International Conference on Condition Monitoring, Diagnosis and Maintenance
CMDM 2019 (5th edition), September 9th -11th 2019, Radisson Blu Hotel Bucharest, Romania

Implementation of a Wireless Sensor Node for Multi-Purpose Blockchain Applications

George Suciu*, Gabriela Bucur, Stefan Daniel Plechi, Ana-Maria Tudor, Ioana Buzau
BEIA Consult International
Romania

SUMMARY

Recently, wireless sensor networks (WSNs) have attracted a lot of interest due to their applications in numerous fields, such as home security, environmental monitoring, critical infrastructure protection and energy power. Moreover, WSNs are combined with blockchain to provide trust, transparency and traceability for electrical power systems, military applications, and commercial applications. This article will present the main units of a sensor node used and the implementation of a sensor node used for multi-purpose applications in the energy field. Also, we will present the hardware implementation of a low-power and low-cost sensor node designed for measuring environmental parameters and storing on blockchain.

KEYWORDS

Wireless sensor networks, wireless sensor nodes, ESP32, blockchain

george@beia.ro

1. INTRODUCTION

Wireless sensor networks have an important role in applications related to environmental monitoring. Nowadays the research is focused on developing an efficient node for a smart network which will be capable of processing data before transmitting it to the base station, reduced power consumption, having a compact size and low cost. A sensor node (also referred to as node or mote) is an autonomous or sensor unit capable of sensing, processing, actuation and communication in a region of interest. The main components of a node are the power source, microcontroller, memory unit, transceiver, and one or more sensors. In sensor networking, a node is designed to be as a small and inexpensive as possible.

A WSN holds a set of nodes, with each node will send the information to the remote base station (also referred to as gateway or gateway node (GWN)). Without the presence of a portal, the user will have to be in the range of the network because a WSN has limited communication. Also, the gateway analyses the message from the nodes and identifies if unusual events happened in the deployed area [1].

In WSN, the energy source provided for the node is usually coming from a battery which can't afford to spend the power needed so that the sensor will operate for a long time without the need to recharge.

All nodes in a WSN share a common sensing task. This implies that not all nodes will be active during the whole system lifetime. Moreover, sensors are intended to be deploying in a hostile environment. Considering the capabilities and the lifetime of a node, a WSN has a large number of sensors implementing in a small area in order to increase data accuracy and system reliability [2].

A solution for increasing the lifetime of a WSN would be to schedule sensors to work alternatively. In this paper, we present the hardware implementation of a node which will be used to measure the air quality. The main advantage of the proposed method is that it will have additional circuits for improving the lifetime of the node without decreasing the performances.

The rest of the paper is organized as follows: Section II describes related work, Section III describes the main units of the WSN, Section IV describes the details of the hardware implementation and Section V concludes the paper.

2. RELATED WORK

This section analyzes related work in the field of WSN nodes for multi-purpose sensing applications.

2.1 Intel® iMote®

The Intel iMote [3] was initially deployed in a pilot for monitoring applications using industrial sensors. The platform has the Bluetooth communication module and the ARM microcontroller on the same chip, the TC200IP from Zeevo. This node integrates vertical stackable connectors to make the architecture flexible. The connectors expose a USB, two UARTs and general I/O ports in order to make the hardware customizable.

2.2 MICAz mote

MICAz [4] model is a potent device and one of the most common wireless sensor nodes. The main advantage is that MICAz is easy to be implemented and the mode can be used for various applications, especially for Deeply Embedded Sensor Networks. The method operates within the 2.4 GHz ISM band and has a capability of 250 kbps data rate.

2.3 Telos

Telos [5] sensor node is an ultra-low power wireless module used in WSN for rapid applications prototyping, monitoring applications and mesh network applications. The revision B of the mode includes increased functionality, performance and expansion.

2.4 Waspmote

The main advantage of Waspmote [6] is that it has been designed to work with minimum consumption without decreasing the performances and capabilities. The digital switches allow controlling the sensor interface and the radio modules. The node can be programmed using Over the Air Programming (OTAP) which enables the software to upgrade without any physical access.

