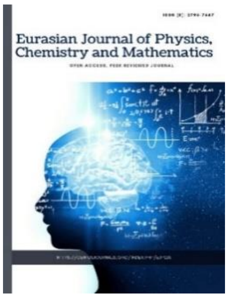

Teaching The Basics Of The Internet Of Things In A Distance Format

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ABSTRACT

The article considers the experience of teaching the basics of the Internet of things in a distance format. The authors describe the chosen approach, the tools used, and the learning outcomes. Simulators such as Wokwi have been used to create virtual models of IoT devices and systems. The process of creating and debugging projects, as well as setting up automation scripts using the Google Colab cloud platform, is described. In conclusion, the authors summarize the results of the experiment and give recommendations for organizing IoT distance learning.

Keywords: *internet of things, IoT, remote format, simulators, Wokwi, MQTT, Python, Google Colab.*

Introduction. Currently, the Internet of Things (IoT) is one of the most promising and rapidly developing technologies. IoT is a network of devices that can collect and exchange data with each other without human intervention. Today, IoT is used in various fields, such as manufacturing, healthcare, transportation, etc. However, despite the growing demand for specialists, learning the basics of IoT can be difficult and require certain knowledge and skills. To master this area of knowledge, deep knowledge in electrical engineering, programming and network technologies is necessary. In this regard, face-to-face study of the subject is the optimal way to learn information. However, in some circumstances, for example, when working or studying remotely, distance learning is more convenient and accessible for students. In addition, distance learning has a number of advantages: flexibility, accessibility, saving time and money, individualization of learning. In this regard, the article discusses the experience of teaching the basics of IoT in a distance format.

To effectively teach the subject "Fundamentals of the Internet of Things" in a distance format, it is necessary to use special online platforms that ensure communication between the teacher and students. The following forms of preparation and delivery of classes are possible: video lectures, online courses, forums and chats for discussing the material, webinars.

Next, we will consider the experience of one of the authors of conducting classes on the subject "Fundamentals of the Internet of Things" in a remote format. To organize video conferences with students, the Yandex Telemost platform [1] was used, for modeling IoT devices - the online simulator Arduino Wokwi [2], to check the connection of the

MQTT client with the cloud broker HiveMQ [3] and to write a bot to control IoT devices - the Google Colab cloud service [4], to exchange text information with students - the Telegram messenger [5].

Educational project in the simulator Wokwi. The most famous Arduino simulator is the online Tinkercad simulator, but unfortunately, some time ago, due to security issues, the developers removed the ability to connect virtual Wi-Fi modules to the Internet. Therefore, the simple and convenient Tinkercad simulator is suitable for distance or face-to-face training in the basics of robotics, but to understand the principles and test the capabilities of network interaction of IoT robotic devices, it is better to use the Wokwi platform.

Wokwi is an online simulator for developing and debugging IoT devices. It allows you to create virtual circuits and test their operation without having to physically connect the devices. Wokwi supports many platforms, such as Arduino, ESP8266, ESP32, STM32, and others. With this simulator, you can create and debug programs in the Arduino language, as well as work with various peripheral devices, such as sensors, displays, keyboards, and others. One of the features of Wokwi is the ability to create circuits in a graphical editor, which makes the development process more convenient and intuitive. This simulator provides the ability to save and load your projects, as well as share them with other users. Wokwi is a free service and does not require the installation of additional software. It is available from any browser and can be used by both beginners and experienced IoT developers.

With the Wokwi simulator, you can create a virtual model of your home and connect all your devices and sensors to it to test and debug the system without having to physically install the hardware. You can also set up automation scenarios and test how they work in real time. This saves time and money on testing and installing hardware in a real home.

Fig. 1 shows the simplest diagram of connecting an ESP32 microprocessor with a Wi-Fi module to an LED and a control program in C++, providing client-server interaction via the MQTT protocol with the HiveMQ cloud broker as a subscriber to wait for a control signal.

