The Technology of a Long-Term Environmental Monitoring of Gas Emmission in the Arctic Region of Russia by WSN Equpment

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Abstract

The aim of our work is the organization of long-term ecological monitoring of modern composition of the atmosphere in the area of active ore mining on the base of modern WSN (wireless sensor network) technologies. Wireless sensor network monitoring (WSN) is last innovation for the industry. WSN are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as gas, temperature, pressure, etc. and to cooperatively pass their data through the network to a main location The WSN is built of "nodes" - from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. The project includes the development of informational and analytical system, which includes a network of rock soil gas emission sensors and internet webpage based on modern WEB-GIS technologies. The first technical and methodical solution was tested in condition of Arctic region - the Khibiny and Lovozero massifs (Kola Peninsula). The developed equipment allows to carry out measurements directly in the zone of blasting operations with high discreteness in time.

1 Introduction

Our work is directed on a solution of the problem of studying of change of modern structure of the atmosphere around active production of ores in the conditions of Far North and an assessment of a contribution of a lithospheric component to balance of the polluting atmospheric components.

A lithospheric gas emission has a strong influence on the lithosphere, the atmosphere and the biosphere. This problem has become more and more relevant, because of greenhouse gas emission increase, which changes the energetic balance in the atmosphere and, as a result, changes global climate of the Earth. These changes are most remarkable on high latitudes of the Northern hemisphere. Today planetary maximum of the main greenhouse gases such as carbon and methane dioxide is registered in Arctic. One of the ecological problems is the global decline of stratospheric ozone and the formation of the ozone holes. The main hypothesis, which explain the destruction of ozone layer, is “Technogenic-Freon” hypothesis. However, exists another theory – “Hydrogen” hypothesis – the emission of ozone-depleting gases (primarily hydrogen and less methane) from geological structures [Syv02]. It is expected that one of these structures are the Khibiny and Lovozero massifs. Hydrogen anomaly are regularly observed in these areas [Iko92; Niv05, Niv09, Niv16].

High concentration of hydrocarbon and hydrogen-hydrocarbon gases in alkaline complexes occluded as fluid inclusions in minerals. The presence of these gases has a number of practical implications and it is therefore important to understand their source and distribution. The inverse relationship between hydrogen emission and total ozone oscillation over the Kola Peninsula is established.

Under certain conditions, combustible and exposable gas components can accumulate in the space of the underground mines. This may be a serious danger for the mining workflows and for human life and health. If you had to forecast an increase of gas emission in the mines, it is necessary to determine their spatial and time variations and a condition of their appearance. According to their mobility, gas components are very sensitive to conditions of geological environment and can be effective indicators of the dangerous and adverse geodynamic factors.

2 Methods

The basic task of project is organization of the ecological monitoring in the district of exploitation of large deposits of rare earth ore deposit (Lovozero massive) on the base of modern WSN (wireless sensor network) technologies, consisting of sensors of gas H_2, CH_4, CO_2, complex autonomous controls of temperature, pressure, humidity and network of telecommunications (used ZigBee protocol).

The advantages of this technology is autonomous work (to several months and more), high-frequency programmable measurement of gas sensor, low cost (on one node of network), and possibility to connect to one node of supervision a several types of sensors. At this moment, ZigBee protocol communication for WSN is set the standard since the 2004. This specification has been repeatedly updated and expanded. Platform MeshLogic software was chosen to create WSN (www.meshlogic.ru) [Bas12]. MeshLogic platform is a complete solution to develop wireless sensor networks for industrial or scientific automation applications, represents a complex of hardware and software that implements a set of network protocols for packet data transfer between any network devices (Figure 1)

