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STRUCTURE, NETWORK PROTOCOLS OF THE INTERNET OF THINGS FOR QUALITY PRODUCTION CONTROL

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The subject of research is the model and structure of the Internet of things (IoT) network for product quality control in industry and agriculture. The purpose of the article is to analyze communication protocols and structures of IoT networks. The method of analysis and structural design of IoT networks is applied. The field of application is automation of monitoring products of enterprises of the aerospace industry. The article provides an overview and analysis of existing IoT technology; it considers the protocols and composition of IoT networks, and provides variations in the structures of building such networks. 4 levels of IoT architecture are described, as well as the communication protocols are used. The directions of building the Internet of things network for product quality control are defined. A multi-agent model of such system is presented, for the implementation of which the structure of the IoT network is given.

The structure of a multi-agent system (MAS) for monitoring product quality in industry and agriculture includes many agents, such as product quality agents, communication agents, database agents, agents for analyzing information received from sensor agents, and decision-making agents. This MAS implements functions to ensure the required class of product quality and it is based on building a local network of the Internet of things. The research proposes an algorithm for processing information in such an IoT network. Analyzers (sensors) product qualities will be periodically polled and their values will be recorded in the server database. The decision-making subsystem sends data on product quality compliance to the enterprise administrator on a mobile device. The server structure is implemented using cloud IoT platforms, for which a brief overview is provided. The one IoT network implementation is developed using LTE NB-IoT technology. This approach can be used in the aerospace industry for product quality control within automation 4.0.

Keyword: IoT network model and structure, monitoring the products quality of aerospace enterprises.

СТРУКТУРА, СЕТЕВЫЕ ПРОТОКОЛЫ СЕТИ ИНТЕРНЕТА ВЕЩЕЙ ДЛЯ КОНТРОЛЯ КАЧЕСТВА ПРОДУКЦИИ

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Предметом исследований является модель и структура сети Интернета вещей (ИВ) для контроля качества продукции в промышленности и сельском хозяйстве. Цель статьи – проанализировать протоколы коммуникации и структуры сетей ИВ. Применен метод анализа и структурного проектирования сетей ИВ. Областью применения является автоматизация мониторинга продукции предприятий аэрокосмической отрасли. В статье приведен обзор и анализ существующих технологий ИВ, рассмотрены протоколы и состав сетей ИВ, приведены вариации структур построения сети ИВ. Дано описание 4 уровней архитектур, а также использующихся протоколов связи. Определены направления построения сети ИВ для контроля качества продукции. Представлена многоагентная модель такой системы, для реализации которой приведена структура сети ИВ.

Структура мультиагентной системы (МАС) для мониторинга качества продукции в промышленности и сельском хозяйстве включает множество агентов, таких как агенты качества продукции, агенты связи, агенты базы данных, агенты анализа информации, полученной от агентов датчиков, агенты принятия решений. Данная МАС реализует функции по обеспечению требуемого класса качества продукции и основана на построении локальной сети ИВ. Предложен алгоритм обработка информации в такой сети IoT. Анализаторы (датчики) качества продукции будут периодически опрашиваться, их значения будут записываться в базу *данных сервера. Подсистема принятия решений будет выдавать данные о соответствии качества продукции администратору предприятия на мобильное устройство. Серверная структура реализуется с использованием облачных платформ интернета вещей, для которых приведен краткий обзор. Реализации сети IoT разрабатывается с использованием технологии LTE NB-IoT. Этот подход может быть использован в аэрокосмической отрасли для контроля качества продукции в рамках автоматизации 4.0.*

Ключевые слова: модель и структура сети интернета вещей, мониторинг качества продукции предприятий аэрокосмической отрасли.

Introduction. Internet of Things (IoT) is a technology that automates input, processing, and optimization based on the obtained values of process characteristics reflected in indicators from industrial and home sensors. IoT technology allows a user to receive data and report on the status of equipment or processes in real time, track the work of industrial and agricultural enterprises [1]. There is a wide range of wireless connection standards available for IoT networks. Each of these standards and protocols has its own strengths and weaknesses [2; 3].

Communication in the IoT network consists of organizing an Internet connection with data storage facilities on a remote server and application software, for integrating wireless sensors and actuators with upper levels (servers, mobile devices). The received information is processed and analyzed using intelligent software in the cloud, that is on a remote multi-access server platform. The use of such cloud technology and services simplifies not only the software, but also the hardware implementation of IoT, deals with the issues of minimizing individual devices and increasing their energy efficiency [4–8].