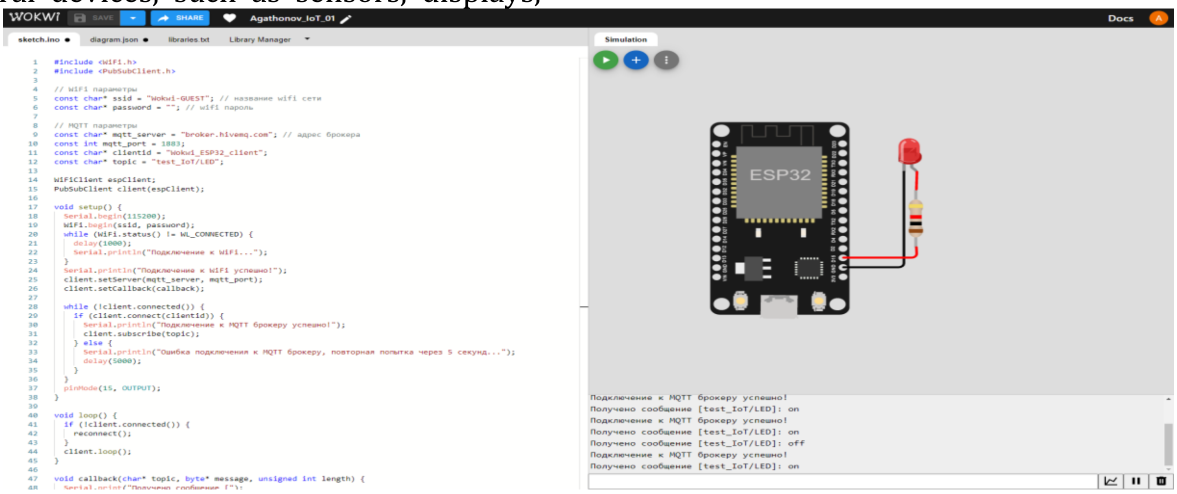

Fig. 1. An example of an educational project to demonstrate the capabilities of interaction between IoT devices via the MQTT protocol, implemented in the Wokwi online simulator. https://wokwi.com/projects/363884918001380353

Testing interaction via MQTT protocol. The MQTT (Message Queuing Telemetry Transport) protocol is a messaging protocol used to exchange data between IoT devices. It is based on the publisher-subscriber model and allows for real-time data transfer with minimal latency and network load. The MQTT protocol works by sending messages to topics to which clients are subscribed, and transmitting these messages only to those clients that have subscribed to the corresponding topics.

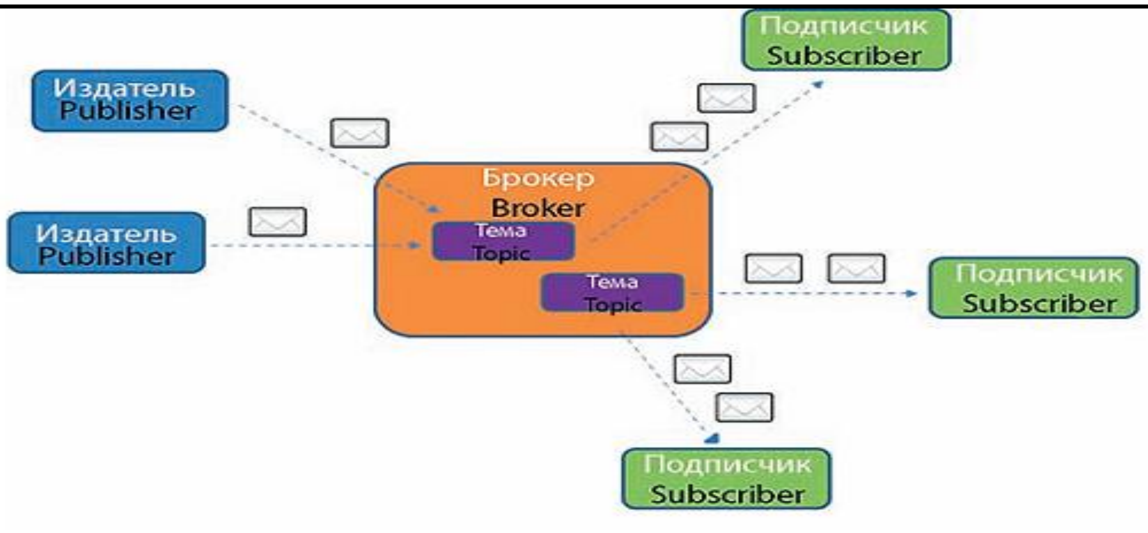

Fig. 2. Model of interaction "publisher-subscriber" of the MQTT protocol from the site http://lib.tssonline.ru/articles2/fix-corp/protokol-mqtt-osobennosti-varianty-primeneniya-osnovnye-protsedury-mqtt-protocol.

