

A Cost- Effective Low Power Measurement for ZigBee in Wireless Sensor Network

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Abstract

This paper presents an empirical characterization of battery consumption in commercial 802.15.4 ZigBee motes. This characterization considers various communication operations in 802.15.4 and measures the current that is drained from the power source. Here, the current of a simple Zigbee system with a transmitter and a receiver is measured with the help of an energy measuring scheme. The measurements are being held while these systems operate (either while communicating or while standing idles) and the resulting measurements provide indications of the operations being held. The implemented energy meter circuit is simple. Cost-effective and easy to implement and can be easily integrated with the existing Zigbee network.

Keywords

Low Current Measurement Circuit, 802.15.4 ZigBee, Energy Efficiency

I. Introduction

Wireless technology is being developed rapidly nowadays. All kinds of portable (or not) applications are able to communicate without any wires. The energy consumption in such devices is really an issue because they depend on a battery for their energy. Zigbee is a low power technology for communicating through the RF frequencies [1]. A set of specifications has been adopted for communicating between small size devices that implements non-intensive tasks, like making infrequent measurements, or controlling remote devices in an automated environment. The aim is to reduction in power consumption and maximize of battery life. Zigbee is a relatively new wireless mesh networking standard with emphasizes on low cost and energy conservation. It is intended for use is in wireless monitoring and control applications such as sensors and remotely operated switches where the end nodes are battery powered.

The use of new wireless transmission standards in measurement systems is described by any industrial application requirements such as those presented in [2] which are (i) integration into existing measurement systems, (ii) coordination of the advanced and traditional monitoring structures, and (iii) design of innovative measurement systems. This paper examines the wireless transmission standard named ZigBee in order to meet the above requirements. This stack aims at providing networking architectures for low-cost wireless embedded devices with consumption and bandwidth limitations. In particular the basic framework of IEEE 802.15.4 has a range of 10 meters and has with a transfer rate of 250 kbps, although this parameter can be decreased even more (down to 20 Kbps in the 868/915 MHz band) to enable a lower power consumption in the ZigBee nodes [3]. IEEE 802.15.4-compliant transceivers, which operate in the Industrial, Scientific and Medical (ISM) radio bands (including 2.4 GHz band), are designed to be simpler and more economical than the modules from other candidate standards for WPANs (such as Bluetooth) [4].

The main attraction and also the main challenge of IEEE 802.15.4/ ZigBee is its potential in setting up self-organizing networks that are capable of adapting to diverse topologies, node connectivity and traffic conditions [5]. Typical applications of 802.15.4/ZigBee usually consist of tens or hundreds of simple battery-powered sensor nodes (or “motes”) which transmit their sensed data periodically (or sporadically) to one or several data sinks (acting as the ZigBee Coordinator or intermediate routers on the way to the Coordinator). The recent advances in wireless communications and electronics have enabled the development of micro sensors that can manage wireless communication. ZigBee is a home-area network specifically designed to replace the proliferation of individual remote controls. ZigBee is a solution to the market’s need for a cost-effective, standards-based wireless network that supports low data rates, low power consumption, security, remote monitoring and reliability. Zigbee has a simple stack when compared to that of other wireless protocols with more features [6]. Ultra-low power consumption is at the heart of the ZigBee technology that promotes for a long lifetime in devices with non rechargeable batteries. ZigBee networks conserve the power of the slave nodes. ZigBee can be easily integrated with the Ethernet while providing application interoperability with enhanced power balancing and mobility [7-8]. A slave device is in deep-sleep mode most of the time and wakes up only for a fraction of a second to confirm its presence in the network. For example, the transition from sleep mode to data transition is around 15ms, and new slave enumeration typically takes just 30ms. Zigbee is supported by many different companies who construct microelectronic devices. Implementations of Zigbee are based on a main processing unit, usually a microcontroller, along with an RF transceiver [9]. The Zigbee protocol is implemented in the firmware program of the microcontroller and varies by company. Nevertheless, all try to maintain the necessary specifications in order for devices from different companies to be able to communicate to each other [10]. So, because of this similar but not same programming, it is expected for these devices to behave differently as far as their energy consumption is concerned. Exploring this energy behavior would be interesting information to develop.

II. Proposed work

Testing equipment consists of:

- PC
- ZigBee mote
- Energy meter circuit

The PC with terminal emulation software is used for communication with USB on the Zigbee module. ZigBee modules use simple commands for configuration and performing tests as well as to display the results of the test. DC Characterization Test provides the current consumption information of the device in different working states such as transmission, reception or idle state.

The integrated circuit consists of a Non-Inverting amplifier with an adjustable gain and DC offset as shown in fig. 1.

