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Microprocessor System for Food Color Monitoring Based on Zigbee Technology

KEYWORDS: microprocessor system, color monitoring, multisensory, Zigbee

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ABSTRACT *This paper presents a novel microprocessor system for food color monitoring based on new wireless technology and ultrasonic product identification. The paper presents a low-cost and highly versatile color monitoring system applicable to all phases of food processing. The design diagram of the microprocessor system is synthesized. The operating principle of the microprocessor system is explained. The microprocessor system for color food monitoring is implemented by new embedded microcontroller CC2430 with x51 core of the Texas Instruments. The schematic diagram is given. An algorithm diagram on the microprocessor system for color food monitoring is synthesized. The novel multisensory principle for food color analyze is used. Analyses of the proposed microprocessor system are made. The system has been tested under laboratory conditions and in real-world operational applications. Recommendations for maintenance are given.*

INTRODUCTION

Modern food processing requires continuous monitoring of color. This design allows realizing the remote monitoring of the food color using the capabilities of the Zigbee technology for the realization of a wireless networks. Wireless sensor networks (WSNs) are more and more frequently seen as a solution to large-scale tracking and monitoring applications, because of their low-data-rate, low-energy-consumption, and short-range link network which provides an opportunity to monitor and control the physical world to a previously unprecedented scale and resolution. Wireless sensor network (WSN) is a group of specialized autonomous sensors with a wireless communications infrastructure, intended to monitor and control physical or environmental conditions at diverse locations and to cooperatively pass their data to a main location and/or pass their control command to a desired actuator through the network. This paper is unique in bringing together wireless communication with new embedded microcontrollers for actual WSN design in field of food process technologies. The design integrates positives of new ZigBee technology with advances of novel true System-on-Chip Solution (SoS) on embedded microcontrollers for 2.4-GHz IEEE 802.15.4 WSN realization.

DESIGN DIAGRAM AND OPERATING PRINCIPLE

Requirements and design diagram

Requirements to parameters of system for color food monitoring are:

- the system must have food recognition subsystem;
- the system must have color calibration;
- the system must have the capability of different network communication architectures;
- local color monitoring via Liquid Crystal Display (LCD);
- wireless connection to control center;
- the system must operate so that it allows to record data;
- low consumption and cost.

Figure 1 shows the block diagram of the proposed microprocessor system.

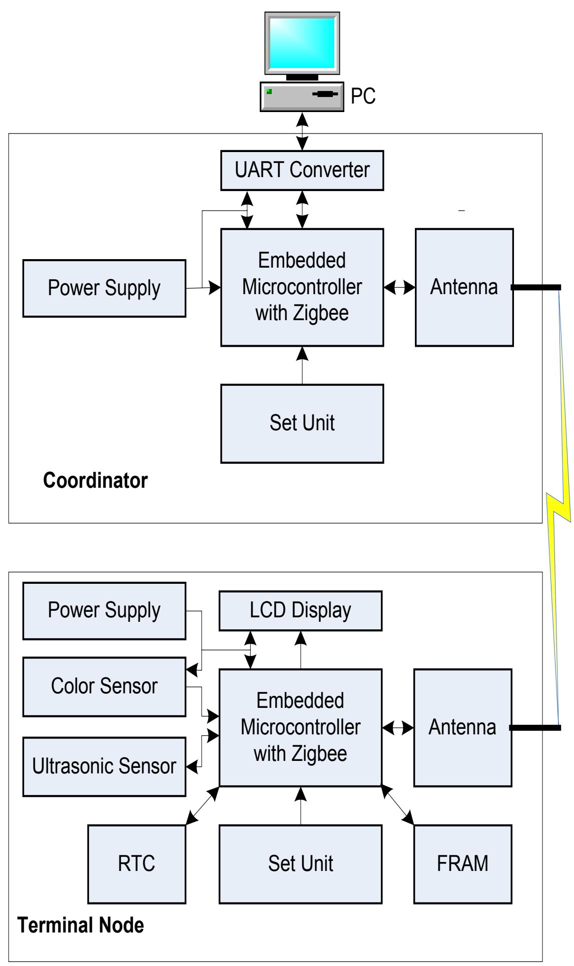

Figure 1: Block diagram of the system

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Terminal node parts of the microprocessor system are located close to the food process line while the coordinator part is located remotely. Coordinator part of the microprocessor system is just one, while the number terminal nodes are equal to the number of food monitoring objects. The microprocessor system in Figure 1 consists of:

