Engineering

CHALLENGES REGARDING THE APPROPRIATE MANAGEMENT OF THE EMERGING INTERNET OF THINGS APPLICATIONS

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ABSTRACT:
IN THIS PAPER, WE HAVE ANALYZED THE MOST IMPORTANT CATEGORIES OF INTERNET OF THINGS (IOT) DEVICES, THEIR CAPABILITY TO EXPAND IN THE FUTURE AND THEIR POSSIBLE EFFECTS ON THE ENERGY MARKET. WE HAVE TACKLED RELEVANT ISSUES RELATED TO THE MOST IMPORTANT IOT APPLICATIONS IN EVERYDAY LIFE, SUCH AS: HOME AUTOMATION AND SECURITY, SMART APPLIANCES, SMART LIGHTING, SMART GRIDS, AUTONOMOUS CARS, VEHICLE CONNECTIVITY, HEALTHCARE APPLICATIONS, TRANSPORT AND LOGISTICS APPLICATIONS, ETC. WE HAVE ANALYZED IMPORTANT CHALLENGES THAT HAVE TO BE OVERCOME WHEN MANAGING EXTENSIVE IOT IMPLEMENTATIONS. IN VIEW OF THE FACT THAT THE DATA PRODUCED BY IOT DEVICES IS GROWING SIGNIFICANTLY, IN THE NEAR FUTURE, ONE OF THE GREATEST CHALLENGES CONSISTS IN THE APPROPRIATE MANAGEMENT OF THE HUGE AMOUNT OF DATA THAT RESULTS AND OF THE ASSOCIATED PROBLEMS RELATED TO DATA STORAGE, SECURITY, PRIVACY AND ANALYTICS.

KEY WORDS: INTERNET OF THINGS (IOT), SMART DEVICES, DATA MANAGEMENT

INTRODUCTION

The United Nations specialized agency for information and communication technologies, International Telecommunication Union (ITU)[3] and the European Research Cluster on the Internet of Things (IERC)[4] have defined the Internet of Things (IoT) as a network infrastructure, having a dynamic characteristic and a global extent. IoT offers self-configuring capabilities and is based on interoperable and standard communication protocols. The virtual and physical entities are endowed with their own identities, virtual and physical attributes, using intelligent interfaces and being integrated easily into the information network. Even though at its introduction, in 2013, the Internet of Things notion seemed to

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[3] The United Nations specialized agency for information and communication technologies, International Telecommunication Union (ITU); http://www.itu.int/en/about/Pages/default.aspx, accessed on 10 May 2017
[4] The Building Technologies Office of the United States Department of Energy; https://energy.gov/eere/buildings/about-building-technologies-office, accessed on 10 May 2017

have a futuristic, imaginary character, lately it has become more and more palpable and has gained increasingly significance in everyday life[5].

In this context, the IoT devices have also gained in popularity, becoming an essential part of the people's life. An IoT device consists in a nonstandard computing device, connected through a wireless connection to a network, having the ability to receive and transmit data, thus being a component of the Internet of Things. The Internet of Things in ensemble and the IoT devices particularly rise a series of challenges to the developers and users. Among these challenges, it is worth to mention the ones concerning the technical, the security and the efficiency issues. Every IoT device communicates with other devices that are components of the same ecosystem, devised in order to automate a home, an industry branch, a business or other domains. The devices also provide useful data to their users (private individuals or businesses), facilitating their daily activities and life[6].

The Internet of Things concept is closely related to business, industry, health, research activities, to smart homes, smart cities and many other fields of the human's life. Examples of IoT applicability in the daily life can vary from fully automated houses which increase the comfort and safety of their inhabitants, to intelligent cars that communicate with each other or even send notifications to emergency services in case of accidents[7], to healthcare systems that assist the elderly or disabled patients and monitor their health, etc. On a larger scale, we should mention the IoT applicability to smart cities, where intelligent systems are integrated in urban planning, in order to improve the efficiency of various services (to reduce the public energy consumption, to improve the public transport, to make the traffic more efficient, etc.), or even to develop more effective urban policies where decision makers can rely on intelligent tools and advanced ICT technologies[8]. For industry, the range of applications of intelligent systems is even wider, such systems can be used for optimizing productivity, automating maintenance operations, managing the distribution or shipping of products, monitoring the environment, increasing the production of green energy and managing its distribution and integration in the existing power grid, etc.

