Application of the IoT technology in agriculture

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Abstract. The article describes the importance of the Internet of Things (IoT) for modern society, and in particular for agriculture. The problems that hinder the successful implementation of the Internet of things in the Russian agricultural sector are revealed. The six-level architecture of the Internet of things is described. The article describes RFID technology, various network technologies. Examples and possible applications of the Internet of things in the Russian agricultural sector are given.

1. IoT application and related issues

The term Internet of Things (IoT) was first coined in 1999 by Kevin Ashton, founder of the Auto-ID research group. IoT is a network of many objects connected through a communication and information infrastructure. IoT is an approach to connecting information received from various sources on any virtual platform or existing Internet infrastructure [1].

According to another definition, the “Internet of things” refers to a global distributed network (or networks) of physical objects that are capable of perceiving or influencing their environment, interacting with each other, other machines or computers [2]. Such “smart” objects can be in a wide range of sizes and applications - from household equipment, industrial robots, cars, trains to items that are present in the everyday life of any person (watches, bracelets, shirts).

IoT can be considered as a "network of networks." Today, IoT consists of weakly interconnected disparate networks, each of which was deployed to solve its specific tasks.

The purpose of IoT is to create an environment in which various smart things can be controlled externally, and data about these things can be processed to accomplish the desired task.

IoT will develop even more rapidly and will cause significant changes in people's lives. It is predicted that by 2022 the number of devices connected to the Internet will grow to 50 billion.

According to various sources [3-5], one of the key factors in the growth of the Russian agricultural industry may be the use of IoT technology. It is expected that by 2022 IoT growth will increase by 17%, more than 500 million sensors will be introduced into the industry by 2025, and more than 2 billion in 2050. Such a breakthrough will provide an economic effect of 470 billion rubles by 2025 by optimizing staff costs, reducing harvest and fuel losses.

The use of "precision farming" technology in agriculture raises productivity on average up to 20% [6]. Such a breakthrough is achieved through the use of smart sensors to diagnose indicators of soil for sowing (moisture, mineralization, temperature), which leads to more accurate planning of sowing dates, optimization of pre-sowing soil treatment, fertilizing, reducing the number of seeds for sowing, the use...
of agricultural chemistry, irrigation. Diagnostics of land for sowing helps to select a crop that will produce the highest yield with the lowest cost for obtaining it [7].

Special sensors are also used in animal husbandry: they monitor livestock behavior, activity during the day, body temperature, and location. The collected data helps to increase production, reduce labor costs and increase the efficiency of the industry as a whole. The companies supplying the sensors are John Deere and Agro-N.

There are a number of problems that hinder the most successful implementation of the Internet of things in Russia:

- **Standards and interoperability.** Devices from different manufacturers use different standards, which complicates their interaction and requires additional gateways to transfer from one form to another.
- **Security and privacy.** There is an increased risk of malware infection at decentralized entry points. In this case, the most vulnerable are low-cost devices.
- **Difficulties in integration.** Currently, the integration and testing of IoT systems based on various platforms, protocols, and APIs is a problem.

The existing Internet architecture, with its TCP / IP protocols, cannot handle a network as large as IoT. Therefore, there is a need for a new open architecture that can send reports on security, quality and class of data services (QoS), as well as can support existing network applications and use open protocols. The Internet of Things cannot be implemented without proper security guarantees. Therefore, data protection and privacy are key tasks for IoT. For the further development of IoT, a number of multilevel security architectures have been proposed, for example, a six-level architecture [3] based on a hierarchical network structure (figure 1):

![Six-level IoT architecture](image)

**Figure 1.** Six-level IoT architecture.

*Encryption level:* this level assigns each object its own unique identifier (ID), which makes it easy to distinguish objects.

*Perception level:* the level of IoT devices at which each object is given a physical meaning. It consists of various types of sensors, such as RFID tags, IR sensors, or other sensor networks that can read object temperature, humidity, speed, location, etc. This level collects useful information about objects from sensors and converts this information into digital signals, which are then transmitted to the network level for further processing.

