IoT as a high degree of autonomy system

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Abstract. The article describes the need for IoT technology in the study of biologists, for the influence of genomes and microclimate on the degree of yield, for a possible increase in the quality and productivity of products. There is a description of questions regarding environmental problems. It also discusses the issues related to the use of the latest IoT technology in agriculture, shows the main role of the Internet of Things in agriculture, which is to control all important information thanks to the equipment equipped with the latest advanced technologies. And also analyzed the possibilities of introducing IoT technology in the agricultural industry, thanks to which you can easily track the necessary data, such as moisture, soil quality, air temperature, and also shows the possibilities that arise due to the use of remote sensors.

1. Introduction
Computing devices and objects that provide unique opportunities and opportunities for data exchange over a network without human intervention are the IoT system or the Internet of things [1].

Organizations across industries are increasingly using the Internet of Things to improve operational efficiency, better understand customers, improve customer service, improve decision making, and increase business value.

With the advent of super-cheap computer chips and the popularity of wireless networks, everything from small tablets to large airplanes can be transformed into part of an IoT system. Adding sensors to all of this equipment and connecting them to the Internet improves the digital intelligence of conventional devices, allowing them to transmit data in real-time without human intervention. Figure 1 shows how the IoT system works from data collection to analysis. IoT technology makes the structure of the world around us intelligent and flexible, combining two environments: digital and physical.

IoT-based smart agriculture can provide great benefits, including more efficient use of water or optimization of inputs and processing methods.

The concept of the Internet of Things represents billions of physical devices located in different parts of the earth that are connected to the Internet with the ability to collect and exchange data.

IoT is one of the stages in the development of the Internet when there are more devices connected to it than people. The main feature of the Internet of Things is the ability to work autonomously without human intervention.
Some fairly large objects themselves can contain many smaller IoT components, for example, jet engines, which are now equipped with thousands of sensors to collect and transmit data to ensure their efficient operation. On a broader scale, smart city projects are filling an entire territory with sensors that help us understand and control our environment.

![Image](image.png)

**Figure 1.** The principle of operation of the IoT system.

The Internet of Things enables companies to automate processes and reduce labor costs. It also reduces waste and improves service delivery, making the production and delivery of goods less expensive [2].

Thus, the Internet is one of the most important technologies in our daily life, and as more and more companies use the power of connected devices to stay competitive, the Internet of Things will continue to gain attention.

2. **Materials and Methods**

Typically, the IoT is most prevalent in manufacturing, transportation, and utilities that use sensors and other IoT devices. However, it has also found use cases for agriculture, infrastructure, and home automation organizations, leading some organizations to digital transformation.

The Internet of Things brings benefits such as cost savings, time savings, better workflows, and a paperless workflow.

Home automation businesses can use the Internet of Things to monitor and control mechanical and electrical systems in a building. More broadly, smart cities can help citizens reduce waste and energy use.

2.1. **The use of IoT in agriculture**

IoT technology is rapidly spreading across all industries and walks of life. As the world's population continues to grow, food production and agriculture must become more productive and capable of producing higher yields. According to the UN Food and Agriculture Organization, our planet will have to produce 70% more food in 2050 than in 2006. To meet this demand, farmers and agricultural companies will have to push the boundaries of their current practice and seek more innovative solutions.
The situation becomes even more critical when one considers that the previous growth in agricultural production was mainly due to the cultivation of new land. However, at the moment, humanity is already cultivating its best plots of land, and around the world, it is possible to increase the area of agricultural land by no more than 5%. As of the beginning of 2021, technologies are sufficiently developed to increase the yield of agricultural crops from existing land through the use of greenhouses, indoor and vertical cropping systems, and creating ideal conditions for plants with the right amount of nutrients and water, pest control, etc.

New technologies, especially the Internet of Things (IoT), are expected to have the same impact on the future of agriculture as the industrial revolution of the 1800s. Smart farming is a high-tech and efficient method of sustainable farming and food production. IoT smart farming solutions are systems that use sensors to monitor the crop field and automate the irrigation system (temperature, light, moisture, soil moisture, etc.).

Based on IoT technologies, smart farming eliminates the need for farmers and producers to do manual labor and thereby increases efficiency in every possible sense. This allows farmers to minimize waste and increase productivity in a variety of ways, from the amount of fertilizer used to the number of trips that agricultural machines take, as well as the efficient use of resources such as water and electricity. Thanks to IoT applications for smart agriculture, farmers can monitor their fields from anywhere [7, 8].

2.2. Linked agriculture system
Linked agriculture refers to the use of technology to monitor, analyze, manage, control, and ultimately improve key agricultural processes throughout the agricultural cycle: pre-production, production, and post-production. It involves the exchange of data between various devices, ranging from sensors in the field to smartphones in the hands of farmers. To practice connected farming, a farmer must have IoT ecosystems in the field, in farm equipment, in the cloud, and in the office, allowing a 360-degree view of the entire agricultural cycle.

This concept is closely related to IoT in agriculture, which involves collecting data using devices with sensors. For example, devices can sense soil moisture, so farmers can decide whether to irrigate or allow users to check soil nitrogen levels so workers can decide whether to add more fertilizer. Technology is also allowing drone images of crops to be taken to decide whether to use pesticides.

