Towards Evaluation Study on Commissioning and Operation of Industrial Wireless Sensor Networks

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***Abstract*—Authors have conducted the research overview of the design principles and operation technologies of the wireless sensor networks (WSN). Several activity domains have been defined where the WSN can be effectively applied. Finally, an experimental model for a valid WSN has been created based on a training set.**

I. INTRODUCTION

Significantly growing interest in research and development has been detected regarding WSNs consisting of numerous simple miniature devices (nodes), each of which contains microcontroller, transmitter-receiver and independent power supply [1, 2]. Nodes are equipped with sensors which register parameters of physical fields of different nature in the places where these nodes are located (e.g., temperature, humidity). The measurement results are transmitted over multilink chain (from node to node) to a central computer for processing and analysis, because the limited capacity of transmitter-receivers makes it impossible for nodes to process data directly.

Today the WSNs are increasingly used as distributed systems for monitoring of various objects and physical processes [3]. Particularity of monitoring tasks often defines the overall structure of wireless sensor networks usually being represented as data measuring systems distributed over a large area. Possible application area of such systems is very broad. The WSNs can be used in construction and architecture [4], industry [5], agriculture [6], seismology [7], transportation / logistics [8], healthcare [9], nuclear power generation [10] and other fields of human activity. Sensor networks are particularly useful in cases when it's impossible or unprofitable to deploy conventional communication networks and field buses. WSNs enhance automation of industrial processes that have previously required some human intervention form.

There are several main types of nodes that can be part of WSN [1]:

- End devices (ED) that are equipped with sensors and perform measurements;
- Transponders or routers that transmit command packets and data messages from EDs;
- Gateways that collect messages from EDs and provide connection between WSN and high-speed data highways that deliver WSN data messages to the computing center;
- Bridges providing connection between different WSNs;
- Coordinator, administering WSNs and acting as a data gateway.

It should be taken into account that only EDs and coordinators are the mandatory components for providing monitoring via WSN.

Wireless technologies used to build monitoring systems offer several advantages compared to traditional solutions: absence of wired communications facilitates and simplifies the deployment and reconfiguration of network; reduces the cost of the system; independence and miniature size of devices allow their placement in hard-to-reach places at large distances.

Wireless solutions are indispensable when you want to link constantly moving nodes or nodes that are frequently moved into one network.

Main requirements for WSN nodes are low power consumption (providing long battery life), high performance, small size and low cost. IEEE 802.15.4 standard is one of the most popular standards used in development of WSN [11]. Monitoring tasks usually don't require transmission of high-density information flows, so reduction of power consumption can be achieved, for example, by switching on the nodes synchronously for communication and switching them off for long sleep-mode periods of time in-between.

Another important requirement for WSN is the possibility of self-organization (the nodes should be able to join and link the network independently and transmit information packages to each other), providing that information packages are transmitted only between nodes that are within the radio coverage area of each other, which is determined by the probability of delivery of information packages between nodes.

II. Article description of the experimental WSN model

Further, we describe functionality of WSN experimental model consisting of the following component types:

- a set of hardware;
- system-level software (SW) on the server side;

resolution 128 x 64 is mounted on board of one of the nodes. This allows monitoring of the values measured by the nodes [13]. This feature makes it possible to use the received values while debugging user applications. A ceramic fan heater has been used for heating the air in the experimental model. The main description form of the devices that are part of the experimental model is the form that contains information about full name of the devices, information on their types, their application and parameter limit values (Fig. 1). WSN configuration contains all the information that is necessary and sufficient for the correct

