Cairo University

SMART SCHEDULING AND ENERGY SAVING IN WIRELESS SENSOR NETWORKS

By

Alamir Labib Awad Attia

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
IN
COMPUTER ENGINEERING

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FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Summary:

Wireless sensor networks (WSN) have a great impact on most of the current applications, so great research efforts have been redirected in order to solve its problems. Some of the WSN applications are critical in which sensors energy is very important to be saved. Sensors might need to work effectively not for days but years. In addition, in some applications, sensors are left unattended and replacing the sensors batteries or even the sensors might not be possible, especially in hazardous and dangerous areas. Therefore, sensors energy has to be managed in a certain way to keep the overall network operating for a long time.

Our contributions in this work are three-fold: 1) Introducing the concept multi-root tree to the WSNs to avoid nodes contention, 2) Proposing a new distributed algorithm based on the fuzzy logic controller to determine the status of each node dynamically based on the global network conditions, and the local nodes conditions, 3) Introducing a new mode of operation for the WSN node, which is the co-operative mode.

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List of symbols and abbreviations

Abbreviation	Expression
A/D	Analog/Digital
ACK	Acknowledgement
ADCFL	Adaptive Duty Cycles in WSNs Based Fuzzy Logic
BMAC	Berkeley Media Access Control
BS	Base Station
CPU	Central Processing Unit
ECN	Explicit Contention Notification
GAF	Geographical Adaptive Fidelity
GPS	Global Positioning System
HCL	High Contention Level
ID	Identifier
ILP	Linear Programming
IP	Internet Protocol
LCL	Low Contention Level
LEACH	Low-Energy Adaptive Clustering Hierarchy
LMAC	Lightweight Medium Access Protocol
LPL	Low Power Listening
MAC	Medium Access Control
MF	Membership Functions
NACK	Non- Acknowledgement
OSI	Open Systems Interconnection
PORT	Price-Oriented Reliable Transport Protocol
PSFQ	Pump Slowly Fetch Quickly
PTW	Pipelined Tone Wakeup
RAW	Random Asynchronous Wakeup
Rx	Receive
SMAC	Sensor Medium Access Control
STCP	Sensor Transmission Control Protocol
STEM	Sparse Topology and Energy Management
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
TRAMA	Traffic adaptive medium access
Tx	Transmit
UDP	User Datagram Protocol
WSN	Wireless Sensor Networks
ZMAC	Zebra Medium Access Control

Abstract

Wireless sensor networks “WSN” have a significant impact on most of the current applications. These sensors are small with limited processing and computing resources, and they can be manufactured at low cost compared to other traditional sensors. They can sense, record and store the environmental conditions such as temperature, sound, vibration, pressure, motion or pollutants. Afterwards, they transmit the measured data to a special node called base station (also known as a sink node). WSN can be used in several applications like Military (in Target tracking, surveillance, and reconnaissance), or in Health (Monitor patients and support the disabled patients) or in other commercial applications (Managing inventories, checking product quality, and control disaster areas). WSN nodes operate with AA batteries, and in Some WSN applications, the sensors might need to work effectively not only for days but years, and on dangerous locations replacing the sensors batteries or even the sensors themselves might not be possible. Therefore, it is vital to save the sensors energy sensors energy has to be managed efficiently to keep the overall network operating for long times. However, sensors in the monitored field are either sensing the monitored area or sending their data to the sink node or one of their neighbors. So, several areas have been investigated to prolong the WSN lifetime; one of these areas is switching off the unnecessary nodes (Duty Cycling). Among this large number of WSN nodes, several nodes can sense the same data; so, switching off the unnecessary nodes will have a great impact on extending the network lifetime. In this thesis, a new algorithm that can increase the network lifetime by using a fuzzy logic controller is proposed. The new algorithm (ADCFL algorithm) can be applied on both of the single feature WSN and the multi-feature WSN. In the single feature WSN, all the nodes measure only one feature, while on multi-feature WSN each node can sense many features. In the new algorithm the fuzzy logic controller run separately on each node to dynamically determine the node will switch on or off, and this prolongs the node lifetime. Also running the algorithm separately on each node saves the communication overhead among the WSN nodes. In addition to the Fuzzy logic controller, this thesis introduced the concept of the multi-root tree to the WSN to avoid nodes contention occurs on the root node. An extensive set of experiments is conducted comparing the performance of the ordinary tree algorithm, the newly proposed ADCFL algorithm, and LEACH algorithm. The conducted experiments have proven the fact “The more nodes densities, the better network performance regarding energy consumption and events delivery rate.” In case of 300 nodes and 500 rounds experiment, the ADCFL achieved delivery rate better than the LEACH algorithm with 22.5 %, and better than the ordinary tree algorithm with 49%. Regarding the energy consumption the experiment showed that at the end of the simulation, the ADCFL algorithm has total residual energy more than the ordinary tree algorithm with 67 %.

