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THE INTERNET OF THINGS IN AGRICULTURE - THE ADVANTAGES AND OPPORTUNITIES

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Abstract

The Internet of Things (IoT) has become increasingly popular in the recent decade. The Internet of Things helps people live and work smarter, as well as gain complete control over their lives. The concept of the IoT went widely into practice in different fields – Infrastructure, Production, Healthcare, Banks, Smart cities, Insurance, Media, Retail, Connected homes / Smart buildings, Agriculture, and many more. Modern agriculture can show its potential and importance by using these innovative technologies. The measuring devices, ensuring the transformation of data for the external environment into machine-readable data, at the same time filling the computing environment with significant information are very important. A wide range of measuring devices is used, from elementary sensors (e.g. temperature, pressure, illumination), consumption meters (e.g. smart meters) to complex integrated measuring systems. Satellites, drones, wireless sensor networks, analytical farming devices systems, farm management systems, big data applied to the farm are very useful and applicable in smart farming. The Internet of Things is a huge opportunity for farmers to monitor their crops and increase productivity, to monitor their livestock, to manage all the processes in their work and to take decisions at the right time. The article analyzes issues related to the modern IoT methods and their usage in general and in the area of agriculture. The main goal is to analyze the current state of IoT and its potential in areas of rural development and agriculture in the Republic of Bulgaria.

Key words: Internet of Things, WSN, M2M, Sensor, Agriculture, Smart Farm, Precision Agriculture

INTRODUCTION

The Internet of Things (IoT) broadly describes a scenario in which vast numbers of objects or organisms are embedded with uniquely identifiable computing devices connected to the internet, enabling them to collect, store, share, and analyze data and be remotely controlled via other internet-connected devices.

The term "Internet of Things" (IoT), introduced in 1999 by Kevin Ashton, a British technology pioneer, the co-founder of Auto-ID Center in the Massachusetts Institute of Technology is becoming more and more important. Upon the opening of the IoT Week event in 2013 with a video message recorded in advance, Ashton insisted on the realization that the IoT was here and now it was a reality. The Internet of Things is not the future, but the present.

IoT was widely applied into practice in different fields – Infrastructure, Production, Healthcare, Banks, Smart cities, Insurance, Media, Retail, Connected homes / Smart buildings, Agriculture and many more (Fig. 1.).

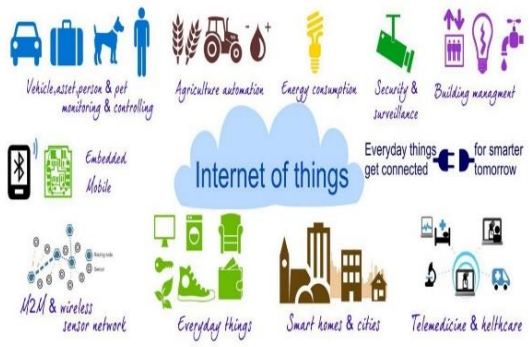

Fig.1. Internet of Things.
Source: www.engineersgallery.com

IoT technology has played a major role in the recent revolution in agriculture, which faces major challenges, including meeting the needs of a growing world population, reducing production costs, and adapting to climate change.

MATERIALS AND METHODS

The article analyzes issues releted to the modern IoT methods and their usage in general and in the area of agriculture. The main goal is to analyze the current state of IoT and its potential in areas of rural development and agriculture in the Republic of Bulgaria.

A small part of Bulgarian farmers is aware of the possibilities of digital technologies in agriculture. A survey conducted in 2018 shows that only 5% of the respondents are familiar with the nature of digital agriculture, 49% are unaware, 27% are partially familiar, and 19% are moderately informed. 86% say they do not use modern digital technology, the rest use only the GPS navigation systems. Only 4% say they intend to invest more than 10% of the funds planned for investment in digitalization, 96% of the respondents plan less money for this purpose or do not intend to engage in digitalization at all. This data is quite alarming. Based on the survey, a draft strategy for the digitalization of agriculture was created to support Bulgarian farmers. (source: http://agroinnovations.bg/)

There are many EU projects that fund the implementation of digital technologies in agriculture in Bulgaria.
(source: https://www.mzh.government.bg/)

The EU has started a €30 million project called "Food & Farm 2020" to assess and improve IoT technologies. In this IoT model, sensors can be deployed in the farm – to the ground, in the water, in vehicles, etc. to collect data. The collected data is stored in the cloud system or a server and accessed by the farmer via the internet or their mobile phones. In some cases, the farmer can remotely control the activities on the farm due to this connectivity.