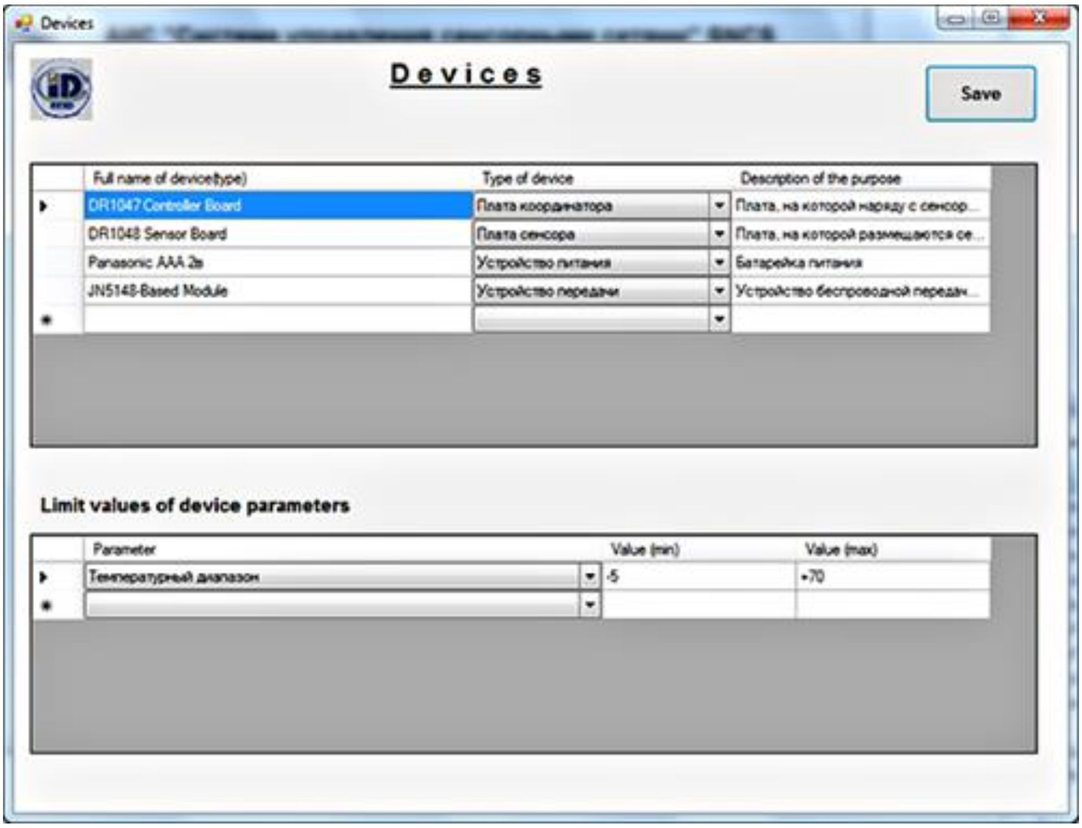

Fig. 1. Description of network node devices

- application SW on the server side;
- data base (DB) on the server side;
- system-level SW on the WSN side;
- application SW on the WSN side.

NXP JN5148-EK010 kit [12] has been used for implementation of the WSN based experimental model. This kit includes hardware and software components that are necessary and sufficient for construction of various WSN based JenNet and ZigBee user applications.

The basis of the kit consists of five sensor nodes powered by batteries, each of which can measure and transmit three parameters of the environment (temperature, humidity and light) to coordinator. An LCD screen with

functioning of the network. As shown in Fig. 2, the form for the WSN configuration allows users to describe all the nodes in the network, composition of every node (devices of a node and their parameters), matrix for transition of nodes from one state into another for modeling the network.

System-level software on the WSN side is represented as modules of the operating system JenOS. This operating system is designed for use in sensor networks with NXP JN5148 devices and provides an interface that makes it easy to develop user applications. JenOS is used in networks supporting ZigBee standard and consists of five modules, each of which includes a defined set of API-functions providing an interface between user applications and JenOS modules, briefly described below:

