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Simulation analysis of wireless sensor network for determination of environmental noise

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Abstract. In the present work, a numerical analysis of a wireless sensor network for measuring noise in the environment is made. Due to the specific data transmission distances, LoRa communication technology was chosen. A simulation analysis of the wireless sensor network in terms of its energy efficiency has been made. It has been found that increasing the number of nodes leads to an increase in the average power consumed in the network, but decreases that in individual nodes. The obtained results show that the choice of communication modules and protocols for data transmission depends on the specific conditions under which the measurement of environmental parameters will be performed. The results of this work can be used in the design of wireless sensor networks to determine environmental parameters.

Keywords: ***Known and Unknown Nodes, LEACH, Node localization, Security, Energy efficiency***

I. Introduction

The updating of the map for the noise in the settlements in Bulgaria is related to the fulfillment of the requirements of the Environmental Noise Protection Act (ENPA) (Promulgated, SG No. 74 of 13.09.2005) and Directive 2002/49/EC for assessment and management of environmental noise. According to these requirements, it is the duty of every agglomeration with a population of over 100,000 inhabitants to update its noise map.

In the larger cities of the Republic of Bulgaria such measures have been taken [1, 2]. Measurements are based on automatic measuring stations, as well as by measuring with portable measuring instruments. The trend is to expand networks for automatic measurement and storage.

In recent years, wireless sensor networks have been developed to detect environmental noise [3]. They can be local, used in public parking lots, garages, buildings. Such systems have also been developed to measure noise in urban environments.

Microphones are used as the main data source in wireless sensor networks to determine noise levels. Van Renterghem et al. [4] prove that low cost microphones can be used to monitor environmental noise. This thesis was further developed by Fernandez-Prieto et al. [5], which state that in order to effectively use this type of sound sensors, it is necessary to apply filters for close to high-frequency noise. Wireless protocols are used to automate the process of measuring environmental noise [6]. Table 1 lists the standards for wireless data transmission and the distances that can be covered by them.

Table 1. Standards for wireless data transmission

Standard	Frequency	Speed	Maximum distance
IEEE 802.15.1 WPAN (Bluetooth)	2.4 GHz	1-24 Mb/s	100 m
IEEE 802.15.4 LRWPAN (ZigBee)	2.4 GHz	250 Kb/s	100 m
IEEE 802.11 WLAN (WiFi)	2.4, 3.6, 4.9, 5 GHz	11 Mb/s-1 Gb/s	1.5 km
LoRa	433, 868, 915 MHz	27 Kb/s	15 km

The difference in bandwidth between them is not large. In addition, power management on 802.15.3 is easier than on 802.11e. For ZigBee and Bluetooth. Baker [7] points out that the ZigBee over 802.15.4 protocol has more application capabilities than Bluetooth due to its long battery life, greater usable range, dimensional flexibility, and reliability of the network architecture. According to Lee et al. [8], the effective use of network protocols depends to a large extent on specific practical applications, as well as network reliability, roaming capability, recovery mechanism, hardware cost and network installation and maintenance costs. The review of the available literature sources shows that in Bulgaria there is a need to create new and expand existing wireless sensor networks to measure noise levels in the environment. There is little research on the energy efficiency of this type of network.

The aim of this work is to analyze the possibility of expanding a wireless sensor network by selecting appropriate technical means and to make a simulation analysis of this network.

II. Material and Methods

The distance at which measurement data can be transmitted depends on the frequency and power of the transmitter. This is described by the following mathematical dependence [9]:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2} \tag{1}$$

where P_t is the transmitted power; P_r - received power; G_t - gain of the transmitting antenna; G_r - gain of the receiving antenna; λ - wavelength; d - distance between the receiving and transmitting parties.

Figure 1 shows a diagram of the sensor network used in the work. It is a system for collecting data on environmental noise. It was realized in the city of Plovdiv, Bulgaria.

The network consists of a total of five process information points located in the city. These points are connected to a central station to which data from the measurements are transmitted.

