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L.N.Gumilyov Eurasian National University, Astana (Nur Sultan), Kazakhstan

ICEMIS‘19

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Forward

Welcome to the 5th International Conference on Engineering and MIS 2019 (ICEMIS 2019). We are pleased in the interest that this conference receives from the research and practitioner communities with representative from Kazakhstan and abroad.

First of all, I would like to take this opportunity to thank the International Association of Researchers (IARES Inc., Canada) for their support throughout all the preparation stages for this conference. Without their help and cooperation ICEMIS 2019 would not have been possible.

As part of our ongoing effort to effectively contribute in the development of research within the middle-east region, we aim for this conference to be the seed for many more conferences to come. ICEMIS 2019 aims to bring together academics, researchers, and students in order to offer the chance for everyone to present their work and scientific achievements, and exchange expertise in the fields of applied engineering, computing, Cloud, IoT, Fog computing, Big Data and other related topics. The ICEMIS 2019 proceedings will be included in the ACM Digital Library.

As shown in the reference section, after the fabulous success in ICEMIS 2015, 2016, 2017, 2018 and 2019 [1-91]; ICEMIS series builds on the last five years' successful events and brings together academics and practitioners in the fields of engineering, computing, information technology, and management information systems. Finally, I would like to thank all those who have contributed towards the success of this conference, especially the members of the organizing committee, the proceedings committee, and everyone else who made a contribution. To all the participants and volunteers of ICEMIS 2019, I hope you find this conference a rewarding experience which will aid you towards more achievements, and I wish you a pleasant and enjoyable stay in Kazakhstan.

Prof. Dr. Shadi A. Aljawarneh

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Environmental monitoring system for analysis of climatic and ecological changes using LoRa technology

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ABSTRACT
In this article, the problem of monitoring of climatic and ecological condition of the region is considered. The problem of environmental pollution in large cities is very significant, and modern monitoring systems have a number of significant drawbacks: low speed of deployment, large size of stations, and high cost of maintenance. The authors propose a new approach to the construction of such systems using the technologies of the "Internet of things". This will make it possible to create easily scalable low-cost systems with high energy efficiency through the use of modern communication technologies.

CCS Concepts
• Computer systems organization → Embedded and cyber-physical systems → Sensor networks

Keywords
IoT; Ecology; Environment; PWAN; LoraWAN; LoRa.

1. INTRODUCTION
Pollution of the environment by industrial enterprises and vehicles, causing degradation of the environment and causing damage to public health, remains the most acute environmental problem of priority social and economic importance. Therefore, the development of methodologies to reduce emissions of pollutants means of pollution control and management in order to reduce the anthropogenic impact on the atmosphere is currently relevant. The environmental monitoring system plays an exceptional role in the analysis and assessment of environmental and technological hazards.

Existing environmental monitoring systems allow the collection and analysis of a wide range of necessary information on the state of the environment. However, their establishment, deployment and operation, even within a single city, are very labor-intensive processes, resulting in substantial regional and municipal budget expenditures. There is a need for operational environmental monitoring in this area, which means that a new strategy and new methods are needed to focus on immediate and future trends and priorities. One of the solutions to this situation can be the use of modern information technologies, in particular, the "Internet of things" (IoT). In this connection, one of the main objectives of this study is to analyze the applicability of the technologies of the "Internet of things" in the interests of the environment. At the beginning, it is planned to conduct a market research of existing environmental monitoring systems and solutions based on "Internet of things" technologies, as well as to develop its own concept of the system of this class.

This article discusses monitoring systems designed to determine the state of the environment in urban agglomerations and suburban areas. The system developed in the course of the study will help to optimize the process of taking readings from various remote sensors installed in the study region using modern LPWAN radio access technologies. The system of mobile monitoring is implemented based on building a network of radio access technology LPWAN using a variety of remote sensors of climatic and environmental conditions in the metropolis.