2.5 Smart-Dust

Smart-Dust [7] was developed by the University of California at Berkeley, USA. The project, in this case, was designed to be a low cost, compact size node with the capability to analyze the sensor data onboard and having a bidirectional wireless power transfer.

2.6 Free2move

Free2move [8] is a wireless sensor node initially deployed as a hardware platform for active Radio-Frequency Identification (RFID), used as a node for WSNs. Based on a low power microcontroller, PIC16F87 from Microchip for communication protocols and the functionality of sensors. The processing resources and memory are limited for keeping the power consumption and price as low as possible.

2.7 ZigBit

ZigBit [9] is a compact, low-power original equipment manufacturer (OEM) module developed by MeshNetics and based on Atmel's hardware platform. The node is designed for wireless sensing and control applications. ZigBit nodes contain an RF/ MCU-related design with passive components. Compared to single-chips, the module-based solutions offer considerable savings in costs for prototyping and development.

3. WSN COMPONENTS

In this section, we will detail the main components of the proposed WSN system.

A sensor node combines four modules: a power supply unit, a sensing unit, a processing unit and a data transportation unit. It can also include different other modules, like an external memory unit or/and an actuator unit. The functionality and performances of a WSN are influenced by many factors including hardware constraints, fault tolerance, scalability and power consumption. These factors represent essential guidelines for designing a node or a WSN.

Also, the production costs of a WSN is an important design factor in developing a node. Since the WSNs consist of a large number of nodes, the cost of every node is high to sustain the overall cost of the WSN. The value of each node has to be lower than other traditional sensors, so the cost of the WSN can be justified.

The main units of a node are presented in the following paragraphs.

3.1 Power supply unit

One of the main constraints in developing the hardware architecture of the wireless sensor node is the energy efficiency since the nodes are battery operated. To deploy a node with increased lifetime, it is necessary to have additional circuits for dynamic power management techniques and to reduce the power dissipation [10]. Since the node will be used in different environments, it is crucial to reduce the power consumption. First of all, the specification of the sensors connected to the device are limited by the size and weight of the batteries [11].

In this case, the hardware constraints are significant because the developer must calculate the power consumption for the circuit. In order to increase the performance of the board, the sensors should be low-power and powered by batteries, a solar panel or other renewable energy sources. One crucial constraint for every node is that the board should include a circuit for charging the batteries during the day and then to use the energy from the batteries at nightfall. The use of the batteries at the evening will be implemented using a prioritizer circuit. This will allow the board to be able to collect data from sensors all the time. Having such information at a real-time interval will allow the use of automated actuators, which can be used to control different processes.

Many sensors may fail due to a lack of power. Fault tolerance improves the availability, reliability, and reliability of the wireless network system. Fault tolerance can be modeled using the Poisson distribution to calculate the failure within the time interval (0, t):

$$Rk(t) = exp(-lamdakt) \qquad [1]$$

3.2 Sensing unit

The sensing unit is usually made up of two subunits: sensors and analog to digital converters (ADCs) [12]. Nowadays for WSNs are used digital sensors which have both analog and digital outputs, but if the user decides to connect analog sensors, ADC units are required to convert the analog signals coming from sensors in the digital signal. The digital signal is then transferred in the processing unit.

3.3 Processing unit

The processing unit can be made up of a developing board or a microcontroller. The processing unit controls all the processes related to power supply, data acquisition, data visualization, data transportation, and actuators.

Also, a processing unit with enough performances can be used to preprocess and store the data collected from sensors.

3.4 Data transportation unit

Regarding data transportation, connectivity is an important issue which should be taken into consideration, mostly for regional areas due to the lack of connectivity for technologies like GSM, Bluetooth, WiFi, and so on. The board should be available to send the data collected from sensors using protocols which enable the low-power Internet of Things (IoT) and machine to machine (M2M) networks. The proposed protocols for a node in regional areas are ZigBee and LoRa/LoRaWAN [13], [14].

