COMPUTER DESIGN SYSTEMS. THEORY AND PRACTICE

Vol. 6, No. 2, 2024

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UNVEILING TECHNICAL ASPECTS OF THE KYPS SYSTEM IN THE HOSPITALITY SECTOR OF UKRAINE

Received: June 03, 2024 / Revised: July 18, 2024 / Accepted: September 10, 2024

https://doi.org/

Abstract. The article explores some technical aspects of the KYPS System, a pioneering Smart Measurement Technology reshaping Ukraine's hospitality sector. It focuses on the technical synergy between the ESP32 SX1276 Lora Development Board and the Si7021 sensor, spotlighting their role in real-time environmental monitoring within the food and beverage domain. As an emblematic case of SMT integration, KYPS showcases the transformative potential and engineering nuances driving efficiency and innovation within Ukrainian hospitality.

Keywords: Smart Measurement Technologies, KYPS system, ESP32 SX1276 Lora development board, Si7021 sensor, hospitality sector in Ukraine, environmental monitoring.

Introduction and Problem Statement

In the era of Industry 4.0, the rapid evolution of technologies has revolutionized economies across the globe. Among the myriad innovations, Smart Measurement Technologies (SMT) have emerged as catalysts for transformative change, integrating advanced systems and devices to collect, analyze, and transmit data in real-time. The 'smart' concept refers to the capability of a system to incorporate actuation and control functions in order to describe and analyze situations and make decisions based on the available data in a predictive or adaptive manner [1].

The adoption of Smart Measurement Technologies within the hospitality industry remains an area with untapped potential. While studies on SMT application abound in manufacturing [2, 3, 4], energy management [5, 6], and healthcare [7, 8, 9], their implementation in service-oriented industries is a less-explored terrain. The hospitality industry, a vast sector encompassing services like hotels, restaurants, and food warehouses [10], has yet to witness a comprehensive exploration of the transformative potential embedded in SMT. Particularly in Ukraine, the infusion of these technologies into the local market is an emerging phenomenon, and this requires attention of both practitioners and the scientific community. The KYPS system, as a representative case in this context, becomes a focal point for our exploration.

This article serves as the next stride in our unraveling the realm of Smart Measurement Technologies within the hospitality landscape, with a specific focus on the KYPS system. Situated in Lviv, western Ukraine, KYPS offers a comprehensive suite of services, including environmental control, data transmission wireless technologies, and user accounts for the food and beverage sector. Our aim is to pivot from a broad overview we conducted in [11, 12], to a more nuanced examination of the technical facets propelling the KYPS system.

Main Material Presentation

A development board is a crucial component in the world of electronics and embedded systems, serving as a platform for engineers and developers to prototype and test their designs. It typically includes a microcontroller, connectivity options, and various peripherals, simplifying the development process and expediting the transition from concept to a functional prototype [13].

In the context of the food and beverage industry, a development board acts as the cornerstone for integrating smart technologies into various processes. It enables the creation of IoT applications that enhance operational efficiency, data accuracy, and overall management within hospitality sectors such as hotels, restaurants, and food warehouses.

For KYPS field applications, the company uses the ESP32 SX1276 Lora Development Board (Fig. 1). The ESP32 SX1276 Lora Development Board stands out as a novel solution within the food and beverage industry for several compelling reasons. Unlike generic development boards, the ESP32 offers a unique blend of features, making it exceptionally well-suited for applications requiring both local network connectivity and long-range communication with low power consumption. Main board's advantages are:

1. *Dual-Core Processing Power*. The ESP32 boasts a dual-core processor architecture, featuring two independently operating CPU cores. Normally these are either Xtensa® dual-core 32-bit LX6 microprocessors, or CoreMark® score: 2 cores at 240 MHz: 994.26 CoreMark; 4.14 CoreMark/MHz; memory normally includes 448 KB ROM or 520 KB SRAM [13]. This dual-core setup enables parallel processing, enhancing the system's overall performance and responsiveness. In the food and beverage sector, where real-time data processing is crucial, the dual-core configuration ensures efficient handling of multiple tasks simultaneously.

