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ANALYSIS OF THE ARCHITECTURE AND PROTOCOLS OF THE INTERNET OF THINGS NETWORKS

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ABSTRACT

The article is devoted to the review of the concept of the Internet of Things. The reference model of the Internet of Things is illustrated and described. The architecture is shown, and the technologies and protocols of interaction within the framework of the Internet of Things concept are also described. The state of standardization of the Internet of Things is analyzed. Modern international standards for the Internet of Things platform are also provided. The paper considers the protocols used in the Internet of Things networks that provide interaction between the technology levels, analyzes their features based on the procedures performed with their help.

KEYWORDS: *Internet Of Things, Internet Of Things Reference Model, Internet Of Things Architecture, Technologies, Protocols, Standardization, Qos, Quality Of Service.*

INTRODUCTION

Today, IoT technologies are being actively implemented in all spheres of human life, thereby allowing the use of various devices that make life easier for society as a whole. The concept of the Internet of Things is that by connecting an object to the Internet, the possibilities of virtual and real functioning are combined.

Devices of the Internet of Things for correct and efficient operation must correctly interact with other devices so that the end result can improve the quality of life of citizens. The Internet of Things copes with its goals, using modern computing, radio frequency identification (RFID - Radio Frequency Identification) technologies, a wireless sensor network (WSN - Wireless Sensor Network), short-range communications (NFC - Near Field Communication) and machine-to-machine communications (M2M - Machine-to-Machine). Nevertheless, in the modern world the variety of technologies and devices is growing, and, consequently, new problems of their interaction appear, which leads to the need to develop new standards [1].

Research methods and results obtained:

In accordance with ITU-T (Telecommunication Standardization Sector -

ITU-T, International Telecommunication Union - Telecommunication sector) Y.2060, Internet of Things (Internet of things - IoT) is a global infrastructure for the information society, enabling advanced services connecting (physical and virtual) things based on existing and developing interoperable information and communication technology [2].

The main organizations involved in the standardization and practical implementation of the individual components of the Internet of Things above are involved in many international companies, such as the International Telecommunication Union ITU-T, the European Telecommunication Standards Institute (ETSI), the oneM2M partner project, the 3GPP partner project, the Federal Agency for Technical regulation and metrology (Rosstandart), all of them make a special contribution to the development of standardization of the IoT network and services.

The main decisions in the IoT architecture have already been identified. Therefore, the main problem of the future is the formation and establishment of standards in order to determine a unified regulatory framework for the practical use of the Internet of Things.

There are currently three Global Standards Initiatives (GSI) under the ITU-T consortium, which are listed below:

- Standardization of the Internet of Things;
- Standardization of next generation networks;
- Internet-based television systems.

Consider the IoT-GSI (Internet of Things Global Standards Initiative), a global standardization initiative for the Internet of Things, which created a reference model for the Internet of Things that includes horizontal levels of device operation (Figure 1).

Figure 1. Reference model for the Internet of Things according to ITU-T Y.2060

Today, in the context of NGN (Next - Generation Network) networks, recommendations on IoT have been approved, namely Y.2060 "Overview of the Internet of Things", Y.2063 "Basis of WEB of Things" and Y.2069 "Terms and Definitions of the Internet of Things" ... Consider the IoT reference model in Recommendation Y.2060, which describes four basic horizontal layers (Figure 1):

- IoT application layer;
- upport level for applications and services;
- network layer;
- Device level.

The Internet of Things consists of a set of different devices and technologies that enable the operation of the IoT, and its architecture shows how these components interact with each other. The architecture of the Internet of Things is based on four functional levels (Fig. 2), presented below [3].

1. Application layer. At this level of the IoT architecture, there are various types of applications for the respective industrial sectors and spheres of activity (energy, transport, trade, healthcare, education, business, etc.).

2. Service level. This is where services are created and managed. We can say that at this level a set of information services automates technological and business processes in IoT: support for operational and business activities, processing of analytical information, data storage, information security, etc.

