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Animal behavior management by energy-efficient wireless sensor networks

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ABSTRACT

In recent years, studies have been conducted on systems based on wireless sensor networks for the detection of animal behaviors. These systems can offer significant information on how to increase the production and animals' health. They consist of low-cost sensor nodes with limited resources. One of the critical resources is the power unit. These systems have an energy problem especially in outdoor environments same as other wireless sensor-based systems. ZigBee-based RF modules are used for data transmissions in these systems. Hence, they have limited battery and memory. To fulfill the requirements of power reduction, this paper proposes a technique based on time-driven systems for controlling the transmission rate of ZigBee-based RF modules based on data aggregation and sleep/wake-up methods. Data aggregation is done in many cases. However, the sleep/wake-up method is related to animal behavior because it may cause changes in the network topology. The proposed system is implemented on cows and the results show that the proposed system can help to achieve a significant reduction in power consumption of wireless sensor networks and improve the lifetime. In additional, it can offer and help to liable of animals in monitoring the health of their animals.

1. Introduction

The detection of animal behavior has been the subject for a wide range of studies. An analysis of animal activity to identify health problems of animals would have a significant impact on practical farming and be useful in alleviating health and economic costs associated with illness (Nadimi, 2008; Robert et al., 2009). Many recent studies have focused to use the remote sensor systems to monitor the animal behaviors (Darr and Epperson, 2009; Guo et al., 2006; Mainwaring et al., 2002; Nadimi et al., 2008; Nadimi et al., 2012). In addition, most researchers state that monitoring of animal behavior represents a class of wireless sensor network applications with enormous potential benefits for practical farming (Nadimi et al., 2008; Umstätter et al., 2008). In the design of wireless embedded sensor devices, most relevant papers employed ZigBee-based RF module nodes as a wireless transceiver in implementation (Nadimi, 2008; Guo et al., 2006; Mainwaring et al., 2002; Nadimi et al., 2008; Nadimi et al., 2012). However, such module requires high power consumption when they are operating in the active mode. These nodes have limited battery and the transferring in high power mode causes consumption of more energy. For example, the current consumption in transmission mode, receiving mode and power down mode are 45, 50 and 0.01 mA respectively (XBee/XBee-PRO RF Modules, 2009). Each node consists of transceiver, processing, sensing and power units and can be embedded on the different objects. So, the power consumption in RF transceiver is more than other parts such as processing and sensing units. This is an important aspect and should be considered because it is directly related to the usability of implemented systems (Diosdado et al., 2015). However, in the analysis and implementation phases of such systems, there have been no studies exploring the way to maintain the power reduction, particularly in the ZigBee RF module. Therefore, the objective of this paper is to reduce power consumption for automated classifying system architecture.

As mentioned, energy is one of the important parameters in the design of Wireless Sensor Networks (WSNs). Sensor nodes have limited energy and memory but their small size and cheap prices are causing to expand their usability in various applications. The energy problem is causing many new challenges in design and development of systems. On the other hand, the energy saving may have a trade-off with some of the other output parameters as data reliability rate in some of the WSNs applications. Thus, the designers must focus on the maintaining balance between output parameters of a target system. Therefore, the power issue should be discussed on efficiency requirements. Indeed, one of the primary design goals is to use this limited amount of energy as efficiently as possible because the recharging battery is usually impossible. In this paper, data-driven duty cycle techniques are used for energy efficiency (Kiani, 2014) as data aggregation sleep/wake-up methods. The data aggregation is usually done all the time. However, the sleep/wake up is related to different parameters such as energy levels of the nodes, system tasks, and their importance levels.

This paper is organized as follows. Section 2 describes the material and method using for reduction of the power consumption on the wireless embedded sensor device. Section 3 explains the experimental

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measurement and evaluates the results. In addition, the last section concludes the paper.

2. Related work

In this section, the current studies are evaluated that have been applied to the animals especially cows. In order to classify the cow behaviors, the systems can be measured in different types of sensors and methods. Most researchers agree that accelerometer is the best device for using in the classified process because these devices have high success rates (Pastell et al., 2009; Valenza et al., 2012; Yin et al., 2013). For instance, reference (Nielsen et al., 2010) has demonstrated reliable results by using accelerometer node. They use the accelerometer node as a data logger by attaching some sensors to the leg of animals and registering the status of the leg. In (Darr and Epperson, 2009), the researchers have designed a wireless embedded sensor device for classifying and monitoring the lying activity of bovine animals by using a 3-axes accelerometer. Their results are shown sufficient outputs in determining lying activity.

In general, the server-centered architecture is used in the classifying and monitoring the animal behaviors on a remote system as in star topology. This architecture comprises of one server and some wireless embedded sensor devices. The server receives data from the embedded device, also known as sensor node (Marchioro et al., 2011). The non-server side consists of accelerometer sensor nodes which nodes can transmit their data to the server directly or indirectly by multi hopping method. This side is called the network. Similar research usually focus on this area.

