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Energy Consumption in Wireless Sensor Network

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Abstract

Energy is a limited resource in wireless sensor networks. In fact, the reduction of power consumption is crucial to increase the lifetime of low power sensor networks. Wireless sensor networks consist of small, autonomous devices with wireless networking capabilities. In order to further increase the applicability in real world applications, minimizing power consumption is one of the most critical issues. Therefore, accurate power model is required for the evaluation of wireless sensor networks. To estimate the lifetime of sensor node, the energy characteristics of sensor node are measured. Research in this area has been growing in the past few years given the wide range of applications that can benefit from such a technology. Based on the proposed model, the estimated lifetime of a battery powered sensor node can be increased significantly.

Keywords*—Sensor, Wireless Sensor Network, Energy Consumption*

1.0 Introduction

A Wireless Sensor Network (WSN) is composed of small sensor nodes communicating among themselves and deployed in large scale (from tens to thousands) for applications such as monitoring of physical phenomena like temperature, humidity, air pollution and seismic events alarm detection, and target classification and detection. Each sensor node is a tiny device composed of three basic units: a processing unit with limited memory and computational power, a sensing unit for data acquisition from the surrounding environment and a communication unit, usually a radio transceiver, to transmit data to a central collection point, denoted sink node or base station. Typically, nodes are powered by small batteries which cannot be generally changed or recharged. Because of these very limited energy resources and considerable distances between nodes and sink, the communication from sensor nodes to sink does not occur directly, but rather, thanks to high node density, through a multi-hop model: each node sends the collected measures to the neighbouring nodes which, at their turns, send them to their neighbouring nodes, and so on (Kaiser et. al., 2001).

Lifetime of wireless sensor node is correlated with the battery current usage profile. By being able to estimate the energy consumption of the sensor nodes, applications and routing protocols are able to make informed decisions that increase the lifetime of the sensor network. However, it is in general not possible to measure the energy consumption on sensor node platforms. Minimizing energy consumption and size are important research topics in order to make wireless sensor networks (WSN) deployable. As most WSN nodes are battery powered, their lifetime is highly dependent on their energy consumption. Due to the low cost of an individual node, it is more cost effective to replace the entire node than to locate the node and replace or recharge its battery supply. Hardware components are characterized at a very detailed level to simulate power consumption of a node as close as possible. Another approach uses hybrid automata models for analyzing power consumption of a node at the operating system level. In this paper describes an energy measurement system based on a node current consumption usage (John et al., 2016).

A WSN is a network composed of sensor nodes in a sensor field to cooperatively monitor physical or environmental conditions such as temperature, humidity, vibration, or pressure. Design of a WSN is shown in Figure 1.