According to our research project's plan of activities within which this research has been conducted, with regard to the above-mentioned aspects, taking into account the national and international concerns for improving the energy efficiency of the Internet of Things in ensemble and of the IoT devices in particular, we have analyzed in this paper the most important categories of IoT devices, their capability to expand in the future and their possible effects on the energy market. We have paid special attention to the most relevant issues related to the IoT applications in everyday life, such as: home automation and security, smart appliances, smart lighting, smart grids, autonomous cars, vehicle connectivity, healthcare applications, transport and logistics applications, etc. As when managing extensive IoT implementations the developers and users have to overcome a series of challenges, in the following we review and analyze them, along with issues regarding the appropriate management of the continuous growing amount of data produced by IoT devices, the emerging problems related to data storage, security, privacy and analytics.

In the following we present a series of issues regarding the energy consumption resulting from using the IoT devices.

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[5] Vermesan, Ovidiu, Friess, Peter; *Internet of Things Applications - From Research and Innovation to Market Deployment,* Aalborg: River Publishers, 2014

[6] Tăbușcă, Alexandru, *Present and future economics of augmented reality, Journal of Information Systems & Operations Management*, București: Editura Universitară, 2015

[7] Căruțașu, George, Botezatu, Cezar, Botezatu, Mihai Alexandru; *Expanding Ecall from cars to other means of transport, Journal of Information Systems and Operations Management*, București: Editura Universitară, 2016

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THE ENERGY CONSUMPTION OF THE IOT DEVICES

The IoT development certainly offers a wide range of opportunities, but also raises many risks and problems for users and developers. Among these, it is worth to consider the necessity of properly managing the potential increase of the energy consumption. Because the IoT devices must be permanently accessible for other devices, it is essential for the communication modules of these devices (or even the devices themselves) to be permanently powered, even when they are not in operation. Although in this state the energy consumption is low, the extremely high number of IoT devices can result in a global considerable energy consumption, especially in view of expanding the use of these devices[9].

When assessing the potential increase in the energy consumption, one must take into account the forecasts regarding the growing use of both standard equipment that employ communication networks (such as computers, laptops, gaming consoles, smart TVs, etc.) and of the novel IoT devices (such as household applications, sensors, equipment for monitoring and maintaining the user's health). In this context, a comprehensive study regarding the energy consumption related to the Internet of Things should consider the use of all these devices and should aim to develop effective policies in order to prevent excessive energy consumption that could result due to these devices.

As shown in[10], the rapid technology evolution of recent years offers a series of technical options for reducing the increasing energy consumption, ranging from implementing smart metering systems that improve consumption management, to using alternative renewable energy sources. The advantages of using renewable energy as an alternative energy source are well known and have been discussed extensively in recent years; the most notable benefits consist of conserving traditional energy resources, reducing pollution, stimulating economic development[11], and even assuring the stability of the national power system[12].

Another relevant aspect with respect to energy consumption is the fact that IoT devices have also the potential to facilitate the efficient use of energy as they offer a wide range of data management capabilities related to the life and habits of the customers who are using them.

A number of international organizations and boards, for example the European Research Cluster on the Internet of Things (IERC)[13], the IEEE Communications Society (Comsoc)[14], the Building Technologies Office of the United States Department of Energy[15], the United Kingdom Government Office for Science[16] aim to develop researches related to

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[9] Friedli, Martin, Kaufmann, Lukas, Paganini, Francesco, Kyburz, Rainer; *Energy Efficiency of the Internet of Things, Technology and Energy Assessment Report*, http://www.iea-4e.org, accessed on 10 May 2017

[10] Căruțașu, George, Coculescu, Cristina, Stănică, Justina Lavinia, Pîrjan, Alexandru; *An analysis of the main characteristics and implementation requirements of the advanced metering infrastructure systems in Romania, Database Systems Journal*, București, 2016

[11] Lungu, Ion, Bâra, Adela, Carutasu, George, Pîrjan, Alexandru, Oprea, Simona-Vasilica; *Prediction intelligent system in the field of renewable energies through neural networks, Economic Computation and Economic Cybernetics Studies and Research*, Bucuresti: Editura Academia de Studii Economice, 2016

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[13] The European Research Cluster on the Internet of Things (IERC); http://www.internet-of-things-research.eu/index.html, accessed on 10 May 2017

[14] The IEEE Communications Society (Comsoc); http://www.comsoc.org, accessed on 10 May 2017

[15] The Building Technologies Office of the United States Department of Energy; https://energy.gov/eere/buildings/about-building-technologies-office, accessed on 10 May 2017

[16] The United Kingdom Government Office for Science; https://www.gov.uk/government/organisations/government-office-for-science, accessed on 10 May 2017

the Internet of Things field, the energy consumption resulting from using the IoT devices, the standardization of these devices, the involved technologies, the potential offered by the IoT devices' market and their implementation in commercial and residential buildings.