Fig. 1(a) shows a block diagram of the wireless embedded sensor device for measuring the cow behavior. It can help in understanding the system's working mechanism for classifying the behavior of cows. In this figure, raw data is converted from analog to digital in sensing unit of the node. Each sensing unit is consists of a sensor and Analog to Digital Converter (ADC) sections. Then, the converted data is sent to the server by transceiver unit. In an ideal condition, the big data stream should be continuously sent from nodes to sever with a high transmission rate to preserve an accurate classification. However, in practical terms, the system employs ZigBee RF module nodes for data transmission that the nodes are operated on an IEEE 802.15.4 standard. It is from the Bluetooth family that is operated in low frequency for transmission low rate data. This module requires the significant power consumption of the system (Nadimi, 2008; Nadimi et al., 2008; Nadimi et al., 2012). Fig. 1(b) shows an example of the wireless system transmitting data in one second. It can be seen that the average power consumption (P) of the system is related to the transmission rate of the wireless transceiver. Naturally, as the data volume increases, the energy consumption will also rise.

3. Proposed system

In this section, a system based on WSN is proposed for monitoring animal health. This system can be effective in productions rate too. It was applied to cows. We explain our system in three phases. Firstly, we show the basic ideal of the proposed system. Secondly, we explain a technique to classify cows' behavior. Finally, we describe a time-driven architecture for determining of transmit times in ZigBee module. We used the XBee module that it is a ZigBee module. In the design of the target architecture, the sensor's data will be sent to the server when the behavior of the cows is changed. The nodes are kept in sleep mode as long as there is no change. Fig. 2(a) shows the architecture of wireless embedded sensor system for classifying and monitoring cow behavior by using the accelerometer sensor nodes. In the proposed system, the cow behavioral classification is processed in the embedded sensor device. These nodes may process the data then send to other nodes or server. During the processing of nodes or server, mode of a node will be activated if the cow shows different behavior. In this case, the node sends the results to the server for system monitoring. The mode of the node in processing step is usually sleep mode. This technique causes reduction of energy consumption in each node. Therefore, this architecture is able to a significant reduction of the data transmission rate instead of sending a sequence of fixed periodic time. This means that this architecture can reduce the average transmitting power in the automated system as shown in Fig. 2(b).

3.1. Classification approach for cow behaviors

There have been various methods to classify cow behaviors. The different classification approaches such as fuzzy logic, neural network, and wavelet analysis were applied for classifying acceleration of data (Nadimi, 2008; Nadimi et al., 2008; Valenza et al., 2012). However, most techniques needed to construct with an excessive amount of mathematical operations and they used highly-resources requirements. These results may be unsuitable to apply to the resource-constrained embedded devices, particularly when employed with a low-cost microprocessor. Therefore, this paper uses a simple classification technique based on a decision tree methodology by classifying the cow behaviors into three types that are standing, walking-grazing, and lying behaviors. The proposed technique uses a much low computational cost

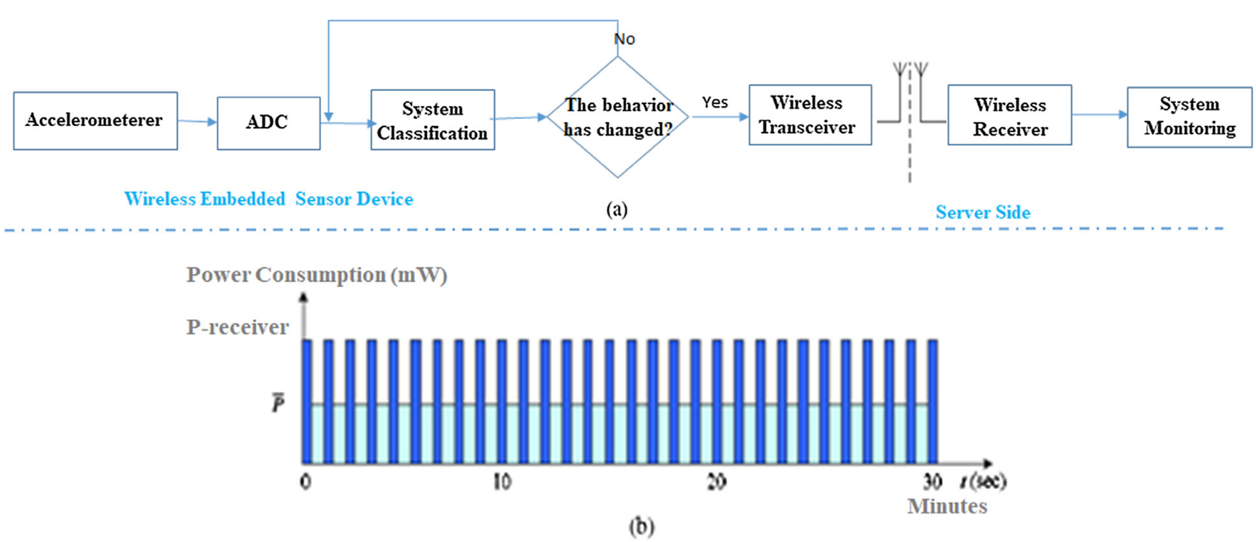

Fig. 1. (a) General system architecture for classifying the animal behavior (b) power consumption of transmitting at 1 s.