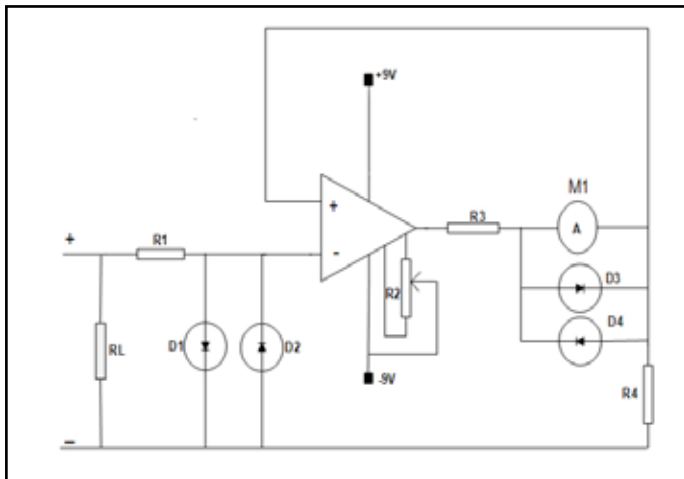


Fig. 1: Energy Meter Circuit Diagram

Initially, the ammeter is exactly made to be zero (i.e. Null stage), by varying the R2, which is a variable resistor and by connecting a feedback resistor at the inverting input. The inverting and non-inverting inputs were connected to the ground.

The input via load resistor RL and R1 is given to the Non-inverting input of the Op-Amp. The inverting input will be the feedback of the output, i.e. the negative of ammeter M1. The output of the Op-Amp is given to the Ammeter through the resistor R3. This R3 & R1 are useful to calculate the gain.

III. Implementation

To increase the flexibility of the application, some network parameters such as radio channel and transmit power do not hard code to the program code, but can be set by the end user before configuring the network. The following explains the configuration and synchronization procedures in more detail. The end user defines the network parameters through a Matlab program which is then transferred to the sink node through Universal Asynchronous Receiver Transmitter (UART). The initial configuration packet contains information regarding the total number of nodes in the network, the number of broadcast packets, transmission interval, radio channel, and transmission power to be used.

This section gives a hardware description of the elements that make up the Power supply parameter measurement with ZigBee connectivity. Looking to the need of a trustworthy power monitoring system for industrial environments, a ZigBee system comprising the following modules has to be designed.

- Transmitter module
- Receiver module.

The Sender mote periodically sends radio packets containing information containing its own identification and location whose current will be measured by the circuit. Fig. 3 shows the layout of the Sender and Receiver motes on tripods while testing.

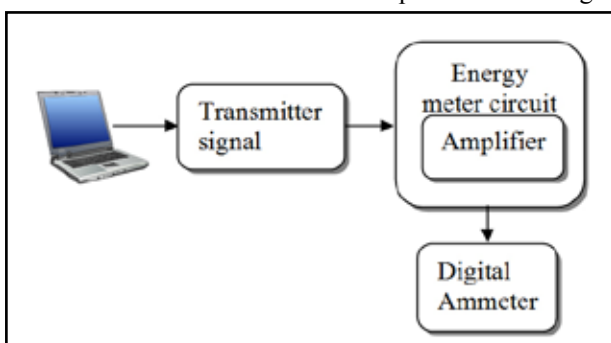
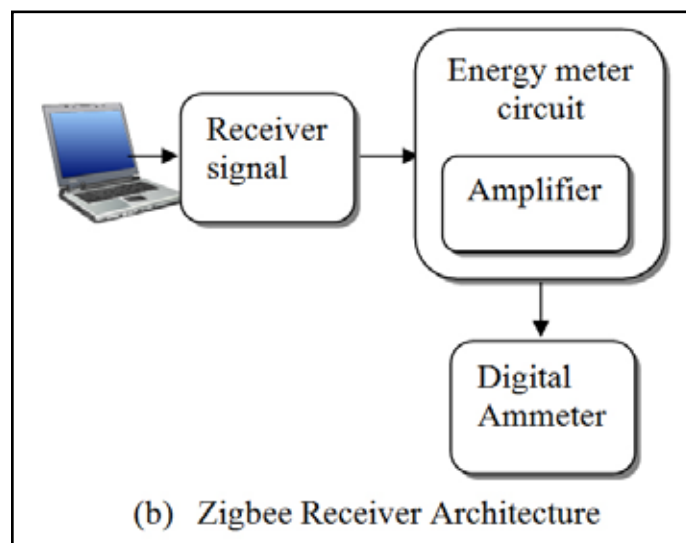


Fig. 2(a): Zigbee Transmitter Architecture

In the proposed module, transmitter module receives the parameters from the device; send it to the receiver side through ZigBee connectivity. In the same way receiver module receives data sent by the energy measuring circuit through ZigBee connectivity and measures the current in the received signal after amplification. This is illustrated by fig. 3(b).



(b) Zigbee Receiver Architecture

Fig. 3: Transmitter and receiver module

IV. Experimental Results

A. Idle Zigbee Current

ZigBee's low power consumption is rooted not in RF power, but in a sleep mode specifically designed to accommodate battery powered devices. A ZigBee-compliant radio switches automatically to sleep mode when it is not transmitting, and remains asleep until it needs to communicate again. For radios connected to battery-powered devices, this result in extremely low duty cycles and very low average power consumption.

