network pattern, (2) Maintenance pattern, (3) Supervisory Control and Data Acquisition pattern, and (4) Intelligent Function pattern. Definitions of those patterns, used in the present work, are given below.

Sensor Network Pattern (SN). Primary aim of application is data acquisition from a sensor or multiple sensors. Data acquired by the sensors are autonomously sent to the recipient over a network. Those data may be also analyzed in the intermediary step. The final consumer of the data is usually a human, who uses the data to make informed decisions.

Data Deployment Pattern. Primary aim of the application is data deployment to one or multiple devices. Data generated by a certain producer are autonomously sent to remote devices over a network. The producer of data is usually a human, who, for example, develops a new piece of software code and seeks an efficient way of updating firmware at target devices.

Supervisory Control And Data Acquisition Pattern (SCADA). Primary aim of this kind of application is the autonomous closed-loop control of a process involving devices with which communication is possible over single or multiple networks. With this pattern both data acquisition from sensors and data deployment to actuators are mandatory. Also some decision center is assumed to exist, which operates autonomously with possible human intervention.

Intelligent Device Pattern. Primary aim of this type of application is to equip a thing (a device) with ability to autonomously carry out certain required actions on behalf of the owner. Unlike in the three previous patterns where the application was viewed from perspective of the whole system, here the view is shifted to the perspective of a single element of this system. The device needs network connectivity to be able to discover necessary data and make some decisions based on those data, in accordance with the rules predefined by the device owner.

5.3 Values of Connectivity of Things – A Single Operator Case

Connecting devices in a network has numerous advantages from the point of view of the Industry. Some of those advantages, which can be achieved already by efforts of only a single operator (or a small consortium of businesses of similar profile), are pointed out below.

No Necessity of Direct Contact. Big savings in business operational costs can be introduced, if it is no longer necessary for the personnel to go to remote locations. Those savings may include work hours and travel expenses.

A very good example is the introduction of smart electricity meters at consumer houses and premises, whose indications can be remotely read at any time thanks to network connectivity (Smart Meter Reading application, Table 2).

Another example is connected with remote operation of pipeline valves and equipment in the oil & gas industry (Oil and Gas Pipeline Cellular/Satellite Gateway, Table 2). Travel costs and work hours are saved, if there is no necessity to send staff to travel long distances to change valve settings for reducing or increasing flow through pipe.

Improved Quality of the Product. Improved quality of the primary function of the product contributes to gaining the competitive advantage by the producer.

In case of mechatronic devices, one of the elements which can be enhanced more frequently than others is software. The developments may include bug fixes and new functionalities which both improve end user experience. If the devices are connected to the network there is a possibility for manufacturer to deploy software updates to devices with small or no involvement of the user (Remote Maintenance Services, Table 2).

Another example may be controlling of power generation by hydroelectric power station using SCADA system (Environmental Monitoring of Remote Locations to Determine Hydropower, Table 2). Accurate information about environment state, especially about available water supply (e.g., from snow) and water levels, matters because it enables accurate predictions of power generation capabilities of the unit. This results in lower electrical energy costs. Apart from that, careful monitoring of environment allows making control adjustments to avoid natural environment damage and fines due to breaking regulations of the environmental law. As a result it may be said that product (energy) of better quality is obtained.

It should be emphasized that all of the above advantages are possible with the current state of the technology and do not require any extraordinary cooperation between business domains.

5.4 Values of Connectivity of Things – Cooperation between Operators

New possibilities to cut down on costs and improve quality of products arise when effective cooperation between resource owners or producers and consumers will become possible across business domains. This transition from the isolated model where every business develops its own solution, which requires similar infrastructure established multiple times, to the shared resources model, where necessary infrastructure and services can be rented, is viewed as the key value of the Internet of Things [30].

Below a number of opportunities introduced by the Internet of Things are discussed.

Lowering Sensor Costs. If data from a single sensor can be shared between many stakeholders instead of each stakeholder deploying proprietary sensor, cost of initial investment will be decreased. Alternatively, while retaining original level of investment costs more sensors can be installed, but in a coordinated manner, which would lead to improved quality of data.

