WIRELESS TEMPERATURE SENSING USING ZIGBEE NETWORKS

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ABSTRACT

The ZigBee technology is ideal for wireless sensing projects. This paper explains the operation of a wireless temperature sensing system possible thanks to this new standard. The introduction provides a brief explanation of the system, and names some possible areas where it could be implemented. After that, section 2 details the network operation, while 3 and 4 provide knowledge about the hardware and the software involved in the system. The paper ends by presenting the results obtained with the system and the conclusion.

1. INTRODUCTION

ZigBee wireless networks are increasingly being used for sensing systems [3-5]. This standard provides low-cost, low-power, self-organized devices [6] that are ideal for this purpose. The wireless sensing systems solve many issues inherent to cable systems, such as poor performance of expansion, deterioration and loss of data.

This paper proposes a temperature sensing system based on the ZigBee standard. The sensor nodes perform temperature measurements and send them to the network. All temperature data travels through the nodes to get to a central point, where it is analyzed and stored in a database. Sensor nodes are powered by 7.5 V batteries with at least 300mAh, enough to power the sensors for at least 2 months. The system would be very useful for shrimp farming, poultry [7] and beekeeping [8], among other examples, since it would help monitoring and controlling the temperature of the crops.

This work is being developed by undergraduate students under a partnership between UFRN and Potychip. It will be tested on aquariums before a prototype can be installed on a shrimp farming company.

2. THE NETWORK

The tree network contains three types of modules: coordinator, router and end device. The latter performs the temperature measurements, so there must be one in each spot that needs to be monitored. They must always be linked to a router or to the coordinator, but cannot connect to another end device. The module linked to an end device is called his "parent". Each coordinator or router can link up to 8 end devices to the network. *Figure 1* illustrates the operation of the net.

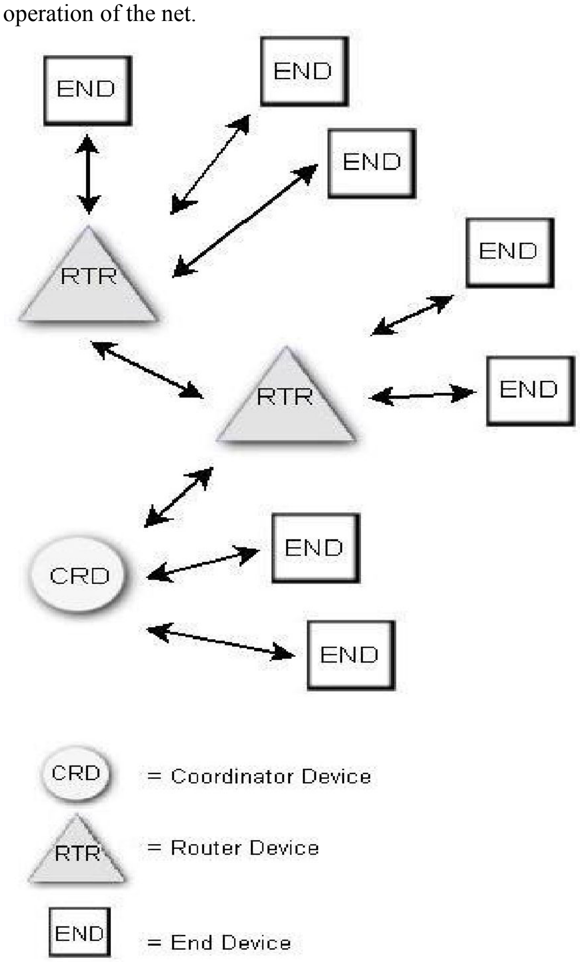

Fig 1. Schematic of the network showing all the possible connections between modules. End devices cannot connect with each other.

To expand the network, new end devices can be added. When they are too far away from the coordinator or the coordinator be already linked with 8 end devices, extra routers must be added to the net. The new devices will be configured by the coordinator, trough a software that is also being developed by Potychip.

In order to have low power consumption, the end devices enter in sleep mode and stay that way until the time they have to perform a measurement. During sleep mode, no RF packages can be sent or received by these modules. The router and coordinator can, though, store any package addressed to an end device until it wakes up. Once awake, it polls for data, and its parent sends any package that has been addressed to it. For that system to work properly, routers and the coordinator device must never enter in sleep mode. Because of that, end devices can be powered by batteries, while routers and the coordinator must have a more durable energy source.

3. PHYSICAL IMPLEMENTATION

The physical implementation involves three types of circuits: Coordinator, router and end device. Each circuit has a XBee module for RF communication, among some peripherals. *Figure 2* illustrates the structure of the network, using an aquarium temperature sensing system as example.