Let's present several options for testing the interaction of devices via the MQTT protocol, which were offered to students in distance learning classes on the basics of the Internet of Things.

1) The simplest testing option is based on the use of free cloud clients. For example, the site [3] provides the ability to test the operation of IoT clients via the MQTT protocol via a web interface. To do this, open the site and select the "MQTT Websocket Client" option on the main page. After that, a window will appear where you can enter the data for connecting to the MQTT broker, such as the host, port, username, and password. Then you can select the quality of service (QoS) level and the topic to which the client will subscribe or publish messages.

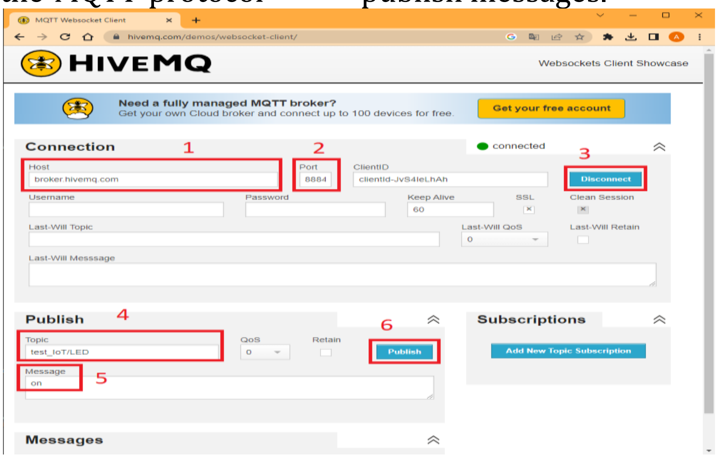

Fig. 3. MQTT client web interface.

Using the web interface, you can send and receive messages, as well as check the operation of the IoT client using the MQTT protocol. This method is simple and convenient for testing and debugging IoT devices and applications that use the MQTT protocol to transfer data.

2) The next test option is to use the Paho library of the Python programming language, which allows you to create and configure an MQTT client and control a virtual IoT device on the Wokwi platform with a few lines of code. For these purposes, it is convenient to use the Google Colab service. Google Colab is a free cloud service provided by Google for performing computing tasks in the Python language. It provides access to computing resources such as processors and graphics accelerators, as well as various libraries and tools for data analysis and

machine learning. Google Colab allows users to create and run interactive notebooks that can be saved and shared with other users.

To test the principle of interaction between IoT clients via the MQTT protocol using Wokwi and Google Colab, you need to create a Python script to send and receive MQTT messages through a broker using the paho-mqtt library, run the project in Wokwi and run the script in Google Colab, make sure that messages are successfully sent and received between MQTT clients via the cloud broker. In this way, you can test the principle of interaction between IoT clients via the MQTT protocol in a virtual environment using Wokwi and Google Colab.