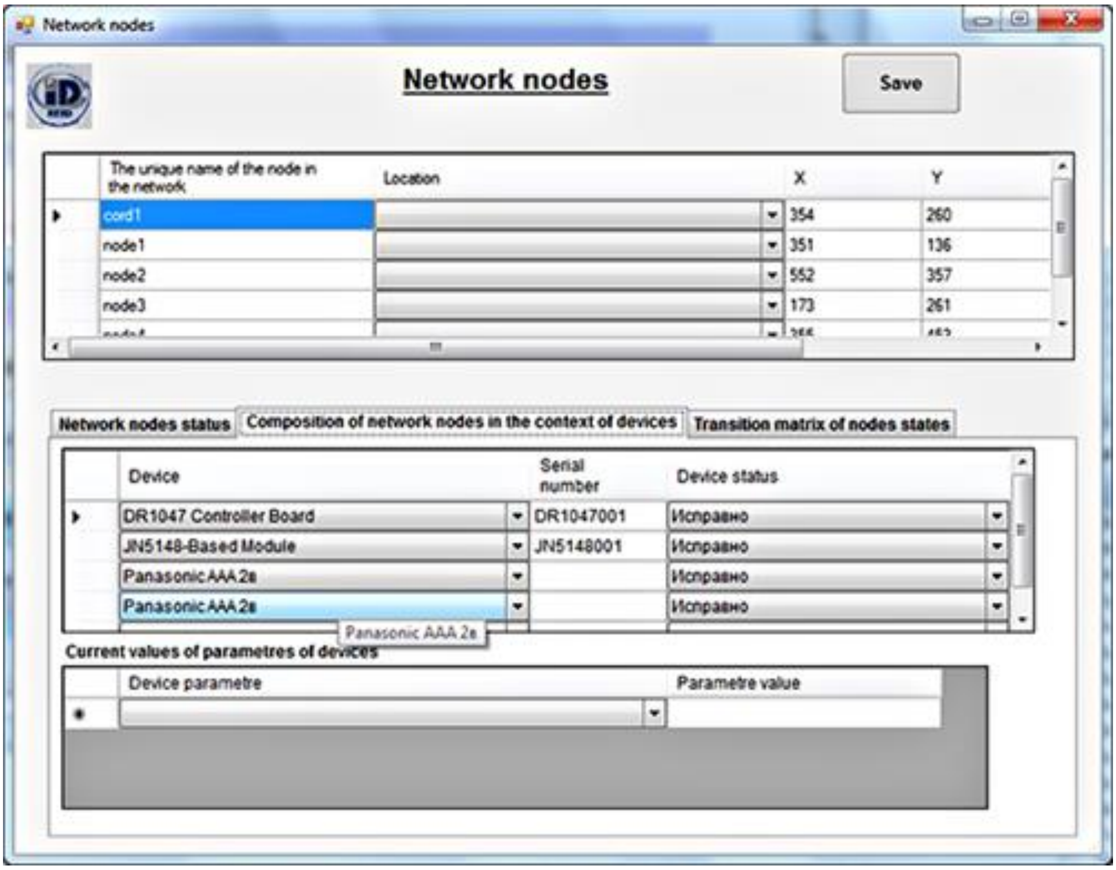

Fig. 2. Network nodes description

Real-time Operating System (RTOS) – provides mechanism that allows reacting to multiple real-time events;

Persistent Data Manager (PDM) ensures storage of code and data in unchangeable area of memory, which makes it possible to continue operation after power failures;

Power Manager (PWRM) is responsible for effective power consumption of the devices, including switching to a "sleep" mode;

Protocol Data Unit Manager (PDUM) ensures operations with memory, including insertion (extraction) of data to (from) messages;

Debug module (DBG) inserts debugging messages and facilitates debugging of user software.

Software architecture for JN5148 devices in the ZigBee network is shown in Table 1.

Application software on the side of WSN is organized as a core of WSN control system (CS). Software is developed in the programming language C#. Model of the WSN CS core is presented in Fig. 3. The model of the WSN CS core includes a server, several computers (optionally) which have functionality of a proxy-server, to which corresponding WSN nodes are connected via USB/COM ports.

