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The Role of Internet of Things as a Key Technology Enabling the Fourth Industrial Revolution

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Abstract

This paper is an attempt to analyze the role of Internet of Things (IoT) as one of the most important elements of the fourth industrial revolution. First, historical aspects connected with the phases of the industrial revolutions are presented and the key factors causing entering industrial revolution into its fourth phase are discussed. Next, the notion of the Internet of Things is presented and the most important elements of the architecture of IoT systems are described. The core part of the paper is focused on the most important opportunities offered by the Internet of Things. Also the most significant challenges emerging in the context of IoT solutions are discussed.

Keywords: IoT; Industry 4.0; new business processes; redesign of business processes

1. Introduction

Modern economy enters a new phase of profound transformations known as the fourth industrial revolution. There are at least three elements indicating that this in fact takes place Schwab, 2016. The first is the velocity of the changes. In contrast to previous phases of the industrial revolution, the fourth phase does not evolve linearly but exponentially Brynjolfsson and McAfee, 2014. The second element is the systems impact. All systems operating in countries, companies or industries, as well as the society as a whole are subjected to the transformation process. The third factor is the breadth and depth of transformations. They take place in the context of the digital revolution and are based on multiple technologies, the use of which leads to profound changes in the paradigms underlying the functioning of the economy, business, society as a whole as well as individuals Schwab, 2016. These are referred to as disruptive technologies, and the Internet of Things is one of them Bisson et at., 2013. This technology, which assumes a ubiquitous combination of people, objects, and machines, is also the essence of the vision of operation of the industrial sector in the context of the fourth industrial revolution referred to as Industry 4.0 Geissbauer et al., 2014; Geissbauer et al., 2016; Schwab, 2016.

The purpose of this paper is to analyze the role of the Internet of Things as one of the key elements of the fourth industrial revolution. And attempt was made in this context to identify the most important opportunities and challenges for the companies with the development of this technology.

2. The fourth industrial revolution and the most important factors stimulating its development

Changes taking place in today's economy and its profound transformation processes are the next wave of great changes taking place in the history of human civilization. The wave which has introduced industrial phase to humanity started around 1760. It was mainly related to the use of a steam engine in the mechanical production systems. The end of the nineteenth century is the beginning of the second industrial revolution related to mass production systems and assembly lines based on electricity. The third phase of the industrial revolution, referred to as a computer or digital revolution, begins in the 60s of the twentieth century. It is associated with the emergence of mainframes, PCs and the

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Internet. The economy began entering the period of the fourth industrial revolution at the beginning of the second decade of the 21st century, when there were more and more capabilities to create cyber–physical systems, i.e. systems integrating the physical and virtual worlds Industrie 4.0 Working Group, 2013; Schwab, 2016.

There are many technological drivers of the fourth industrial revolution. According to Schwab, we can divide them into three groups, i.e. physical, biological, and digital. The first includes technology megatreds, such as autonomous vehicles, 3D printing, advanced robotics systems or new materials. The advancements in biology include genetic research, synthetic biology, the use of 3D technology in medicine (*bioprinting*) or new ways of monitoring health and physical activity. Digital factors include such technologies as *blockchain*, technology platforms enabling the development of the on-demand economy and the Internet of Things, which is one of the key bridges between physical and virtual world Schwab, 2016; Tapscott and Tapscott, 2016. The latter technology is also the basis for the creation and implementation of Industry 4.0. It is understood as an end-to-end digitalization of all physical resources and their integration into digital eco-systems created with value chains partners PWC, 2016.

3. Internet of Things and the main elements of the IoT systems architecture

Despite the growing number of publications and research on the Internet of Things, there is no single comprehensive definition. According to Porter and Heppelmann, the phrase "Internet of Things" was created in order to "reflect a situation in which there is a growing number of smart, connected products and highlight the new opportunities they may bring about" Heppelmann and Porter, 2014. Dobbs et al describe this concept in much more detail. Namely, they identify the Internet of Things as "physical sensors and actuators embedded machines and other objects that have been used for data collection, remote monitoring, decision-making, and optimization processes in all areas from production through infrastructure to health care" Dobbs et al., 2015.

