Innovative: International Multi-disciplinary Journal of Applied Technology
(ISSN 2995-486X) VOLUME 02 ISSUE 11, 2024

Monitoring System of Microclimate Parameters during Storage of Agricultural Products

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Abstract:

Monitoring of microclimate parameters in different environments makes a significant contribution to many areas of human activity and production processes. One of them is the storage of agricultural products, where the measurement of microclimate parameters can influence the decision to take appropriate measures and protect the stored products. It is also important to maintain optimal conditions in warehouses to facilitate the process of different chemical and physiological damage. Monitoring systems have been commonly employ in recent years appropriate to the creation of modern computer technologies. This article presents a model of a monitoring system based on the principlet of an intelligent sensor. The system components are based on ultra-low power consumption MSP430 microcontrollers. They use cordless communication to exchange data within a system that has been structured according to the principle of an intelligent converter. User applications from the network can admission the system interface via the HTTP protocol, where a web server can be run on a computer or it can be an embedded web server running on a microcontroller-based device.

Keywords: monitoring, microclimate, storage, intelligent sensors, low-energy system.

Introduction

Monitoring of human activity and its environment is commonly employ in many fields, such as industry, healthcare, the army, agronomy, tracking systems, etc. Measurement and control of microclimate conditions are of the greatest importance for the storage of agricultural products in storage facilities. First of all, the temperature and relative humidity in the protected storage, among other parameters, should be in the optimal distance for unhindered growth and creation of cultivated plants.

Every agricultural product stored in protected areas, such as storage, has its own specific requirements for microclimate conditions, which must be met in order to create a favorable environment. Within the same type of crops, the temperature and humidity regimes are not the same throughout the storage period, so there are differences depending on the storage stage (maturation, etc.).

Creating an optimal microclimate for storing products in storage facilities plays an important role in preventing different chemical and physiological damage. In supplement, monitoring and regulation of temperature conditions and relative humidity in storage facilities are commonly employ to maintain optimal conditions for the preservation of products, especially different types of rot that develop in conditions of high relative humidity.

All these presented facts put forward the regulation of microclimate parameters as a priority, which means that measurements and control of climate parameters are necessary throughout the entire process of growing crops. This can be performed by equipping a protected space, storage, with small computer devices that contain sensors and that could communicate with every other, thus forming a monitoring system. The system can be widened to maintain a favorable microclimate by controlling other appropriate devices for ventilation and air cooling. The result of using the monitoring system in storage would be the accomplishment of high-quality stored agricultural products.

The process of collecting climate parameters is transferred out by many types of sensors. The main problem was adding some intelligence to the sensors so that they could be easily connected to networks and also be able to work independently. This has been overcome thanks to advances in modern computer and communication technologies in recent years. Converters, or sensors in a broad sense, are modules that convert physical values into electrical signal.

The connection of converters from different manufacturers and automation of their use became possible thanks to the introduction of the IEEE 1451 family of standards. In accordance with the proposed IEEE 1451.0 standard, the functionality of intelligent converters and commands for managing their workflow were defined. Admission to smart sensors from a network application has been standardized using a clear interface format described in the standard as a sensor maintenance interface. The sensor module, as part of an intelligent sensor system employ to collect values from an object of interest, can communicate and send data cordlessly. In this case, the module is a cordless node with all the limitations typical of a small independent computer device. In supplement to the limitations in computing and memory, one of the main problems was the limitation of power. Small devices, usually based on microcontrollers, were created for autonomous operation, using a battery for power. The power consumption often rely on the required operating modes and functionality, but also the size of the battery affects the weight of the device and its cost. Whenever the purpose and requirements of the application allow it, a good solution would be to use microcontrollers with ultra-low power consumption. One of the families of microcontrollers belonging to this group were the MSP430 microcontrollers. The purpose of this work was to present a cordless network of sensor modules based on MSP430 microcontrollers with ultra-low power consumption, including an intermediate software module that was implemented together with a computer, or with supplemental equipment to run an embedded web server [1-15].

THE BASIS FOR THE CREATION OF THE SYSTEM

The IEEE 1451 family standard defines general rules for intelligent converters and their connections to networks or microcontrollers. The standard contains functions and commands for controlling intelligent converters, communication protocols, and formalized electronic TEDS documents. The principle of intelligent converters has a structure containing a converter interface module - TIM and a network application processor - NCAP.

