SOFT COMPUTING IN WIRELESS SENSOR NETWORKS

Edited by
Huynh Thi Thanh Binh and Nilanjan Dey

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Preface

Recently, the Internet of Things (IoT) has received huge interest from scientists and technology designers throughout the world and is considered the next network generation in the near future. This concept starts from the idea of building a network consisting of all real-life objects (things) in which they can connect, interact, incorporate, and communicate data and information, accomplishing complex tasks. This way, the strength of the Internet is fully investigated in a highly effective way, bringing in practical applications in many fields such as economy, information technology, military, etc. In practice, some specific applications of the IoT, namely smart home, smart traffic, etc., have proven its feasibility, convenience and promising benefits.

However, the IoT can only be successfully applied within the support of wireless sensor networks (WSNs). Today, the development of the Internet, radio communications, and information technology has brought the potential development of WSNs. The sensor network might include different types of sensors, such as earthquake sensors, magnetic field sensors, low-rate sampling sensors, camera sensors, infrared sensors, sound sensors, radar, and so on, which can monitor large areas under different conditions.

This volume is comprised of nine chapters, providing different techniques for solving optimization problems in WSNs. An overview about WSNs is given in Chapter 1, followed by an introduction to optimisation problems in WSNs in Chapter 2, including major factors that need optimisation; problem classification and well-known approaches to solve them; and current achievements and results. These first chapters provide readers with basic theoretical knowledge about the topic and why it is demanding to push the boundaries in this field. Chapter 3 discusses the application of machine learning (ML) algorithms in WSNs, which play a crucial role in WSNs as they simplify huge amounts of data generated and gathered at the central nodes in WSNs. To elaborate the importance of using soft computing in this research topic, Chapter 4 presents the relevance of soft computing techniques in the significant management of WSNs and introduces soft computing techniques like ant colony optimization and particle swarm optimization (PSO), artificial neural networks (ANNs), perception, fuzzy logic, evolutionary computing, and genetic algorithms in the management of WSNs. There is also a broad analysis of this intelligence-based soft computing strategy as connected in the different operational parts of wireless sensor networks. After that, the following chapters discuss more narrowed optimization problems in WSNs including their challenges, solutions, and achieved results. Chapter 5 concerns intrusion detection systems in mobile ad hoc networks, in which the definition of mobile ad hoc networks and different kinds of attacks are well-elaborated. The performance of grammatical evolution is also analysed with ad hoc flooding and route disruption attacks on various mobility patterns of the nodes on the network. Chapter 6 presents an introduction to coverage optimisation in WSNs. The problem is classified into smaller categories of area coverage, target coverage and barrier coverage including an in-depth discussion about state-of-the-art solutions and recent achievements. Chapters 7 and 8 concern cluster formation and sensor positioning in WSNs, respectively. For any cluster-based routing technique, the major challenge is to efficiently elect the cluster head (CH) nodes. The wrong choice of CHs lead to early death of nodes and network collapse. Chapter 7 addresses this problem and introduces an energy efficient protocol for cluster formation in WSNs. Chapter 8 discusses alternative effective and efficient techniques to replace the traditional ones that are more expensive, more energy-consuming, face connectivity failure problems, and are less accurate in performance. This chapter mainly focuses on sensor deployment strategies to achieve optimum coverage areas and minimize energy consumption. Finally, Chapter 9 is concerned with an elaborate and illustrative discussion about the application of IoT in the healthcare sector. The IoT healthcare system acts as a platform between wearable and implantable body sensor networks (WIBSNs) with specific needs. This chapter examines the various attributes associated with WIBSNs and analyses its workings with respect to healthcare. It also gives the reader an overall perspective of the entire ecosystem of IoT–based healthcare and the functioning of the associated components.

