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COURSE WORK

INTERNET OF THINGS AS A DRIVER OF CONSUMER GOODS INDUSTRY TRANSFORMATION

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Abbreviations

B2B - Business-to-Business

B2B2C - Business-to-Business-to-Consumer

CBM - Condition-Based Maintenance

CoAP - Constrained Application Protocol

CoT - Cloud of Things

CPG - Consumer Packaged Goods

D2D - Device-to-Device

EMR - Electromagnetic Radiation

EPC - Electronic Product Code

FMCG - Fast-Moving Consumer Goods

GSM - Global System for Mobile communication

HTTP - Hypertext Transfer Protocol

HVAC - Heating, Ventilation, Air Conditioning

ICT - Information Communication Technology

IERC – IoT European Research Cluster

IIoT - Industrial Internet of Things

IoT - Internet of Things

IPv6 - Internet Protocol version 6

M2M - Machine-to-Machine

NFC - Near-Field Communication

QoE - Quality of Experience

QR - Quick Response

RFID - Radio Frequency Identification

TaaS - Thing as a Service

UWB - Ultra-Wideband

UX - User Experience

WWW - World Wide Web

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Summary

This research paper is dedicated to study the Internet of Things (IoT) applications in the Fast-Moving Consumer Goods (FMCG) sector of the Consumer Goods industry. It provides the description of the current state of technology and its implementation in the industry. The research includes the assessment of the potential of this new technology to transform the industry. At the end of the paper, the recommendations were proposed, which can be taken into consideration by the FMCG industry companies in order to realize the potential of the IoT.

The Internet of Things is a new technological framework that allows ordinary objects to wirelessly communicate with each other and with a common data platform. This concept has the potential to create a global network of interconnected devices. However, even today's rather chaotic implementations of the IoT offer various opportunities for businesses and ordinary people. The FMCG sector can also benefit from this technology; however, a lot of effort should be made in order to overcome current problems of the underdeveloped technology, lack of infrastructure and competences in the companies, and increasing concerns of data privacy and security.

The research consists of the introduction, 2 chapters describing the concept of the IoT and its applications in the FMCG industry, and the conclusion. The main methods utilized in the research are literature review and case study.

Key words: Internet of Things, Smart Objects, Industry 4.0, FMCG, Consumer Goods.

Introduction

The fast growing industry of portable devices, vast usage of wireless connectivity technology and appearance of affordable sensors available for consumer electronics brought numerous applications and new ways of using interconnected devices in various areas. The application of connected smart objects or “things” in consumer world as well as in industrial settings facilitated the development of the concept of the Internet of Things (IoT). The concept outlines constant connectivity, data collection and sharing, and remote control application in the world of physical objects. This means that in the coming wave of new electronic devices we shall see their increasing interconnectivity that will allow sharing and analyzing data without the human intervention.

Although the Internet of Things (or Internet of Everything) concept was first mentioned by Kevin Ashton in 1999 (Ashton, 2009), it has become a big thing just 5-10 years ago with dramatic increase of the Internet usage and emergence of affordable smart electronic devices, i.e. smartphones or tablets. The possible applications of the IoT and its great potential were quickly identified by industry and governments around the globe, and billions of dollars were invested in the foundations of smart infrastructure. Today, the industry sees the IoT as strategic innovation that creates new forms of values by redesigning the companies’ operations and potentially bringing significant impact on wider society (Prince, Barrett, & Oborn, 2014). The huge support of the IoT by the governments also indicates that this is one of the priority areas in national ICT strategies. Among the big initiatives aimed at the development of IoT technology are: National IoT Plan by Ministry of Industry and Information Technology of China, the European Research Cluster on IoT (IERC), the Future Internet Initiatives in the UK and others (Gubbi et al., 2013).

It is expected that IoT will have significant impact on the industry and the society, although the concept and the technology behind it are still at the early stage of development. There is no standard definition of the IoT, the protocols and standards are not fully developed, and it is still not clear which spheres of life will be most impacted from the implementation of IoT (Shin, 2014). Nevertheless, the IoT industry grows with a steady pace.

According to Cisco report, the number of connected devices in the turn of the 21^{th} century exceeded 200 million, and with the development of mobile technologies this number grew by 50 times to 10 billion in 2013. Cisco estimates that, with the current trend of increasing usage of the IoT in industrial settings and its implementation in consumer world, by 2020 the number of such interconnected smart objects will reach 50 billion (Bradley, Barbier, & Handler, 2013).

It has been shown that due to the wide range of the IoT applications it is hard to categorize the technology’s impact by vertical industry markets (Manyika et al., 2015). The technology’s applications are typically classified either according to the settings where the IoT is utilized, or by the function that the IoT objects fulfil. For example, Borgia (2014) distinguished 3 domains for IoT implementation:

- Industrial domain
    - Logistic and product lifetime management
    - Agriculture and breeding
    - Industrial processing
- Health and well-being domain
    - Medical and healthcare
    - Independent living
- Smart City domain
    - Public safety and environmental monitoring
    - Smart home/building
    - Smart grid
    - Smart mobility

However, McKinsey researchers provide a different classification based on the areas of utilization that captures broad set of effects and allows to estimate the value of IoT implementation (Manyika et al., 2015):

- Factories: operations management, predictive maintenance;
- Cities: public safety and health, traffic control, resource management;
- Human: monitoring and managing illness, improving wellness;
- Retail: self check-out, layout optimization, smart customer-relationship management;
- Outside: logistics routing, autonomous vehicles, navigation;
- Work sites: operations management on customized working areas (e.g. mining), equipment maintenance, health and safety;
- Vehicles: condition based maintenance, reduced insurance;
- Homes: energy management, safety and security, chore automation;
- Offices: organizational redesign and worker monitoring augmented reality for training.

In the McKinsey report, it is estimated that by 2025 around 30% of projected $4-11 trillion economic impact from IoT will come from its application in the Factories setting (process management, predictive maintenance and inventory optimization), and IoT for cities will account for 15-23% of that volume, whereas other IoT applications will amount for the remaining 50% . However, the classification proposed by McKinsey does not include a separate category for consumer applications of the IoT. It is argued that even though the various applications of the IoT in consumer world recently has caught great attention, the B2B applications of such technology offer far greater potential for value generation.

Due to the great opportunities for implementation of the IoT in industrial settings, in 2011 all its non-consumer applications were honored with a separate term "Industrial Internet of Things" (IIoT). However, it is estimated that in the next 5 years only 39 per cent of total number of IoT devices will be installed in enterprise or industrial settings (Van Till, 2018). This fact may only mean that an IoT device utilized in industrial settings will on average provide much more value than a consumer IoT object; however, the number of consumer applications and the penetration of the technology in consumer world will continue to grow with a steady pace.

The positive economic effect of the IoT applications in various spheres is now relatively obvious; however, it is still not clear how and where the IoT will bring value. And the problem of identification of the spheres in which it can provide greater opportunities lays in the fact of industry convergence, meaning that the technology is applied across different industries and form a common technological platform (Geum, Kim, & Lee, 2016).

The IoT is one of the bright examples of the industry convergence. The concept implies the blurring of the physical and virtual worlds and interconnectedness of the objects in order to decrease inefficiency of otherwise not connected processes. Therefore, it could be said that the industry convergence is at the core of the IoT, as it will allow to release the full potential of the technology. And it is because of this feature that in the above mentioned classification McKinsey researchers were not able to estimate the IoT's economic effect for vertical industries, and instead proposed the grouping by settings where the IoT could be utilized (Manyika et al., 2015).

Due to the fact that many of the processes in various business spheres are similar to each other and the IoT technologies and applications in different processes usually overlap, the researchers previously did not focus a lot on the analysis the IoT application in separate industries. This deficit does not allow industry managers to obtain the full understanding of the value from IoT applications in their business. Therefore, this research is aimed at filling this gap by reviewing the applications and understanding the potential of the IoT in Fast-Moving Consumer Goods (FMCG) industry.

