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SURFACE ENVIRONMENTAL MONITORING SYSTEM

Alex Rudzenis
e-mail: alex.rudzenis@gmail.com
Scientific advisor – Associate Professor, Lykov Y.
Kharkiv National University of Radio Electronics
Department of CRETISS, Kharkiv, Ukraine

Climate change monitoring is one of the most critical tasks of our time, as climate change has a profound impact on the environment, the economy, and human safety. Traditional monitoring methods have several limitations, highlighting the need for new solutions.

Developing a monitoring system based on LoRaWAN, GPS, and satellite communication offers new opportunities to improve forecasting accuracy and expand geographic coverage, including remote and hard-to-reach areas.

Modern climate change is one of the most serious threats to humanity. Rising global temperatures, increasing sea levels, and the growing frequency of droughts, hurricanes, and wildfires devastate ecosystems, economies, and public safety. These changes lead to biodiversity loss, worsening living conditions, infrastructure destruction, and significant economic losses.

Accurate and timely monitoring of climate processes is critical to counter these challenges effectively. This not only allows us to track ongoing changes but also to develop timely adaptation measures. However, traditional climate monitoring methods, such as satellite observations and ground-based weather stations, require significant financial and energy resources. In addition, they have limitations in geographic coverage and data update frequency, which reduces their effectiveness for real-time forecasting.

As a result, there is a growing need for new, more affordable, and energy-efficient solutions, such as LoRaWAN technology. This wireless data transmission technology features low power consumption, long communication range, and the ability to connect numerous sensors. Its application opens new possibilities for creating a global climate change monitoring system.

One of the most promising directions is using floating ocean sensors as weather stations. These autonomous devices can collect and transmit data on water temperature, salinity levels, current speed and direction, and atmospheric conditions. Thanks to LoRaWAN technology, the collected information is transmitted in real-time to ground stations or satellites, enabling accurate weather forecasting, early detection of storms and hurricanes, and long-term climate change monitoring.

The use of LoRaWAN in climate monitoring addresses several tasks at once: it reduces the cost of data collection, enables rapid response to environmental changes, and improves the accuracy of extreme weather forecasting. However, there are also challenges associated with integrating this technology into existing systems. Successful implementation requires the development of data processing standards, ensuring data reliability and accuracy, and establishing coordination with meteorological services. Additionally, large volumes of data from numerous sensors must be processed efficiently.

Thus, developing and deploying a global climate monitoring system based on LoRaWAN is a promising area that requires a comprehensive approach. It will improve the quality of weather forecasting and enhance preparedness for potential natural disasters, minimizing damage and reducing risks to the population and the economy.

Various methods of climate monitoring exist, each with its advantages and limitations. The most important include satellite technologies, ground-based weather stations, ocean buoys, uncrewed aerial vehicles (UAVs), and IoT sensor networks.

Effective climate change monitoring uses various technologies and methods, each with strengths and weaknesses. Modern monitoring systems include satellite technologies, ground-based weather stations, ocean buoys, uncrewed aerial vehicles, and IoT sensor networks.

At present, several key technologies are employed for climate monitoring, each with specific functions, advantages, and limitations:

1) Satellite Monitoring

Capabilities: Satellite monitoring enables the observation of global changes in temperature, greenhouse gas concentrations, ice cover, humidity, and other key environmental parameters.

Advantages: Wide geographic coverage, high measurement accuracy, and the ability to conduct retrospective data analysis.

Disadvantages: High costs of satellite deployment and maintenance, delays in data transmission, and dependence on weather conditions.

2) Ground-Based Weather Stations

Capabilities: Measurement of temperature, humidity, precipitation, atmospheric pressure, and wind speed at specific local sites.

Advantages: High accuracy of measurements and the availability of long-term observational data.

Disadvantages: Limited coverage area and the requirement for installation and ongoing maintenance.

3) Ocean Buoys and Autonomous Sensors

Capabilities: Measurement of water temperature, salinity levels, ocean currents, and carbon dioxide concentration in seawater.

Advantages: Real-time data collection and resilience to external environmental factors.

Disadvantages: Limited spatial coverage and the need for regular technical servicing.

4) Drones and Autonomous Aerial Vehicles (UAVs)

Capabilities: Data collection on atmospheric conditions, land surface states, vegetation health, and glacier monitoring.

Advantages: Flexibility in deployment and the ability to conduct localized monitoring of hard-to-reach areas.

Disadvantages: Limited operational time, weather-dependent functionality, and high operating costs.

Competing Long-Range Data Transmission Technologies

Several alternative technologies to LoRaWAN are used for long-distance data transmission in climate monitoring systems. Each offers specific advantages and limitations:

1) NB-IoT (Narrowband IoT) – an analogue of LoRaWAN, which has high energy efficiency and operates via mobile networks. It has such advantages as high network capacity and reliable data transmission. But it is not without its disadvantages, such as the need for mobile coverage and higher operating costs.

2) Sigfox is a narrowband IoT network with low energy consumption. It has such advantages as Easy integration and low operational costs. It has the following disadvantages: limited bandwidth and a shorter communication range compared to LoRaWAN.