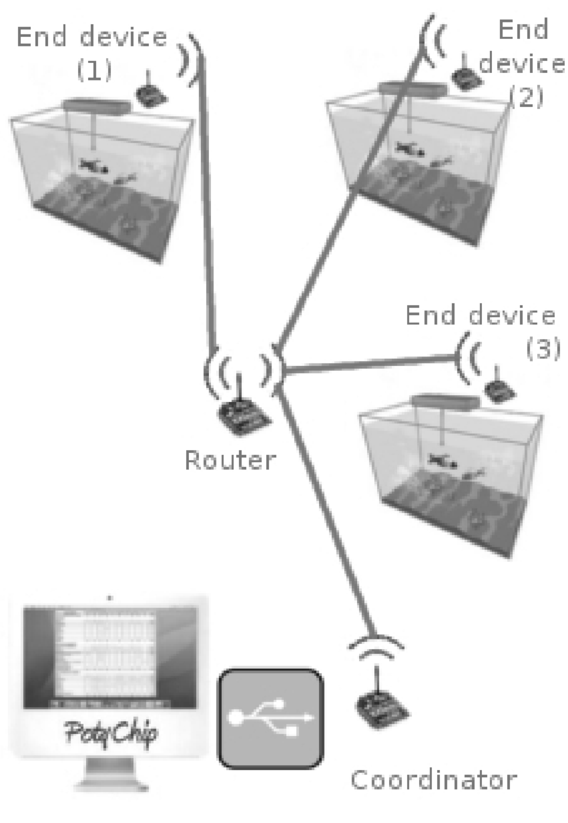

Fig 2. Aquarium temperature sensing system.

An end device circuit in each aquarium measures the temperature and sends it to the router. The router sends all data to the coordinator, which passes it to the computer through USB.

The XBee ZigBee modules have been chosen due to ease of use and to the availability of development kits to help the learning process. They also have integrated AD converters, eliminating the need for purchasing an avulse converter per end device. In addition, these modules can be programmed remotely and their firmwares are constantly being updated.

Each type of circuit (coordinator, router or end device) must have a different configuration to work properly. *Figure 3* illustrates the simplest of them, the router.

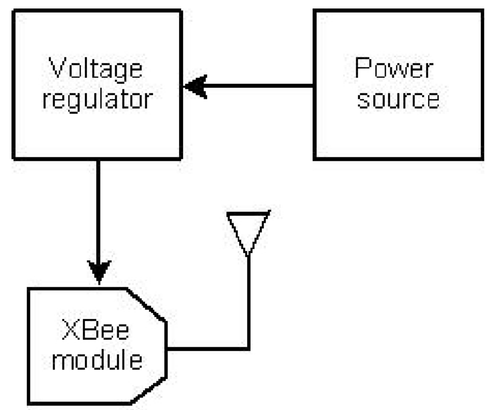

Fig 3. Router circuit block diagram.

The router requires only a power source whose voltage is adequate. The voltage can vary from 2.8 to 3.4V. The module will not communicate with the computer nor measure temperature. Thus, it does not need any peripheral other than the voltage regulator.

Following the sequence (from simplest to most complex) the next circuit is the coordinator's one, shown in *figure 4.*

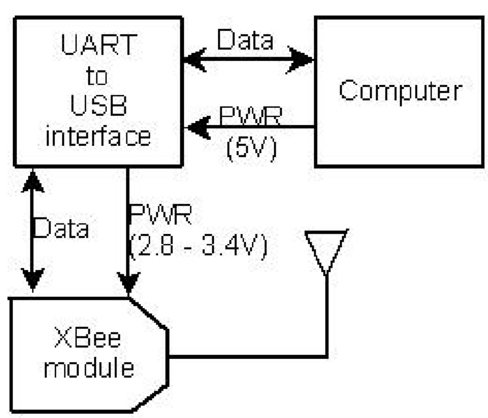

Fig 4. Coordinator circuit block diagram.

The coordinator device needs not only a power source with controlled voltage, but also has to be able to communicate with the computer. Hence the use of a UART to USB interface chip. That chip also helps obtaining a power source with the adequate voltage, because it usually comes with a 3.3V output source.

