802.15.4 Microsystem for Sensor Applications

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Abstract — **This paper focuses in studying the IEEE 802.15.4 communications standard and its implementation in a development board. The specification is focused to a sensor application, such as presence detection or the capture of variables such as temperature, light, etc… To communicate with the nodes, programming them or to view the information received, a viewer software (Graphic User Interface) has been developed in LabView. This way, programming and the visualization of data is done in real time, in a clear and simple way. The developing platform used to test the system is an Atmel RZRAVEN, offering an easy to deploy sensor network board kit. The code is based on the ATMEL–MAC stack, adding more flexibility and functionality for the desired application.**

Keywords: IEEE 802.15.4; WSN; sensor network; ATMEL-MAC; RZRAVEN; LabView.

I. Introduction

Today, sensor networks have taken a great prominence. A sensor network is an application in which several independent measuring devices intercommunicate with each other in order to perform a common task. They are usually based on a large number of nodes or devices with sensors, which can cover large areas and are capable of transmitting data in an ad-hoc basis without predetermined physical infrastructure. Therefore, they can self-organize and self-configure a network between them and route messages to their destination without static routing tables.

Certain applications have the need to take values in different points simultaneously against a single location. This data can be optionally transmitted to a central node. Environmental management, monitoring vital signs of patients and smart-homes are just some of these applications. This last one is very important, especially controlling energy consumption by air conditioning systems. A system that can acquire the temperature distribution inside a room is essential for obtaining the key parameters of the managing model [1][2][3].

Other applications have to detect a change in a variable and alert the system if it exceeds a threshold level. In the field of security is necessary to protect restricted areas. Intruders who access them will wake up a node with an attached motion sensor, generating an alarm message with its location and transmitting it to the network. Another clear example is fire detecting systems, that activate when one of the nodes exceeds the predefine temperature or gas limit [4][5].

New sensor applications take advantage offered by wireless communications. An immediate benefit of wireless technology is the drastic reduction in wiring costs, providing also a simple and quick deployment. Another one is its ability to reach inaccessible or complicated places, such as collecting data in hazardous, remote, or even hostile environments. Another advantage is mobility: if the measuring system has an autonomous power system, is small-sized and has reduced weight, the system may be mobile. This feature is desirable for control and tracking animals [6][7].

Therefore, wireless sensor networks (WSN) enable the capture, processing and data processing effectively. Networks are based on a large number of independent nodes that thanks to their sensors, can capture data of interest, and with their microprocessor, are able to pre-process the data to be sent efficiently to a server. The IEEE 802.15.4 was developed specifically for the requirements and functionality required by sensor networks [8][9]. A low data transfer, synchronization and a low power radio allow nodes to successfully implement the applications discussed.

II. Solution Study

After a full study of several software and hardware solutions provided by different companies and manufacturers [10], the following ones where chosen:

A. RZRAVEN

The RZRAVEN 2.4 GHz Evaluation and Starter Kit enables development, debugging and demonstration of a wide range of low power wireless applications including IEEE 802.15.4, 6LoWPAN and ZigBee networks. The kit contains two RAVEN boards and one USB dongle. They use the AT86RF230 a low-power radio transceiver. It is a true SPI-to-antenna solution and high integrated solution, since all RF critical components except the antenna, crystal and de-coupling capacitors are integrated on-chip. It consumes only 16 mA while providing +3dBm power transmission and -101dBm sensitivity. The Raven boards come with expansion headers, providing flexibility to connect the sensors and actuators needed for a desired application [11].

B. Atmel—MAC Stack

Atmel's kit provides an instant begin to study and understand the basis of sensor networks, their operation and implement them in practical ways. The compatible stack chosen for the RZRAVEN is the Atmel 802.15.4 MAC [12]. This approach allows us to investigate IEEE 802.15.4 fully, which is the basis for other advanced standards. With other stacks, such as ZigBee BitCloud, studying and understanding would be more difficult due to the extra complexity associated to tasks such as message routing, security policies, and so on.

