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MONITORING OF ENVIRONMENT PARAMETERS BASED ON WIRELESS SENSOR NETWORK

The main goal of the article is to design an automated wireless sensor system to monitor environment parameters from different locations. If we want to control our environment, we have to know the measurable parameters of it. These parameters are temperature, humidity, light intensity, etc. All of these measurements can help us to improve the efficiency of home automation systems or to save money. The theoretical part contains an overview of the technologies used for the design of a system. The next part contains an explanation of the software part of the work and the electrical interconnection of the equipment used. The last part is devoted to the cloud environment where the data was collected and visualized.

The article presents the results of scientific-methodological research (description of the problem, task).

Keywords: *sensor network; cloud; wireless communication.*

Fig.: 9. Table: 2. References: 11.

Urgency of the research. Automated data collection and its accessing is a must in modern sensor networks. For the purpose of a solution explanation an example system is proposed. This kind of automated systems are not limited by location only by the power and network connectivity.

Target setting. The main goal of this work is to design and test a wireless data collection system for measurement of light intensity, temperature and humidity from different locations.

The proposed system should document the necessary steps to create such monitoring system, which consists of microcontrollers with wireless communication interface, sensors and the cloud infrastructure to collect and process data.

Actual scientific research and issues analysis. Currently, wireless solutions are becoming the standard for their easy implementation and expansion. In the field of wearable, home and industrial automation we find different communication and data collection solutions. Home automation systems integrates devices from various vendors. All these devices are networked to monitor and control the environment around us in everyday life. By application of sensors to our surroundings we can collect and use the available data. These data allow us to get top of our energy use, optimize our systems and save money [1-3].

There are available cloud infrastructures and services to help us with data visualization and analysis. In our case the Ubidots cloud system was used [2-5]. The cloud support devices as microcontrollers and smart sensors enable to collect, save and process data. The data is not passively collected but also there are functions to interact with the real world [7-8]. Technical progress in this area brings constant innovations. The dominant feature of today automated system is to work autonomously without human control [6-11].

Uninvestigated parts of general matters defining. As wireless communication can be based on different protocols and it is not possible to test them in one study. The following article will focus on Wi-Fi based network devices and their interconnection via cloud system.

The research objective. The objective of the article is to propose an automated system that collects data from different locations and that data can be accessed from any location on the globe with internet connection. This type of technical solution is suitable as a template solution for different parameter measurement in various locations e.g. vibrations, noise, fire, movement, etc. For the technical parameters of used devices, the application shouldn't be placed in harsh industrial environments.

The statement of basic materials. For this task we used the following components:

As we are creating a low-cost wireless monitoring system the ESP32 microcontroller was one of the most suitable for the application. It integrates a low-power system on a chip and also dual-mode Bluetooth and Wi-Fi interfaces. With its Tensilica Xtensa LX6 microprocessor, variations of

ESP32 with dual-core and single-core options, internal or external antenna switches, RF balun, power amplifier, low-noise receive amplifier and other modules are available. In our particular solutions the ESP-WROOM-32 boards were used. These boards have the following specifications:

- dual core processors
- Wi-Fi and Bluetooth interface
- The clock frequency of processor: 240MHz
- Processing memory: 512 kB RAM
- 30 pins, 15 on each side with different programmable functionalities.
- Integrated peripherals: capacitive touch, ADCs, DACs, UART, SPI, I2C
- built-in hall effect sensor and built-in temperature sensor [2-3].

Fig. 1. ESP-WROOM-32

For the purpose of testing and datapoint generation, a combined temperature and humidity sensor, the DHT11 was used. The sensor is based on negative temperature coefficient principle (NTC) to measure temperature. After that an 8-bit microcontroller outputs the values as serial data. Because of the factory calibration it's easy to interface with any microcontrollers, and there are a lot of available example solution for implementation of this sensor.

The measuring range for the temperature is from 0°C to 50°C and humidity from 20 % to 90 %. The accuracy is ±1°C and ±1 %. The resolution for measurements is 16-bit.