We would like to express gratitude to the authors for their contributions. It would not have been possible to reach this publication quality without the contributions of the many anonymous referees involved in the revision and acceptance process of the submitted manuscripts. Our gratitude is extended to them as well. As the editors, we hope this book will stimulate further research in medical imaging applications-based algorithmic and computer-based approaches and utilize them in real-world clinical settings. We would also like to thank the reviewers for their diligence in reviewing the chapters. Special thanks go to our publisher, CRC Press/Taylor & Francis Group.

We hope that this book will present promising ideas and outstanding research results supporting further development of soft computing approaches in solving optimization problems in WSNs.

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Introduction to Wireless Sensor Networks

G. Bhanu Chander and G. Kumaravelan

CONTENTS

1.1 Introduction

As the result of significant developments in the field of electronic communication, computer science, and information technology, we now have a new computing and communication architecture known as wireless sensor networks (WSNs). In the past, wired sensors implemented into restricted appliance areas produced low results only. Meanwhile, the convention of adapting wireless technology produced sensor nodes which formulated more feasible solutions prior to wired sensor nodes. Recently, there is a measurable benefit with an immense possibility of connecting various devices and networks together in an eloquent effort to address important issues and challenges.

The first wireless sensor network was a sound surveillance system developed by the US military in the 1950s to detect and track Soviet submarines [1]. This servicing technology is still at work today for monitoring undersea wildlife and volcanic activity. Nowadays, with the rapid development of the aforementioned WSN, this technology is easily deployed in the largest geographical area that allows alike sensor nodes to gather the raw data and communicate and transfer it in new applications [2].

1.2 Wireless Sensor Networks

Wireless sensor networks are a collection of undersized individual sensor nodes. Depending on the application scenario, this number may be raised to hundreds to thousands apiece, where a node is connected with additional nodes. Each sensor node in a wireless sensor network observes its environmental phenomena and this collected information is transmitted to one or more sink stations through a wireless link depending on the network deployment.

There are three main functionalities of sensor node: the first is sensing its neighboring atmosphere, the second is processing the data which was initially observed, and the third is communicating or connecting through

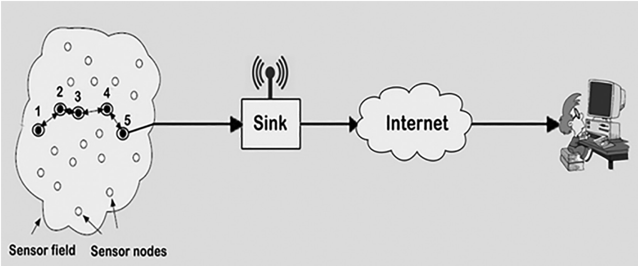

FIGURE 1.1
Communication architecture of a wireless sensor network.

additional sensor nodes or sink stations within the network. Among these above specifications, sensing the environment is the most important one.

WSNs can be structured in centralized, distributed, and ad hoc ways. Figure 1.1 shows the general communication structure of a WSN. It primarily consists of sensor field, sink node, and user or task management component. Sensor nodes are deployed in a specific area is known as a sensor field. Each sensor node in the sensor field is capable of sensing its own respective environment phenomenon and routing the observed data to the sink node through a multi-hop connection. A sink node is a special kind of sensor node which collects data from the sensor field and performs the necessary operations or simply forwards the collected data to the user or task manager node. In addition, it also sends queries to the sensor nodes in the network and retrieves the required data. Finally, the user or task manager node accords an assignment to each sensor node in the sensor field. Nevertheless, the sink node connects with the user or task manager node via an Internet or satellite connection [1,2].

1.3 Types of Sensor Nodes

The sensor is used in a large range of constraints which correspond to healthiness forms, such movements, electrical signals, thermal, and compelling energy.

Sensor nodes are mainly two types (1) passive sensors and (2) active sensors.

1.3.1 Passive Sensors

Passive sensors observe the data by active probing, which means their energy is used only to amplify the analog signals. Passive sensors don't require external resources as their energy is used only to generate analog signals. These sensors can change their physical properties (like capacitance) and generate electrical signals. Again, these passive sensors are divided into two types' *passive omnidirectional sensors* and *passive narrow beam sensors*.