However, the typical Internet of Things system consists of similar components regardless of the adopted definition. The simplest version of its architecture can be presented in a way such as the one shown in Fig. 1. It consists of various types of sensors (S1–Sn) gathering data and transmitting them through various transmission channels (persistent connections, WiFi, cellular or Bluetooth) to a gateway. After the initial data processing or without this process, it transmits them to the processing system, i.e., the analytics cloud. In this case, the connection is ensured through the use of a permanent connection, LAN or WiFi Perera, 2015.

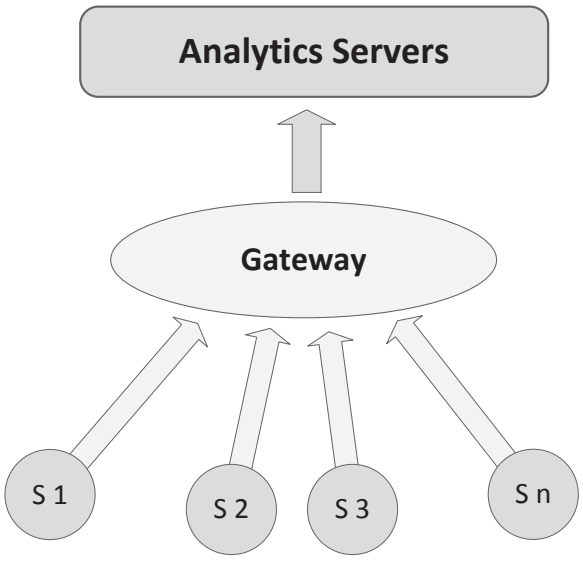

Fig. 1. The basic components of the IoT system architecture (source: based on Perera, 2015)

Alas, we have to note that it is not possible to create the technological infrastructure of the IoT system without the use of a number of leading technologies, which in itself carry an enormous transformation potential. This applies to cloud computing, big data tools and mobile solutions Aharon et al., 2015; Burkitt, 2014; Deichmann et al., 2015; Heppelmann and Porter, 2014; Heppelmann and Porter, 2015; ITU, 2015; KPMG, 2015; Olszak, 2014; Wielki; 2015.

4. Opportunities and benefits related to the use of the Internet of Things by enterprises

The possibilities related to the use of smart connected products, which allow the creation of value in Internet of Things solutions result from four basic functionalities. These are: monitoring, control, optimization, and autonomy. The first ones are sensors built into smart products that enable to monitor:

- Its health, operation, and use.
- External environment.

In turn, software contained both in the product itself and in the infrastructure layer offers even more possibilities. Namely, it enables to remotely control the product and its functions and personalization of its operation on a scale which previously was not possible to achieve. Monitoring capabilities and the resulting wide data stream combined with the control opportunities offered by smart products allows the organizations to optimize their performance in an extremely wide range. This applies to aspects such as the significant improvement in the operation of the product itself or its predictive diagnostics and repair. The three functionality types discussed above allow the smart products to achieve an unprecedented degree of autonomy Heppelmann and Porter, 2014.

These four functionalities offered by smart combined products provide business organizations with two basic types of opportunities:

- Transformation of business processes.
- Enabling new business models.

When it comes to the reconstruction of business processes, there are a number of related opportunities which differ depending on the settings to which they apply. These are, e.g. changes in the design of domestic appliances in the home setting. Namely, the process is based on the analysis of usage-based design. In the retail setting, the key application areas of the Internet of Things solutions are: check-out automation, goods layout optimization or individualization of promotional activities in stores. On the other hand, in the office setting, the IoT applications include: organizational redesign and the monitoring of employees or the use of augmented reality for training purposes. Regarding the transformation of business processes in the factories, the key issues include: optimization of operations and the related improvement in productivity, optimization of the use of equipment and supplies, predictive maintenance, the maintenance of equipment, and the occupational safety and health. Another setting which enables a deep reconstruction of business processes is related to non-standard production worksites, such as oil and gas or construction sites. In this case, the most important capabilities are similar to the previous case, with additional IoT enabled R&D activities. When it comes to the setting associated with the various types of vehicles, the key areas of IoT-based solutions include: repair and condition-based maintenance, equipment design based on an analysis of their usage or pre-sales analytics. Vehicles are also related to the capabilities of reconstruction of logistics processes. This applies to things such as real-time routing, the use of connected navigations or the use of transport monitoring systems Aharon et al., 2015.