2. EXISTING ENVIRONMENTAL MONITORING SYSTEMS
In the "Environmental Code of the Republic of Kazakhstan" article 141 identifies the following types of environmental monitoring [1]:

- Monitoring of the state of atmospheric air is a system of observations of the state of air pollution in the settlements of the Republic of Kazakhstan.
- Monitoring of soil condition-a system of observations of the state of technological soil pollution on the lands of settlements, irrigated areas and agricultural lands.
- meteorological monitoring-system of integrated meteorological observations
- Radiation monitoring-a system of observations of technological and natural radioactive contamination of environmental objects and territories.

- Monitoring of transboundary pollution - a system of observations carried out in the framework of international cooperation with border States on the state of transboundary waters and transboundary air pollution, as well as the effectiveness of measures taken to prevent, limit and reduce transboundary environmental impact.
- Background monitoring - a system of observations of the state of the atmosphere and other media in their interaction with the biosphere at a specialized network of stations for integrated background environmental monitoring.

Currently, observations of the state of atmospheric air are carried out by RSE "Kazhydromet" in 49 settlements at 146 observation posts, including 56 manual sampling posts and 90 automatic posts. Moreover, observations are carried out with the help of 14 mobile laboratories.

Observations of the state of atmospheric air are carried out [2]:

- Incomplete program (3 times a day – 07, 13, 19 hours.);
- Full program (four one-time 01, 07, 13, 19 hours);
- On an abbreviated program (twice 07 and 13 hours.);
- In continuous mode 90 automatic posts.

Existing up to the present time monitoring system of atmospheric pollution, based on the selection of samples and their subsequent analysis do not correspond to modern requirements from the point of view of labor costs, automatic continuous measurements. Therefore, in order to solve such problems related to monitoring and forecasting of climate-ecological changes, the work aimed at automated control systems with new modern technical means is of great importance.

For example, the monitoring system of Almaty, where all types of monitoring listed above are carried out by the Ministry of Energy of Kazakhstan, RSE "Kazhydromet". However, the main drawback of this system is the inability to monitor the readings in real time. In this connection, in addition to the official monitoring systems for the state of the environment, there were private projects such as AUA and AirKAZ.

In the framework of the system AirKaz observation is conducted in 5 districts of Almaty city. Measurements are carried out by a dust meter using a laser sensor to calculate the field particles per unit time. Depending on the particle size, they are divided into PM 1.0, PM2.5 and PM10, and each species is measured separately.

In September 2018, a mobile application "AirKZ" of RSE "Kazhydromet" was created to monitor the air quality in Kazakhstan. With its help, the user can monitor the air quality throughout Kazakhstan. In AirKZ, data are available for 46 settlements and 84 environmental posts. The user can manually select the necessary posts, or the application will automatically determine the nearest post according to the geolocation data [3].

Project AUA, launched in 2017, is using the dust meter BAM-1020 established in the territory of KazNMU them. S. D. Asfendiyarov. The Kazakhstan Institute of Metrology carried out verification of the measured readings. In the future, based on this project, a mobile application was created [4].

Automated Industrial Emission Control System NL-2308 (“HORIBA Scientific”), Automated Pollution Control System(Scientific Production Company “DIEM”), Atmospheric pollution control stations(«IMC SYSTEMS»), Atmospheric pollution control -A(Ecros Engineering) [5].

In 2016, the Eco-routes service was launched in Nizhny Novgorod, which determines the pollution of the urban environment by vehicle emissions in real time [6]. This system works as follows: on the map of the city you need to mark the start and end points of your route and click "assess risk". After that, the service makes calculations and reports the degree of air pollution on the route. In the calculation of the concentration of nitrogen oxides NOx using mathematical Gaussian model of dispersion of pollutants in the atmosphere.

In addition, in the article [7] there are examples of web technologies used, where the key elements of the new interface are the background base map and observation data in the form of a translucent layer. The user of the web application is provided with controls such as the selection of one of the indicators and the time interval. With the help of additional tools, you can view data with a certain time step in one direction. To search for anomalies, the data output is provided as a graph of maximum values with a quick transition to viewing the data at a certain point in time.

