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A short overview of IoT based energy metering system
Part I Internet of things and the energy sector

O scurtă trecere în revistă a sistemului de contorizare a energiei electrice dotat cu internet

Partea I Internetul obiectelor şi domeniul energiei

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Abstract

This paper focuses on the presentation of a new and modern technology, namely the Internet of Things (IoT). In addition to the definition and history of the IoT in this article we briefly present the architecture and its essential components as well as the advantages and disadvantages of this new technology. Energy experts have shown that the IoT offer a wide number of applications in the energy sector, For this reason in the last part of this paper we present some aspects regarding the application of IoT in the energy sector.

***Key words**: internet of things, architecture of IoT, components of IoT, IoT for energy sector*

Rezumat.

Această lucrare se concentrează pe prezentarea unei tehnologii noi și moderne, și anume Internetul obiectelor (IoT). Pe lângă definiția și istoria IoT in acest articol, prezentăm pe scurt arhitectura și componentele sale esențiale, precum și avantajele și dezavantajele acestei noi tehnologii. Experții în energie au arătat că IoT oferă un număr mare de aplicații în sectorul energetic, motiv pentru care, în ultima parte a acestei lucrări prezentăm câteva aspecte privind aplicarea IoT în sectorul energetic.

***Cuvinte cheie:**, internetul obiectelor, arhitectura IoT, xomponentele IoT, IoT pentru sectorul energetic*

1 Introduction

Energy is a vital element of all human activities. Between 2001 and 2010, the world energy consumption increased by 29% and it has been estimated to grow by 57% by 2040. Today, coal, crude oil and gas are the primary sources of energy and they form approximately 80% of the world energy supply [1]. As a result of the rapid depletion of these energy resources, mankind is striving hard to uncover new avenues of energy security and management. Energy utility companies can achieve efficient management of electricity networks, ie reduce electricity losses and theft by means of an electricity measurement system based on the Internet of Things **(**IoT**)** For this reason in the first part of this paper we will present some general notions about the IoT and its use in the energy sector

2 What Is the Internet of Things (IoT)?

With the great developments in the field of Internet and technologies, everything has become digital. Internet has become an important part of our lives. A new technology has entered into this picture known as Internet of Things (IoT). Thus type of Internet is a network comprises of many electronic devices and sensors which are connected together to collect and exchange data or information over the web [2-4].

Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure [4]. The IoT allows objects to be sensed or controlled remotely across existing network infrastructure [6], creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention [5-6].

In other words IoT as is defined by ITU[1] and IERC[2] is a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols, in which, physical and virtual "things" have identities, physical attributes and virtual personalities, use intelligent interfaces and are seamlessly integrated into the information network. [5], [7]

3 History of internet of things (IoT) [8]

The idea of devices exchanging information without human appeared not long ago. Full automation of data transmission was discussed in the late '70s. At that time this approach was considered as "pervasive computing" or "embedded internet". It took several decades for technologies' development to start talking about the Internet of Things. In the second half of the nineties, Briton Kevin Ashton worked for Procter and Gamble enterprise and was engaged in the production process optimization. He noticed that optimization directly depends on the speed of transmission and processing of data. It can take days for people who collect the data. The use of Radio Frequency Identification (RFID) has allowed accelerating the process of data transfer directly between devices. He had an idea of things to be collected, processed and transmitted with no human involvement. He decided to call it an "Internet of Things" and became a visionary at that time.

While the phrase came about in 1999, the concept of connected devices dates back to 1832 when the first electromagnetic telegraph was designed, and allowing direct communication between two machines through the transfer of electrical signals. However, the true Internet of Things history began with the invention of the Internet in the late 1960s

[1] ITU is the International Telecommunication Union, a United Nations specialized agency for information and communication technologies – ICTs fonded in 1865

[2] IERC is a European Center for Research Cluster on the Internet of Things

Today there are more than 27 billion devices connected to the Internet of Things, with experts expecting this number to rise to over 100 billion devices by 2030

4 Architecture of IoT

Architecture of IoT (see Fig. 1) [9-10],] depends on various applications of IoT.

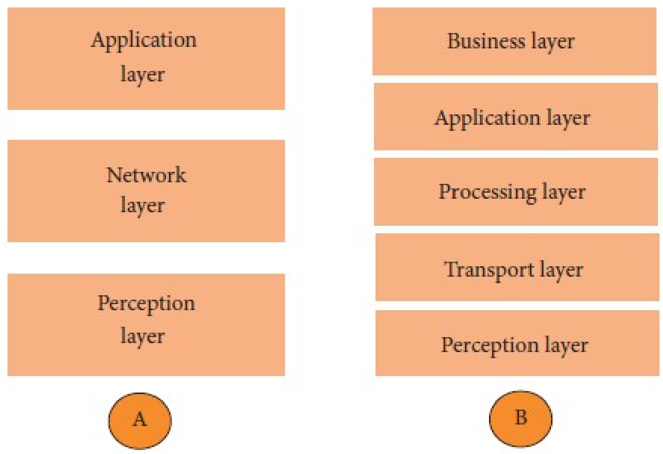

Fig. 1 Architecture of IoT (A: three layers) (B: five layers). [11]