C. *IEEE 802.15.4*

A full study has been made to understand the IEEE standard [9]. One recurring thing the standard always uses is primitives, which can be one of the following four types: Request, Indication, Response and Confirm. The primitives define different actions that can be invoked to start and maintain a PAN, associate and disassociate nodes, synchronize, transmit and receive message, or manage security.

III. Design & Implementation

Due to the lack of LEDs in the AVRRAVEN boards, an auxiliary board was designed and built. The files associated to the platform layer were modified to incorporate these new outputs. The example *App_1_Nobeacon* provided to test this platform has reduced functionality. USB communication with the coordinator RZUSBSTICK is not present, so the USB–CDC library and USB functions were added to the main code. Furthermore, new primitives were extracted from the standard and added to the example code, such as MCPS–Data.Indication, to receive data from the end nodes. The End nodes had also new functions, such as the possibility of receiving and instruction and turning on or off the led on the auxiliary board. They also sent periodical messages to the coordinator with the present analog value of one of their ADC channels.

Finally, the GUI was developed in LabView. The layout was made to provide an easy view of the data and instruction selection. The final GUI window is shown in Fig. 1. The data received by the coordinator, the instructions sent to the nodes and all the status messages regarding the network state are shown on the GUI in real time.

IV. Verification & Test

After uploading the modified firmware of the stack to the boards, a full test was carried out on the boards, as shown in Fig. 2. This included the start up of the network and the periodical data sent by the nodes showing on the message window and the graphs plotting the analog values. Another action was trying to send a 'LedOn' instruction to a nonexistent address and to the node with the auxiliary board. The outcome of all the test carried out was correct, and validated the design and implementation of the system.

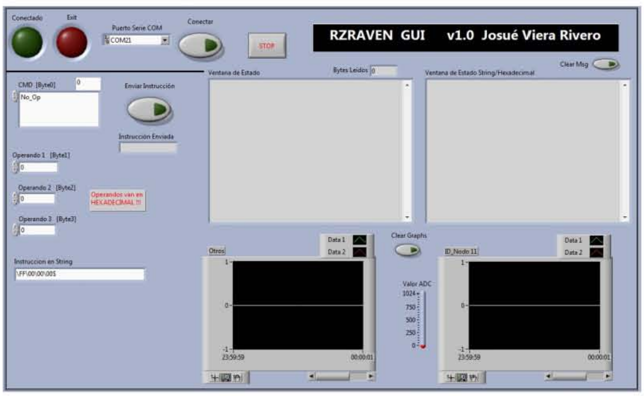

Figure 1. Graphical User Interface

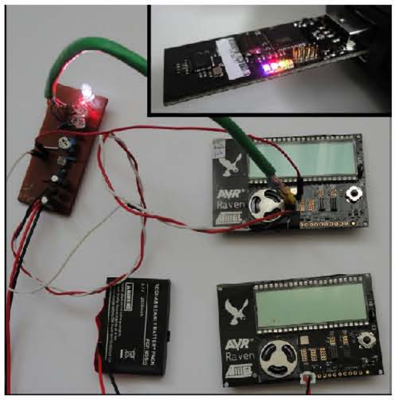

Figure 2. Microsystem under Test

V. Conclusions

Studying the IEEE 802.15.4 has provided a full knowledge and understanding of the structure, nomenclature, the definition of primitives and functions associated with it. This learning has been supported and strengthened due to the practical use of the stack developed by Atmel and its development kit. Thanks to this tandem, a wireless sensor network was started and maintained. The implementation of additional features to extend the functionality of the stack resulted in a system that performs communication in both directions, Coordinator-End nodes. These messages were sent from the develop GUI and received data was clearly shown on the graphs. This application is fully upgradable, increasing functionality by adding new instructions or sensors.

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