- power supply which provides safe continuous voltage with battery back up for the operation of the system;
- LCD display for local monitoring;
- color probe to sense the color of food;
- set unit for selecting the operation mode;
- embedded microcontroller with implanted Zigbee technology, memories and peripherals;
- new fast write non-volatile memory FRAM for data records. The memory has resistance to radiation and electromagnetic fields, and writes endurance more than 10^{15} cycles;
- real-time clock with calendar (RTC) as time logger of the food processing.
- antenna which converts electric power into radio waves;
- UART Converter interfaces the microprocessor system to host personal computer (PC).

The presented system is suitable for remote food color monitoring for all types of meat, cheese and flour products. Some basic algorithms are developed for system performance tests.

Zigbee communication and operating principle

The IEEE 802.15.4 standard defined in 2003 [1] was created for low-power devices that operate in the 868 MHz, 915 MHz, and 2.45 GHz frequency bands. Before this standard was developed, the ZigBee Alliance worked on a low-cost communication technology for low data rates and low power consumption. The IEEE and the ZigBee Alliance ultimately joined forces and ZigBee has become the commercial name for the IEEE 802.15.4 technology. One of the differences of the IEEE 802.15.4 standard is that it defines two types of node in the network. The two types of node are referred to as full-function devices (FFDs) and reduced-function devices (RFDs). An FFD is similar to a Bluetooth device and it can serve as the coordinator or master of a piconet or as a common node or a full-function slave. An FFD can communicate with any other device and it can help routing messages throughout the network. The RFD nodes are defined to be extremely simple with very modest resource and communication capabilities, only used as a slave node to communicate with an FFD. This provides flexibility for implementation of a variety of topologies addressing more diversified applications. IEEE 802.15.4 supports star, tree, cluster tree, and mesh networks. Any RFD device can talk only to its parent FFD device and cannot directly talk to any other RFD device. FFD devices can be router (RN) and resend data to their parent FFD device. Mesh topology can be a single cluster network or a multi-cluster network [5].

The mesh topology for this color food process monitoring design is used because of reliable connection to coordinator. The Zigbee is very similar to others as wireless technology. Many applications and the coverage for ZigBee are similar to those of the Bluetooth. ZigBee provides data integrity check and Authentication. It uses collision avoidance mechanism, and at the same time it reserves a dedicated time slot to require a fixed bandwidth of the communication service. Transmitting and receiving information has lower power consumption. ZigBee network can accommodate a maximum of 65536 devices. ZigBee network has self-organizing and self-healing capabilities. The performance comparison of Zigbee with other wide spread wireless technologies is given in table 1.

TABLE 1. PERFORMANCE COMPARISON FOR WIDESPREAD WIRELESS TECHNOLOGIES

Features	ZigBee	Bluetooth	Wi-Fi
Working frequency	2.4GHz, 868/915MHz	2.4GHz	2.4GHz
nodes per network	65536	7	32
Wake-up time	30ms	10s	3s
Data rate	250 Kbps	1Mbps	11Mbps
Topology	star, tree, mesh	tree	tree
Extension	Manually	None	Auto
Range	0.1~1.5 km	0.1 km	0.1 km
Battery Power Profile	Years	Days	Hours
Standby current (Amperes)	$3x10^{-6}$	$200x10^{-6}$	$20x10^{-3}$
Low power consumption	Support	Not support	Not support

Finally, module costs of Bluetooth and Wi-Fi are relatively high. In addition, the power consumption of Bluetooth and Wi-Fi compared to ZigBee is much higher. Although transmission data rate of Bluetooth and Wi-Fi is higher than that of ZigBee, the 250kbit/s data rate of ZigBee is enough for use in monitor system for color of food, thus the ZigBee technology is selected.