There are four phases of associated agriculture:

- **Data collection.** At this stage, data is collected by several sensor devices installed on drones, equipment, and in the fields. For example, a drone can take pictures to collect information about crop health and soil conditions, map fields, and operate them efficiently.
- **Data transfer.** At this stage, disparate systems from different IoT devices send data to the cloud, platform, or application for further storage and processing. Connectivity is a vital element in connected farming and the methods for sending information from the field to the cloud or app range from Wi-Fi and mobile networks to satellites.
- **Datastore.** For data to be analyzed, it needs to be stored somewhere. In terms of solutions, some offer private, public, or hybrid servers, or more commonly cloud storage [13].
- **Data processing.** Analyze the collected and accumulated big data using machine learning and artificial intelligence algorithms to generate actionable information that will help farmers make decisions, for example, in crop management or yield management. This phase typically occurs on technology-specific platforms or in software applications deployed within a specific connected farm setup [9, 10].

2.3. IoT system architecture
The Internet of Things includes various information and communication technologies that make it work. The IoT architecture shows the connection between various technologies and the principles of their interaction with each other. The Internet of Things includes three main layers (Figure 2).
Figure 2. The architecture of the IoT system.

The tier of things is the lowest tier of the IoT architecture, which consists of smart objects connected to sensors. They collect and process information in real-time for relevant purposes. The development of microprocessors has led to a reduction in the physical size of hardware sensors, allowing them to be used anywhere.

Basically, objects are connected to the gateway in a local or global network, but there are also stand-alone devices that can operate on the basis of networks of cellular operators (using Wi-Fi or Ethernet connections). The gateway itself is a hub that supports a certain standard or protocol that allows you to interact with “Things” [3, 4]. As an example of an IoT system without a gateway, Figure 3 shows an image describing the operation of the GPS tracker.

Figure 3. Scheme of work of a GPS tracker with NB-IoT module.

Based on this, there are devices that do without a gateway, and they have a standard communication interface – they are self-sufficient and to coordinate with the cloud they have enough access to the Internet via wire, GSM/3G/LTE, NB-IoT, WI-Fi, etc.

The sensors, which are characterized by low power consumption and low data rate, create wireless sensor networks (WSN – WirelessSensorNetwork). They are becoming more popular as they can house more battery-powered sensors and cover huge areas. This is achieved through the mesh network topology. An example is the ZigBee standard (IEEE 802.15.4), which is increasingly used in home automation systems using the “Smart Home” method [5, 6, 20].
To solve a wide range of problems in the Internet of Things, it is necessary to ensure that many different technologies and protocols work together. The access network must provide the required value of information transfer in terms of latency, bandwidth, and security, while the gateway layer is designed to connect heterogeneous networks to a single network platform.

The service layer contains a set of information services that can automate technological and business operations in the Internet of Things. At this level of the IoT architecture, there are different types of applications for the respective industries. Applications can be “vertical” if they are specific to a specific industry, or “horizontal” used in different sectors of the economy. Gateways allow users or autonomous systems to connect to IoT infrastructure endpoints through supported communication standards.

A more promising sales method in relations between agricultural producers and participants in the supply chain is the direct sales model. Thanks to it, manufacturers can see end consumers and find out the structure of demand for a particular product. Due to the use of predictive analytics models, it is possible to produce exactly what the consumer needs, and control of food supplies is carried out on the methods of automatic exchange of information between participants in the supply chain and minimal use of the warehouse and logistics infrastructure of wholesale intermediaries.

3. Results and Discussion
The introduction of a model of direct sales of relationships in the value chain for agricultural production (Figure 4), based on IoT technology and an end-to-end automated production system, will allow:

- Reduce prices for basic foodstuffs in the Russian Federation by about half and improve their quality due to the implementation of the direct supply model.
- Based on this, the market for food and agricultural products may grow by half.
- To dramatically increase the automation of the main production processes in agriculture, including small ones, due to which the consumption of digital technologies by agricultural enterprises will increase.

To solve the problems of increasing labor productivity in agriculture by 3-5 in the framework of IoT-based models, you will need:

- To increase the use of mineral fertilizers by 9 times.
- Form qualified jobs in rural areas with good salaries (because of one such job it is possible to create another 10-15 jobs).
- Significantly increase the level of mechanization of the main types of activity in agriculture, which will create a rental market for mechanized equipment and create additional demand for agricultural tractors in Russia.

For the farm, there are various types of technology investments, for example:

1. Investments to improve efficiency (software/robotic systems, computer hardware, sensors, high-precision GPS, etc.). They are invariably offered by well-known equipment manufacturers who have invested heavily in technology and tend to compete in global markets.

2. Investing in services that provide useful information (re-probing, cloud-based decision models, etc.). These services are offered by a wide variety of companies – from global corporations to small technology companies.