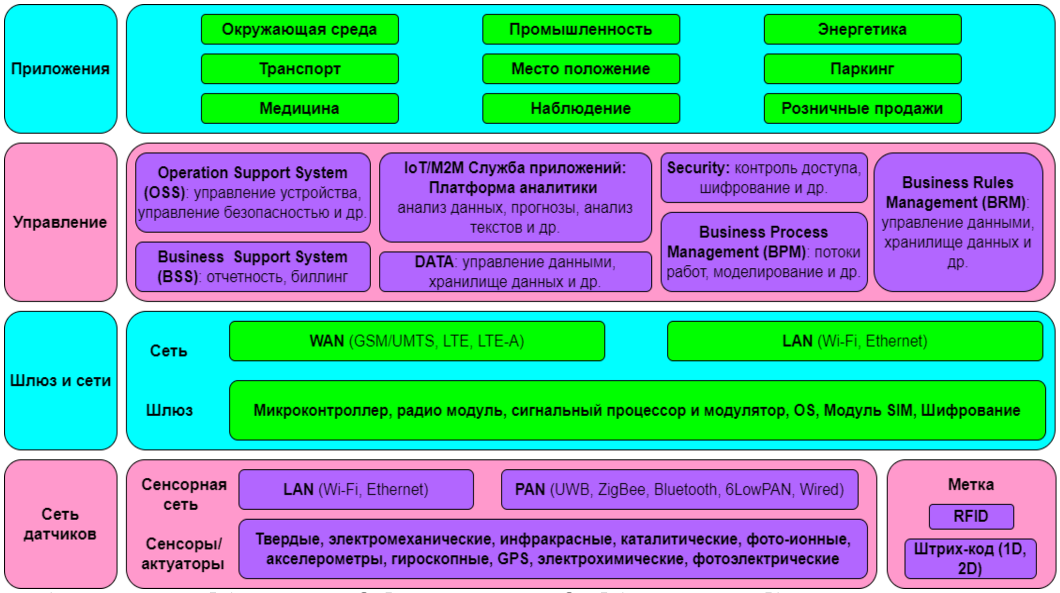

Figure 2. Architecture of the Internet of Things according to ITU-T Y.2060

3. The level of gateways and networks. The huge flow of information from the first layer of the Internet of Things requires a reliable and high-performance wired or wireless network for transport. These networks must conform to the quality of service (QoS). Therefore, we can conclude that one of the important factors is the provision of QoS for the IoT, which is very critical due to the heterogeneity of the network.

4. The level of sensors and sensor networks. This level consists of "smart" (smart) objects, combined with sensors (sensors). With the help of sensors, the process of connecting physical and digital objects takes place, which collect and process information in real time.

If you look into the future, IoT will capture all spheres of activity, while it is important to understand what requirements and characteristics the upcoming IoT systems should have: "self-configuration, self-optimization, self-defense and self-healing", large memory capacity, ample processing capabilities, as well as the ability to reason [4].

The lower level of the architecture of the Internet of Things is based on the following technologies [3]:

Identification tools. In order for an object to be automatically identified, various systems are used, for example, a radio frequency tag that is attached to each object, optical (barcodes, Data Matrix, QR codes), infrared tags, etc., all of them allow to simplify, automate and protect a wide variety of processes. But in order to ensure the reliability and uniqueness of identifiers of different types, it is necessary to work on their standardization.

Measuring. This type of technology makes it possible to process information about the external environment into data suitable for transferring them to means of transformation. These can be as separate sensors for temperature sensitivity, tens sensitivity, moisture sensitivity, illumination, etc.

In the modern world, promising methods of generating energy, alternative to traditional methods, are already widely used, for example, solar energy, geothermal energy, wind energy, biomass energy, etc. In this regard, the issue of introducing autonomous measuring instruments becomes urgent, so as not to waste time and money on recharging batteries or replacing batteries, thus providing power to the sensors.

Data transmission facilities. Wireless and wired technologies are used to transfer information, but taking into account the peculiarities of each of them. In the first case, much attention is paid to improving the reliability of data transmission. The second method is based on the widespread use of data transmission technologies over power lines (PTL), since many objects are connected to power grids.