The last circuit is the one required for the end device, illustrated by *figure 5.*

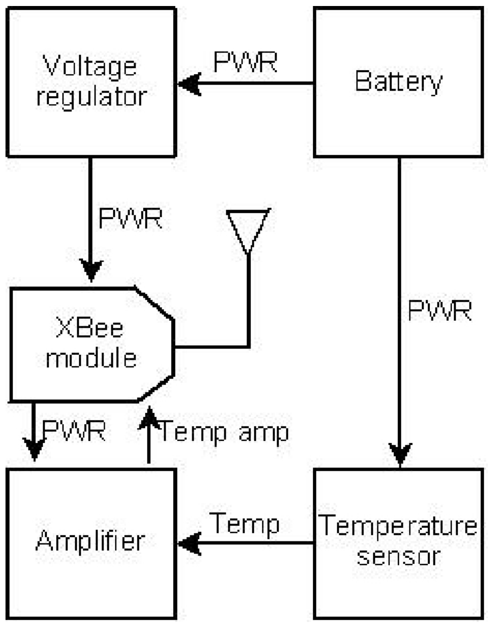

Fig 5. End device circuit schematic.

The end device is expected to last at least 2 months with no changing of battery. It needs, thus, to be a low power consumption circuit. That is why it is the most complex circuit.

An amplifier is used to fit the temperature variations to the reference voltage of the AD converter. That way, its accuracy is raised. The amplifier, however, would be wasting energy with no purpose while the module sleeps, reducing the battery's lifetime. To solve that, the module must feed the amplifier, and is programmed to do so only when awake. That way, the amplifier is shut down when the module sleeps, consuming no power.

The temperature sensor, though, can not be shut down, because it would cause "imprecision" on the measurements. Since the most common sensors usually do not consume much for our standards (LM35, for instance, works with less than 450µW), this does not constitute an issue. Also, it was connected directly to the battery because it works with a higher tension level than 3.3 V.

4. SYSTEM SOFTWARE DESIGN

The software required has two main functions: network management and information storage. Obviously, a graphical user interface must be created to facilitate the user access to those functions.

4.1. Network management

The software should allow the user to easily change the network parameters such as the end devices sleep time and identifiers. Also, it must automatically discover the modules associated to the network and show a wizard guide to specify and add each one of them to the database. Once the network is configured, it can start to receive the temperature measurements.

These requirements are achieved once the USB interface with the coordinator is established and methods for communication using the XBee API protocol are implemented.

4.2. Information storage

In order to store the information, a database is required. One table will be used to store information about all the nodes of the network and there will be an extra table for each end device of the network, responsible for storing its temperature measurements.

These tables must fit the following models exemplified by *Table 1* and *Table 2*.

Device	Identifier	Address	Description
END1	Aquarium1	64F0	Fishes aquarium
END2	Aquarium2	84DA	Shrimp aquarium
END3	Aquarium3	F31B	Lobster aquarium
RTR1	Router1	FFFE	Router

Table 1. Network information table for aquarium temperature sensing system shown in figure 2.

Date	Time	Temperature
06/04/2009	10:00:00	27.0 °C
06/04/2009	10:15:00	27.3°C

Table 2. Temperature measurements table for, for instance, aquarium1.

Table 1 stores the network information, very important for the network management performed by the software. It contains: each device that is connected to the net; the devices Id's, given by the user; the devices addresses, needed for the ZigBee wireless communication, and a description of each device, also given by the user. It allows the software to configure the network and also shows the operating system to the user.

A table like *table 2* will be created for each end device. It is responsible for storing the temperature measurements and for showing them to the user. It contains the temperature registered by the end device in each time and date.

5. ACHIEVEMENTS AND EXPECTATIONS

The project is in development, but several objectives have already been achieved after eight months.

There is a prototype of the hardware of the end device operating. The power consumption is already low for our application, but can still be reduced. The final prototype is expected to, using a battery of 7.5V, 450mAh, work for about 2 months.

Using the circuits of the development kit to install a coordinator and routers, and our circuit for the end devices, an operating network has been established successfully. The software prototype was able to configure remotely every module of the net. It was also able to receive and store the temperature information sent by the end devices and show it to the user trough a friendly interface.

Currently, the software is being developed to become more automatic, requiring less knowledge from the user. It still needs the user to insert AT commands in order to configure the network, for instance. This kind of operation will be hidden behind a friendly interface on the future. The fully functional software is expected to be complete by the beginning of July.

Once the system is fully working in the laboratory, it will be tested on a shrimp company, named Aquamar, located on the south coast of the Rio Grande do Norte state, Brazil. The system will help improving the survival of shrimps that are farmed in tanks, raising the company's production. After that, it can be fully commercialized.

6. CONCLUSION

The system proposed presents versatility, being able to help any kind of activity that demands temperature measurement of many spread points through an area. The wireless nature of the network simplifies its installation on many possible kinds of environments. Also, the remote devices can work for about 2 months without needing to recharge batteries, facilitating the maintenance of the system. In addition, thanks to the measurement system, a temperature control system applied to shrimp farming, also imagined by PotyChip, is starting its development in June.

7. ACKNOWLEDGEMENTS

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