Analysis of the use of IoT networks in the aerospace industry. Leaders in the aerospace and defense industries must work faster to meet the growing demands of modern reality. This follows from the increase in defense spending, the development of space technologies, and the geopolitical situation [9]. One of the breakthrough technologies in this direction is IoT. Augmented reality in integration with analytical data extracted from IoT data in real time allows developers to apply data analysis technologies where they are needed [9].

The use of IoT technologies in the aerospace industry is advisable in three main areas: using operational data in product development; providing high quality and timely data for maintenance and repair of equipment; optimizing the production process [10]. The approach discussed below can be applied in this industry.

Communication standards in IoT networks. At short distances, IoT networks use such communication standards as Bluetooth, ZigBee, and less popular protocols: Thread, WirelessHART, MiWi, SNAP, and others [2]. All of them use non-licensing bands of the radio frequency spectrum from the so-called ISM band (Industrial, Science, Medical), allocated for the needs of industry, medical equipment and scientific equipment. In practice, this frequency range, taking into account the restrictions adopted for it, is also used for organizing communication channels within cells and clusters of IoT cellular networks. For long distances, Wi-Max and LTE protocols are used (see table).

IoT network structures. IoT communication technologies that enable the exchange of information and management teams are diverse [4]. The 2.4 GHz region is used worldwide for Wi-Fi and other personal LAN protocols. The wireless communication standards used in this area (Bluetooth, ZigBee, Wi-Fi, and several others) have been popular in many areas for several years [3]. Implementation of such solutions is available because there are a large number of chips and complete modules that can be integrated and used in the development of an IoT device.

Most of the standards for short-range wireless communication systems relate to the organization of the so called «personal network» - the one that is built around a user. Such network is sometimes abbreviated as PAN (Personal Area Networks), although other names are common, for example, WLAN (Wireless Local Area Network). PAN is a data transmission network that connects personal electronic devices of one user (phones, pocket personal computers, smartphones, laptops, wireless headsets, and others.). Typically, such networks have a coverage radius of 10 to 30 meters (although in good conditions, all of them can provide a long range of communication).

Communication protocols used in IoT networks

Name of protocols	Transmission rate	Frequency band	Communication range
RFID	424 Kb/s	135 KHz	>50 sm
		13.56 MHz	>50 smм
		866–960 MHz	>3 m
		2.4 GHz	>1.5 m
NFC	106–6780 Kbod	13.56 MHz < 10 sm	13.56 MHz < 10 sm
ZigBee	20/256 Kb/s	900 МГц/ 2.4 ГГц	10 m
Bluetooth	1 Mb/s	2.4 GHz	10 m
BLE	10 Mb/s	2.4 GHz	>10 m
UWB	50 Mb/s	broadband	30 m
Wi-Fi (IEEE 802/11ac)	up to 6.77 Gb/s	2.4/5 GHz	100 m
Mobile networks 3G/4G (LTE)	up to 150 Mb/s	800/900/1800/2400 MHz	More ten Km

Devices for organizing a short-range personal network are sometimes optimized for certain applications using protocols called «application profiles» or using similar identifiers. These protocols are adapted to specific areas: health, sports, control and industrial automation, monitoring of buildings and structures, and others.

For simple point-to-point RF links, higher-level specifications have been developed: protocols for network, transport and even application layers. The final choice of wireless technologies will include software solutions related to the set end goal and the area of use of data from certain end sensors.

The disadvantage is that technologies with different communication protocols in the radio frequency environment are not reliable enough, since several devices use the same frequency spectrum band and interfere with each other.

The Internet of things belongs conceptually to the next generation of networks, so its structure is similar to the well-known four layer of NGN architecture, which includes smart sensors, transport environment, services and applications [1; 7; 8].

Large network sizes in IoT. A number of applications that use IoT networks require long distances from monitoring objects to processing services. Such networks with limited capacity and significant distances belong to the LPWAN class (Low-power Wide-area Network-energy-efficient long-range network) [11]. The areas of application of these networks are as follows: medicine (monitoring and diagnostics of patients at home or away), control of natural resources (water quality, indicators for oil and other minerals), industry and trade (monitoring and control in distributed organizations that occupy large territories), agriculture (condition and location of livestock, product quality, and control in crop production).

LoRaWAN network technology is used to transmit small amounts of information over long distances. The technology was developed for distributed control networks, machine-to-machine interaction (M2M). A network based on this technology is one of the most promising wireless implementations that support collecting information from sensors, devices, and sensors. In various regions, this network uses radio frequencies in the non-licensing range (30-300 MHz), (300 MHz – 3 GHz) and 800–930 MHz.