The FMCG industry was chosen for this research because of its high complexity and the opportunity to analyze the potential of both consumer and non-consumer applications of the IoT. The chosen industry includes different operations from product design and manufacturing to selling goods to consumers through different channels. It also deals with food and non-food short shelf life products and, hence, allows to look, for example, at the IoT in agriculture sector, or analyze the potential use of the IoT for communication with consumer. Another characteristics of the FMCG industry is that the low cost of the products, the large volume of production and high turnover rates result in great number of innovations in products, processes, business models etc. This means that the industry has a big potential for utilization of the IoT and have means to provide relatively quick diffusion on new consumer IoT applications. Therefore, focusing on IoT in FMCG industry will allow us to cover a wide range of the IoT applications and to get a finer understanding of the scale of the interconnectedness of the smart objects within consumer and non-consumer worlds.

According to the above, this paper is aimed to answer the following research questions:

RQ1. What are the current consumer and non-consumer applications of the IoT in the FMCG industry?

RQ2. In which areas of the FMCG industry the IoT can bring the most value?

The main objective of this paper is to provide the overview of the implementation of the IoT in the complex set of FMCG companies' operations and highlight the areas with most potential for value generation from the IoT application. In order to accomplish this objective, the following tasks are specified:

1. Provide definitions of the IoT and FMCG industry
2. Determine the value chain of the FMCG industry to understand areas for IoT usage
3. Specify the technologies behind the IoT and their applications related to FMCG industry
4. Trace the dynamics of the IoT applications in FMCG to understand the potential for further improvements in different areas
5. Analyze the possibility of connecting consumer and industry via the IoT and the potential of such applications to transform the industry
6. Explore the challenges for IoT driven innovations in FMCG environment

The specified tasks will help to verify the following hypotheses:

H1. The IoT is one of the key technologies in FMCG industry that will allow its transformation.

H2. Most value from IoT implementation in FMCG is expected to be captured from the optimization of the internal processes, whereas consumer applications of IoT in FMCG will be limited and their value will lie in consumer data collection and its further usage for business purposes.

In this paper it is intended to map the possible applications of the IoT in the value chain of the FMCG companies which in turn will allow to conclude what areas of the industry will be more affected by introduction of the new technology. As existing studies of the economic effects and strategic significance of the IoT implementation typically do not focus on the industry specifics due to the industrial convergence feature of the IoT applications, by disclosing the value of IoT application for the Consumer Goods companies this paper will provide additional contribution to the field. This justifies the novelty of the research.

The significance of the research is in its theoretical and practical applications. The practitioners may use it as the guidance for identification of strategies for further development of Consumer Goods companies in order to capture value from the IoT implementation. The researchers and analytical companies may use the provided background for further study either for the same or for other industries. Moreover, the research can be used as the introduction to the IoT sphere for the interested individuals because it provides a general overview of the significance of the IoT in a specific complex industry.

The limitations of the research originate from the early stage of the development of the IoT. Because of this it is hard to imagine the full scope of the application of the new technology and anticipate the possible risks. Moreover, this paper does not aim to provide thorough analysis of the technological background behind the IoT. In the conducted research the emphasis was made on the end applications and approaches instead of the technical characteristics of the smart objects that can make them possible. The research also limits its scope to the Fast-Moving Consumer Goods (FMCG) part of the Consumer Goods industry and does not discuss the implementation of the IoT in the industry of durable products such as home appliances, consumer electronics etc.

The research consists of the three main parts, each devoted to a separate topic or issue. The first chapter is intended to provide the necessary background for the further discussion. It describes the details of the IoT, provides the stages of the IoT development and lists problematic areas of the IoT at current stage of the concept's development.

The second chapter maps the possible applications of the IoT in the FMCG industry, specifies the potential for value generation in each link of the value chain. The chapter provides the overview of the IoT application for the FMCG companies and points out the most promising areas for the implementation of the IoT. It ends with the discussions of the limitations and key challenges for the IoT implementation in FMCG and recommendations for further development of IoT applications if FMCG companies.

Methodology and Approach

This research paper consists of three main parts. The first part starts with providing the basics of the IoT, then the discussion progresses to the description of the dynamics of the development of the technology, then the potential and the limitations of the technology is studied. The main research method for the first part is literature review.

The second part of the research provides the discussion of the potential of the Internet of Things implementation in the Consumer Goods Industry and identifies the actions needed from the companies to realize it. It starts with the definition of FMCG and describes the specifics of this sector. Then the applications of the IoT are analyzed in the context of FMCG companies operations. The areas of the FMCG business are listed, and the possibility of the value generation from the IoT introduction to them is studied. In this part the literature review is used, and the case studies are conducted in order to illustrate the effects of the IoT application in the context of the specified industry.

The majority of the publications used in this research are obtained from scientific journals and belong to the period of 2010 – 2017. This range of the years of the publications was chosen because the sphere of the IoT is relatively new and the majority of the discoveries and applications appeared just recently, and due to this fact more early texts do not bring additional value to the research. This publications are retrieved from Google Scholar and Science Direct databases of scientific literature, and their relevance for the research is identified by the content analysis. Although, for the description of the FMCG industry, a wider range of sources is used due to the specifics of this business. These sources include reports of consulting companies and publications in online newspapers and magazines such as The Wall Street Journal and Wired. The analysis of cases that are provided for illustration of different ways of use of the IoT in FMCG industry starts with the description of the applications and continues to the discussion of their effect on the industry's stakeholders based on the previously mentioned information and the author's expertise in the field.

Chapter 1. The background behind the Internet of Things

1.1 The definition of the Internet of Things

The vision of the IoT stated in the early 2000s was defined at one of the RFID conferences: “A world, where everything that moves can talk to everyone, everywhere, all the time”. At that time it was envisioned that the RFID based innovation would allow the regular objects to interconnect with each other and become a part of the network of smart “things” that would create new forms of value by transforming the way of human interaction with the environment and releasing the potential of higher level of automation of various operations in the industry. From this point of view, the IoT is seen as a strategic innovation that provides the opportunity for the redefinition of business operations, markets, customers and potentially it may have a noticeable effect on the wider society (Prince et al, 2014).

Since the Internet of Things concept first appearance at the end of the 20th century, it has become one of the major topics for discussion among researchers and industry experts. However, a great amount of the research on the IoT was directed to studying not the wide concept, but just some of its parts, often using the hype effect of the IoT to generate attention to the already mature technologies and approaches that are in fact just the supporting elements of the IoT. The example of such elements are RFID, network architectures based on, for example, the Internet Protocols (especially IPv6), network integration technologies, new computational algorithms and solutions, or sensing technologies (Shin, 2014; Atzori, Iera, & Morabito, 2017).

From the early stages of the development of the IoT, it has been associated with very different concepts, solutions and technologies. The abuse of the term resulted in the fact of blurring of the notion of the Internet of Things, the term became literally synonymous to every architecture or technology that allows objects to connect to each other to provide any kind of services. Therefore, at first it is important to introduce the definition of the concept, to provide the understanding of what the IoT is and what it is not. However, with such a broad usage of the term, the task to specify the definition of the IoT is not trivial.

In the work (Ibarra-Esquer et al., 2017), the authors analyzed 38 different definitions that appeared from late 1990s to 2016. The analysis of the definitions showed that the concept is closely associated with multiple technologies and concepts. Among the most frequent notions appearing in the selected descriptions of the IoT are the sensing technologies, intelligence, actuators, security and privacy concerns, business processes and data mining. The frequency analysis of the usage of the mentioned words reveals the diversity of issues discussed within the IoT concept.

A fundamental work on the identifying of definition of the IoT was done by Atzori et al. (2017). The researchers analyzed the technologies overlapping with the IoT, separated the exclusive features of the IoT, and studied different definitions of the term that were previously developed. This allowed them to come to a new definition that should capture the specificity of the new concept and point out to the value it is intended to bring.

