Distributed Sensing Solution for Home Efficiency Tracking

Carolina Dionísio[1,2], Gonçalo Simões[1,2], André Glória[1,2], Pedro Sebastião[1,2], Nuno Souto[1,2]
[1] ISCTE – IUL, Av. Forças
[2] Instituto de Telecomunicações, Av. Rovisco Pais, 1, Lisbon, Portugal
garss@iscte-iul.pt, cadoo@iscte-iul.pt, afxga@iscte-iul.pt, pedro.sebastiao@iscte-iul.pt, nuno.souto@iscte-iul.pt

***Abstract*— With the rapid increase of smart devices, keeping track of household consumptions is a service that starts to be automated. This paper presents a proposal for a system based on wireless sensor networks designed for the purpose of monitoring and controlling environment parameters of a smart home. In order to obtain an efficient and inexpensive system, a study was made to select the best hardware and software solutions for this system. This system allows the user, through an Android application, to view all the information collected by the sensors, and consequently act in a way to make his home more sustainable. The main advantage of this system is to take into account that all its components are small, practical and with high efficiency, in addition it allows an easy installation and in order to get involved with the inner environment, another advantage is to allow system interaction with the user.**

Keywords— Internet of Things, Smart Homes, Wireless Sensor Network, ESP32, LoRa, Android

I. Introduction

In the course of the 21st century, the human being tends to change his routine with the evolution of technology, either to make the day-to-day life easier or for entertainment. The Internet of Things (IoT) has the capacity to transform a simple physical device into a smart one, connected to the Internet with communication and computational capacities. Consequently, it is easier to claim this reality is present in our homes in order to make them more efficient and intelligent, the designated *smart homes*. These types of homes are considered one of the most prominent applications of IoT, because the main characteristic of a *smart home* is automation and monitorization, resulting in the reduction of the human effort [1].

The monitorization of a *smart home* can be done according to the parameters the user intends to have, such as: temperature, gas, noise, humidity, brightness and water consumption. In order to perform this data acquisition a wireless sensor network (WSN) is often used, where some sensors are strategically distributed around the house to collect information and, after being transmitted and analyzed, decide actions and alert the user. WSN technology supports the IoT concept, since its main advantage is gathering measurements using devices connected to the Internet, where the results become immediately available to the user wherever he is. Nonetheless, the use of this technology depends on its own efficiency, the reliability and the safety of the data, since they can compromise the user.

The search to accomplish a sustainable way of consuming energetic resources of the planet Earth, is a global concern, due to the tremendous consumption of natural resources by human beings, planet Earth's state is turning critical. Through IoT systems, due to their monitorization and automatization capabilities, it will be possible to reduce the impact human beings have in their consumption, sparing Earth's resources and saving monetary costs to the user.

Nowadays, the necessity to create projects that can monitor homes, to avoid risk situations and also keep track of consumptions, has increased, something we can see in various projects already developed.

The authors in [2] developed a low-cost home automation system, using WSN technology to monitor and control the environment, safety and electrical parameters of an interconnected home using an Android application so the user can control the devices in a smart home. The disadvantage of this system is the Wi-Fi communication protocol that has a high power consumption and low range, making it impractical to use in a large scale environment.

The authors in [3] implemented a WSN for a small area in a building that allows sending data in short distances, with the disadvantage that when packets have more than 10 bytes they get delayed, making packet size something to keeps in mind in order to get the optimal transmission speed at the selected network configuration. Another disadvantage is that the network cannot operate more than five days without additional energy.

In [4], the authors propose a solution where the devices can transmit information up to eight floors without compromising its data flow, in other words, without losing any information packets. This can be useful to extend the monitorization from a simple house to a building.

