11TH INTERNATIONAL SCIENTIFIC CONFERENCE
ON DEFENSIVE TECHNOLOGIES
OTEH 2024
Serbia, Tara, 9-11 October 2024

IMPLEMENTATION OF ZIGBEE TECHNOLOGY IN THE PROCESS OF SENSOR CALIBRATION IN WIRELESS SENSOR NETWORK SYSTEMS

IGOR MEDENICA
Elektrodistribucija Srbije d.o.o. Belgrade, Serbia, medenicaigor@gmail.com

MILOŠ JOVANOVIĆ
Technical Test Center, Belgrade, Ministry of Defense Republic of Serbia, Serbia, mjovanovic@raf.rs

SLOBODAN SUBOTIĆ
Technical Test Center, Belgrade, Ministry of Defense Republic of Serbia, Serbia, slobodansubotic80@gmail.com

DRAGAN LAZIĆ
Technical Test Center, Belgrade, Ministry of Defense Republic of Serbia, Serbia, astazu.lazic@gmail.com

Abstract: *The compatibility of sensor functionality requires periodic calibration in an accredited laboratory. The calibration process involves temporarily disconnecting the sensor from operation, performing necessary preparations, and determining the sensor's condition. As a solution to improving the calibration process, the use of mesh networks is presented to avoid disconnecting sensors from active states. Using ZigBee technology, all sensors are represented through nodes with specific functions in the network. Information exchange occurs wirelessly among all nodes in the network, which are involved in communication with the main node (gateway). The main node serves the function of storing and processing data based on specified standards. To gain complete control over the system, observed state changes are stored in the main node's memory, which communicates with all nodes in the network during its operation. Deviations from reference sensor values are determined based on collected parameters from other nodes in the wireless sensor network. To expedite network operation, there is a need to categorize nodes into different types. Definitions of all node types are stored in a dynamic state table, with parameters defining the node type and its state. To facilitate access to all defined nodes from the dynamic state table, node types, in addition to the main node, are divided into reference and regular nodes. Reference nodes in the network do not have a constant role, and their role is separate from regular nodes to expedite communication and parameter retrieval for necessary analyses. Retrieved parameters from the state table are included in the comparison and analysis process based on node type. Obtaining results enables the identification of deviations, issues during operation, and the correctness of retrieved data compared to reference sensors.*

Keywords: *Sensor, calibration, ZigBee, mesh network, sensor network, gateway.*

1. INTRODUCTION

In current practice, wireless sensor networks are used in a variety of applications, including environmental monitoring (e.g. temperature, humidity, air quality), resource monitoring in industrial processes, infrastructure monitoring (e.g. road, bridge condition monitoring), smart agriculture, security and many others. To enhance and accelerate the deployment of communication systems between nodes, ZigBee technology is utilized, which has increasingly gained prominence as a commercial solution. Communication based on this technology allows the network to be flexible and easy to expand.

In this paper, we focus on the proposed solution for facilitating and speeding up calibration based on the mentioned technologies. The advantage of this approach is significant for large systems that have a large number of sensors.

In order to carry out all the calibration processes, the main step is to physically switch off the required sensor and transfer it to the laboratory in order to carry out the calibration under special conditions. The use of a network would facilitate the current calibration method and the sensor itself would not have to be switched off. This method streamlines the calibration process and reduces costs.

Through various researches, the concept of blind calibration has been presented which is designed for general sensor networks. The idea is to achieve great similarity in the measurements of all sensors in the network for the same purpose through this concept [1]. This method of testing does not always give correct results, but through a larger number of measurements and the inclusion of comparison with a reference sensor, this concept could be applied through a wireless network of sensors. The mesh network through various applications has shown flexibility and cost reduction [2][3]. This

Corresponding author: I.Medenica
E-mail: medenicaigor@gmail.com
DOI: 10.5937/OTEH24120M

network topology allows all network participants to send and receive data, thus all sensors within the sensor network can communicate with each other.