According to the researchers' analysis, the IoT has the following features:

- The presence of a global network infrastructure or network connectivity
- Consists of not only of ICT devices, but of everyday objects. This implies that physical objects shell have sensors and actuators inside, which will allow the, to connect to a digital overlay information system
- Autonomy and autonomicity, meaning that the system shell be able to operate without the external control
- Uses effective and intelligent human-"thing" and "thing-thing" interfaces
- Enabling the coexistence of heterogeneous technologies within one platform
- Services provided by the objects are associated with them and built upon the information collected by the object

Therefore, the IoT is defined as a "conceptual framework that leverages on the availability of heterogeneous devices and interconnection solutions, as well as augmented physical objects providing a shared information base on global scale, to support the design of applications involving at the same virtual level both people and representations of objects" (Atzori et al., 2017). Although the proposed definition looks vague at the first glance, it clearly points out that the IoT has a global application and is aimed at connecting physical and virtual world in order to generate value from such connections. The defined boundaries therefore provide evidence that the framework has a great disruptive potential, which can be unraveled with the use of pre-existing and further development of enabling technologies.

1.2 Stages of the development of the Internet of Things

The Internet of Things concept has been present in the research literature from the late 1990th; however, the first approach to today's understanding of the framework was made by Bill Joy in Six Webs taxonomy. He outlined the concept of D2D of device-to device web that allowed the devices to communicate information too each other in order to manage, control and monitor processes (Ibarra-Esquer et al., 2017). However, the first vision of the IoT and the term itself are defined by Ashton in the presentation at Procter & Gamble. Ashton envisioned that the sensors technologies like Radio Frequency Identification (RFID) will enable the computers to gather data without human help and transform it into useful information (Ashton, 2009)

Ashton's idea formed the basis of the first generation of the IoT, which was associated with the applications of tagged objects. From the time of the concept's introduction 2 more generations of the IoT were developed: the second generation represented by the interconnection of things via the Web, or the Web of Things, and the third generation oriented towards the development of social objects concept, cloud approaches in IoT architecture and semantic data representation efforts.

The first generation of the Internet of things was built almost entirely on the applications of RFID and Electronic Product Code (EPC), and these applications were often limited to solve particular problems of supply chains, for example, inventory management (Atzori et al, 2017; Ibarra-Esquer et al., 2017). Another technology that was at the core of the first generation of the IoT was M2M or machine-to-machine communication. The first implementations of M2M appeared in the 20th century, and utilized wired connection; however, the wide spread of the technology started with the introduction of GSM data module "M1" by Siemens in 1995 (Preiss, 2014).

The second generation of the Internet of Things is associated with the development of the IPv6 started by the Internet Engineering Task Force in 2005 and integration of wireless sensing devices into the World Wide Web (WWW). This resulted in the appearance of the Web of Things concept, in which devices are considered as web resources. The communication with such devices is therefore executed with the means of the HTTP methods. For example, GET method could be used to receive the data from sensors of a device, and SET method could be used for configuration purposes. This approach was applied in the Sun SPOT platform that is composed of a system with sensors, actuators, radio transceiver and the battery. This Web of Things approach can also be applied for RFID technologies: the tagged objects can be indexed, searched for, bookmarked and exchanged.

However, the complexity of the existing protocols and constrained functionalities of the objects that were supposed to be incorporated in the Web uncovered the issue of the importance of the development of new standards and protocols. One of the examples of an effort to introduce new standards for the connection of physical objects to the Web is the development of the Constrained Application Protocol (CoAP). By design, the CoAP provides the HTTP-like protocol that is chategarized by simplicity, low overhead and multicast communications support, and can be directly translated to HTTP (Atzori et al., 2017).

Another feature of the second generation of the IoT is the efforts to utilize social networking concepts in the application to smart objects. The data collected by such objects can be made available to humans at social network platforms, and shared with their friends. An example of the implementation of this approach is the SocialFarm, a project which allows farmers to check the status of their animals on Facebook by connecting the sensing devices with the social network (Kamilaris, Papadiomidous, & Pitsillides., 2011).

The third generation of the IoT is characterized by the shift towards services and data-oriented applications and the focus on more advanced sensing technology rather than RFID applications. This generational leap is possible due to the current evolution of the Internet towards service centricity. However, the development of the approaches and the standards for the 3rd generation of the Internet of Things started just recently.

The limitations of the already existing standards and protocols were faced with the implementation of the second generation of the IoT, and now lots ow works are directed towards developing the new approaches. Several architectures and designs for the Internet of Things of the new generation have already been proposed. In (Atzori et al., 2017) some of the new approaches of the IoT implementation were mentioned, among which are Information Centric Networking, Content Centric Networking, Named Data Networking, the Social Internet of things and the Cloud of Things. All of them are aimed at overcoming the problems of complex networks of numerous heterogeneous objects with very limited resources, while at the same time leveraging the characteristic features of such networks. The new approaches and standards will then help to achieve the needed high level of scalability of the system, seamless mobility and ability for content and service delivery in the network of smart objects within the Internet of Things.

The vision of the Cloud of Things approach is based on the idea the IoT will use the vast resources of cloud computing to overcome the issues that are implied by heterogeneity and resource limitations of the “things” in the concept. The cloud solutions will provide a common application development level for the IoT for virtualization of devices with different interfaces, performance and capacities. Also it will allow to optimize the usage of the computational power and energy resources by moving all manipulations with data collected from smart objects to the cloud. This will bring significant value as such approach will release the Big Data potential of the IoT and will significantly decrease the costs of the devices, their energy usage and, hence, their autonomy. It has been also pointed out that the cloud solutions for the IoT have the potential to connect the Internet of Things with the Internet of People via the Internet of Services (Atzori, 2017).

The proposed design of the described above approach consists of four layers (Distefan, Merlino, & Puliafito, 2012):

- IntraNode layer responsible for the virtualization of the services provided by sensing smart objects
- IntraCloud/InterNode layer connecting virtualizations of the nodes within the same cloud

- InterCloud/Platform layer that connects separate clouds of the smart objects and basically is responsible for the execution of the Thing as a Service (TaaS) module of connected objects within different clouds
- Software as a Service for the Internet of Things layer that allows the use of different applications connected to the network of smart objects through the TaaS module

The interest to the Cloud architectural implementation of the Internet of Things is very high at the moment. Some of the projects have already emerged, among them are EU-Japan collaboration ClouT that aims at the development of API, infrastructure and tools for the CoT, and Nimbits that already provide CoT services. Such industry giants like Oracle are also developing the capabilities in the sphere of cloud services for the IoT and target to occupy the niche of the Platform as a Service (PaaS) providers.

The third generation of the Internet of Things is also characterized with the efforts to implement the approaches of social networks to the world of smart objects, creating the so called Social Network of Things. The difference with the usage of social networks in the second generation is in the fact that the things will not be connected to the human social networks via the Internet, but will create their own network with similar relationships, where each object provides some kind of a service to the "society" and, therefore, brings value to the subset of things – "friends", and to the overall population of objects.

The detailed explanation of the concept and its potential is provided in a research done by Atrozi with team (Atzori et al., 2012). Developing the concepts and architecture of the Social Network of Things, the authors tried to project the human social relationships to the world of interconnected physical objects. The analysis of the researchers resulted in the definition of several possible relationship types between objects in the social network approximation of the Internet of Things:

- Parental object relationship among objects produced in the same butch
- Co-location object relationship among the objects located in the same limited location
- Co-work object relationship for the objects functioning within the same application
- Ownership object relationship among the objects belonging to the same user
- Social object relationship that occurs when objects come in contact

The social network design of the objects connections will allow more efficient usage of the resources and will make possible the navigation among the "friend" objects instead of the usage of the standard Internet search tools.

1.3 The properties of “things” in the Internet of Things concept

The Internet of Things is possible with the use of various physical objects that have both physical and virtual representations. A most common name given to them is “smart object”, they are considered as building blocks of the IoT and described as everyday physical things with the ability to provide local intelligence and connect to each other of to the cyberspace by the means of embedded in them electronic devices. Smart objects are characterized to possess common characteristics (Sanches Lopez, 2012; Miorandi, 2012):

- Physical embodiment and physical features
- Have a unique identifier within a network
- Associated to at least one name and one address
- Able to sense and store data from sensors
- Use communication technologies to connect to other objects and systems
- May include technologies for manipulations with the physical environment
- Possess some computational capabilities

These characteristics imply that smart objects within the Internet of Things have a minimum set of properties. The work of Ibarra-Esquer et al. (Ibarra-Esquer et al., 2017) systemizes these properties to provide the better understanding of the objects ecosystem in the IoT. The authors distinguish identification as the most fundamental property that was widely utilized since the first generation of the IoT. The identification is at the core of the technology, it forms one of the pillars that enables the IoT as it makes possible the communication with the object within a network.