Data processing facilities. According to Microsoft, the main part of the Internet of Things is cloud systems that provide high bandwidth and provide prompt action in various situations (for example, to be able to calculate from the readings of sensors that no one has been in the house for 10 minutes, and the iron has remained on). Cloud technologies will allow you to cope with huge data flows. Also, it is worth abolishing foggy computing, with the help of which data, their processing and applications are not in the cloud, but in computing centers at the edge of the network, which allows you to be as close to the device as possible. All of this makes fog computing optimal for the Internet of Things. The above, fog and cloud computing have close interaction with each other, which allows them to effectively compensate for each other, for the effective operation of the IoT as a whole.

Actuators are designed to modify digital electrical (command) signals coming from communication networks in various operations that affect the control object. For example, in order to be able to turn on the power supply in the “Smart Home” with the help of modern gadgets, you need a device to which a signal will be sent. In practice, sensors and actuators are combined with each other.

Due to the fact that the IoT architecture at the level of sensors and sensor networks consists of sensors, sensors and actuators, it is important to use the appropriate protocols to ensure the guaranteed exchange of information between:

- devices;
- device and gateway;
- gateway and data center;
- gateway and cloud;
- Data centers.

All this is necessary for the transmission of reliable information to the end user. International organizations such as ITU-T [2], IEEE (Institute of Electrical and Electronic Engineers, Institute of Electrical and Electronic Engineers) [5, 6], ETSI (European Telecommunications Standards Institute) [7], OASIS (Organization for the Advancement of Structured Information Standards, Organization for the Development of Structured Information Standards) [8]; non-governmental associations: oneM2M (Open source implementation of the ETSI M2M standard) [9]; alliances of manufacturers and operators: IERC (European Research Cluster on the Internet of Things) [10], ISO / IEC (International Organization for Standardization, International Electro technical

Commission, International Electro technical Commission) [11] ; partner projects: IoT-A (Internet of Things - Architecture, Internet of Things - Architecture) [2].

In 2020, a group of experts of the International Organization for Standardization (ISO, International Organization for Standardization), in the field of developing standards for the Internet of Things, published three new standards.

The first of these, ISO / IEC 21823-2, includes a framework and interoperability requirements at the transport layer to enable the construction of an IoT platform with data exchange, peer-to-peer connection and continuous communication between IoT systems.

The second is ISO / IEC TR 30164, which provides general definitions, characteristics and technologies for data management, networking, security, hardware and software optimization, and remote computing services for IoT applications. ISO / IEC TR 30166 is the third new standard found its application in the general platform of the Industrial Internet of Things (IIoT, Industrial Internet of Things). It describes the characteristics, technical and functional components [20].

Internet protocols such as Telnet (Teletype network), HTTP (Hyper Text Transfer Protocol), UDP (User Datagram Protocol), SSH (Secure Shell), SNMP (Simple Network Management Protocol), ICMP (Internet Control Message Protocol) have been taken over by IoT applications.

The IEC 60870-5-104 protocol, taken from the industrial Internet network, is used in telematics. This protocol is designed to transmit data of serial binary codes to control and manage geographically distributed processes; it was also used in the Internet of Things. In special cases, protocols are specially designed for low power consumption networks. The positive side for the Internet of Things is the use of existing Internet protocols, an example would be the IPv6 protocol, since this allows you to directly access IoT objects via the Internet [12].

For the implementation of the IoT, it will be advisable to use the classification of IoT protocols according to the zones of their application in the network between the client and the server, such as:

- D2D (device-to-device) - protocols that allow terminal devices to communicate directly;
- D2S (device-to-server) - protocols that are designed to transfer information received from devices to the server infrastructure for data processing;
- S2S (server-to-server) - protocols that allow servers to “communicate” with each other.

A protocol such as MQTT (Message Queue Telemetry Transport), a data exchange protocol for transmitting information from various devices using remote monitoring, is widely used in IoT networks at the application level. MQTT is used for data interchange, i.e. send and receive messages when an interaction occurs between clients that send data (publishers, Publisher) and clients that receive data (subscribers, Subscriber) on the TCP transport layer. This protocol uses fourteen messages based on request and response, through which it is possible to control the sending of messages using three QoS classes.

Another of the most common protocols used by devices and applications of the Internet of Things, which is used at the same level as the MQTT protocol, is the Constrained Application Protocol (CoAP), which is a web transfer protocol that uses the UDP transport protocol.

