# KAPITEL 2 / *CHAPTER 2* [2]
# EMPOWERING PUBLIC INSTITUTIONS THROUGH IOT- REGIONAL CLIMATE MODELS SYNERGY

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## Introduction

The urgency of empowering government agencies through the synergy of IoT and regional climate models is due to several factors. The first is the need to address climate-related issues. Intensive human development has had a negative impact on nature, the scale of which is difficult to assess without the use of modern concepts, one of which is IoT. The Internet of Things is a concept of a network consisting of interconnected physical devices that have built-in sensors and software that allows for the automatic transmission and exchange of data between the physical world and computer systems using standard communication protocols. IoT-based solutions mainly address consumer and business problems, but some important global climate issues can also be addressed using IoT technology. The combination of IoT technologies and regional climate models can provide government agencies with opportunities to address water ecosystem management, energy consumption, waste management, air quality measurement, and organic farming. The solution to the problem of waste management with the help of IoT is described in works [1-3], and electricity consumption in works [4,5]. It has also been proposed to use the Internet of Things as an ecosystem of devices to ensure energy efficiency and safety [6].

As the importance of territorial communities has increased, they have acquired new responsibilities and serious tasks, one of which is to address climate change, which requires additional funding and control. The introduction of IoT for financial control in a territorial community is described in work [7]. A framework for the reasonable creation, interpretation, and use of climate change forecasts, as well as for continuing innovations in climate and environmental science based on the Internet of Things, is presented in work [8]. Also, in the context of climate and environment, IoT is considered in works [9,10], where models for climate forecasting and monitoring are

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created. For the wider use of IoT based on regional climate models, it is necessary to attract large financial and technical resources, which can only be done by a governmental organization or public institution. Examples of the use of the Internet of Things by the Chinese government to solve climate problems are given in works [11,12].

**Problem statement**

Formulating a potential strategy for empowering public institutions through the synergy of the Internet of Things and regional climate models is a complex process that requires the analysis of several different factors, such as conservation of momentum, energy, mass, and water. The productivity of public institutions depends on the realization of the synergy of the Internet of Things and regional climate models. However, before realizing this synergy, it is necessary to evaluate it and understand what impact it will have on the activities of public institutions in the future.

In order to form a potential strategy for expanding the capabilities of public institutions through the synergy of the Internet of Things and regional climate models, it is necessary to first analyze the advantages of regional climate modeling. This may include an assessment of regional climate modeling challenges based on configuration, physical structure, and other factors.

The next stage is an assessment of the benefits of using the Internet of Things. It involves analyzing the strengths and weaknesses of this concept to identify possible points of convergence. After that, a strategy should be formed, which may include the development of technologies to build the Internet of Things that meet the needs of the public institution.

The first stage is the formation of general requirements for the synergy of the Internet of Things and regional climate models. At this stage, general requirements are formulated that must be taken into account to build a strategy for combining the Internet of Things and regional climate models.

At the second stage, the environment of public institutions for solving climate-related problems is assessed and a general synergy policy is formed. The assessment is based on information from open sources. At the third stage, the strategy of synergy between the Internet of Things and regional climate models is implemented.

The fourth stage evaluates the implementation of the synergy strategy of the Internet of Things and regional climate models to expand the capabilities of public institutions. At the fifth stage, an information system for monitoring climate change is being built, based on the synergy of the Internet of Things and regional climate models.

**Scientific methods**

A number of general scientific methods were used to perform the stages of the research, such as:

Monitoring method: used to collect, systematize and analyze information on regional climate models. Comparison method: came in handy when researching methods of using regional climate models and comparing them with regards to how they operate using all applicable prompts.

Method of abstraction: this was used in the course of the study in order to highlight the main concepts and categories.

Abstract-logical and dialectical methods of scientific knowledge, as well as the method of scientific abstraction, were used in the research to form theoretical generalizations, clarify the conceptual apparatus, and formulate conclusions.

That is why several unresolved issues arise in these conditions. The issue of creating a software application based on the synergy of the Internet of Things and regional climate models that will allow monitoring the climate in a convenient mode for representatives of public institutions requires additional research. Another area of research may be the creation of a strategy for the interaction of regional climate models that will monitor the climate of the entire earth using Internet of Things tools.

**Information system for climate change monitoring based on the synergy of the Internet of Things and regional climate models**

The first step of this scientific research is to define the concept of regional climate models and the advantages of their use.

Regional climate models are numerical models that simulate the climate of geographic regions typically covering a few thousand square kilometers to a continent. During zoning, the following factors are taken into account:

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- similarity of physical and geographical conditions;
- uniformity of manifestation of climate-forming factors;
- relative homogeneity climatic fields of temperature and precipitation;
- administrative-territorial division of the state.