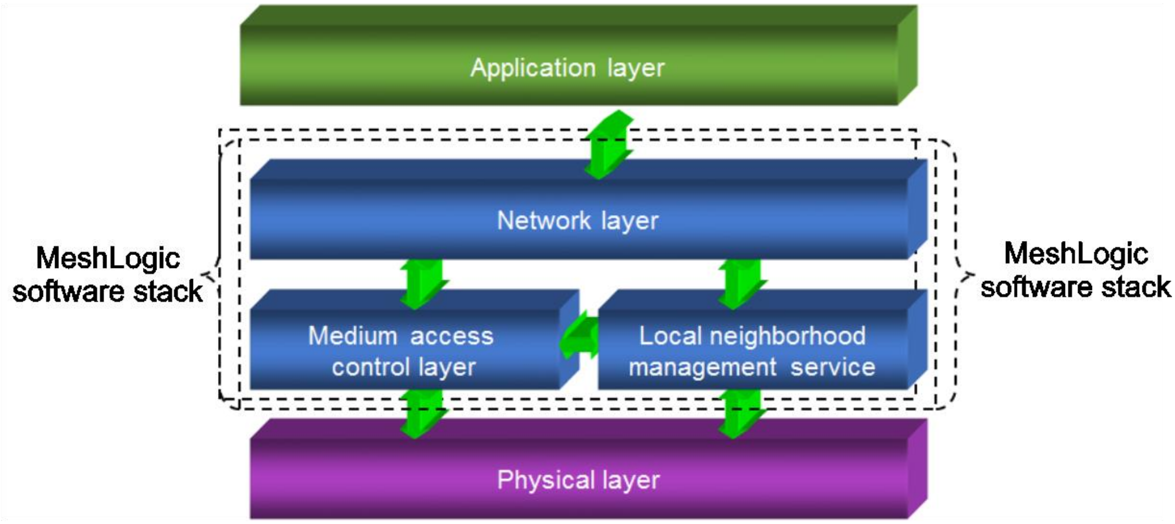

Figure 1: MeshLogic platform is an universal basis and is adaptable to specific application requirements

MeshLogic standard to be distinct from other products its own network protocol stack that provides the following key benefits:

- Fully homogenous network topology and algorithm of calculation position nodes in spatial;
- All nodes are equal and are routers;
- Self-organization, and automatic search routers;
- Resistance to conflicts between nodes with simultaneously inter transmit data;
- High scalability and reliability of data delivery;
- Ability all the nodes to work on independent power supply.
- Special software for service monitor radio equipment and sensors tools.

Because all MeshLogic nodes are equal and serve as routers, so there is no need to plan nodes placement in advance (Figure 2). And it increases tolerance to faults of individual nodes and links and it ensures network ability to self-adapt to environment conditions.

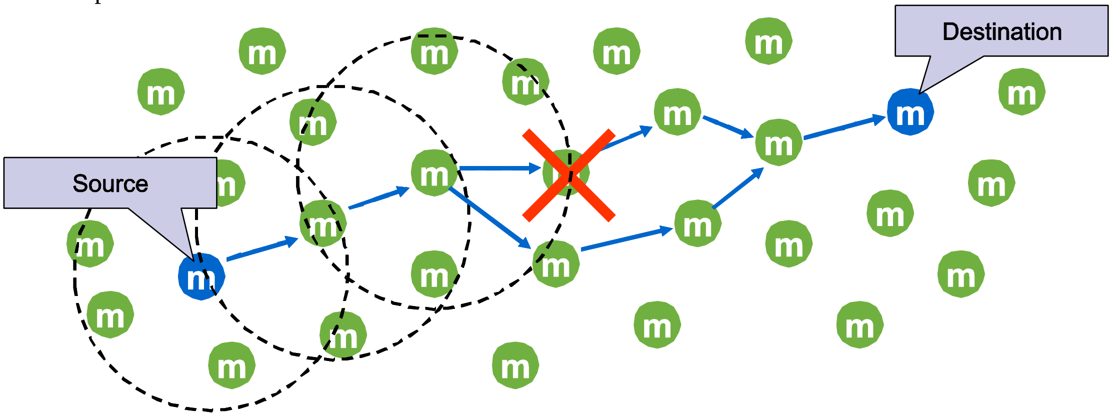

Figure 2: Packet delivery path is determined on the fly ensuring high scalability and robustness to network topology changes

The universal modular construction of the ML-SM-N wireless node allows you to install in each node up to 4 interface external modules with various types of sensors in any combinations. Thus, each ML-SM-N wireless node is a multi-channel (up to 64 external channels) measuring system with a flexible configuration that can be changed during operation. It is also possible to automatically determine the spatial position of the node, which allows in case of failure of a single node to rebuild the network topology. At the same time, the nodes independently determine the optimal data delivery routes and correct network topology and node spatial position.

Unique devices have been developed for maintenance service of gas emissions monitoring. Tools were constructed in department of physics and nano system of National Research Nuclear University of Moscow Engineering Physics in laboratory «Mining and examination of sensor controls on the basis of MDP structure». Heart of gas analyzer is device D-1. Data device D-1 represent sensing devices for measuring of concentrations of hydrogen, hydrogen sulphide, dioxide of nitrogen, chlorine and ammonia. A basic element is MDP (metal-dielectric-semiconductor) - structure of type Pd-Ta2O5-SiO2-Si which electric capacitance changes at interaction with gas. The sensing device can be used for definition of concentrations of any of the numbered gases in a ambient temperatures from-30 to +40 [Nik07].

To transmit real-time data and store them on remote server we use GPRS cellular mfodem.