For passive omnidirectional sensor nodes, a particular geographical area is given to each sensor node so that area sensor node moves and collect reliable information and forward to the base station for further processing. The present theoretical research work in wireless sensor networks assumes that sensor nodes are omnidirectional. However, for passive narrow-beam sensor nodes, a prearranged direction or notation is given to each sensor node in the same way that cameras are able to shoot photos from only one direction. Sensor nodes can move and collect data and transform to the base station from only one direction.

1.3.2 Active Sensors

Active sensor nodes sense the data by manipulating the environment which means they need continuous energy to generate analog signals. Active sensor nodes dynamically probe the neighboring environment and use an external power supply of energy, which is needed to monitor and operate. Digital sensors generate distinct indications which are later converted to digital characterization based on the parameters measured. A single byte group discrete values output is measured as the quantity. Analog sensors generate continuous signals (such as temperature, pressure, and water flow), which are measured as continuous analog signals.

Each sensor node is also called a *mote* but all motes are not always called sensor nodes. Motes receive and transmit the data and employs some processing techniques inside the sensor node, like compression, encryption etc. So, sensor node operate like motes, but motes do not always operate as sensor nodes [1–3].

1.4 Sensor Node Description

A sensor node is a tiny device that consists of four major hardware components, namely the sensing unit, processing unit, transceiver, and power generator. In addition, the sensor node also uses location devices such as global positioning system (GPS) and a mobilizer. Figure 1.2 shows the basic configuration of a sensor node.

1.4.1 Sensing Unit

A sensing unit observes its environmental phenomena for gathering information (such as temperature, pressure, light, and displacement) as well as producing the corresponding output as an optical or electrical signal. A sensing unit basically consists of two parts; a sensor and an analog to digital converter (ADC). In the sensor part, one or more sensors there produce the analog signals, and these analog signals are transferred into digital signals

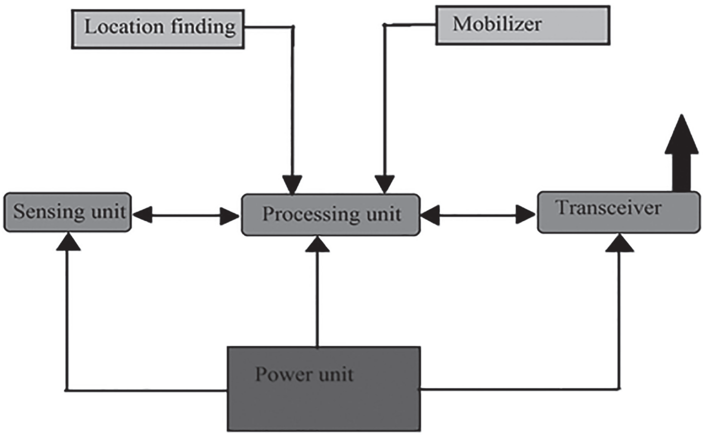

FIGURE 1.2
Basic configuration of sensor node.

through the ADC and fed into a processing unit for supplementary operations. Based on the observed or gathered phenomena, sensor nodes are classified as thermal, optical, acoustic, or mechanical sensors.

1.4.2 Processing Unit

A processing unit includes two parts; storage plus a processor. A storage component, which works as nonvolatile memory used to store programming instructions, temporarily stores sensed data. Also, it will store processed data on occasion. The processor in sensor node makes the sensor node collaborate with other nodes in the network to complete the designated exercise. The microcontroller performs tasks, processes the data, and controls the other functionalities of a sensor node. Because of some special characteristics of microcontrollers, like low cost, easy attachment with supplementary apparatuses, effortlessness of training, and squat power utilization, microcontrollers are used in sensor nodes. ATMEL, At mega 128L, and MSP430 are the most commonly used microcontrollers because they have power saving capabilities. Among these, MSP 430 has six different power modes from wholly energetic to wholly powered down. These kinds of power reduction approaches enlarge the system lifetime and make the sensor node live longer.

