MEASURING SYSTEMS

SMART SYSTEM FOR MONITORING WATER QUALITY PARAMETERS

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Abstract. Water is the most crucial factor for all living organisms, so it is essential to protect it. And water quality monitoring is one of the first steps required in the rational development and management of water resources. Smart systems used for real-time quality control and power consumption are rapidly developing. Their implementation in water quality assurance systems is essential and actual. The three-level smart system presented in this article involves the processing of water samples testing results from water supply sources, from the distribution network (consumers), test results of testing laboratories, and data from water consumption accounting systems. Transmission of the obtained results to consumers applying wireless communication technologies is an important system feature.

Key words: Smart system, Drinking water, Quality, Sensors, Wireless technology.

1. Introduction

Ensuring the quality and safety of drinking water is an urgent problem because, in today's conditions, there are many sources of pollution, most of which are created by man. Excessive exploitation of natural resources is also a significant cause of water quality problems [1].

Therefore, the development of a smart system for monitoring the quality parameters of drinking water in real-time is an urgent and necessary condition for ensuring its quality. This makes it possible to promptly respond to deviations of quality indicators from established requirements and, at the same time, inform consumers about the quality of drinking water supplied to them [2]. Such a smart system can be part of a more extensive Smart City system, which has been actively implemented in European cities recently.

2. Drawbacks

Drinking water quality parameters can change daily. They can also vary on the way from the water supply source to the consumer under the influence of various factors. At the same time, consumers remain utterly uninformed about the quality of the water they drink. To date, some works describe the use of a network of wireless sensors for water quality monitoring [3–8]. However, the general structure of monitoring systems within the framework of environmental monitoring of the city and the existing data flows in such a system are not described.

3. Goal

This work aims to develop the general structure of a smart system designed to collect information on water quality parameters, their processing, storage, and transmission of the obtained results to consumers. The data sources in this smart system are results obtained from testing laboratories, data from consumers' water meters, and sensors installed at water intake points and directly at consumers. Collected information will be sent to base stations through communication channels with subsequent transmission to remote monitoring stations. Stored data should be processed using appropriate modeling and visualization tools for future forwarding and other actions.

4. Structure development of the water quality monitoring system

Counters and sensors, which can be used in smart-system for drinking water quality control, must be digital. With the rapid development of microelectronics and the reduced prices for electronic components, digital control systems are gradually replacing their analog competitors. One of the main advantages of digital control systems based on microcontrollers is flexibility and multifunctionality, which are achieved not by hardware but by software without additional material costs, as well as increasing the accuracy and reliability of accounting.

In fig. 1 shows a three-level monitoring system, which includes:

1. Subsystem for collecting and initial processing of information. It consists of a system of multi-parameter sensors and additional wireless communication devices for transmitting information from the sensor to the controller. The controller collects data and processes it;
2. Data transmission subsystem consisting of wireless communication devices with built-in security features that transmit data from the controller to the cloud for data storage;
3. The data management subsystem. It includes an application that accesses the data storage cloud and displays it to the end user

- Connecting link I – measuring channels, which include all measuring devices and communication lines from the metering point to the controller.

Connecting link II – communication channels. Physical wired and wireless communication lines are used as communication channels.

Let's consider each level of the system in detail.

