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AN APPROACH TO INFRASTRUCTURE FOR ENVIRONMENT SENSOR NETWORK

Krassimir Kolev[1], Rositsa Maksimova[1]
[1]University of Food Technologies, Technical Faculty, Plovdiv, Bulgaria
e-mails: kr_kolev@abv.bg, rossirm@abv.bg

Abstract: The paper focuses on a systematic architectural approach for modular implementation of Infrastructure for environment sensor network. The requirements for devices to realization of infrastructure for the environment sensor network are defined. A model of sensor network is proposed. A model of computer system is synthesized on the basis of modern modules and devices for building a local infrastructure for the sensor network based on LoRaWAN technology. The end-node for sensor network is synthesized. The synthesized sensor end-node is based on a modern 32-bit microcontroller STM32 and LoRa transceiver SX1276. Proposed are variants of information services to the computer system on the basis of existing modern cloud technologies.
Key words: environment, sensor network, LoRaWAN, computer systems

INTRODUCTION

In recent years, sensor networks has evolved at a rapid pace, creating a separate direction of Internet of Things (IoT) [7]. Because the environment has separate objects with specific requirements, it is possible to define a separate connectivity based on their specific features. This new network connectivity of individual sensors, technological zones and ecosystems requires particular attention in the design of monitoring sensor systems. For this purpose is currently looking for different solutions to build sensor networks [3]. This new direction in computer systems and technologies will significantly change the way we can make data acquisition, transfer, store and process information about an ecosystem. The ability to track, identify and control an ecosystem in real time for individual regions and countries using the integration of sensor networks to existing network infrastructures is one of the most promising applications of the Internet of Things. As a basis for building sensor networks for the environment, the experience gained from the development of Internet of Things (IoT) technology can be used, taking into account the features of the distance of the observed objects from the existing network infrastructures.

MATERIAL AND METHODS

The end hosts of the environmental sensor networks consist of many sensor nodes located close to the observation object located in different territorial locations. These sensor nodes should be more functional, such as:

- to have wireless network capability greater than 1 km;
- to have the possibility of low consumption for the purpose of battery power;
- -to "capture" and discretize relevant technological signals describing the state of the ecosystem;
- to have the ability to locally buffer and store the received data in cloud structures;
- be able to measure the parameters for the environment of the sites and ecosystems;
- to have a low price;
- to have small dimensions for integration into typical environments and ecosystems.

These basic requirements automatically exclude wireless sensor nodes that support Bluetooth and Wi-Fi, due to the limited range of network connectivity, and wireless network nodes based on mobile 3G/4G, due to the high cost of hardware, monthly network support plan and high-energy efficiency. Alternatively, modules that support the LoRaWAN Low Consumption Network (LPWAN) standard may be used. The specifications of the LoRaWAN standard vary depending on the communication spectrum allowed. For Europe, the frequency range is 867 MHz to 869 MHz, divided into ten channels (eight for 5.5 kbps, one for 11 kbps and one for 50 kbps) and a maximum output power of +14 dBm

Terminal nodes of this standard allow two-way communication up to 5 km [10]. LoRaWAN has two security levels based on 802.15.4 Security. Network security guarantees the authenticity of the node in the network, while the application security layer ensures that the network operator does not have access to the end-user application data as shown in Figure 1.

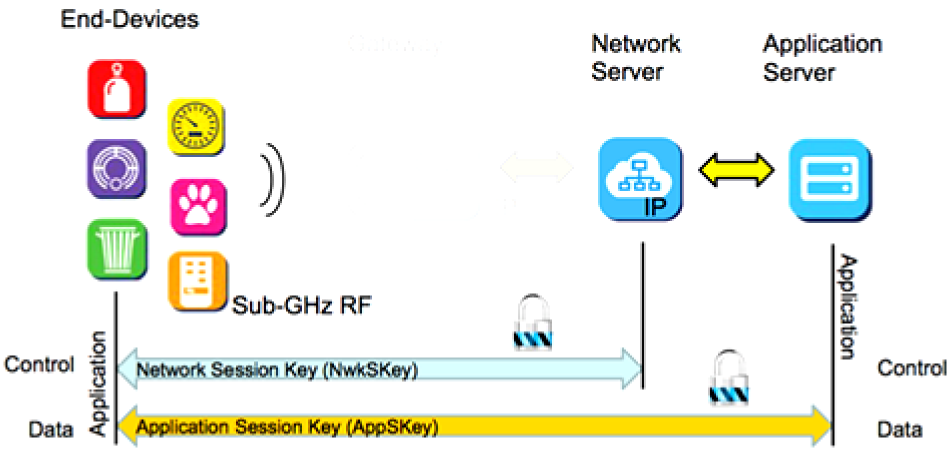

Figure 1. Flow diagram of data protection [4]

One possible variant of a functional structure for building separate branches of an environmental sensor network infrastructure based on existing Internet of Things systems is shown in Figure 2.