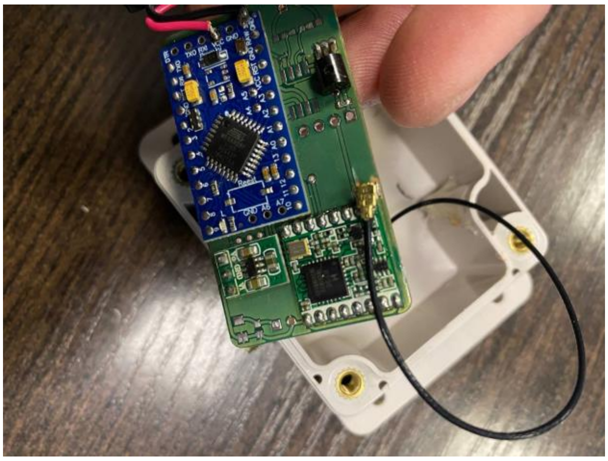

Fig. 1. The ESP32 SX1276 Lora Development Board

2. *Wi-Fi and Bluetooth Capabilities*. The ESP32 microcontroller is designed with built-in Wi-Fi and Bluetooth capabilities, making it a versatile and powerful component for IoT applications. These capabilities are inherent to the ESP32 chip, enabling wireless communication through Wi-Fi and Bluetooth protocols. This combination provides versatile wireless connectivity options, essential for data transmission and communication within local networks. In hospitality settings, such as restaurants and hotels, the coexistence of Wi-Fi and Bluetooth facilitates seamless integration with various smart devices and networks, enhancing operational fluidity.

3. *Radio Frequency (RF) Performance*. Notably, the ESP32 SX1276 board's Wi-Fi/Bluetooth module boasts exceptional RF performance. This encompasses the board's effectiveness in wireless communication, particularly in the 2.4 GHz Wi-Fi and Bluetooth frequency bands. Factors like signal strength, range, and interference handling contribute to reliable wireless communication. In environments like restaurants and food warehouses, where interference and signal reliability are critical, the robust RF performance ensures consistent and effective communication.

4. *Versatility and Rich Peripheral Support*. The ESP32 comes equipped with a rich set of peripherals, including GPIO pins, ADCs, and more (Fig. 2). This versatility allows developers to interface with a wide array of sensors and devices, expanding the scope of IoT applications. In the food and beverage industry, where diverse environmental parameters need monitoring, the ESP32's rich peripheral support accommodates various sensors for comprehensive data collection. All IO pins of the ESP32 have

GPIO and some have RTC_GPIO pin functions, these IO pins are multifunctional and can be configured for different purposes based on the requirements; some IOs have restrictions for usage and it is essential to consider their multiplexed nature and the limitations when using these IO pins [14]. Generally, it is possible to highlight the following types:

• Input GPIO – Input only pins, output is not supported due to lack of pull-up/pull-down resistors.

• Communication GPIO – allocated for communication with in-package flash/PSRAM (not recommended for other uses).

• GPIO with additional functions – have one of the following important functions:

– Strapping pins – need to be at certain logic levels at startup.

– JTAG interface – often used for debugging.

– UART interface – often used for debugging.

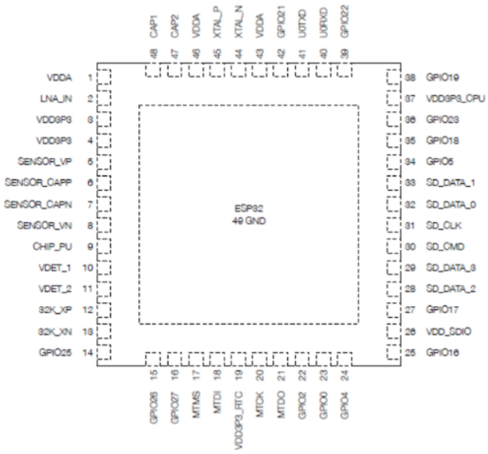

Fig. 2. The ESP32 Pin Layout (*source* [13])

The ESP32 SX1276 Development Board includes also the SX1276 LoRa transceiver module (Fig. 3), which is specifically responsible for Long Range (LoRa) communication and operates in a different frequency band than the Wi-Fi/Bluetooth module. The SX1276 LoRa transceiver module utilizes spread spectrum modulation, specifically the LoRa (Long Range) spread spectrum modulation technique. Spread spectrum modulation involves spreading the signal across a wide frequency band, allowing for increased resistance to interference and improved communication performance. In the case of LoRa, the modulation technique enables long-range communication with low power consumption, making it well-suited for applications such as the Internet of Things and other wireless communication systems where extended range and energy efficiency are crucial.

