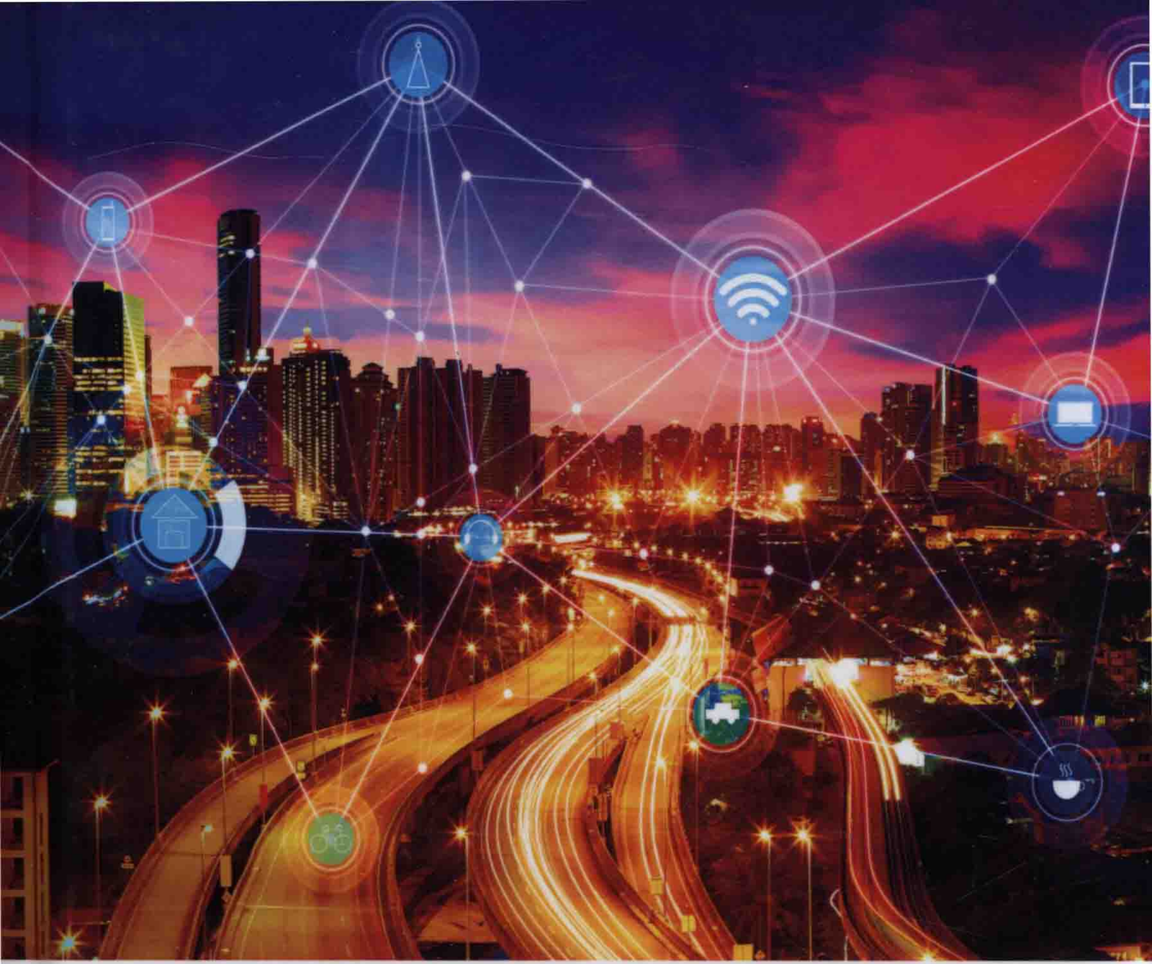

Energy Management in Wireless Sensor Networks

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Preface

This book addresses the issue of energy management in wireless sensor network (WSN) implementation. In this context, it remains insufficient and inadequate to seek a material solution only to guarantee efficient functioning alongside an increase in the lifetime of the network. It is therefore necessary to focus on other software solutions that allow efficient information processing upon acquisition and until the final destination by taking account of sensor characteristics, i.e. weak storage capabilities, processing power and related energy constraints. Partial fulfillment of these needs entails the development of low-consumption computational tools and formal strategies using mechanisms based on information routing technologies.

In the first two chapters, we deal with latest WSN developments, before presenting the structure and composition of a sensor node, the functional architecture of a WSN and the different choices for improving energy autonomy and conservation. We then set out the taxonomy of different technologies used for energy optimization and finish by illustrating the problem to be addressed.