A good example here is the Environmental Monitoring of Remote Locations to Determine Hydropower, mentioned earlier. Sensors of snow level, water level, temperature, pressure, etc. can be shared with national weather services and governmental agencies involved in crisis management activities.

Lowering Networking Costs. Similarly as in the case of sensors, network infrastructure can be shared by parallel applications. Most of the network the infrastructure for the communication between machines (devices) can be the same as the ordinary Internet infrastructure. However, there is also need for dedicated solutions to enable networking between devices of constrained energy resources (e.g. batteries) and Internet gateways. If those solutions can be standardized, then this last-mile infrastructure can be shared as well. Existence of widely accepted standards allows production of networking equipment in high volumes, which results in lower costs to the user.

Lowering Electrical Energy Costs. One of the key possibilities associated with introduction of the smart electric grid is to manage the demand for power over time so as to reduce power demand peaks [22]. Generation of additional energy to satisfy power peaks is the more expensive for the energy producer the higher is the peak. If the peaks can be made more flat, this would allow reduction of energy prices. Power peak management can be based on changing energy prices during the day, and equipment at the side of energy consumers reacting to those prices when possible (buy cheap).

An example is charging of batteries of an electric car described in the application named Plug-in Electrical Charging Vehicles and Power Feed in Home Scenario, Table 2. Vehicle can be equipped with a device that seeks the lowest energy rates from different energy suppliers based on their current tariffs updated in real time, and decides when to start and stop charging, according to rules set up by the vehicle owner.

This example is a vision of the future, but if realized then costs of electrical energy may be lower for the consumers. Similar management of electrical energy consumption may include also other devices and home appliances.

Improving Customer Satisfaction. Today it becomes more and more important for the manufacturer to deliver a product, which makes the buyer satisfied.

One of the possibilities introduced by the Internet of Things is collecting data about patterns of use of products by the customers, after they express appropriate consent. This already happens in the computer software domain, because most computers are connected to the Internet, so the information can be easily gathered. The same opportunity arises when various things become connected. If manufacturers have this data available, they can develop products which better suit the needs of a statistical buyer or even the custom made products.

An example of a product (envisioned) which improves customer experience can be the home lightning equipment: intelligent lamp and switch (Semantic Device Plug and Play, Table 2). After positioning equipment in their appropriate places in the room, the devices will autonomously communicate and register themselves in the local devices management system after power on. No configuration activity will be required from the user. This removes or reduces requirement of laying power wires in the walls for the purpose of light switching. Also the consumer can install the equipment all by themselves, because electrical skills are not necessary (if the lamp is powered through the conventional power cord with a wall plug). A graphical presentation of values described above on a blueprint of application patterns is presented in Fig. 2.