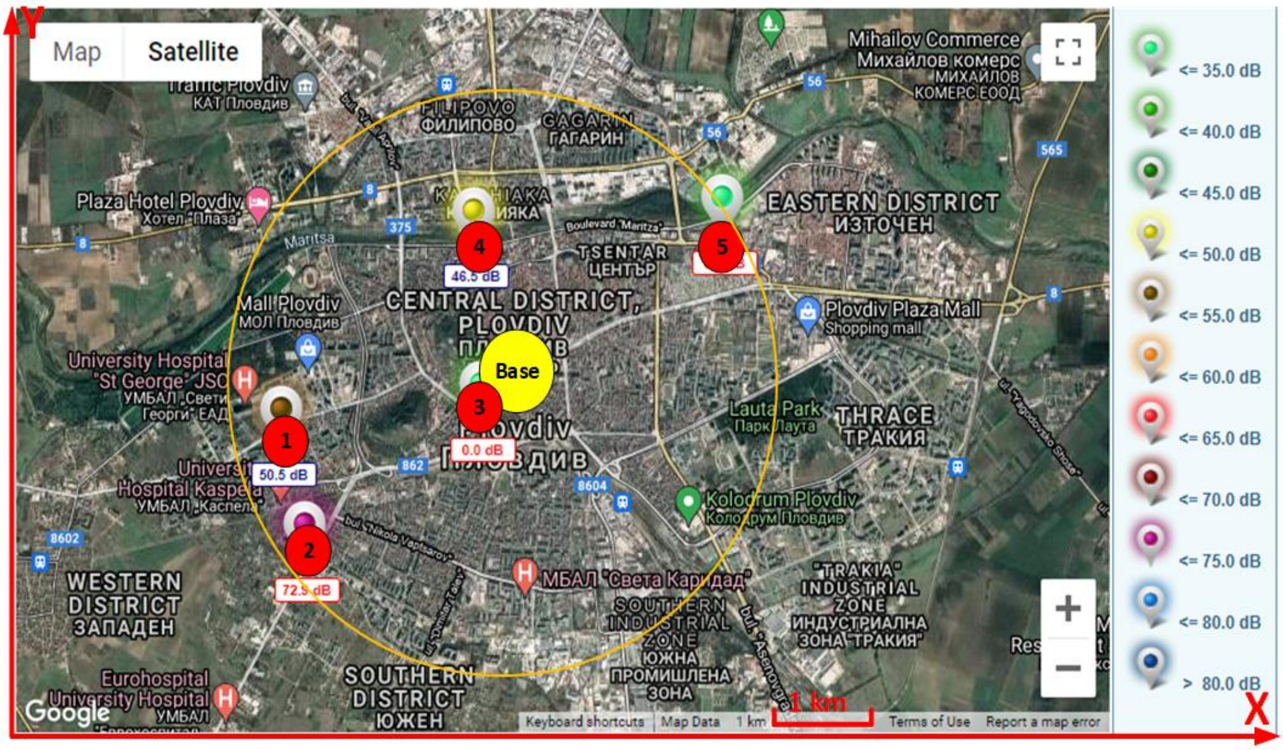

Fig. 1. Location map of sensor devices with wireless communication (source [10])

Dragino DLOS8 - Outdoor LoRa WAN Gateway, 868MHz (Shenzhen Dragino technology development co., LTD, China) was used as a base station.

Figure 2 shows a block diagram of a process information point for measuring the noise level. It consists of a single-board Arduino Uno microcomputer; LoRa Wan module operating at 868 MHz; sound sensor with built-in Max9814 amplifier. The advantage of this sound sensor is that it filters near loud noise and detects significantly better distant noise compared to other sensors in this class. The power supply of the process information point is carried out through a solar cell control module. Connected to this module are: Li-Po battery 3.7V and capacity 2500 mAh; 2W solar cell.