In the implementation of global monitoring systems, special attention is paid to monitoring the state of the environment from space. Where it is possible to obtain unique information on the functioning of various ecosystems at the regional and global levels, on the levels of natural disasters and ecological catastrophes with the help of the earth's space remote sensing (ERS) system. For example, the US global monitoring system Environmental Observation System (EOS), which is based on the processing of data obtained from three satellites equipped with video spectrometers, radiometers, radio altimeters and other equipment [8].

The structure of the automated subsystem of collection and processing of data

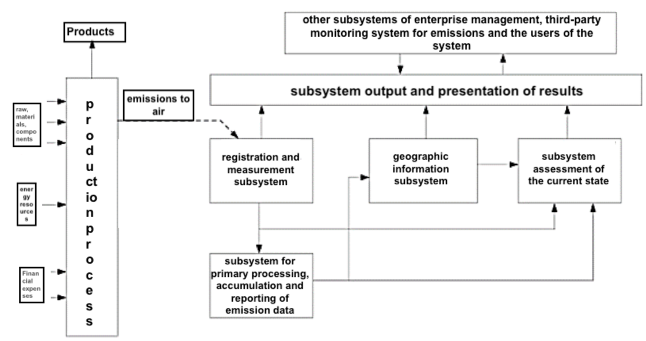

Figure 1-Subsystem for collecting and processing data on emissions of pollutants into the atmosphere

Figure 1 shows the system of data collection and processing where the full range of monitoring tasks is solved:

- the definition of the critical objects of monitoring polluting emissions;
- determination of the control method for each object emitting harmful substances;
- the determination of the placement and the necessary equipment of the control points;
- collection of sensor data about the levels of concentration of pollutants;
- primary processing of time series of measurements obtained from control points and comparison of data with standard values;
- assessment of the current state of atmospheric emissions and output of the necessary information to the user;

- accumulation and storage of information in the databases of the monitoring system;
- geographic information display of current data with reference to the terrain and objects of control at the local level.

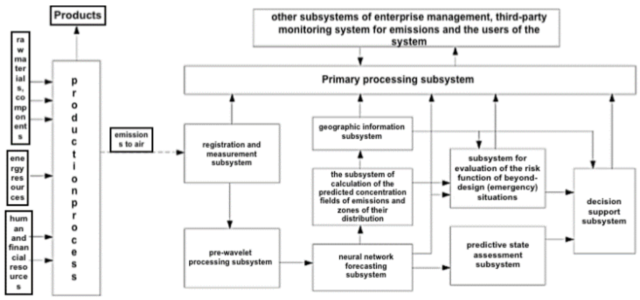

Figure 2-Subsystem of secondary processing of time series of pollutant emissions into the atmosphere

According to the structure of the subsystem of secondary processing of time series of data of emissions of pollutants into the atmosphere, the following tasks are solved:

- pre-processing of time series of data on emissions of pollutants into the atmosphere
- getting the forecasted data about change of level of pollutants;
- calculation and evaluation of the risk function of emergency situations;
- support in making decisions aimed at minimizing possible damage, as well as decisions on the necessary measures to eliminate excess emissions [9].

3. THE TECHNOLOGY USED FOR DATA TRANSFER IN THE SYSTEM OF ECOLOGICAL MONITORING

Environmental monitoring is an extensive application for the Internet of things, which includes everything from monitoring the level of carbon dioxide in the premises of industrial enterprises to monitoring national parks for the presence of smoke. The use of IoT technologies can simplify and make more efficient the time-consuming process of environmental monitoring.

Below is a list of the six most common uses of IoT for environmental monitoring, a few considerations when choosing an IoT network, and why a Low Power Wide Area Network (LPWAN) might be the best solution.

- Monitoring of air quality for carbon dioxide, carbon oxides, sulphur, nitrogen, organic compounds, heavy metals and particulate matter
- Monitoring of water quality, pollutants, thermal pollutants, chemical leaks, lead and flood levels
- Monitoring soil moisture and vibration levels to detect and prevent landslides
- Monitoring of forests and protected lands from forest fires
- Monitoring of natural disasters such as earthquake and tsunami warnings
- Monitoring snow levels in ski resorts and national parks to track weather and prevent avalanches.