The main objective of this paper is to design and implement an IoT system to monitor household consumptions, analyzing and gathering data in real time on the installation site, using a low-cost sensor network, in order to understand if there is any abnormal consumption or any dangerous situations. It should consequently lead to natural and material resources savings, as well as reducing monetary costs for the user. There are already some IoT systems using WSN to monitor smart home, although with some limitations that compromises its use in an efficient way. This proposal aims to answer the efficiency problem, using low power hardware, combined with a more optimized software and a long range, low power and reliable communication protocol, in order to improve the WSN lifespan.

II. Proposed System Architecture

In order to achieve the main goal of this work is to develop a distributed solution based in WSN that gathers information according to pre-established parameters. Subsequently, this information will be sent to a server, through an appropriate communication protocol given the range, number of nodes, reliability and cost. This data will be analyzed and make available to the user through an interactive dashboard, also sending warnings via email or notification when dangerous situations occur. To develop this system and achieve the main goal it is necessary to

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consider the hardware and software solutions, which will be described, in detail, in the following subsections.

A. Hardware

The proposed system, represented in Figure 1, follows the structure of a normal WSN, composed by a few nodes with the ability to collect data and communicate with other nodes. This specific network is only constituted by a Broker and sensor nodes.

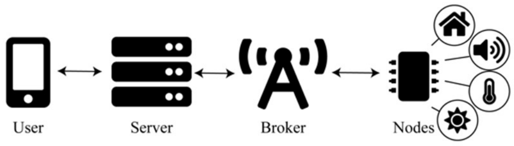

Fig. 1. System Architecture

The main node is the Broker, which is an aggregation node since it does not collect data, it just sends the information received from the other nodes to the server. In this case, the Broker serves as a bridge between the sensor nodes and the server.

The communication between the Broker and the sensor nodes, was chosen based on the best low power and long range wireless technology to serve this system in the most efficient way. The authors in [5] evaluated the main communication protocols associated with IoT and concluded that currently, the best choice was to use LoRa, since it is a bidirectional communication protocol that can provide a low power long range communications, and besides that, can support a large number of devices and increase the battery life, with a reduced device cost.

After receiving the data from the sensors nodes, the Broker transmits the information to the server using Message Queuing Telemetry Transport (MQTT), a protocol used in IoT systems due to its ability to provide routing for low power and low memory devices [6], via a Wi-Fi connection.

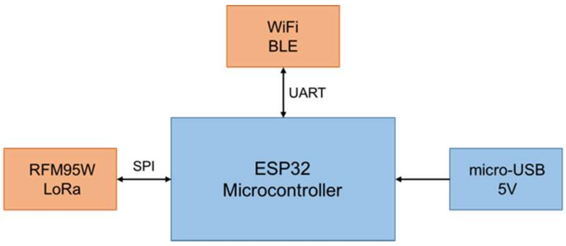

Fig. 2. Broke node block diagram

Analyzing Figure 2 in detail, we can verify that the Broker only consists of two main elements. The first is an ESP32 chip ultra-low-power microcontroller that comes with a built-in Wi-Fi and BLE, being a versatile, low price, high performance and reliable solution for a wide variety of applications and power scenarios [7],[8]. The other element is a RFM95W, a radio module capable of transmitting information using the LoRa protocol, capable of transmitting data between a multi-point network, with individual node addresses, ensuring a range of 2km between nodes [9].

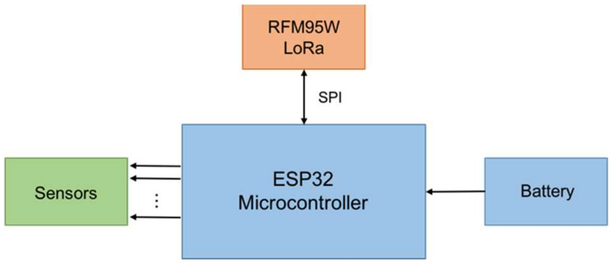

Fig. 3. Sensor node block diagram

As shown in Figure 3, the sensor nodes are composed by an ESP32 microcontroller, a RFM95W radio and an array of sensors. One of the ESP32 features is allowing the node to enter a deep sleep mode when it is not sending information, reducing the normal electrical current consumption form 20 mA to 150µA. This allows the node to be connected just for short periods of time, enabling it to be powered from batteries.