TIME is a module that communicates with the physical world through sensors or drives, and has one or more conversion channels. TIM has functionality such as signal generation, A/D or digital conversion analysis, and a communication interface. NCAP acts as a gateway between the existing time and the network or host processor, and it is employ to control the workflow within the existing time modules. The connection of these two main components is established using a converter-independent interface - TII, but the definition of the communication protocol and transmission medium refers to one of the other IEEE 1451. X standards, where the IEEE 1451.5 standard is employ for cordless communication.

One of the features of the converter, which makes a significant contribution to its "intelligence", is the use of electronic technical passports of the converter - TEDS. It is a standardized and formatted electronic document that is machine-readable and allows you to work on the principle of "plug and play" with the supplement of a specific set of commands. TED was usually hosted on time, but appropriate to some possible limitations, the standard allows, as a rule, hosted remotely, usually on NCAP.

Admission to IEEE 1451.0 NCAP from the network is provided by the sensor Services interface - TSI. In fact, it is an NCAP API that contains methods for reading and writing sensor data, reading and writing TED, and sending different commands and configurations to TIM. Based on the TSI standard, it is divided into several interfaces.

Time detection contains a method for detecting available communication modules, existing time slots, and sensor channels at a specific time. Sensor admission is an interface that is invoked by applications to admission sensor channels. This interface will be employ to perform read and write operations in TIM. Some more advanced methods have been moved to the TransducerControlr interface, which avoids complications. The methods of the TransducerControlr could be employ if applications need more control over admission to TIM. Tscontrolr contains methods for reading and writing TED. Comm Controlr is employ to control available communications in NCAP. The application callback interface defines admission to non-blocking I/O and measurement flow.

Admission to the methods of intelligent TSI converters from the network can be provided via the HTTP protocol using the IEEE 1451.0 HTTP API. The focus will be on transmitting sensor data and TEDS information. The HTTP protocol provides admission to the IEEE 1451.0 layer via a web server running on NCAP hardware. The user sent an HTTP query to the HTTP server via NCAP with his application. When the server receives an HTTP query, the corresponding IEEE 1451.0 API method is called according to it. This layer communicates with TIM and receives the result from them. The server receives the result, generates an HTTP response and backs it to the user [9].

Another solution for distributing measurement data would be to use the Smart Transducer - STWS web service and thus ensure compatibility of the standard database (Fig. 1.). If NCAP has a working web server, it can be employ as a web service provider for the sensor. Information about an existing web service will be defined in the Web Service Description Language (WSDL) with a description of the type, message, and operation of the web service. According to this rule, a user application can be implemented to communicate with a web service. A simple object admission protocol - SOAP was employ as a data carrier through different platforms and operating systems. It is employ to exchange structural information between software applications regardless of background. STWS is a standards-based approach to ensure compatibility between IEEE 1451 applications or smart converters and other applications[7].

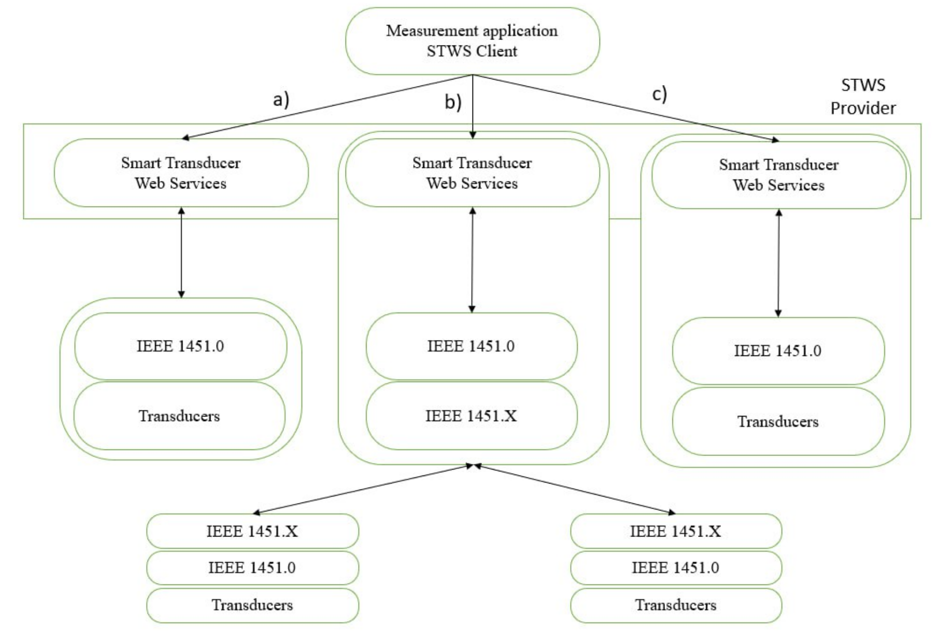

Fig. 1. Service-oriented architecture of intelligent converters.

