INTERNET OF THINGS (IOT) SOLUTIONS IN SMART TRANSPORTATION MANAGEMENT

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Abstract

To overcome very common problems of the supply chain and transportation management such as uncertainty, cost and complexity, smart transportation management paired with the Internet of Things (IoT) gives one of the plausible solutions for processing lots of data, monitoring products and vehicles.

This paper is based on the analysis of a usage of IoT in transportation management, in terms of increasing delivery productivity and improving supply chain performance. The advantages and disadvantages of using embedded Internet technology in transportation management to become smart transportation, as well as capabilities for IoT network security and energy efficiency, are presented. The technical characteristics will be described and compared with technologies used in transportation management. Developing smart transportation management enables companies to collect and analyse lots of data, hence big data management will be discussed in combination with IoT and artificial intelligence (AI), where AI is in charge of data preparation in supply chain management and its usage in smart transportation management.

Key words: Internet of things, smart transportation management, network security and privacy, big data

1. INTRODUCTION

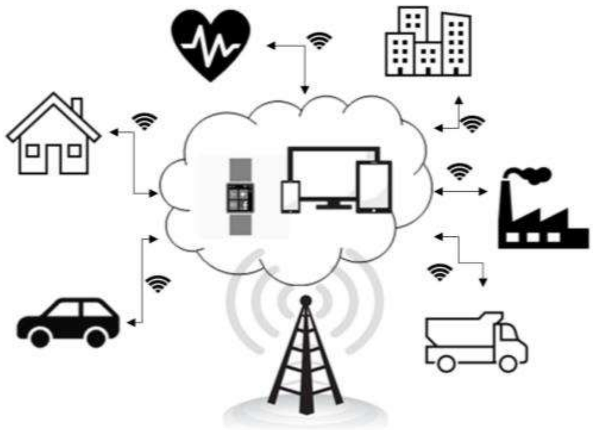
Supply chain participants must act in an integrated way to meet modern market requirements, in particular the satisfaction of the end customer. Supply chain management is a complex process that involves the connection of different partners daily, requiring effective communication, cooperation, risk management and acceptance of fast changes. Information and communication technologies play a key role in increasing supply chain efficiency.

It provides access to relevant information which are needed for planning and performing processes related to the flow of goods, information transfer, financial and human resources. That frees business organizations from routine tasks and improves communication. Technologies like big data, predictive analytics, IoT, supply chain analytics, robotics and autonomous vehicles are being used to help solve modern challenges, including supply chain risk and sustainability. That allows technologies to reach its common goals: making it easier to gather more detailed supply chain data, analyse it and act on it quickly (Rouse, 2019). The connection of different sensors and devices, as well as their ability to collect large amounts of data, became exceptionally useful in helping companies operate their logistics operations more efficiently, concerning to saving money and reducing redundancies.

According to (Stankovic, 2014; Wortmann & Flüchter, 2015) the IoT connects objects to the Internet to exchange information and communicate through the information communication protocols.

Today, a vast number of devices have the possibility to be a part of the IoT, thus enabling them to form a complete interconnected system (such as smart houses, smart health, smart towns etc.), as presented on Figure 1.

Figure 1. The IoT general concept



Source: authors

For the IoT, intelligent learning, fast deployment, best information understanding and interpreting, against fraud and malicious attack, and privacy protection are essential requirements (Chen et al., 2014). According to (LTXSolution, 2018) the IoT is the wave of the future with regards to transportation management. Analysts predict that 75% of new cars will feature the IoT connectivity and in the shipping and logistics sector, connectivity could reach as high as 90% to the end of