TABLE I. SOFTWARE IN ZIGBEE NETWORK

<table>
<tr><td colspan="3">Application</td></tr>
<tr><td>JenOS</td><td rowspan="6">ZigBee PRO stack</td><td rowspan="6">Integrated API functions</td></tr>
<tr><td>RTOS</td></tr>
<tr><td>PDM</td></tr>
<tr><td>PWRM</td></tr>
<tr><td>PDUM</td></tr>
<tr><td>DBG</td></tr>
</table>

Server WSN_Core is the main part of the WSN CS core software which performs all the functions relating to configuration of WSN, nodes data collection, processing.

Plugin WSN_Core is the part of software that enables work with specific equipment used for WSN.

WSN_Core proxy is a proxy server which allows communication at request between computers of the network and the primary server.

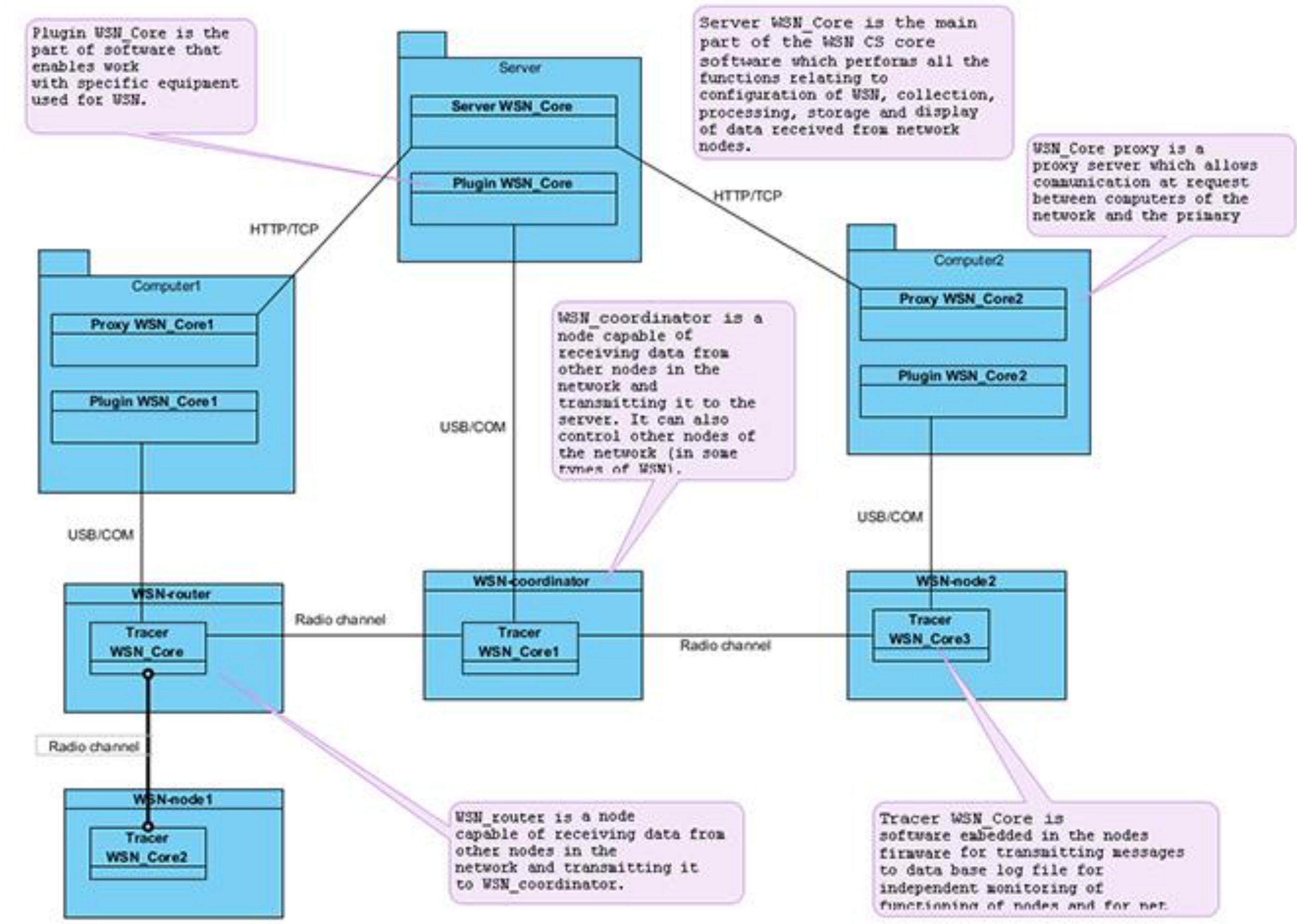

Fig. 3. Wireless sensor network control system core model

WSN_coordinator is a node capable of receiving data from other nodes in the network and transmitting it to the server. It can also control other nodes of the network (in some types of WSN).

WSN_router is a node capable of receiving data from other nodes in the network and transmitting it to WSN_coordinator.

Tracer WSN_Core is software embedded in the nodes firmware for transmitting messages to data base log file for independent monitoring of functioning of nodes and for net modeling.

Fig. 4 shows a model of the internal structure of the server. As can be seen from the model the server receives data either from coordinator or from the proxy server. Finally, all information is accumulated in the data redistribution module, which saves the processed data in the database. If necessary, this module can transmit control data for other network components.

III. Operation logic of experimental WSN model

Application implemented in the experimental model together with the hardware represents a system that is organized as a finite state machine [14]. Experimental model (Fig. 5) operates as follows:

- some minimum and maximum values for the ambient temperature near the sensors are indicated in the application window;
- measured data from the temperature sensors comes to the system in a certain time interval (parameter of the system);
- once the temperature value received from the sensor becomes less than the minimum value, the system automatically activates the heater. The heater raises the temperature and when it exceeds a certain maximum value, the system sends a command to turn off the heater.