If two ZigBee devices A and B need to communicate with other and device A has two slots, which correspond to the two sensors on devices B respectively. If slot 1 on device A wishes to establish communication with the color sensor on device B, it can request device A to establish a wireless communication channel to the device B, using either its IEEE 802.15.4 64-bit extend address or its 16-bit network address. The ZigBee specification defines a sub-level addressing mode—Endpoint, to help the system distinguish the multiple objects existing on one physical device. ''Endpoint'' is a kind of categorization, which virtually exists in the stack. Each ZigBee device can support up to 240 virtual objects (endpoint 0 is used for endpoint management). Each virtual object has its own property and can be independent from other objects. If the starter of the communication specifies which endpoint it is looking for, the ZigBee stack running on the destination ZigBee device can easily locate the target object. The concept of Endpoint in the ZigBee specification is useful, particular for wireless sensor networks [6]. The terminal node recognizes type of food by ultrasonic identification. The form and amplitude of ultrasonic echo signal depend of type of food. Data acquisition of the ultrasonic echo is made by embedded controller. Before monitoring of food color, the terminal node has to train and calibrate. The calibration is made by Macbeth ColorChecker. This color card is the traditional standard for visual and measuring reference. Training is made by different type of food for their ultrasonic identification. The terminal node measures color and sends data to the coordinator. The terminal node visualizes the current measured color on a LCD. The coordinator sends data to monitoring and control personal computer (PC). The coordinator recognizes terminal notes and controls the data traffic. Every terminal node can be a router to resend data to the coordinator. Nodes memorize their local data in non-volatile memory.

DESIGN OF THE MICROPROCESSOR SYSTEM

Hardware Structure

Schematic diagram of the designed coordinator microprocessor system for color food process monitoring is given in Figure 2, and schematic diagram of the designed terminal node microprocessor system for color food process monitoring is given in Figure 3.