Regarding the opportunities associated with the implementation of new business models, we can identify ten basic types in this context. These include:

- Business models based on “anything-as-a-service” concept.
- Business models based on the use of new forms of outsourcing.
- Business models based solely on the data and their use.
- Business models based on additional services related to the physical product offered to customers.
- Business models based on smart products which are sources of added value for the customer.
- Business models based on behavioral profiling.
- Hybrid business models.
- Business models based on offering IoT platforms.
- Business models based on offering comprehensive IoT infrastructure solutions.
- Business models based on offering extended services.

The model being the product-as-a-service is the “mainstream” in the first group. Its development is related to more and more widely observed processes of migration from the customer buying the product to the one in which the manufacturer retains ownership of it, and the customer uses it, paying for its real use. The development of functionalities related to intelligent, connected products provides big opportunities in this area. Rolls Royce, which offers their engines to airlines in the “power-by-the-hour” model, is one of the companies pioneering in this field. In this model, the airlines pay for the real engine use time, instead of incurring a one-off cost of its purchase and additional costs of maintenance and repair. Xerox also employs such a model by monitoring the actual use of their photocopiers via the installed sensors Heppelmann and Porter 2015.

The development of smart systems also allows for the implementation of business models based on offering new forms of outsourcing. Another such example is Pacific Control company operating in Dubai. It offers the remote monitoring of buildings, airports, and hotels based on the Internet of Things The Economist, 2010.

For the third category, the development of smart connected devices enables to collect vast amounts of different types of data that can be used to create business models based on their usage. Skyhook Wireless company, which offers specific information acquired based on geolocation data they collect, is an example of this approach. They can include information such as which local bars will be the most popular on a specific day and time, how many people will go near the billboard at a given date and a specific time, or what is the density of people in a specific urban area on a given day and time. The company uses anonymous geolocation data collected from mobile users of its services in every major American city during the past twenty four months to carry out this analysis The Economist, 2010; Mims, 2010.

The development of the Internet of Things also enables to implement business models based on providing customers with additional services related to the physical product they purchased and use. Caterpillar company is one example of this approach. Specialized teams advise customers on how to optimize the deployment of equipment, when a smaller number of machines suffices and how to achieve better fuel efficiency through the stock of machines based on analysis of data collected from each their machine used on the construction site Heppelmann and Porter, 2015. Heidelberger Druckmaschinen, a manufacturer of printing presses offers a similar type of service based on over a thousand sensors installed in them The Economist, 2010.

Another group is business models based on providing customers with smart products which are sources of additional benefits to them. Play Pure Drive is an example of such a solution. In this case, Babolat company has transformed a traditional product into a smart one which provides players with the opportunity to improve their technique by the use of a dedicated application, a tennis racket equipped with appropriate sensors and a system enabling the connection to the smartphone. Clothing manufacturer Ralpf Lauren made a similar move by offering smart PoloTech Shirt. It collects all parameters including pulse, the intensity of the movement, calories burned, and many others with built-in sensors in real-time during exercise and transmits them to a smartphone or smartwatch Heppelmann and Porter 2014.

Another group of business models are those based on behavioral profiling. The system for establishing insurance rates based on monitoring of the driving behavior through the suitable telemetry device mounted in the vehicle is an example of this type of solution. The American insurance company Progressive offers this solution under the name of Snapshot Burkitt, 2014. Coverbox uses a similar system on the British market The Economist, 2010.

Hybrid business models are a compromise between the models of product-as-a-service and traditional purchase of products by customers. They connect sales with e.g. different types of service contracts based on the monitoring of the device operations.

Another group is business models based on offering IoT platforms to the users. Apple HomeKit is an example of such a solution. It controls various home devices from different manufacturers through the smartphone application. HealthKit platform, which enables the integration of devices for monitoring people's health and activity, is another example of a solution by the same company Burkitt, 2014.

The next group of business models is those based on providing comprehensive IoT infrastructure solutions. ThingWorx platform is one of well-known examples of this approach. It provides comprehensive services for the creation of Internet of Things solutions ThingWorx, 2016.