The use of IoT allows using various sensors, meters and gas analyzers to monitor changes in the environmental situation in different areas, type and purpose. IoT systems enable you to build a flexible, scalable, and fault-tolerant system with low implementation and maintenance costs.

The ability to monitor the slightest changes in real time will allow taking timely measures to reduce or eliminate the harmful effects on the environment. Among the available features of smart-devices there are such as monitoring of seismic activity, weather conditions, changes in the composition of the atmosphere, soil and water bodies, monitoring the vibration field of rocks in order to prevent mudflows and many other examples.

The collection of various indicators is the first step towards improving the environment, improving the safety of citizens and the preservation of natural resources of any state.

Recently, personal environmental devices and monitoring applications have become increasingly popular. The possibilities of such devices are very extensive, from the product of measurements of the environment (air composition, temperature, humidity, etc.) to measure the level of radiation. Compact size and support for modern communication technologies such as Bluetooth and Wi-Fi allows you to use them 24/7 and track their readings remotely on your personal smartphone.

An example of such devices is the development of air quality eggs (Fig. 3), implemented through a crowdsourcing company on Kickstarter in 2012 and awarded the "Best project Kickstarter 2012".

Figure 3 - Air Quality Egg

Air Quality Egg is a Wi-Fi-enabled device that uses sensors to monitor changes in the levels of certain air pollutants. Each device can measure at least one air pollutant - NO_2, CO_2, CO, O_3, SO_2, particles and volatile organic compounds. It tracks any changes and automatically uploads the data to the cloud, where it can be accessed through a web portal, mobile application or manual download by connecting Egg to your computer.

There are other examples of the use of IoT devices for environmental monitoring, such as sensor control illegal logging Invisible Tracck, the Bigbelly containers with sensors fullness with subsequent notification of public utilities of the city, and many other "smart" devices.

Some considerations when selecting the type of network for the IoT to monitor the environment:

- Bluetooth and BLE are often not suitable for long distance operation, making them not the best choice for environmental sensors. Wi-Fi also has long-distance performance limitations, and the infrastructure costs associated with setting up a Wi-Fi network can be prohibitive;
- Mesh topologies such as ZigBee will also not work properly for monitoring the environment as the sensors are

not close enough to each other (and may be on the ground), so obtaining reliable point-to-point connections will prove difficult;

- Cellular M2M networks require a lot of energy, are expensive to deploy, and will not work in many rural areas without cellular services.

All of the above makes LPWAN an ideal choice for environmental monitoring systems using IoT.

Long-range energy efficient network (LPWAN) technology is ideal for environmental monitoring because it can connect devices that need to stay in range for a long period and send small amounts of data over long distances. Some IoT applications only need to transmit tiny amounts of information - for example, a sensor that sends data only if it detects smoke in the forest.

There are two main areas where LPWAN technology is best-suited [10]:

- Fixed connections with high density. In cities or buildings, LPWAN technology is an excellent alternative to cellular M2M connections. Some examples include intelligent lighting controllers, distribution automation (smart grid), and GPS resource tracking in campuses or cities;
- Battery-powered devices where long-term operation is required. LPWAN can be a good example when you need more battery life than older technologies can provide. Examples include water meters, gas sensors, intelligent farming, and battery-powered door locks and access control points.

Different wireless technologies meet the needs of a particular application with changes in modulation schemes and frequency. Long-range devices with low bandwidth requirements, which are typical for IoT applications, are poorly supported by these existing technologies. LPWAN targets similar applications and devices [11].

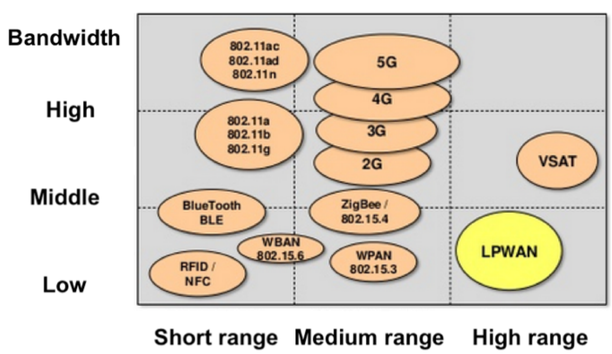

Figure 4-data sampling Algorithm

One of the possible solutions to the problem of wireless network connections with cellular topology is ZigBee technology. The main disadvantage of this technology is the limited supply of bandwidth due to the high data rate and low sensitivity of the receiver. Some ZigBee connections have problems sending data over a distance of more than 20 to 30 meters because the power coming from the transmitter is lost too quickly.