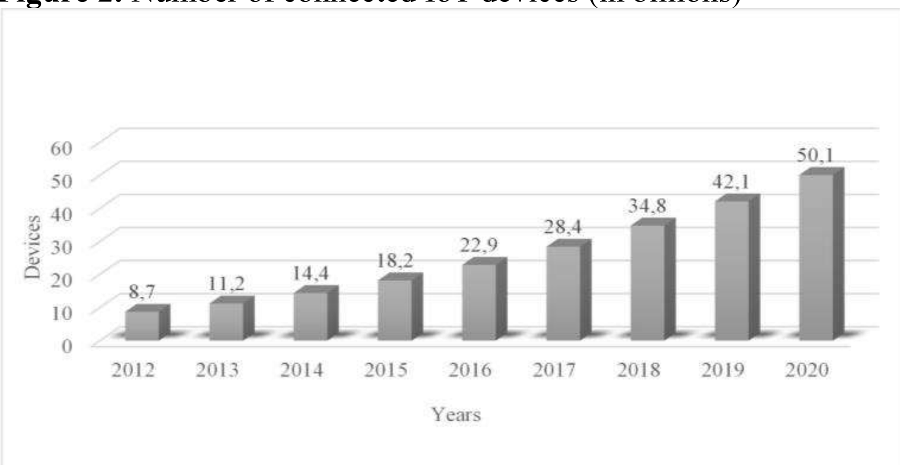
2020. Guided by the above information and the assumption that the IoT solutions in smart transportation management have to be more researched, this paper is based on secondary data extracted from books, scientific and professional papers. The methods of classification, deduction, analysis and synthesis were used. By using IoT application examples, we will point to the contribution of its implementation in transportation management. A special emphasis will be paid to the existing technologies used for IoT implementation in transportation management, delivery productivity and improving supply chain performance. The paper will describe the IoT architecture and technical characteristics, keeping in mind the security of transportation and logistics, but also it will point out the various possible ideas for IoT implementation in transportation management.

This paper is organized as follows. In Section 2, a general overview of the internet of things purpose, its Architecture and its Protocols is presented. Section 3 provides usage analysis of the internet of things (IoT) in transportation management, whereas Section 4 provides the analysis of the IoT in Intelligent transportation industry. Section 5 concludes the paper with suggestions for further research.

2. THE INTERNET OF THINGS: GENERAL PURPOSE

Developing devices and services in agriculture, industry, household, markets, transportation, etc. and their connection to the internet is the main idea of the IoT. The IoT is a technology in a global network of connected "things" and used to communicate with each other and exchange information through the information devices with agreed protocols. The IoT devices depend on the properties of network connection - availability, speed, reliability. Because of the main idea of the IoT, that provides a comfortable life, and realizes successful outcomes of the work better than humans, the number of the IoT devices are increasing daily, as shown on Figure 2. According to (Yaqoob et al., 2017) the IoT taxonomy is based on applications, enabling technologies, network topologies, IoT platform architecture types, architectural requirements and business objectives.

Figure 2. Number of connected IoT devices (in billions)



Source: Authors, based on (Burhan et al., 2018)

2.1. General Architecture of the IoT

Because of interconnecting more than billions of objects through the Internet, it is needed for a flexible layered architecture.

In recent literature, various models of the architecture have been proposed. This paper shows the IoT technology which includes five main layers which are a more applicable model for the IoT applications (Ben-Daya et al., 2019; Manoj Kumar & Dash, 2017; Tuwanut & Kraijak, 2016; Al-Fuqaha et al., 2015; Yaqoob et al., 2017):

1. *The Sensors, or Objects Layer, or Perception Layer* - represents the physical sensors to collect, process and send the information to the monitoring system. This layer includes sensors and actuators for data collections such as radio frequency identification (RFID), Zigbee, QR code, Infrared, etc.
2. *The Network layer, or Communication layer* - is based on secure transfers of confidential information from sensor devices to the central information processing. Communication is carried out through 3G/4G/5G, UMTS, Wi-Fi, WiMAX, RFID, Infrared, Satellite, etc. It depends on the type of sensor devices.
3. *Service, or middleware layer* - it is a service-oriented software layer that includes service management and has the capability to process the information and allows software developers to communicate with various devices.
4. *Application layer* - enable interactions between devices with each other and to provide smart services to meet customers' needs. The application layer includes applications such as a smart postal, smart car, smart home, smart transportation, etc., which can present data, identify problems and suggest solutions.
5. *Business layer* - it includes high-level analysis and reports, i.e. it handles control mechanisms of accessing data from the application layer. It consolidates the overall the IoT services and system activities. The main aim of this layer is to build a business model, graphs, etc., to support decision-making processes based on Big Data analysis, compare the outputs with expected output to enhance services and maintain users' privacy.

