Network of agricultural probes for development of Russian digital farming

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Abstract. A model of a wireless network for collecting and transmitting agroclimatic parameters is presented in the paper. The method of data collection, the technology of their transmission is described. Organization diagram of agroclimatic probes network is given. The block diagram, composition and parameters of agroclimatic probes and the results of testing agroclimatic probes in the village of Mazalovo (Tomsk Region, Russia) are given in the article.

1. Introduction

The food problem [1] has existed since the inception of mankind, but it is most acute today. According to the latest estimates, more than 820 million people suffer from chronic hunger [2]. The current growth rate of agricultural output does not correspond to the growth rate of the Earth's population, so, from 1927 to 2011, the population grew by 5 billion people [3]. The main tool for solving the food problem is high-productivity agriculture by increasing the productivity of a limited area, rather than expanding its area. To do this, it is necessary to use new tools, such as "precision" and "digital" farming [4]. Digital farming involves creating a digital field model that includes field parameters in the past, present and future. To solve this problem, it is necessary to design a network of sensors that will continuously and comprehensively measure and transmit climate data to a remote server.

Including the food problem applies to the Russian Federation. Russia is the largest country by area in the world. Its territory immediately lies in several climatic zones: the Arctic, subarctic, temperate and subtropical climatic zones. In each climate of the Russian Federation there is an agricultural or livestock farm (Figure 1), each of which needs its own approach, for example, in the southern latitudes, the sowing period begins earlier and ends later than in the northern ones. It is worth noting that the amount of moisture and fertilizer also needs to be varied depending on the region. To minimize farm costs, it is necessary to know exactly in which period it is better to start sowing, how much fertilizer needs to be delivered, at what humidity and soil temperature the highest productivity is achieved, etc. At present, the vector of agricultural development in the Russian Federation is aimed at increasing innovative activity in rural economy through the introduction of precision and digital farming technologies [According of «Government of the Russian Federation. Resolution of August 25, 2017 No. 996 «On approval of the Federal Scientific and Technical Program for the Development of Agriculture for 2017-2025. »]. The purpose of the resolution is to ensure stable growth in agricultural production obtained through the use of precision and digital farming technologies.

Figure 1. Agriculture and livestock map of Russian Federation [5].

2. The concept of the network of agricultural probes

To implement digital farming in Russia, it is proposed to use a network of agricultural meteorological probes to constantly monitor the state of soil parameters. The advantage of such a network is that it can be located in any part of the country, and the data collected by such a network can be viewed from any device with Internet access. The network of sensors is built on the basis of probes, the functionality of which is to collect and transmit data on the state of the soil with a given period. Sensors measure the temperature and relative humidity of both soil and the environment, as well as atmospheric pressure. It is worth noting that there is the possibility of connecting other sensors to the probes, for example gas sensors, soil acidity sensor, etc.

It is proposed to deploy the above network (Figure 2) in key areas of the country's agricultural and agrarian segments. The network will consist of agricultural zones, a base station with Internet access and a server. Data exchange between the probes and the base station in the radio band at a frequency of 868 MHz using the LoRa WAN protocol will be carried out. It is worth noting that when placing an agricultural probe outside the coverage area of a base station, it is possible to use another agricultural probe as a repeater. The relay system will make the network easily scalable. At the base station, data