Instead of a mesh network, most of the LPWAN technologies use a star network. As with Wi-Fi, star-type network endpoints connect directly to the access point. In addition, it is possible to use a repeater to easily fill gaps in coverage, which for most applications is a good intermediate solution in terms of latency, reliability and coverage.

In order to reach a large distance in wireless communication, a large channel reserve is required. In other words, when a signal is transmitted, it needs enough energy to be detected upon receipt. Because a certain amount of energy is lost in the process of spreading through space and materials between them.

LPWAN technologies typically operate at 140-160 decibels (dB) from a common path, which can increase the range to several kilometers under suitable conditions. This is primarily achieved due to the high sensitivity of the receiver. The sensitivity of the receiver, comprising more than -130 dBm, is common for technologies LPWAN, compared with -90 to -110 dBm, which is observed in many traditional wireless technologies. Technology with -130 dBm can detect signals 10,000 times weaker than technology with -90 dBm, which is a significant advantage of LPWAN.

There are a number of reasons to consider GPON technology for an environmental monitoring system:

- Long battery life. After installing LPWAN sensors for couple of years, there is no need to replace the battery, which making them ideal for areas that are difficult to maintain. Many LPWAN technologies also allow to power the environmental sensors from solar panels, which is an excellent "green" method for remote areas;
- Inexpensive. If you need to measure a large number of indicators, from air quality to forest fires, and require a relatively high sensor density, the use of LPWAN technology will reduce costs;
- Higher range. End nodes and antennas of the LPWAN system can be deployed at a distance of 500 meters to 10 kilometers from each other, depending on the technology.

At the moment there are two LPWAN standards-Larawan and NB - IoT. LoRa is a patented frequency extension of the frequency spectrum. In 2008, the technology patent was granted to Cyclo (France), and in 2012 Cycleo acquired Semtech (USA).

NB-IoT is developed by 3GPP group on the basis of existing mobile communication standards. There are two main versions of this specification: one released by Nokia, Ericsson and Intel, and the other by Vodafone&Huawei. LoRaWAN is an open Protocol for high-capacity (up to 1,000,000 devices in one network) networks with a large range and low power consumption, which LoRaAlliance has standardized for global networks with low power consumption (Low Power Wide Area Networks, LPWAN). The LoRaWAN network is organized as a star-type network and includes various classes (a, B and C) of nodes to optimize the trade-off between information delivery speed and battery life.

4. ARCHITECTURE OF THE SYSTEM

To solve the problems of forecasting and monitoring of ecology, climate and meteorological conditions, it was decided to design a platform for the collection and transmission of heterogeneous environmental data in Almaty and Almaty region.

The main purpose of the system is to monitor the air quality, forecast, assess and identify trends in the state of the atmosphere to prevent negative consequences that adversely affect human health and the environment. It allows real-time monitoring of environmental and meteorological conditions and monitoring of all major sources of pollution for subsequent management decisions. When designing the system, the following requirements were set: low cost of creation and operation, autonomy of end measurement stations, scalability, operational access to the collected data, data security and stability of the system as a whole.

A scheme of the system network fragment was developed based on the analysis of the parameters necessary for the assessment of the environmental situation, the specifics of the relief and development of the city territory. The scheme consists of data collectors, which include several local and one base station (Fig. 5). Data collectors are located in different parts of the city. Within the area, the collection of data done based on LoRa technology. Data transmission from data collectors is carried out using cellular mobile communication systems. Each local station is mobile. The structure of the local station includes sensors for measuring the necessary parameters, electronic processing devices, radio module LoRa technology. The base station is stationary. It also contains sensors for measuring parameters, electronic processing devices, as well as equipment for transmitting information over cellular networks (GSM or LTE standard) and LoRaWAN gateway. The data received from the local and base stations is transmitted to the server and can be further accessed by the user of the system through the web interface or mobile application, as well as third-party software products through the API.