Smart transportation of goods or people is based on the five-layer architecture of the IoT.

The IoT elements are to be affiliated and proper usage is:

1. Identification – it is important to assign the correct name and address of the identification of each smart device in the network, because of the ability to control and access remote devices. The name of the devices assigned by two different base methods of matching the name of the devices are EPC (electronic product codes) and uCode (ubiquitous codes) (Al-Fuqaha et al., 2015). Addressing smart devices is critical to assign unique smart devices for communication. IPv4, IPv6 and 6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks) provide unique addresses. Often, IPv6 is used because it uses large address spaces, 128-bit number addressing schemes (Burhan et al., 2018).
2. Sensing - represents the processes of collecting information from smart devices sent to the storage media such as data warehouse, database (remote or local), or cloud (Burhan et al., 2018; Al-Fuqaha et al., 2015). The gathered data are analysed and used for specific actions based on required services (Zhu et al., 2015).

The sensors used for these processes are humidity and temperature sensors, wearable sensing devices, mobile phones, etc. (Zhu et al., 2015).

3. Communication - the gathered data are sent to the storage media through the communication technologies and protocols: RFID (radio frequency identification), NFC (near field communication), WSN (wireless sensor network), Wi-Fi, Bluetooth, IEEE 802.15.4, Z-wave, LTE-advanced, UWB (ultra-wide bandwidth). Which technologies are used depends on the communication range of devices (Al-Fuqaha et al., 2015; Zhu et al., 2015; Tiwary et al., 2018).

4. Computation - essential concept of the computational ability of the IoT is to remove unnecessary information collected from devices through sensors. Various hardware processing units (e.g. microprocessors, microcontrollers, FPGAs), hardware platforms (e.g. Arduino, UDOO, FriendlyARM, Intel Galileo, Raspberry PI, Gadgeteer), software platforms (RTOS (real-time operating systems), TinyOS, LiteOS, RiotOs) for the IoT environments are developed. Additionally, cloud platforms are developed for computational parts of the IoT. (Al-Fuqaha et al., 2015; Zhu et al., 2015)

5. Services - application layer requires detailed information from sensors layer which gets service layer through the communication layer (Manoj Kumar & Dash, 2017). In recent literature different IoT services are categorized under four classes (Al-Fuqaha et al., 2015; Burhan et al., 2018):

a) Identity-related services - identification of objects that have sent the request.
b) Information Aggregation - purpose is to collect the information from objects.
c) Collaborative-Aware - according to collected data makes decisions and sends responses to the devices.
d) Ubiquitous - amenable to provide Collaborative-Aware services to anyone immediately without the time and place sternness.

6. Semantic - facilitate to extract knowledge and get all information to make appropriate decisions to provide the required services. Semantic IoT includes discovering and using resources, modelling information, recognizing, and analysing data. Semantic IoT commonly is based on web technologies: RDF (Resource Description Framework), OWL (Web Ontology Language), EXI (efficient XML interchange). (Al-Fuqaha et al., 2015; Zhu et al., 2015; Burhan et al., 2018)