Location and tracking is the second property of objects that bases on the ability of objects to identify themselves and be identified by others. This property becomes important for the devices that can move in space, providing the capability to track their location. However, it is also noted that the tracking of individual history of an object from manufacturing to the end of its lifetime can also provide useful information that can be utilized within the network of things.

The next distinguished property of smart objects is their sensing ability. Objects with embedded sensing devices can collect and share the information from the environment. Although the use of such “feeling things” was envisioned at the conceptualization stage of the development of the IoT, they became widely used just recently with the focus during the first generation of the IoT being made on the identification and tracking abilities of objects. The use of sensing devices within the IoT led the appearance of objects with actuation property. Such objects allowed to remotely influence the environment and formed the foundation of the application of the IoT in processes automation.

The processing capabilities of an object is the last property defined by Ibarra-Esquer. It implies the utilization of computational power within objects in order to increase the autonomy of a local network of things. Such devices have the capability to become not only providers of data, but also providers of services.

1.4 Technological aspects of the Internet of Things and socio-cultural perspective

The technological issues for further development of the IoT were discussed in the descriptions of its generations. They include the need for significant improvement in all of the parts of the IoT. The improvements in the following areas will allow to release the potential of the Internet of Things and formalize the third generation of the framework (Friess, 2012; Shin, 2012):

- Emergence of efficient architectures designed specifically for the IoT applications
- Further efforts for the transition to the IPv6 and the development of new identification technologies
- Appearance of new smart sensing technologies integrated with the reasoning capabilities into connected devices
- Advances in the communication and network integration technology to increase the flexibility and the efficiency of the networking
- Introduction of intelligent information processing technology that will leverage Big Data analysis approaches in order to transform information from physical sensors to machine and human understandable form
- Design of the power-intelligent ecosystem combining energy harvesting and power efficiency approaches, and development of charging infrastructure of smart sensing devices

Apart from technical aspects of the IoT development there also are socio-cultural issues of the adoption of the technology that need to be taken into consideration. One of the prime concern of the IoT is its security. With the absence of standardization of protocols appears a concern about the safety of the data shared within the network of objects. This issue is very important for such types of information as personal health and other medical data. Another security issue is the regulation of the limits for the IoT applications, for example, the amount and variance of data that the system collects, stores and analyzes. This concern as very clear now as it reveals the contemporary problem of the boundaries for the technology trustworthiness and the acceptable limits for the agreement to personal data sharing by individuals (Shin, 2012).

The privacy issue is one of the factors that can prevent the infusion of wearable IoT devices. The users of health and medical trackers, for example, are often concerned with the use of the personal data collected by the devices without their consent. PwC research showed that 82 percent of the consumers of such wearables think that the current technology may compromise their privacy (PwC Research Institute, 2014). The privacy concerns of the daily usage of the health trackers are not the only ones that affect the consumer adoption of the technology, other problems being related to the reliability and accuracy of the obtained data and the exposure to electromagnetic radiation (EMR) (Marakhimov, & Joo, 2017). This is an indication that the infusion of the consumer IoT is linked to the technological issues of the new framework and the lack of regulations of standardization in the field.

The discontinuation of the Google glass project provides evidence of another problematic area of the IoT. It became obvious that the user experience is very important to the development of both consumer and industrial applications of the framework; wide adoption of the technology is only possible when its utilization does not cause more problems to users than the value it brings. Due to this fact, significant efforts in the improvement of UX (user experience) can already be noticed.

The work of Shin (Shin, 2017) conceptualizes the measurement of the quality of experience for the IoT applications. In the research it is noted that the hedonic aspect of the consumer applications of the IoT plays an important role in the mass adoption of the technology. However, the author found that there is no formal system for identification of user perceptions in the assessment of the end products' quality. Among the factors influencing the acceptance of new technology Shin distinguished such concepts as coolness and affordance and tried to formalize their usage in the measurement of a new metrics – quality of experience (QoE). During the research it has been also found that the users' age has a significant impact on the perception of the IoT coolness, when the gender does not affect the factors for the IoT adoption. This fact indicates that wide spread of consumer IoT will be most likely be associated with the acceptance of the technology by younger generation of people.

However, it has been argued that the assessment of the success in providing value to consumers should not be based on just the UX and should include the study of the technical characteristics and overall design features of an IoT device (Papetti et al., 2016). It is true that the perceived quality of a product greatly depend on the ease to understand the way it works, users' feelings about the device and the ability to serve the specified purpose; however, the variety of the devices present in the IoT market developed independently from each other and the lack of uniform standards led to the situation when users often could not choose the right solution among similar offers. Therefore, the usability becomes not the only factor that a user takes into consideration while assessing the quality of an IoT device. Due to this fact, the researchers propose to use a new objective evaluation protocol to describe the quality of a smart object.

The proposed approach assesses several features of a connected device that provide a complete picture of the user's perception of a device. Among the characteristics that were proposed for evaluation are:

- Connectivity
- Cost
- Installation and configuration experience
- Compatibility and provided services
- Reliability
- Device characteristics
- Design
- Ease of use
- Ease of installation

Summarizing all of the above, it could be said that the further development of the IoT greatly depends not only on overcoming technical issues and introducing of new technologies, but also on dealing with the socio cultural aspects of the mass implementation of new technology. However, many of the people's concerns on the usage of IoT devices reveal the problems of early development of the technology.

1.5 New business model framework for the Internet of Things applications

The barriers to adoption of the IoT devices in the consumer world raised the problem of ineffective business models of the applications of the IoT. Therefore, it is needed to develop new efficient approaches for exploitation of the potential for value generation by the IoT. The unused opportunities can be captured with the utilization of new business models adapted specifically to the characteristics of the IoT.

The research of Dijkman et al. (2015) is directed towards the transformation of a standard approach towards development of business models to incorporate and utilize the characteristics of the Internet of Things concept. It bases on the Business Model Canvas proposed by Osterwalder and Pigneur and widely used by business practitioners and adds new building blocks to it that alow to capture the value chain of the new technological approach. The authors came to the conclusion that the standard building blocks of the Osterwalder's Canvas (key partners, key activities, key resources, value propositions, customer relationships, channels, customer segments, cost structure and revenue streams) are sufficient for the IoT business models; however, they identified new types of these building blocks characteristic for IoT applications and evaluated their relevance and importance. The developed canvas is represented in figure 1.

Figure 1: Business model framework for IoT applications

Key Partners	**Key Activities**	**Value Propositions**	**Customer Relationships**	**Customer Segments**
Hardware producers Software developers Other suppliers Data interpretation Launching customers Distributors Logitics Service partners	Customer development Product development Implementation; Service Marketing; Sales Platform development Software development Partner management Logistics	Newness Performance Customization „Gettng the job done“ Design Brand/status Price Cost reduction Risk reduction Accessibility Convenience/usability Comfort Possibility for updates	Personal assistance Dedicated assistance Self-service Automated service Communities Co-creation	Mass market Niche market Segmented Diversified Multi-sided platforms
	Key Resources		**Channels**	
	Physical resources Intellectual property Employee capabilities Financial resources Software Relations		Sales force Web sales Own stores Partner stores Wholesalers	

Cost Structure		**Revenue Streams**	
Product development cost IT cost Personnel cost	Hardware/production cost Logistics cost Marketing & sales cost	Asset sale Usage fee Subscription fees Lending/renting/leasing Licensing	Brokerage fees Advertising Startup fees Installation fees

Source: Dijkman et al., 2015

The authors of the IoT applications business model framework conducted a survey among employees of 11 companies developing different IoT solutions. Their research resulted in the identification of the importance of different parts in the business models for IoT. It was found that among all building blocks, value proposition plays the most significant role, other two key building blocks being customer relationships and key partnerships.