There is no single consensus on architecture for IoT, which is agreed universally. Different architectures such as three- and five-layer architectures have been proposed by different researchers. [11-14],

The most basic architecture is a three layer architecture (see fig. 1 A). It was introduced in the early stages of research in this area and has three layers, namely:
a) The *perception layer* is the physical layer, which has sensors for sensing and gathering information about the environment. It senses some physical parameters or identifies other smart objects in the environment; **b)** the *network layer* is responsible for connecting to other smart things, network devices, and servers. Its features are also used for transmitting and processing sensor data, **c)** The *application layer* is responsible for delivering application specific services to the user. It defines various applications in which the Internet of Things can be deployed, for example, smart metering, smart grid, smart meter smart city etc.

This architecture defines the main idea of the IoT, but it is not sufficient for research on IoT because research often focuses on finer aspects of the IoT. That is why, we have many more layered architectures proposed in the literature. One is the five layer architecture, which additionally includes
a) The *transport layer* which transfers the sensor data from the perception layer to the processing layer and vice versa through networks such as wireless, 3G[3], LAN[4], Bluetooth[5],

[3] 3G (short for third generation) is the third generation of wireless mobile telecommunications technology
[4] LAN or local area network is a computer network that interconnects computers within a limited area such as a residence, school, laboratory, university campus or office building
[5] Bluetooth is a wireless technology standard used for exchanging data between fixed and mobile devices over short distances using ultra high frequency (UHF) radio waves in the ISM bands, from 2.402 GHz to 2.480 GHz,

RFID[6], and NFC[7] and **b)** The *processing layer* also known as the middleware layer. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It employs many technologies such as databases, cloud computing, and big data processing modules.

5 Elements of IoT [3]

Essential components [15] (see fig. 2) which are required to build IoT are

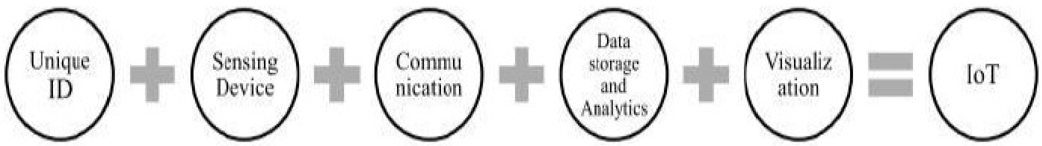

Fig. 2 Essential Key elements of IoT [16]

a) *Unique identification for each smart device* to identify the source of data (e.g., sensors, devices), **b)** *sensing devices* to collect information**, c)** *communication* **[**to send data from smart devices to the database through the communication technologies such as Radio Frequency Identification (RFID), Bluetooth, Near Field Communication (NFC), Wi-Fi,[8] ultra-wide bandwidth(UWB)[9], Z-wave[10], 3G, 4G[11] and Long Term Evolution-Advanced (LTE-A)[12]., **d)** *Data storage and analytics* **[3]** of data supplied by smart devices, **e)** *Visualization*. By using smart phones or laptops of data so that user can interact with centralized database and get the useful information about the actual environment.

6 IoT Characteristics [4]

reserved internationally for industrial, scientific and medical purposes and building personal area networks i.e a computer network for interconnecting electronic devices centered on an individual person's workspace

[6] Radio-frequency identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to objects. An RFID system consists of a tiny radio transponder, a radio receiver and transmitter. When triggered by an electromagnetic interrogation pulse from a nearby RFID reader device, the tag transmits digital data, usually an identifying inventory number, back to the reader. This number can be used to track inventory goods.

[7] Near-Field Communication (NFC) is a set of communication protocols for communication between two electronic devices over a distance of 4 cm or less

[8] Wi-Fi is a family of wireless network protocols, based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and Internet access.

[9] Ultra-wideband (UWB) refers to a signal that has a −10 dB bandwidth greater than 500 MHz or a fractional bandwidth (bandwidth divided by the band centre frequency) greater than 20%. There has been intense recent interest in the use of such signals for high data-rate, low power, short-range communications

[10] Z-Wave is a wireless communications protocol used primarily for home automation

[11] The term 4G stands for 'fourth generation' and refers to mobile network technology that enables 4G compatible phones to connect to the internet faster than ever before

[12] LTE Advanced is a mobile communication standard and a major enhancement of the Long Term Evolution (LTE) standard LTE (Long Term Evolution) is a standard for 4G wireless broadband technology that offers increased network capacity and speed to mobile device users

The most important features of IoT include: **1)**. *AI* – IoT essentially makes virtually anything “smart”, meaning it enhances every aspect of life with the power of data collection, artificial intelligence algorithms, and networks.**2)**. *Connectivity* – New enabling technologies for networking, and specifically IoT networking, mean networks are no longer exclusively tied to major providers. Networks can exist on a much smaller and cheaper scale while still being practical. IoT creates these small networks between its system devices. **3)**. *Sensors* – IoT loses its distinction without sensors. They act as defining instruments which transform IoT from a standard passive network of devices into an active system capable of real-world integration. **4)**. *Active Engagement* – Much of today's interaction with connected technology happens through passive engagement. IoT introduces a new paradigm for active content, product, or service engagement. **5)**. *Small Devices* – Devices, as predicted, have become smaller, cheaper, and more powerful over time. IoT exploits purpose-built small devices to deliver its precision, scalability, and versatility.