Chapter 1: Introduction

This chapter gives a brief introduction for the wireless sensor networks "WSN" along with its architecture. This introductory chapter is divided into eleven sections as follows: 1) the first section gives an overview about the wireless sensor networks, 2) the second section contains the WSN Sub-systems, 3) the third section mentions the main advantages of the WSN, 4) the fourth section lists some of the main WSN applications, 5) The fifth section displays the WSN architecture, 6) the sixth section contains some of the challenges facing the WSN, 7) the seventh section contains the network model of the WSN, 8) the eighth section introduces some of the WSN classifications, 9) the ninth section contains the problem statement, 10) the tenth section contains the contributions introduced in this theses, 10) finally the tenth section contains the main theses layout.

1.1 Wireless Sensor Networks "WSN" Overview.

The sensor is a device that measures input from the physical environment and provides the corresponding output in the form of electrical or optical signals [37]. The input may be motion, moisture, pressure, light, heat, or any environmental phenomena. The output is a signal that can be read at the location of the sensor or transmitted electronically through a network for further processing. Sensors can be scattered over wide geographical areas, so there is a high demand for the wireless communication between the sensors. Hence the WSN has a wide usage in the current applications.

WSN have attracted worldwide interest in recent years [1,2,4]. Due to the increasing demand for the Wireless Sensor Networks in many applications and practical fields in our life, a lot of research efforts are directed to the WSN [3,4,7,39]. The WSN nodes are small devices with limited processing and computing resources. They can be manufactured at low cost compared to the other traditional sensors [1, 3, 4, 12,14,39].

WSN are heavily distributed networks of small, lightweight, and low-cost wireless nodes. The nodes are deployed in large numbers to monitor the environment or system [1, 3,5,6,7,14,39]. The major features of WSN nodes are Limited sensing region, limited processing power, and limited energy [1, 3, 6, 7, 14, 39]. A sensor node can contain many sensing elements to sense different features, then the node sends the measured data to the sink station [1]. The base station receives all the sensed data from all nodes and runs summarization algorithms to make benefit from this data or sends the data to the agent. The WSN architecture overview can be illustrated in "Figure 1-1.