The Bulgarian farmer must look to the future, to accept these technologies as something that would be extremely useful. **The purpose of the study is to highlight the advantages and opportunities of IoT technologies in agriculture and how they can be applied.**

According to FAO (The Food and Agriculture Organization of the United Nations), the current world population of 7.3 billion is expected to reach **9.7 billion** in 2050, according to the UN. The world will consequently need to produce **70% more food** in 2050 compared to 2006 to feed the growing population of the earth, according to the Food and Agriculture Organization of the UN. (source: http://www.fao.org/e-agriculture/news/why-iot-big-data-smart-farming-are-future-agriculture)

Farmers will need to turn to new technologies to meet the growing demand for food production in the world.

We compared the increase in the global quantities of cereals, vegetables and fruits (Fig.2.). In a recent study a detailed analysis is given (Dimova, 2018).

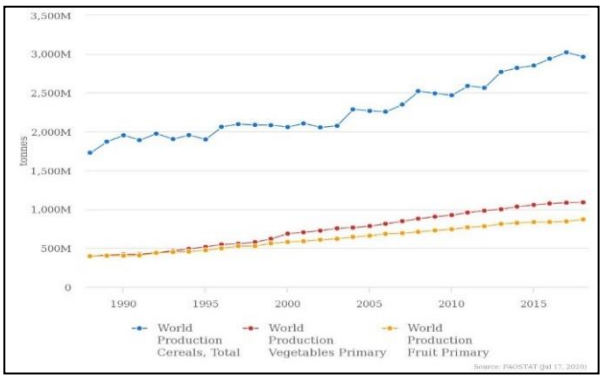

Fig.2. FAOSTAT – World production of Cereals, Vegetables, and Fruits from 1988 – 2018. (source: http://www.fao.org)

According to FAO - the cited study above and (Fig. 2.), we see the enormous rate at which the amount of food for humanity is growing and should increase. To keep up with this rate, the world economy often resorts to genetic modification, which is not the right way in our opinion. That is why here come the new and modern technologies that can deal with this problem. They are the preferred and cheaper option to deal with the growing trend for producing more food worldwide. Our goal is to show how important IoT technologies are in agriculture and how they can be applied. The Republic of Bulgaria, as part of the world, must also pay attention to these technologies and apply them to agriculture.

In our study, we emphasize the nature of IoT and the application in agriculture, examples, advantages, negatives, devices used, and conclusions for Bulgaria.

1. Concept of IoT.

Internet of Things is the internetworking of physical devices that have network connectivity enabling to collect and exchange data between them. The Internet of Things is a huge opportunity for farmers to monitor their crops and increase productivity. Satellites, drones, wireless sensor networks, analytical farming devices systems, farm management systems, big data applied to the farm, and a food management chain are all examples of IoT and smart farming.

IoT uses some of the better-known technologies and combinations of these technologies:

- **M2M(machine-to-machine communication)** is communication Internet of Things infrastructure. It refers to communication technologies that allow embedded computing devices to exchange data with each other via wireless or cable connections without the need for human interaction or activation of communication. M2M communication will enable devices to communicate directly with each other.

- **WSN (Wireless Sensor Network)** refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. WSNs measure environmental conditions like temperature, sound, pollution levels, humidity, wind, and so on. The WSN is built of "nodes" – from a few to several hundred or even thousands, where each node is connected to one (or sometimes several) sensors. WSN sensor nodes consist of microcontrollers, a radio frequency receiver and a transceiver, a power source, and memory.