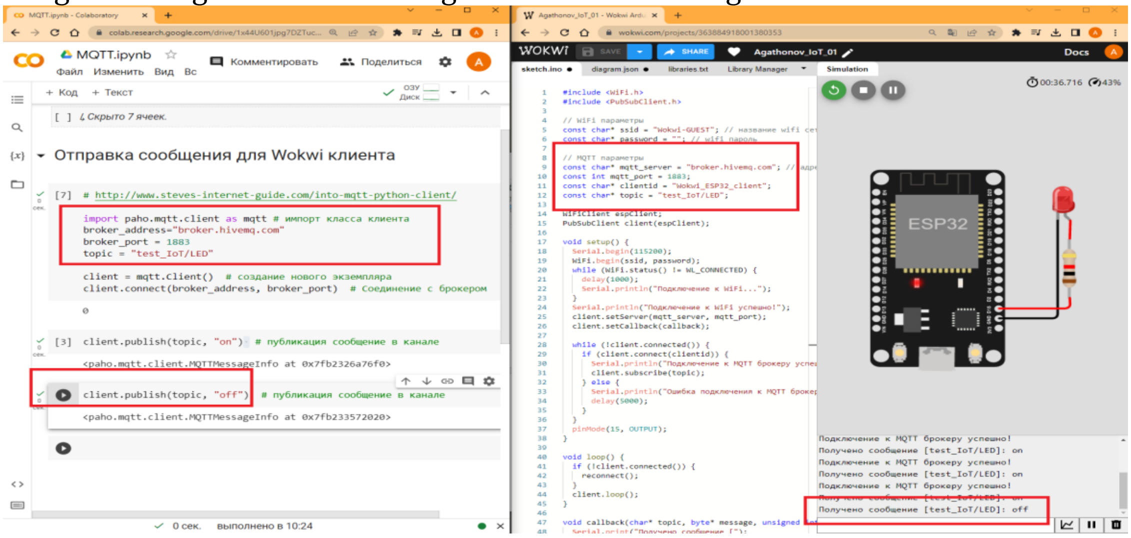

Fig. 4. An example of inter-client interaction via the MQTT protocol to control the operation of a virtual device using the Python library.

3) The last considered test of the operation of IoT devices consists of writing a Telegram bot with support for the MQTT interaction protocol and equipping the bot with the functionality of sending messages to a specific topic to the broker depending on the user's actions. To combine the functionality of the bot and the capabilities of the paho-mqtt library, the Telegram bot must also be written in Python in the Google Colab service.

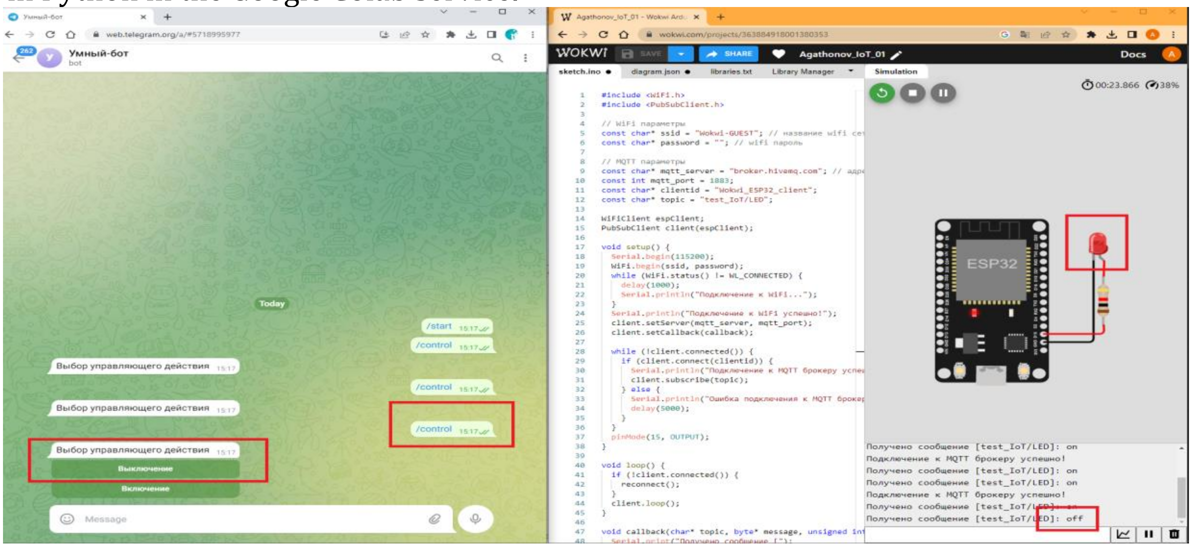

Fig. 5. Managing a virtual IoT device using a Telegram bot.

Conclusion

Thus, it has been shown that the subject "Fundamentals of the Internet of Things" can be effectively taught in a distance format using a number of open cloud services to ensure the formation of practical skills in assembling and programming a network of IoT devices. Details of the educational project can be found in the presentation [6]. In conclusion, let us consider some practical tasks that can be completed with students in a distance format:

Development of a virtual smart home project using various Internet of Things devices: from temperature sensors to lighting control systems and security monitoring.

Design of interaction schemes with sensors, programmable microcontrollers and methods of transferring data to the server.

Creating an interface application for managing Internet of Things devices using programming languages, libraries and frameworks.

Design of a smart street lighting control system that will respond to the environment and be controlled via mobile applications in real time.

Creation of a room climate control system via a mobile application, with the function of data collection and analysis.

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