The rest of the work is organized through four sections. Section 2 introduces wireless sensor network technologies and ZigBee technologies. Section 3 shows the proposal of the system architecture and Section 4 describes the implementation of the calibration based on the proposed architecture. In Section V conclusion of the work.

2. WSN AND ZIGBEE

A wireless sensor network (WSN) is a self-organizing, ad hoc multi-hop network comprised of sensors distributed across a wide area [4]. It functions as a distributed real-time system where nodes possess the capability to both transmit and receive data. Consequently, a WSN facilitates the concurrent collection of physical parameters, real-time processing, and wireless communication, enabling efficient and synchronized data handling across the network.

WSN consists of multiple sensor nodes that generate sensor readings that are delivered via multi-hop paths to a specific node in the network for data collection. The node to which readings are delivered is called a sink [5].

This system has two types of nodes, a sensor node and a coordinator node. Sensor nodes have a role in the network to detect physical changes in the environment, such as temperature, humidity, and forward all collected parameters to the network. Coordinator nodes have the task of collecting all the data forwarded by the sensor nodes and forward them either to the end user or for processing [6].

ZigBee is a worldwide open standard of low-speed wireless networking based on IEEE 802.15.4. The aim of this standard is to enable [7]:

- Low cost
- Ultra-low power consumption
- Use of unlicensed radio bands
- Cheap and easy installation
- Flexible and extendable networks
- Integrated solutions for message routing

The mentioned characteristics enable quick installation of external power supplies without the need for cables due to low levels of vibration during operation.

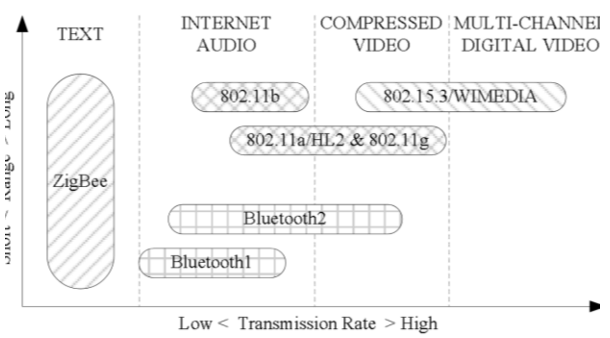

Figure 1. Wireless landscape

This technology finds its application in smart home communication, security systems and remote control and reading of devices. Compared to other wireless protocols such as Bluetooth (802.11), ZigBee exhibits a wide range in communication distance and a low transmission rate. It is characterized by fast and short transmission of text format. The figure (Figure 1) below shows wireless network protocols with an emphasis on two characteristics, wireless radio range and data transfer rate [8].

Routing a message through the network from one node to another depends on the network topology, which is divided into star, tree and mesh.

Star topology relies on a central node and all messages travel through it.

A tree topology has a main node at the top that branches into branches and leaves. In order for the message to reach the required destination, it travels up the tree and then down the chain.

The mesh topology is the most similar to the tree topology, only that the nodes have a direct connection to other nodes.

Unlike the star topology, which has a single coordinator node that distributes traffic in the network, a mesh network can communicate without the help of a coordinator. Nodes in this network serve as routers that form a flexible and reliable structure with the possibility of mobility of the end nodes of the network. Thanks to these characteristics, ZigBee has the ability to cover a large area and therefore has applications in various industries.

ZigBee technology has found its application in many fields such as smart homes and cities, agriculture, industrial production and many more. The choice of this technology for communication within the WSN system is low-cost, low-power and multifunctional sensor nodes.

Based on the mesh network structure, it is possible to communicate over long distances. One of the applications of this technology is that it can be used in testing the correct operation of sensors and testing their accuracy in operation. The previous method of checking the operation of the sensor required disconnecting it from operation and testing it in laboratory conditions. Through the wireless method of testing the correctness of sensors, costs would be reduced and the effectiveness of the system would be increased. In order for this method to work, it is necessary to predefine the types of nodes in the network, which ZigBee communication provides in its work. One of the ways is to create a dynamic node state table that has the purpose of defining all nodes in the system.

