INTERNET OF THINGS IN LOGISTICS

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Abstract: *Internet of Things is based on the most contemporary information and communication technologies that enable marking, identification, communication and intelligent management of things. In this concept, things become smart objects that have the possibility of identification, communication and interaction. The paper gives a description of IoT, a proposal for the architecture and shows the possibilities and significance of applying the IoT concept in the field of logistics.*

Keywords*: Internet of Things, Logistics, Identification, Communication.*

1. INTRODUCTION

Internet of Things (IoT) is a new business paradigm that is based on unique identification of things and modern wireless communications (Atzori et al., 2010). Various things – objects from the real world are equipped with IoT devices that enable their identification, location, generating and receiving information. Full realization of IoT will enable formation of a virtual model of reality, in which business systems will be able to manage processes and activities in real time based on timely information on current state of their facilities. The aim of this paper is to outline the possibilities and significance of the IoT concept in the field of logistics. Initial IoT solutions that connect objects, users and companies through the Internet are already being applied in logistic processes. The paper consists of five parts. The IoT concept is described in the second part. The third part gives a proposal for IoT architecture and the four basic layers. The fourth part reviews the possibilities and effects of applying IoT in logistics. A conclusion is presented in the fifth part.

2. INTERNET OF THINGS

IoT is a new model of connecting real world objects into a unique system whose elements will be able to communicate with one another. The basic idea of this model is the existence of various devices (tags, sensors, mobile phones, etc.) that can exchange information through a wireless network in order to achieve mutual goals. The term Internet of Things was first introduced by Kevin Ashton in 1999 when he was researching new possibilities of applying RFID technology and the Internet in Procter & Gamble supply chain. Most of the data available on the Internet were created by human beings, by manually entering data, pressing a record button or scanning a bar code. The basic problem is that people have limited time, attention and accuracy, which means they are not good enough for acquiring data on things in the real world. If computers had

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all data and information on things, acquired without the help of people, losses and costs would significantly be reduced, planning, decision making and control processes improved (www.rfidjournal.com, 2009). IoT is based on the most contemporary information and communication technologies (ICT) that enable marking, identification, communication and intelligent management of things. In this concept, things become smart objects that have the possibility of identification, communication and interaction.

IoT can be viewed on three levels (Miorandi et al., 2012):

- At the single component level, the IoT is a set of smart objects connected to the Internet network. A smart object is an entity with a physical embodiment, unique identifier, address, characteristics and a minimal set of communication functionalities. A smart object possesses computing capabilities and can trigger activities having an effect on physical reality.
- At the system level, the IoT is a dynamic and distributed networked system, composed of a very large number of smart objects that generate and use information. Smart objects register physical phenomena and translate them into information streams which are further distributed through the network.
- At the service level, the IoT is a set of functionalities offered to the end users in various fields. The architecture of IoT systems is a virtual model of the real world with defined methods of information acquisition from smart objects and distribution of certain information given as services to the end users.

From a user point of view, the IoT will provide a large amount of new services which shall answer all requirements and needs in various fields. The user will receive a service that suits his state, physical surrounding and current conditions. IoT is a new concept of information and management linking which is yet to develop; new models are proposed and new technologies developed which should support identification, communication and control for a large set of objects, various fields and users and a large number of services.

The basic features of the IoT concept are (Miorandi et al., 2012):