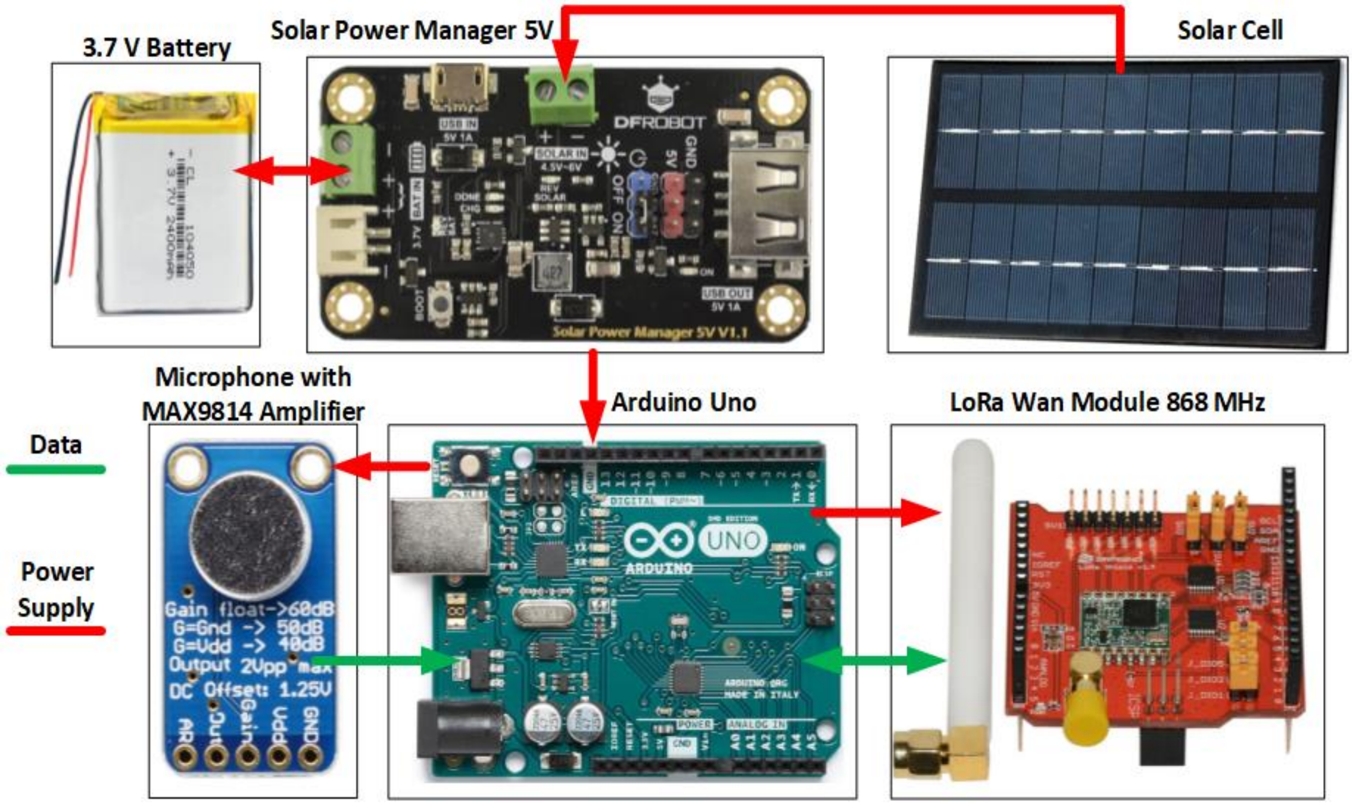

Fig. 2. Block diagram of a process information point.

The conversion between the measured analog signal supplied by the sound sensor to the noise level NL is made according to the formula presented in [11], according to the formula:

$$NL = \frac{ADC + 83.21}{11}, dB \tag{2}$$

where ADC is the reading of the analog-to-digital converter of the single-board microcomputer.

The numerical simulation analysis was performed in the Matlab 2017b software system (The mathworks Inc., Natick, MA, USA). The program tools suggested in [12] were used. The software tool offers tools for analyzing wireless sensor networks in terms of their energy efficiency.

III. Results and Discussion

Figure 3 shows a simulation diagram of the sensor network. The topology is Star Multi-hop. Five nodes and a base station were used. Distances are entered in km. the radius of the sensor network relative to the base station is 6 km. Simulation program settings were used for direct air transmission without latency.

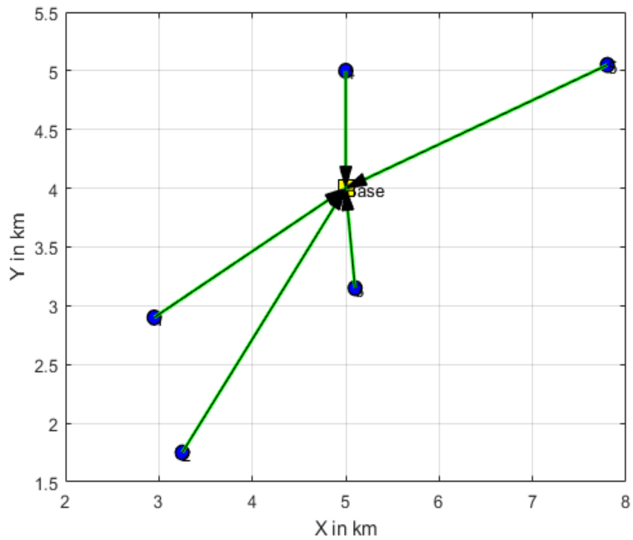

Fig. 3. Simulation scheme of sensor network

Figure 4 shows an example of the average power consumption of the analyzed wireless sensor network. Power settings per unit distance 0.01W, transmission of 50 data packets, with a delay of 0.05s. the graph shows that after transmitting more than 30 data packets, the power consumption is set to 0.77W.