7 IoT– Advantages and disadvantages

The advantages of IoT span across every area of lifestyle and business. Here is a list of some of the advantages that IoT has to offer:

1) *Improved Customer Engagement* – Current analytics suffer from blind-spots and significant flaws in accuracy; and as noted, engagement remains passive. IoT completely transforms this to achieve richer and more effective engagement with audiences.

2) *Technology Optimization* – The same technologies and data which improve the customer experience also improve device use, and aid in more potent improvements to technology. IoT unlocks a world of critical functional and field data. **3)** *Reduced Waste* – IoT makes areas of improvement clear. Current analytics give us superficial insight, but IoT provides real-world information leading to more effective management of resources. **4)** *Enhanced Data Collection* – Modern data collection suffers from its limitations and its design for passive use. IoT breaks it out of those spaces, and places it exactly where humans really want to go to analyze our world. It allows an accurate picture of everything.

Though IoT delivers an impressive set of benefits, it also presents a significant set of challenges. Here is a list of some its major issues:

1) *Security* – IoT creates an ecosystem of constantly connected devices communicating over networks. The system offers little control despite any security measures. This leaves users exposed to various kinds of attackers. **2)** *Privacy* – The sophistication of IoT provides substantial personal data in extreme detail without the user's active participation. **3)** *Complexity* – Some find IoT systems complicated in terms of design, deployment, and maintenance given their use of multiple technologies and a large set of new enabling technologies. **4)** *Flexibility* – Many are concerned about the flexibility of an IoT system to integrate easily with another. They worry about finding themselves with several conflicting or locked systems. **5)** *Compliance* – IoT, like any other technology in the realm of business, must comply with regulations. Its complexity makes the issue of compliance seem incredibly challenging when many consider standard software compliance a battle

8 IoT in the energy sector [18]

Today, the energy sector is highly dependent on fossil fuels. Excessive extraction and combustion of this fuel has a major economic impact due to air pollution and climate change.

The age of equipment in the power sector and poor maintenance problems can lead to high level of energy losses and unreliability. Assets are sometimes more than 40 years old, very expensive, and cannot be replaced easily. IoT can contribute to reducing some of these challenges in the management of power plants. By applying IoT sensors, Internet-connected devices are able to distinguish any failure in the operation or abnormal decrease in energy efficiency, alarming the need for maintenance. This increases reliability and efficiency of the system, in addition to reducing the cost of maintenance [18]

For reducing fossil fuel use and relying on local energy resources, many countries are promoting renewable energy sources (RESs) such as wind and solar energy. This variable renewable energy (VRE) sources pose new challenges to the energy system known as "the intermittency challenge". In an energy system with a high share of VRE, matching generation of energy with demand is a big challenge due to variability of supply and demand resulting in mismatch in different time scales. IoT systems **1)** offer the flexibility in balancing generation with demand, which in turn can reduce the challenges of deploying VRE, resulting in higher integration shares of clean energy and less greenhouse gases (GHG) emissions. [19].
2) , a more efficient use of energy can be achieved by using machine-learning algorithms that help determine an optimal balance of different supply and demand technologies [22].

Smart grids are modern grids deploying the most secure and dependable Information and communications (ICT) technology to control and optimize energy generation, by connecting many smart meters, a smart grid develops a multi-directional flow of information, which can be used for optimal management of the system and efficient energy distribution [20]. The application of smart grid can be highlighted in different sub sectors of the energy system individually, e.g., energy generation, buildings, or transportation, or they can be considered altogether. In a smart grid batteries can be charged wirelessly using an inductive charging technology and in addition, in a smart grid, the energy demand pattern of end users can be analyzed by collecting data through an IoT platform,

IoT can play a crucial role in reducing energy losses and lowering CO_2 emissions.
An energy management system based on IoT can monitor real-time energy consumption and increase the level of awareness about the energy performance at any level of the supply chain [17], [21]. By monitoring and controlling equipment and processes, early stages of IoT started to contribute to the power sector by alleviating the risk of loss of production or blackout. [22]. Moreover, IoT can be applied in isolated and micro grids for some islands or organizations, especially when energy is required every single moment with no exception, e.g., in databases.

9 Conclusions

Putting all the above together you can come to the conclusion that IoT is the network of things, with clear element identification, embedded with software intelligence, sensors, and ubiquitous connectivity to the Internet. This „network of networks" enables things or objects to exchange information with the producer and supplier of electricity and/or other connected devices such as smart electricity meters (see part II and III of this paper). In the energy sector smart meters become an essential part of the IoT. One of the main advantages of installing smart meters is the connection with a reduction in carbon emissions.

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