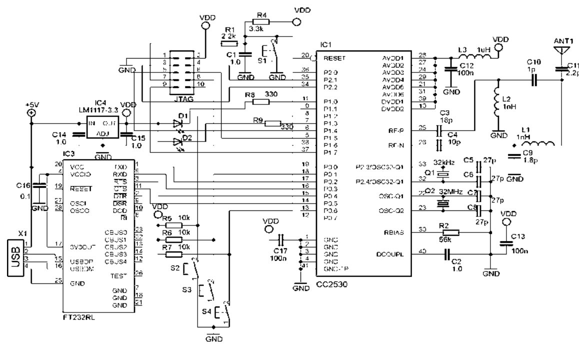

Figure 2: Schematic diagram of the coordinator microprocessor system

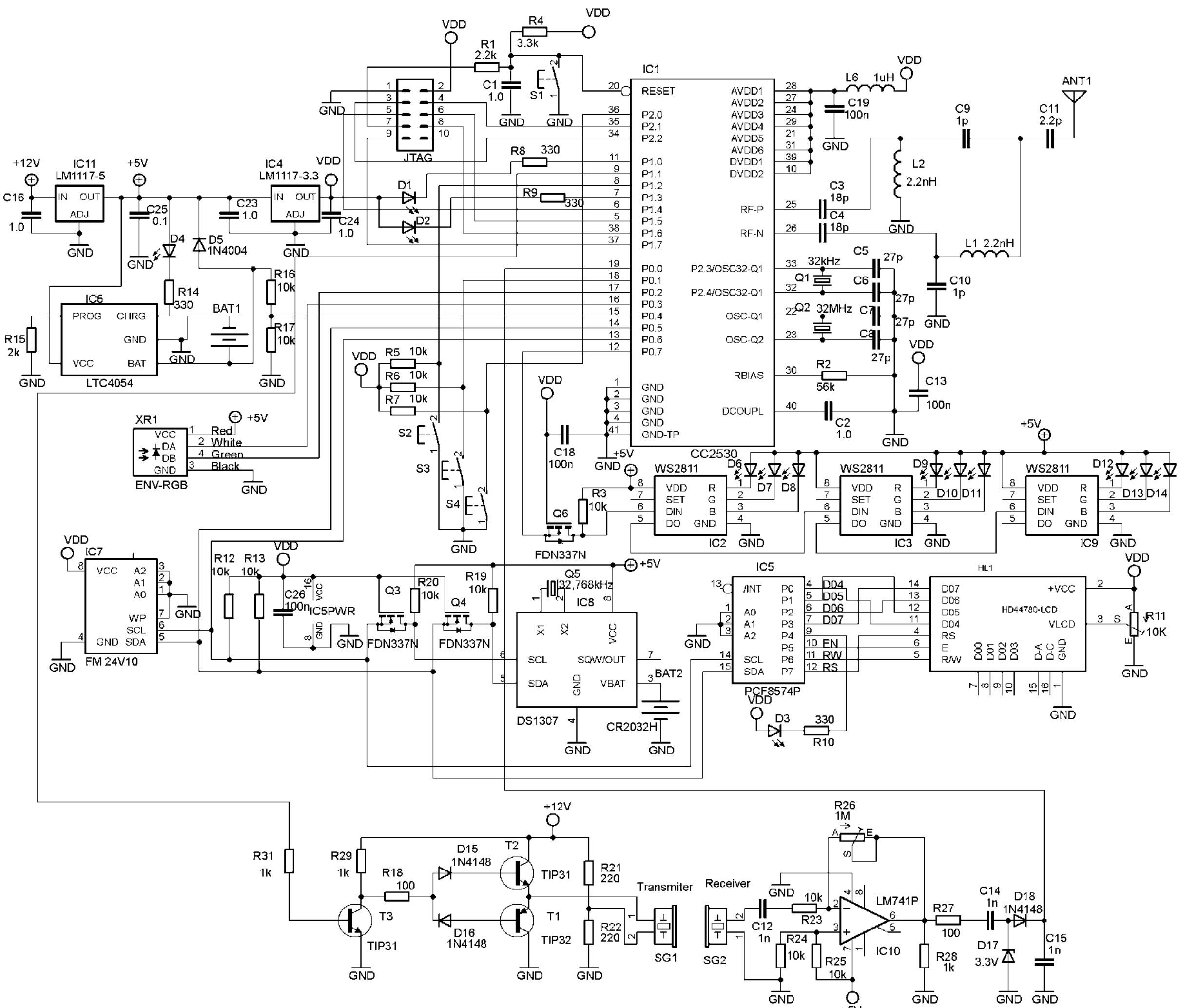

Figure 3: Schematic diagram of the terminal node microprocessor system

Hardware synthesis is base on System-on-Chip Solution (SoS) on embedded microcontroller CC2530 (IC1) with IEEE 802.15.4-compliant radio transceiver. The CC2530 combines the excellent performance of a leading RF transceiver with an industry-standard enhanced 8051 MCU, in-system programmable 256 KB flash memory, 8 KB RAM [2]. The selected microcontroller also provided with the A/D converter, multi-general timer, AES128 coprocessor, watchdog timer, sleep-mode timer with 32 kHz crystals, reset circuit, power detection circuit and 21 programmable I/O pins. The I/O controller is responsible for all general-purpose I/O pins. CPU interrupts can be enabled on each pin individually. Each peripheral that connects to the I/O pins can choose between two different I/O pin locations to ensure flexibility in various applications. The RF core of CC2530 controls the analog radio modules. In addition, it provides an interface between the MCU and the radio which makes it possible to issue commands, read status, and automates and sequence radio events. The radio also includes a packet-filtering and address-recognition module [4]. The microprocessor system is programmed by the JTAG connector with external CC Debugger for RF System-on-Chips of Texas Instrument. The UART converter for communication with host personal computer is realized by FT232RL. This solution allows to use USB interface as bridge between host PC and the coordinator microprocessor system. The FT232RL builds a free Virtual Com Port (VCP) and eliminate the requirement for USB driver development. Data transfer rates from 300 baud to 3M baud. The color senses via the latest waterproofed ENV-RGB color sensor from Atlas Scientific. It has ability to detect red, green and blue light and convert that light into true 8-bit RGB format where each color has a value from 0-255. The DS1307 is used as real-time clock with calendar (RTC) as time logger of the food processing. The RTC is connected by I^2C interface to the embedded microcontroller. The local LCD is base on HD44780 display interfaced by parallel to I^2C converter PCF8574. The LCD is connected to the embedded controller via the I^2C bus. The FRAM 24V10 is used to store data of food color. The LTC4054 provides a buffer against power supply interruptions. The microcontroller generates ten rectangular pulse packets with 25 kHz frequency to activate ultrasonic transmitter SG1. The ultrasonic received SG2 capture echo signal and send information to CC2530 for type of food. The button S1 resets the systems. The others buttons are for local configuration of the coordinator and terminal node.

Software Structure

Software design is based on the ZigBee free protocol stack of Texas Instruments (TI) for x51 core and C programming Embedded Workbench as the software platform. It includes the software design of coordinator and terminal nodes. The program flow chart of ZigBee coordinator is showed in Figure 4.

