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# Handbook of Wireless Sensor Networks: Issues and Challenges in Current Scenario's

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Editors

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 Springer

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# Preface

Wireless sensor networks are being used in several kinds of applications varying from the health care, military, home, monitoring and industry. The prime objective of this book is to explore the current areas of research and challenges to be faced by different researchers. So, it can help the increasing number of scientists who depend upon sensor networks in some way. The book is organized into five parts, each part including chapters exploring a specific group of topics. The first part of the books covers the topics related to algorithms, protocols, communication strategies and data aggregation in wireless sensor networks (WSNs). The second part of the book is composed of topics related to energy conservation and management in WSNs. The third section of the book includes the chapters related to security and QoS in WSNs. Some of the useful applications of WSNs are covered in section four. Finally, the advancements on wireless sensor networks are included in section five. Book contains total 33 chapters.

The main readers of this book are expected to include the scientists, scholars and researchers in the field of computer science engineering and communication engineering; along with this, it is going to be very useful for the UG and PG students who are studying the wireless sensor networks as an elective or core course. Specialists, as well as student readers will find all the articles encouraging and helpful for their projects.

The main objective of this edited book is to concentrate on all aspects of current and future research directions related to the wireless sensor networks. Number of novel techniques that lead to future improvements in the area of wireless sensor networks are also included.

We would like to extend our sincere thanks to all the reviewers for providing the constructive feedback for the improvement of the quality of chapters. We also acknowledge the several authors who have contributed their chapter in this edited book. We are thankful to Dr. Thomas Ditzinger, Editorial Director, Interdisciplinary and Applied Sciences, Engineering, Springer, for his constructive comments for the

improvement of this book project. Finally, we would like to express our special thanks to Prof. Janusz Kacprzyk, Editor, and AISC Springer Series for believing in us and providing us constructive feedback during the approval of the book proposal.

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**An Introduction on WSN Algorithms,  
Protocols, Communication Strategies  
and Data Aggregation**



# Introduction on Wireless Sensor Networks Issues and Challenges in Current Era

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## 1 Introduction

Wireless Sensor Networks (WSNs) issues and challenges in current scenarios, covers the latest principles of WSNs, algorithms, protocols, architectures and technological advancements across all aspects of sensor systems, including the security and synchronizations related considerations. Here, an attempt has been made to identify the latest developments in the area of wireless sensor networks. Chapters of this book cover the recent advancements from architecture to protocols design, algorithm development, security issues, QoS parameters, to advance topics, including Internet of things, fusion and use of artificial intelligence for WSNs, one by one, in separate chapters. At the end of each chapter, future challenges are summarized, to help the researchers along with some challenging topics that can be taken as topics of their future research. This book is organised into five parts. Part 1 covers the latest developments in term of features, platforms, standards, algorithms, protocols, communication strategies and data aggregation issues in WSNs. Part 2 presents topics related to energy conservation and management in WSNs. Part 3 describes security & quality of service (QoS) requirements in WSNs. Several applications of WSNs are discussed in Part 4. Finally, Part 5 concludes discussion of advanced topics on WSNs, including use of IoT, data mining and fusion approached along with application of artificial intelligence in smart cities.

The scope of our book is to cover the recent issues and challenges specific to WSNs only. Prime objective of the book is to cover the recent developments. Numerous protocols and modification in architectures came into existence for WSNs due to change in day to day technological requirements along with the support of better communication channel bandwidth (4G&5G). This book covers the most recent technological advancements in the area of WSNs and also identifies the major issues and challenges for WSNs. It will help scholars, academicians, students, working in the area of WSN, to further lead their work and may serve as an essential reference material.

## 2 Summary of Book of Chapters

Let us now summarize content of all 33 book chapters, including this, introductory, chapter. There are eight chapters in the first Part of this book. Current chapter provides an overview of all chapters in the book, and an overview of wireless sensor networks and summary of current issues and challenges. Second chapter delivers a detailed overview of WSNs and their applications in smart grid, transportations, smart homes and smart agriculture along with the integration of internet of things (IoT). These two chapters can be seen as an overview and foundation for the remaining material.