- **RFID Technology (Radio Frequency Identification Technology)** - in the IoT design, distinctive infinite objects could be a vital issue. Such objects typically mimic the functions of animate things like an observance heart trans-plant or inanimate things like sensors are fixed in the automobile system. The article fitted with RFID chips contains all its info that is shifted and allot with the reader devices throughout the operation, whereas the antenna transmits/receives the radiation from the reader in shut proximity. Then the knowledge data forwarded to the back-end server by the reader for confirming the received information, before any appropriate action is initiated (Hota, 2020).

- **RTS Technology (Real Temperature System Technology)** - At the core of its focus, IoT seeks to tackle adverse environmental conditions like pollution, disaster, and global warming by applying real-time data. The physical objects in the IoT ecosystem display higher levels of awareness of the context for better sensing of the environment, besides enhanced interaction among objects. In such scenarios, objects were shown responding by taking real-time decisions like, for example making safe switching in lanes on roads as well as automatic maneuvering switches in rooms when not occupied (Hota, 2020).

- **CC (Cloud Computing)** is a paradigm in computer technology where a large number of systems are connected in private or public networks to provide a dynamically scalable infrastructure for applications, data, and file storage. With the advent of this technology, the cost of calculations, hosting applications, content, storage, and delivery is significantly reduced. The most appropriate definition of cloud computing is provided by Borko Furht of the Florida Atlantic University, which defines it as "a new style of computing in which dynamically scalable and often virtualized resources are provided as a service over the Internet." The integration of IoT and cloud computing is of great significance (Patil, 2012).

2. Precision agriculture and IoT.

"Precision farming" also known as "smart farming" is a combination of three main elements: **information, technology, and management**. Information is the most valuable resource for farmers. Accurate and timely accurate information is important for all stages of production. The information includes the characteristics of the crops, the properties of the soil, the requirements for the use of fertilizers, the population of weeds, yield data. Modern technology is the second step to success. With the rapid development of new technologies the farmer must keep pace with changes that can bring benefits to production. Specialized software, spreadsheets, databases, geographic information systems (GIS), and other types of application software have long been developed and available on the open market. Information and technology, in return, could support and facilitate management. Intelligent agriculture aims to optimize yields per unit of agricultural land through the most modern means to achieve the best in terms of quality, quantity, and financial return. Precision farming, using several technologies, some of which include GPS services, sensors, and large databases, seeks to optimize yields. The farmer has the opportunity to support decision-making with real-time data that can further provide information on all aspects of agriculture that was not possible before and achieve its main objectives: **increase production efficiency, improve product quality, cost reduction, efficient use of chemicals, energy savings, protection of soil and groundwater,** which are characteristic of any precision agriculture.

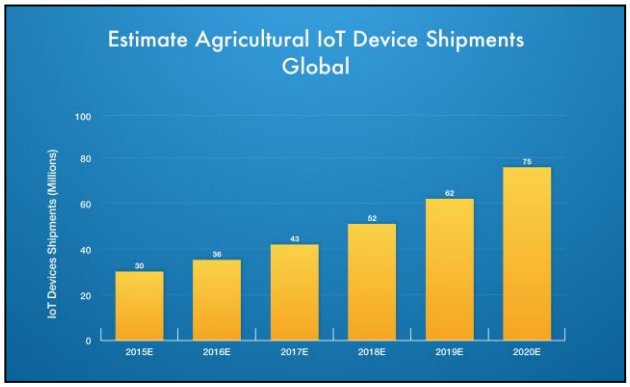

Fig.3. Agricultural IoT device shipments. Source: https://www.cleveroad.com/blog/iot-and-agriculture-what-options-are-there-and-how-to-develop-your-own-smart-farming-solution

The graph (Fig.3.) is showing the shipment growth of IoT devices for agriculture over the years.