These protocols will allow the node to deploy for monitoring and controlling applications since the low-power usage will enable a longer life of the node with smaller batteries and will improve the high reliability of the WSN.

For urban areas, we can use all kind of communication.

4. ARCHITECTURE OF THE SYSTEM

In order to analyze the system and obtain different measurements we have proposed the architecture presented in Figure 1:

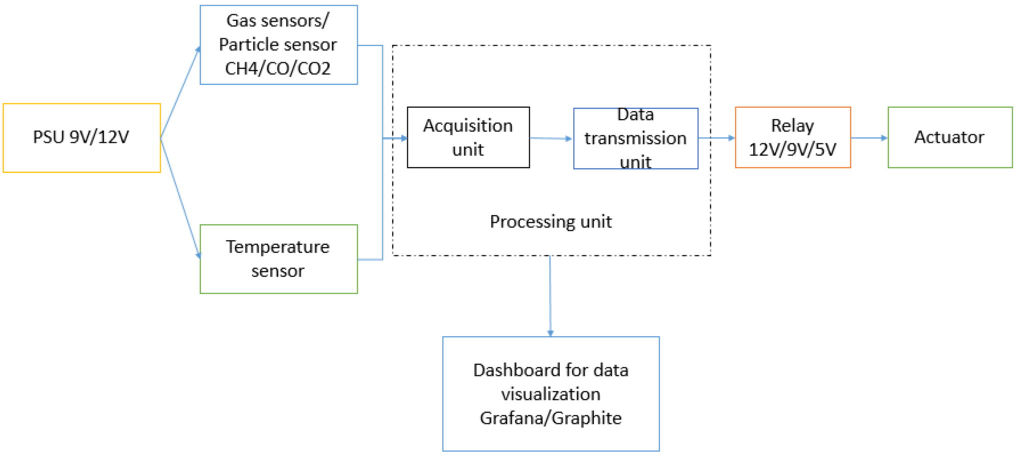

Fig. 1. Schematic of the WSN system

In the proposed architecture the node is intended to measure the air quality both inside and outside given the dramatic effects of high carbon dioxide (chemical formula - CO_2) and Particulate Matter (PM) levels, including energy consumption. The node is responsible for collecting the data from sensors and storing on distributed ledger technologies such as Ethereum blockchain or IOTA [15].

The main units of the node are presented in the following subsections.

4.1 Processing unit

In our case, the node consists of an ESP32 wireless microcontroller from Adafruit [16], [17]. It is low power and low-cost Microcontroller Unit (MCU) designed from WiFi and IoT (Internet of Things) related projects. The node is capable of powering the sensors both at 5V and 3.3V. The board includes a build in USB-to-Serial converter, Lithium Ion/Polymer charger; automatic bootloader reset and enough GPIOs for connecting different sensors.

4.2 Sensing unit

The sensor module applies different types of sensors which are PM (SM-PWM-01C), gas (MQ135, MQ2), temperature and humidity sensors (DHT11). But the MCU allows the user to connect several types of sensors.

In the sensing module, SM-PWM-01C is a complete signal-processing unit which uses infrared detection. The infrared light emitting diode (IR LED) will illuminate the dust particles and converts the signal to the of Pulse-Width Modulated (PWM) output streams.

The MQ series (in this case are used only MQ2 and MQ135) of gas sensors are low-costs and sensitive for a range of gasses. The sensors are mainly used for closed environments due to the fact that the heating filament's temperature should be kept constant.

4.3 Power supply unit

In order to ensure the power supply, we will use a single cell LiPo battery. We will also put on the board a connector for a solar cell in order to increase the life of the node. This way, we will enhance the performances of the node, since the battery life of a node is one of the most important aspects related to the performances of a WSN. The batteries will be charged during the day and used at nightfall. Also, a prioritize circuit will be used.

For the stability of the system, we can put a step-up converter connected to the solar cell, so we can be sure that the sensors and the board will be fully charged. The step-up converter was analyzed and simulated using LTspice. The simulation presented in Figure 2.