The LoRa spread spectrum modem, that the SX1276 incorporates, is capable of achieving significantly longer range than existing systems based on FSK or OOK modulation. The sensitivity is 8dB better than FSK at maximum data rates of LoRa, but using low-cost materials with a 20 parts per million (ppm) crystal oscillator (XTAL) LoRa can improve receiver sensitivity by more than 20dB compared to FSK; LoRa also provides significant advances in selectivity and blocking performance, further improving communication reliability [15]. In other words, a crystal oscillator with lower ppm provides better frequency accuracy, which is crucial in communication systems like LoRa, where precise frequency control contributes to achieving optimal performance, especially in terms of receiver sensitivity. It ensures that the communication devices can operate on the designated frequency with high accuracy, enabling reliable and efficient long-range communication.

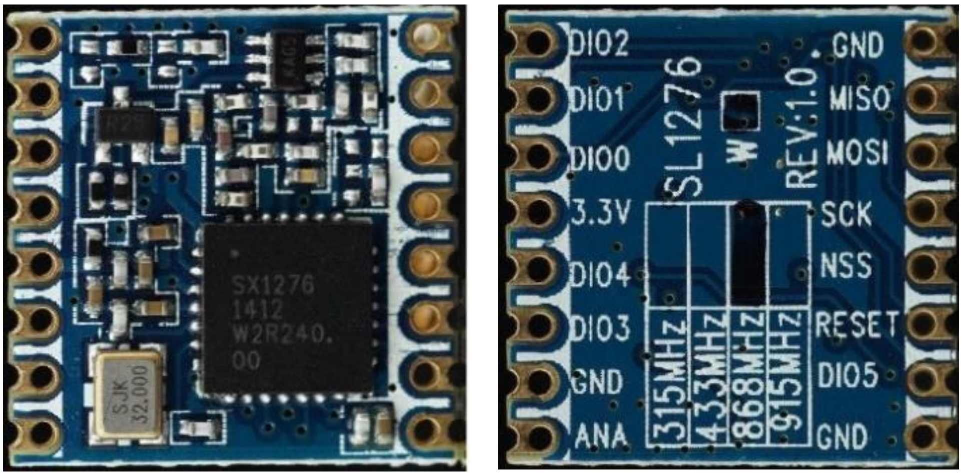

Fig. 3. The SX1276 LoRa transceiver module

The ESP microcontroller communicates with the transceiver using the SPI (Serial Peripheral Interface) protocol, which is a synchronous serial communication protocol commonly used to interface microcontrollers with peripheral devices such as sensors, displays, memory chips, and transceivers. The SPI (Fig. 4) operates in a master-slave architecture where the microcontroller (master) initiates communication and controls the data exchange with one or more peripheral devices (slaves). Communication is arranged over four communication lines:

• SCLK (Serial Clock): The master generates clock pulses to synchronize data transmission. The clock speed is configurable and can vary depending on the specific requirements of the application and the capabilities of the devices involved.

• MOSI (Master Out Slave In): The master sends data to the slave(s) on this line.

• MISO (Master In Slave Out): The slave(s) send data to the master on this line.

• SS/CS (Slave Select/Chip Select): The master uses this line to select the specific slave device with which it wants to communicate.

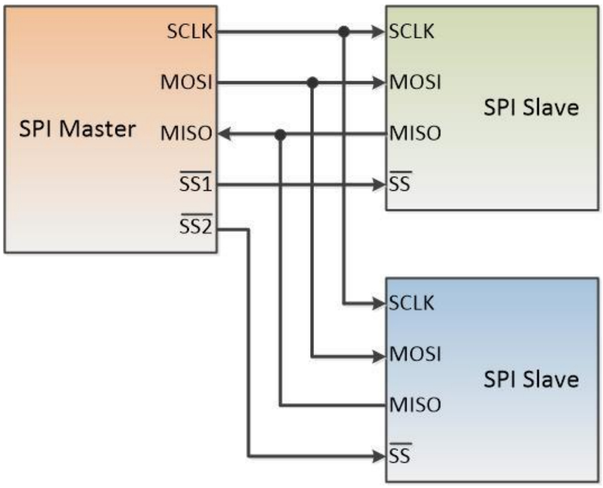

Fig. 4. The SPI bus (with two slaves) (*source* [16])

The SPI supports full-duplex communication, meaning data can be transmitted and received simultaneously. It can operate in different data formats such as SPI Mode 0, Mode 1, Mode 2, and Mode 3, depending on the timing relationship between the clock signal and data. Data transfer in SPI occurs in a sequential manner, with the master sending data bits and simultaneously receiving data bits from the slave(s) over the MOSI and MISO lines, respectively.