3. Prerequisites of IoT Applications in Agriculture:

- Improvement in the use efficiency of inputs (Soil, Water, Fertilizers, Pesticides, etc.)
- Increased business efficiency through process automation
- Reduced cost of production
- Increased profitability
- Sustainability
- Food safety
- Protection of the environment. (Hota, 2012)

4. Different sectors of agriculture in which IoT can be successfully applied:

- **Greenhouses and closed farms** - Sensors have long been used in greenhouses and stables - to monitor humidity, the availability of animal feed, and many other indicators. Connected to centralized systems, field management, and greenhouse sprayers can be done remotely and at any time the day, according to the weather forecasts, optimized for quality and quantity.
- **Pest control** - Pheromones can be extremely effective and useful, especially combined with technologies from the Internet of Things. Wireless sensor networks monitor the number of pests in an area, and when found that the population is too high, the system activates devices for controlled release of pheromones to disrupt pest mating patterns. This minimizes, and in some cases completely replaces the use of pesticides. (source: https://venturebeat.com/2014/12/07/surprise-agriculture-is-doing-more-with-iot-innovation-than-most-other-industries/.)
- **Management of agricultural machinery** - Monitoring important real-time information on critical technical indicators such as engine oil application, operating hours, the battery voltage can save expensive repairs. Collecting and processing GPS information can demonstrate the efficiency of machines and offer solutions to optimize the process of sowing, processing, and harvesting of agricultural products. Using cloud services and information from large data sets, tillage machines can be sent automatically to harvest at the most appropriate time of day, so that cost optimization is achieved.
- **Livestock monitoring** - The cost of raising livestock continues to rise every year. At the same time, the public is also pushing for a more humane treatment of animals as the animals reared humanely produce higher quality meat that is more nutritious. Under pressure to reduce costs and raise their livestock in a more humanely manner, farmers are starting to turn to the Internet of Things technology. For example, farmers can embed internet-connected sensors on their livestock that do not cause discomfort. Using the information from these sensors, farmers can monitor the overall health of the animal by analyzing blood pressure, heart rate, and other parameters. Not only can these sensors help monitor the health of the animal, but also in some cases, GPS technology can also help track the animal's location. Location monitoring can be extremely useful to farmers rearing free-range or pastured livestock, as it would enable farmers to better account for their livestock. (source: https://davra.com/iot-and-agriculture-how-the-internet-of-things-is-changing-agricultural-operations/)

5. Examples of applying IoT in agriculture in the world.

Example 1. An appropriate example of agricultural machinery management is Rowbot, an automated motor vehicle for monitoring and correcting nitrogen levels in soil fields sown with maize. The project was developed in the USA. Worldwide, many acres of corn are grown, a crop that grows very quickly. The rapid growth challenges farmers to provide essential nutrients efficiently - especially nitrogen. Weather plays an important role, as nitrogen is easily lost during heavy rains. Fertilizing at a time when it would be used by a fast-growing crop is most appropriate. The problem for many growers is that a fast-growing crop mixed with

uncertain field conditions leads to a situation where, at the beginning of the seasonal application of nitrogen fertilizers, it cannot always be carried out as planned. Moreover, Rowbot is a vehicle especially designed with large enough tires, at the same time small enough to be able to pass below the basic height of the plants. It "sneaks" between the rows of sown corn, using sensors to monitor nitrogen levels and, if necessary, spreads fertilizers where needed. The machine is controlled remotely using GPS services. (source:https://www.rowbot.com/blog)

Example 2. The Korean Telecom is developing a management system that will improve the current process of managing eel farms using the Internet of Things technology. Based on wireless sensor networks, manufacturers are offered the ability to remotely monitor their aquariums in real-time via smart devices and smartphones. The technology is implemented in a farm that has twenty-six water tanks, each 6m in diameter. To achieve a high-quality production, several indicators in the tanks are monitored at all times, including water temperature, oxygen levels, and water pH. Even the small changes in the environment, such as changes in temperature, lack of oxygen, or water pollution, are fatal to the young generations of eels. The data is sent to cloud systems and after analysis and processing, employees can monitor the levels of indicators and take timely action if necessary. Also, after filling in the reported data on the amount of food and the growth of the production, the system generates significant statistics and information about the production, as well as forecasts expectations for profit and realization.(source:http://telecomdrive.com/iot-helping-sk-telecom-fish-farm-management/)

Example 3. Intelkia, a Spanish start-up focused on projects related to the Internet of Things, has developed a Smart Garden solution based on the Libelium Waspmote sensor platform to optimize the use of resources sustainably and save costs to their customers. The city of Ontinyent in Valencia has been the first municipality in Spain to take advantage of the wireless sensor networks technology applied to green areas projects. The aim of Intelkia has been to develop a technological solution aimed to monitor, measure, and manage conditions and needs of green areas in real-time. Smart Garden is a fully integrated solution that covers different areas: water quality, air quality, soil quality, water flow measurement, controlling irrigation system, and security (Fig. 4).

