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Design and implementation of low power consumption wireless sensor node

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Abstract

This work proposes an implementation of wireless sensor node characterized by its very low power consumption. The node comprises three main components: Xbee module, low power PIC microcontroller and digital sensor. The node can be set to sense then transmit data via one of two transmission methods: periodic and by interruptions. To evaluate the power consumption; currents in the node is measured during the different transmission stages for both methods. As a result, a significant reduction in the power consumption is shown particularly in sleep mode compared to conventional transmission methods. The characteristic of low power consumption makes the proposed node practically ecologic. It can also be fed with the extrem low power supplied by an energy harvesting system.

Keywords: *energy efficiency, energy harvesting, power consumption, WSN nodes*

1. Introduction

The recent developments in communications field reflected in 4G and 5G systems have opened new application horizon such as Internet of things (Io T) and Machine to Machine (M2M) [1-5]. This will bring more services into our daily lives. In addition to that, this has drawn the interest of researchers and industrials to develop the wireless sensor networks (WSNs) which are important actor for the deployment of these emergent technologies [6, 7]. A WSN comprises generally a set of components referred to as “nodes”, capable to detect, treat and transmit information wirelesselly and in real-time [8, 9].

One of the biggest problems that hinder the widespread use of WSN systems is the issue of power supply to the nodes, this because, WSN nodes are often placed in harsh areas where it is not possible to change batteries [10-12]. In addition to that, batteries are not much desired for environmental interests [13, 14]. An important solution is being investigated in the recent time which suggests the idea of harvesting energy from the surrounding environment [15-20]. Thus, the WSN node can be equipped with a mechanism to obtain electrical power from different sources such as electromagnetic waves, vibrations, sun, and wind. However, the amount of power recolted is relatively very small and therefore it is crucial to design WSN nodes with low power consumption [21-24]. So, the motivation nowadays is to come up with WSN that has a low power consumption, which is suitable to work upon energy harvesting systems, and reduce gradually through time the utilization of batteries.

In this communication, the authors propose the design and implementation of a WSN node suitable for point-to-point transmission where data is sent periodically or through interruptions. The node is built using low-cost and low power consumption components. It is intended to reduce the power consumption by adopting two transmission algorithms to efficiently manage the power consumption in the proposed node. The next sections explain well the design methodology and the experimental validation.

2. Power Requirement in WSN Nodes

Technically, power consumption in WSN nodes is related to three operations which are sensing, processing and transmission [25, 26]. As detailed in Figure 1, type and manufacturing performance of the sensor as well as the processor can give an overview on how much power

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the node can consume. Obviously, the largest amount of power consumed in a node is due to transmission operation. Besides, it is related to data rate, transmission range as well as the physical characteristics of the radio module. Also, the power consumption can be affected the communicating protocol inter-nodes. Therefore, to efficiently manage the power consumption, it is worthy to select the proper devices and protocol for such an application.

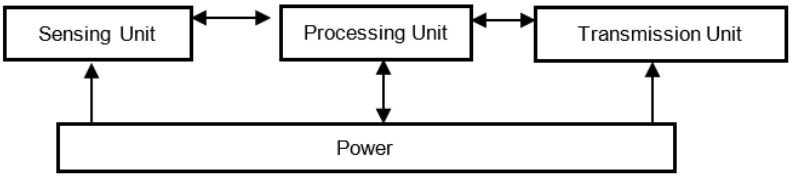

Figure 1. Power requirement in WSN node

2. Proposed Methodology

As shown in Figure 2, the node consists of a DS18B20 sensor, low power PIC 16LF722 and Xbee module. The three components are chosen with the criterion of low power consumption. According to the datasheets delivered by the constructors, the amount of the power consumed by the three components in sleep/active modes is summarized in Table 1. In traditional nodes, the sensor and transmitter are generally set in sleep mode waiting the interruptions, which means an important amount of power is dissipated along the sleep mode time (750 nA + 60 µA). Therefore, a low power microcontroller is associated to control power supply in the node. So, it is intended to suppress the power consumption of the sensor and the Xbee transmitter in sleep mode (750 nA + 60 µA).