Third chapter of Part 1, is focused on Medium Access Control (MAC) Protocols for Wireless Sensor Networks (WSNs). MAC is responsible for controlling access to the common wireless medium. Depending upon the type and level of information processed by MAC, coordination among the nodes is another big challenge, in terms of local and global aspects. Energy efficiency is still the open challenges, while designing the MAC protocol, due to limited energy capacity of sensor nodes. MAC protocol should also support the variations, in terms of network size, network topology and node density during scalability. In addition to this, fairness, bandwidth utilization of network, minimized latency and gain in throughput are also the significant features in the design of medium access control protocols for WSNs. Author has also considered the latest progress in cognitive radio research and developments, in the context of the design of MAC protocol for WSNs. This chapter reports two methods that are being used during MAC implementation; (i) first is based on the use of microcontrollers and RF communication modules, while (ii) the second method is based on implementation of full system on a single chip. As far as the first method for MAC is concerned, the microcontroller runs a RTOS or devoted software and usages the communication protocols to manage RF peripherals, on the other side all characteristics and functionalities of the WSN may be implemented on a single chip.

Fourth chapter is entitled “Performance of energy and distance based modified threshold for LEACH”. Author focuses on saving the energy to improve the network lifetime in WSNs. Emphasize is given on cluster head selection scheme, which is important to save the transmission energy. This chapter discusses the threshold conditions for selection of cluster head to save energy using improved LEACH. Simulation results deliver clear evidence of satisfactory lifetime extension with change in the density of nodes.

Fifth chapter considered the MAC Protocols for Mission Critical Applications using WSNs. Initially the review on existing MAC protocols and their mechanism is carried out. Thereafter, authors have identified the need for mission critical MAC protocol requirements. Next section of the chapter, covers use of matrices for performance analysis including a case study. Finally author has discussed the integration of machine learning algorithm for MAC protocol followed by recent issues and challenges for the MAC protocol.

Sixth chapter is entitled “QoS Routing for Data Gathering with RPL in WSNs”. This chapter reports on two key issues; “(i) tools using traffic engineering (TE) to manage the packet forwarding, and (ii) QoS aware routing to compute routes offering the asked guaranties”. Initially the issues related to QoS constrained routing are taken into account, followed by routing in WSNs. Routing Protocol for Low-Power and Lossy Networks (RPL) is reported as a better solution and QoS aware routing using RPL. It is identified that, in future simple multi-parent solutions using RPL, handling uncertainties by multi-path and opportunistic routing should be explored. Coupling of routing with traffic engineering is still an open research issue.

Seventh chapter covers a comparison of Neural Network Training Functions for RSSI based Indoor localization Problem in WSNs. Performance of eleven types of training function is analysed, for feed forward neural network, for the RSSI-based indoor target localization in WSNs, in terms of Average Localization Error. Based on performed analysis, it is found that Levenberg-Marquardt (LM) based FFNT implementation gives better results and is more consistent in providing quality location estimates.

Eighth chapter is entitled “Performance Assessment of the Fixed Node Assisted Col-lection Tree Protocol (FNA-CTP) in a Mobile Environment”. In an indoor sport field, using tinyOS, FNA-CTP algorithm is applied on a set of sensor nodes. Exciting part of the analysis done in the chapter is that CTP outperformed FNA-CTP in the field experiments, on the contrary to the simulation results that showed exactly the opposite. Authors have also included the experimental challenges during data pre-processing and capturing packets by a sniffer in the field and at the sink as well.

Part 2 is composed of six chapters and covers issues related to energy conservation and management in WSNs. Ninth chapter of the book and first chapter under this Part is entitled “An Effective Analysis and Performance Investigation of Energy Heterogeneity in Wireless Sensor Networks”. Three level of heterogeneity are investigated for LEACH, SEP, DEEC, HEED, and PEGASIS. This chapter also highlights the benefits of the heterogeneous models, over the homogeneous ones, in term of WSNs.

In chapter ten, efforts have been put on “A Firefly Optimization Algorithm for Maximizing the Connectivity in Mobile Wireless Sensor Network”. Initial issues, related to the mobile WSNs, are discussed followed by related work on mobile WSNs. Experimental results have been shown for the FACM algorithm, using a MATLAB tool box. Proposed FACM algorithm has shown better and promising results as compared to the existing Firefly Algorithm (FA) algorithms.

Eleventh chapter is entitled “Energy conscious packet transmission in wireless networks using trust based mechanism: A Cognitive Approach”. This chapter discusses effectiveness of trust-based mechanisms for early detection of malicious nodes in WSNs. Authors have reported the summary of trust-based mechanisms, followed by contributions and gaps in trust-based mechanisms for WSNs. Finally a trust-based framework has been designed to identify the malicious nodes.