In the fourth chapter, we cover the issue of routing in hierarchical architectures, particularly networks with high density. In the fifth chapter, we explore the range of routing solutions developed in the relevant literature by focusing on factors improving and/or damaging the performance of networks and highlighting their adaptability.

Chapters 6 and 7 present some formal solutions developed at the LIASD[1] research laboratory at Paris 8 University. A first adaptable routing solution implements a new non-linear energy model with a child–parent communication concept, while a second solution allows problems caused by data instability and asymmetry in communications links, particularly during the recognition phase, to be avoided. The outcomes will be evaluated in the eighth chapter on the basis of a comparative study with other existing routing mechanisms.

This book is aimed at people who are not necessarily experts in wireless sensors, and can be used by engineering students, students pursuing professional or research masters, or doctoral students in the field of new communication technologies. It may also be suitable for manufacturers wishing to develop partnerships with universities on optimizing energy and computing resources. It can also act as basic guidance for developing support courses for university lecturers and researchers.

Y. TOUATI
January 2017

1 Advanced Computer Science Laboratory of Saint-Denis (Laboratoire d'Informatique Avancée de Saint-Denis).

List of Abbreviations

AOA: Angle Of Arrival

AODV: Ad hoc On Demand Distance Vector

APTEEN: Adaptive Periodic TEEN

AQFSN: Active Query Forwarding in Sensor Networks

ASCENT: Adaptive Self-Configuring Sensor Networks Topologies

B-MAC: Berkeley MAC

CADR: Constrained Anisotropic Diffusion Routing

CH: Cluster Head

CPU: Central Processing Unit

CRC: Code Cyclique Redondant (Cyclical Redundancy Check)

CSMA: Carrier Sense Multiple Access

CSMA/CA: Carrier Sense Multiple Access/Collision Avoidance

D-MAC: Dynamic MAC

DSP: Digital Signal Processor

DSR: Dynamic Source Routing

EACHS:	Energy Adaptive Cluster-Head Selection
FEED:	Fault tolerant, Energy Efficient, Distributed Clustering
FLAMA:	FLow-Aware Medium Access
GAF:	Geographical Adaptive Fidelity
GBR:	Gradient-Based Routing
GDIR:	Geographic Distance Routing
GEAR:	Geographic and Energy Aware Routing
GMRE:	Greedy Maximum Residual Energy
GOAFR:	Greedy Other Adaptive Face Routing
GPS:	Global Positioning System
GPSR:	Greedy Perimeter Stateless Routing
GRF:	Geographic Random Forwarding
H-PEGASIS:	Hierarchical-PEGASIS
HEED:	Hybrid Energy-Efficient Distributed Clustering
HHRP:	Hybrid Hierarchical Routing Protocol
HRP-DCM:	Hybrid Routing Protocol based on Dynamic Clustering Method
ISO:	International Standards Organization
LEACH:	Low Energy Adaptive Clustering Hierarchy
LEACH-H:	Low Energy Adaptive Clustering Hierarchy-Hybrid
M-LEACH:	Multi-hop LEACH
MAC:	Medium Access Control
MECN:	Minimum Energy Communication Network
MFR:	Most Forward within Radius
MULE:	Mobile Ubiquitous LAN Extensions

NiMH:	Nickel-Metal Hydride
MN:	Member Node
OSI:	Open Systems Interconnection
PEGASIS:	Power-Efficient Gathering in Sensor Information Systems
QoS:	Quality of Service
RR:	Rumor Routing
RSS:	Received Signal Strength
RSSI:	Received Signal Strength Indication
S-MAC:	Sensor MAC
SAR:	Sequential Assignment Routing
SGNFD:	Stateless Geographic Non-Deterministic Forwarding
SMECN:	Small Minimum-Energy Communication Network
SOP:	Self Organizing Protocol
SPIN:	Sensor Protocols for Information via Negotiation
T-MAC:	Timeout MAC
TBF:	Trajectory-Based Forwarding
TDMA:	Time Division Multiple Access
TDOA:	Time Difference Of Arrival
TEEN:	Threshold-sensitive Energy Efficient sensor Network protocol
Tiny-OS:	Tiny-Operating System
TL-LEACH:	Two Level-LEACH
TOA:	Time Of Arrival
TOSSIM:	TinyOS-SIMulator

TRAMA:	TRaffic-Adaptive Medium Access
UOV:	Unit of Value
V-LEACH:	Vice-LEACH
WBAN:	Wireless Body Area Networks

Introduction

Technological advances connected to the miniaturization and integration of electronic components and to computer programming have brought about drastic changes in the field of wireless networks, giving rise to a new generation of small sensors that are able to operate independently and interact according to established communication protocols, as happened in WSN. These sensors operate around a dedicated OS and have similar functions to those of a traditional computer with microcontroller, transducer/actuator and transmitter/receiver components.