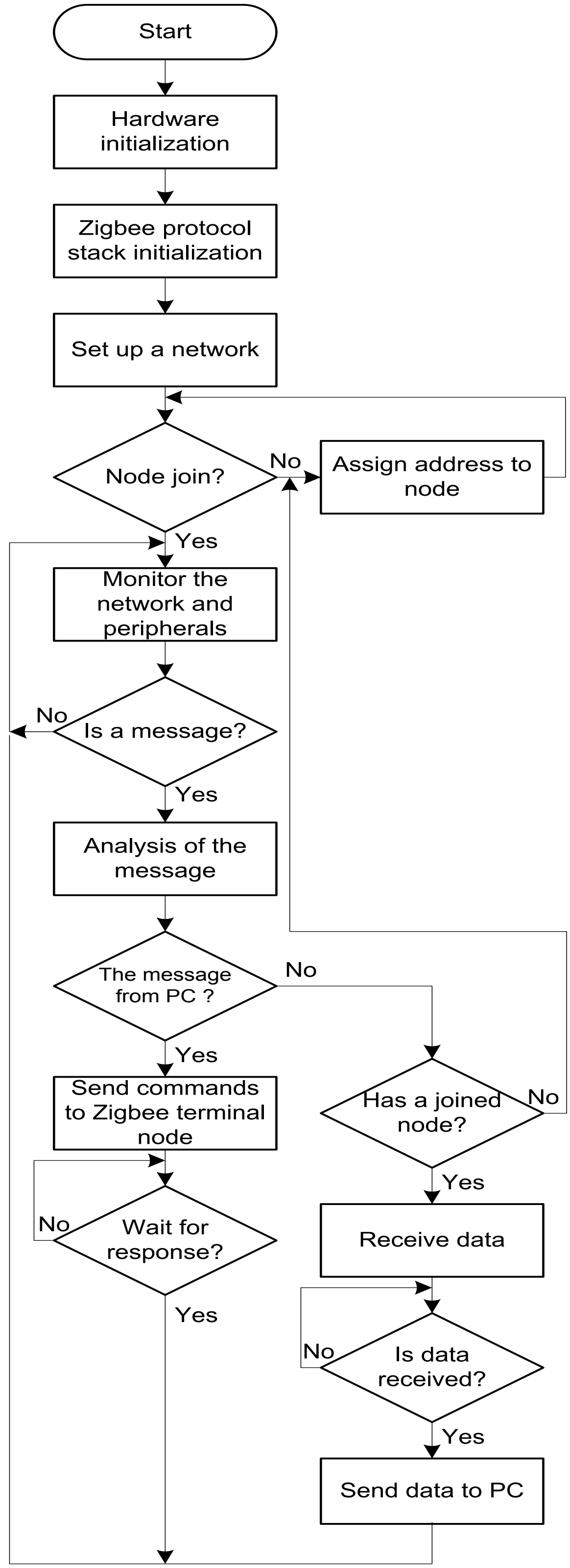

Figure 4: Coordinator program flow chart

Visualization of data is made by Visual Basic platform and includes serial communication program, data and command console. The Z – Stack is constructed by the idea of the operating system of TI and it was adopted for specific tasks of color food monitoring. The program flow chart of

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ZigBee terminal node is showed in Figure 5.