2.2. The IoT Protocols

As the IoT aims to connect various objects or things to each other, they are using different communication protocols (Rahman & Shah, 2016). The IoT uses a new technology called “connectivity for anything”, i.e. connecting anything, anytime, and anywhere. The IoT communication protocols can be categorized to Low-Power Wireless Area Network (LPWAN), and short-range network (Al-Sarawi et al., 2017; Naik, 2018). Various objects, such as sensors and devices with machine-to-machine applications, consume low power batteries to allow low-power wireless devices to communicate. Such IoT technologies are designed by SigFox and Cellular (Al-Sarawi et al., 2017; Rahman & Shah, 2016). The commonly used standard in the IoT communication protocols is 6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks). It is a network protocol, which allows direct connection to the Internet and plays a major role in the IoT wireless communication after IPv6. The sensor network standards based on IEEE 802.15.4 standard, which works on low power, over a short distance and with low data rates is ZigBee. Other representatives of the group of short-range network protocols are BLE (Bluetooth smart), RFID, NFC and Z-Wave (Al-Sarawi et al., 2017).

3. USAGE ANALYSIS OF THE IoT IN TRANSPORTATION MANAGEMENT

According to (Manoj Kumar & Dash, 2017), transportation is facing a lot of problems in terms of security, accountability, service reliability, conveniences, issues in navigation, the cost for service etc., and they have direct impact on the development activity of transportation sector.

Generally, usage of the IoT application in the transportation sector is very wide:

- exact monitoring and presentation of information in real-time,
- resources tracking and traceability used for fulfilling supply chain related to activities,
- increasing the visibility of the functioning of transport and supply chain in general,
- modernization of business processes,
- regulatory compliance and business transparency,
- reducing operating costs, increasing the efficiency and profitability of the supply chain.

Tracking in-transit visibility and inventory is how several companies have initially deployed IoT logistics technologies. With the IoT logistics technology, it becomes possible to know where the goods are in real time. From a visibility perspective, using sensors on pallets allows companies to track and trace products once they are on trucks heading to their destinations. These sensors collect and send location information to dispatchers via cloud-based fleet management systems that can be distributed to the companies shipping the goods, as well as to their customers (Stankovic, 2014). Knowledge related to delivery can optimize a stock of goods. In addition to the delivery time, having an insight into where groups of products are with the level of the pallet and the truck load are also helpful information for customers when planning their truck unloading time.

In terms of warehousing and inventory of goods, the selling companies should have an obligation to have a real-time insight into their purchaser’s inventory so they can take necessary action to quickly deliver the products to the right place. Companies utilize radio frequency identification (RFID) and the Global Positioning System (GPS) to track assets as they move from point to point. Nowadays, not only they just put RFID chips in pallets, but they also use various integrated IoT logistics devices. It enables them to share data about environmental factors, such as weather information. Also, if sensitive items are transported, different sensors can help by warning if the conditions are inadequate for transport. For example, it is possible to measure the conditions inside the truck, such as the temperature, humidity, light conditions, etc. Hence, potential problems could be predicted on the time what minimizes possible damage. This is especially important for food distribution. Additionally, by using the IoT, other important information can be provided to the companies, such as when a product is to be shipped and how long it will take to get to the retailer. The collected information may indicate how fresh the product is, and if it ever was exposed to unacceptable conditions for that food product.

As well, the IoT enables companies an insight into what is happening with their vehicles. A connected vehicle can alert a dispatcher if it has been idling in one place for too long, which could mean it has broken down or that someone is tampering with it or its contents. Generally, intelligent transportation implies traffic state notification and perception, traffic control and guidance, vehicle scheduling and positioning, remote vehicle service and monitoring and also road and vehicle coordination. It is used equally in the transport of people and goods. So, the related installation of the IoT infrastructures are fundamental support for quality usage of that kind of technologies.

According to (Anand et al., 2015), the integration of sensors and communication technologies provides a way for us to track the changing status of an object through the Internet. The IoT is our present and future in which a variety of physical objects and devices around us, such as various sensors, RFID tags, GPS devices, and mobile devices are associated to the Internet and allows these objects and devices to connect, cooperate, and communicate within social, environmental, and user contexts to reach common goals. The summary of the capabilities of the IoT applications according to transportation management, considering the guidance and navigation control systems of the vehicles (road transport, air transport, water transport) is given by Table 1.