- Devices heterogeneity – the IoT comprises of a large number of devices found in physical objects and have different computational and communication characteristics. Management of a heterogeneous set of devices should be supported by architecture of systems and communication protocols.
- Scalability – The development of the real world virtual model and the informational integration of a large number of objects requires scalability with: unique naming and addressing of objects, data exchange and connectivity, information and knowledge management, and service provisioning and management.
- Wireless data exchange – the IoT is based on wireless communication technologies which enable objects and wireless mediums that collect and distribute information to be connected with each other.
- Energy-optimized solutions – IoT comprises of a large number of energy consuming entities. Since IoT is a global system, optimization of energy consumption at all levels is necessary as well as application of solutions that enable reliable operation with minimal energy usage.
- Tracking objects possibilities – Smart objects have the possibility of identification and wireless communication which enables their tracking in the physical realm. This is particularly important in fields where it is necessary to track objects during whole life cycle.
- Self-organization capabilities – Devices that enable automatic identification and communication and make the objects smart also have the possibility of reacting to changes of some parameters in the environment. Smart objects possess the intelligence to independently react to different situations.
- Semantic interoperability and data management – The concept of IoT consists of exchange, safekeeping and processing of a large amount of data. In order to turn data into useful information and knowledge, it is necessary to provide interoperability among various applications and define standardized formats, models and semantic description of data.

- Embedded security and privacy-preserving mechanisms – The concept of IoT should ensure data security and privacy-preserving of participant. The system consists of data on all smart objects and their owners are also the owners of their data. The existence of security procedures is a prerequisite for accepting the IoT concept by the user.

3. INTERNET OF THINGS ARCHITECTURE AND TECHNOLOGIES

IoT architecture consists of all elements, mutual connections, technologies, applications and services in the IoT concept. Various multi-layer models of architecture are proposed in literature, and they include: smart objects, identification, data acquisition, communication networks, data management, applications and services (Atzori et al., 2010; Miorandi et al., 2012; Tadejko, 2015; Gaitan et al., 2015). This paper gives a proposal of IoT architecture concept with four layers (Figure 1):

- Perception layer,
- Network layer,
- Middleware layer and
- Applications layer.