The last factor was taken into account in order to adapt the research data for the strategic planning of farming and regional development.

The advantages of using regional climate models are the ability to predict changes in temperature, precipitation, sea level rise, and various extreme natural events with sufficient accuracy. Since the impact of climate change is heterogeneous, it is necessary to create separate forecasts for different regions. Regional climate models traditionally include only atmosphere and land components with prescribed sea surface temperature and sea ice.

Like global climate models, regional climate models numerically and simultaneously solve the energy, momentum, and water vapor conservation equations that determine the state of the atmosphere.

These equations are based on the Navier-Stokes equations:

- for fluid flow (conservation of momentum) with approximations that apply to the atmosphere;
- the thermodynamic energy equation (conservation of energy);
- the continuity equation (conservation of mass);
- the equation of state (ideal gas law).

In regional climate models, solving these equations over limited areas requires boundary conditions that can be derived from global climate modeling or global analysis to describe large-scale atmospheric conditions. In addition to the numerical solution of equations, regional climate models include parameterization of physical processes, such as radiation transfer, convection.

Thus, regional climate models represent the fundamental laws of physics applied to the Earth's climate system.

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Regional climate modeling advantages are:

- physically based downscaling;
- nesting within different global climate models or analyses of observations;
- wide variety of applications (paleoclimate, climate change, seasonal prediction);
- high resolution through multiple nesting (currently 10-30 km grid interval).

However, the disadvantage of regional climate models is that the boundary conditions at the edges of the model area must be prescribed.

The second step of scientific research is the determination of the rules for building regional climate models and general requirements for the synergy of the Internet of Things and regional climate models.

Regional climate models are characterized by a certain level of internal variability due to the model non-linearities. The rules for building a regional climate model are based on the conditions of the region where it is built and additional parameters:

- the region used to build the model must be large enough to include relevant circulations and forcings, and to allow the model to fully develop its own internal dynamics;
- the resolution of the model should be sufficient to capture the relevant forcing and providing useful information;
- model results usually depend on the model configuration (although this dependency should be minimal).

The general requirements for the synergy of the Internet of Things and regional climate models in the context of their further use by the public institutions are:

- clarity and comprehensibility of the constructed strategy;
- the possibility of creating an information system for climate change monitoring based on this strategy;
- the climate change monitoring information system based on the synergy strategy of the Internet of Things and regional climate models can be transferred to a

software application.

The general policy of the synergy of the Internet of Things and regional climate models is built on the basis of the environment of public institutions in solving problems related to climate change. The most visible consequences of climate change are emergency situations such as severe droughts, floods, storms, hurricanes, extremely hot days. The main task of public institutions is to overcome the consequences of these extraordinary phenomena, but it is always better to prevent something than to deal with the consequences, so the proposed strategy of synergy of the Internet of Things and regional climate models will be aimed at monitoring.

The third step of the scientific research is a review of the proposed algorithm for obtaining data by representatives of public institutions during monitoring, which was created on the basis of the synergy of the Internet of Things and the regional climate model: its elements and advantages.

To monitor the state of the climate, it is possible to use sensors for monitoring and forecasting the state of the environment. They measure temperature, air humidity, the concentration of chemical pollutants in the air, water, and soil, as well as check the level of noise, radioactive pollution, and much more, depending on the monitoring goals. The algorithm for obtaining data by representatives of the public institution during monitoring according to the chosen strategy is shown in Figure 1.

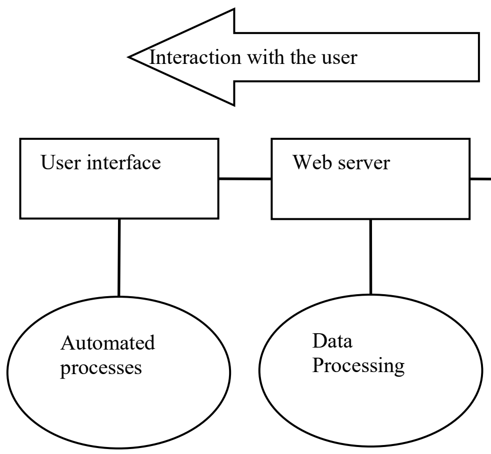


**Figure 1 - The algorithm for obtaining data by representatives of the public institution during monitoring**

The advantages of the proposed algorithm for obtaining data by representatives of public institutions during monitoring, which was created on the basis of the synergy of the Internet of Things and the regional climate model, are:

- ease of understanding and implementation, which significantly saves time;
- automation of the process allows you to respond to climate changes faster;
- cheapness, since you only need to have a gadget to run the user interface, gateway and sensors, it is more appropriate to rent a server.

The monitoring data acquisition algorithm shown in Figure 1 shows how physical values (such as temperature, for example) are transmitted to public institutions for processing using sensors, a router (gateway), machine-to-machine interaction technologies, a web server, and a user interface.