The importance of the value proposition building block shows that is still hard to articulate the potential of application of the IoT at the current stage of its development. Although one of the main values from the implementation of IoT could come from cost reduction, the importance of this type was found to be lower than the others'. This fact is supported by the findings of Openshaw et al. (2014) who state that although IoT could potentially provide significant optimization of costs, larger value of the technology should be unlocked by business models aimed at generation of additional revenues from the utilization of collected data.

In the work of Rymaszewska, Helo, & Gunasekaran (2017) it is identified that the value from IoT solutions could come either from utilization of monitoring and control functions of a system, or by leveraging data analytics of the collected information. The IoT applications can be utilized to gather and analyze data from devices installed within different business processes in order to identify the potential for improvement of operational effectiveness and efficiency, which then will lead to the increase of profitability. The monitoring and control can, for example be used to increase the reliability of process, which is especially important for complex operations in heavy industries, by implementing condition-based maintenance (CBM). CBM depends on the analysis of the state of assets, which can be done with the use of IoT devices, and it allows to reduce costs from inspection and repairs by conducting systemic monitoring of assets of their parts. This application shows the example of the cost reduction type of the value proposition building block.

Additional revenues from the IoT utilization can be made with the analysis of collected by smart objects data. IoT solitions can transmit the information to cloud, where it will be stored and will become available for further analysis with the use of modern business intelligence tools. The collected data on customer usage of products can be transformed into valuable customer insights and be utilized for new marketing approaches. It will allow to identify customer behavior patterns and create new value added services. Moreover, the collected data can be used not only for in-house analysis, but it may also be resold to side organizations, generating new revenue streams.

The IoT also enables companies to utilize the potential of customer relationship development with the use of co-creation approach either during the development or at the exploitation stage of a technology. Another important aspect that could be leveraged within business models is the possibility of appearance of user communities. However, the customer data from IoT devices can be also successfully used to provide personalized service to the technology users and strengthen a company's relationship with customers (Dijkman et al., 2015).

Key partners is another important block in business models for IoT applications. Its significance comes from the observation that the companies often do not have capabilities to develop a complete IoT ecosystem themselves. In order to launch a new IoT product they may outsource software and hardware development or infrastructure operations to their partners. This approach allow the companies to focus on the areas where they excel instead of making an effort to develop capabilities in technical issues of the IoT. The outsourcing of some of the activities and operations to side organizations also may bring significant cost reduction. However, the partnerships for the IoT ecosystem creation are characterized to be significantly more complex than the ones for the development of regular products. Therefore, it becomes important to develop close relationships with outsourcing companies in order to jointly optimize business processes, lower the potential risks and eliminate any unnecessary costs.

Case studies conducted by Rymaszewska et al. (2017) reveal that servitization strategy allows businesses based on IoT technology to better use the its potential. Such companies may capture more value from providing complex IoT solutions for customers rather than just after sales services. They may utilize the gathered data to study the use of a product in order to modify services related to products and better fulfill the needs of end users. This will result in the development of close customer relationships and provide the opportunity to influence customers' purchasing decisions. The servitization implies that the companies transform their business models towards being more focused on providing the services associated with a product, and this approach may significantly enrich the value chain of companies providing IoT products.

Chapter 2. The Internet of Things in the Consumer Goods Industry

2.1 The overview of the Consumer Goods industry

Consumer goods are products that are intended to be used by end consumers rather than as raw material or as a production asset for manufacturing. These goods can be either durable or nondurable. The first ones are associated with the products characterized by long life span, the examples of such goods are consumer electronics, or automobiles. Nondurable goods are characterized by a short life span, fast turnover, relatively low cost and they include everyday products like food and beverages, or household chemicals. This research is focusing on the influence of IoT applications for the industry of nondurable goods, which is often called Fast Moving Consumer Goods (FMCG), or Consumer Packaged Goods (CPG) industry.

Among the FMCGs there are various types of products and they range from soda drinks to razor blades. There is no standard classification of the whole variety of such products, as FMCG is an umbrella term that includes goods with similar characteristics. Sometimes clothes are also considered FMCGs; however, the analysis of product portfolios of the largest companies in FMCG industry in 2015 that include Nestle, Procter & Gamble, PepsiCo, and other multinational corporations reveals that the clothes industry should not be really associated with FMCG[1]. The core products manufactured by companies that are widely considered to operate in FMCG are associated with the following categories (Celen, Erdogan, & Taymaz, 2005):

- Meat, fish, fruit, vegetables, oils and fats
- Dairy products
- Grain mill products, starches, animal feeds
- Other food products (Chocolate, macaroni etc)
- Beverages
- Tobacco products
- Paper and paper products
- Chemicals and chemical (household) products

However, this list is not exhaustive as it does not include such products as razor blades or toothbrushes that are present in the product portfolio of, for example, Procter & Gamble. With such uncertainty in the categories of products that could be characterized as FMCGs in this research we well refer to FMCGs as products that are manufactured and sold by companies that are typically associated with the FMCG industry. Such products could be divided into food, beverages, personal hygiene and household cleaning utensils categories.

[1] Top 50 FMCG companies worldwide in 2015, based on net sales, statista.com

FMCG is one of the largest sectors of economy with estimated market size of $8 trillion in 2014 (Hirose et al., 2015). A big share of this industry is occupied by several multinational corporations that usually spread their business to many different regions creating some of the biggest and most complex supply chains. FMCG is characterized to be a highly competitive sphere, and therefore a lot of the focus of FMCG companies is directed towards innovations in products, marketing approaches, supply chain operations, organizational structure or business models. The innovations help the companies to increase their margins and grow their businesses. For example, in order to defend market share from potential losses due to customers shift to alternative low-cost products, P&G decided to launch new technically superior products in US diapers market each 6 month (Bascle et al., 2012). In order to cope with this rate of new product launches, the company should have not only fast development cycles, but also resources and operations flexibility to support constant changes in product manufacturing and distribution.

FMCG companies consist of multiple departments and business units, but the functions that exist within them can be defined as research and development, marketing and sales, procurement, manufacturing, and distribution (Chatterjee et al., 2010). However, to analyze the effect of IoT development on FMCG industry it is not right to look just at the internal processes of companies. As FMCG utilizes B2B2C model by typically selling products not directly to consumers but through various channels, it would be important to also analyze IoT applications in the retail domain. The potential for the growth of the industry could be also found in some of the applications in Smart Home domain.

In this research, we will study the IoT in the following areas of the Consumer Goods industry: product supply, retail and consumer products. We will analyze the application of IoT in these spheres separately; however, as the IoT has the potential to link all of the processes in the industry's value chain, we will also try to find links of IoT applications with other fields. At the end we should obtain a holistic understanding of how IoT influences the FMCG industry and what opportunities it provides for its further development.

2.2 The Internet of Things in Fast Moving Consumer Goods Product Supply

Product supply in FMCG companies is extremely complex system that consists of raw materials sourcing, manufacturing and logistics. The production and delivery of products are very important operations for such companies due to the volatile and demand for consumer goods and geographical complexity of production facilities in transnational companies. Therefore, a lot of efforts in FMCG industry are directed towards the optimization of their supply chains in order to satisfy the needs for goods of different regions and provide competitive prices of products to end consumers. The companies focus on the operational efficiency in product supply by automation of processes in manufacturing, warehousing and transportation and increasing the accuracy of demand forecasting and production planning.