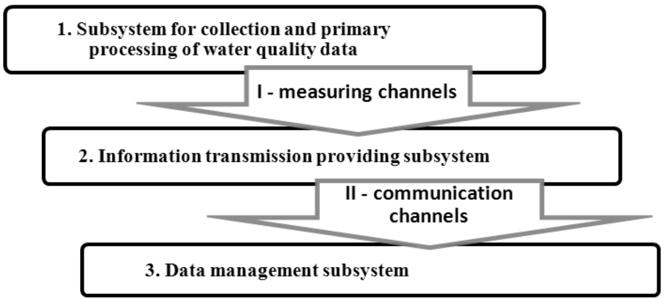
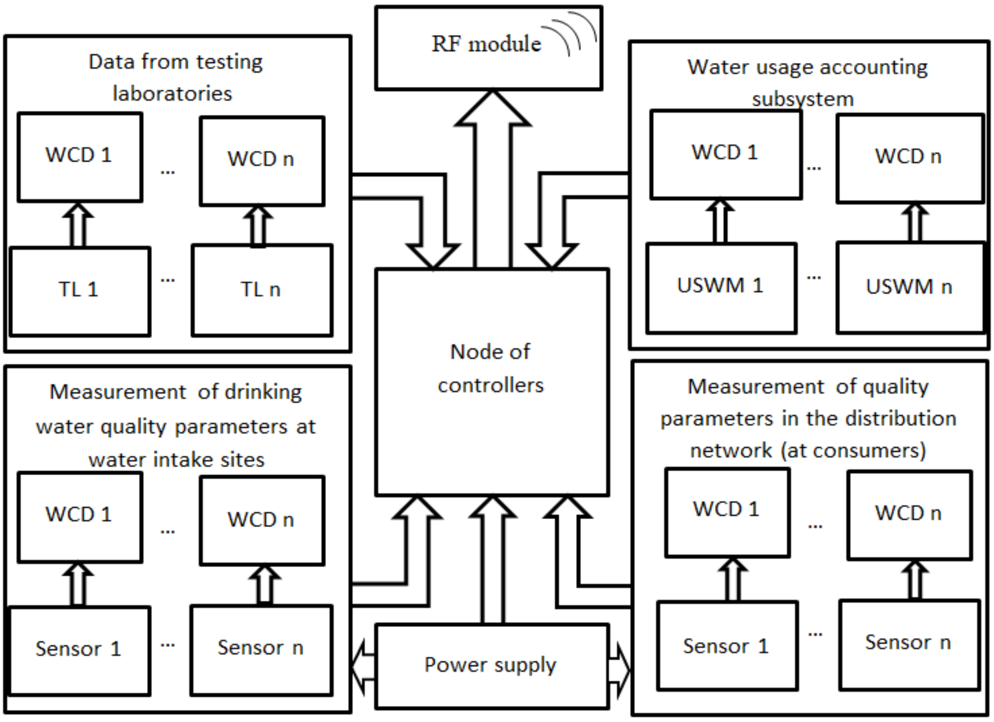


Fig. 1 Architecture of a three-level system for real-time monitoring quality parameters of drinking water



WCD – wireless communication device; TL – testing laboratory; USWM – ultrasonic water meter

Fig. 2 Data monitoring nodes

The structural diagram of the data collection subsystem is shown in Fig. 2.At the first level, data collection and initial processing take place. Four primary sources of information are provided here: from sensors located in water supply sources, research results obtained from testing laboratories, data from sensors located at consumers, and data on the amount of water consumed.

To quickly determine the quality parameters of water at water intake sites when the water has undergone treatment and purification and is ready to be fed into the distribution network, can be used specialized sensor nodes containing a pH meter, a turbidity sensor, and an electrical conductivity sensor. Modern sensors of this type are highly accurate and inexpensive, allowing real-time measurement of parameters. They can also be connected to a specialized computer monitoring system. It is necessary for their use in smart water quality control systems.

Similar sensor nodes can be installed in drinking water consumers. This will make it possible to monitor the decrease in water quality that occurred during its transportation and may be caused, for example, by pipe breaks.

Data from testing laboratories, which are obtained through regular sampling and control of drinking water quality indicators by laboratory specialists, are important and informative. The list of monitored indicators meets the requirements of the primary standard in the field of drinking water supply [9].

To control effectively water consumption in the smart system, it is advisable to switch to the use of ultrasonic water meters by consumers. The ultrasonic water meters adopt ultrasonic flow measurement technology and have a built-in NB-IoT or LoRa or LoRaWAN wireless meter reading module. The water meter is small in volume, low in pressure loss, and high in instability, and can be installed at multiple angles without affecting the measurement of the water meter. The whole meter protected on IP68 level can be immersed in water for a long time without any mechanical moving parts, therefore is characterized by long service life. Users can manage and maintain water meters remotely through the data management platform. The benefits are that they are suitable for the metering of unit residential buildings and meet the demands for accurate metering and settlement of end users and customers' demand for big data [10].