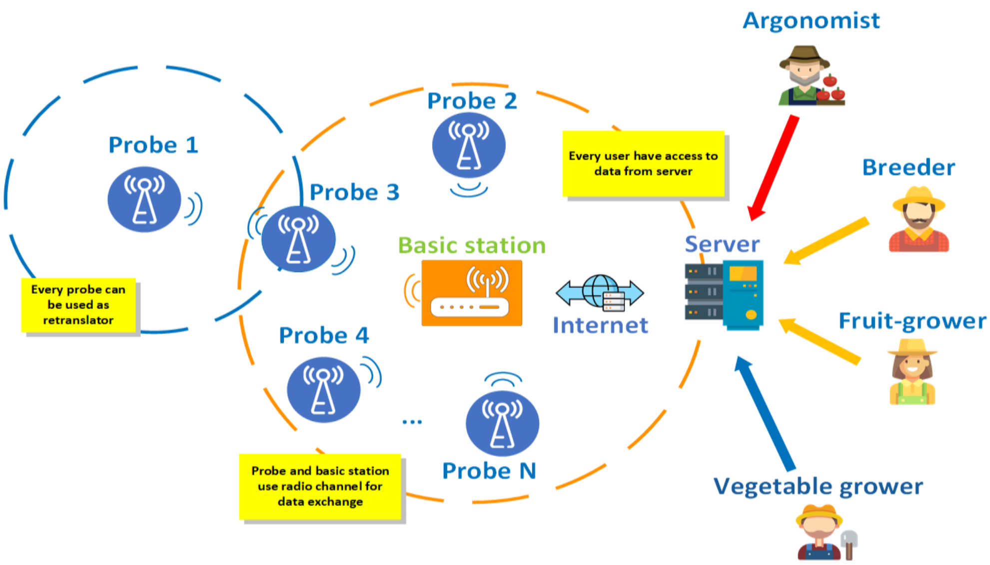

Figure 2. Scheme of probes network.

will be processed and downloaded to the server via the Internet. As a result, all interested parties will have access to data from the field or pasture, for example, an agronomist, a breeder, etc.

The structure of the agricultural probe (Figure 3) includes a data collection system, a data processing system, a data transmission system, power and charge systems.

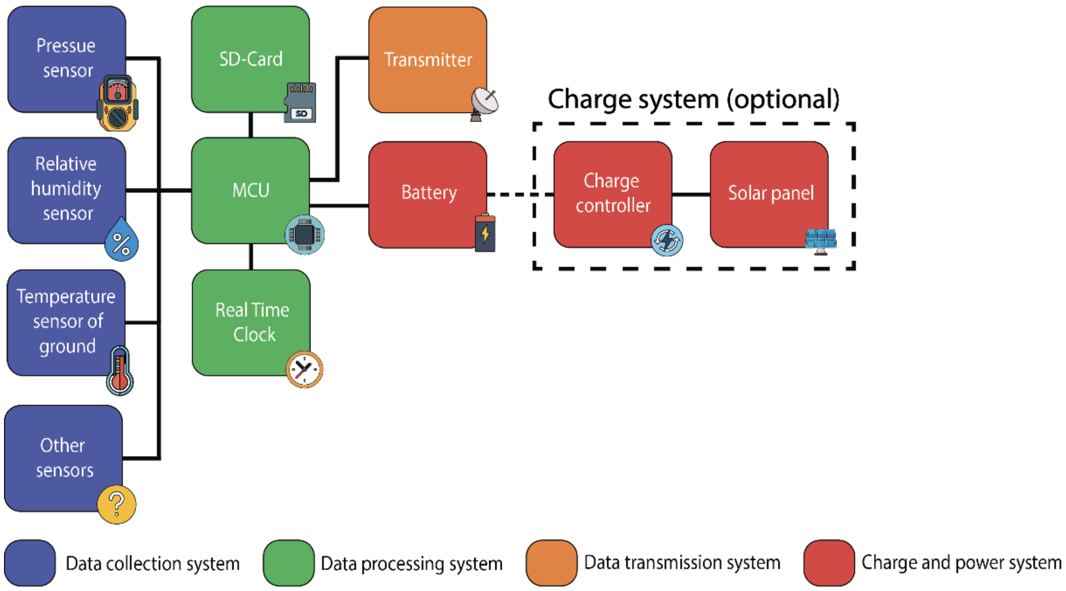

Figure 3. Block-diagram of agrometeoprobe.

3.Data collecting system

The data acquisition system includes a BMP280 pressure sensor, an HTU21 moisture sensor, DS18B20 soil temperature sensor and allows you to connect any external sensor with an available data exchange interface. A memory card is necessary to prevent data loss in the event of a transmission system failure.

BMP280 is a piezo-resistive pressure transducer manufactured by Bosch Sensortec. The sensor allows you to measure atmospheric pressure in the range from 300 to 1100 hPa with an accuracy of ± 0.12 hPa (at *t*= 25 °C). The advantage of this sensor is its small overall dimensions of 2.0x2.5x0.95mm^3. One of the important features is the ability to calculate accurately the temperature (± 0.01°C) in the range from -40 to +85 °C due to the high temperature coefficient of the pressure sensor. Two microcontroller connection interfaces are supported - SPI and I2C [6].

HTU21 - Resistive Relative Humidity Sensor, manufactured by Measurement Spec. The operating range is 0 ... 100% with an accuracy of ± 2% RH (at t = 25 ° C and 20% - 80% RH). Overall dimensions of the sensor are 3.0x3.5x0.9 mm. There is the possibility of measuring temperature in the range of -40 ... + 125°C with an accuracy of ± 0.3 °C. HTU21 can be connected to the microcontroller in two ways, both via the I2C bus, and in a simple analog way [7].