1.4.3 Transceiver Unit

The transceiver attaches the node to the network. It is an amalgamation of transmitter and receiver to a solitary device which works on specific radio frequency (RF). The RF message requires modulation, filtering, multiplexing, band bass, and demodulation, which makes it more complex and expensive. Basically, sensor node uses industrial scientific medical bands (ISM) which provide a radio band at no cost with comprehensive accessibility. There are three transmission technologies offered in wireless transmission; optical communication, infrared, and radio frequency. First, optical communication requires low power, line of sight, and squat at atmospheric circumstances. Second, infrared communication has no need for antennae, but has a low broadcasting capacity. Third, radio frequency communication is the most relevant method best suited for wireless transmission because it provides free spectrum at 173, 433, 868, and 915 MHz and 2.4 GHz. The progression of a mote template is a 4 MHz Atmel AVR 8535 microcontroller amid 8 KB instruction flash memory, 512 bytes random access memory (RAM) and 512 bytes electrically erasable programmable read only memory (EEPROM). Tiny OS Operating systems consist of 3500 byte space of OS code as well as 4500 byte space offered for code. The evolution of another sensor node template, namely an AMPS posse 59–206 MHz SA-1110 microprocessor, is run on a multithreaded operating system [2–4].

The majority of sensor nodes use low-rate, wireless personal area networks which are IEEE 802.15.4 standard. Standard meaning the transceiver has four operational modes, like transmit, receive, idle, and sleep. In receive and idle mode, the power consumption of the transceiver is the same. However, the transceiver should initiate sleep mode and not be left in idle mode when it is not actively working, otherwise considerable energy will be wasted. It will simply interchange from sleep state to the active broadcast or receive state [1].

1.4.4 Power Unit

The sensor node is a small microelectrical appliance which consists of low energy. The power unit sustains the sensor node in a rough and unconditional environment where changing batteries is expensive and difficult. Mainly, sensor nodes use their energy for sensing, transmission, and data aggregation purposes. Among these aforemention operations, the transmission of information consumes the majority of energy, compared to the other operations. The power source of a sensor node is constituted by a rechargeable or nonrechargeable battery. Rechargeable sensor nodes are capable to renovate their power from the nature circumstances like solar, high temperature differences, and pulsation. Non-rechargeable sensor nodes must be competent to operate until either the assignment time is completed or the battery is replaced. However, based on the application scenario, the lifetime of sensor node will be decided. For example, scientists monitoring the presence or age of ice (especially in the form of glaciers) or observing the bed slides in the ocean need the sensors able to work continuously. When the sensors are deployed in the battlefield, finding the temperature in particular area may need a few hours or days. In the past, the batteries of tiny sensor nodes were manufactured with vanadium and molybdenum oxide. Future energy exploration from the environment occured because sensor nodes operated in irregular places. The battery for sensor nodes should be as small and efficient as possible. Nickel–zinc, lithium–ion, and nickel–metal hydride electrochemical objects are used for their electrodes.

In addition, some routing protocols and specific applications need the location of a sensor node because they are generally deployed in unconditional areas and need to collaborate with other sensor nodes about their present location for the transmission of data, which is possible by a location finding system. A mobilizer is an optional component in the description of a sensor node which moves the sensor node from one place to another place to complete the assigned task.

1.5 Applications of Sensor Nodes

Wireless sensor networks are deployed in an irregular environment with a wide range of applications. There are many types of sensor nodes (seismic, acoustic and thermal, radar, visual, etc.) in WSNs which extend their basic applications. WSNs are comprehensively used in areas such as environment monitoring, tracking, crisis management, monitoring patients, radioactivity detecting, detecting dangerous material such as explosives, security and surveillance, underground material structures, critical infrastructure, office and home automation, traffic control, disaster and flood intimation, and identification [5–7].