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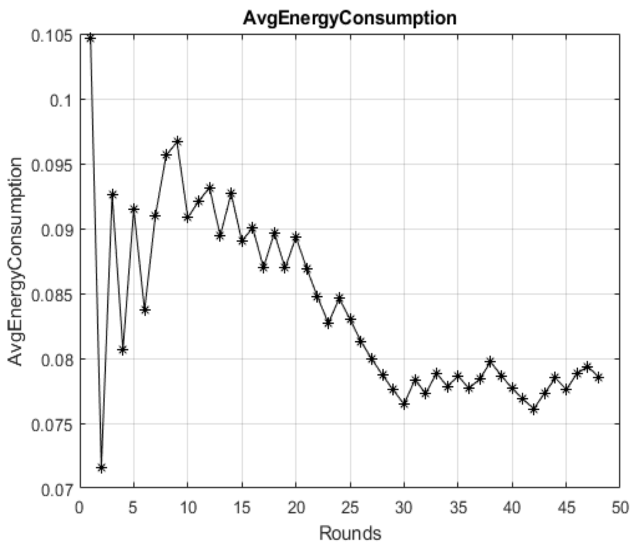

Figure 4. Example of energy consumption from a wireless sensor network, with different number of transmitted data packets

Figure 5 shows the results for the average energy consumption at different numbers of nodes in the network.

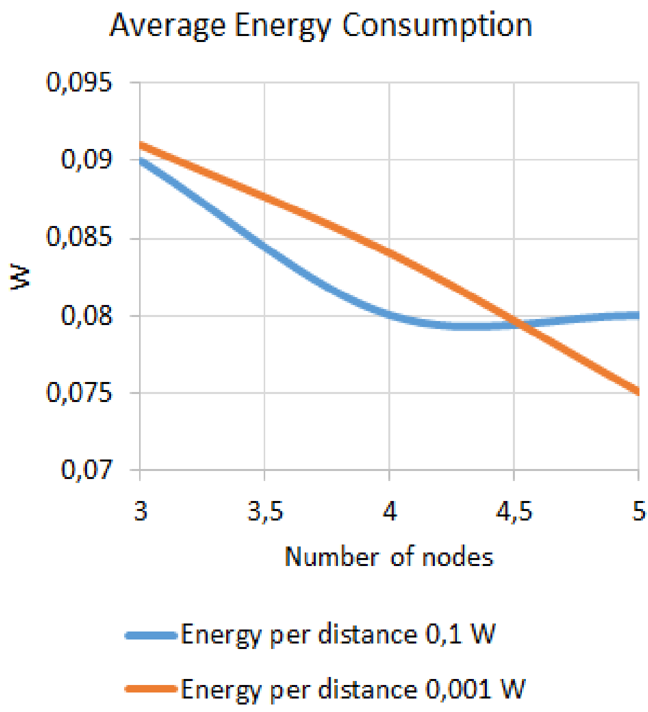

Figure 5. Average energy consumption of a wireless sensor network

From the obtained results it can be judged that it is possible to prolong the life of the network by preventing the continuous movement of messages through it and the sensor modules are available, which ensures low energy consumption. As can be seen in the figure, the average energy consumption increases with the number of nodes in the network. But the figure also shows that with different grid sizes, there is a reduction in energy consumption. It also depends on the energy required to transmit data per unit distance.

The results obtained complement those of Rezazadeh et al. [13]. According to the authors, increasing the number of nodes leads to an increase in the average energy consumed in the network, but decreases that in individual nodes.

The results obtained in the present work can be refined using the methods proposed by Elshrkawey et al. [14]. The authors propose two methods for improving the energy efficiency of wireless sensor networks. Through these methods, the life of the wireless network has been extended compared to, for example, the LEACH protocol.

When looking for methods to reduce energy consumption in wireless sensor networks, some limitations must be taken into account. For example, Arumugam et al. [15], offer a protocol for routing data from sensors, which depends on the optimal choice of base station location. This protocol extends the life of the network. The problem with this overly complex method is that there are multiple delays. They are caused by the large number of operations of the running algorithm.

IV. Conclusion

The analysis of the existing wireless sensor networks showed that the choice of communication modules and protocols for data transmission depends on the specific conditions under which the measurement of environmental parameters will be performed.

It has been found that increasing the number of nodes leads to an increase in the average energy consumed in the network, but decreases that in individual nodes.

The results proposed in this paper can be used in the design of wireless sensor networks to determine environmental parameters.

The work can be continued by making more analyzes to replace the measuring points, which are determined manually and visually by people with a wireless sensor network. Also, at the next stage, an analysis can be made of the extent to which environmental noise measuring devices can be used in different mobile sensor network applications, how different types of transmitted data are affected by the location of sensor devices and how the security of data transmission can be ensured.

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