Table 16. Capabilities of the IoT applications according transportation management

Location sensing and sharing location information	• **Mobile asset tracking**: track and monitor the status of commodity using the position-sensing device and communication function installed on the commodity. • **Fleet management**: can schedule the vehicles and drivers based on the business requirements and the real-time position information collected by the vehicles. • **Traffic information system**: can get traffic information such as road traffic conditions and congested locations by tracking the location information of a large number of vehicles by assisting the driver to choose the most efficient route. • **Monitoring the fuel range** of the vehicle and nearest fuel station based on the fuel price and proximity. This system creates a fuel station map from which the user can have better decisions to choose the nearest one without wasting much time for searching it.
Environment sensing	• **Environment detection**: the IoT systems offer environmental and ecological monitoring. • **Remote medical monitoring**: the IoT can analyse the recurring indicator data collected from the device placed on drivers' body. It is especially important for indicating driver illness and it can provide the users health advice if it is necessary.

Remote Controlling	• **Appliance control**: remotely controlling operating status of appliances through the IoT system. • **Disaster recovery**: users can remotely start disasters treatment facilities to minimize losses caused by disasters according to the monitoring mentioned before.
Ad Hoc Networking	• Self-organized networking and the possibility of interoperating with the network/service layer to provide related services. (for example, in the vehicle network, in order to transfer the data, the network between vehicles and/or road infrastructures can be rapidly self-organized) • It helps in managing the imports and exports of materials and goods and it also offers a live and integrative services for monitoring the delivery status indicating the location using geographic information system (GIS) mapping.
Secure Communication	• The IoT system can establish secure data transmission channel between the application or service platform and IoT terminals based on service requirements. • The IoT can help run internal diagnostics on trucks to alert to maintenance issues much earlier than the truck itself can even know. This allows for a safer drive while also increasing the lifetime value of the vehicle. • Self-driving trucks can react to incidents much faster than a human can, and they are even able to predict (and avoid) potential accidents before they occur.

Source: authors, based on (Chen et al., 2014; Manoj Kumar & Dash, 2017; Weis et al., 2017; LTXSolution, 2018)

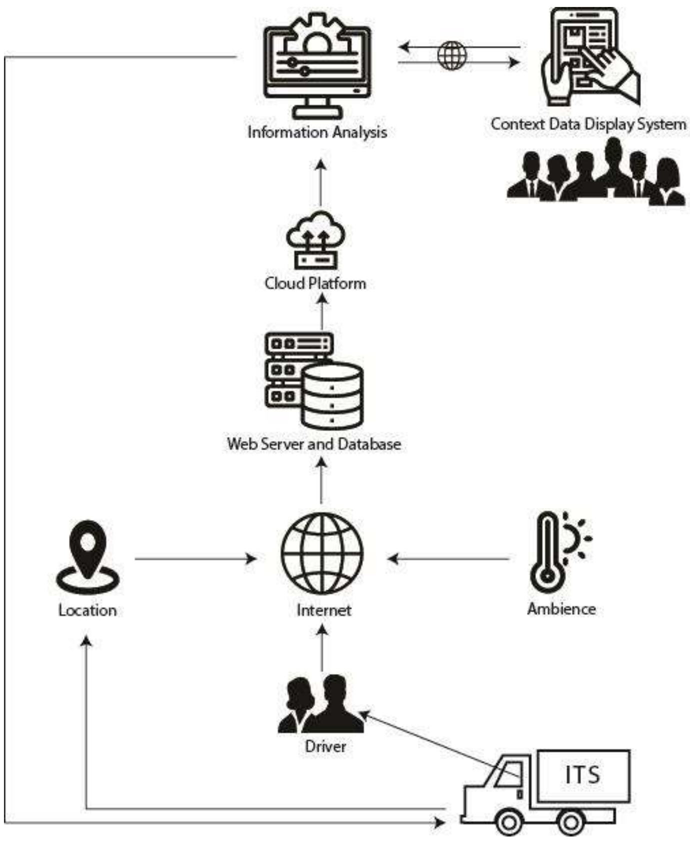
According to the facts presented in the table above, it can be noticed that the IoT implementation in transport has achieved a significant intellectualization of the supply chain. It is especially worth mentioning its enabled visualization using smart devices and technologies such as computers, chips and sensors, and all supported by the Internet. Communication and the creation of trust among suppliers and consumers are becoming easier. The possibility of rapid innovation and advanced decision-making processes are the aspects affected by IoT in all segments of economic activities, including the transportation of goods.