1.5.1 Military Applications

Wireless sensor network implementation primarily began with the military application with the formation of DARPA and enemy tracking. Since sensor nodes are densely deployed, if some sensor nodes are destroyed by antagonistic actions, it doesn't influence or affect the military operation. This makes sensor nodes ideal for the battlefield. Using appropriate sensors in the specific network area, the identification of enemy forces, movement detection, analysis, and progress of their movement can be achieved. Sensor nodes provide the following services in the battlefield [5]:

Battlefield Surveillance: Information from the border, battlefield and some other vital behavior in the area will be gathered by the sensor node.

Targeting: Sensors are placed in weapons and collect information about targets (like motion, movement, angle, distance, etc.) which can be sent to the shooter. This sensor is used for better target estimation.

Intrusion Detection: Sensor nodes are used to identify the intrusion in the network and sounding an alarm. The defense system will then assess an appropriate recourse for the attack.

Monitoring Forces: Sensor nodes monitor the movement of troops and tanks, and report that information to the base station.

Target Classification: Some particularly designed sensors can monitor suspicious objects to better track potential enemies. An endocrine-based intelligent distributed cooperative algorithm (EIDCA) is proposed for soldier tracking.

Battle Damage Evolution: Sophisticated sensor nodes can be deployed to estimate the damage of battle affected areas.

1.5.2 Environmental Observation

Sensor nodes play an important role to supervise and estimate the environmental conditions of large geographic areas (like temperature, humidity, rainfall, etc.) which help in pollution monitoring, forest fire detection, and flood detection. The first well-known wireless sensor network for weather coverage was an automated real-world evaluation in real time (ALERT). ALERT can produce real-time information concerning rainfall and water levels to estimate the possibility of flooding. Environmental monitoring is broadly divided into two types; indoor and outdoor monitoring. Indoor monitoring is used for buildings and offices. This application involves sensing humidity, temperature, and air quality. Examples of outdoor monitoring applications are volcanic eruptions, earthquakes, chemical hazard detection, and weather forecasting [6].

1.5.3 Forest Fire Detection

Sensor nodes placed in forests are used to detect fires. Some specially designed sensor nodes are used to measure the temperature, humidity, air direction, and the speed of air, which helps to determine the level of fire risk. Wireless sensor networks locate the starting point of the fire and alert the respective authorities to put it out.

1.5.4 Pollution Monitoring

Wireless sensor networks can be employed towards monitoring and examining the pollution intensity in a particular area. Sensor nodes, which are deployed around the city, can be used to estimate the respective environmental factors, and accordingly producing a warning signal when these factors reach their aforementioned threshold limit. For example, LTE-M module–based Zigbee wireless sensor nodes are kept on the stations of public vehicles to collect data, and are sent to the cloud base station for further processing of the pollution level.

1.5.5 Industrial Monitoring

Industries are mostly using wireless sensor networks for determining the level of output quality in its operation and also in cost-reduction procedures. For example, in nuclear power projects, sensors are used to monitor the water level in the tank and the temperature and pressure in refrigerators. One more central application of sensor networks is to supervise machine health. The aspiration of this application is to detect the defective parts of equipment which need to be repaired or replaced. Inventory control is another important problem in big industries. The globalization of larger industries makes it difficult to manage their equipment and products, so, the management of these companies achieved through wireless sensor networks.

1.5.6 Agriculture Monitoring

The use of wireless sensor networks in the agriculture research community has been increasing rapidly. Sensor nodes sense parameters like temperature, humidity, soil moisture, and sunlight of the agriculture field so the necessary precautionary measures will be given to its stakeholders to increase the harvest. The LOFAR-Agro project is used in potato fields for crop monitoring. Here, wireless sensor networks are used to detect where the potatoes are infected by disease. By locating such areas, the use of pesticides is minimized and confined to susceptible areas.