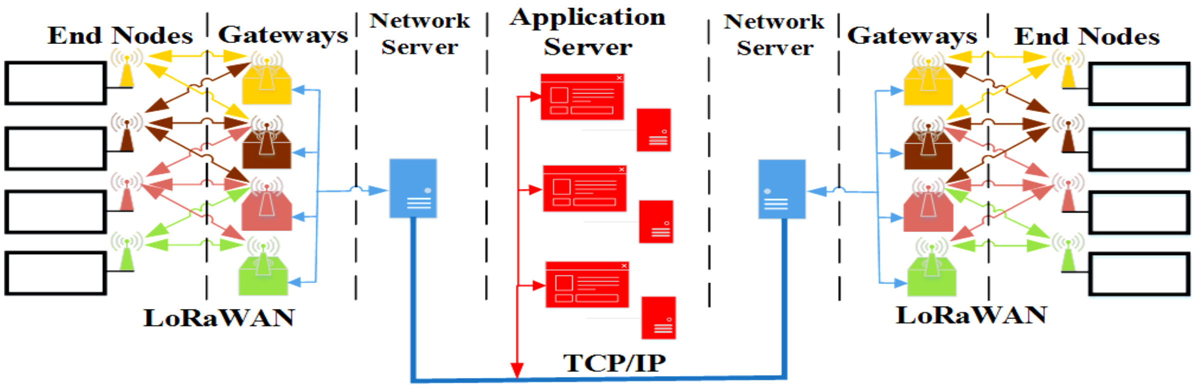

Figure 2. Functional diagram of the infrastructure for environment sensor network

RESULTS AND DISCUSSION

Based on the proposed network infrastructure for sensors, by integrating LoRa embedded microprocessor modules, a model of a computer system was developed to build infrastructure for traceability, identification, monitoring and remote environmental control (Figure 3).

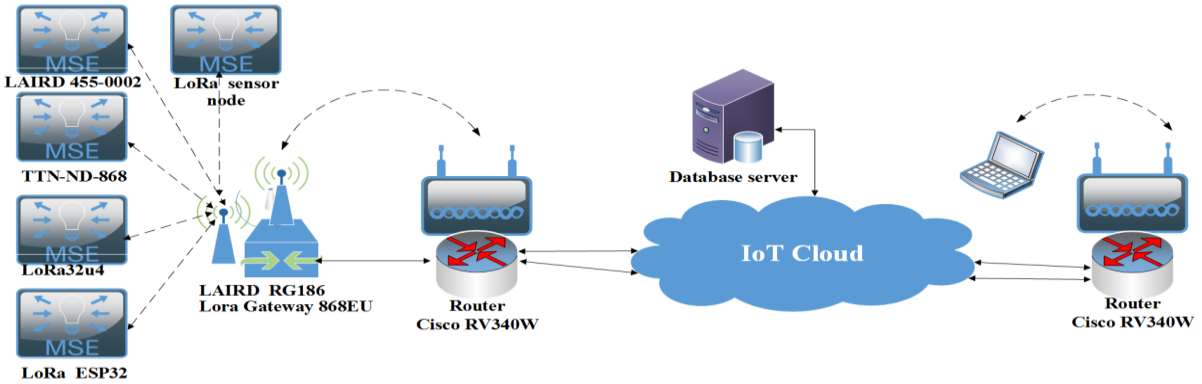

Figure 3. Model of computer monitoring system

Modern computer modules have been selected for the hardware implementation: LAIRD 455-0002 (for temperature and humidity), TTN-ND-868 (for temperature, acceleration, illumination), LoRa32u4 (for temperature, color, pressure, humidity), LoRa ESP32 with OLED display were used as specific devices at terminal units. (for temperature and pressure), LAIRD RG186 as gateway (supports Wi-Fi / Bluetooth/Ethernet), Cisco RV340W router with dual-port Wan for balancing and redundant load with combined connection (supports Wi-Fi) and wired Ethernet). Sensor modules for environment are of the integral type for given technological parameters. The input interface of the end nodes supports digital and analog sensor inputs, so that the sensors can have different interface signals. Sensor selection can be:

- for temperature LM75A, LM35D, TMP36, DS18B20 and others.
- for color TCS3200, TCS34725, TCS3414 and more.
- for pressure MS5540, MPX5500 and others.
- for humidity Si7021, HS1101, etc.
- combined for temperature, humidity and pressure BME280 and others.
- for gases MQ-2, MQ-3, MQ-4, MQ-5, MQ-6, MQ-7, MQ-8, MQ-9, MQ-135, etc.