4. THE IoT IN INTELLIGENT TRANSPORTATION INDUSTRY

The Intelligent transportation industry has been recognized as one of the industries with the greatest potential to achieve success by utilizing the industrialization of the IoT in the practice. The industrialization of the IoT will vigorously promote the great development of the intelligent transportation industry (ITI) in China (Chen et al., 2014). Artificial intelligence (AI) is important in the IoT in ITS, helping the connected “thing”, which could be a vehicle or inventory system, make smarter decisions. Many efforts have been done in scope of smart cities, where emerging technologies, such as blockchain technology and artificial intelligence, has many complimentary characteristics such as trust free, automation, decentralization, democracy and security (Singh et al., 2020).

The possible system architecture should be created considering the sensing, monitoring and displaying systems. As the Internet is crucial for the IoT systems, all leans to it when thinking of system architecture. Multiple sensors connected in this system produce raw data, which will be stored in a central database as shown in Figure 3.

Figure 3. System Architecture



Source: Authors, based on (Bojan et al., 2014)

This raw information flow is constant, creating a big amount of data that should be carefully monitored, analysed, and then used as meaningful context with appropriate semantics. Nevertheless, this system should have a security protection protocol with proposed actions that are taken automatically by the system. The goal is that the end user is able to receive all relevant information in user friendly graphical user interface (GUI) but also to ensure object to object communication.

Sensors network is a group of small electronic devices located in the vehicle with the main purpose to collect data about various information in ITS, such as information about the vehicle, the goods that are transferred in the vehicle, microclimate etc. Sensors, actuators, and controllers (also called Sentrollers) are installed inside truck storage, to monitor the quality of goods transferred ensuring that the ambience conditions are always optimal. In crucial situations, like if the cooler truck temperature is above normal, the driver should be informed to stop the vehicle and inspect the cooler truck, where sensors and controllers communicate directly, overriding cloud storage.

As all information gathered by sentrollers are to be transferred elsewhere, communication between all devices is very important. Information about the cargo can be transferred to a central server over various wireless networks, like 3G/4G, while information about vehicle location can also combine different communication technologies, such as satellite network and wireless network.

The goal is to provide real-time and on-demand services to customers; therefore, security should also be kept in mind when constructing such an environment. A low security level of vehicular data clouds is unacceptable due to transportation safety and possible malicious attacks. Interconnected IoT devices have fewer storage capabilities and lower computing power, due to which they become an ideal target for hackers. The integration of the IoT and Blockchain technologies improves transportation and logistics by providing several benefits, including smart pay, better fault tolerance, real-time information sharing, privacy, and security. According to literature (Humayun et al., 2020), they propose a layered framework BCTLF (BlockChain for smart Transportation and Logistic Framework) that integrates IoT and Blockchain in transportation and logistics to make it efficient and resilient against several security attacks.

Real case scenario could be that roadside attackers may send false information where the driver needs to stop the vehicle and inspect the goods, where his life could also be in danger. Nevertheless, many drivers are not satisfied with the possibility their vehicle locations can be tracked or monitored due to the worries about their privacy. So, security authentication in technology terms must be ensured as well as efforts in law and firm regulations for vehicular data clouds.