Each of the elements of the algorithm is responsible for its functions in its work:

- sensors convert the monitored value (pressure, temperature, flow, concentration, frequency, speed, movement, etc.) into a signal (electrical, optical, pneumatic) that is convenient for measuring, transmitting, converting, storing and recording information about the state of the object of measurement;
- router (gateway) converts protocols of one type of physical medium into protocols of another physical medium (network);
- machine-to-machine interaction allows machines to exchange information with each other, or transfer it unilaterally;
- the web server is designed to store data. It is also designed to deliver information to users;
- the user interface provides the transfer of information between the human user and the hardware and software components of the computer system.

The last step of scientific research is the creation of an information system for monitoring climate change by organizing the automatic interaction of various information and measurement devices using the Internet of Things technology.

For the development of an information system, based on the proposed monitoring algorithm, Bluetooth is a good option for network technology, since this technology is already able to route network traffic, connect industrial programmable logic controllers, support web servers, and connect various types of measuring devices and sensors.

Also, taking into account the large-scale distribution in the world, guaranteed compatibility with most devices, high data transfer speed and high network reliability, Wi-Fi technology is a good choice for using it as a data transmission network in IoT systems. It is advisable to create an information system for monitoring climate change on the basis of the Arduino Uno platform, given its availability, wide opportunities for modernization, good documentation and a large number of free open source libraries.

For analytical processing of monitoring data based on the synergy strategy of the Internet of Things and regional climate models, it is advisable to use a complex of ArcGIS programs, special web services, including those based on the Gaussian model. Processing of data on the concentration of atmospheric air pollution or meteorological data can be carried out either immediately in the form of a three-dimensional model, taking into account the height at which each sensor of the monitoring information system is located, or in the form of horizontal sections (concentration fields at the same height above the earth's surface).

The created information system for climate change monitoring consists of 5 elements:

- sensors: to obtain the value of the ambient temperature, you should use the DHT22/AM2302 sensor (SHT11, HT15 Arduino), to determine the CO2 concentration, it is recommended to use the SKU: SEN0159 sensor, to measure the humidity — the DHT11/22 sensor, the atmospheric pressure indicator should be obtained from the BMP180 sensor;

- IoT devices: in the information system, IoT devices are proposed to be made on the basis of an Arduino Uno board with connected measurement sensors and an established automated system for collecting, analyzing and exchanging this data (driver);

- central router: Intel gateways for IoT are equipped with Quark, Atom and Core processors. Intel Quark and Intel Core processors exist in variants with one, two or four cores. The gateways are equipped with data stores and RAM that meet the requirements of the processor and the purpose of the devices. Gateways based on Intel Quark, for example, based on the Intel Galileo board, are quite capable of meeting the requirements of the created information system;

- the server part of the information system: the web API and website (HTML + CSS) are proposed to be implemented using ASP.NET Core MVC technology, the database using MS SQL. Azure cloud services should be used to place the entire server part in cloud storage;

- the client part of the system: can take the form of a mobile, computer or website application.

Signs of the fundamentality of the conducted research are:

- research results can form the basis for new fundamental, applied research and development;

- high internal scientific effect, which determines the emergence of a new direction in the development of public institutions;

- the research has a broad theoretical base and is in-depth.

The scientific novelty of the conducted research is that:

- the specificity of the synergy strategy of the Internet of Things and regional climate models was revealed;

- the regularities of building the data monitoring algorithm in accordance with the proposed synergy strategy were revealed;

- for the first time, based on the strategy of combining Internet of Things technologies and regional climate models, an information system for monitoring climate change was developed and proposed for use by representatives of public institutions.

The created information system will make it possible to prevent potential threats to the flora and fauna of the regions where it will be used.

**Conclusions**

1. The main requirements for the synergy of the Internet of Things and regional climate models in the context of their further use by public institutions are simplicity and convenience, the ability to create an information system and an application for working with it.

2. The strategy of the synergy of the Internet of Things and regional climate models made it possible to use an algorithm for monitoring the state of the climate and the environment, which will help public institutions to prevent the consequences of emergency situations, such as droughts, floods, storms, hurricanes, and extremely hot days.

3. Based on the synergy of the Internet of Things and regional climate models, a cheap and fast information system consisting of sensors, IoT devices, a router, a server, and a user interface was created.

4.The use of the information system obtained as a result of the conducted research requires minimal additional knowledge of climatology, which makes its implementation much simpler compared to classical methods of analyzing changes in the regional climate.

5.The effectiveness of the scientific research is confirmed by the fact that, with the help of the proposed scientific research methods, an information system for climate change monitoring was first developed and proposed for use by representatives of state institutions based on the strategy of combining Internet of Things technologies and regional climate models.