Twelfth Chapter is titled “Energy Distance Neighbourhood Based Weighted Hierarchical Clustering Algorithm”. This chapter reports a new algorithm “EDN”, which is based on a weighted scoring model, using the residual energy concept, and distance from the BS to neighbourhood stations, to further improve network lifetime. Proposed algorithm is found to be better in terms of network stability and longevity for WSNs.

Thirteenth has title “Recent Advances in Wireless Sensor Network for Secure and Energy Efficient Routing Protocol”. It summarizes state-of-the-art of secure and energy efficient routing protocols in WSNs. It discusses security requirements in WSNs and how different protocols are meeting these requirements.

In the similar direction of the previous chapter, the next chapter (number fourteen; entitled “Energy Efficient Routing Protocols for Wireless Sensor Network”) delivers a comprehensive coverage of parameter comparison of homogeneous and heterogeneous routing protocols in WSNs.

Part 3 of this book combines and covers topics related to security and QoS in WSNs. This Part contains total of seven chapters (numbered 15–21).

Chapter 15 is entitled “Low-cost architecture of the universal security threat detection system for Industrial IoT”. Here, the wired communication environment is reported for WSNs, from the algorithmic view point. Focal angels of results contained in this chapter are: intelligent data analysis and biologically inspired methods. Initially the industrial information systems architectural and security issues are discussed, followed by properties of the threat detection system and hardware architecture. Finally, reference vectors, k-nearest neighbours, neural networks and decision trees algorithms are analyzed in term of correctness, completeness and precision.

Chapter 16 is devoted to “SYLOC: hybrid key generation in sensor network”. It covers hybrid key generation approach to provide security in WSNs. The proposed approach is claimed to secure the network against the wormhole, sinkhole and sybil attacks.

Chapter 17 is written on the topic “Diffie-Hellman Algorithm Pedestal to authenticate nodes in WSNs”. Author focuses on use of authentication key, to bring security in the network. Diffie-Hellman Algorithm is used for generating the keys. Proposed technique has minimized the forge and replay attack and it also conserves the energy with improvement in reliability of the network.

“Privacy Aware prevention of Sybil Attack in Vehicular Ad Hoc Networks” is discussed in Chapter 18. This chapter applied the public key and symmetric key encryption for securing the communication path in VANET. Token based scheme is used in clusters to detect the attackers, whenever two identical token are spotted the algorithm revokes access to other vehicles in the cluster.

In order to gain insight to security in the area of the Internet of Things (IoT), Chapter 19 is devoted to “Key Management Schemes in Internet of Things: A Matrix Approach”. This chapter gives overview of matrix based key management schemes in IoT, followed by security mechanisms to secure the communication channel. BLOM’s, CARPY, Kronecker Product and pair wise key management schemes are covered and compared.

Chapter 20 concerns “Black Hole Attack and Its Security Measure in Wireless Sensors Networks”. This chapter mainly focuses on black hole attack, along with security measures that can be applied in this case. Author discusses various attacks in WSNs, followed by analysis on common attacks at various layers in WSNs. Finally, power variation with attack and with security is analyzed in the network.

The last chapter of Part 3, Chapter 21, is entitled on “Detection and Tracking of Mobile Intruder in Harsh Geographical Terrains using Surveillance Wireless Sensor

Networks”. This chapter summarizes issues related to several real-time challenges for WSNs in intruder detection and tracking.

Part 4 is devoted to applications of Wireless Sensor Networks (WSNs) and it is composed of five chapters (22 to 26). First chapter of this Part covers the opportunities and challenges with Wireless Sensor Networks (WSNs) in smart/precision agriculture. Specifically, it is focused on three main issues; (i) what are the possibilities of use of WSN and IoT in agriculture? (ii) what are the newly developed sensors, to be used for making smart agriculture a revolution? and (iii) what are various issues and challenges researchers may face, when they are working with WSN in agriculture? Discussion covers data analytics in decision making for prediction of agriculture related attributes. In addition, hardware deployment and resistance of hardware to environmental factors as well as data storage, data security and deep analytics, device management from the remote sensing techniques, sensors deployed in field and for images received from drones are discussed.

Chapter 23 is on “Detection and Monitoring of Forest Fire using Serial Communication and Wi-Fi Wireless Sensor Network”. NodeMCU an open IoT based platform is used for forest fire detection. A domain specific case study shows how the data is collected. Thereafter, implementation challenges for the forest fire system are reported.