LoRa technology is more detailed at the physical levels that are the lowest in the network structure from both the LoRa consortium and the IoT technology. At the top levels of the network, the company defines specifications that depend on the implementation location. Information is transmitted via LoRa channels to the gateways to which sensors and devices are connected. IoT devices are connected to cloud or on servers via gateways.

LoRa defines testing and certification requirements for the compatibility of various LoRa devices on the network in order to implement a security policy. To maintain information security in the network in General and information in particular, LoRa technology uses special communication keys: at the network level, and at the level of software applications. This is due to the fact that radio signals are distributed over a large area of the network [11]. Although LoRa technology is relatively new for developers, the latter are offered ready-made chips, individual modules, and a variety of test tools.

Two solutions are good suggestions for developers of IoT networks in the framework of fourth-generation LTE mobile communication technology: the relatively low-speed NB-IoT standard and the faster, but also expensive Cat-M1 standard. This gives flexibility to choose developers. NB-IoT technology is part of GSMA's Mobile IoT initiative and it is more suitable for our implementation.

Platform for Internet of things. IoT platforms are developed by large Internet companies to automate the creation of application projects for IoT networks. These platforms represent a service that manages network deployment, sensors, and transmitted data. IoT network platforms manage hardware and software components, support network security, implement authentication technology, and support user interaction. There are several hundred service providers on the IoT platform market with various offers, ranging from software and hardware to SDKs and APIs [12–14]. The typical composition of many IB platforms includes:

– IoT network gateway for converting the format of transmitted information;

– authentication and sensor management tools, user interfaces;

– cloud service models (infrastructure, platform, etc.)

– use of additional applications.

Models and structure of IoT network for production quality control. We use a multi-agent approach to create a model of IoT network for monitoring production quality for various companies [15]. In this multi-agent structure, we will distinguish a set of agents for production quality sensors, agents for converters, agents for storing quality production indicators, agents for processing production quality indicators to obtain conclusions, agents for monitoring these indicators and conclusions. This multi-agent model is represented by the set:

$$IoT_{ccm} = \{A_{pq}, A_c, A_{mq}, A_{pmq}, A_{dmq}, A_{imq}, M_{Ai}\},$$

where IoT_{ccm} – a IoT network model, A_{pq} – a set of sensor agents (from portable analyzers of production quality), A_c – the set of agents converters (gateways), A_{mq} – agents storage of quality indicators, A_{pmq} – agents of their processing, A_{dmq} –agents to make decisions about the quality of production, A_{imq} – agents interface to display indicators, M_{Ai} – monitoring agents (mobile devices to monitor production quality indices).

Based on this model, the structure of the production quality monitoring system network is developed [16]. It is composed of portable analyzers for production quality of the monitored industry (agricultural) companies. These analyzers usually output the results to a computer or printer via a serial port (avtomatization 3.0). In our structure, these indicators are fed to the gateways-converters. The latter are necessary for converting and transmitting the captured production quality indicators to the cloud environment (CC). Its structure realizes elements of avtomatization 4.0.

In the cloud environment, we use the server that contains databases and knowledge, tools of security, solver, and a notification service. The database stores data received from company, taken quality characteristics by time (number, time of day, checked parameters and others), from different enterprisers. This data is sent to the database. The knowledge base contains rules for evaluating the quality of production. Data and knowledge bases are sent to the solver, which, based on the accepted indicators of the rules for processing quality indicators from the knowledge base, issues solutions for certain quality parameters. These decisions are also recorded in the database. The site serves as a means of displaying captured and obtained results on the quality of production for user.

On each of the mobile devices, specialists installed an application that allows them to display information of interest from the cloud database through the site. On a cloud server a user can install a software system for making decisions about changing the quality production content to improve its characteristics according to the rules from the knowledge base.

Conclusion.

1. The concepts, models, and IoT part show the variation of the architectures of network construction IoT. The research describes 4 levels of IoT architectures, as well as the communication protocols used for IoT networks. It also briefly analyses the use of IoT networks in the aerospace industry.

2. The model of multi-agent system for quality control of production is developed. The structure of the IoT network is proposed, which includes production quality analyzers, gateways and a cloud structure where the server platform is rented. The server database stores the quality indicators of control production. These indicators can be monitored from specialists' mobile devices.

3. The proposed system is realized on IoT platform. The most popular IoT cloud platforms are considered. As a communication network for transmitting information from company sensors to the cloud platform, the 4th generation LTE network with its variant for the IB-NB – IoT network is chosen. This approach can be used in aerospace industry enterprises.

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