As all data collected by sentrollers interflows in databases located in the cloud, so effective operations on big data must be incorporated, i.e. AI and machine learning (ML) could give us “smart” data, semantically connected with the ability to predict issues that could cause irreversible damage. Data clouds contain a variety of heterogeneous data and information resources, but to ensure right semantics, data mining service must be developed to quickly detect important information. Dangerous road situations, problems with the cargo or vehicle itself must be promptly detected and early warning messages should be issued to assist drivers to make informed decisions to prevent accidents. The core of any data mining service is the data mining models (Anand et al., 2015). In (Anand et al., 2015) they propose using the two modified data mining models (Naive Bayes Classifier and Logistic Regression Classifier) to cluster and classify the real car warranty and maintenance data, which they collected from a local automobile company.

Information Processing System (IPS) is the “brain” of the system. It converts the raw data, collected by the sensors, into context data, so meaningful information is extracted with appropriate semantics. In above mentioned crucial situations, IPS has the functionality to trigger some events automatically inside the cargo compartment and provide information to the truck driver.

5. CONCLUSION

Integrating the IoT technology in transportation system gives many benefits: optimizing distance to be travelled by the vehicles, avoiding traffic or stalling implies reducing the fuel consumptions. It is important to save the environment and make better profits. Optimizing or diverting the routes is also important in dangerous conditions. Operating and providing services based on the demands with the assistance of centrally controlled network. It improves the quality of life of drivers because they do not have to deal with the paperwork, and they can spend fewer hours on the road getting to their destinations. Improving public safety through the control of traffic based on the vehicle count. The flow of material, goods and people can be effectively monitored. Provides higher profits for companies, especially for logistics and transport are the main business by increasing delivery productivity and improving supply chain performance. It increases the transparency of the transportation process, which consumers appreciate.

Internet security, which concerns every networked environment, is a major issue for the IoT. Indeed, both it is the IoT side and cloud side are vulnerable to a number of attacks. In the IoT context, encryption can ensure data confidentiality and integrity.

A study which is done in this paper about the IoT usage in transportation management can help for further research about opportunities and benefits that it could give and make transportation more effective, productive, and profitable. For supporting the enormous number of smart devices expected in the future, the key requirements are developing IoT architectures. The possible future directions of research are resource control, energy awareness, quality of service, interface management and security. As data is distributed through the information-communication technology, possible future research in this field would engage in numerous data security of the transportation system.

6. REFERENCES

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M. & Ayyash, M. (2015). *Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications*. IEEE Communications Surveys and Tutorials. 17 (4). p.p. 2347–2376.

Al-Sarawi, S., Anbar, M., Alieyan, K. & Alzubaidi, M. (2017). *Internet of Things (IoT) communication protocols: Review*. In: *ICIT 2017 - 8th International Conference on Information Technology, Proceedings*. 20 October 2017, Institute of Electrical and Electronics Engineers Inc., p. 685–690.

Anand, T., Banupriya, K., Deebika, M. & Anusiya, A. (2015). *Intelligent transportation systems using iot service for vehicular data cloud*. International Journal for Innovative Research in Science and Technology. 2 (2). p.p. 80–86. [available at: https://www.academia.edu/download/40851891/IJIRSTV2I2055.pdf , accessed: June 10, 2020].

Ben-Daya, M., Hassini, E. & Bahroun, Z. (2019). *Internet of things and supply chain management: a literature review*. *International Journal of Production Research*. 57

(15–16) p.p. 4719–4742.

Bojan, T., Kumar, U. & Bojan, V. (2014). *An internet of things based intelligent transportation system*. In: *2014 IEEE International Conference on Vehicular Electronics and Safety, ICVES 2014*. 2014, Institute of Electrical and Electronics Engineers Inc., p. 174–179.

Burhan, M., Rehman, R., Khan, B. & Kim, B.-S. (2018). *IoT Elements, Layered Architectures and Security Issues: A Comprehensive Survey*. Sensors. 18 (9). p.p. 2796. [available at: http://www.mdpi.com/1424-8220/18/9/2796 , accessed: June 9, 2020].