1.5.7 Health Monitoring

In this application, patients are outfitted by collective sensors on special points of their anatomy to supervise patient metrics, such as blood pressure, heart rate, etc. Home-based wireless ECG monitoring systems exploiting Zigbee technology are considered some of the applications that take advantage of health monitoring. Such methods can helpful for supervising people in their homes, along with periodic supervising by a general practitioner. Electrocardiograms (ECG) are imperative for detecting heart disease abnormalities. Clinical ECG equipment may be functional for short-range inspection, but are impractical for home health use. In recent times, wireless ECG supervising systems have been created that are compatible with Bluetooth, as well as Zigbee, protocols. A Zigbee device is capable to advocate unfailing multi-hop, self-organizing, and mesh network which steadies the appliance software layers considered by the IEEE 802.15 plus Zigbee alliance. Zigbee can provide with diminutive energy connectivity along with an undersized rate for the equipment that necessitates prolonged battery continuation [8].

Wireless capsule endoscopy (WCE) suggests an illustrated inspection of the entire gastrointestinal (GI) tract and the rationalized analytical progression of undersized bowel illness, moreover the triumph over the boundaries of conventional diagnosing equipment. In order to strengthen the WCE, computational procedures can be implemented for specific capsule localization and tracking. For perfect understanding of the wireless capsule endoscope (WCE) location point toward the wrongdoing position which plays an essential role for dissimilar reasons including perfect localization of injuries plus mechanized CE direction-finding. Localization is fulfilled by several localization techniques such as received signal strength (RSS)–based localization, time of arrived (TOA)–based localization, magnetic-based localization, image-based localization, and date of arrived (DOA)–based localization [9].

1.5.8 Smart Home

Remote management of home applications is achievable by using some integrated, specially designed sensor nodes. Sensor nodes can be deployed in household devices like microwaves and washing machines, and can be maintained without the need for human interaction. Sensor nodes share some common resources like water, heaters, and electricity in the intelligent home projects.

1.5.9 Power Grids

Wireless sensor nodes deployed in power grid applications provide necessary information regarding eclectic utilization, which makes them more efficient. Sensor nodes are used for measurement and tracking energy production and consumption to monitor the entire surrounding area. If there are any abnormal positions detected, the nodes will send that diagnostic information to an authority to solve these problems.

1.5.10 Automobiles

Sensor networks have been used to monitor and track vehicles for a long time. A common example would be video cameras that are fixed at a particular area to observe traffic. The videos are sending to a human operator, and as a low-cost replacement for video cameras, small sensor nodes are installed to monitor traffic. Sensor nodes take pictures of traffic, which are sent to a human operator or automatic controllers, and take control signals. Sensor nodes are installed in particular vehicles to monitor and track their movements.

1.6 Protocol Stack of WSNs

In WSNs, sensor node energy consumption has an effect on the configuration of protocol layers in addition to managing the sensed data at every level. Protocol stacks (see Figure 1.3) are used in sensor and sink nodes inside the network and consist of a physical layer, data link layer, network layer, transport layer, application layer, power management plane, mobility management plane, and task management plane [1–4].

1.6.1 Physical Layer

The physical layer is designed for modulation, carrier frequency generation, and transmission, as well as for receiving techniques, signal detection, and frequency selection. The transmission links of wireless sensor networks are twisted based on infrared, optical, and radio. Sensor nodes present employment based on radio frequency design. So, the physical layer typically takes care of communication-based radio links.