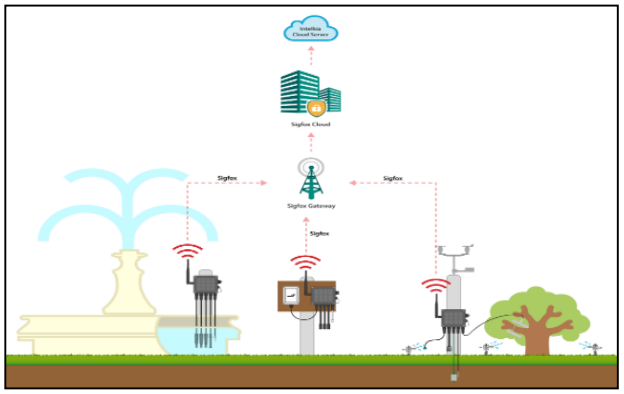

Fig. 4. Spanish smart garden.
Source:https://www.libelium.com/libeliumworld/success-stories/monitoring-green-areas-in-spain-to-develop-a-smart-garden-system/

Example 4. To help food producers cope with the challenges ahead, the Russian company developed a dairy production management service, the Dairy Production Analytics (DPA), supported on the cloud-based analytical service. DPA gives extra information about the environmental conditions to veterinarian teams such as temperature, humidity, pressure, cow health, and other parameters. DPA has been implemented on one farm in Voshazhnikovo in Russia. This smart farm has the capacity of 8000 heads of cattle, 4,500 of which are dairy cows. Before the implementation, it used to produce 125 tons of milk daily, almost 28 liters per cow a day. To improve forecasting performance, DPA collects data with external sources: weather station and sensors by Libelium (temperature, pressure,

wind speed and direction, precipitation, humidity level, illumination), RFID tags, ERP-system, Excel reports and different external data sources to the cloud-based data platform in the farm. As a result, the correlation was found between temperature, nutrition, and even the daily performance of farm workers. DPA found out that if temperature decreased in the farm, the cows' needs for food increased. The system warned the staff about these changes and farmers received notifications by e-mail or SMS. With proper feeding, milk yield has been raised. As a result, Voshazhnikovo smart farm got better results: the savings from feeding 2000 dairy cows were €340,000 for 180 days.

This project is designed to predict herd reproduction, milk production, and animal diseases based on a combination of external and internal factors, statistical data, economic indicators, staff information, and laboratory data. It allows not only for reducing the costs associated with the maintenance of the health of cows, labor and reproduction, but also for completing the strategic tasks of the business: expanding production, opening new units, etc. Three months after implementing DPA, the milk production in Voshazhnikovo Smart Farming increased to 33 liters per cow a day, this is an impressive **18% more** than in the previous months (Fig. 5.).

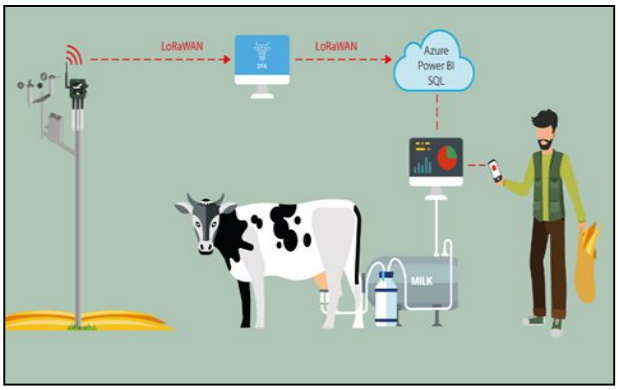

Fig. 5. Smart farm in Russia.
(source: http://www.libelium.com/how-a-dairy-farm-increased-their-milk-production-18-with-iot-and-machine-learning/#!prettyPhoto)

Example 5. The Spanish wine sector faces the problems derived from rural depopulation and global warming. Wineries in numerous countries are starting to develop new IoT technology to face climate change. Several Waspmote Plug & Sense! Smart Agriculture PRO was installed to control the parameters of vineyards: temperature, humidity, atmospheric pressure, soil moisture, soil temperature, weather conditions (wind direction, wind speed, and pluviometry), leaf wetness, solar radiation. This information must be sent to the Microsoft Azure cloud via 4G every 15 minutes. In the cloud, the devices' condition must be managed, and information needs to be available and accessible. Thus, valuable information can be extracted, and this information will help agriculturists so that they can make better strategic decisions based on real data (Fig. 6).