Table 1

DHT11 pin-out

1	Vcc	power supply 3.5V to 5.5V
2	Data	Outputs both Temperature and Humidity through serial Data
3	Ground	Connected to the ground of the circuit

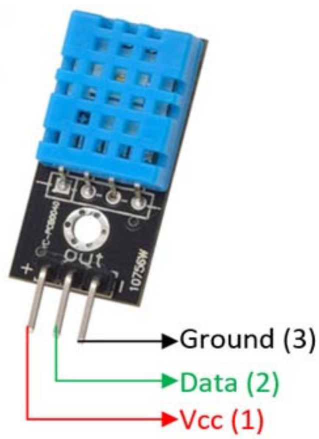


Fig. 2. DHT 11

As we are monitoring household environment we wanted to measure the light intensity. For that purpose, a photoresistor or the Light Dependent Resistor (LDR) was used. These are non-oriented bipolar devices, meaning they can be connected in any direction in the dc circuit. LDRs are used to sense Light. The can be soldered or used on prototyping breadboards. Because of the resistor-like characteristics it's easy to connect them to microcontrollers.

Fig. 3. Photoresistor

A light dependent resistor will change its resistance based on the light intensity around it. Without light source around it, or in a totally dark room it will have high resistance. On the other hand with rising light intensity the resistance will decrease to a few Ohms.

In our system the LDR was connected in a voltage divider to the analog input of the ESP. This means that there was constant current flow trough the photoresistor and a classic resistor, where based on the light intensity the resistance varied. The ESP measured and processed the voltage with its ADC and the processed values were uploaded to the cloud.

The following wiring diagram was created in Fritzing and represents the real electrical connection of the control unit and the sensors. As the power supply and USB cable or power bank was not shown in the diagram below.

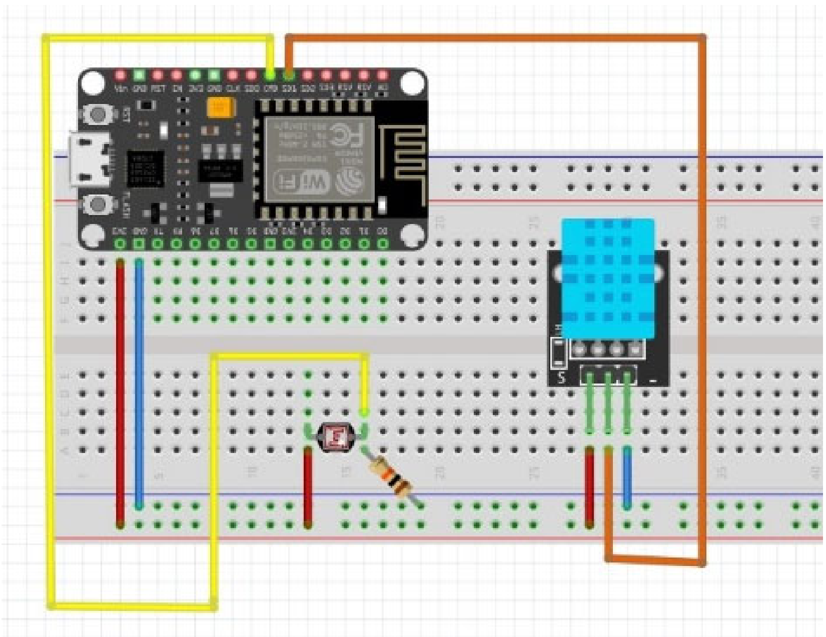


Fig. 4. Wiring diagram

Used method and measured data.

The Ubidots cloud environment offers multiple subscription program, with restriction on number of devices, variables and datapoint uploaded during 24-hour cycle. In our system we used the stem subscription, which is free, but limited to 3 devices, with total of 20 variables. On the cloud platform, it's possible to create multiple dashboards with user like limitations. These dashboards are used to visualize widgets based on the uploaded data, or variable. There are available multiple types of indicators, and calculated numerical tools, e.g. graphs, bar chart, tables, histogram, gauges, pie chart, scatter and others.

Each user has their API key, token to be identified, while the devices use ID numbers. Within a device, there are the variables with API label and ID. These raw values can be processed or downloaded from the backend of the cloud.

All the measurement stations had the same principle of program. The identificators and the variables were defined at the setup part. The loop of data collection and sending was repeated after that. A 10-minute cycle was chosen for measurements and upload because of the datapoint limitations.

A simple flowchart of used code is shown in figure below. Main code is executed in a loop and runs while the ESP is powered on.

The DHT 11 works at 16 Bit resolution and maximal sampling rate 1 second.