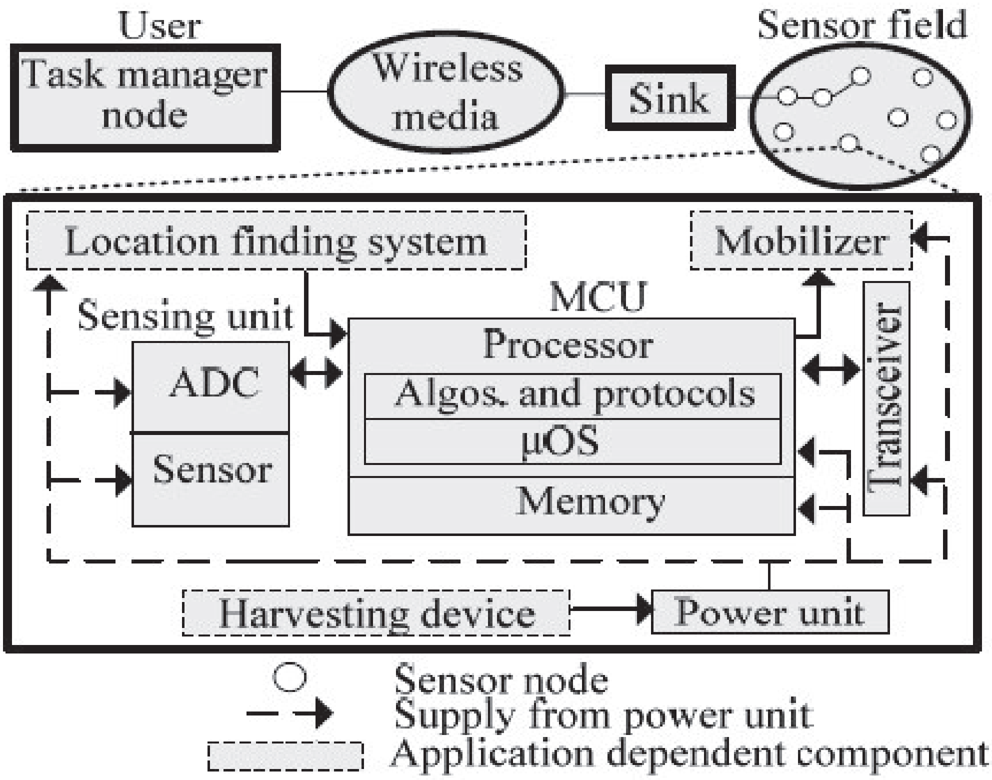

Figure1: WSN design and organization of components of a sensor node (Akyildiz et.al. 2002).

1.2 Research Objective
The specific objective is to design a dynamic power management technique that considers the applications constraints to exploit active and idle states.

1.3 Applications of Wireless Sensor Network
Sensor networks may consist of many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared and radar, which are able to monitor a wide variety of ambient conditions that include the following:-

i. temperature,
ii. humidity,
iii. vehicular movement,
iv. lightning condition,
v. pressure,

.

2.0 Energy Consumption in WSNS
As a microelectronic device, the main task of a sensor node is to detect phenomena, carry out data processing timely and locally and transmit or receive data. A typical sensor node is generally composed of four components a power supply unit; a sensing unit; a computing/processing unit; and a communicating unit. The sensing node is powered by a limited battery, which is impossible to replace or recharge in most application scenarios. Except for the power unit, all other components will consume energy when fulfilling their task. Extensive study and analysis of energy consumption in WSNs is available (Schurghers et. al., 2002)

2.1 Sensing Energy
The sensing unit in a sensor node includes the embedded sensor and/or actuator and the analogue–digital converter. It is responsible for capturing the physical characteristics of the sensed environment and converts its measurements to digital signals, which can be processed by a computing/processing unit. Energy consumed for sensing includes:
(1) Physical signal sampling and conversion to electrical signal;
(2) Signal conditioning; and

(3) Analogue to digital conversion.
It varies with the nature of hardware as well as applications. For example, interval sensing consumes less energy than continuous monitoring; therefore, in addition to designing low-power hardware, interval sensing can be used as a power-saving approach to reduce unnecessary sensing by turning the nodes off in the inactive duty cycles. However, there is an added overhead whenever transiting from an inactive state to the active state. This leads to undesirable latency as well as extra energy consumption. However, sensing energy represents only a small percentage of the total power consumption in a WSN. The majority of the consumed power is in computing and communication (Benini and Micheli, 2002).

2.2 Computing Energy

The computing/processing unit is a microcontroller unit (MCU) or microprocessor with memory. It carries out data processing and provides intelligence to the sensor node. A real-time micro-operating system running in the computing unit controls and operates the sensing, computing, and communication units through micro device drivers and decides which parts to turn off and on. Total computing energy consists of two parts: switching energy and leakage energy. The switching energy is determined by supply voltage and the total capacitance switched by executing software. The pattern of draining the energy from the battery affects the total computing energy expense. For example, a scheme of energy saving on computation is dynamic voltage scaling (DVS), which can adaptively adjust operating voltage and frequency to meet the dynamically changing workload without degrading performance. The leakage energy refers to the energy consumption while no computation is carried out. Therefore, it is critical to minimize leakage energy (Dharma et. al., 2011).

2.3 Communicating Energy

The communicating unit in a sensing node mainly consists of a short-range RF circuit that performs data transmission and reception. The communicating energy is the major contributor to the total energy expenditure and is determined by the total amount of communication and the transmission distance. Processing data locally to reduce the traffic amount may achieve significant energy savings. It is not hard to show that the power consumption due to signal transmission can be saved in orders of magnitude by using multi hop routing with a short distance of each hop instead of single-hop routing with a long-distance range for the same destination. Therefore, minimizing the amount of data communicated among sensors and reducing the long transmitting distance into a number of short ones are key elements to optimizing the communicating energy.