In the context of the KYPS system, the ESP microcontroller serves as the SPI master, initiating communication with the SX1276 LoRa transceiver module, as the SPI slave. This communication enables the microcontroller to control the transceiver, send commands, and exchange data for tasks such as configuring transmission parameters, initiating data transmission, and receiving incoming data packets.

The combination of the ESP32 microcontroller and the SX1276 LoRa transceiver on a single board allows the company's developers to leverage the capabilities of both components for LoRa-based IoT applications [12]. Operating in Long Range frequency bands, typically ranging from 7.8 kHz to 500 kHz with spreading factors ranging from 6 to 12, and covering all available frequency bands [15], it enables extended communication distances with low power consumption. LoRa's long-range capabilities are particularly beneficial in large hospitality settings, enhancing connectivity and data transmission across expansive areas.

So, it is possible to state that the ESP32 SX1276 Lora Development Board's innovative design and multifaceted capabilities make it a standout choice for implementing Smart Measurement Technologies in the food and beverage industry. Its dual-core processing power, wireless connectivity features, and specialized peripherals cater to the unique demands of the sector, providing an advanced platform for environmental monitoring and data transmission.

The SI7021 sensor and the communication protocol

The broad application of SMT, including the hospitality industry, became possible due to recent development of easy-to-use, low-cost sensors, featured by energy efficient radios and sensor circuits with extremely low power consumption [17]. The environmental monitoring hardware utilized by the KYPS system centers around the Si7021 sensor (may also be labeled as HTU21), a critical component providing precise measurements of both relative humidity (RH) and temperature (Fig. 5). Temperature indicators still play a critical role in maintaining the safety and quality of perishable and frozen food products because they are eco-friendly and cost-effective [18], and this same notion completely applies to humidity monitoring for food safety. The choice of Si7021, produced by Silicon Laboratories, stems from its exceptional accuracy, reliability, and suitability for low-power applications.

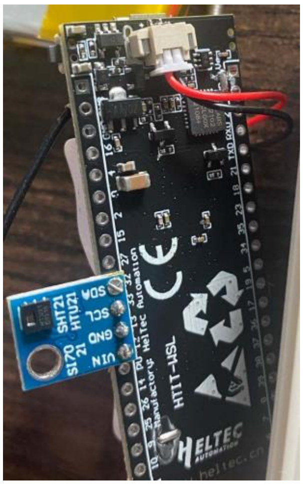

Fig. 5. The Si7021 humidity and temperature sensor

The Si7021 sensor excels in accurately measuring RH in the range of 0% to 100%, with a remarkable precision of ±3%. Its capabilities extend also to temperature measurement in the range of -40°C to +125°C, ensuring ±0.4°C accuracy. Temperature measurement is performed using an integrated temperature sensor based on a bandgap circuit [12], and by employing a bandgap reference circuit, temperature sensors can provide reliable and precise measurements, even in environments with fluctuating temperatures. Therefore, in applications where maintaining precise environmental conditions is vital, such as in food storage or food servicing processes, the Si7021's high accuracy ensures reliable data collection.

Designed for low power consumption, the Si7021 is well-suited for applications where energy efficiency is crucial, making it suitable for battery-operated or energy-efficient devices. The sensor offers various power-saving modes and low standby current, minimizing overall power consumption in line with modern energy-efficient standards, what is very important for Ukraine nowadays.

The Si7021 sensor communicates with the ESP32 SX1276 LoRa Development Board using the Inter-Integrated Circuit (I2C) interface, which is chosen for its simplicity and efficiency in serial communication, making it an ideal choice for connecting peripherals within embedded systems. The I2C communication protocol is a two-wire serial communication bus that allows multiple devices to communicate with each other using a single pair of wires [19]. Fig. 6 shows a typical schematic of the I2C bus. Compared to SPI, the I2C protocol is chosen for communication between the sensor and the board due to its simplicity, lower pin count, and better support for communication with multiple devices over a shared bus. This makes it suitable for connecting multiple sensors or peripherals to the ESP32 microcontroller in a resource-efficient manner.