Soil temperature sensor DS18B20. It is capable of measuring temperature in the diapason from -55 to +125 ° C with the required accuracy (± 0.5 ° C). The main feature is the ability to connect up to 127 sensors on one bus. A system of such sensors can be used to measure soil temperature at different depths [8].

It is also possible to connect other external sensors, such as a soil moisture sensor, a CO2 level sensor. A set of sensors for each consumer can be unique.

4. Data processing system

The basis of the device is an ATmega328P microcontroller. The microcontroller runs on five-volt logic. It has 14 digital inputs / outputs (6 of which can use pulse-width modulation) and 8 analog inputs (using an 8-bit ADC). The maximum clock frequency is 16 MHz (from an external quartz resonator). The device has 32 KB of flash memory, 2 KB of RAM and 512 bytes of non-volatile memory [9].

To create timestamps, a real-time clock based on the DS3231 chip manufactured by Dallas Semiconductors and non-volatile memory is used. This microcircuit has a system for compensating the temperature effect on the frequency of operation of a quartz resonator. The time accuracy is ± 2 ppm (at t = 0 ... + 40 ° C) and ± 3.5 ppm (at t = -40 ... + 85 ° C). The module is connected via the I2C interface [10].

5. Data transmission system

The data transmission system is based on EByte's E19-868M20S module based on the SX1278 microcircuit platform using the LoRa WAN protocol at a frequency of 868 MHz.

The LoRaWAN (Long Range) protocol uses LoRa modulation - spread spectrum modulation. The basis is in-pulse linear frequency modulation (Chirp-FM). A large transmission range is achieved by setting a low transmission speed. Operating frequency range 862-893 MHz, transmission range up to 5 km., Transmitter power +20 dBm (100 mW), IP3 input -12 dBm, sensitivity -147 dBm, current consumption 620 mA (transmission mode), 14 mA (mode reception), 1 μA (standby) [11].

It is worth noting that for the correct use of the transmitting module, network registration is required. To register using the Activation By Personalization method, you need to set 3 parameters: device address (DevAddr), network session key (NwkSKey), application session key (AppSKey). After that, the base station will begin receiving data from the device. The size of the packet of transmitted data is 10 bytes, where 2 bytes are occupied by temperature, pressure, humidity and 4 bytes are occupied by date and time in Unixtime format.

The base station is a similar microcontroller and transceiver, as well as a Wi-Fi module ESP8266. The base station always listens on the air and expects data from the agricultural probe. After successful reception over the air, the data is transmitted to the server via Wi-Fi. ESP8266 - Wi-Fi module, manufactured by Espressif Systems, which allows you to transfer data via Wi-Fi wireless networks. The module is connected via the SPI interface [12].

6. Charge and power system (optional)

For continuous operation, stable nutrition is required. A lithium-ion battery of type 18650 with a capacity of 1100 mAh and a voltage at the battery terminals of 3.6 V are used as a power source. A voltage of 3.3V powers all elements of the device. For voltage conversion, a MT3608 switching voltage converter manufactured by Aerosemi with high efficiency (up to 93%) is used [13].

The main goal of the charge system is to ensure the autonomy of the agro probe. The system consists of a charge controller and a solar panel. The charge controller is based on the MP1405 chip from Linear Technology and supports a maximum charge current of 1A. A 5-watt solar panel is used as a source of electrical energy.

7. Test results

Agricultural probe (Figure 4) was tested in an agricultural holding located in the village of Mazalovo (Tomsk Region, Russia). The test was provided on summer period in July 2019. The test results are shown in the graphs below. Relative humidity from the sensor (Figure 5) was compared with data from the RP5 service. The data is different, because there are a number of reasons, for example, condensation forms on the sensor at night, and in the daytime the sensor is under the sun, so the probe’s humidity sensor readings are lower than in the RP5 service. Soil temperature data (Figure 6) were compared with data from the RP5 service (https://rp5.ru/), as well as with the average soil temperature of Siberia in July [14]. Thus, the readings of the soil temperature from the sensor correspond to reality. The ambient temperature (Figure 7) in the middle of the day reaches 40 °C, because the agroclimatic probe was located on the field under the sun, and the RP5 sensor was located in the shade.