Each node can have up to 8 sensors connected, since the ESP32 includes a high number of Analogic Digital Converters (ADCs), allowing the node to have different sets of sensors depending on room/division necessities, since the parameters from different divisions of a house may differ.

B. Software

In order that the user can check all the information that has been gathered from the sensors, an Android application serves as an information center, a place where all the consumption parameters and data is displayed. This information will be sent periodically, with daily reports as well as graphic charts every month, to ensure the user has all the details on demand.

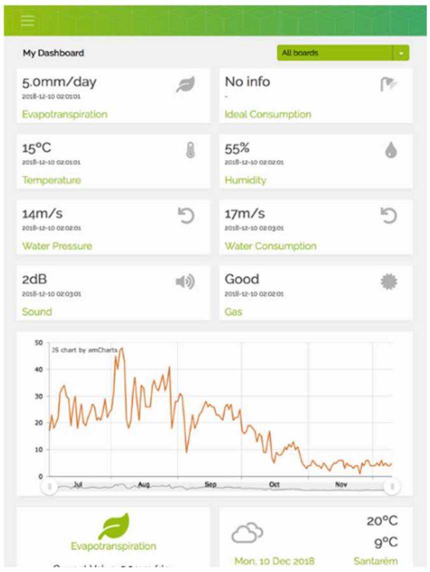

Fig. 4. Android Application Mockup

With this information, the user can realize if any resource is being spent in an unnecessary way, as show in Figure 4, either daily or monthly, consequently saving money and natural resources. In addition, the software will forward an alert if any dangerous situation occurs, like for example, a gas leak.

The process when a new sensor value arrives at the server is simply a comparison with a threshold value for the type of sensor. This process is done in real time, ensuring that the user is alerted when the problem starts. Figure 5 shows a flowchart of the proposed algorithm.

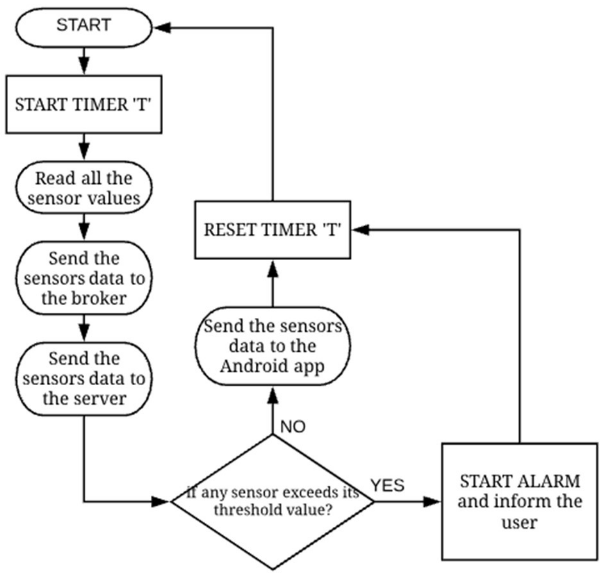

Fig. 5. Proposed data analizes algorithm flowchart

To determine the best threshold for each sensor, an exhaustive analysis of the sensor data in multiple environments needs to be done. In some cases, such as carbon monoxide, the threshold value can be obtained online, since it is a common issue for human beings. Others, such as temperature and humidity, the threshold needs to be adapted to every scenario, so a Machine Learning algorithm can be applied in order to get the individual value for each sensor.

To make sure that all the system performs as needed, it is necessary to guarantee a good communication between the nodes, through a reliable LoRa connection, where no messages are lost. For this, the RadioHead library [10] is used, which allows the individual addressing of each node. Communication can be done in two ways: with broadcast without acknowledgment from the receiver, which is used when the Broker needs to send a message to the sensor node; and the second is to send a message to a specific address with acknowledgment from the receiver, which is used when the sensor nodes send data to the Broker.