3) 5G networks enable IoT sensors with advanced data processing capabilities and support for large volumes of information.

Advantages: high data transmission speeds and the ability to handle large datasets.

Disadvantages: high equipment costs and significant energy consumption.

An autonomous climate monitoring system is proposed based on integrating LoRaWAN, GPS, and satellite communication technologies.

The system will rely on autonomous floating stations with sensors to measure water temperature, salinity levels, current speed, atmospheric pressure, and humidity.

As these stations drift across the ocean, they transmit collected data via LoRaWAN to satellites or ground-based stations, ensuring global coverage and real-time data acquisition.

Advantages of the Proposed System

1. Energy efficiency – The devices can use solar panels or other autonomous power sources.
2. Wide coverage area – The system enables data collection in remote regions of the world's oceans.
3. Timeliness – Real-time data transmission with minimal delays.
4. Flexibility – Adding new stations can quickly scale the network.

This system will significantly improve the accuracy of climate forecasting, enhance resource management, and reduce the risks associated with climate change.

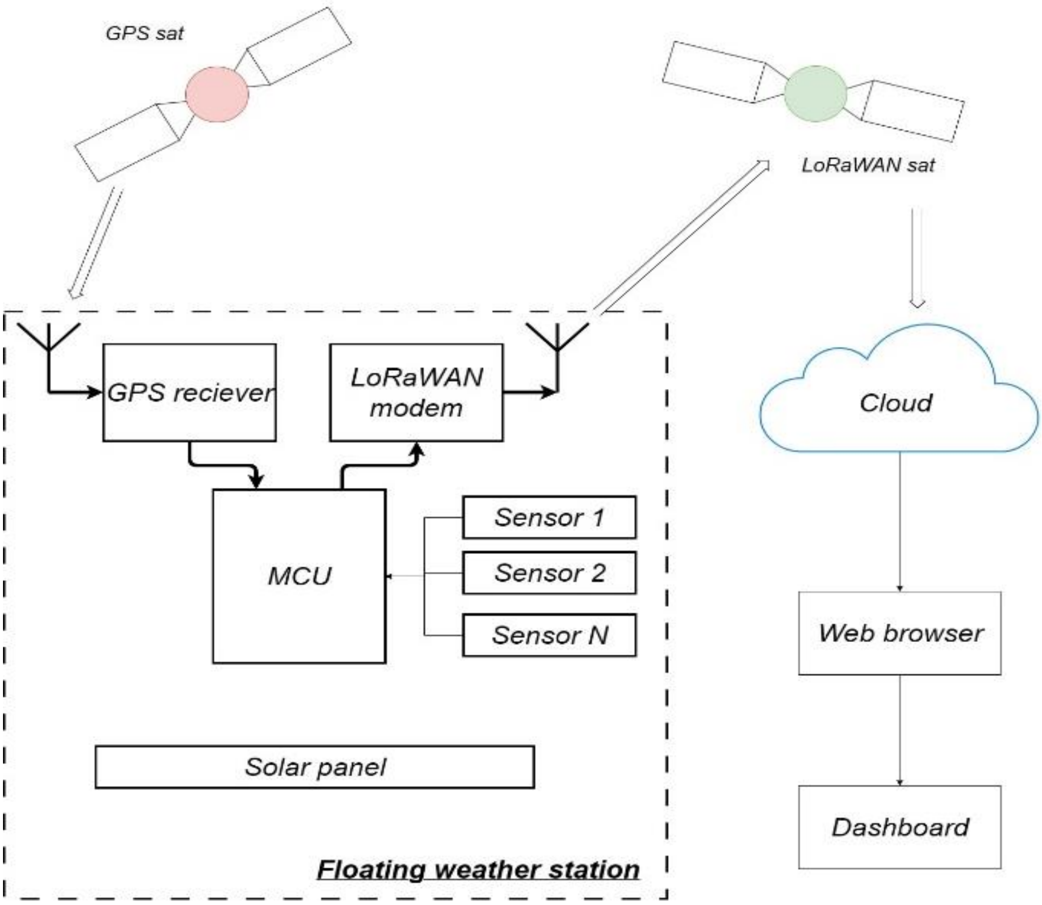

Figure 1 – Structure of the surface environmental monitoring system

Conclusion

Climate change monitoring is one of the most critical tasks of our time, as climate change has a profound impact on the environment, the economy, and human safety. Traditional monitoring methods have several limitations, highlighting the need for new solutions.

Developing a monitoring system based on LoRaWAN, GPS, and satellite communication offers new opportunities to improve forecasting accuracy and expand geographic coverage, including remote and hard-to-reach areas.

In addition, such a system has significant scalability potential, allowing it to be integrated into international meteorological projects and global climate monitoring networks.

Autonomous floating stations will enable establishing a global climate data collection network, ensuring the timely detection of climate changes and extreme weather events.

This technology is characterized by high energy efficiency, wide coverage, and real-time data transmission, making it a promising solution for further development and integration into existing meteorological systems.

Scalability prospects include expanding the network by adding more sensors and connecting new regions, as well as using collected data to develop global strategies for climate change adaptation.