The temperature and humidity sensor uses a predefined library which controls if the measurement is successful or not, and in that case we can also create an action to check our device, or to light up a control indicator on the cloud interface.

The measured values are not corrected by any coefficient and not compared to any reference values. This system was a proof of concept and not laboratory accurate measurement system. For home environment monitoring and testing the accuracy is acceptable. The calibration of the sensor should be carried out at laboratory environment with comparison to a professional measuring device. After that the values should be corrected and a separate library for new values would be created. However, the sensor has +- 2°C and 5% accuracies which is more suitable for hobby applications.

The communication is based on Wi-Fi data transfer – 802.11 b/g/n while the newer versions of this microcontroller are updated with IEEE 802.15.4 connectivity as well. The reliability of the connection is based on the Wi-Fi standard. The malfunction of the measuring stations can be monitored and used as a signal on the cloud interface and can be also integrated to the control program of the microcontroller.

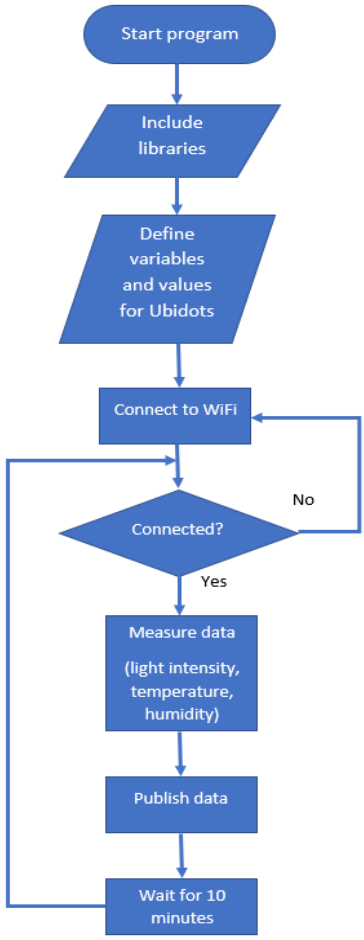


Fig. 5. Flowchart

Cloud platforms and solutions enable the use of remote data centers before building your own IT structure. Thanks to the cloud, the company's employees are not tied to specific workplaces or workstations. The following section compares multiple cloud platform that are available for developers.

Microsoft Azure is an advanced, secure platform from Microsoft that accesses the company's data centers. It integrates tools, pre-built templates, and managed services that accelerate the creation and management of enterprise, mobile, and web applications. It has been designed to handle variable workloads, from small development test projects to global product launches. [29]

Azure provides more than 600 different services that focus on: computing services, mobile services, storage services, database services, messaging, content delivery services, development services, machine learning and more.

Amazon Web Services – AWS is a platform that provides cloud services to individuals, companies and governments on a subscription basis. The technology allows customers to have a set of virtual computers available via the Internet. AWS virtual machines have the same attributes as real computers, they are hardware (CPU, GPU, RAM, storage), optional operating system, networking and various applications. Every single virtual device is also equipped with virtual input / output elements that allow access through a browser from anywhere in the world. The browser works like a window into a virtual device, just as if it were a real computer.

AWS has implemented server "farms" around the world that make services available to customers. The price of individual services is formed by a combination of the use of hardware / software / OS / connection and the required availability, security and use. Like all other cloud platforms, AWS provides services for computing, storage, device connectivity, database systems, analytics, application services, management, development tools and the Internet of Things. The most popular tools are Amazon Elastic Compute Cloud (EC2) and Amazon Simple Storage Service (S3). Most features are not available to end users but are part of developer applications.

Google Cloud Platform is a set of cloud services. It offers the same or very similar services as other suppliers. The most frequently used services include:

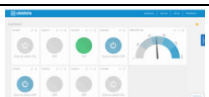
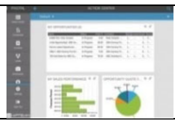
• App Engine - PaaS for accessing applications;
• BigQuery - IaaS designed for large database analyzes;
• Cloud AutoML - a set of tools for machine learning;
• Compute Engine - IaaS providing virtual machines;
• Storage- IaaS storage for online files and objects.

In addition to the intermediaries mentioned above, others are also available, such as: IBM Bluemix, Ubidots Cloud, Thingworx, Pivotal Big Data Suite, olOne, CloudMe, Baidu Cloud, Dropbox, Predix.