To make sure that all types of communication are reliable, when the Broker needs to send a message to a specific node, it sends a broadcast message to all nodes with the desired node ID, if the node is the node with the message ID it sends an ACK to the Broker, if not, the node discards the message. Through this messaging algorithm it is guaranteed that the messages are delivered and that the IoT system is reliable.

III. Proposed System Implementation

Designed and presented the system architecture capable of monitoring household consumptions, analyzing and gathering data in real time, a real case scenario can be proposed. Firstly, is important that laboratory tests be performed so that all parts of the system do not fail in their implementation. Also, it is necessary to define which sensors will be distributed by each node, since each division has different needs, and lastly decide the best position for the broker.

The proposed implementation will be done in a house with the following features for each type of division.

- Kitchen: will be implemented with a gas sensor (MQ2) that has lower conductivity in clean air, because the sensor conductivity is more higher along the gas concentration rising [11], a water pressure and consumption sensor (water flow sensor) [12]. Due to the high hypotheses of failures in this division, this proposal intends to give the user warnings in case of gas or water leaks.
- Bathroom: to control water consumption will be implemented with water pressure and consumption sensor (water flow sensor) that consists of a plastic valve body, a water rotor, and a hall-effect sensor. When water flows through the rotor, rotor rolls and the speed changes with different rate of flow [12].
- Garage: A gas sensor (MQ7) [13], to obtain the levels of carbon monoxide with a detection range between 10 up to 500ppm.

For all of the above and the remaining divisions sensors for humidity and temperature (DHT22) that measure the temperature between -40º and 80º Celsius [14], luminosity (LDR) that his applications include smoke detection, automatic lighting control [15], an electrical consumption sensor (electricity meter sensor) that can transform AC signals of large current into small amplitude signals. [16] and noise (sound sensor) [17] will be implemented. According to the type of division and its needs, these sensors will be warning the user if conditions such as temperature and humidity values can affect the power consumptions, for example contributing to the correct use of air conditioner in a bedroom or living room. Also combining these measurements with the luminosity sensors can recommend or even directly control the opening or closing of the blinds to help control the temperature.

Since the proposed system is flexible, it is possible to add as many nodes as the divisions of a house, including multiple nodes per division, without jeopardizing the efficiency of the house or network.

With the implementation of the system, it will be possible to visualize the information collected by the parameters in the developed application and later the consumption graphs.

IV. Conclusions and Future Work

In this paper, we described a monitoring system designed using WSNs technology in order to make an ordinary home into a smart one with the objective of keeping track of consumptions to promote sustainability. The proposed system relies on low power WSNs that can communicate either with the online server as well as between nodes spread far apart. Modules that can communicate over LoRa and MQTT like the RFM95W and ESP32 microcontroller were chosen for the implementation due to their characteristics, which allow this system to be efficient, low cost and with a good battery life.

A proposal for the implementation of this system was described with details on how each division can be equipped with a set of sensors and how with that data the user can be warned of potential failures or misusage of consumptions.

The next step is to implement the proposed system and test it in real environments in order to evaluate its efficiency, to ensure that the main goal is achieved, in order to promote sustainability and reduce the household consumptions. Another step is to create actuator nodes, capable of acting in the environment based on the data collected by the network, such as turn on/off lights, blinds or other appliances.

Although this project was designed for smart homes, it can be extended to buildings or even commercial areas. This way it would be possible to promote sustainability in larger environments affecting several users at the same time.

ACKNOWLEDGMENT

This work was supported in part by ISCTE – Instituto Universitário de Lisboa from Portugal under the project ISCTE-IUL-ISTA-BM-2018 and by the FCT - Fundação para a Ciência e Tecnologia and Instituto de Telecomunicações under project UID/EEA/50008/2013.

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