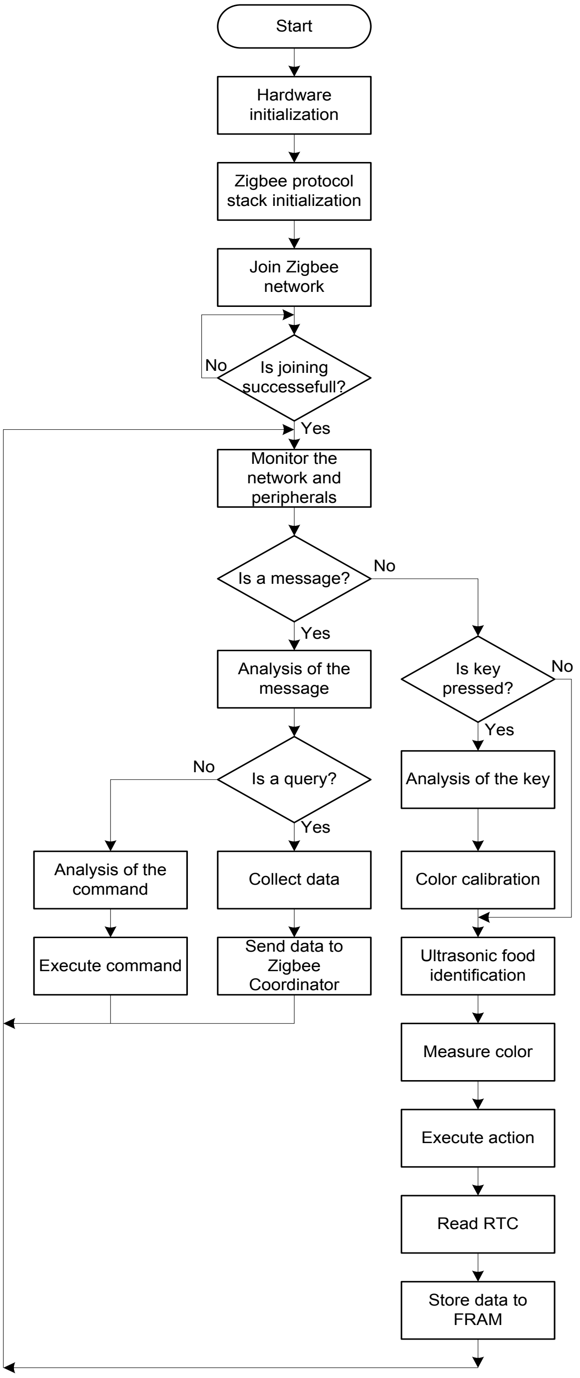

Figure 5: Terminal node program flow chart

When no events happened, the system enters a low-power mode. When an event occurs, the system is woke up and begins to handle the event, then the system enters a low power mode. If several events are occurred at the same time, system determines the priorities and processes the event one by one. This software framework can greatly reduce the power consumption of the system. Every part of microprocessor system has different tasks. The coordinator is the core of Zigbee network, which is responsible for network establishment, address assignment, information management, data receiving and commands transmission to nodes. In addition, it communicates with the PC.

The main function of terminal nodes is to join the existing wireless sensor network, gather color data, calibrate color, send data to coordinator and execute relative commands. The calibration procedure minimizes color difference:

$$\Delta E = \sqrt{(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2} \quad , \quad (1)$$

where L*, a* and b* are coordinates in CIE L*a*b* color space obtained by Bradford transform colorimetric matrix from RGB color space [3].

SYSTEM ANALYSIS

The prototype microprocessor system is shown in Figure 6.

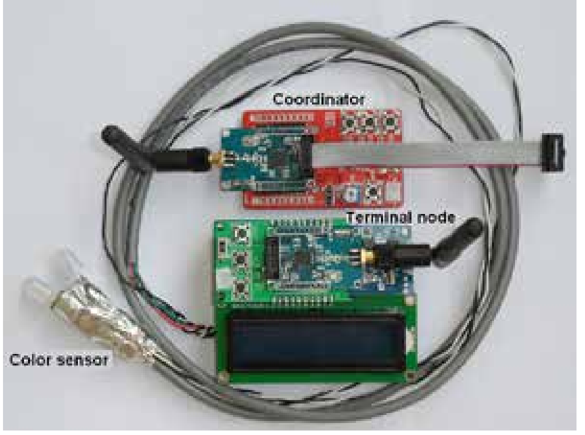

Figure 6: Prototype microprocessor system

The system test is made in real color food processes. The system configuration is visualized by GUI application as is shown in Figure 7.

The user can change network architectures, wireless communication channels and transition power. The configuration parameters are loaded by CC debugger.

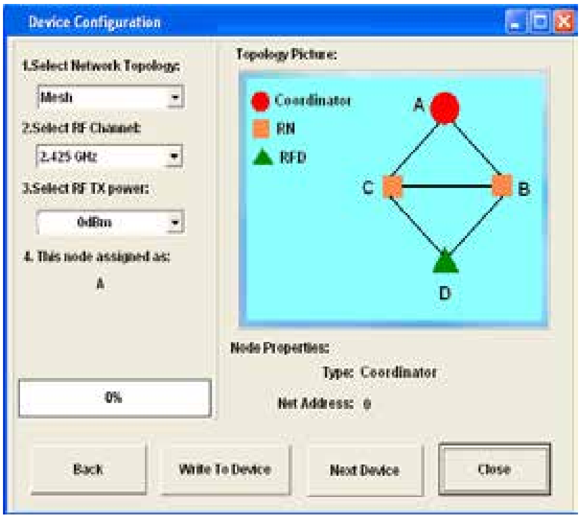

Figure 7: System configuration

The color of food is visualized by GUI application as is shown in Figure 8.