The last group is business models based on the provision of extended services. This forward-looking category includes solutions based on the use of data and information collected by the providers of various IoT services and providing their own services based on them. Operations of insurance companies working on solutions which include creating their own portfolio based on cooperation with companies offering various types of IoT systems designed to monitor health and physical activity are an example of this approach Burkitt, 2014.

5. The most important challenges, impediments, and limitations related the use of the Internet of Things by enterprises

There is a whole range of different kinds of impediments and limitations related to the Internet of Things, and the scale and diversity of IoT ecosystems is significant because they are complex solutions based on various technologies.

There are three key areas in the technical context related to the creation of IoT ecosystems, which could both limit and stimulate their development. They concern Aharon et al. 2015:

- Technology, both in terms of hardware and software necessary for the creation of the Internet of Things infrastructure.
- Security.
- Interoperability.

At the same time, one can indicate a whole range of non-technical challenges. Value in the Internet of Things systems is mainly created on the basis of acquired, transmitted, processed, and analyzed data, the related issues are one of the key aspects that can be impediments to the development of this concept or stimulate its development Heppelmann and Porter, 2014. The most important ones relate to various legal issues. Undoubtedly, one of the key such challenges related to data are those concerning intellectual property, and the ownership of collected data is one of the most important aspects in this area. Legal challenges also apply to a number of other issues related to privacy and confidentiality. They relate to such issues as: data protection, sharing and methods of their use, data storage and access location or the applicability of the law relating to data protection.

Also, behavioral impediments may play an essential role in the development of systems based on the Internet of Things concept. They are related to things such as consumer attitudes in the context of acceptance, or lack thereof, of specific IoT solutions due to e.g. trust towards them Duggan and Rainie, 2016. Another area is noteworthy that could be important to the development of Internet of Things, which is structural changes in various sectors (e.g. transport industry in the context of autonomous vehicles) Aharon et al., 2015.

At the same time it should be noted that the impediments or challenges that could turn into stimulators exist at different levels, i.e.:

- Global – e.g. the global price trends of IoT infrastructure components, global standards, (e.g. in "cloud" solutions for Big Data systems [ITU 2015]).
- Regional – e.g. EU standards and regulations on various aspects of the Internet of Things.
- National – e.g. standards and regulations in the markets of individual countries.
- Sector – e.g. industry regulations and standards.

A whole series of challenges will also occur at the level of individual organizations.

6. Conclusions

Organizations in today's economic reality are on the verge of profound changes in their operations. They are related to a quick progress in information technology and the economy entering the fourth phase of the industrial revolution. More opportunities to create systems integrating physical and virtual worlds are one of its key differentiators, and the Internet of Things is the underlying technology.

This gives the companies a number of unprecedented opportunities Bauer et al., 2014. As in the previous phases of the Internet evolution they concern two fundamental issues when it comes to value creation processes Wielki, 2010. They are the implementation of new business models and deep reconstruction of business processes they carry out. As a result, it enables to implement the vision of Industry 4.0.

In this new situation, each enterprise has to run a deep analysis of how the Internet of Things is a part of their operations and the processes of digital transformation and decide on a strategy for IoT use. There are a lot of opportunities in this area Aharon et al., 2015; Burkitt, 2014.

It is necessary to create the vision of one's own activity in this context. When creating it, the organization also has to take into account a number of factors (e.g. the current state of technology development, experience and capabilities in the development and implementation of solutions based on the Internet of Things concept or the challenges it will have to face) and plan the necessary activities and changes both internally and externally. As the changes are very dynamic, and at the same time they involve long-term consequences, the choice of appropriate and well-thought course of actions in relation to IoT is an extremely critical decision for any organization from the point of view of both future competitive position and further development.

References

Aharon, D., Bisson, P., Bughin, J., Chui, M., Dobbs, R., Manyika, J., Woetzel, J., *The Internet of Things*, http://www.mckinsey.com/~/media/McKinsey/dotcom/Insights/Business%20Technology/Unlocking%20the%20potential%20of%20the%20Internet%20of%20Things/Unlocking_the_potential_of_the_Internet_of_Things_Full_report.ashx, (2015).