The fig. 4, represents the instantaneous current consumption after the mote is turned on. Initially, the ZigBee processor is deactivated. The consumed current is 3.23 mA approximately. Then, the architecture maintains this state and waits until the user press the button on the board to start the wireless communications.

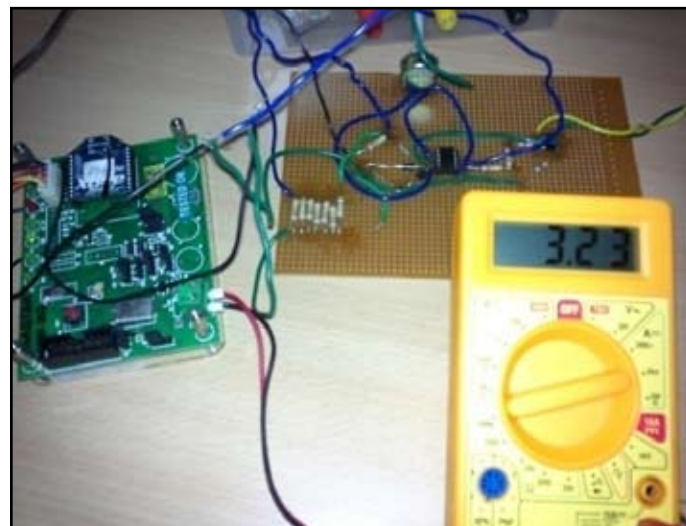


Fig. 4: Measured Supply Current During the Start-up of the Mote

B. Transmit Zigbee Current

Before transmitting any data, the sensor has to detect the presence of the Coordinator and proceed to its association. The measurement of the required current during this operation is illustrated in fig. 5.

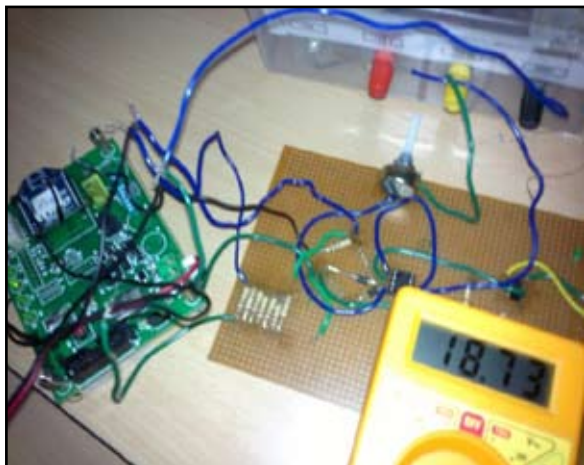


Fig. 5: Measured Supply Current During the Start-up of the Transmitter

The radio transceiver is switched on. The current consumption rises to 18.73 mA as the module is listening to the radio channel to check whether it is idle or not.

C. Receiver Zigbee Current

If a valid RF packet is received, the data are transferred to the serial transmit buffer.

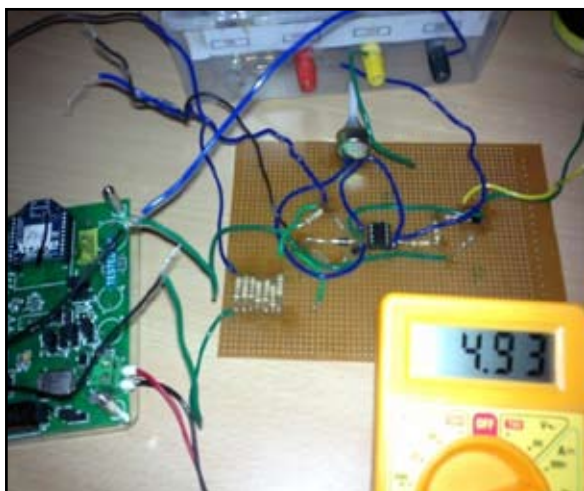


Fig. 6: Measured Supply Current when the Receiver Starts Reception

Table 1: ZigBee Current Consumption in Different States

Idle	3.23mA
Transmit	18.73mA
Receive	4.93mA

The above table provides the measured current values by the circuit using the existing Zigbee network during the various states of the Xbee series 2 motes like (transmitting, receiving and idle states).

V. Conclusion

ZigBee and the underlying IEEE 802.15.4 standard provides a promising low-cost, low-power and reliable wireless network technology for a wide range of control and monitoring applications within the home and industrial environment. This paper has provided a full experimental characterization of current consumption in actual 802.15.4/ZigBee sensor motes through a simple low cost circuit that can be easily integrated with the existing Zigbee network. The characterization thoroughly takes into account the different operations required by 802.15.4 protocol, not only during transmission of data, but also during the connection phase of the end devices. Two devices, a coordinator and a router, have been measured and their energy behavior has been recorded.

References

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