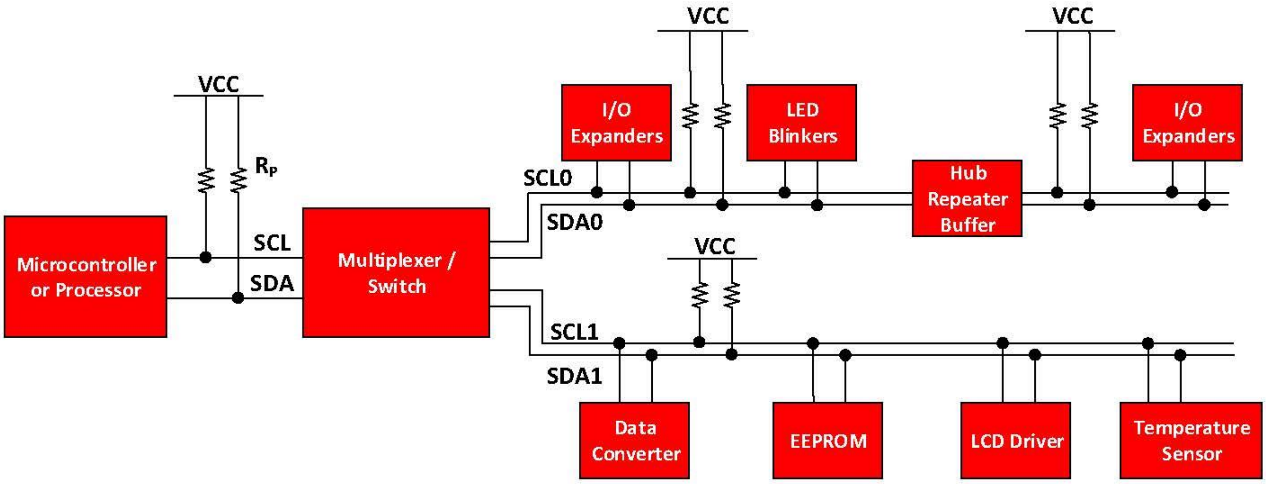

Fig. 6. Typical schematic of the I2C Bus (source [20]

I2C uses an open-drain/open-collector with an input buffer on the same line, which allows a single data line to be used for bidirectional data flow. The microcontroller represents the I2C master, and controls the IO expanders, various sensors, EEPROM, ADCs/DACs, and much more; all of which are controlled with only 2 pins from the master [20]. Physically connected to the ESP32 development board using two wires—Serial Data Line (SDA) and Serial Clock Line (SCL)—the I2C interface facilitates data exchange with the Si7021 sensor.

The reliability of data exchange depends on the proper configuration of the I2C bus, ensuring the correct clock frequency and slave address settings. More specifically, the ESP32 microcontroller needs meticulous configuration to employ the I2C protocol for communication with the Si7021 sensor. The clock frequency must be specified to synchronize communication between the microcontroller and the sensor, ensuring seamless data transfer. Defining the slave address of the Si7021 sensor is crucial for the microcontroller to recognize and communicate with the sensor effectively.

In the I2C communication, the master initiates the communication and controls the data flow, while the slaves respond to the master's commands and provide data when requested. In the KYPS system, the ESP32 microcontroller, functioning as the master, initiates communication with the Si7021 sensor to request humidity and temperature measurements, and the sensor responds accordingly. Both the master and the slave (Si7021) devices adhere to the I2C communication protocol, which employs open-drain or open-collector configurations for the SDL (data) and SCL (clock) lines. These lines are typically connected to the power supply voltage used in the system (the ESP32 operates at a lower voltage level of 3.3V), ensuring proper signal levels. Commands are transmitted by modulating voltage levels on the SDL and SCL lines, with the assistance of pull-up resistors and the open-drain or open-collector configurations, thereby adhering to the specified voltage standards for I2C communication. The entire process looks as follows:

- Standardized commands, either from the sensor's datasheet or a software library, are sent from the ESP32 microcontroller to the Si7021 sensor. These commands request humidity and temperature measurements, initiating the sensor's data acquisition process.

- Upon receiving the command, the Si7021 sensor performs the requested measurements, capturing both humidity and temperature data. Real-time data acquisition ensures that the KYPS system receives up-to-date environmental information, crucial for making informed decisions.