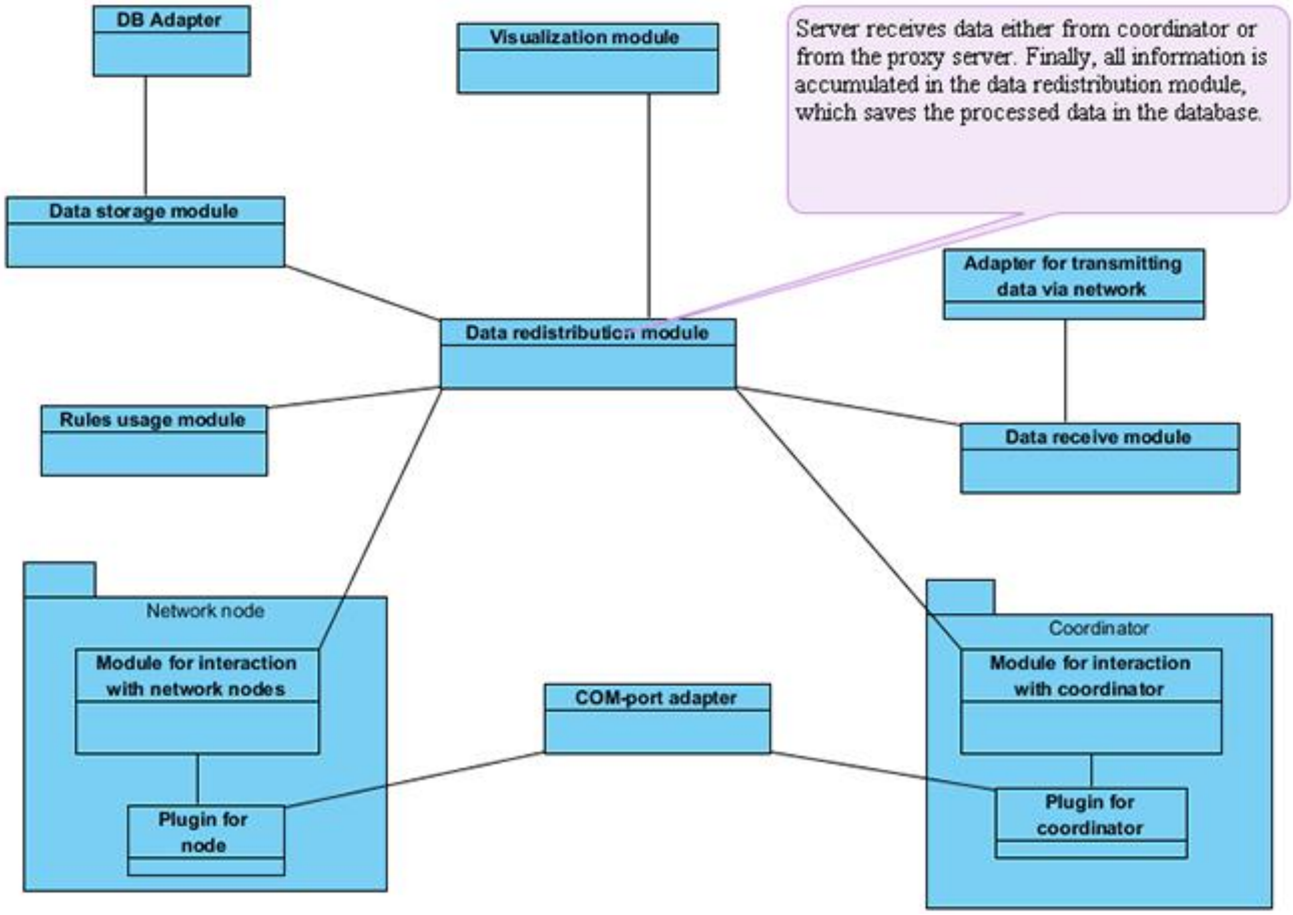

Fig. 4. Internal server structure model

Fig. 5 represents a chart describing the logic of operation of the experimental model regarding management of the heating element. Fig. 6 represents a form for entering control range of temperature values (thresholds).

After starting experimental model application an operator observes the values measured by the sensors. The values are represented on a screen in a graph form at Fig.7.

VII. Conclusion

Despite of the simplicity of the controlled physical device (heater) used in the experimental model, the WSN CS core and principles of building of applied applications implemented in the experimental model are applicable to devices of arbitrary complexity. Functioning of such applications is based on collecting of the measured data from the sensors and placing this data to the system database, analysis of the received values and making decisions on managing certain physical devices in various fields [15], such as:

- monitoring of temperature, air flow, presence of people and management of heating equipment, ventilation and air-conditioning in order to maintain the microclimate;
- lighting control;
- power supply management;
- data collection from home utility meters (electricity, gas, water, etc.);
- fire-alarm system;
- monitoring of condition of load-bearing structures of buildings;
- remote monitoring and diagnostics of industrial equipment;
- condition-based maintenance of equipment (forecasting of reliability margin);
- industrial processes monitoring;
- telemetry for research and testing.