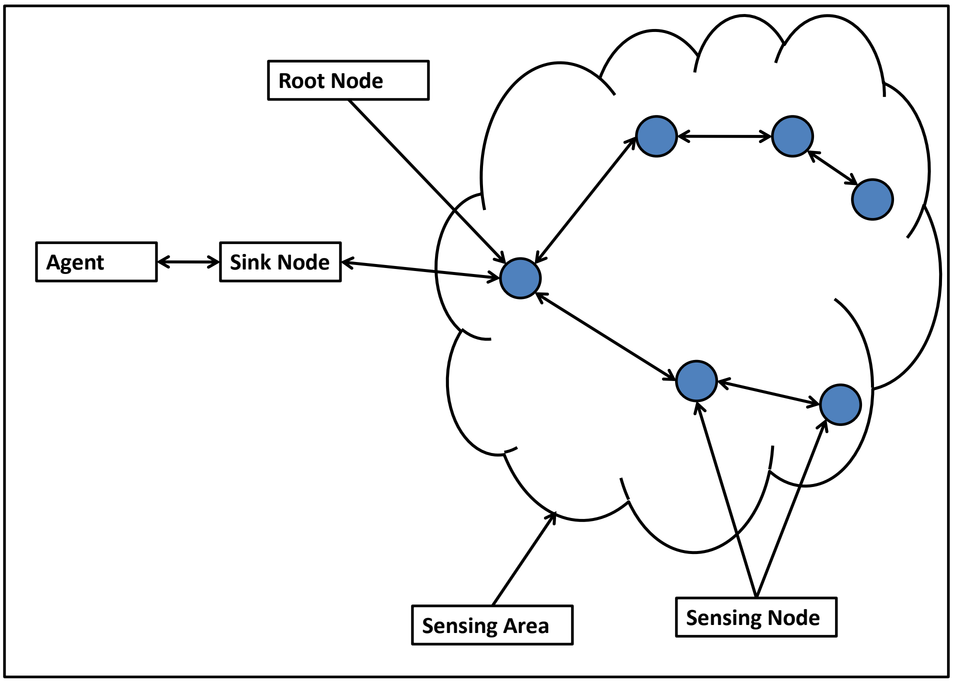

Figure 1-1 Wireless Sensor Networks architecture.

Figure 1-1 shows the Wireless sensor network architecture; sensing nodes are scattered in the sensing area in either a structured manner or an unstructured manner. Sensing nodes send their measured data to the root node along the tree. Then the root node sends the received data to the base station (sink node). Finally, the base station makes the necessary calculations on the data or sends it to the agent.

1.2 Wireless Sensor Networks Subsystems.

The main four subsystems of every sensor node are the power subsystem, the sensor subsystem, the processing subsystem, and the Communication subsystem. The power subsystem provides the other components with the necessary power. The sensor subsystem senses the environment and generates the required data. Processing subsystem carries out local computations on the sensed data. Finally, Communication subsystem is in charge of message exchange with the neighboring sensor nodes [39].

1.3 Advantages of Wireless Sensor Networks.

There are many advantages of sensor networks which make it widely used compared to the other types of networks. The main benefits of WSN are Robustness, Accuracy, and Fault-tolerant. WSNs are Robustness as the network has a significant number of sensors. WSNs cover a wider region, so it is accurate. As many nodes are sensing the same event, so if a node suffers from any failure the other nodes can do its job, So WSNs are fault-tolerant [5].

The sensor node also has a location and positioning knowledge that is acquired through a global positioning system (GPS) or local positioning algorithm like triangulation in which the node can approximate its position based on the signal strength from some predefined points [5,14,37]. Another significant advantage of WSN is that it can be deployed in dangerous locations where the wireline systems cannot be deployed (e.g., places that are subject to radiation or high temperature) [1]. These advantages make the WSN ideal for the national security.

1.4 Applications of Wireless Sensor Networks.

WSN node can sense the environmental phenomena, and transfers its data to its neighbors and the sink. Also, it can make some processing on the sensed data [7, 39]. The phenomena which can be sensed by the WSN could be pressure, humidity, temperature, wind direction, wind speed and pollution levels [37]. As a result, WSN can be used in many applications like environment sensing, vehicle tracking, inventory management, and military (battlefield management) [1, 4, 7, 14, 37, 39]. WSN nodes may be distributed in wide fields to track enemy vehicles [1] or distributed in forests to detect fires or distributed in dangerous areas to detect volcanoes [1]. In the upcoming section, we will discuss some of the WSNs applications in detail.

1.4.1 Military Applications.

One of the most critical applications in which the WSN can be used is the Military applications [1,7,39]. Ability to scatter the Wireless Sensor Networks nodes among the dangerous/hazardous areas, node`s low-cost [1], and node self-organizing capabilities makes the WSN ideal to be used in military applications [7]. The WSN can be used in many military applications like the following.

1. Battlefield surveillance and monitoring [39].
2. Identifying and tracking the friendly or inimical objects, vehicles, aircraft, and personnel [39].
3. Detection of attack by mass destruction weapons such as chemical, biological, or nuclear [39].

Also, Wireless Sensor Networks can be used in military applications in borders monitoring. Assume the following situation in which the usage of WSN could be very essential. In monitoring the border, the ideal case is assigning many soldiers along the borders. It is required to make sure the distance between each soldier and his neighbor is short enough to avoid gaps between them. A better way to do this mission is deploying WSN nodes along the border; these nodes send their measured data to a central point which sends alert to a specific camp.

1.4.2 Environmental Applications.

WSN can be used in many environmental applications. For example, they can be used in forest fire detection, water pollution measurements, flood detection, habitat exploration of animals [7, 39]. In the upcoming subsection, we will discuss some of the most important applications where the WSN is used in environmental applications.