The measurement results obtained at the first level of the smart system, in the data collection and primary processing subsystem (Fig. 2), are transmitted through the data transmission subsystem. The block diagram of this subsystem is shown in Fig. 3.

Effective, uninterrupted, and secure data transmission in a smart water quality monitoring system should be provided by a set of technological and software tools that meet modern requirements for data transmission systems. The data transmission subsystem should include the following components:

1. Internet connection technologies, such as Ethernet, Wi-Fi, 4G/5G communication, and the use of TCP/IP protocols.
2. GSM modules, as it is intended to inform authorized persons and consumers about the emergency deterioration of water quality also utilize SMS messages. It is advisable to do this since the mobile connection is more stable than the Internet connection, which is especially important in critical situations with possible interruptions in the power supply.
3. Network servers and wireless communication technologies are designed to ensure uninterrupted and coordinated exchange of measured and processed data via the Internet and connection of this monitoring system to the city-wide smart system.
4. RF modules and ZigBee modules are designed to ensure the transmission of measured data via wireless communication channels. ZigBee modules deserve special attention. ZigBee modules are wireless modules based on the IEEE 802.15.4 ZigBee protocol. This protocol is a low-power mesh networking protocol that has been designed to transmit data wirelessly. ZigBee modules use the 868 MHz, 900 MHz, and 2.4 GHz frequency bands. It uses DSSS (Direct Sequence Spread Spectrum) modulation and can be used to connect a network of up to 65,000 nodes. The ZigBee protocol uses 128-bit AES encryption and has low latency.
5. All data transmitted in the smart system must be reliably protected by applying the appropriate encryption protocols and information protection technologies.

At the third level of the smart system presented in Fig. 1, the data processing, storage, and visualization subsystem is placed. The data from all nodes from the first subsystem is collected at the database station consisting of an ARM processor (for example, LPC2148), as shown in Fig. 4. The data is collected one after another, i.e. using time multiplexing. Also, this data is forwarded to the remote monitoring station via RF and ZigBee modules.

The database formation subsystem and database servers ensure the processed data's storage.