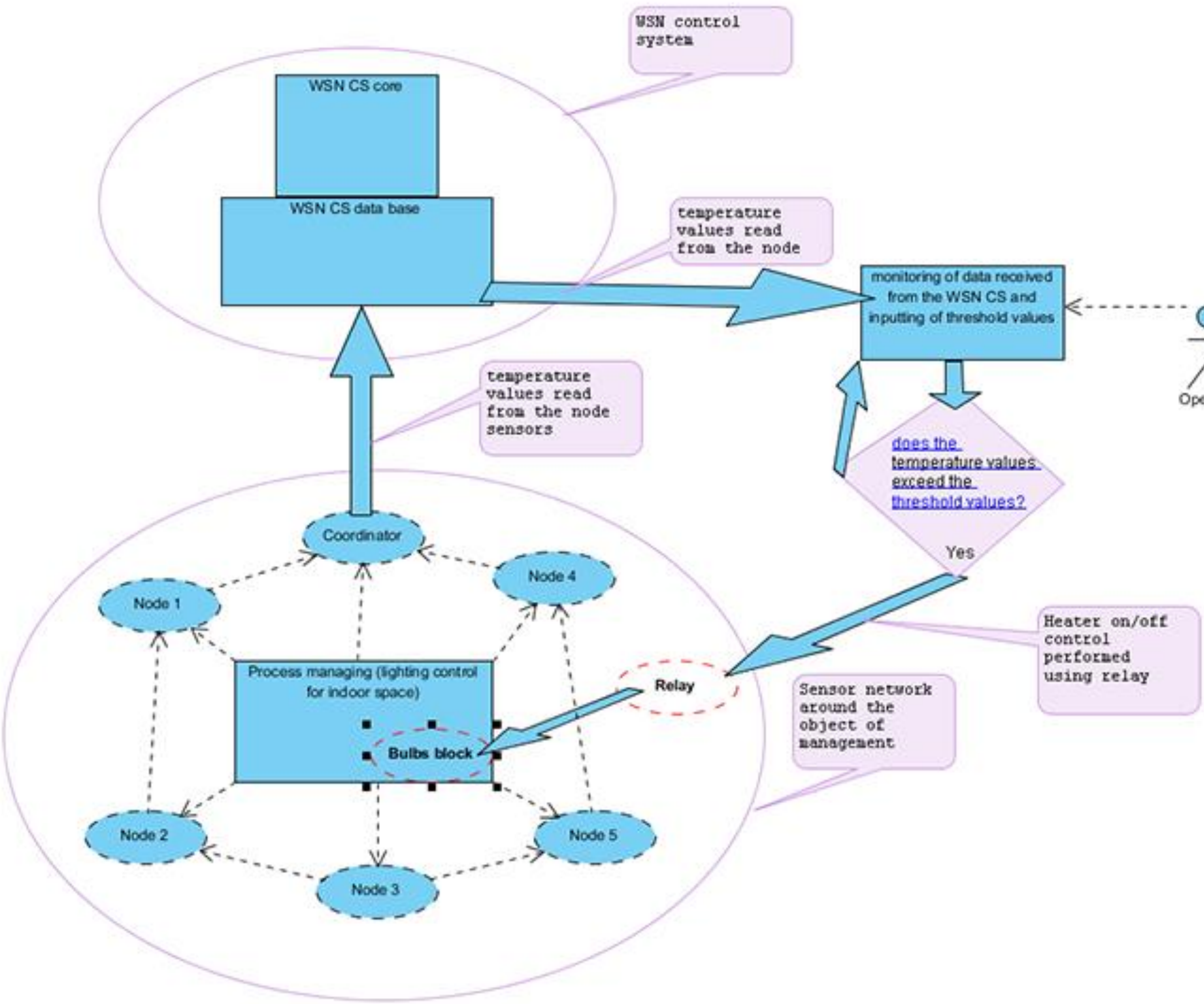

Fig. 5. Experimental model operation logic chart

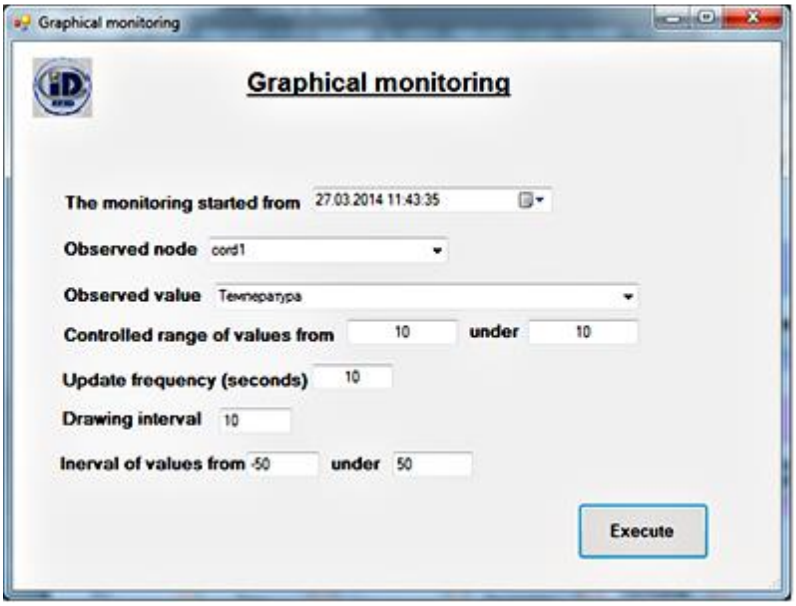

Fig. 6. Control values input form