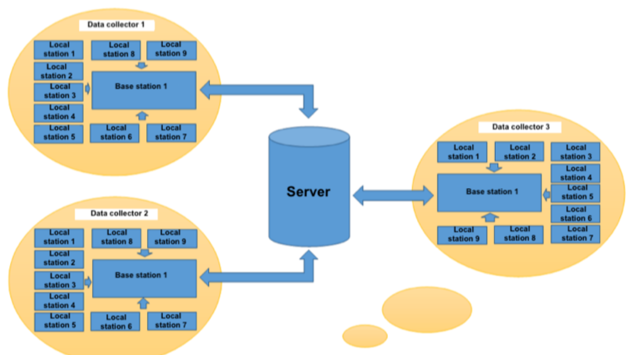

Figure 5-Block diagram of a network fragment

The core of each local station is a Board based on ARM Cortex-M3 controller, and the core of each base station is a single Board computer based on ARM Cortex – A53 microprocessor. Gas analyzing sensors and other measuring equipment connected to them. A list of air pollutants whose concentrations should be monitored was identified. This list includes substances such as carbon monoxide, nitric oxide, ozone, methane, and suspended particles in the air. Also station of the connected temperature sensors, humidity, pressure, GPS. Stations can be completed at the request of the user depending on the installation location. The architecture of the stations is shown in Fig. 6.

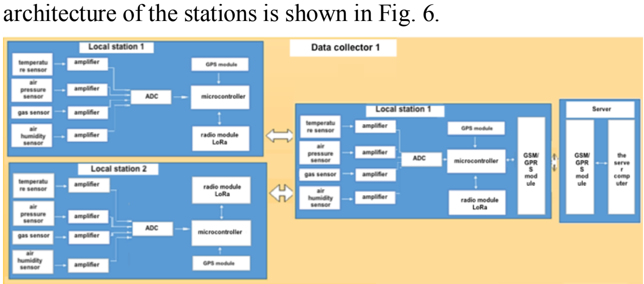

Figure 6-Block diagram of a network fragment

The network based on the LoRa standard was chosen as the data transmission technology. As mentioned earlier, low data rates in the LoRa network are compensated by a large area coverage with low power consumption. Among other things, LoRa networks use the unlicensed radio frequency range LPD433 and ISM-range 915 MHz [12], which will allow to deploy the network in a short time without additional permissions, as well as to expand it with new devices as necessary without the cost of a subscription fee.

In addition, a significant advantage of LoRa is the open hardware specifications of the data transmission module from SemTech and the existence of The Lora Alliance consortium. The Lora Alliance includes many major software and hardware manufacturers, such as Intel, IBM and Cisco, which gives confidence that this technology has prospects for development and presence in the market in the next few years [13].

Local stations collect data from sensors and transmit it to the nearest base station (LoraWAN gateway). If no base station is within range of the local station, the data is stored on a removable SD flash drive. As soon as the local station re-enters the coverage area of the base station, all accumulated information will be automatically sent to the base station. The base station also collected evidence at the place of installation, and transmit the obtained information to the server, not the processing. In addition to stations, there is a control server in the LoRa network that organizes data transfer from end devices to the storage server and back. The network server resolves network collisions, changes transmitter power and data rate, monitors the battery charge of end devices, and sends the data to the storage server. On the server of data processing and storage is the extraction, storage and processing of data obtained from measuring stations. Third-party applications receive data on the state of the environment from the data processing and storage server, bring them in line with the units of measurement adopted in the region and display to the end user both in the form of summary information from all stations and for each station in the network separately. Interactive maps, summary tables, histograms are used for visual display of information, available both through the website and through the mobile application.

The developed scheme, implemented on a modern element base, will provide the statistical data necessary for the analysis of the automatic network for the collection of environmental and meteorological information at different times of the day, under different weather conditions.

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