In the following table 2 is a comparison of some cloud service providers.

Table 2

Comparison of cloud platforms

	Ubidots Cloud	**Thingworx**	**Pivotal Big Data Suite**	**C3 Energy Managment**
Operation system	Mac, Linux, Windows	Web browser	Windows	
Types	Online	SaaS	Installed	Installed
Op. Field	Healthcare, Oil industry, IT, device developement	Healthcare, Machines,Devices, IT, device developement	Automotive Industry, Telecommunication, IT, device developement	Electronics, embedded systems,Machines, Devices, IT, Diagnostics, Logistics
Price/ Availability	Average/ Amount limited test version	Average/ Time limited test version	Priemerná	Lower price/ No test version
Preview				

Out of the available cloud platform the Ubidots was chosen for testing.

Each of the measuring station has loaded code into the ESP32 and performed measurements for 48hrs. Some of the stations were using powerbanks as a power supply, but it's not compulsory. Electric consumption of ESP32 is low, so it could easily power up the components for the entire time of measurement. Data was sent to UBIDOTS in 10-minute intervals. An example of the measurement station setup is shown on the following figure.

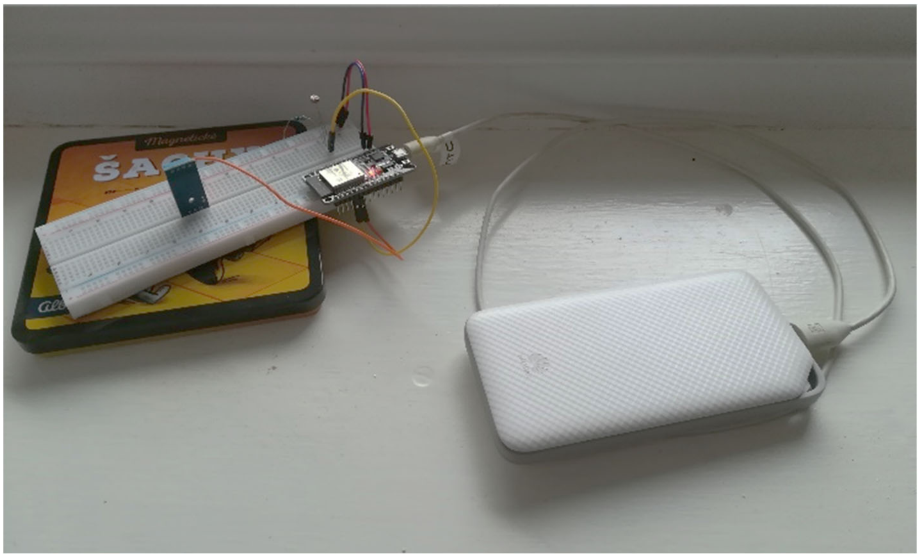


Fig. 6. Measurement station

The data was sent to one UBIDOTS account, with two created devices, and each device was collecting 6 variables – intensity of light, temperature and humidity from two people. This was performed because of the restrictions of the free version of the cloud, it's not possible to create more than 3 devices separately. In the figure below a dashboard from UBIDOTS is created, where graphs are representing the measured data. Each line represents different ESP unit.

Fig. 7. Dashboard in Ubidots

Figures below represent the collected data. This data can exported from Ubidots to .xlsx document, but they are suitable for further evaluating or processing also. There are available tools to indicate limit values, to turn on alarms, or send a report of collected data.