Next, Chapter 24, is entitled “Application of Supervised Learning Approach for Target Localization in Wireless Sensor Network”. It compares localization performance in terms of supervised algorithms, using Generalized Regression Neural Network (GRNN), Multilayer Perceptron (MLP), Radial Basis Function Network (RBFN), and Feed Forward Neural Network (FFNT), for the WSNs indoor localization. Overall, the proposed GRNN-based localization algorithm is found to perform better than the other algorithms.

In next two chapters, efforts have been put to discuss interesting applications of WSN and IoT. Chapter 25 is devoted to “Implementation of Automated Aroma Therapy Candle Process Planting Using IoT and WSN” while Chapter 26 concerns “Implementation of Automated Retractable Roof for Home Line-Dry Suspension Area Using IoT and WSN”. In both chapters, specific applications are discussed, with attention paid to WSN aspects of developed solutions.

Last Part of this book is focused on recent advancements of wireless sensor networks. This Part contains total of seven chapters (27 to 33). Chapter 27 deals with “IoT enabled Air Pollution Monitoring in Smart Cities”. The proposed solution may be useful for the current time for smart cities as it delivers real-time pollution matrices for better control. In the next Chapter (28), author discusses use of data mining and fusion techniques, applied to WSN data, for better event prediction. Specifically, data analytics are used to predict the forest fire with better accuracy.

Chapter 29 deals with “Internet of Things for Enhanced Living Environments, Health and Well-being: Technologies, Architectures and Systems”. Here, the focus of presented work is on human-centred use of IoT in different areas of day-to-day life. Moreover, detailed summary of technologies, architectures, and systems utilizing IoT in Ambient Assisted Living (AAL), for enhanced living environments, is presented. Future challenges, in terms of implementation of such systems, are also added.

Chapter 30 concerns “Energy Efficient Data Collection in Smart Cities Using IoT”. As data size is rapidly increasing, in almost every application area, and in smart cities

in particular, energy efficient data collection is one the key requirements. This chapter reports on one of efforts focused on exploring challenges during data collection, for various applications in an energy efficient way, using WSN within IoT as applied to smart city scenarios.

Chapter 31 is entitled “A Review on Hybrid WSN-NGPON2 Network for Smart World”. There, it is claimed that several shortcomings of WSN may be overcome using the passive optical network (PON). Next generation passive optical network stage 2 (NG-PON2) is considered as an improvement over the WSN, in terms of higher data rate and better Quality of Service (QoS) at low cost.

Chapter 32 shows one of the new directions of research concerning “Internet of Things in Forensics Investigation in Comparison to Digital Forensics”. A detailed comparison, in term of set of steps involved in the investigation process in digital versus IoT forensics is presented.

As artificial intelligence is one of the popular area of research and is used in various application focused on betterment of life, combining use of AI and WSN, is the topic of the last Chapter (33) of this book (“A Review on The Artificial Intelligence Algorithms for The Recognition of Activities of Daily Living Using Sensors in Mobile Devices”). Specifically, recognition of Activities of Daily Living, on the basis of data available in mobile devices is analysed and associated challenges identified.

### 3 Open Research Challenges for Wireless Sensor Networks

Wireless Sensor Networks (WSN) consists of self-organized network of large number of distributed sensor nodes. The sensor nodes are resource constrained, application oriented, and comprise a dynamic topology. The major research in the field of sensor networks concerns: architecture, operating system(s), deployment, localization, data aggregation, Quality of Service, and security [1]. In addition to the unreliable communication within the sensor network, there exist also other challenges, such as nodes in the WSN that have to work with the limited energy, memory, computation, and limited processing capacity [3]. This section highlights some of the key current research challenges in the area of WSNs.

#### 3.1 Challenges of WSNs in Terms of Design

WSNs are more challenging, due to the lack of resources such as limited battery, bandwidth and processing power [2, 4]. The following design requirements should be considered by the designers of WSN-based ecosystems.

##### a. Energy Efficiency

Shortage of energy is major issue in sensor networks, as most of the WSNs are powered through batteries. The performance of the network is badly affected when the battery of a sensor device is depleted. The WSNs consist of thousands of energy constrained sensors that are deployed for an application; thereby designing an energy efficient routing protocol it is the foremost requirement. Here, energy conservation has to include all aspects of the system, each one of them separately, and their interactions.

**b. Complexity**

The second design issue is the complexity of routing protocols. Too complex routing protocols may affect adversely the performance of the sensor network. However, protocols that are too simplistic may not be able to effectively deal with complexity of ecosystems. Here, note that, heterogeneous capabilities of existing hardware, and pronounced energy constraints are the reasons for the complexity of deployed WSNs. Therefore the right balance needs to be found to effectively deal with complexity, while not degrading WSN performance.