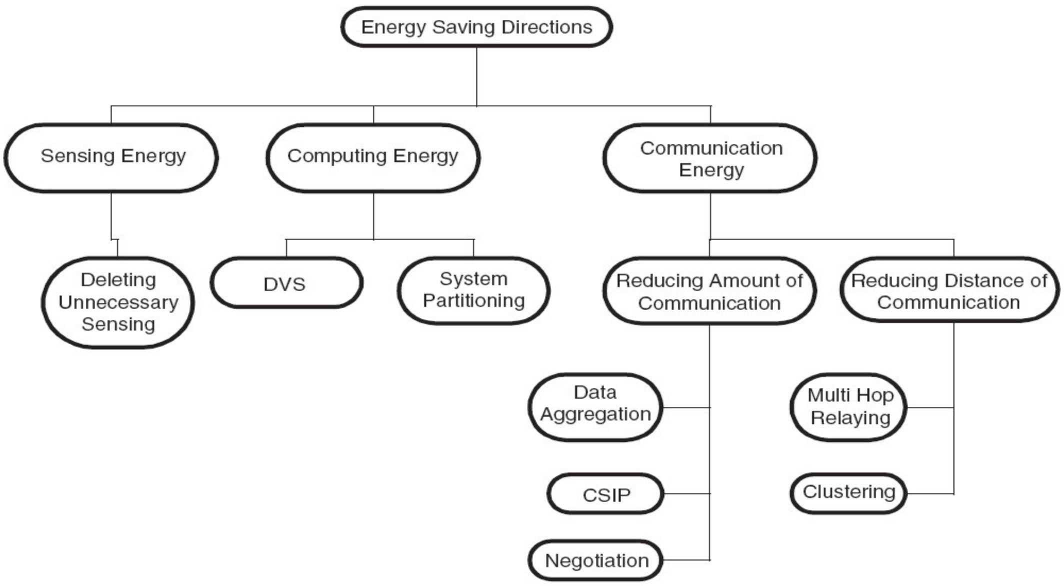

Figure2.1: Energy-conserving directions in WSNs. (Dharma et. al., 2011).

Similarly, in order to decrease signal transmission distance, multi hop communication and clustering- based hierarchies have been proposed to forward data in the network Figure 2.1 summarizes energy-conserving directions with respect to optimizing sensing, computing, and communication energy consumption. Such approaches exhibit a high degree of dependency on one another. For example, eliminating unnecessary sensing could reduce data communication; in turn, communication energy consumption is reduced. However, this requires more sophisticated control schemes, which are supported by higher complexity computation, and may result in higher energy use for computation. Therefore, trade-offs should be made and some specific direction may take greater importance based on the nature of the application scenario (Dharma et. al., 2011).

3.0 Power Management in Sensor Networks

Power management consists of turning off sensor's hardware components that are not used. In a sensor network, the communication protocols shall ensure that peripherals such as microprocessor, memory or radio transceiver are powered only when needed. Thus, significant energy savings is achieved by turning off completely some parts of the sensor circuitry when it does not receive or transmit data, instead of keeping the sensor node in the idle mode. This scheme simply attempts to reduce wasted energy due to idle listening, that is, lost energy while listening to receive possible traffic that is not sent. Turning off the communication interface when not used allows important gains because transceivers are often

the highest power consumer of the node. Accordingly, the sensor's duty cycle, that is, the fraction of time the sensor node spends awake is reduced below 1% which highly improves the network lifetime. Wireless sensor networks are similar to wireless ad hoc network in terms of networking topology and multi-hop routing. But, sensor networks are also different from other wireless ad hoc networks in that they consist of hundreds or thousands of autonomous nodes and the direction of most sensor traffic is from the sensor nodes to the base station. Another unique characteristic of wireless sensor networks is that the sensor nodes in WSNs are equipped with batteries of limited capacity and are expected to operate without human interaction for a long time. Therefore, the power management of each sensor node plays a very important role in increasing the lifetime of the sensor networks (Anna H. and Anastasi, 2006).