Figure 4. Test of agricultural probe (Mazalovo, Tomsk region, Russia)

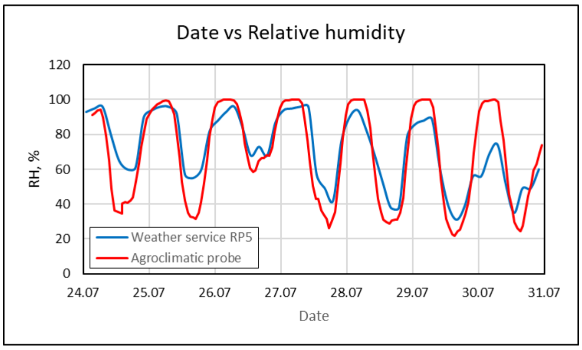

Figure 5. Date vs Relative humidity

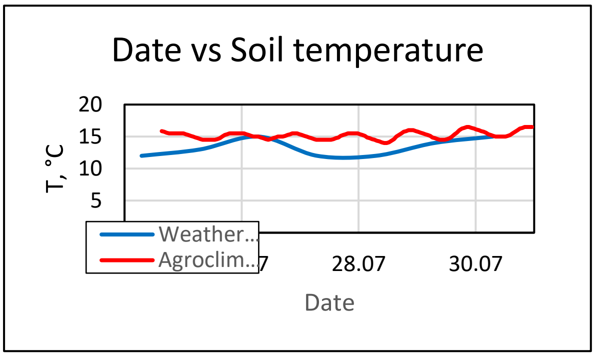

Figure 6. Date vs Soil temperature

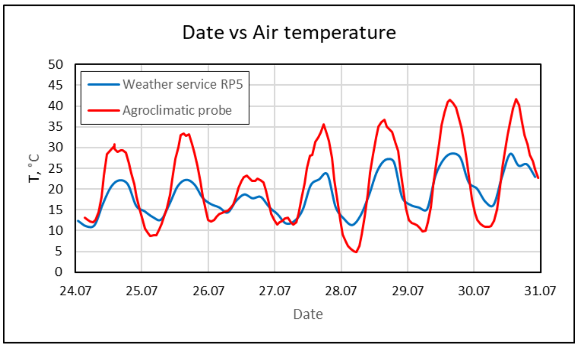

Figure 7. Date vs Air temperature.

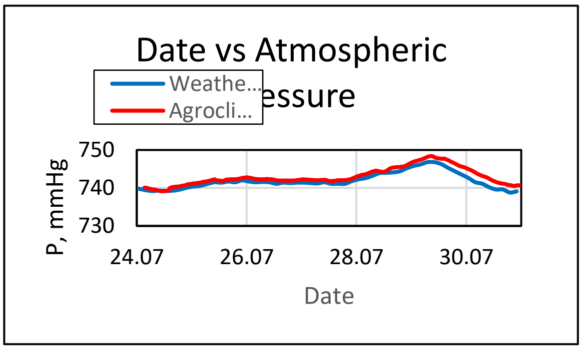

Figure 8. Date vs Atmospheric pressure

The nature of the change in atmospheric pressure is true. The discrepancy between the readings of the agroclimatic probe and the RP5 service is due to the fact that the RP5 sensor is lower relative to sea level than the agroclimatic probe.

8. Resume

Thus, the digitalization task of agriculture in Russia can be solved by introducing the model of a wireless network for collecting and transmitting agro-climatic data presented in the article, the basis of which will be an agroclimatic probe. The developed agroclimatic probe is capable of recording soil temperature at a depth of 20 cm, relative air humidity at a height of 50 cm, ambient temperature, atmospheric pressure, and also illumination due to the solar panel. It is worth noting that other digital or analog sensors are connected to the agroclimatic probe, for example, a leaf moisture sensor, a precipitation meter, gas sensors (for example, CO_2), an ultraviolet radiation sensor, and a solar radiation sensor. The information received by the network can be used in the agricultural segment of the economy and will reduce the costs of agricultural enterprises. For example, an agroclimatic probe can determine the acidity of the soil, and based on the pH, the agro-manager will decide whether to add fertilizer to a specific area or not. Also, by the change in atmospheric pressure, one can judge the approaching precipitation and temperature change. Based on data on temperature, soil moisture and the environment, it is possible to determine the optimal time for sowing and harvesting. On the other hand, in greenhouses based on moisture and light readings, one can judge the lack of moisture or light in a particular area. The data received from the device are correct, the device is also able to work for 5-6 months (depending on the period of data collection), which corresponds to the period of sowing and harvesting in Russia. It is worth noting that such a system can be applicable in any other country, since it is universal. And the protocols used can be applied not only in Russia.

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