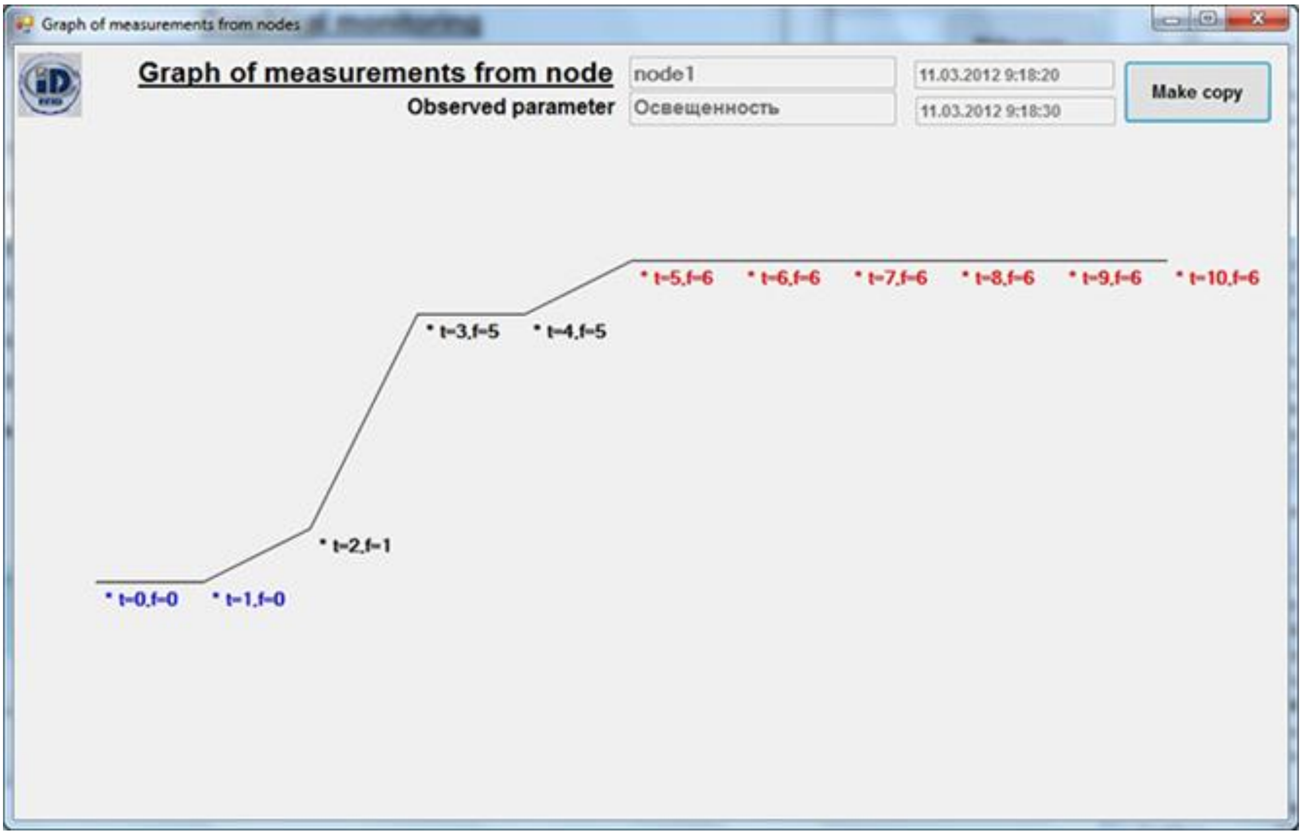

Fig. 7. Values monitoring provided by WSN

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