*Network level:* receives useful information in the form of digital signals from the perception level and transfers it to processing systems presented at the middleware level through communication tools, such as WiFi, Bluetooth, WiMaX, Zigbee, GSM, 3G, using the IPv4, IPv6, MQTT, DDS protocols.
**Middleware level:** It processes information received from sensors using such technologies as cloud computing, global computing, providing direct access to the database in order to record all the necessary information. Using Intelligent Processing Equipment, information is processed, and then a fully automated action is performed based on the results of processing this information.

**Application level:** this level implements IoT applications for all types of industries based on processed data. This level is useful in the large-scale development of the IoT network. Smart homes, smart shipments, smart planet can be connected with IoT.

**Business level:** this layer manages IoT applications and services and is responsible for all IoT related research. It generates different business models for effective business solutions.

2. **IoT technologies**

The following technologies will enable the large-scale development of IoT:

**Radio Frequency Identification (RFID).** RFID is a technology designed to uniquely identify objects. The small size of the tag and its low cost make it possible to integrate the technology into any object. A tag is a microchip transceiver similar to a sticker, which can be either active or passive, depending on the type of application. The active tags have a built-in battery, since they are constantly active and, therefore, constantly emit data signals, while passive tags are activated under certain conditions. Obviously, active tags are more expensive. The RFID system consists of readers and RFID-related tags that generate identification, topographic and other data about the object, activated by generating the corresponding signal. The emitted signals are transmitted to readers using radio waves and then processed to analyze the data depending on the type of application.

There is also another identification technology - a barcode that has the same function as RFID, although RFID is considered more efficient. Being a radio technology, RFID does not require direct visual contact with the reader, while barcode is an optical technology that does not work if the reader is not directly in front of it. Moreover, RFID can trigger various events and can be modified, unlike a barcode.

**Wireless Sensor Network (WSN).** WSN is a network built of several nodes connected to sensors that can capture object data such as temperature, humidity, speed, etc., and then transfer this data to processing equipment. Each sensor is a transceiver having an antenna, a microcontroller and interface circuits, as well as a power source, which can be either a battery or any energy storage device. Also, an additional element can be added to the node to save data.

**Cloud Computing.** The cloud is considered the only technology that can analyze and store all data efficiently. Cloud computing is an intelligent technology in which several servers are connected in one cloud platform in order to share each other’s resources anytime, anywhere. Cloud computing not only unites servers, but also processes and analyzes useful information received from sensors at increased capacities. But the potential of this technology is much higher. Using millions of potential sensors, cloud computing can help the large-scale development of IoT.

**Network technologies.** These technologies are responsible for communication between objects. In order to process data from a huge number of potential devices, a fast and efficient network is needed. For broadband transmission networks, they usually use 3G, 4G, but mobile traffic is very predictable since it began to perform only simple things, such as making calls, sending text messages, etc. However, as humanity enters the modern era of ubiquitous computing, mobile traffic will no longer be so predictable, which necessitates an ultrafast, ultra-efficient fifth-generation wireless system.

**Nanotechnology.** This technology is useful for small versions of connected objects. It can reduce the consumption of the system during the development of devices on the nano-scale, which, in turn, can be used as sensors or as active elements, as well as conventional devices.

**Microelectromechanical Systems Technology (MEMS).** MEMS is a combination of electrical and mechanical components that work together to support certain applications, including perception and activation, that have already been commercially implemented in many areas (converters, accelerometers, etc.). MEMS in combination with nanotechnology is a fairly effective solution for
reproducing the IoT communication system, and also has a number of other advantages, such as reduced sensor sizes, integration of computing devices and an extended frequency range.

Optical technology. The rapid development in the field of optical technologies (for example, Li-Fi and BiDi) makes them promising for the development of IoT. Li-Fi is Visible Light Communication (VLC) technology that provides excellent connectivity over a wide frequency range.