The programming of the end nodes is done independently depending on the specific environmental sensor selected. In doing so, the end nodes allow bootloader programming modes and an external programmer. Linux-based open source software is used to implement the sensor programming utility.
In the attached structure, the main component for data collection is the end node. We offer our own version of the end sensor node. On the basis of the proposed structural diagram, the schematic-technical part of the computer system of the final node was developed, based on the general principles for implementation of embedded microprocessor systems and choice of modern architectural solutions. On Figure 4 is shown the schematic diagram of the realized end-to-end environmental traceability node.

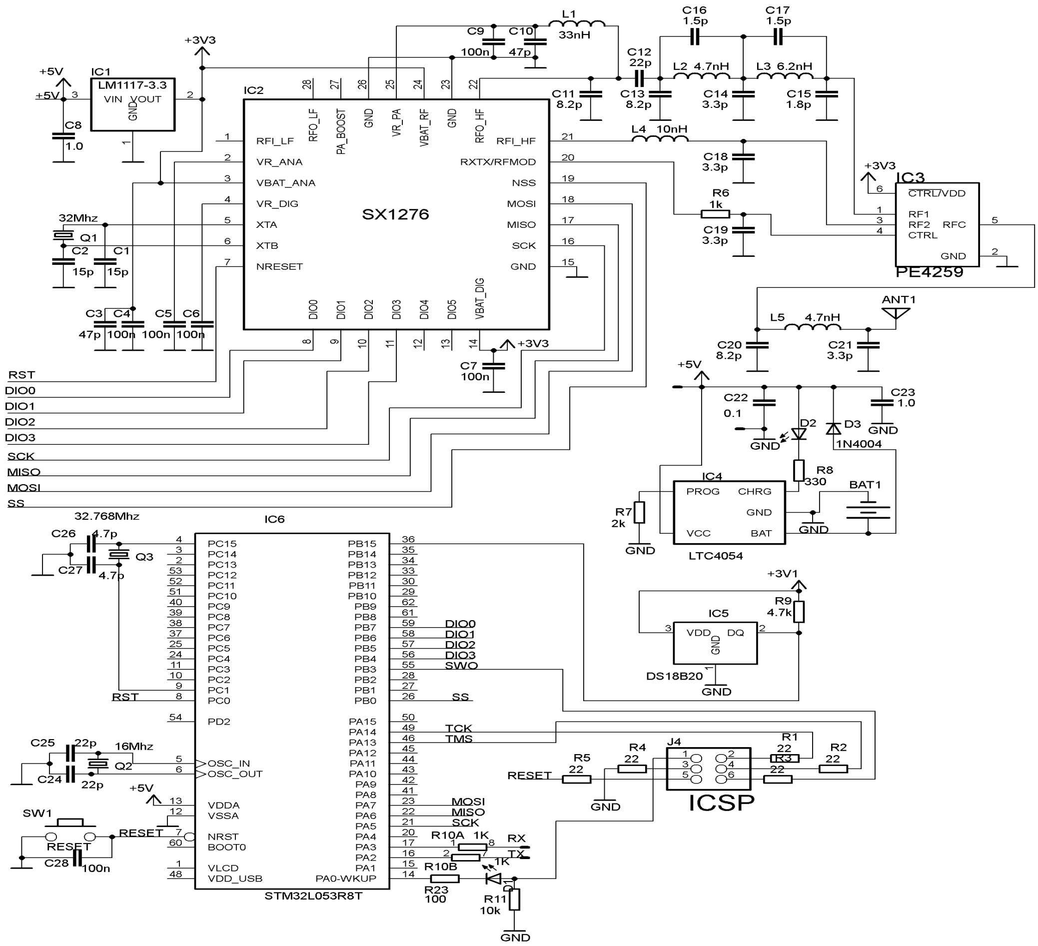

Figure 4. Schematic diagram of the end node

The synthesis of the microprocessor system is based on a built-in microcontroller in a single chip STM32L053R8 (IC6). The STM32L053R8 is a high-speed ultra-low consuming 32-bit Arm CortexM0 RISC based microcontroller with 64KB flash memory, 2KB EEPROM, 8KB SRAM, 51 input-output terminals, five timer modules / counters with comparison mode, internal and external interrupt sources microprocessors, two sequentially programmable USART universal synchronous and asynchronous transceivers, one RTC (real-time clock), two I^2C interfaces, four SPI interfaces, 16-channel 12-bit ADC, single-channel 12-bit DAC, programmable watchdog timer with internal clock generator as well selectable modes with reduced power consumption. The microcontroller operates with a voltage between 1.8 and 3.6 volts [9]. STM32L053R8 uses free software from the manufacturer and the free development environment of CoIDE and STM32Cube. The proposed end node is programmed via a ST-LINK / V2 debugger / programmer.