Light intensity

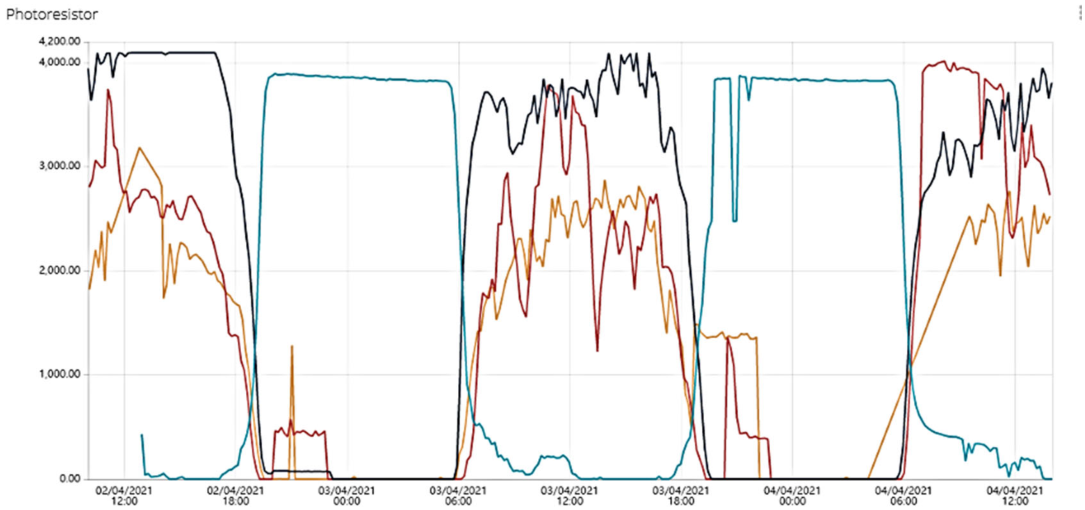


Fig. 8. Light intensity

The highest recorded value was 4095, which is also the limit value, was recorded by several photoresistors in sunny afternoons of monitored days.

Temperature

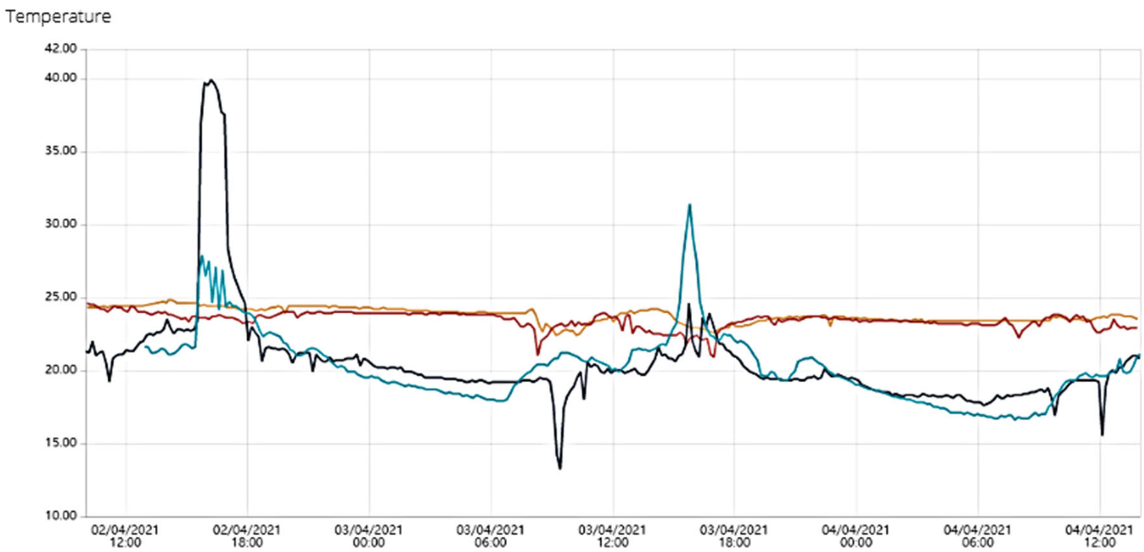


Fig. 9. Temperature

The highest and also the lowest temperature was recorded by the same DHT11. The warmest value was due to direct sunlight onto the measurement unit. The coldest was due to placement of the whole unit, as it was placed on the windowsill and was caused by opened window.