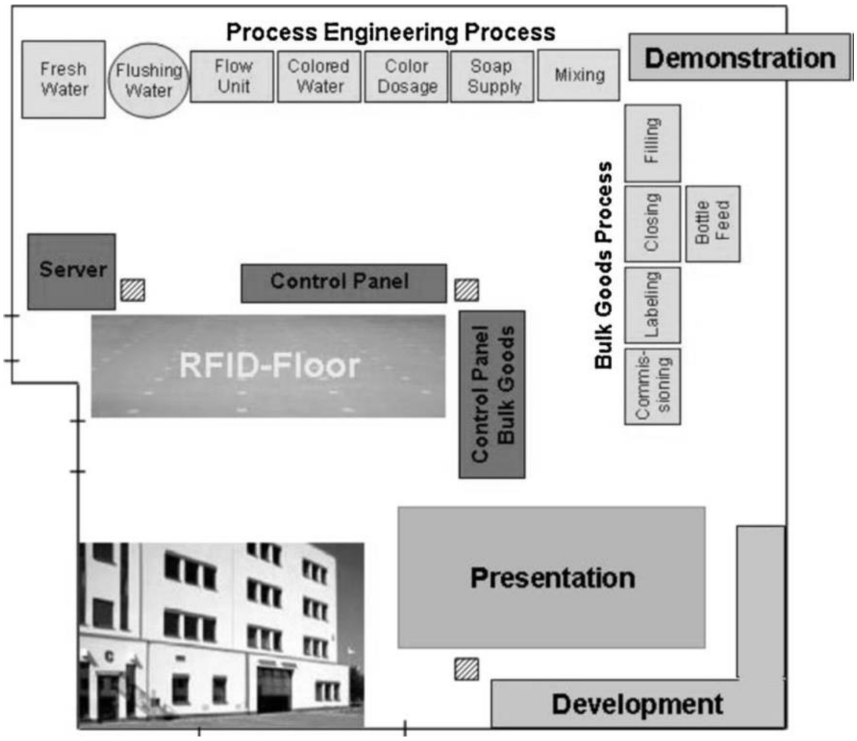
In FMCG supply chains, the implementation of the IoT can significantly improve the efficiency and automation of processes at the same time reducing costs. Tremendous amount of IoT solutions using interconnected sensors and actuators and wearable smart devices will enable the implementation of Industry 4.0 concept (Alicke et al., 2017; Fritzen et al., 2016).

Among the most widely used IoT technologies in FMCG product supply is radio frequency identification (RFID). This technology is relatively old, its application to industrial processes led to the development of the very concept of the IoT (Atzori et al., 2017). RFID technology allows the identification of data capture and it includes a tag and a reader communicating trough radio waves. There are three types of tags: passive, semi-passive and active. Each of these tags are designed to implement different tasks. Passive tags do not have power supply and depend on the energy transferred from the reader with radio waves. They are most of the most frequent applications of such tags is to track the location of various assets on production floor. Semi-passive and active RFID tags are both battery powered, they can be used to collect date from external sensors and communicate it to the reader. However, while active tags can initiate the communication to the reader, the semi-passive tags do not have such functionality (Lee, & Lee, 2015).

Although the wide use of RFID started about 20 years ago, currently the applications of this technology are often not fully incorporated into supply management systems. Therefore, the full potential of the IoT approach to the RFID technology is not utilized and this is an opportunity for FMCG companies too (Miorandi et al., 2012).

The SmartFactory initiative is an illustration of efficient use of RFID and other core IoT technologies. The initiative was initiated in 2005 and it was aimed at the development af a new approach to production process design and operations. The developed SmartFactory was represented by a facility for production of colored liquid soap and it included almost all processes and units that a typical household chemicals FMCG company could have at its production site. The factory included making (mixing), packing (filling to dispenser bottles and labeling) and storing processes, and it even included the post-production delivery to a customer that ordered products (Zuehlke, 2010). Figure 2 shows the floorplan of the SmartFactory.

Figure 2: The floorplan of the SmartFactory



Source: Zuehlke, 2010

The SmartFactory project utilized several technologies for the optimization and automation of all processes, among which are radio frequency identification (RFID), Near-field communication (NFC), Bluetooth and ultra-wideband (UWB) wireless communication technologies, ZigBee protocols. The used technologies allowed to connect sensors and actuators to one system of interconnected devices. Because of the use of wireless communication and modular approach, the developed model of a factory made possible simple replacement, modification or addition of separate modules in order to adjust to changing production processes.

The “smart” components of SmartFactory could identify their functions and position within the process chain and then implement the tasks depending on the manufacturing situation. Therefore, they operated within service-oriented rather than function oriented control architectures. With this approach, the processes of the factory became much more flexible, and the use of new technologies and wireless communications made possible the control of processes via mobile devices instead of use of stationary control panels. The use of mobile solutions for control of different devices within the process has great potential as it allows to significantly decrease the time and resources for their maintenance and for processes reconfiguration.

The SmartFactory also utilized the appriaches developed within “SemProM” or Semantic Product Memory project. RFID technology and sensors were embedded into products which allowed record all relevant product and process data, transmit it to other products, surroundings and end users (Zuehlke, 2010). Such technology has a great potential as it allows to monitor the parameters of individual products, quickly identify quality issues and adjust production processes to decrease possible risks. With the spread of this technology, companies could significantly improve their process control and guarantee the quality of end products to consumers (Miorandi et al., 2015).

Another very important area where IoT can bring significant improvements is production units' maintenance. As stated in chapter 1, the IoT can enable condition-based maintenance approach that will allow to make significant savings on unnecessary replacement of machines or their parts. With the installation of connected sensors that transmit assets' real-time parameters to the cloud, it will become possible to do complex analysis of this information in order to identify unusual behavior of machines, for example appearance of vibrations. The results of such analysis can be passed to the workers and they will conduct necessary maintenance of the unit. With condition-based maintenance, FMCG companies can save up to 40 percent of repairs costs. Some of the industry players have already implemented this approach in their manufacturing sites. For example, CBM was implemented in diaper manufacturing, where sensors were studying microstructure of a semi-finished product to detect indications of a production machine's blades dullness and trigger a request for its replacement. This case illustrates that the IoT applications can bring not only cost reductions, but also the increase of quality of end products (Alicke et al., 2017).

The implementation of IoT in manufacturing environment can also enable the use of mobile devices, wearable electronics and augmented reality tools. The workers can significantly benefit from the use of such devices as they may do their work much more convenient. Although Google Glass project was shut down, we still can expect the appearance of similar augmented reality devices in the future, and they will most probably find industrial applications. The workers, wearing such glasses will be able to get the analytics of the processes or the state of machines by just looking at them. The glasses will identify the machines by reading QR codes placed on them or wirelessly transmitted identification information, then they will make a request for the information about the machines from the cloud, receive it and project the needed graphs on the lenses. With such device the workers will get real time data analytics on the processes at any location at the production unit without the need to be near a computer or control panel. This application has the potential to transform human interaction with machines and increase the speed of decision making (Hao, & Helo, 2017).

For the food FMCG companies IoT provides a range of applications in agriculture settings. IoT systems on crop fields allow to monitor and control various parameters i.e. plant growth rate, soil and air moisture, sunlight intensity etc. The connection of various sensors to the internet increases the automation on the field and the transparency of processes (Mohanraj, Ashokumar, & Naren, 2016). For animal farms IoT provides the possibility to track the location and the state of animals in real time, the collected information can be accumulated in the cloud, but some farmers may use the ability to post the information on social networks as described in SocialFarm project (Kamilaris et al., 2011).

In warehouses, IoT devices can be used to collect data on the characteristics of environment (temperature, humidity etc.) and transfer it to actuators linked to heating, ventilation, air conditioning (HVAC) system via the internet connection. However, a more interesting application of IoT approaches can appear with the use of RFID technology. As mentioned below, RFID can be used for tracking the location of items. A net of RFID receivers can be placed on the floor af a warehouse or on shelves, and tags can be placed on pallets or containers. When a pallet is within close proximity to a receiver, the receiver reads the identity of this pallet and sends the pair of pallet's id and self id to the cloud, specifying the location of the products. This location technic can be used for redesign of warehousing operations.

The standard approach to storing in warehouses is that the pallets with the same product and same characteristics are placed at the same location. This may result in high complexity of the lift trucks operator's route if they need to collect several pallets with different products. However, the route of the truck lift driver could become more optimized if the products were distributed over the entire area of the warehouse. This will allow the driver to choose the optimal route to pick the order that would on decrease the average time for order collection. To implement this approach the driver would need to have the information on the location of the needed pallets and computational algorithms would help them to choose a route. Therefore, the application of RFID technology for location will enable the companies to utilize this approach.