The RESET button is standard on this type of microcontroller and produces a signal for the initial establishment of the microprocessor system. The C24, C25, and Q2 element group is standard for the implementation of an external frequency group of the microprocessor clock generator, and C26, C27, and Q3 for the real-time clock. The power supply to the microprocessor system is realized by means of battery power, providing the possibility of charging via a specialized integrated circuit LTC4054 (IC4) for charging batteries to provide autonomous power supply to the designed sensor unit for the environment. The IC1 controller provides 3.3V DC for the transceiver and microcontroller. The Lora transceiver is based on Semtech's SX1276 (IC2) IC. The SX1276 has an acceptance sensitivity of about -148dBm. Power consumption of the transceiver in sleep mode is 0.2uA and standby 1.6 mA. The transmit power output is 13 dBm. The SX1276 has a built-in 256 byte RAM for data buffer available in LoRa mode **[8].** The C1, C2, and Q1 element groups are standard for the implementation of an external SX1276 clock frequency group. The transceiver uses a common antenna, therefore a dedicated analog high frequency switch type PE4259 (IC3) is used for multiplexing and demultiplexing the signals to / from the antenna. The antenna is interchangeable with the SMA / UFL connector for the use of different antenna systems depending on the gateway coverage. The IC4 temperature sensor is a DS18B20 type - Maxim digital single wire. It measures temperatures in the range of -55 ° C to 125 ° C with an accuracy of +/- 0.5 ° C, using a 12-bit digital data representation. The algorithmic diagram of the designed end node is shown in Figure 5.

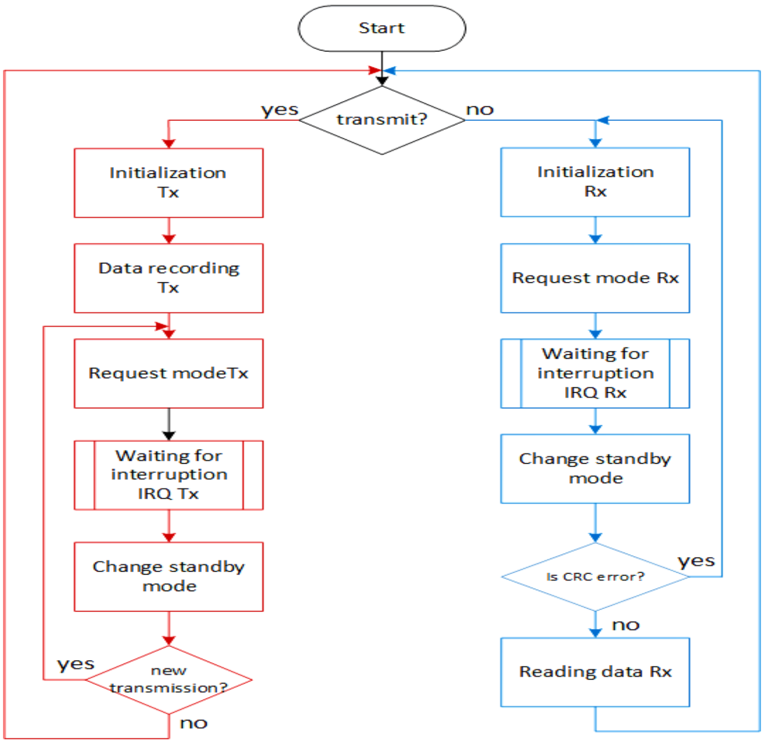

Figure 5. Algorithmic diagram of the sensor node

The end node firmware was developed based on the adaptation of the IBM LoRaWAN C-Libraries (LMiC) to control access to the transmission medium (MAC).
Different LoRaWAN based platforms can be used to implement the system software application such as:

- The Things Network, an open source free LoRaWAN network provider developed and maintained by a wide group of enthusiasts [6];
- LORIOT.io, a global public LoRaWAN operator for private and public networks [5];
- Everynet, a global public LoRaWAN operator [2];

The ResIOT remote monitoring platform [1] was used to develop the application software (Figure 6).