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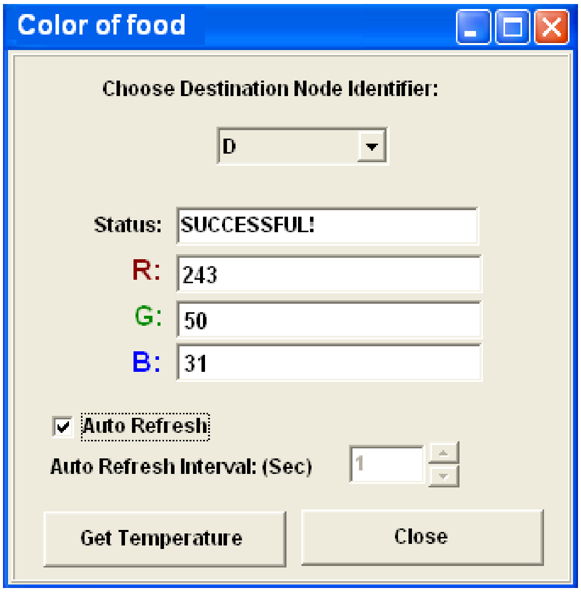

Figure 8: Data visualization for color of food

In every moment the operator monitors all terminal nodes and can send command to terminal node. If operator sends command to archive the all process data, terminal node data are archived on local host personal computer. The system was tested for network range terminal node discovery. RF received signal strength test is shown in Figure 9.

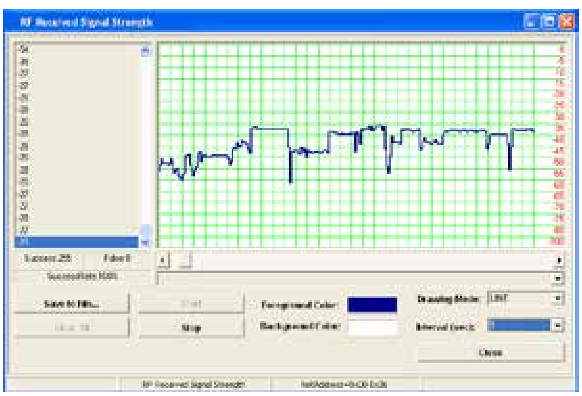

Figure 9: RF received signal strength test

In industrial environment, the experiment shown, that terminal node has stable network connection with range more than 100 m.

CONCLUSIONS

The color food monitoring system based on ZigBee technology is a new solution that used to meet the demand of high intelligent automation. The presented microprocessor-based system is low priced and ensures implementation of various algorithms for remote food color monitoring. The details of hardware and software design in color food monitoring system are given, which include the design of coordinator, terminal nodes. Operating results of the device are very good so far, no defects and failures. Experimental results of actual food color processing show that the proposed system not only overcome the lack of traditional wire network, but also can monitor the food color processing efficiently. The microprocessor system with five nodes and one coordinator has low price below 180 EUR and high reliability because it is built on the quality embedded microcontroller CC2530. The mesh architecture allows extended communication in industrial environment with range more than 100 m. The proposed system has significance advance over classic systems for food color monitoring with wire connection. An innovative microprocessor system for food color quality evaluation is show in this paper.

REFERENCE [1] IEEE Computer Society (2003), IEEE Standard 802.15.4-2003: Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs), Institute of Electrical and Electronics Engineers | [2] Mazidi M., R. McKinlay, J. Mazidi, The 8051 Microcontroller: A Systems Approach, Pearson Education Ltd., 2014. | [3] Pascale, D. (2003), A Review of RGB Color Spaces, Babel Color Company. | [4] Texas Instruments Incorporated (2011), CC2530F256 A True System-on-Chip Solution for 2.4-GHz IEEE 802.15.4 and ZigBee Applications, SWRS081B. | [5] Wang C., Jiang T., Zhang T. (2014), ZigBee Network Protocols and Applications, CRC Press. | [6] Yang, S. H. (2014), Wireless Sensor Networks: Principles, Design and Applications, Springer-Verlag. |