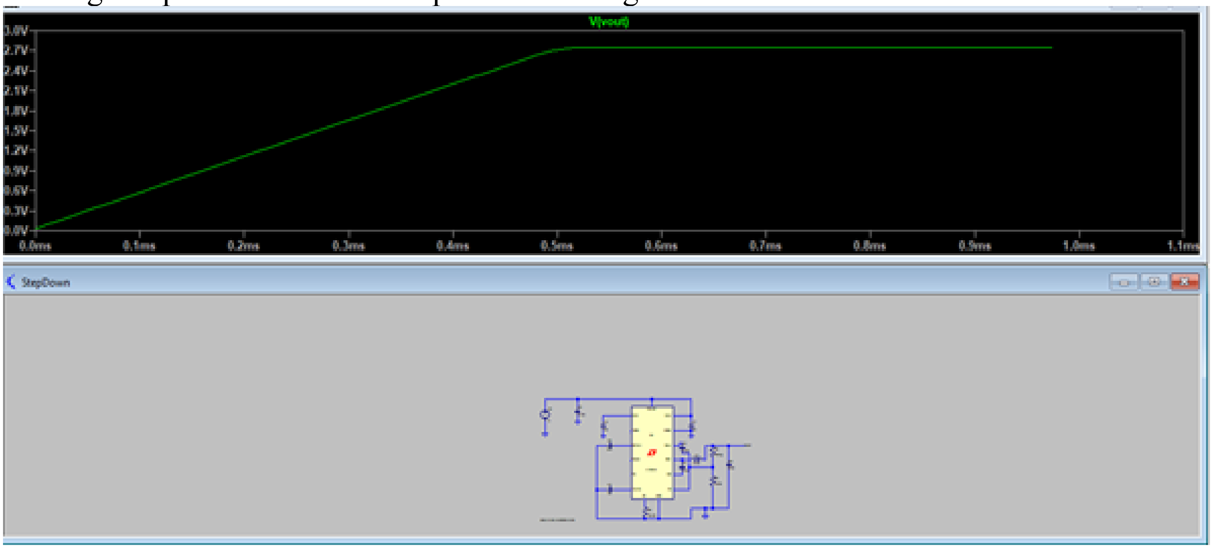

Fig. 2. LTSpice simulation step up converter for solar cell

4.4 Data visualization unit

For data visualization, we can use Grafana [18], an online platform which allows the user to monitor and alert the user. The requested protocol, in this case, is Message Queue Telemetry Transport (MQTT) which provide services like an MQTT broker for subscribing and publishing the data or sensors events [19].

MQTT is a standardized communication mechanism with capabilities to connect to remote locations and efficient distribution of information using minimized data packets [14].

The advantages of using the MCU from Adafruit is that it generates an Internet Protocol (IP) address for every device and this will allow the user to make his own web page.

4.5 Data transportation unit

In this project we use to send data via WiFi since the board has the ESP32 unit which can be used as a slave to a MCU or a complete standalone system. The advantages of using ESP32 is that it can interface to other systems in order to provide both Bluetooth and WiFi functionality through SPI/ UART/I2C interfaces.

4.6 Actuating unit

For connecting the actuators, in the proposed architecture we have established to connect all the devices through a relay.

The relay is used to automatically control the devices with the help of the electric signals. In our case, we can connect a 5V device through the relay connected to the node [20]. The chosen MCU allows the user to control the general-purpose Input/Output (GPIO) pins via the web page using the IP of the board [21].

5. CONCLUSION

In this article, we have presented several details regarding the primary units of a sensor node for WSN.

Also, we have presented the hardware implementation of a sensor node. The advantages of the proposed method consist in creating a low-cost and low-power node which can be used to measure parameters for both indoor and outdoor environments.

As future work, we plan to analyze the proposed architecture related to the attacks regarding the protocols and particular communication methods of sensor nodes.