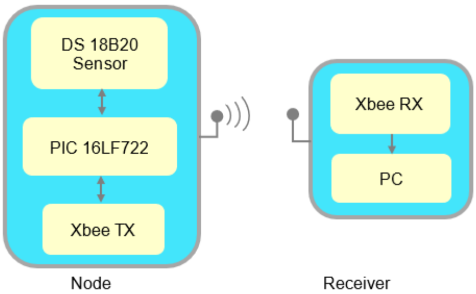

Figure 2. Schematic view of the proposed transmission WSN node

Table 1. Power Consumption Summary of the Three Components

Operation modes	Power components seen by current by Amper (A) or voltage by (Volt)		
	DS18B20 Sensor	PIC 16LF722	Xbee
Sleep	750 nA, 3 v	Watch Dog Timer sleep mode 300 nA, 3v Deep sleep mode 20 nA, 3v	60 µA, 3,3 V
Active	1mA, 3 v	30 µA, 3v	39 mA, 3.3 V
Off	0 A, 0 v	0A, 0 v	0 A, 0 v

As shown in Figure 3, tow algorithms are developed to derive the transmission operation for both transmission modes (periodical and with external interruption) and in the same time, the power consumption is taken into consideration. The two algorithms are developed using C language and can be easily loaded into the microcontroller. The first case shown by Figure 3 (a) exhibits transmission by interruption. The sensor and Xbee module are in off mode.

So, no currents run in them I=0 A, while the microcontroller is set in sleep mode waiting an event of the external interruption there is only current I_{WD} = 20 nA which means the power consumption in this case belongs only to the watchdog timer (WDT) of the microcontroller in its deep sleep mode. For instance, the interruption is come, the micro-controller turns to active mode then it activates the sensor and the Xbee transmitter so the consumption belongs to the three modules I_{PIC} = 30 µA, I_{sensor} = 1 mA, I_{Xbee} = 39 mA. After transmitting the data, the PIC set back the sensor and the transmitter into OFF mode (I_{sensor} = 0 mA, I_{Xbee} = 0 A) and it goes back to sleep mode again (I_{WDT} = 20 nA). Furthermore, the node can be programmed to send data periodically as it is shown by the algorithm presented in Figure 3 (b). At the beginning, the microcontroller activates the sensor and the transmitter while the WDT starts to increment. The power consumption in this instance is I_{PIC} = 30 µA, I_{sensor} = 1 mA, I_{Xbee} = 39 mA. When transmission is finished, the PIC goes into sleep mode, while the sensor and transmitter in OFF mode (I_{sensor} = 0 A, I_{Xbee} = 0 A). Hence, the power consumption of the node will depend only to the PIC in sleep (I_{WDT} = 20 nA). The WDT counter remains counting until the overload state which re-initializes again the program execution periodically. The WDT counting period determines the period of data transmission which can be reconfigured in the software kernel program. In summary, the proposed WSN node consumes only 300 nA rather than 60.75 µA which isthe case of traditional WSN nodes that comprise only sensor and transmitter. Thanks to the proposed method, as it saves a significant amount of power during sleep about 60,450 µA.