The database was developed to collect and store online data of gas monitoring. This database provide a secure centrally administered data repository for information imported from the field data collection system. In addition, this database connect with GIS system and processing program of time series. The developed geo-information system of monitoring contains geological, geophysical maps and 3D model of Hibiny and Lovoozero massifs.

3 Results

The first technical and methodical solution was tested at the northeastern Lovozero massif (Kola Peninsula), in the underground Karnasurt Mine exploiting the same name section of the rare-metal deposit. The presence of freely emitted hydrogen-hydrocarbon gases is a peculiar feature of the Lovozero rare metal deposit related to the same-name agpaitic nepheline-syenite massif. A monitoring station was equipped at a blind drift of mines at +430-m horizon (~ 300 m below the day surface.

Unfortunately, low temperatures in the tunnel and high measurement frequency led to a rapid discharge of autonomous power supplies. The network node together with the power battery allow working autonomously approximately 2 to 3 weeks. Thus, the working scheme of the network is as follows: The sensor is in the zone closest to the explosion zone; it is connected by cable to the network node; the node is equipped with sensor radio control equipment; the system of data collection and transfer of information to a neighboring node and further to the central hub was established (Figure 3). There were 3-5 nodes in the segment of the network. It was done in order to duplicate the measurement near the explosion and to maximally secure the hub data collection

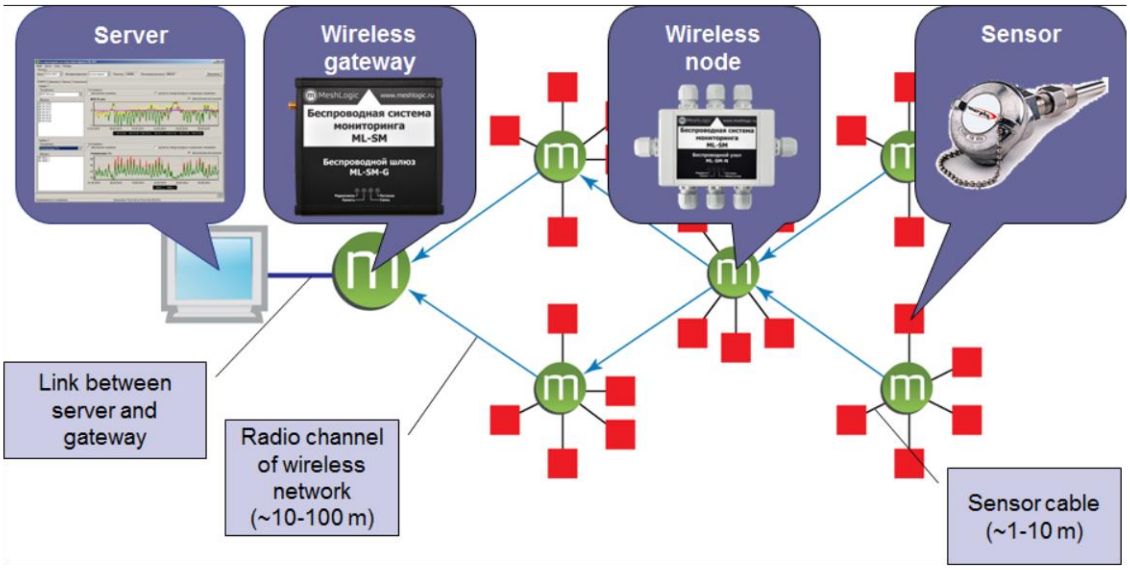

Figure 3: Application network consist from sensors of gas H_2, CH_4, CO_2, complex autonomous equipment for measurement temperature, pressure, humidity and network of telecommunications

The tests were carried out in two drifts (Figure 4). They are quite different of a level of water saturation condition. The maximal water flow was in the network segment of upper track number 13. This created the most unfavorable conditions for radio communication. It was the working network segment, where was the explosion station.