3.1 Power Consumption Analysis of 802.11 Basic Mode (ad-hoc)

For comparison purposes, we examine the power consumption of the 802.11 protocol in ad- hoc mode. The initial design of this protocol assumes that all nodes are within transmission range of each other. All nodes attempt to send *BEACON packets* to synchronize with each other. Only one *BEACON* packet is sent among all nodes in a neighbourhood during a beacon interval. If a node has a packet to transmit and the medium is free for the duration of a (DIFS), the node starts sending the packet as we assume no collisions and no collision avoidance. As shown in Figure 3.1, nodes are always in receiving mode unless they are transmitting (Anna H. and Anastasi, 2006).

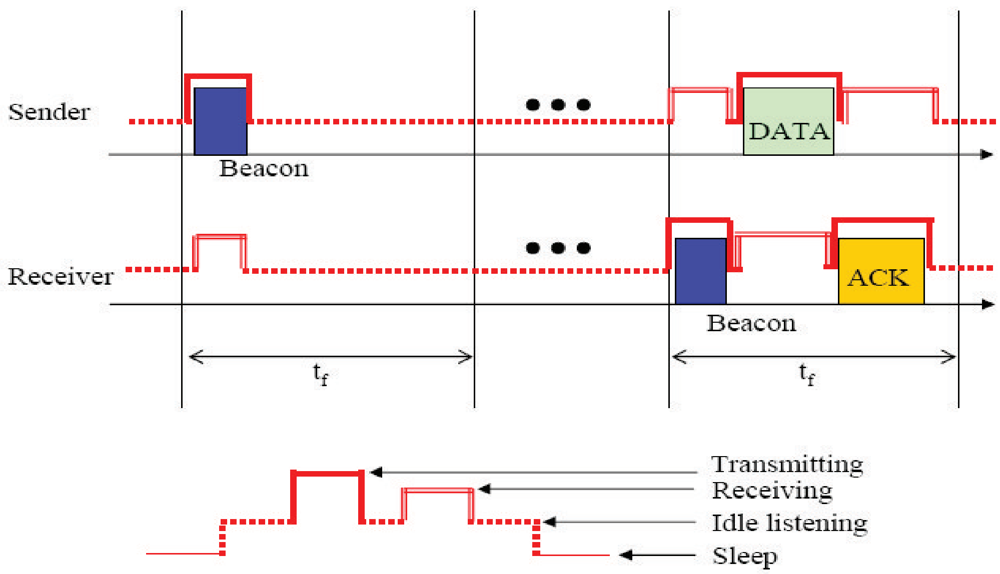

Figure 3.1: Data exchange in 802.11 in ad-hoc mode (Anna H. and Anastasi, 2006).

3.2 Energy Consumption of the Nodes

The analyses presented in this research assumes the use of IEEE 802.11b interfaces operating in ad hoc mode at 11Mbps using the Distributed Coordination Function (DCF), with RTS/CTS handshake. We can model the average power (P_m) consumed by the interface as

$$P_m = t_{sl} * P_{sl} + t_{Id} * P_{Id} + t_{Rx} * P_{Rx} + t_{Tx} * P_{Tx} \quad . \quad . \quad (3.1)$$

Where t_{sl}, t_{Id}, t_{Rx} *and* t_{Tx} are the fractions of time spent by the interface in each of the possible states: Sleep, Idle, Receive, and Transmit respectively, these fractions of time satisfy the condition. Analogously, P_{sl}, P_{Id}, P_{Rx} *and* P_{Tx} are the powers consumed in the four states considering P_m and the initial energy of the node (E), we can calculate the node lifetime (T_v), which represents the time before the energy of the node reaches zero, as

$$T_v = \frac{E}{P_m} \quad . \quad . \quad . \quad (3.2)$$

It also shows the consumption of the four states relative to the Idle, Sleep, Received and Transmit. We can compute the Power Management (Pm) and the node Lifetime (T_v), which represents the time before the energy of the node reaches zero (John et al., 2016).

4.0 Conclusion

Generally, lifetime of wireless sensor node is correlated with the battery current usage profile. By being able to estimate the power consumption of the sensor nodes, applications and routing protocols are able to make informed decisions that increase the lifetime of the sensor network. As most WSN nodes are battery powered, their lifetime is highly dependent on their power consumption. From the formula it is easy to compute the power management **(Pm).**

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