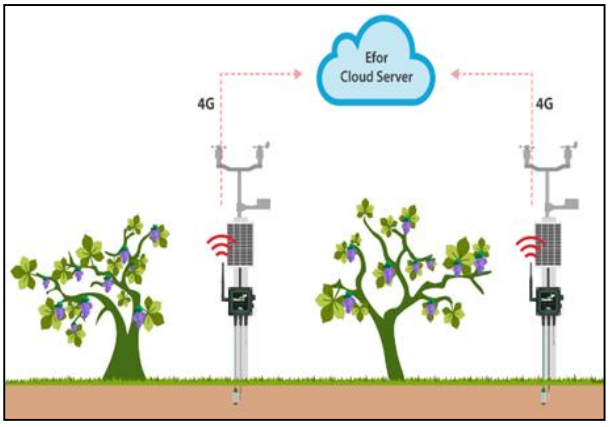

Fig. 6. Spanish Vineyard.
Source:https://www.libelium.com/libeliumworld/success-stories/new-vineyard-project-developed-with-libelium-iot-platform-on-agrotech-the-app-for-crop-management-powered-by-efor-and-ibercaja-on-microsoft-azure/

There are many more examples and they are all successful and working. They show the meaning of using IoT in agriculture along with the experience, results, and efficiency of these modern technologies. It is also important for the Bulgarian farmers.

THE HARDWARE AND THE SOFTWARE

In smart farming, sensors are applied for gathering data from various fields like temperature sensor, Humidity sensor, Soil moisture sensor, Think to speak IoT app, Water motor, and sprinklers. These sensors are well connected with the microcontroller. The microcontroller receives data from the sensors and checks for the threshold values. Then according to the threshold values, it takes the needful action and informs the farmer by sending a message. All the processes are completed by the Wi-Fi module (Kashyap, 2019).

Hardware: To build the agriculture in IoT, we needed to be first selecting the most important things that are the sensors for the device. Moreover, the selections of the sensors are dependent on the different types of requirements, information, and related solutions. **Brain:** The core part of the agricultural production system is data analytics. Therefore, we require an understanding of the capabilities for powerful data analytics. It should be applied in the predictive algorithm and machine learning to get actionable insight based on data. **Maintenance:** The challenges in agricultural IoT products are present in its maintenance. So, the field sensors used in the agriculture grounds can be damaged easily. Therefore, we need to ensure that the hardware devices are robust and easily maintainable. **Mobility:** Mobility issues can be effectively handled if the customization of the farming applications is done before they are used in the field. In this process, data can be easily accessed by the farm managers or executives on the site or remotely by using smartphones or a desktop. (source: https://easternpeak.com/blog/iot-in-agriculture-technology-use-cases-for-smart-farming-and-challenges-to-consider/)

1. **Sensors –** The effective management of agricultural land requires an information collection system that operates quickly and is comprehensive. The remote monitoring is the collection of data from a distance and is a solution for such a system. With the help of the sensors, it is possible to detect important data remotely. There are different kinds of sensors and they are extremely important for the modern precision agriculture – rain sensor, soil temperature sensor, soil moisture sensor, wind speed sensor, sensor for temperature, humidity, and atmospheric pressure, etc.
2. **Drones** - The reason is that drones can easily be monitored and controlled, respectively to keep the plants healthy at a relatively low cost. Farmers can use the many characteristics of drones to ensure that the sowing and planting processes are successful. The drones are equipped with high-resolution cameras that make both 2-D and 3-D images and videos of the farm. The farmer can use the drone for information on the topography of the land, the composition of the soil in different parts of the farm, as well as the distribution of weeds and pests, for spraying crops, for animal surveillance, for security surveillance, etc.
3. **Robots** - Trends show that robots will be widespread in the coming years - both automated field machines and small robots performing tasks such as weeding and harvesting
4. **Arduino** is an open-source electronics **platform** based on easy-to-use hardware and software. Thanks to its simple and accessible user experience, Arduino has been used in thousands of different projects and applications. Arduino also simplifies the process of working with microcontrollers, but it offers some advantages: inexpensive, cross-platform, simple, clear programming environment, open-source and extensible software, and open source and extensible hardware. Arduino is a free access platform consisting of three important components - **hardware, software, and community**. The hardware and software are designed in such a way as to allow a person,