In the following we present the main application areas of the IoT devices and the most important categories of IoT applications.

THE MOST IMPORTANT CATEGORIES OF IOT APPLICATIONS

According to[17], when speaking about the IoT applications one can classify them into several main application areas, namely:

- the smart home area (comprising as main applications the smart lighting, the home automation, the smart appliances);
- the smart health area (comprising as main applications the physical activity monitoring, the weight monitoring, the sleep monitoring, the health monitoring, the emergency notification, the medicines management, the fall detection, the nutrition monitoring);
- the smart retail area (that comprises the product tracking, the location based services and the smart vending machines application);
- the smart grid (that comprises the smart meters, the smart appliances, the renewable energy resources and the energy efficient resources);
- the smart mobility area (comprising as main applications the emergency notifications, the smart road, the smart parking guidance, the traffic monitoring, the public transport ticketing, the communications between cars, the communications between cars and infrastructure, the smart street lightening);
- the smart logistics (comprising as main applications the products tracking, the monitoring of the storage and shipment quality, the fleet tracking, the waste management);
- the smart agriculture (comprising as main applications the animal tracking, the irrigation and pest monitoring);
- the smart office area (comprising as main applications the office automation, the access control, the intrusion and fire detection);
- the smart factory area (comprising as main applications the asset tracking, the machine monitoring, the machine diagnosis, the machine remote control and the inventory management);
- the smart environment monitoring (comprising as main applications the monitoring of the water quality monitoring, floods, forest fire, avalanches, earthquakes, glacier).

As mentioned in[18], based on the above-mentioned classification, the most important IoT applications that should be considered when studying the impact of IoT devices on the global energy consumption are those implied in the everyday life's fields of activities, such as: home automation, smart appliances, smart lighting, smart street lighting and smart roads. Even if all these applications cause an additional energy consumption in their standby mode, they also have a considerable impact on energy saving. In most of the cases, the extra power consumption brought by these devices is inferior to the energy savings that they can bring.

[17] Friedli, Martin, Kaufmann, Lukas, Paganini, Francesco, Kyburz, Rainer; *Energy Efficiency of the Internet of Things, Technology and Energy Assessment Report*, http://www.iea-4e.org, accessed on 10 May 2017

[18] Friedli, Martin, Kaufmann, Lukas, Paganini, Francesco, Kyburz, Rainer; *Energy Efficiency of the Internet of Things, Technology and Energy Assessment Report*, http://www.iea-4e.org, accessed on 10 May 2017

According to[19], analyzing the impact of the above-mentioned most important IoT applications on the worldwide energy consumption, one can observe that the energy consumption in the standby mode is expected to grow with an annual rate of 20%. It is expected that, in 2025, the most important IoT applications causing an additional energy consumption in their standby mode will be the home automation (with a percentage of 78% from the total additional consumption), the smart appliances (with a percentage of 15%) and the smart lighting (with a percentage of 7%).

On the other side, taking into account the permanent and sustained development in the IoT domain, the impact of the IoT devices in the energy efficiency will become more and more substantial, both for existing technologies and for the new, emerging ones.

In the following, we discuss a series of challenges that have to be overcome by the developers and users when managing extensive IoT implementations.

CHALLENGES THAT THE IOT POSES TO ITS DEVELOPERS AND USERS

When speaking about the Internet of Things and IoT devices' future development, one must consider the appropriate management of the continuous growing amount of data, produced by the IoT devices, the emerging problems related to data storage, security, privacy and analytics.

The main steps before implementing the Internet of Things at a large-scale extent are to obtain a model validation from the technological and business points of view, to address in an integrated manner the issues regarding the security and trust, to validate and certify the ecosystems in the IoT field. The developers should focus their interest in solving the technological impediments, especially those related to the security, approaching the integration potential of the IoT devices with the existing technologies, gaining the users' acceptability and trust, implementing novel applications as to facilitate the communication between the users and the smart devices, validating the specific technological concepts involving interlinking and compatibility between the novel and existing technological means.

According to[20], as each category of users has its own interests and needs, the IoT applications developers should consider the three main user categories: the individuals, the community within a certain area (a city, a country or even the whole human society) and the enterprises. At an individual level, the users' expectations from the IoT applications refer to ensuring their own and their families security, offering the possibility to conduct certain daily activities in an easier, more effective and safer manner, thus improving their life-style and decreasing the expenses. At the society's level, it is expected that the usage of IoT applications ensures an improved public safety, offers new possibilities of protecting the environment, creates new jobs and ensures the sustainability of the existing ones. Regarding the enterprises as a category of IoT users, the IoT application developers should take into account their needs in view of obtaining an increased productivity, offering the products' diversification on the market, reducing the costs in order to obtain an improved economic efficiency.