ACKNOWLEDGMENT

This work has been supported in part by UEFISCDI Romania and MCI through projects CitiSim, ESTABLISH and PARFAIT, funded in part by European Union’s Horizon 2020 research and innovation program under grant agreement No. 777996 (SealedGRID project), No. 787002 (SAFECARE project) and No. 826452 (Arrowhead Tools).

BIBLIOGRAPHY

[1] A. Mainwaring, D. Culler, J. Polastre, R. Szewczyk, & J. Anderson, “Wireless sensor networks for habitat monitoring.” in Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications, pp. 88-97, 2002.

[2] J D. Tian, N. D. Georganas, “A coverage-preserving node scheduling scheme for large wireless sensor networks” in Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications, pp. 32-41, 2002.

[3] R. I. Ciobanu, R. C, Marin, C. Dobre. “A Framework to Support Decentralized Ad-Hoc Networking”, in Modeling and Simulation in HPC and Cloud Systems, pp. 87-119, 2018.Prospectiva del Sector ElEctrico 2002-2011. (Secretaría de Energía. Mexico, 2002).

[4] R. Banerjee, S. Chatterjee, S. D. Bit, “Performance of a Partial Discrete Wavelet Transform Based Path Merging Compression Technique for Wireless Multimedia Sensor Networks. Wireless Personal Communications”, 1-15, 2018.

[5] http://www2.ece.ohio-state.edu/~bibyk/ee582/telosMote.pdf, Accessed December 2018

[6] http://www.libelium.com/products/waspmote/overview/, Accessed January 2019.

[7] M. Ilyas, I. Mahgoub, “Smart Dust: Sensor network applications, architecture and design” in CRC press.

[8] A. Silvestri., S. Foudi, A. B. Felsmann “Synthesis report on the" low carbon mobility" case study, 2019.

[9] http://www2.ee.ic.ac.uk/t.clarke/projects/Resources/BitCloud/M-251~01-%28ZigBit%20OEM%20Module%20Product%20Datasheet%29.pdf, Accessed January 2019.

[10] J A. Milenković, C. Otto, E. Jovanov, “Wireless sensor networks for personal health monitoring: Issues and an implementation. Computer communications”, pp. 2521-2533, 2018.

[11] I. F. Akyildiz, W. Su., Y. Sankarasubramaniam,, E. Cayirci, “Wireless sensor networks: a survey. Computer networks”, pp. 393-422, 2002.

[12] M. A. M Vieira, C. N, Coelho, D. C, Da Silva, J. M, Mata, J. M. “Survey on wireless sensor network devices”, in Emerging Technologies and Factory Automation. Proceedings. ETFA'03. IEEE Conference, pp. 537-544, 2003.

[13] Nayak, C. K., & Das, S. “Efficient Energy Sensor Arrays with Uneven Transport Interval in WSN”, in Information and Communication Technology for Competitive Strategies, pp. 293-301, 2018.

[14] A. Lagerqvist, T. Lakshminarayana, “IoT Latency and Power consumption: Measuring the performance impact of MQTT and CoAP”, 2018.

[15] G. Suciu, C. Nădrag, C. Istrate, A. Vulpe, M. C. Ditu, and O. Subea. "Comparative Analysis of Distributed Ledger Technologies." In 2018 Global Wireless Summit (GWS), pp. 370-373. IEEE, 2018.

[16] https://www.adafruit.com/product/3405, Accessed January 2019.

[17] L. P. Maguluri, T. Srinivasarao, R. Ragupathy, M. Syamala, N. J. Nalini, “Efficient Smart Emergency Response System for Fire Hazard using IoT”, International Journal of Advanced Computer Science and Applications (IJACSA), 9(1), pp. 314-320, 2018.

[18] https://grafana.com/, Accessed January 2019.

[19] C. Lozoya, A. Aguilar-Gonzalez, A. Favela-Contreras, A. Zamora, “An Internet of Things Platform for Academic Projects”, in Internet & Information Systems, 12(12), 2018.

[20] https://openlabpro.com/guide/relays-and-actuators/, Accessed January 2019.

[21] https://openhomeautomation.net/control-relay-anywhere-esp8266/, Accessed January 2019.

.