3. Investment in agricultural knowledge, which includes the development of effective practices for a particular farm, herd or growing environment (animal feeding, rationalized seeding, pest control, etc.). This type of investment includes the collection of investment data discussed in paragraphs (1) and (2), which are analyzed to provide specific recommendations for the farm. These innovative investments are made locally by consultants who work in partnership with farm managers [11].
Digital services such as remote sensing and decision-making models are highly scalable technologies that typically do not require upfront financial or intellectual inputs from farm owners or managers, but are paid on a rolling basis as they become available. However, effective digitization still requires a farm-specific knowledge base that includes a greater commitment to investment in technology and analytics, and this requires both well-educated farmers and consultants trained in digital farming. Digital agriculture, according to the global ranking of the positive impact of global technologies, takes the leading place in the world. In this way, farming drones dramatically improve the efficiency of precision farming systems by providing field monitoring and timely yield analysis to provide accurate, real-time crop health data across the entire field. This approach avoids making decisions about how to handle fields based on guesswork and guesswork. They allow you to accurately determine the area of the lesion and, if necessary, edit it point by point.

The cost of drones has dropped significantly in recent years, and their reliability and functionality have skyrocketed, making them an extremely lucrative purchase for farmers. The demand for drones in agriculture is expected to increase dramatically in the future. They can be used in the following ways:

- Research and analysis of fields and crops.
- Detailed analysis of fields, identification of weeds, and treatment of specific areas.
- Analysis of the state of crops.
- Observing animals.

They can be equipped with GPS systems, automatic flight planning systems, infrared cameras. With the help of special software, you can receive data in real-time and immediately make management decisions.

Drones provide farmers with a wealth of data about their fields, which they use to increase yields and profits. The data collect information on soil quality, nutrient levels, plant health, and the extent of the fungal attack and other diseases [22, 24, 25].

In the agro-industrial complex, high-tech tools are actively used: course indicators, control systems for the flow of working fluids, agro-navigation complexes. Agricultural drones are the next stage in the development of agricultural management systems [12, 15, 21].

Unmanned aerial vehicles (Figure 5) – equipped with a different number of propellers, which allows you to accurately survey the area, explore a small area of the terrain, perform three-dimensional modeling and spraying. They have a simple design, easy maintenance, reliability, and flight stability. Cons: limited time, low speed, and flight radius [17-19, 23].

The flying wing (airplane type) is the most suitable option for observing large fields. This drone has high aerodynamic characteristics, which can significantly reduce power consumption and increase flight time. However, due to its design features, the drone cannot hover over a certain area and must move all the time. Drones of this type are equipped with an electric or gasoline engine [13, 16, 26].

The purpose of drones in agriculture:

1. Soil field analysis.
   Unmanned aerial vehicles (UAVs) provide data on soil quality and condition. They render soils in 3D. It helps diagnose nutrient and soil composition problems by identifying dead spots.
   Using maps, you can determine the most effective soil care, planting and growing regimes. Continuous monitoring in the field ensures the rational use of water and control of the nutrient content of the soil.
2. Planting crops.
Recently, drone manufacturers have begun to master not only field observation and processing, but also planting seeds. This method is very recent and is still under development. Using specially programmed UAVs, companies are experimenting with sowing seeds and researching the cost and effectiveness of the method. A small device is used for planting seeds, which can lift 25 kg of seeds, herbicides or fertilizers. This allows you to reduce the time you personally spend planting your plants. This technology is applicable to many types of farms and reduces labor and fuel costs.

3. Spraying fields.
To ensure a good harvest, you need to constantly fertilize and spray the fields. Currently, the processing is carried out using vehicles that are expensive to maintain and consume a lot of fuel. Using drones for spraying is much safer and more economical. Drones can operate autonomously and be programmed to fly according to a schedule and a specific route.

4. Irrigation.
Irrigation is a rather complicated process. Irrigation structures can stretch for many kilometers. With the help of drones equipped with thermal imaging cameras, it is possible to identify irrigation problems, where there will be an excess, and where there is a lack of moisture. By gathering information about the irrigation system, you can use the most efficient crop planting patterns, improve water drainage, and avoid stagnation and water accumulation.

5. Monitoring fields.
Simplicity, speed, and efficiency are the main advantages of drones designed for the complete analysis of crops. You can use photos from airplanes, helicopters, or satellites, but this is very expensive and no one guarantees good quality photos. However, with the help of a drone, it is realistic to monitor the field at any time, weather permitting. Pictures can be taken in real-time and a chronology of the life of the field, showing the growth of plants. Using sensors that create near-infrared (NIR) images, crop health can be judged by light absorption, allowing a comprehensive assessment of the health of the farm.

4. Conclusion
Summing up, I would like to note that this article touches upon the main problems related to agriculture and analyzes the possibilities provided by IoT technology to solve problems, such as grain harvest, loss of production due to inadequate care or delivery to the point of delivery – problems that in fact entail serious financial problems.

The importance of the development of innovative technologies in the field of communication networks and the importance of the need to integrate all systems into a single whole for more efficient automation are noted. Methods for introducing IoT into agriculture and the effectiveness of such consequences are described. The analysis of the main problems that can have a significant impact on the implementation of this technology in agro-industrial complexes is carried out.

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