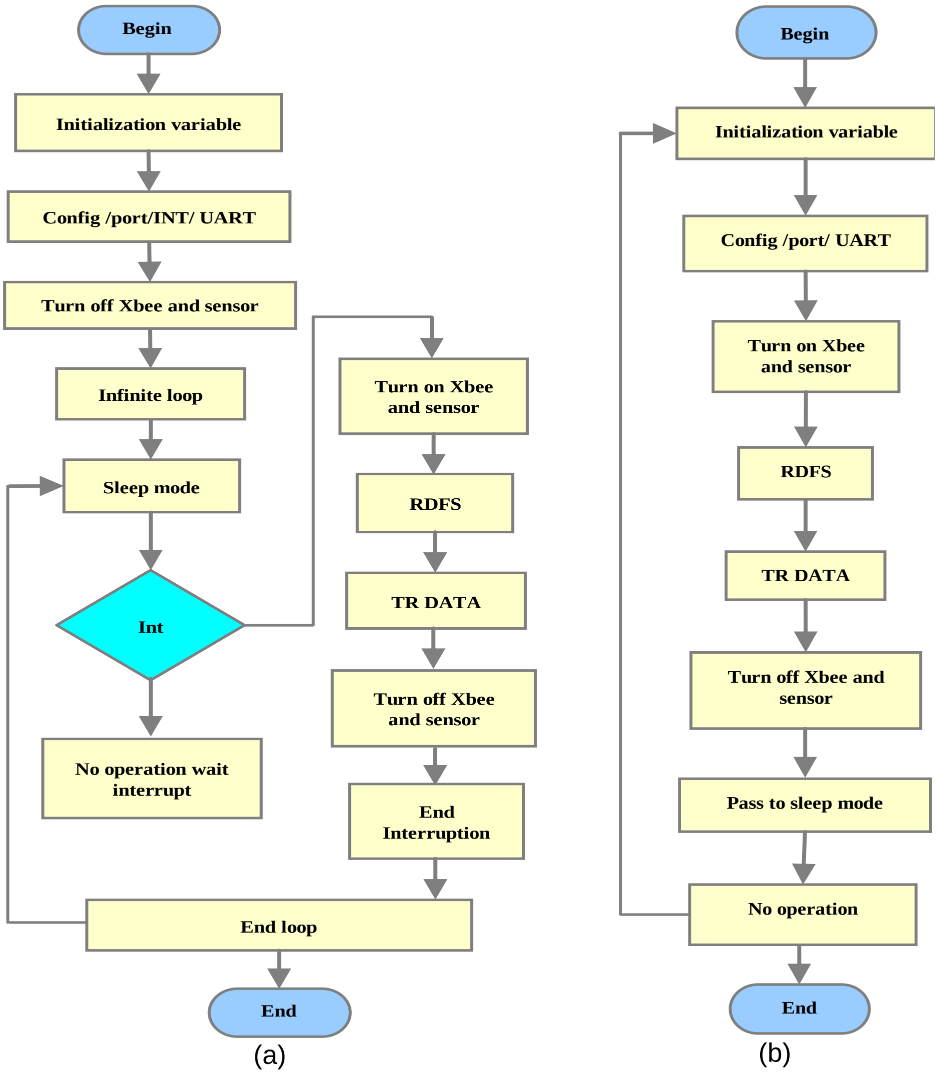

Figure 3. Organigrams show the principle of operations of the nodes
(a) periodic transmission, (b) interrupted transmission

3. Implementation and Measurements

In order to verify the functionality of the proposed node, a hardware prototype of the circuit is fabricated. As it can be seen in Figure 4, the prototype is built using the three basic components: Xbee transmitter, PIC16LF722A and DS18B20 Sensor. A power source is used to feed the node with 3.3 V. The functionality of the node is tested for the two proposed transmission methods. For that, the node is set to send data towards an Xbee receiver, while measurements of the currents circulating within the node are captured using a nano-amperemeter as shown in Figure 5. The result of the measurements performed during sleep mode is shown in Figure 6 (a). As it is shown in the graph, a current of 0.01 mA is found circulating within the node during transmission by interruption, whereas it is 0.02 mA during the periodical transmission.

Additional current measurement is performed on a traditional node which comprises only a sensor and Xbee transmitter, this is to show the consumption differentiation between the proposed and the traditional node which is composed by only a sensor and an Xbee transmitter. As observed in Figure 6 (b), it is clear that, for active mode, it is found that consumption is almost the same for both traditional and proposed nodes. However, during sleep mode, the proposed node has the lowest power consumption than the traditional node. This proves the validity of the proposed node with its good power consumption management.