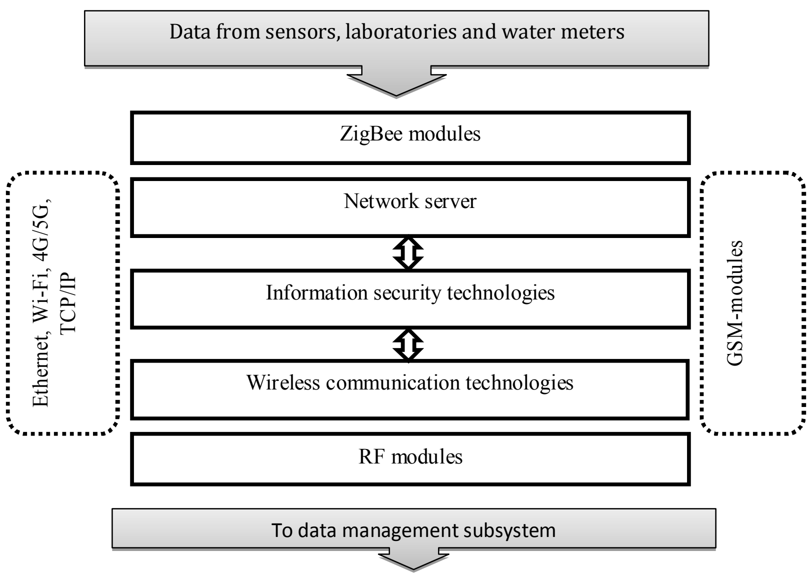


Fig. 3 Block diagram of proposed Wireless Sensor Network

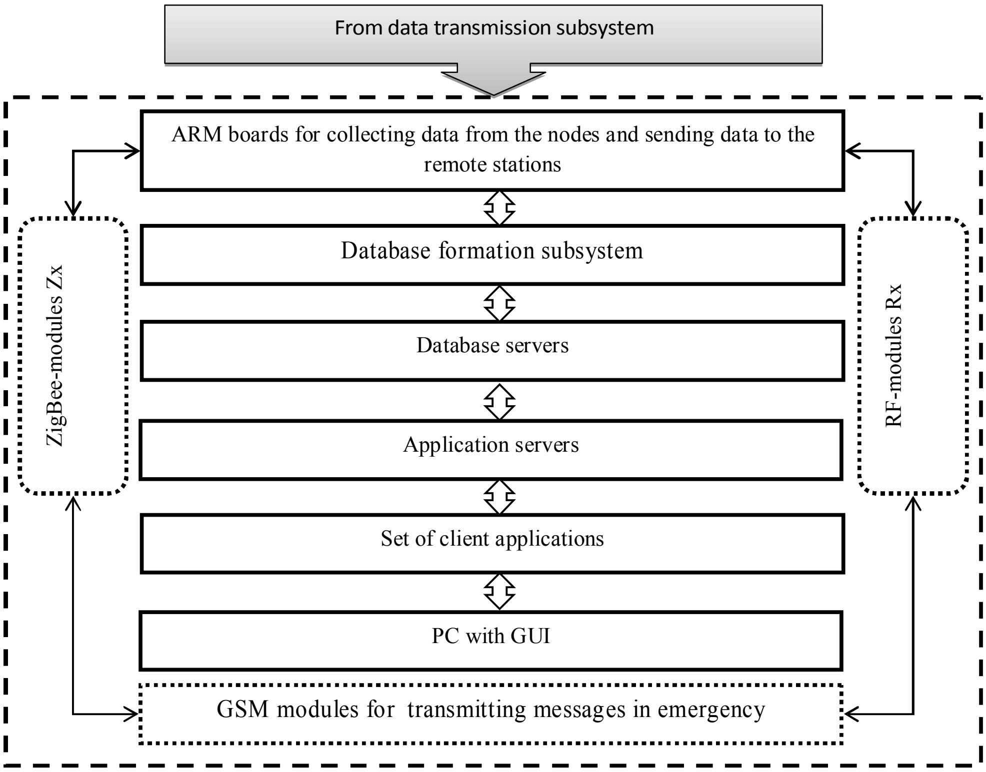


Fig. 4 Structure of data management subsystem

Table. Analysis of data visualization tools

Name	Features	Purpose	Languages	Price
1	2	3	4	5
QlikView	Customizable interface equipped with a wide range of functions, a powerful tool for business analytics, analytics, and enterprise reporting.	Professional business analytics and analytics	C, C++, SQL Server VBscripting	$1350 per user
Tableau	The ability to process a large volume of rapidly changing data, including Machine learning. Integrates with Hadoop, Amazon AWS, MySQL, SAP, and Teradata.	The external representation of rapidly changing data	C, C++, Java, Python2	$70/month
FusionCharts	A widely integrated platform, it contains 965 maps, 90 types of charts, and more than 800 templates. It comes with open-source plugins for libraries like jQuery and frameworks like AngularJS and React. Supports JSON and XML data formats, exports renderings to .png, .jpg, .svg, .pdf	Create dashboards for internal reporting, SaaS products, or distributed products.	JavaScript, ASP.NET, Ruby on Rails, Java, PHP	$497
Highcharts	Provides support for users with visual impairments and those who navigate only with a keyboard. It has powerful extensibility and connectivity for experts who need advanced animations and functionality.	Suitable for both non-technical users and experts.	.Net, PHP, Python, R Java, Swift	$535 per user
Grafana	An open multi-platform web application for analytics and interactive visualization of data, including industrial automation and IoT systems. It provides charts, graphs, and alerts for the Internet when connected to supported data sources.	Visualization of metrics, logs, and traces from various sources (Prometheus, Loki, InfluxDB, Postgres), and data from technical means (sensors).	Go, Node.js, MySQL, PostgreSQL	$49/month

For graphical representation and visualization of data, specialists need to apply personal computers with GUI (Graphic user interface), as well as application servers. Processing, saving, and visualization of data on quality parameters of water is an important stage of smart-system operation. Therefore, a collection of applications that will ensure the correct and informative display of data on personal computers or mobile devices of users is necessary.