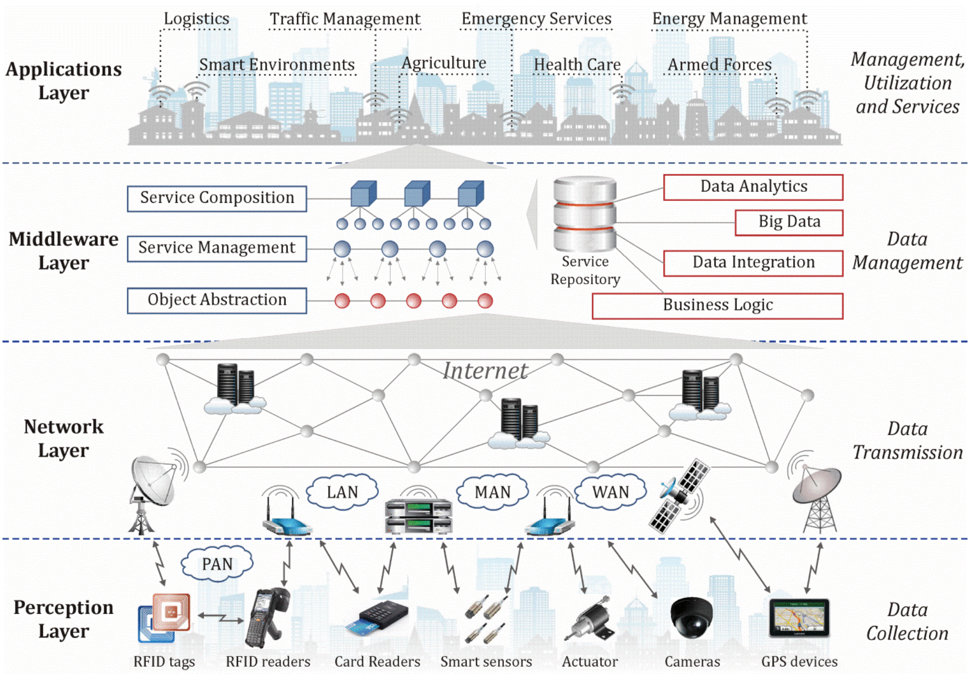

Figure 1. IoT Architecture

Perception layer consists of physical layers equipped with devices which enable identification, computer processing, sending and receiving of communication messages. The most widely used technologies for identification are RFID (Radio Frequency Identification), GPS (Global Positioning System) and WSN (Wireless Sensor Networks). The devices which make objects smart may be RFID tags and readers, card readers, smart sensors, actuators, cameras, GPS devices, etc. The basic challenge of the IoT concept is the use of devices that are low-power, inexpensive, networked and compatible with standard communication technologies (Miorandi et al., 2012). According to some research (www.gartner.com, 2015), it is estimated that more than 20 billion devices will be connected in the IoT concept in 2020. One of the basic problems of the IoT concept was the unique identification of physical objects. This was overcome by the development of the IPv6 internet protocol which provides 1038 unique addresses, which should be enough for making all objects in the near future (Atzori et al., 2010).

Network layer enables data and information transmission between smart objects and the system which processes them. This layer includes access networks and core networks. Access networks used for sending messages are PAN (Personal Area Network), LAN (Local Area Network), MAN (Metro Area Network) and WAN (Wide Area Network). Intensive efforts are being made in the world today to develop a unique core network and communication protocol (Al-Fuqaha et al., 2015). Data collected from smart phones are transmitted to hubs and further to clouds where they are stored, processed, analyzed, transferred to other systems or returned to devices.

Middleware layer is found between the technological and application levels and contains software systems which process data and information and form services for users in various fields. By applying the business logics rule, data collected from smart objects are integrated in a unique system where different analytical applications are applied. Since a large number of heterogeneous data from various sources are in question, contemporary hardware and software technologies are used for storage and data processing which belong to the field Big Data. The Middleware layer has SOA (Service-Oriented Architecture) architecture which enables breakdown of complex systems to applications and components. Object Abstraction provides a virtual model of a large set of heterogeneous physical objects and their characteristics. Service Management consists of a set of all individual services which are stored in the Service Repository and provide physical objects. Service Composition is a set of functionalities for the complex services composition.

Applications layer consists of a set of all services which are provided to users in various fields. IoT services are the result of processing of data that have been collected from physical objects and enable timely and good-quality decision-making in conformity with the current state of the objects, system and environment. Numerous possibilities in various fields are given in literature: Logistics, Traffic Management, Emergency Services, Energy Management, Smart Environments, Agriculture, Health Care, Armed, Forces, Personal and Social domain, Smart City, Futuristic applications (Atzori et al., 2010; Miorandi et al., 2012; Tadejko, 2015; Borgia, 2014). Today, the fields of applying IoT services are limited only by our imagination (Whitmore et al., 2015).

4. INTERNET OF THINGS IN LOGISTICS

Contemporary logistics is based on information and communication technologies that support realization of business processes and enable connection of users in supply chains It is of great significance in logistics to provide identification of objects and communication among participants. Identification technologies applied to various objects in logistics have led to the existence of smart containers, pallets, packaging, packing materials, vehicles, shelves, forklifts, infrastructure, ports, terminals and others. RFID, GPS and WSN systems have wide uses in logistics and supply chains:

- RFID systems enable automatic identification of objects and wireless data reading. RFID tags can be active, passive and semi-passive and contain a large quantity of data on objects on which they are placed. RFID tags are used for marking traffic, transport and reloading means, logistic units, individual articles and shelves in retail, special types of goods (money, gold, medicine, dangerous goods), post office packages, location and traffic in warehouses, identification cards, documents and others.
- GPS systems enable positioning of objects in real time. GPS devices receive satellite signals, determine their position in space and time, preserve data on location and transmit them to user of system. GPS is used in almost all segments of logistics, providing data on exact position and time where and when some object is found. GPS devices are placed on transport

means of all types of traffic, semi-trailers, pallets, containers and individual goods, industrial and reloading mechanization, any devices that workers use in business processes.
- WSN enable collection and transmission of data between sensor nodes, access devices and network users. A sensor node consists of a set of active and passive sensors and can communicate, preserve and process collected data. Sensors are used for identification of objects and their physical characteristics – characteristics of goods, transport and reloading means, containers, locations in warehouses and sale facilities, equipment and traffic infrastructure, and others.