Chen, S., Xu, H., Liu, D., Hu, B. & Wang, H. (2014). *A vision of IoT: Applications, challenges, and opportunities with China Perspective*. *IEEE Internet of Things Journal*. 1 (4) p.p. 349–359.

Humayun, M., Jhanjhi, N., Hamid, B. & Ahmed, G. (2020). *Emerging Smart Logistics and Transportation Using IoT and Blockchain*. IEEE Internet of Things Magazine. 3 (2). p.p. 58–62.

LTXSolution (2018). *How AI and IoT Can Change Transportation Management – Redwood Logistics : Redwood Logistics*. 2018. [available at: https://www.redwoodlogistics.com/how-ai-and-iot-can-change-transportation-management/ , accessed: June 10, 2020].

Manoj Kumar, N. & Dash, A. (2017). *The Internet of Things: An Opportunity for Transportation and Logistics Blockchain applications for sustainability and resilience View project Water based photovoltaic systems (WPVS): Floating and Submerged PV View project The Internet of Things: An Oppor*. In: *Proceedings of the International Conference on Inventive Computing and Informatics*. 2017, p. 194–197. [available at: https://www.researchgate.net/publication/321242420 ,.

Naik, N. (2018). *LPWAN Technologies for iot systems: choice between ultra narrow band and spread spectrum*. In: *4th IEEE International Symposium on Systems Engineering, ISSE 2018 - Proceedings*. 26 November 2018, Institute of Electrical and Electronics Engineers Inc.

Rahman, R.A. & Shah, B. (2016). *Security analysis of IoT protocols: A focus in CoAP*. In: *2016 3rd MEC International Conference on Big Data and Smart City, ICBDSC 2016*. 26 April 2016, Institute of Electrical and Electronics Engineers Inc., p. 172–178.

Singh, S., Sharma, P.K., Yoon, B., Shojafar, M., Cho, G.H. & Ra, I.H. (2020). *Convergence of blockchain and artificial intelligence in IoT network for the sustainable smart city*. Sustainable Cities and Society. 63. p.p. 102364.

Stankovic, J.A. (2014). *Research directions for the internet of things*. IEEE Internet of Things Journal. 1 (1). p.p. 3–9.

Tiwary, A., Chidar, A., Shrivastava, M., Mahato, M., Chandrol, M.K. & Tripathi, M. (2018). *Internet of Things (IoT): Research, Architectures and Applications*. International Journal on Future Revolution in Computer Science & Communication

Engineering 23 IJFRCSCE. 4 (3). p.p. 23–27. [available at: http://www.ijfrcsce.org , accessed: June 10, 2020].

Tuwanut, P. & Kraijak, S. (2016). *A survey on IoT architectures, protocols, applications, security, privacy, real-world implementation and future trends*. In: 22 March 2016, Institution of Engineering and Technology (IET), p. 6 .-6 .

Weis, A., Strandskov, M., Yelamarthi, K., Aman, M.S. & Abdelgawad, A. (2017). *Rapid deployment of IoT enabled system for automobile fuel range and gas price location*. In: *IEEE International Conference on Electro Information Technology*. 27 September 2017, IEEE Computer Society, p. 452–455.

Wortmann, F. & Flüchter, K. (2015). *Internet of Things: Technology and Value Added*. *Business and Information Systems Engineering*. 57 (3) p.p. 221–224. [available at: https://link.springer.com/article/10.1007/s12599-015-0383-3 , accessed: September 3, 2020].

Yaqoob, I., Ahmed, E., Hashem, I.A.T., Ahmed, A.I.A., Gani, A., Imran, M. & Guizani, M. (2017). *Internet of Things Architecture: Recent Advances, Taxonomy, Requirements, and Open Challenges*. IEEE Wireless Communications. 24 (3). p.p. 10–16.

Zhu, C., Leung, V.C.M., Shu, L. & Ngai, E.C.H. (2015). *Green Internet of Things for Smart World*. IEEE Access. 3. p.p. 2151–2162.