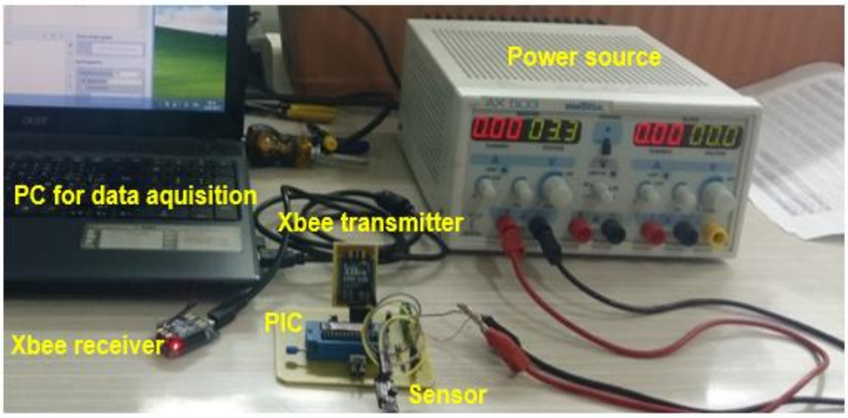

Figure 4. Test of the functionality of the fabricated prototype

Figure 5. Measurments of the currents circulating in the node

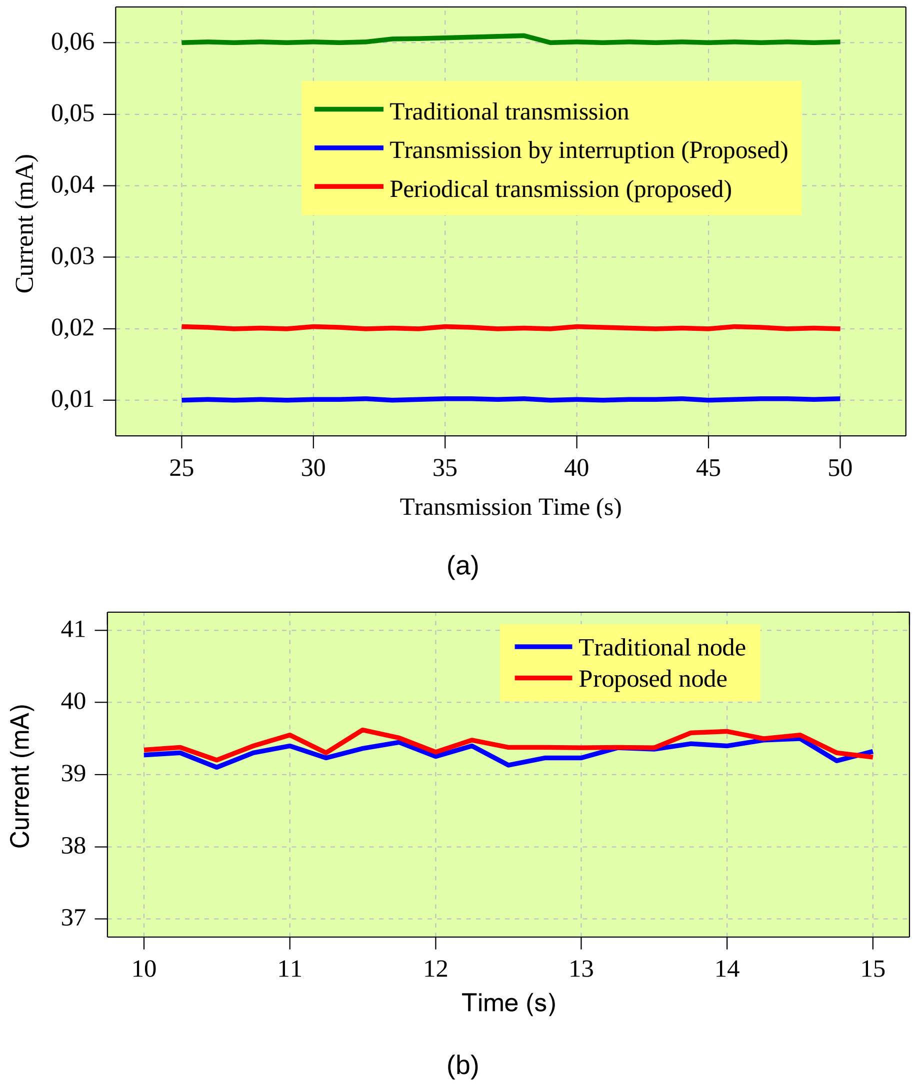

Figure 6. Current consumption measurmetns of the proposed node:
(a) sleep mode current consumption comparaision between traditional transmission, perdiodeic transmission and transmission by interruption, and (b) active mode current consumption comparision between traditional and proposed nodes

4. Conclusion

Power supply to embedded WSNs is a difficult task because they are usually implemented in harsh environments. Also, there has been a large call for excluding batteries and reduce their industrialization due to its negative impact on the environment. This is a major concern in nowadays WSNs industrialization. Therefore, design of less power consumption systems is crucial to to reduce batteries usage as a partial solution. However, energy-harvesting systems are intended to provide a very promising solution. The present paper has been proposed a WSN node with methods to reduce its power consumption, which makes it suitable to work with the energy harvesting system. Design, implementation and measurements are presented and argued. For the record, it is worthwhile to mention the large volume of the proposed WSN node, yet the present design is not dedicated for commercialization. Future implementation using surface components would reduce considerably the size and power consumption of the proposed node.

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