3. NETWORK SYSTEM ARCHITECTURE

In order to take full advantage of the advantages of ZigBee technology, the definition of node types is performed depending on the role in the system, structuring and storage of data exchanged between nodes.

3.1. Types of nodes

By using a mesh network, it is necessary to introduce the definition of network nodes in order to adapt to the solution of the calibration problem within the wireless sensor network.

Nodes are divided based on their roles in the network into the main node (orange), reference (blue) and regular (green) nodes (Figure 2).

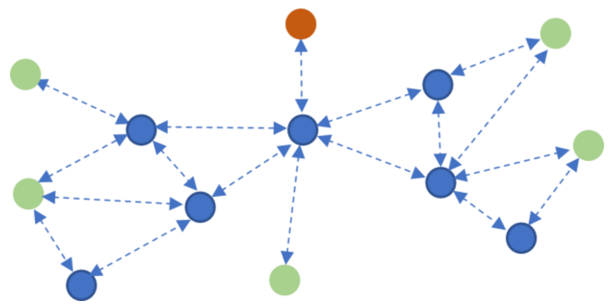

Figure 2. Communication between different types of nodes

The main or input node has the role of coordination in the system as well as receiving and sending data outside the network. Within the main node, information related to the state of nodes in the network and data measured through measurements on reference and regular nodes are stored.

Reference nodes are occasionally active nodes within the network that assume their role at certain time intervals. After successful measurements, they are disconnected from the network.

Regular nodes are all other nodes that have a daily function within the sensor wireless network. Through this system functioning model, their work is constant without planned disconnections from the network, as long as they provide the required functionality.

3.2. Table of dynamic states

In order for communication to be uninterrupted and reliable in the network, the state of each node and the type of node it belongs to are recorded. On the basis of the above information, a decision is made about the necessary storage of parameters and the analysis thereof. The parameters are entered into the table of dynamic states, which has the following structure:

- Node address
- Node type
- Purpose/Function
- Routing time
- Status

Based on the routing time, an assessment is made on the need for a new node status update. The state of a node determines its activity in the network, which can be active or deactivated.

Nodes that cannot be accessed during each subsequent routing are given the status deactivated, while deactivated nodes are examined first with each pass. By definition, if a node is inactive in the network for a certain period, it is deleted from the status table.

Recognizing a new node in the network during routing, its function or type of sensor in the WSN system is recorded, the node type is basically added for regular, while in reference connection situations this type changes and the status of the node becomes active and visible in every subsequent routing.

The table is stored on the main node to facilitate subsequent data analysis because all data is available in one place.

3.3. Table of sensor parameters

During dynamic state table routing through the network, nodes forward their sensor reading parameters to the master node. All measurement parameters for all sensors in the network are stored within the main node. For these needs, a table is created that records the address of the node, the type of measurement, the time of measurement and the values of the performed measurements. Based on the entered data, it is possible to follow the complete measurement history for each node in the network from the beginning of its activation. Based on the stated values of the sensors, it is possible to establish deviations in the operation of each sensor in different conditions, and based on the data from the table of dynamic states, the type of node is determined. In order for the calibration to be carried out successfully after storage, on the basis of establishing the type of node, the reference values for the selected sensors are determined, on the basis of which the calibration process is entered.

4. SENSOR CALIBRATION IN WSN SYSTEM

Wireless sensor networks usually consist of inferior sensors that are deeply integrated into the physical environment and as a result, the performance of the network is undermined by poor hardware and sums in data measurement [9]. Through various researches, calibration solutions have been proposed at the device level, which do not perform well in larger systems.

Through this work, a new concept of thinking within the mesh network is explained, with the definition of communication between nodes and the definition of data types in the system. Stored data within the main node contributes to tracking deviations of regular sensors in operation. With this work model, calibration includes a reference model that is defined in the system as a reference node, based on the parameters of which comparison is made with regular nodes of the same type of purpose.