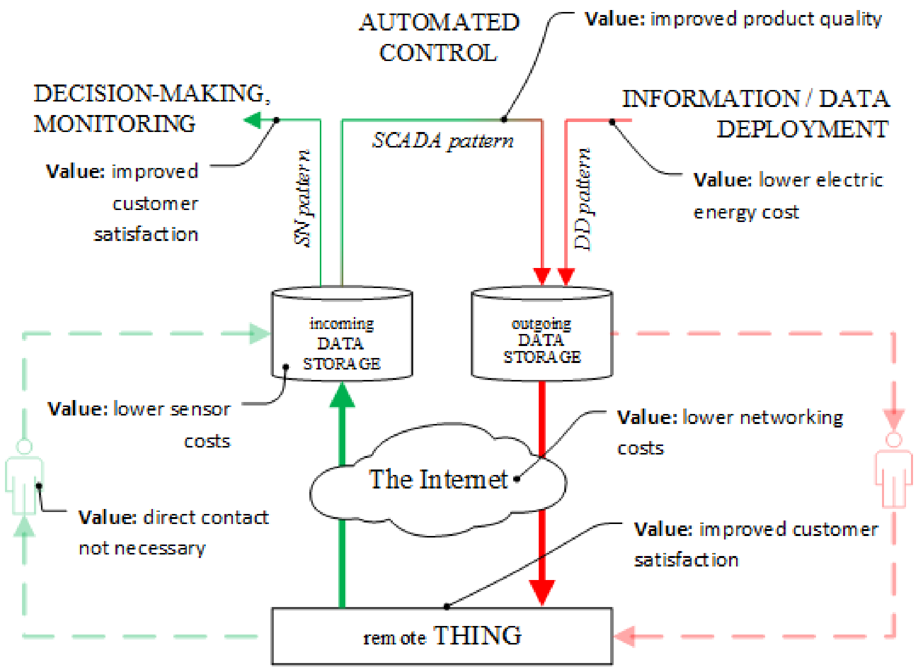

Fig. 2. Values of the Internet of Things for the Industry on a blueprint of application patterns

5.5 Business Models for Industry Enabled by the Internet of Things

The previous sections focused on the ways of improvement of a business by exploiting devices connectivity in general and their connectivity based specifically on the Internet of Things paradigm. In the present section, the basic business models, understood as methods of making profit, available with the Internet of Things are described.

Make Thing, Sell Thing. With this model, a manufacturer produces goods from raw materials and makes the profit by selling the goods to customers. When the Internet of Things is considered, this model will be used (and is already used) by manufacturers of hardware and software necessary to enable IoT functioning from the technical point of view. The market players sharing the market of the Internet hardware and software will benefit in the first place, but there may be also scope for new businesses oriented specifically to supply the IoT market, e.g. small size and low power communications modules, sensors, microcontrollers or microprocessors as well as firmware developed for those constrained embedded systems.

Selling Data from Sensors. The work [31] describes one possible model of selling data from sensors by a sensor owner to a sensor data consumer. This model assumes existence of a Sensor Publisher entity, a broker, who maintains available sensors database, provides means to find necessary sensors according to data consumer needs, and arranges contracts between the sensor owner and the data consumer. Data consumer can be, e.g. a food production company that wants to know preferences of its clients by monitoring contents of the end consumer refrigerator. In return for the data, the consumer receives either discounts on company's products or a monthly fee – the decision is made by the customer upon signing the contract.

Providing Services. The services known to be possible with the ordinary Internet, like providing access to the network, providing cloud computing services (Infrastructure-, Platform-, Software-as-a-Service), providing analytics services, etc., will probably proliferate with development of the Internet of Things. There are also opportunities for creating new services that will make the process of setting up the IoT applications easier or possible at all. One example is the Sensor Publisher service mentioned in the preceding point. Another interesting example can be management of home energy systems described in the oneM2M collection of Use Cases [9] (Use Case 9.2) for energy consumption minimization, provided by an external company on the basis of agreement with a home owner. This exemplifies a whole class of possible services, where professionals can offer their knowledge and expertise to fine tune or manage the user system.

The topic of making money from the Internet of Things is very important from the point of view of the Industry. IoT experts employed at renowned global companies (Ericsson, Nissan and Continental) share the view that the biggest challenge to overcome with the Internet of Things is monetization of the solutions [32]. The IoT solutions will likely involve agreements between multiple service providers having slightly different business models by themselves, and this will make those agreements highly complex and difficult to reach, maintain, manage and make profitable in the end.

6 Conclusion

In the article the concept and solutions associated with the Internet of Things are examined in order to get some insight in the value of this phenomenon for the Industry understood as production of goods and services. Based on the presented definition, review of global standardization initiatives, brief survey of existing and developed technologies and conducted analysis of applications from the point of view of potential value for the Industry following from introduction of the IoT, it can be concluded that the Internet of Things phenomenon is not a temporary buzz, but it is the evolution of the ordinary Internet which has capability to transform the Industry.

Availability of data from billions of connected devices containing variety of sensors may contribute to discovery of new knowledge, which will be used to improve people quality of life, to limit energy consumption and to protect natural environment. In the time span of a decade we should witness creation of *smart* environments in various domains – smart home, smart city, smart industry, etc.

Today leading automation equipment manufacturers seek their participation in the potential profits associated with the present and future Internet of Things implementations.

With rapidly increasing number of machines going on-line questions about ability of the existing and planned hardware and software to accommodate this growth should be discussed even more often to ensure harmonious development of the Internet of Things.

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