The application of these systems enabled the development of new business models and the concept of digital logistics in which a company automatically manages business processes and connects with its suppliers and buyers. In logistic systems, there are various models of connection through the Internet which relate to one or more companies or participants in supply chains. These models represent the initial IoT solutions which lead to global connection of all participants and objects. According to some research (Macaulay et al., 2015) 75% of companies used IoT solutions in 2014 in relation to 15% in 2012. The development of the IoT concept and universal communication network will enable a virtual model of business connecting whereby all participants will have data on objects available in real time. In literature, logistics is cited as the first field for application of IoT, (Atzori et al., 2010; Miorandi et al., 2012; Borgia, 2014; Whitmore et al., 2014). The reason for this is that logistics depends on the quality of logistic network, connectivity of all participants in supply chain, fast and reliable information, everywhere and at all times. Logistic decisions are brought on the basis of available information and influence all other participants in supply chains. IoT connects identification technologies (RFID, GPS i WSN), built-in intelligence, advanced analysis of large quantities of data, software applications and systems of decision making at different control levels. The software systems in logistics (LIS, WMS, TMS, OMS, CRM, SCM) will realize maximum effects since high quality data and information on current state of objects on network will be used. Figure 2 shows the application of the IoT concept in logistics. The significance of the IoT concept can be viewed at the level of logistic processes, participants in supply chains and on the global level. The greatest effects in the field of logistics are:

- Monitoring transport and reloading means, logistic units, goods and people in real time.
- Measuring resource performances and planning in conformity with current state.
- Logistic controlling of activities and processes, reacting to deviation and disturbance conditions and applying corrective actions in order to realize the set goals.
- Analytics of all data and information in order to analyze the existing state and identify the possibilities for new business promotions.
- Automating of business processes by eliminating manual work along with improvement of quality and reduction of costs.
- Optimizing people, the system and means and their coordination and integration.

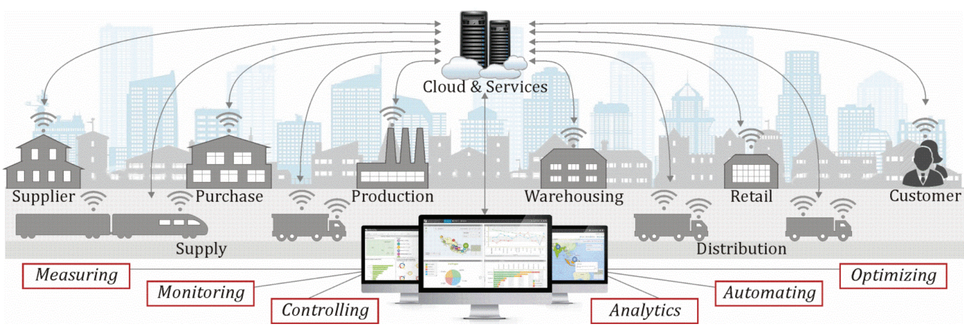

Fig. 2. IoT in Logistics

5. CONCLUSION

This paper describes the IoT concept which will bring great changes in all fields in the near future. According to research on contemporary ICT, this technology is the leading from the aspect of development and future implementation (www.gartner.com, 2015). Intensive efforts are being made worldwide for the development of a unique communication network, standard and protocol which will enable connectivity of all smart objects. The open questions for this concept refer to the security of data and privacy protection.

IoT can be applied to all segments of life and business, but the greatest application and effects are expected in the field of logistics. When all transport and reloading means, equipment, goods, logistic units, individual packaging, objects, positions in objects and devices become smart, when a virtual model of the physical world is developed and IoT services provided to all users, logistics will get a new dimension. IoT will enable the formation of an intelligent network of smart objects between which there is a horizontal and vertical integration along the supply chain.

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