Another category of challenges for the developers refers to the novel network technologies that have to deal with the ever-increasing amounts of data, the large number of users and the huge number of devices, offering a low latency, low energy consumption and being cost-effective.

[19] Friedli, Kaufmann, Paganini, Kyburz, r; *Energy Efficiency of the Internet of Things…*

[20] Vermesan, Ovidiu, Friess, Peter; *Internet of Things Applications - From Research and Innovation to Market Deployment,* Aalborg: River Publishers, 2014

A recent study conducted by Juniper Research[21], shows that the number of connected IoT devices will triple from 2016 to 2021, reaching over 46 billion devices. The research predicts that the highest growth of IoT applications will be in the industrial sector and public services. On the same note, another research conducted by Cisco[22], forecasts that the global data generated by IoE (Internet of Everything) applications will reach the extraordinary amount of 600 Zettabytes per year by 2020, compared to the 2014 figure of 134.5 Zettabytes per year. However, the study pointed out that, fortunately, only slightly above 1% of those data (about 6.2 Zettabytes) will have to be stored.

Under these circumstances, the biggest challenge end-users and providers must cope with consists in managing the huge amount of data produced by the increasing number of devices. The Juniper research author Steffen Sorrell cautioned that the technical architecture cannot handle these data: "*The platform landscape is flourishing. However, analytics and database systems are, for the most part, not architected to handle the Big Data 2.0 era that the IoT brings*"[23].

Another fact highlighted by the Juniper research[24] consists in the fact that the security threats for business and individuals will increase, due to the huge growth of IoT devices. The IoT DDoS (distributed denial-of-service) attacks recorded in 2016 are considered to be only "*the tip of the cybersecurity iceberg"*, since on the long and medium term the IoT hackers might focus on other directions such as the theft of personal or corporate data or physical asset damage.

The Internet of Things development rises emerging challenges for the researchers and developers in order to lay the foundation for a new smart world, in which the energy, the transport, the cities and many other aspects of the daily human life become more intelligent and usable. The capacity of the Internet of Things devices to connect with each other, to interact at any moment and place with other devices and with their users represents a huge step in improving the human health and quality of life.

When analyzing the Internet of Things impact among the human society, one must take into account not only the type of developed applications and devices or the security concerns, but also aspects regarding the data generated by the IoT devices and its management. Therefore, in the following, we tackle significant issues regarding the management of data generated by the Internet of Things and by the IoT applications.

MANAGING DATA GENERATED BY THE IOT APPLICATIONS

Considering the fast development of the Internet of Things, one of the most important issues that have to be considered is the growing amount of data produced by the IoT applications that have to be stored, used and managed securely. The data produced by the Internet of Things and IoT applications is characterized by their huge dimension, being unstructured and non-static. The traditional systems used in managing databases are the relational database management systems.

Despite their undeniable qualities (performance, flexibility, simplicity, scalability, robustness), the usage of the above-mentioned systems in the Internet of Things field faces a series of limitations, deriving from their static schema. In this context, a newer class of

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[21] Juniper Research; *The Internet of Things: Consumer, Industrial & Public Services 2016-2021*, cited in Juniper Research press release: *'Internet of Things' Connected Devices to Triple by 2021, Reaching Over 46 Billion Units,* https://www.juniperresearch.com/press/press-releases/'internet-of-things'-connected-devices-to-triple-b, accessed on 27 May 2017

[22] Cisco; *Cisco Global Cloud Index: Forecast and Methodology, 2015–2020,* https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.pdf, accessed on 27 May 2017

[23] Juniper Research; *The Internet of Things: Consumer, Industrial & Public Services 2016-2021…*

[24] Juniper Research; *The Internet of Things: Consumer, Industrial & Public Services 2016-2021…*

database systems, the NoSQL databases, have arisen, offering an improved performance compared to the traditional SQL ones[25].

The main elements that worth to be highlighted when comparing the SQL and the NoSQL databases have been synthetized in (table1)[26].