The TIM module can be based on ultra-low power consumption microcontrollers, such as MSP430 microcontrollers. The MSP family of microcontrollers contains a 16-bit RISC processor for ultra-low power consumption applications. It is equipped with a flexible cooking system, multiple low-power modes, and autonomous intelligent peripherals. These characteristics allow you to truly optimize power consumption and increase battery life.

Ultra-low power consumption microcontrollers as the basis of systems are of great use in many areas, such as healthcare, where small portable devices were employ to perform the necessary measurements. The MSP430 microcontrollers with integrated RF module are an inexpensive solution with good performance and a small size for remote sensor monitoring. The MSP430 can be an excellent choice for controlling a DC motor or a stepper motor that can power some other devices thanks to their high-performance peripherals. Thus, the MSP430 family of microcontrollers has more options with different functions that can be selected according to the query for a specific application [11].

The representative of these microcontrollers with ultra-low power consumption is the CC430F5137IRGZ microcontroller, which can be integrated into one module with a cordless data transmission chip. The module with such characteristics is the MSP430-CCRF creation board, which contains a CC430F5137 microcontroller and a built-in CC1101 RF transceiver. The maximum distance between the two modules rely on the output power of the RF chip, the selected radio frequency distance, and the data transfer rate. In accordance with this value and the specified technical characteristics, the measurement distance could ideally be from 60 to 150 meters.

The CC430F5137IRGZ microcontroller has a wide power supply distance from 1.8V to 3.6 V. It has a 16-bit RISC architecture, extended memory, and a system clock frequency of up to 20 MHz. In supplement, it is equipped with a 12-bit analog-to-digital converter, a comparator, and two 16-bit timers. The power consumption for the other mode will be [12]:

- CPU Active Mode - 160 A/MHz
- Standby Mode - 2.0 A
- Off Mode - 1.0 A
- Radio (RX): 15 mA, 250 kbps, 915 MHz

- Active processor mode - 160 A/MHz
- Standby mode - 2.0 A
- Off mode - 1.0 A
- Radio (RX): 15 mA, 250 kbit/s, 915 MHz

The battery power source for this module may have a solar panel to recharge the battery.

Results

The principlet of intelligent converters was presented in the article [10] as a practical implementation in agriculture. Within the framework of this article, the architecture of the IEEE 1451 system was proposed and the advantages of its use in precision agriculture were discussed. The climate conditions given in this article and the specific physical implementation provide a good basis for testing our intelligent ultra-low power consumption sensor system. Another application of the "intelligent sensor" approach was presented in the article [8] for an intelligent transport system. Solutions for storage monitoring systems were presented in the articles [2-5,11,13,15].

The system principlet presented in this article consists of TIM modules based on CC430F5137 microcontrollers. Sensors of the SHT15 type (Sensor SHT15) employ for measuring temperature and relative humidity will be connected to sensor channels. Communication between the TIM modules is established cordlessly using the CC1101 radio frequency transceiver built into the chip.

NCAP was also implemented using the same CC430F5137 microcontroller in supplement to another component that could provide admission to data from the network. In this case, the CC430F5137-based module gets the role of middleware or gateway between TIM modules and an supplemental component. There are two variants of the system, depending on the hardware solution, which provide external admission. The first is the case when the central module based on the CC430F5137 microcontroller was connected directly to the computer (Fig. 2.a.). Another solution is to connect the module gateway to another device based on a microcontroller with the inclusion of a built-in HTTP server (Fig. 2.b.).