CoAP is a specialized transport protocol developed by the IETF working group - CORE, built for resource-constrained networks and devices, M2M applications, and more. [14]. CoAP can be defined as an adjunct to HTTP, but with one difference, CoAP is targeted for use in restricted devices.

CoAP uses the following request-response messages: GET - Requests a resource representation; PUT - replaces all current resource representations with the request data; HEAD - requests a resource in the same way as the GET method, but without the response body; POST - used to send entities to a specific resource; DELETE - deletes the specified resource; CONNECT establishes a "tunnel" to a server identified by a resource. User applications use these messages to manage and monitor the resource. At the request of the client, the watch flag is set after the first message is sent, the server continues to respond, allowing them to stream the sensor state changes. [15]

Because the Simple Object Access Protocol (SOAP) uses the Remote Procedure Call (RPC) access mechanism, it is often used in distributed computing and Web services.

SOAP is a protocol for the exchange of structured and free messages in XML (eXtensible Markup Language) format in a distributed computing environment [16]. This protocol uses a basic connection model, which provides a consistent transfer of information from the sender to the receiver, potentially allowing the presence of intermediaries that can process part of the data or add additional components to it [15].

SOAP supports access mechanisms such as SOAP RPC and SOAP Message [16]. The first is SOAP RPC, a simple request-response protocol that builds on a Call object for synchronous remote procedure calls using XML. The second mechanism, SOAP Message, is a protocol for sending and processing SOAP messages that is used for asynchronous communication and implies an immediate or delayed response to a request. This protocol is based on the Message object.

A commonly encountered protocol in IoT is the DDS (Data Distribution Service) protocol, which is designed to provide communication between sensor nodes and sensors. This protocol distributes data between devices [17]. The DDS protocol implements direct bus communication between devices based on a relational data model. DDS implements a multicast system using UDP as its transport. This protocol provides two operations, read and write, using the appropriate classes. Of these, the most elementary is the operation, for this reason the read operation will be described in more detail.

The read operation is deployed to all available devices. As a result of this operation, the information is not deleted from the local DDS cache, and can be read again when certain parameters are requested. Data can be obtained in three ways: [17].

- Polling - the application (usually interval) polls the DDS to receive new data or inform about a state change. The frequency of polling depends on the application and on the message.
- WaitLists (WaitSets) - The application registers waitlists with DDS and waits until one of the incoming events occurs.
- Listeners - the application registers in the DDS (in the classes where the events are characterized) special listener classes that will be informed when these events occur.

I would also like to note the protocols that are used at the data link and transport layers. Ethernet is a networking standard based on the experimental Ethernet Network. The IEEE 802.15.4 protocol is a standard that provides two-way, half-duplex data transmission over low-speed wireless personal networks. NFC (Near Field Communication) is a short-range wireless data transmission technology that enables the exchange of messages between devices that are about 10 cm away.

ANT is a low power consumption wireless sensor communication protocol that operates in a specific frequency range, etc. To control devices, the most often used protocol is CWMP (CPE WAN management protocol) - monitoring by customer premises equipment (CPE) in accordance with the TR-069 specification (Technical report 069), which describes this protocol [15].

CONCLUSION:

In the future, the Internet of Things will be defined not only as objects of “Smart Things”, but also as “Smart Cities” and “Smart Countries”. In this regard, the Internet of Things is a promising concept, which has already received active distribution and popularization [18], but this is a concept about which there is no definite idea, hence many questions arise on the way of its development [19].

The IoT architecture assumes the presence of the following functional levels: sensor network, gateway, control, application. Since the lower layer consists of components such as sensors, sensors, and actuators, there is a need for protocols that allow these devices to communicate with each other and with higher layers. The descriptions of the protocols that were given above show pronounced differences between them, namely the functionality and the need for use. Some of the protocols were introduced into the Internet of Things from other technologies, but the rapid development of this concept leads to the creation of new protocols [19]. Given the intensive penetration of devices, the Internet of Things leads to the need for timely research aimed at studying the quality of service QoS. To ensure that, technical standards, specifications must be developed that define the exchange of information and its processing, as well as the relationship between things.

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