However, such approach works best for orders including small quantities of a big variety of products, and it may not be the most suitable for picking orders for wholesalers that usually need big quantities of a limited number of products. However, it can be successfully used for collecting products for small shops that do not often order in bulk. Another sphere where such approach can be utilized is e-commerce: if the products are placed on shelves individually (not stored in pallets), and each item has RFID tag, then picking multiple orders at the same time will become much more efficient as it will be possible to find a more optimized route. Although it can be argued that this approach can also be implemented with the use of bar of QR codes, the RFID technology may bring much more value. It will increase the automation level and allow to collect not only location data, but also the parameters collected by sensors if RFID tags are connected to them. Another important benefit of the IoT-based implementation of product allocation planning is that it allows to automatically detect if incompatible products are stored near each other and trigger the actions for separating such products from each other (Trab et al., 2015).

The transportation of products can also benefit from the ioT. The RFID tags on pallets and sensors located either in trucks or on pallets can help to track the delivery of products and provide the information on delivery status, location of the carrier and transportation conditions to all the interested parties. The utilization of the communication via the Internet makes possible the use of mobile devices by workers to receive the information anytime, anywhere. This allows the stakeholders to monitor the delivery and take important decisions if any problems occur during the transportation. Such application of the IoT is mostly aimed to ensure of the quality of service (QoS) of transportation companies (Gnimpieba, 2015).

The IoT applications for monitoring the level or the properties of the inventory in warehouses or in trucks, however, does not utilize the whole potential of the IoT concept. The vision behind the IoT is that all of the things in all processes, domains or environments can connect to each other directly or via the cloud and the data collected from all of them can be analyzed and used for interventions to the environment. Therefore, more opportunities could be captured by connecting all of the IoT devices within one company to one platform where it could be analyzed in order to get valuable insights or to identify the needed actions and send special instructions either to the workers, or directly to actuators embedded into processes. The connection of all devices within the supply chain of a company, for example, can significantly improve production and logistics planning, optimizing manufacturing processes and decreasing inventory buffer (Bottani, Montanari & Volpi, 2010).

However, for an even better accuracy of planning, more information from the FMCG company's customers or from its end consumers is required, and it can also be obtained with the IoT. The retailers are also implementing different in-store IoT approaches that help them to control inventory, regulate prices based on current stock availability, and sell more products. Therefore, it is very important for FMCG companies to build strong relationships with their customers in order to obtain the access to their IoT infrastructure and synchronize businesses. The IoT applications for consumer products can also help to get some data on consumer behavior that can be used in production for better demand forecasting and production planning. If an FMCG company succeeds in connecting with their customers and consumers via the means of the IoT, it will significantly improve the efficiency, reliability and autonomy of operations and will result in high cost reduction in product manufacturing and delivery.

2.3 The Internet of Things in Retail

Large FMCG companies are operating within B2B2C business model; therefore, they usually to a great extent depend on their customers – retail organizations. Although some of the companies are making an effort to develop new approaches for selling products directly to consumers, high competition on the market and established consumer behavior aspects will most probably limit the use of such channels (Krings et al., 2016). The utilized model increase the complexity of the processes within the FMCG industry value chain because the manufacturing companies have to connect to logistics operations of retailers which vary significantly from company to company. Moreover, by delegating sales activities to side organizations, FMCG companies lose the opportunity to collect the data on in-store consumer behavior that could be used in order to optimize their marketing approaches. The presence barriers between intermediary organizations and FMCG companies results in the loss of potential value for all stakeholders. This fact has been identified by many organizations and a lot of effort is now being made on the improvement of collaboration between the companies and retailers in order to receive and share more data, provide better transparency and, at the end, synchronize their businesses.

The synchronization of the manufacturing companies and retailers can be achieved with the use of common data sharing platforms. However, in order get a complete picture of the operations of each other, the partners should share as much data as possible. And the implementation IoT approaches and the use of connected smart objects in different processes can significantly help to improve the synchronization of the entities by collecting all the necessary data on manufacturer's and retailer's processes in the cloud. However, it could be argued that such synchronization can be only possible if the partners are in non-competitive relationships (Alicke et al., 2017).

There can be also found a lot of applications of the IoT in retail environment that does not imply the collaboration with the suppliers. The IoT application in this setting can potentially transform current consumer communication approaches and change consumers' shopping behavior. This may happen if retailers manage to find an effective way to use the IoT for targeted marketing and dynamic price formation.

In the retail supply chain the same IoT applications can be implemented in the retailers supply chains as for the FMCG companies; however, the retailers can also benefit from the implementation of inventory tracking approaches for the monitoring of store shelves. Moreover, the real-time monitoring of product availability in retail settings can be used for dynamic price adaptation. This approach can increase product turnover, minimize inventory level and at the same time optimize profit (Alicke et al., 2017).

The utilization of RFID tags for products opens the opportunity for the use of smart carts. Such carts will be able to identify the products put in them and transfer this information directly to online payment system in order to make a transaction (Manyika et al., 2015). The use of product identification by carts may also enable targeted promotions and recommendations based on what consumers put in them. To implement this, either a screen may be installed into the cart's handle to show the recommendations or promotions, or this information can be passed from the retailer directly to the consumer's mobile electronic devices. In order to implement the second approach, the cart will need to identify the consumer, which can be done, for example, by reading their loyalty cards, or some other personal ID. The implementation of the augmented reality can provide the means for even more seamless interaction with consumes. Overall, this IoT application can reduce the retailers' costs, increase sales and save time for the consumers.

The retailers can also use the connection to consumers' wearable devices in order to provide recommendations. This can be especially successful for the health trackers, which can transmit to the retailer the information on the current state of the consumer, and the system will then be able to recommend meals with optimal nutritional content (Benson-Armer, Noble , & Thiel, 2015).

To sum up, the IoT implementation in the retail domain can bring value not only to the business owners, but also to their partners (suppliers) and to the end consumers. The applications of the IoT can increase revenues and optimize processes for retailers, and decrease the inaccuracy of production and logistics planning for the FMCG companies. Consumers, on the other hand, will benefit from increased product availability, lower prices, special offers and improved quality of service.

2.4 Consumer applications of the Internet of Things and the FMCG industry

In the beginning of the chapter we defined FMCGs as consumer products with short life time, with which people deal every day and which are often meant for the immediate consumption. This characteristics imply that such products are produced in big quantities and are relatively cheap. Therefore, not many IoT applications can be imagined for the FMCGs. However, FMCG companies can use some other interesting approaches to benefit from the Internet of Things. For the FMCG companies it is very important to collect the information about their consumers in order to get insights that can be translated into sales growth; such information can be obtained, for example, from the databases containing the logs of consumers' wearable devices. But the companies do not have the access to these databases as they do not produce such devices. Therefore, the FMCG companies may be very interested in buying this data or analytic reports based on it from the companies that develop and sell wearables. However, the increasing concerns of the users of such devices about their privacy and the security of the collected information force the companies to treat the users' data carefully and limit the opportunity for sharing it with side organizations.

Due to the described issues, the FMCG companies interested in the potential value enabled by the IoT are developing new IoT products, entering the world of consumer electronic devices. However, as the companies do not have expertise in the electronic products, they develop such devices in collaboration with software and hardware companies. The example of such collaboration is the Gatorade's Hydration Communication Platform that was developed in partnership with Smart Design (Esterl, 2016).

Gatorade, a PepsiCo brand of sport drinks, presented an IoT solution for athletes that allows to track the level of their hydration during sport activities. The platform consists of a hydration-sensing patch, smart bottle, and an application for data analysis. The patch contains the sensor for the analysis of an athlete's sweat composition and intensity, and can wirelessly communicate this information to the application and smart bottle. The smart bottle contains a liquid with the optimal mineral composition adjusted for a concrete athlete, and it has a "smart" cap that receives the signal from the patch and lights up when the athlete needs to drink. The cap also has a turbine and a microchip that allows measuring liquid consumption and communicating it to the digital platform and the web application for further analysis. This IoT enabled solution enables a new business model that is centered not around the product, but around the services that the company provides. At the same time, the company gets an access to the consumer's personal information that can be used for product development, marketing and other purposes.