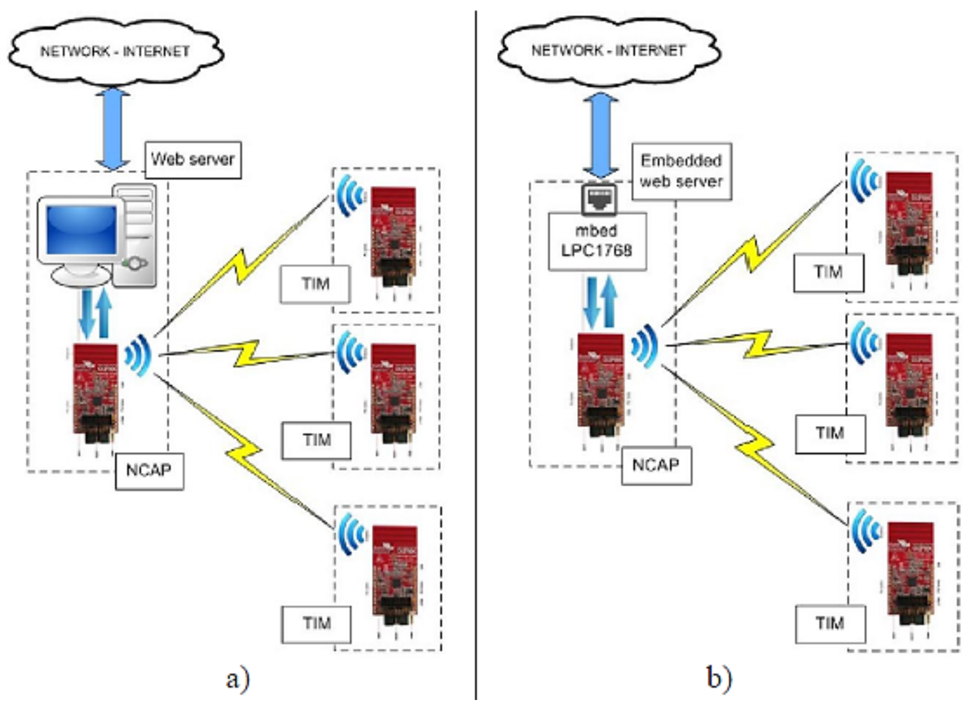

Fig. 2. a) a web server on the computer; b) a built-in web server

In the first case, the gateway module established a serial connection with the computer. The gateway is located next to the computer and communicates with the server-side software responsible for storing data and responding to user querys. The data received from the serial port of the computer was captured by an application deployed on a web server that runs on the computer. Thus, user applications can admission the sensors' service interface over the HTTP protocol by sending an HTTP query to a web server, where it is analyzed, and calling the appropriate methods on a connected microcontroller-based device. When the result of the method call was received from TIM, it was transmitted via serial communication back to the computer, where an HTTP response was generated and sent back to the user. In this solution, an supplemental module would be the Mbed platform employ for direct connection to the USB port of the computer, and in another variant, it could be employ to run an embedded web server.

Data distribution to an external network can be implemented using a web service. In this case, the connection to the gateway will be the same, but admission from the network will lead to better compatibility of the sensor software with other applications.

The solution without computers near the measurement site is shown in Figure 2.b. This is the case when the Mbed platform is also connected to the CC430F5137 gateway microcontroller using a serial communication type, but the web server runs directly on the Mbed platform, which has an RJ45 screen for connecting to the network. Mbed creation support should offer a library for running an HTTP server, and it was necessary to create other methods of the sensor service interface so that work with TIMs could be done.

In supplement, in a variant of a system with a built-in web server, web services can be installed that offer client applications a way to connect to STWS in accordance with the general principlet of an intelligent converter.

If there are no networks nearby, the central module can be connected to a GSM/GPRS modem, which has the ability to transmit data cordlessly over long distances to a remote computer. For these purposes, it would be possible to use the Telit GM862-GPS module and transmit data over the cellular network in the same way as mobile phones. It has a built-in GSM/GPRS modem and a GPS receiver. The quad-band GSM/GPRS modem provides remote communication using a mobile network that is available almost all over the world. This modem could be employ to exchange SMS messages, in supplement to its ability to communicate via Internet services via GPRS, such as HTTP, FTP, and email. Such solutions allow users to admission data from any place where there is Internet admission, using their personal computers or smartphones.

Conclusion

In this article, a sensor system for monitoring microclimate conditions in storage based on ultra-low power MSP430 microcontrollers was presented. The principlet of the system was implemented in accordance with the IEEE 1451.0 standard for intelligent converters. The structure of the monitoring system is characterized by flexibility appropriate to the small size of the sensor module, the possibility of cordless communication, and an independent power source with the supplement of a solar panel. In every case, a computer is not required to transfer data to the user, and admission to the system can be installed on a built-in web server. Further work will consist of the implementation of a system in storage facilities with special microclimatic conditions for measuring and analyzing the values of their parameters in order to promote better protection of crops.

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