without significant and even no prior knowledge in these areas, to be able to work with these components and quickly and easily implement their projects. Arduino boards can read a variety of input data from a variety of sensors and devices, including messages from a phone or a social network. It can also respond to these input signals, depending on how the microcontroller is programmed. A USB cable and a built-in development environment (IDE) are sufficient for issuing commands, in which a program written in the Arduino programming language can be written, compiled, and uploaded to the board. Since it is distributed as open-source hardware and software under the LGPL/GPL license, its production and distribution are not restricted. Everyone has access to diagrams, drawings, and the source code. There are options for complete self-development and assembly or it could be purchased ready-made, according to needs and capabilities. Arduino IDE - Integrated Development Environment is a set of basic software tools for writing and testing software (Enkov, 2017). In his work, each developer uses a wide range of tools such as text editors, libraries, compilers, and testing platforms. The role of an integrated development environment is to bring them all together in the form of a server, software application or framework depending on the case. Its purpose is to facilitate the work of the programmer and assist in the detection of errors (Enkov, 2015).

In agriculture – a Smart Farming System is a mixture of hardware and software additives. The hardware part includes embedded systems and the software program is developed using the Arduino IDE. The sensors used are a temperature and humidity sensor, soil moisture sensor, etc. The gathered information may be displayed in an Arduino IDE. A GSM module is hooked up to the Arduino to facilitate the messaging service, which updates the farmer's present climatic conditions on the subject - very easy and comfortable for the farmer to collect data and make decisions.

RESULTS AND DISCUSSION

The following conclusions we could suggest: IoT in Bulgaria is still gaining popularity. If we look at the data from the survey, we see that they are worrying that they are indicating that Bulgarian agriculture should move in the direction of new digital technologies. In this article we gave examples from other countries in various fields of agriculture, namely to show how useful IoT can be. Bulgarian farmers will be able to measure temperature, humidity, soil composition; drones and robots can monitor and report data. All this is a great help; cloud services can provide additional benefits in terms of data access, synchronization, storage and even reducing the costs for the farmer.

If we look at the world situation, we notice that the need for all kinds of food is growing and will grow in the future more and more. Bulgaria can participate effectively in this production, namely through IoT. We recommend giving more attention to funds allocated for EU projects that stimulate the development and implementation of digital technologies in agriculture and rural areas. All this is done precisely so that every farmer can benefit from the new technologies and make his work more efficient, precise and well controlled. The purpose of our article was to show the good examples in agriculture that use IoT and explain the hardware that is used. We even paid attention to Arduino, the open source platform that anyone can use freely.

The Bulgarian farmer has the opportunity to support decision-making with real-time data anywhere and anytime, increase production efficiency, improve product quality, make cost reduction, control the use of chemicals, save energy, etc., all of these are the

characteristics of the modern precision agriculture.

CONCLUSION

A few of the recent reports tell that the IoT device installation will see a compound annual growth rate of 20% in the agriculture industry. Moreover, the number of connected devices (agricultural) will grow from 13 million in 2014 to 225 million by 2024. Using IoT can still open doors for the agriculture industry and farmers in Bulgaria by way of implementing these digital technologies in their work to improve the quality, quantity, sustainability, and cost-effectiveness of agricultural production. The advantages and opportunities of the Internet of Things in Bulgarian Agriculture are great, so that the objectives are increasing productivity and minimizing time and human efforts in addition to developing well-functioning smart farms.

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