Bauer, H., Patel, M., Veira, J., *The Internet of Things: Sizing up the opportunity*, http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things-sizing-up-the-opportunity, (2014).

Bisson, P., Bughin, J., Chui, M., Dobbs, R., Manyika, J., Marrs, A., *Disruptive technologies*, http://www.mckinsey.com/~/media/McKinsey/dotcom/Insights%20and%20pubs/MGI/Research/Technology%20and%20Innovation/Disruptive%20technologies/MGI_Disruptive_technologies_Full_report_May2013.ashx, (2013).

Brynjolfsson, E., McAfee A., *The Second Machine Age*, W. W. Norton & Company, New York, (2014).

Burkitt, F., *A Strategist's Guide to the Internet of Things*, http://www.strategy-business.com/article/00294? tid =27782251&pg=all, (2014).

Deichmann, J., Roggendorf, M., Wee, D., *Preparing IT systems and organizations for the Internet of Things*, http://www.mckinsey.com/industries/high-tech/our-insights/preparing-it-systems-and-organizations-for-the-internet-of-things, (2015).

Dobbs, R., Manyika, J., Woetzel, J., *No Ordinary Disruption*, PublicAffairs, New York, (2015),

Duggan, M., Rainie, L., *Privacy and Information Sharing*, http://www.pewinternet.org/files/2016/01/ PI_ 2016.01.14_Privacy-and-Info-Sharing_FINAL.pdf, (2016).

Geissbauer, R., Koch, V., Kuge, S., Schrauf S., *Industry 4.0.: Opportunities and challenges of the industrial internet*, https://www.pwc.pl/pl/pdf/industry-4-0.pdf, (2014).

Geissbauer, R., Schrauf, S., Vedsø, J., *A Strategist's Guide to Industry 4.0*, http://www.strategy-business.com/article/A-Strategists-Guide-to-Industry-4.0, (2016).

Heppelmann, J., Porter, M.: How smart, connected products are transforming competition, *Harvard Business Review*, November, pp. 64–88, (2014).

Heppelmann, J., Porter, M.: How smart, connected products are transforming companies, *Harvard Business Review*, October, pp. 96–114, (2015).

Industrie 4.0 Working Group, *Recommendations for implementing the strategic initiative Industrie 4.0*, http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Material_fuer_Sonderseiten/Industrie_4.0/Final_report__Industrie_4.0_accessible.pdf, (2013).

ITU, *Big data – cloud computing based requirements and capabilities*, https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-Y.3600-201511-I!!PDF-E&type=items, (2015).

KPMG, *The Changing Landscape of Disruptive Technologies*, https://techinnovation.kpmg.chaordix.com/static/docs/TechInnovation2015-Part2.pdf, (2015).

Mims, C., *Follow the Smart Phones*, https://www.technologyreview.com/s/ 418451/follow-the-smart-phones/, (2010).

Olszak, C., Business intelligence in cloud, *Polish Journal of Management Studies*, Vol.10, No.2, pp. 115-125, (2014).

Perera, S., *IoT Analytics*, http://resources.idgenterprise.com/original/AST-0163543_wso2_whitepaper_iot-analytics-using-big-data-to-architect-iot-solutions.pdf, (2015).

PWC, *Industry 4.0: Building the digital enterprise*, https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf, (2016).

Schwab, K., *The Fourth Industrial Revolution*, World Economic Forum, Cologny/Geneva, (2016).

Tapscott, A., Tapscott, D., *Blockchain Revolution*, Penguine Random House, New York, (2016).

The Economist, *Augmented business*, http://www.economist.com/node/17388392/, (2010).

ThingWorx, *One Platform – Limitless Possibilities*, http://www.thingworx.com/, (2016).

Wielki, J., The impact of the Internet on the development of Web-based business models, *Journal of Internet Banking and Commerce*", Vol.15, No.3, http://www.arraydev.com/commerce/jibc/ 2010-12/Wielki.pdf, (2010).

Wielki, J., The social and ethical challenges connected with the Big Data phenomenon, *Polish Journal of Management Studies*, Vol.11, No.2, pp. 192-202, (2015).