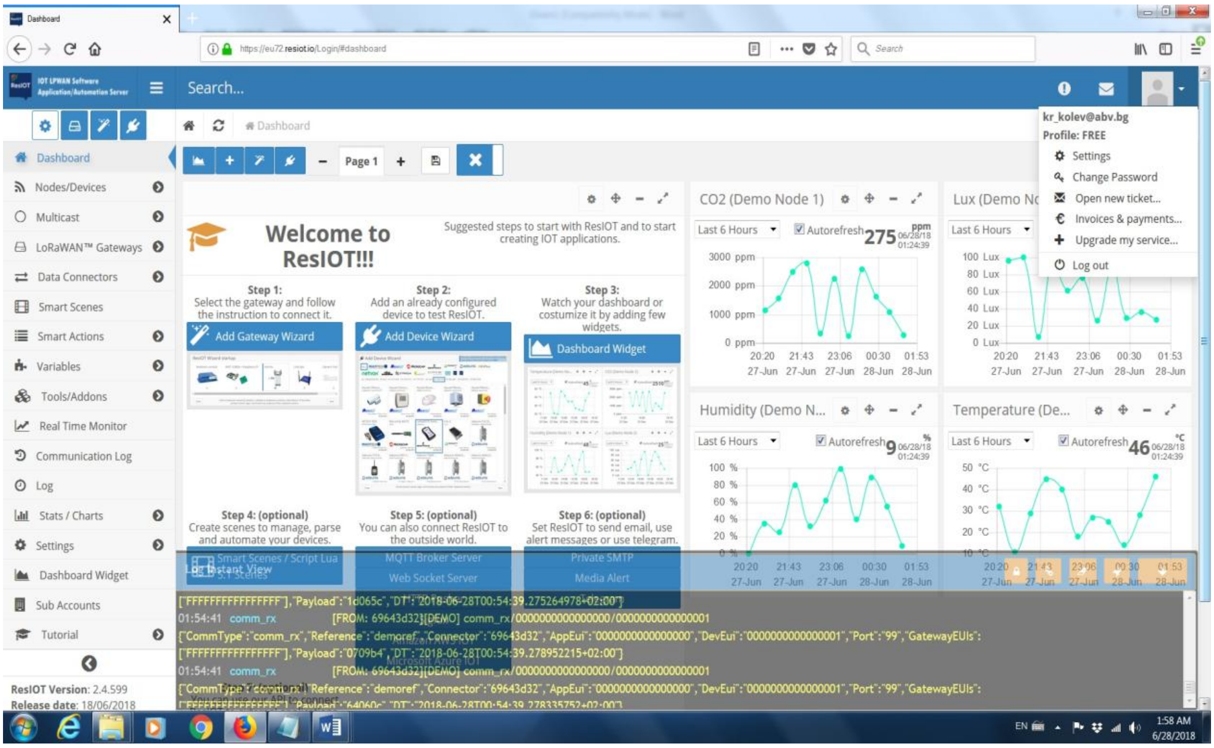

Figure 6. Remote monitoring platform for environment sensor network

The functionality of the environment sensor network is determined by the collaboration of all components - sensors, end nodes, gateways and system and application software. All components are configured remotely by collecting data in a central database with built-in hierarchical access rights to prevent data manipulation and traceability when triggered by environmental catastrophe alarms. Threats and prevention of environmental disasters are realized by triggered statistical functions of tracking unregulated deviation of environmental parameters and incommensurable activities. The functionality of the entire system depends on the correct selection of end nodes and the tuning of the cloud for monitoring and control.

CONCLUSION

The construction of the Infrastructure for environment sensor network requires special attention to the selection and design of the sensor end node. These devices work with different objects with different characteristics at different environmental parameters. The presented structure for the implementation of a system based on the microcontroller STM32L053R8 and the SX1276 transceiver allows basic environmental parameters to be controlled. The proposed system is hardware open and allows to expand with different types of sensors. The proposed structure adapts working models and technologies, which is why it will find application in the construction of expandable sensor networks. The proposed end node is reusable and as low cost as possible for mass battery powered use. Main application of developed system is to be used for monitoring and data acquisition with environmental sensors. The future design of the Infrastructure for environment sensor network also needs to take into account the development of emerging wireless technologies, as well as standards more closely focused on cloud technologies for data collection and processing.

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