For data visualization, it is necessary to choose tools that would provide user-friendliness, work with various types of data, provide technical support, and more. Several tools can provide effective data visualization (QlikView, Tableau, FusionCharts, Highcharts, Grafana, and others). The analysis (see table below) showed that the Grafana tool is the best for visualizing collected and processed data from sensors on water quality parameters because with an intuitive way of use and at an affordable price, it is possible to collect, process, visualize and transmit the necessary information to consumers [11].

A detailed flowchart for the working of the whole system as well as software design is shown in Fig. 5.

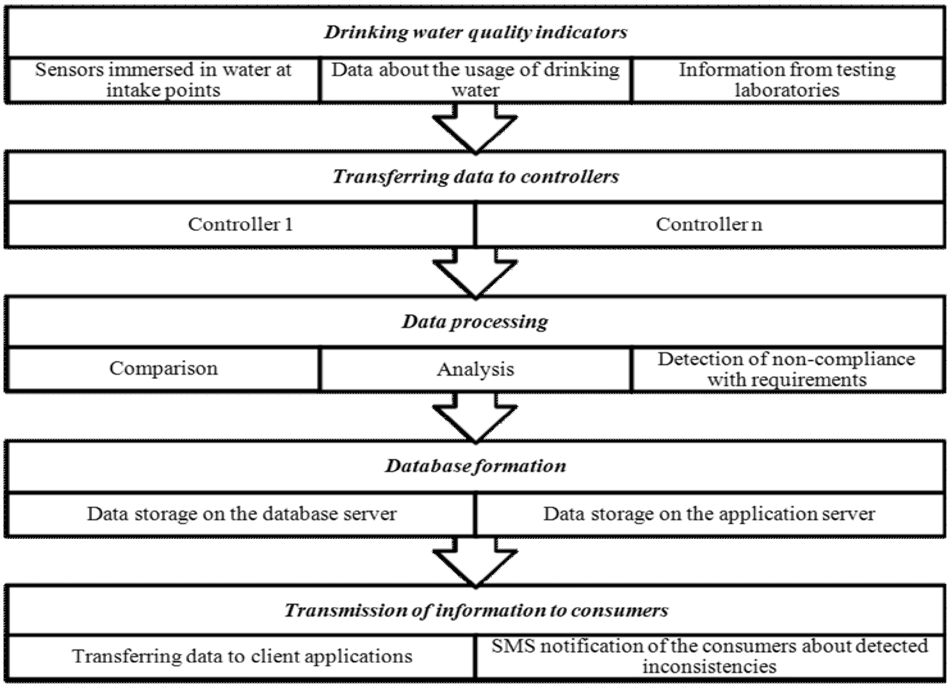


Fig. 5 Data flow diagram

The system provides for the collection of data on drinking water quality indicators from three main sources:

- Data received from sensors at drinking water intake locations (water supply sources);
- Data on water use obtained based on the collection of water usage meter readings;
- Data on water quality indicators are obtained from testing laboratories of water supply enterprises (Vodokanal).

5. Conclusions

Quality assurance and operational control of drinking water parameters are significant in today's conditions. An innovative drinking water quality monitoring system as a component of a more extensive smart-city system is relevant.

The sources of information about water quality are multi-parameter sensors, data from testing laboratories, and data about the amount of water usage from drinking water consumption accounting systems.

For data transmission, it is suggested to use the Internet, wireless communication systems, and a GSM modem for SMS-informing consumers about deviations from controlled parameters.

6. Gratitude

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