3. IoT scope

There are areas that are completely influenced by the Internet of things: a smart home is the integration of technologies and services through a home network to improve the quality of life; a smart city is an urban region that has advanced infrastructure and communications; smart city environment includes intelligent management of mobility, utilities, buildings; smart enterprise - IoT enterprise solutions are designed to support infrastructure and more versatile industry functionality.

The application of IoT can be divided into three areas: industry (including both agriculture and the agricultural processing industry), ecology and society [9]. Industry also refers to activities related to financial or commercial transactions between companies, organizations and other subjects.

At the moment, the use of IoT to protect the environment is relevant. The article [9] identifies such agroecological problems as pollution and soil quality degradation of agricultural lands; surface and groundwater pollution in areas of intensive agricultural production; emissions from livestock complexes and agricultural machinery; generation and accumulation of agricultural waste.

The solution to these problems is the active use of high technologies in the field of agriculture, for instance, technologies of locally differentiated, adaptive fertilizer application (for example, application of ameliorants using a 10-N sensor) and the use of plant protection products; precision irrigation; Earth remote sensing for real-time monitoring of land and water resources, the use of unmanned aerial vehicles to conduct an accurate analysis of the soil and crops state [10, 11].

The social sphere is connected with the development and integration of society, cities, and people. All these areas are closely interconnected with each other. Areas are divided into sub-areas in which the Internet of things can be used. We can distinguish such areas as transport, healthcare, construction, energy, agriculture, logistics, etc.

IoT in Agriculture has a number of successful applications. For example, in many farms, the Smart Greenhouse technology is used, which provides automatic watering and an effective temperature condition, optimization of the consumption of fertilizers, chemicals, power, control of pests and plant diseases. Information from sensors is processed on a computer with specialized software installed, which is designed to analyze input information and decide on actions that are performed using various kinds of electro-mechanical devices. This technology provides up to 25-30% savings in both labor and material resources in production.

The use of Smart Farm technology (which also uses smart sensors, devices, and monitoring software [12]) can improve animal productivity and product quality. According to experts, automated systems for feeding, milking and controlling the health of livestock and poultry can increase milk yield by 30–40%, and egg production by 20%. [6].

GPS monitoring of vehicles reduces fuel consumption (experts predict a possible reduction of up to 20%), and also provides opportunities for optimizing routes and staff working hours [13].

In Russia, the issue of the safety of raw materials in the process of collecting and moving them is relevant - the relevant sensors can track both the location and weight of the moved raw materials, thereby virtually eliminating the potential for fraud.

The automated IoT “Raw Materials Management” systems are designed to reduce losses (up to 25%) due to non-optimal storage conditions for agricultural products. Special algorithms in real time monitor the condition of products (in particular, the temperature inside the storages, humidity, level of carbon dioxide) and help to decide on the need for the sale or further processing of stored products.

With the use of RFID technology in animal husbandry, the whole range of production and management tasks is solved, from livestock census, monitoring its movement and all current indicators, to vaccination and optimization of breeding work - which usually remains outside the standard IT
solutions of a smart farm, but is easily implemented in RFID solution. Thus, labor costs are significantly reduced, the possibility of errors caused by the human factor is eliminated, information processing is accelerated even in large farms, and the identification of positive and negative heredity is simplified. All this allows to significantly increase the profitability of agricultural enterprises and their competitiveness in the world market. The aspect of food safety is crucial here. Accurate and timely detection of sick animals will not allow infected products to enter the market, preventing epidemics of dangerous diseases.

Thus, the use of IoT in the Russian agro-industrial complex can significantly accelerate and complicate production, while reducing costs and improving the quality of the finished product. Digital integration will lead to organizational changes in business and government, increase the level of education of the rural population, and change many aspects of the interaction of related sectors of the economy.

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