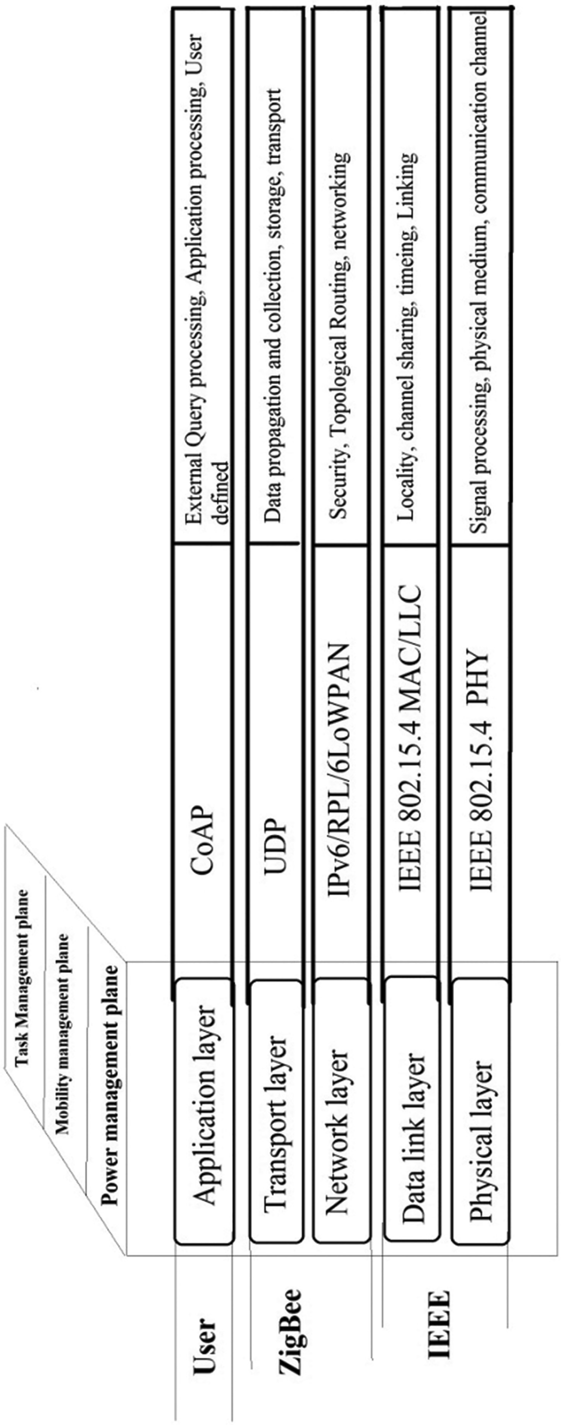

FIGURE 1.3
WSN protocol stack suite.

1.6.2 Data Link Layer

The data link layer is compiled with error detection, error control, and medium-access control plus data stream. The medium access control (MAC) layer set of rules deal with energy conservation and avoiding a collision with neighboring nodes. MAC layers also handle another important issue called energy consumption, where the MAC layer allows sensor nodes to self-organize by establishing communication links hop-by-hop. For designing a MAC layer protocol for a wireless sensor network, we ought to obtain dissimilar limitations like recovery failures, power preservation (suitable for low-power devices), and limited computational ability.

1.6.3 Network Layer

The network layer permits direction-finding of statistics data throughout a wireless communication channel. Sensor networks are without infrastructure and are multi-hop, where each sensor node as source node collects sensed data and transmits the sensed data to the reliable sink node. So, it is important for the network layer to route the data in the direction of sink node. Because of limited power resource protocols which are designed in traditional and ad hoc networks, this method is not appropriate for wireless sensor networks. We have numerous tactics to route the data as a routing power expenditure through a vacant power platform on vigor metrics, and data-centric routing stands on important dissemination.

1.6.4 Transport Layer

The transport layer affords logical communication among the application process operations on different hosts within the main network and supplementary networks. The transport layer mostly preserves data flow when the application layer demands it. Designing a set of rules on the network layer is very complicated, since the sensor node parameters are mostly affected by numerous limitations like restricted power and memory. This layer is principally compulsory, while the organization is premeditated to be contacted via the Internet or extra peripheral networks.

1.6.5 Application Layer

The application layer sustains several contradictory software applications on the sensibility assignment. There are many application areas which are well-designed, although prospective relevance layer protocols for sensor networks are still laregly unsophisticated. There are three eventual relevant layer procedures designed for the application layer, which are as follows: the sensor management protocol (SMP), the sensor query and data dissemination protocol (SQDDP), and the task assignment and data advertisement protocol (TADAP).