The fields of application are numerous and can include detection and environmental surveillance, transport management, traffic control and intelligent spaces, industry, health, home automation, the military, space and so on. In health-related applications, for example, the use of a WSN can improve the quality of care by using surveillance and monitoring in patients' homes. This allows medical personnel to make diagnoses quickly and therefore plan accordingly for any subsequent operations. There is also a type of advanced WSN, i.e. WBAN[1] or physical networks, widely used in the field of e-health, where data collection is carried out through the implantation of microsensors on targeted parts of the human body, as in electrocardiograms of electroencephalograms, for example.

1 Wireless Body Area Networks.

A WSN can be deployed specifically in structured environments or randomly in hostile ones which makes it vulnerable to multiple failures, ranging from physical defects provoked by environmental factors to a lack of energy resources caused by exhausted battery devices. A human intervention is generally difficult, or almost impossible, to carry out because of sensors' locations. Consequently, energy consumption management remains an unsolvable problem when designing and implementing WSN. It remains inadequate to guarantee efficient functioning alongside an increase in network lifetime by seeking only a material solution. It is therefore necessary to turn to other software solutions that allow information use to be controlled from the acquisition to its final destination by taking into account innate characteristics of sensors, i.e. weak storage capabilities, processing power and related energy constraints. Partial fulfillment of these needs entails the development of low-consumption computational tools and formal strategies applying mechanisms based on information routing technologies.

It should be noted that, in this book, a part of the proposed work has been addressed in the context of a PhD thesis [AOU 15b] that Mr. Touati and Mr. Ali-Chérif have supervised at the LIASD research laboratory at Paris 8 University.

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Energy Management in Wireless Sensor Networks

Over the last few years, the technological advances in wireless sensor network (WSN) applications have sparked great curiosity and a growing interest among both users and manufacturers, as well as in the research community. Significant challenges have been overcome to ensure their implementation by addressing problems arising from deployment and connectivity, and from routing and securing information, although much remains to be done at the energy management stage. A WSN is made up of a set of sensor nodes, using supply devices or batteries to operate and interconnected via radio links to ensure data reception, processing and transmission. Increasing the autonomy of sensors and extending the network lifetime can therefore be considered among the main objectives by examining interesting methods and studies that optimize energy consumption, and suggesting mechanisms to improve it. These mechanisms can involve several action levels which can range from the deployment stage to the information exploitation stage.

This chapter briefly describes the latest developments in WSNs and presents the structure and composition of a sensor node, the functional architecture of a WSN and guidelines for enhancing autonomy and energy conservation.

1.1. Introduction

Wireless sensor[1] networks are a type of ad hoc network comprised of mobile and/or static sensor nodes capable of being deployed in known or unknown environments. These sensors have an energy capacity allowing them to operate independently and intelligently, and to communicate via radio link according to established routing mechanisms [YIC 08, AKY 02, CHO 03, TUB 03]. Unlike ad hoc networks concerned with guaranteeing a better quality of service, i.e. bandwidth and the transmission delay [PIR 11, ULE 06, SAN 05], WSNs promote the optimization of energy constraints as they have limited resources in term of energy, data storage and calculations. This focus is shown through the implementation of mechanisms allowing the network's lifetime to be extended (Table 1.1).

Characteristics	WSN	Ad hoc networks
Network density	High	Low/Average
Likelihood of interference	High	Low/Average
Division of network	Possible	Unlikely
Resources	Limited	Acceptable
Type of communication	Distribution	Peer to peer
Addressing	Geographic localization	IP addressing
Energy source	Irreplaceable	Replaceable
Duplication	Highly likely	Unlikely
Breakdown	High risk	Low risk

Table 1.1. *WSN versus ad hoc network*

A WSN is in fact composed of a number of nodes with the same roles, deployed in a structured or random operational environment at a high risk of breakdown. Breakdowns can stem from a lack of energy resources (battery attrition) or physical faults caused by environmental factors (rain, wind, etc.), which can complicate data transmission. Human involvement is at times absent and therefore unable to provide solutions (i.e. replace used batteries), although this is not the case with ad hoc networks where mobile nodes are built in to resolve breakdown issues. It would thus be very

1 A sensor is an extremely small device with very limited resources (energy, memory), which is autonomous and able to acquire, process and transmit information, using radio waves, to another entity (sensors, processing units, etc.) over a distance of several meters.