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TEMPERATURE MONITORING THROUGH WIRELESS SENSOR NETWORK USING AN 802.15.4/802.11 GATEWAY

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Abstract: The wireless sensor network (WSN) has a wide range of uses. It can be used, for example, as a powerful tool for gathering several kinds of environmental information. This type of monitoring fits in the concept of Internet of Things (IoT), which aims to optimize the real world processes by monitoring their variables. In this study, a WSN developed in the IEEE 802.15.4 standard was used with the objective of measuring the local temperature. The access to the data was available through a WLAN network in the IEEE 802.11 standard (also known as Wi-Fi), an already existing network or a solution's dedicated network were used. Quality tests of signal and maximum range of communication of the WSN were made, as well as the network's battery lifetime usage estimates. Finally, the study also shows the monitoring of the temperature of some environments.

Keywords: Internet of things (IoT). IEEE 802.15.4. Wireless sensor network.

1. INTRODUCTION

The Internet of things is expected to have a huge number of physical objects connected to the TCP/IP network. Evans (2011), Cisco's chief futuristic and chief technologist for Cisco Internet Business Solutions Group (IBSG), predicts that there will be 50 billion devices connected to the Internet by 2020. Such huge increase shows a great market opportunity for equipment manufacturers, Internet service providers and IoT application developers**.**

The architecture standardization is still a challenge for the IoT world but a great part of these devices will be linked using wireless sensor networks (WSN).

WSN offers the basic infrastructure for communication amongst sensors that will provide information about temperature, humidity, carbon dioxide concentration, public lightning levels and other environmental data. This data sensing can be employed into different scenarios like transportation, healthcare or industrial automation. In most of the cases, all this information is sent to a service layer (smart grids, smart cities, cloud services, etc) using an existing global TCP/IP network. The main issues on integrating a WSN to the internet are the differences between the protocols, especially in the physical, data link and network layers.

Nowadays, the WSN available for sensing and monitoring pull together several communication protocols like Wi-Fi, Bluetooth, IEEE 802.15.4, Z-wave and LTE-Advanced. Unfortunately, none of these technologies hold all the broad IoT applications range. Each protocol is designed to support communications within a specific range coverage area, bandwidth, data-rates and energy consumption. Having that said, IoT application developers have to deal with many protocols to create IoT services that can be deployed.

This work gives a wireless sensor network for temperature monitoring. The connection between the data tags is given by an IEEE 802.15.4 network. The tags sense and send the temperature information to the central computing unit. This unit works as an IEEE 802.11 gateway, providing access to the Internet.

Wireless networks with similar functionalities are presented on other works like in the temperature WSN based on ZigBee, employed in BIN *et al.* (2011), using a thermocouple as temperature sensor, and in DI and SHENGPENG (2013), that uses infrared temperature sensor and transfer the data to a computer by RS232. MAINWARING *et al.* (2002) applied wireless sensor networks to real-world habitat monitoring, with internet access and sensors for environmental conditions, like temperature, humidity and pressure.

The Section 2 provides some background about the areas covered by this project, including the wireless networks patterns and the microcontrollers used. The development of the system, which involves hardware and firmware, is explained in the Section 3, while results of the tests are exposed in the Section 4.

2. THEORETICAL BASIS

2.1 Wireless Sensor Network

According to KRCO et al. (2013), WSN are communication networks among constrained devices (limited computational power, memory and energy). These networks are composed of a large number of sensor nodes, which are deployed either inside the phenomenon or very close to it. Every node has

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components for sensing, data processing and communication. The most important constraint on sensor nodes is the low power consumption requirements. In general, the nodes carry limited power sources. This requires protocols focused on power conservation, lower throughput and higher transmission delays. (AKYILDIZ et al., 2002, p. 393-394)

This work employs the IEEE 802.15.4 standard which determines the specification for Wireless Personal Area Networks (WPANs). These networks are used to convey information over short coverage areas, involve little or no infrastructure. Its general idea is to allow small, power-efficient, inexpensive solutions to be implemented for a wide range of devices.