- Once the data is transmitted back from the sensor, the ESP32 microcontroller processes the raw data. This processing may involve converting raw data into meaningful humidity and temperature values, calibration procedures, or additional calculations to enhance data accuracy.

The humidity and temperature data acquired from the Si7021 sensor becomes an integral part of the ESP32 microcontroller's application logic. Depending on the application, the data can be displayed on an LCD screen, transmitted over the LoRa network using the SX1276 transceiver, or stored in memory for further analysis. Currently, most KYPS applications encode measurements from sensors into the JSON format and transmit them further over the local network.

Summarizing this section, it can be stated that the Si7021 humidity and temperature sensor serves as a crucial element in the KYPS system, contributing to its ability to monitor and control environmental conditions. The communication between the Si7021 sensor and the ESP32 microcontroller through the I2C interface ensures a reliable flow of accurate data, facilitating optimal decision-making and operational efficiency within the food and beverage industry. The scope of the paper doesn't allow us to consider the actual analysis of the KYPS' network specifics and functioning. This topic remains a goal for our future research endeavors.

Conclusions

The 'sensing' concept refers to the capability that a system has to detect events, acquire data, and measure changes that occur in a physical environment [21]. And in the food and beverage sector SMT are employed to monitor and control variables such as temperature, pressure, humidity, and flow rates [12]. As SMT gradually infiltrates the Ukrainian market, there is a compelling need for continued research and exploration to address the unique challenges and opportunities posed by this technological transition. In the exploration of Smart Measurement Technologies within the context of the hospitality industry, our focus has pivoted to the KYPS system, situated in Lviv, western Ukraine.

Unlocking the Power of Smart Measurement Technologies, the KYPS system represents a paradigm shift in how the hospitality industry harnesses SMT for enhanced food and beverage servicing. From environmental control to data transmission, the KYPS system exemplifies the transformative potential of these technologies, amplifying decision-making and operational efficiency. This article has transcended the conventional narrative by dissecting the technical underpinnings of the KYPS system, delving into the symbiotic relationship between the ESP32 SX1276 Lora Development Board and the Si7021 humidity and temperature sensor.

The ESP32 SX1276 Lora Development Board stands as a technological marvel, offering dual-core processing, Wi-Fi and Bluetooth integration, and a robust RF performance. Coupled with the Si7021 sensor, with its accuracy in humidity and temperature measurements, the KYPS system achieves a technical synergy, crucial for real-time monitoring and data-driven decision-making. The communication between the Si7021 sensor and the ESP32 microcontroller through the I2C interface, as well as the SPI protocol utilized between the microcontroller and the SX1276 LoRa transceiver, showcases the meticulous orchestration of data exchange. From physical connection and bus configuration to data acquisition and processing, both I2C and SPI communication protocols ensure a seamless flow of accurate environmental data.

While this article illuminates some important technical aspects of the KYPS system, future research endeavors can delve deeper into the engineering principles governing the entire system's functioning, and specifics of data utilization for enhanced customer satisfaction. As we navigate this landscape, future research can reveal untapped potentials, ensuring the continued evolution and refinement of Smart Measurement Technologies within the emerging horizons of Ukrainian hospitality.

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ТЕХНІЧНІ АСПЕКТИ СИСТЕМИ KYPS ДЛЯ МОНІТОРИНГУ ПОКАЗНИКІВ СЕРЕДОВИЩА В СЕКТОРІ ГРОМАДСЬКОГО ХАРЧУВАННЯ УКРАЇНИ

Отримано: червень 03, 2024 / Переглянуто: липень 18, 2024 / Прийнято: вересень 10, 2024

Анотація. У статті досліджуються деякі технічні аспекти системи KYPS, передової технології вимірювання показників середовища, яка змінює сектор ресторанного бізнесу в Україні. Технологія зосереджена на технічній синергії між платою ESP32 SX1276 Lora та датчиком Si7021, і стаття висвітлює їх роль у моніторингу показників навколишнього середовища в режимі реального часу в сфері громадського харчування. Як показовий випадок застосування інтернету речей, KYPS демонструє значний потенціал та інженерні знахідки, що сприяють ефективності та інноваціям в сфері громадського харчування України.

Ключові слова: технології розумного вимірювання, система KYPS, плата ESP32 SX1276 Lora, датчик Si7021, сектор громадського харчування в Україні, моніторинг середовища.