Another example of the implementation of the IoT for consumers made by FMCG companies is the connected Oral B toothbrush. The toothbrush can connect to the smartphone of a user and provide analytics on the everyday brushing routine by using the data collected by sensors within the brush. The application also uses the camera of the smartphone to track the time spent for brushing each quadrant of the user's mouth. By providing daily analytics on brushing and employing gamification approaches to the routine, the device allowed to increase the time of the brushing from less than 60 seconds to average 2 minutes 16 seconds, surpassing the recommended by professionals 2 minutes (Lee, & Lee, 2015). The data collected by the device can be further transferred to the consumer's dentist for analysis, which may be convenient to some consumers. However, the manufacturer can also receive it and use for studying the process of brushing and consumer behavior. The opportunity for direct communication with the consumer via the application can be also utilized to sell the refills or the adjacent products like toothpastes, oral rinses, dental flosses and other. Although the electric brush itself is not an FMCG but a consumer electronic device, it can allow to grow sales of other FMCGs from the company's portfolio.

A similar example is the L'Oreal's Kérastase Hair Coach smart hairbrush. This device uses microphones to listens to the sound of the brushing in order to identify the problems with a consumer's hair: dryness, split ends, breakage etc. The brush connects to a smartphone over WiFi or Bluetooth and a separate mobile application provides analytical information to the user allowing them track the quality of their hair over time. The application collects not only the data from the brush, but also retrieve weather information from the Internet and based on it provides the recommendation on the hair care routine for a specific day (Burgess, 2017). With this brush, the company can also have a direct communication channel to consumer where it can promote its products.

The IoT devices for the Smart Home domain can also bring changes to the FMCG industry. One of such products is the "smart fridge" described by Miorandi et al. (2012). Such fridge can identify the products stored in it with the use of RFID or an equivalent technology, understand the quantity and variety of stored items and recommend the owner to buy new products if it understands that they are missing, present in insufficient quantity or they approach the end of their shelf lifetime.

For the efficient implementation of the smart fridge concept, the FMCG companies will need to embed RFID tags into all their products, which will probably happen sometime. Also the fridge will need to have direct access to the suppliers of products in order to provide the ability to easily order the needed products or to receive special offers from them based on the fridges' contents. The current stage of development of IoT infrastructure and the lack of standards does not allow this. However, in the future we may see the implementation of a brokerage service within such refrigerators that will collect products information, owner's dietary constraints and preferences, and, for example, his agenda (scheduled dinners with friends) to negotiate quality food for best price.

Overall, the FMCG actors can benefit either from the consumer applications of the Internet of Things or by acquiring the data collected by the consumer electronics companies developing IoT devices. While there may be significant barriers in obtaining the data from side organizations, the companies can turn to the development of IoT solutions themselves. These solutions will enable them to transform their business models by introduction of new value propositions and switching their focus from manufacturing and selling products to providing different services to consumers.

2.5 Limitations and key success factors of the Internet of Things applications in the Consumer Goods industry

The Internet of Things concept implementation in the FMCG industry can bring significant value to all of its stakeholders. It has a great potential for optimizing the processes, increasing the transparency of the operations, providing the means for fast decision making, and improving the quality of products. It was also shown that by using this new approach FMCG companies are able to find new sources of revenues and transform their business models by introducing new value propositions to consumers. This proves the first hypothesis that was stated at the beginning of the research paper.

However, the current state of the development of the IoT is characterized by lack of standardization and absence of unified architecture. Big FMCG companies and retail enterprises also do not have the needed infrastructure and the level of collaboration that will enable them to utilize the full potential of the technology. Moreover, the companies do not have the expertise for the efficient application of the IoT as their main strengths are in developing, manufacturing and selling relatively cheap everyday products. In order to realize the potential of the IoT such companies need to hire other organizations or new people with unique set of professional skills. The companies are also very limited in the use of IoT in their products and they need to find new creative solutions and sometimes enter new business areas in order to capture the opportunities provided by the technology. This proves the second hypothesis of the research.

In order to overcome the described problems and transform their business, the companies operating in FMCG industry should consider the following recommendations:

- Hire the people with technical expertise and skills in advanced data analytics. The implementation of the IoT requires the presence of people who have unique set of technical skills and competences. However, until recently, such professionals were not typically employed in the FMCG companies as there was not enough demand for them. The companies should start attracting these highly skilled people and develop new career tracks for such employees in order to retain them.
- Enhance internal infrastructure. The advanced data analytics can be enabled only if there is the information in convenient form for analysis. However, the current digital infrastructure in the companies is represented by separate non-connected platforms with different interfaces that limits the potential for the use of modern analytics tools in the sphere of Big Data and Machine Learning. Therefore, the companies need to transform their approach for data collection and storage in order to realize the potential of the IoT.

- Build close relationships with partners within supply chain. Further development of the IoT will enable different entities to connect to each other's infrastructures in order to synchronize businesses and significantly increase the speed and reliability of the processes, at the same time reducing costs caused by inefficiencies. Therefore, it is very important for the FMCG industry actors to build and sustain trusting relationships to be able to benefit from such connections.
- Partner with IT organizations. The IoT has an extremely complex architectural design, and, therefore, it is impossible to build effective solutions by the resources of one organization. Hence, the companies in FMCG industry should consider partnering with other organizations that will develop hardware and software, provide the needed IT infrastructure and data analysis capabilities, do the installation and maintenance of the systems etc.
- Develop and test new business models built on the specifics of the IoT. It is hard to implement the IoT approaches for the FMCGs due to their characteristics; however, some ways to do this can still be found. This is a very hard task to identify the possible applications of the IoT that will bring value to both consumers and manufacturers, but successful implementation of the IoT in the consumer world can be very profitable. Therefore, the companies should allocate a lot of resources to identify the ways for utilization of the new technological approach.
- Start the transformation journey now. The implementation of the IoT will require a lot of changes in the traditional operations of the FMCG industry; however, the pace of the development of the IoT is very high and it is important to initiate the transformation at the formation stage of new technologies development in order to not lose new opportunities. Hence, the companies have to start adopting IoT applications even though they are not fully developed yet.

Conclusion

This research aimed to analyze the potential of the Internet of Things applications to transform the industry of Fast-Moving Consumer Goods and identify the key directions for further development of the technology within the industry. The research showed that the Internet of Things indeed can play a big role in the changes in the industry, supporting the initial hypothesis (H1) stated in the introduction. The second hypothesis that the industrial applications of the technology brings more value to FMCG companies than its application in consumer products is also proven by showing the great potential of the IoT in the optimization of industrial processes. Although, the IoT for consumer products has a significant effect on the industry and it can initiate the evolution of the companies' business models, such applications are very limited and face the security and privacy concerns of the end users.

The analysis of the IoT in the FMCG sector led to formulation of key limitations, potentials and recommendations that the industry stakeholders can take into consideration while developing the strategies for the implementation of this new technology. However, the research also provides a thorough analysis of the current state of the IoT and can be used by the decision makers in other spheres. It also can be referenced by researchers as it contains the overview of the IoT and identifies the issues that require further study.

Although the IoT is not yet fully developed, its potentials can be identified even at this point. A lot of the applications of the IoT are already present and a lot of them are expected to come once the technology development lets to overcome current issues. In order to facilitate the adoption of the IoT, the governments should also step in by launching initiatives and projects supporting its development. Also they should be interested in introducing new regulations that define the boundaries for the use of the IoT as this technology imply certain security issues that can have negative consequences. Therefore, it is very important for the companies interested in the IoT and governments to collaborate with each other in order to and utilize the opportunities of the IoT and avoid risks.

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Declaration in Lieu of Oath

by Maksim Lavrentev

(Student's name)

This is to confirm my Course Work was independently composed/authored by myself, using solely the referred sources and support. I additionally assert that this Course Work has not been part of another examination process.

Moscow 02.10.2017 (Date)

(Signature)