Humidity

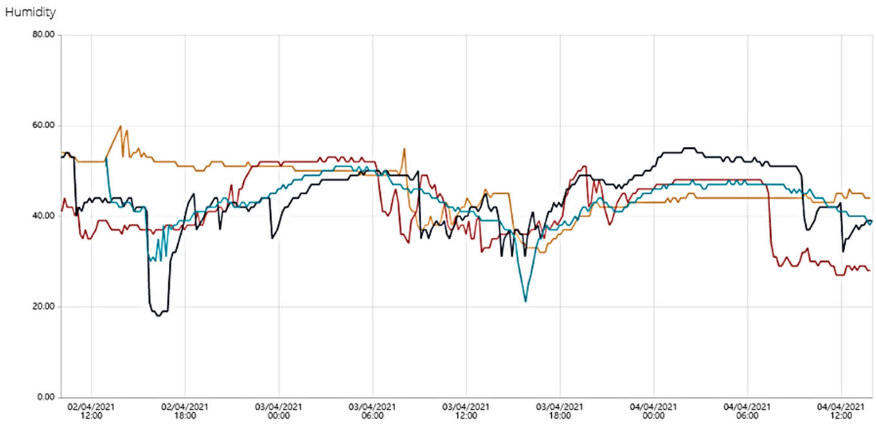


Fig. 10. Humidity

Humidity was usually kept between 40 to 60%. Lowest recorded value was caused by exposing the DHT11 to direct sunlight.

The acquired values are so-called raw values and every measurement is uploaded instantly to the cloud database. The microcontroller process the measured values in every program cycle and there is no local post processing. As a part of further data processing there are various tools as a part of the cloud environment such as avarage value for given time interval and also personal post processing is available with the developer tools.

The next table shows the maximal and the minimal recorded values.

Table 3

Lowest and highest values

	Photoresistor	Temperature [°C]	Humidity [%]
Maximal	4095	39,9	60
Minimal	0	13,2	18

Conclusions. The testing and measurement was performed for 48 hours and collected data was sent via the Wi-Fi module to cloud. There were some problems with connection, which we were continuously fixing when they have been detected. Sometimes ESP get stuck and stopped sending data. Desired behavior of the unit was then restored by pushing the EN button. Data was evaluated in Dashboard by creating graphs.

The article described the proposal and testing of an automated wireless monitoring system for measuring light intensity, humidity and temperature. All the data was sent to a cloud system, Ubidots, which is suitable for data monitoring, processing and logging. The sensor stations were based on ESP microcontroller, dht11 sensor and LDRs. The designed monitoring system offers the possibility of expanding it with other functionalities. The system can be supplemented with other sensors, and the cloud interface with new functions and rules to analyze the collected data.

The next step should include the possibility to interact with the environment by controlling the heating, ventilation and the light source in the monitored environment.

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МОНІТОРИНГ ПАРАМЕТРІВ НАВКОЛИШНЬОГО СЕРЕДОВИЩА НА ОСНОВІ БЕЗДРОТОВОЇ СЕНСОРНОЇ МЕРЕЖІ

Автоматизований збір даних та доступ до них є необхідним у сучасних мережах датчиків. З метою пояснення рішення запропоновано приклад системи.

Основною метою цієї роботи є розроблення та випробування бездротової системи збору даних для вимірювання інтенсивності освітлення, температури та вологості з різних місць. Запропонована система повинна задокументувати необхідні кроки для створення такої системи моніторингу, яка складається з мікроконтролерів з інтерфейсом бездротового зв'язку, датчиків та хмарної інфраструктури для збору та обробки даних.

Нині бездротові рішення стають стандартом для їх легкої реалізації та розширення. Системи домашньої автоматизації об'єднують пристрої різних постачальників. Застосовуючи датчики до навколишнього середовища, ми можемо збирати та використовувати наявні дані.

Оскільки бездротовий зв'язок може базуватися на різних протоколах, і неможливо перевірити їх в одному дослідженні.

Метою статті є запропонувати автоматизовану систему, яка збирає дані з різних місць і до яких можна отримати доступ з будь -якого місця на земній кулі.

Тестування та вимірювання проводилися протягом 2 днів, а зібрані дані надсилалися через модуль WiFi у хмару. Дані були оцінені на інформаційній панелі шляхом створення графіків. У статті описано пропозицію та випробування автоматизованої бездротової системи моніторингу для вимірювання інтенсивності світла, вологості та температури. Усі дані були надіслані до хмарної системи Ubidots, яка підходить для моніторингу, обробки та реєстрації даних. Станції датчиків базувалися на мікроконтролері ESP, датчику dht11 та LDR. Розроблена система моніторингу пропонує можливість її розширення іншими функціональними можливостями. Система може бути доповнена іншими датчиками, а хмарний інтерфейс - новими функціями та правилами для аналізу зібраних даних.

Ключові слова: *мережа датчиків; хмара; бездротовий зв'язок.*

Рис.: 9. Табл.: 2. Бібл.: 11.

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