During the sensor calibration, the measurement data is stored on the main node in the network, while the regular nodes, as permanent participants in the communication, only perform their measurement function.

Reference nodes are part of the system while measuring in similar conditions based on other sensors under test. During calibration, it is possible to take one or more sensors into the process, given that the architecture explained in Section 3 allows communication with multiple sensors and that all data is related to measurements on the main node, which has recorded the complete history of a particular sensor.

In addition to this, the calibration process incorporates advanced algorithms that adjust for environmental variations and sensor drift over time. By continuously comparing the measurements of the regular sensors to those of the reference node, the system can dynamically update calibration parameters and ensure that sensor data remains accurate and reliable. This approach not only improves the overall accuracy of the sensor network but also enhances the robustness of the network by minimizing the impact of individual sensor failures or discrepancies. Thus, this calibration method represents a significant advancement in maintaining the integrity and performance of wireless sensor networks.

5. CONCLUSION

The presentation of the wireless calibration model in relation to the traditional one shows the increasing need for sizes and number of nodes in wireless sensor network systems. ZigBee is one of the technologies that finds its application and facilitates this access model. By defining dynamic states, assigning node types and storing data, it gives full control over the network and creates a new environment that gives the possibility of expanding functionality and opening new fields of application.

This work represents the first step in the exploration of advanced calibration techniques for wireless sensor networks. Future research will focus on extensive testing to evaluate the performance of the calibration model under various conditions. These tests will aim to identify the most efficient components of the system, pinpointing which aspects of the calibration model perform optimally and where further improvements may be needed. The insights gained from this testing phase will be crucial for refining the calibration approach, enhancing the accuracy and reliability of the sensor network, and guiding future developments in this field.

References

[1] BALZANO,L., NOWAK,R.,: *Blind calibration of sensor networks*, Proc. of IPSN. IEEE/ACM, (2007) 79-88.

[2] FRANCESCHINIS,M., SPIRITO,M., TOMASI,R., OSSINI,G., PIDALA,M.: *Using wsn technology for industrial monitoring: A real case*, Sensor Technologies and Applications, SENSORCOMM, (2008) 282-287.

[3] HEILE,B.: *Emerging Standards: Where to ZigBee/UWB fit*, ZigBee Alliance, ZigBee Alliance, 2004.

[4] KARL,H., WILLIG,A.: *Protocols and Architectures for Wireless Sensor Networks*, John Wiley & Sons, 2005.

[5] BARONTI,P., PILLAI,P., CHOOK,W.C.V., CHESSA,S., GOTTA,A.,FUN HU,Y.: *Wireless sensor networks: A survey on the state of the art and the 802.15.4 and ZigBee standards*, Computer Communications, (2007) 1655-1695.

[6] ONDREJ,S., ZDENEK,B., PETR,F., ONDREJ,H.: *ZigBee Technology and Device Design*, International Conference on Networking, International Conference on Systems and International Conference on Mobile Communications and Learning Technologies, IEEE, (2006) 129-139.

[7] BAKER,N.: *ZigBee and Bluetooth strengths and weaknesses for industrial applications*, Computing & Control Engineering Journal, (2005) 20-25.

[8] FITRIAWAN,H., MAUSA,D., ARFIN,J.,A.A., TRISANTO,A.: *Realization of Wireless Sensor Networks for Temperature and Humidity Monitoring*, Proceeding of International Conference on Electrical Engineering Computer Science and Informatics, 2015.

[9] RAMANATHAN,N., BALZANO,L., BURT, M., ESTRIN,D., HARMON,T., HARVEY,C., JAY,J., KOHLER,E.,ROTHENBERG,S., SRIVASTAVA,M.: *Rapid Deployment with Confidence: Calibration and Fault Detection in Environmental Sensor Networks*, Technical Report CENS-TR-62, Center for Embedded Networked Sensing, 2006.