2.2 IEEE 802.15.4

This stack, according to IEEE 802 (2011), defines the two first layers (physical layer (PHY) and medium access control (MAC) sublayer) specifications for low-data-rate wireless connectivity over relatively short distances. The IEEE 802.15.4 specifications target devices performing WPANs which have very limited battery consumption and relaxed data-rates requirements.

The 2400 MHz frequency band is used for this work (ISM free-licensing worldwide band). This choice is due to its greater number of channels in comparison with the other available frequencies. Also, the PHY specifications determine the maximum data rate of 250 kb/s for this band.

It is important to notice that the IEEE 802.15.4 does not define any topology. Its implementation should be done by the upper level layers (application layer). The tree topology is applied to the project. The advantage in using such communication architecture is the scalability it provides along with its easy implementation when compared with another scalable topologies (mesh topology, for instance).

There are two kinds of devices inside this network, the Full Function Devices, called of Repeaters and Coordinators, and the Reduced Function Devices, called End Devices.

The communication is made in the direct way, where the receiver of the message needs to be listening to the network to receive the data. Because of this operation mode, the transmission is made from the End Devices to the Coordinator, so the End Device can run in low power mode, saving battery, and the Receiver and Coordinator keep listening to the network.

Each device at the IEEE 802.15.4 can have two types of address, the IEEE address, with 64 bits, and the short address, with 16 bits. The short address is used on the messages in this project, which is requested when the device associates on the network and allows reducing the size of the package and optimizing the network.

2.3 IEEE 802.11 (Wi-Fi)

As stated in the IEEE 802 (2012) specifications, this pattern covers several types of applications and purposes. The overall goal set by this standard is to offer wireless connectivity for fixed, portable, and moving stations within a local area.

2.4 Microcontrollers

This project makes use of wireless microcontrollers especially developed to radiofrequency applications. As the system integrates two different network protocols, two microcontrollers were chosen to provide communication links amongst the sensor network and the web.

2.4.1 IEEE 802.15.4 Microcontroller

The JN5168-001-M00Z module from NXP Laboratories was chosen for this work. It uses, according NXP Laboratories (b) a JN5168 microcontroller which features a 32-bit RISC processor and offers a 2.4 GHz IEEE 802.15.4 compliant transceiver (network stack as well).

2.4.2 IEEE 802.11 Microcontroller

The Wi-Fi connection is made using the ESP8266 microcontroller from Espressif (2014). According to the company, it integrates a 16-bit RISC processor and provides an IEEE 802.11 b/g/n stack.

2.5 Temperature Sensor

The temperature sensor used in this paper is the LM60 from Texas Instruments. According to Texas Instruments (2015), this device can sense a −40 ºC to +125 °C temperature range while operating from 2.7 V supply (Power-Supply Voltage Range: 2.7 V to 10 V). The output voltage has a Linear Scale Factor of 6.25 mV/°C and has a DC offset of 424 mV. The nominal output voltage of the sensor ranges from 174 mV to 1205 mV (for a −40 °C to +125 °C temperature range).

3. MATERIALS AND METHODS

The block diagram of the system is shown in Figure 1.

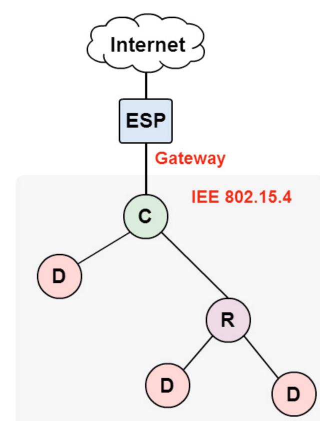

Fig. 1. System's structural diagram.

Each device forming the WSN is represented by a circle. The gateway, composed by a Wi-Fi module, is showed as a square. The "D circles" corresponds to the end devices. The end devices are responsible for the temperature sensing and its transmission to a parent device (Repeater or Coordinator).

The "R" circle symbolizes the repeater which is involved in managing the data sent by the end devices and retransmitting them to its parent node.