Table 1. A comparison between the SQL and the NoSQL databases

The database's type / **The compared elements**	**SQL Database**	**NoSQL Database**
The emerging moment	Since 1970	Since 2000
The model	Relational	Non-relational
The development model	Mix	Open Source
Schemas	Fix (structure and data types are fixed in advance)	Typically, dynamic (records can add new information on the fly)
Scaling	Vertically	Horizontally
Consistency	Atomicity, Consistency, Isolation, Durability	Basically Available, Soft state, Eventual consistency
Types	One type with minor variations	Many different types (key-value stores, document databases, wide-column stores, graph databases)
Examples	MySQL, Postgres, Oracle Database, MSSQL, DB2	MongoDB, Cassandra, HBase, Neo4j, Riak, Voldemort, CouchDB, DynamoDB
Data manipulation	Through a specific language (using Select, Insert, Update statements)	Through object-oriented APIs

As described in[27], the main characteristic of the NoSQL databases is their non-relationality, as they can incorporate any kind of data in a single database. In addition, the NoSQL databases offer an easy replication support, they are horizontally scalable, suitable for data having a schema-free structure. These databases can be distributed with ease and provide a high level of scalability and availability.

Comparing the SQL and the NoSQL databases, it is almost impossible to state that one of these databases systems is better than the other without specifying first the type of the application in which the data definition and querying are required. Nevertheless, NoSQL

[25] Joshi, Bhamiti, Khobragade, Shreya, Joshi, K.K.; *A Survey on Database Requirements and Security of IoT, International Journal of Innovative Research in Computer and Communication Engineering*, Tamilnadu: Ess & Ess Research Publications, 2017; Rautmare, Sharvari, Bhalerao, Mangesh; *SQL & NoSQL Database Study for Internet of Things, International Journal of Innovative Research in Science, Engineering and Technology,* Tamilnadu: Ess & Ess Research Publications, 2016

[26] Joshi, Bhamiti, Khobragade, Shreya, Joshi, K.K.; *A Survey on Database Requirements and Security of IoT…*

[27] Rautmare, Sharvari, Bhalerao, Mangesh; *SQL & NoSQL Database Study for Internet of Things, International Journal of Innovative Research in Science, Engineering and Technology*, Tamilnadu: Ess & Ess Research Publications, 2016

databases are more suitable for the heterogenous type of data than traditional SQL databases[28].

According to[29], in the case of IoT applications, the NoSQL databases are more efficient than the traditional SQL ones. The requirements of a database system designed to manage data produced by IoT applications consist in a system that has to be flexible, scalable, capable of handling real time and dynamic data types, efficient in managing large amounts of data. As they are able to store and process such types of data, the NoSQL databases seem to be the best choice for the developers when managing data generated by the Internet of Things and the IoT applications.

Both SQL and NoSQL were, at the moment of their release, the best solution for the purpose for which they were designed: the data management, storage and retrieval. Even if regarding the data generated by the IoT domain, NoSQL databases offer great advantages, it does not mean that NoSQL is always the best and only solution. Both technologies are useful and it remains at the choice of the developer to select the best option, depending on the particular situations and his own needs. Establishing the most suitable database type is not a universal truth, but requires a thorough study that takes into account the specific of the application.

CONCLUSION

We have analyzed in this paper a series of challenges regarding the appropriate management of the emerging Internet of Things applications. Of course, the existence of these challenges (as well as others that have not been mentioned) does not represent an impediment to the development of Internet of Things, of emerging applications and devices. As in the last decades there have been technical developments that seemed unimaginable twenty or thirty years ago, it is expected that the next decades will bring other significant evolutions and challenges. This is the reason why in the future, the emergence of new devices that will be part of the IoT universe, as well as the development of new applications for these devices, will bring new challenges to the users and developers.

Regarding the future work, corresponding to the project's objectives, the research team will develop a custom-tailored IoT solution using Microsoft Azure IoT Suite[30] that will retrieve from the smart meters data that will be further analyzed using Stream Analytics[31]. Thus, based on the analyzed IoT data we will design and implement a NoSQL database that will scale efficiently to the large volume of produced IoT data. Once stored, the data will be further analyzed using machine learning techniques in order to obtain o forecasting solution regarding the consumption of energy according to the users' profiles.

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[28] Rautmare, Sharvari, Bhalerao, Mangesh; *SQL & NoSQL Database Study for Internet of Things…*

[29] Joshi, Bhamiti, Khobragade, Shreya, Joshi, K.K.; *A Survey on Database Requirements and Security of IoT, International Journal of Innovative Research in Computer and Communication Engineering*, Tamilnadu: Ess & Ess Research Publications, 2017

[30] https://docs.microsoft.com/en-us/azure/iot-suite/ , accessed on 3 July 2017

[31] https://azure.microsoft.com/en-us/services/stream-analytics/, accessed on 3 July 2017

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