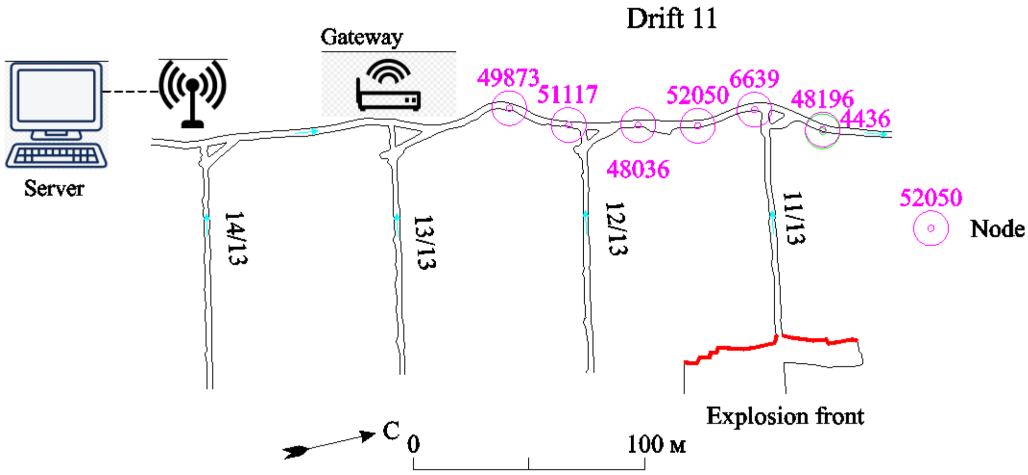

Figure 4: Location of WSN network nodes in driveways 11. Circles on schema show node location. The explosion zone is located in the rising tunnel 11/13. The closest node to the explosion is 6639

Figure 5 shows typical patterns of hydrogen content associated with explosions. Blasting operations are usually performed once a day almost at the same time. There were no explosion operations on 29 august, and there are no peaks on the graph on this day. Reduction of hydrogen content occurs quickly, because of good ventilation system. At the same time, an unexpected fact, which was established by our measurements, is the significant difference between background and peak hydrogen content. Even in our time-limited monitoring, this difference reaches to 800-1000 ppm, usually hydrogen content is changed in 12-40 times. These data indicate the possibility of dangerous hydrogen contents in the atmosphere immediately after the explosion, and the occurrence of seriously explosive and dangerous situation. Interpretation of the revealed pattern of gas flow distribution requires further research, but even now some assumptions can be made. Also we calculated volume of H_2 emission corresponding for each peak and analyze relationship between them. These are interesting estimates because it turns out that very large quantities of gas were not previously taken into account in calculations or were randomly included as abnormal deviations. The advent of high-resolution monitoring tools can reveal new aspect of the behavior of high volatile gases.

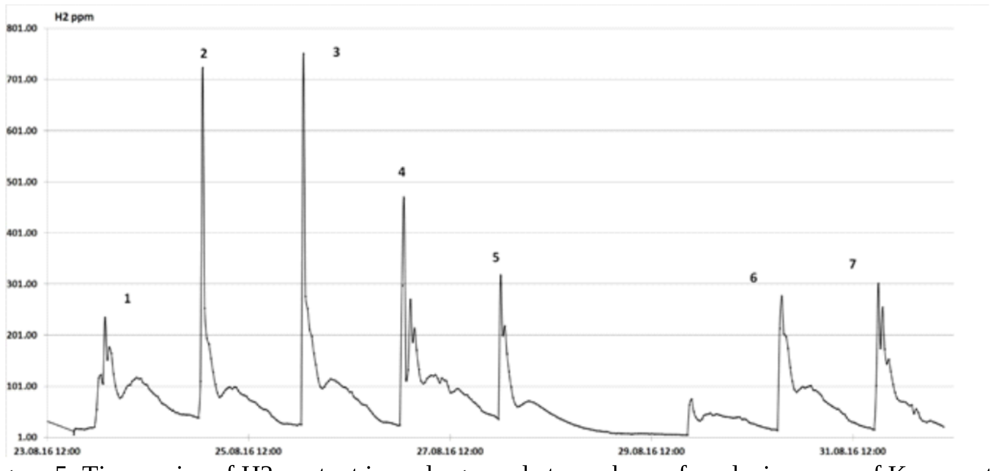

Figure 5: Time series of H2 content in underground atmosphere of explosive zone of Karnasurt mine

Analyzing temporal series of hydrogen concentrations obtained in about a year with the flicker-noise spectroscopy has revealed the following set of resonance frequencies: 198.4, 65.9,28.2, 24.6, 16.4, 7.6, 7.1, 6.4, 5.6 and 3.2 days and 25.9, 24.1, 22.5, 12.4, 11.6 and 8 hours periods [Tim11]. Presumably, some of them (close to daily and semidiurnal ones) are connected with the Earth's rotation and solunar tides. However, the preliminary analysis of a longer temporal series of hydrogen emission at the Lovozero deposit does not confirm these suggestions and testify to H2 dynamics depending mainly on meteorological and anthropogenic factors as well.

4 Conclusions

This work is the first experiment in technical decision for long-term monitoring of gas emission on the base of WSN, the high-sensitive sensors of hydrogen and methane, software and equipment attended with a transmitter network. The advantages of this technology is autonomous work (to several months and more), high-frequency programmable measurement of gas sensor, low cost (on one node of network), possibility to connect to one node of supervision a several types of sensors. In addition to scientific task, this monitoring system also allows to monitor an explosive situation in mines as a result of high concentration of explosive gas mixtures.

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