**c. Scalability**

The routing protocol must support scalable network deployments, because sensors are getting cheaper. As a result very large numbers of sensors can be easily deployed in WSNs-based ecosystems. Moreover, when ecosystems are to be merged, to deliver novel services, sizes of resulting WSNs may even double at a moments notice. The addition of any number of sensor nodes into a network, at any time, should be supported by the WSN protocol.

**d. Real Time Challenges**

Sensor nodes collect sensed information of the environment and have to deal with practical environments. The sensed information must be delivered within a certain (restricted) time so that the necessary action can be undertaken. Here, some applications may even require an instant response, without any delay. Examples of such situations are fire detection, weather monitoring, etc. Therefore, a routing protocol in WSNs should offer minimal delay in terms of sensor stream processing. The time required to transmit sensed information should be as minimal as possible and this remains a considerable challenge for WSNs applications.

**e. Robustness**

The real time applications of WSNs may require deployment of sensor nodes in harsh and non-typical environments. There is also a possibility that sensor node(s) may expire, or leave the network, during ecosystem lifetime. Therefore, a node must be adaptable to such conditions including severe and harsh environments. So, the adaptability and dynamic routing are two big challenges. Note that this means also that more research on autonomy and self-\* WSN ecosystems is needed.

**3.2 Challenges of WSNs in Terms of Architecture**

The architecture of the WSNs is one of major reasons, which limits the progress of sensor networks. The architecture of network may be referred to as basic building blocks for the implementation of functionalities, along with the set of interfacing devices, routing protocols, functionalities and basic hardware. The software architecture addresses a bridge among the raw hardware and the other system. The continuous monitoring, data encoding and its transmission required to be calculated in parallel. Additionally, the sensor events, and calculation of data, should be processed continuously along with the progress of communication. The topological changes for the durable and scalable architecture must require only a minimum transmission of updating messages across the network. The system should be flexible enough to serve wide range of applications, as the WSNs can be realized using different communication protocols. The architecture must also facilitate accurate control over the transmission timing of a

channel. This condition is motivated by the requirement of ultra low communication power for the collection of data. An efficient WSN architecture must increase the speed of data path and rate of radio transmission because the energy performance of a network depends on the processing speed and the communication rate [3].

### 3.3 Challenges of WSNs in Terms of Network Layer

In the past decade, sensor nodes have been built to serve specific applications. Network layer is responsible for routing the sensed data from the sensor node to the base station [5, 15]. The current issues related to network layer for WSNs are as follows:

1. The power efficiency is the major issue for the transmission of collected information. It is a challenge in network layer to discover the efficient route for the transmission of data, such that the lifetime of the ecosystem (consisting of a large number of battery operated devices) can be optimized.
2. The routing protocol should consider multiple path design procedure. In case of primary route failure, the data can be transmitted to the base station through the alternative path.
3. The maintenance of route is also of major concern as, in case of node breakdown, the routing algorithm must be capable of finding new possible path for data transmission.
4. In order to minimize the power consumption, a sensor network must provide flexible and adaptable platform for performing the path discovery and its management.
5. The design must overcome redundancy which is significant among each node in order to make good use of bandwidth and improving power efficiency.

### 3.4 Challenges of WSNs in Terms of Transport Layer

The transport layer is responsible for providing end-to-end reliable communication. The transport layer fragments the data into packets at the transmitter and defragments them at the receiver. It is the foremost requirement for a transport protocol to guarantee the ordered transmission of segments for reliability. This layer should be reliable enough for delivering packet to several sensors, at any condition. The low bandwidth availability may results in congestion, which further results in loss of packet. The communication among nodes, and with base station, may get affected because of two reasons: (1) the predetermined placement of sensor nodes and (2) external factors, which result in poor communication [6].

### 3.5 Challenges of WSNs in Terms of Data Aggregation and Data Dissemination

Data aggregation is the process of collecting data from several sensors and transmits it to the base station for processing in an aggregated form. The sensor node senses environmental parameters and transmits information to the sink or to the base station periodically. The regularity of reporting data to the base station is application specific. The

information, collected from the sensors, may be redundant and too large for the base station to process it. Therefore, aggregation of data is a method to process such huge amount of data into smaller and need-specific information by converting sensed data to high quality information using queries. Data aggregation is the procedure for combining sensed information and facilitating analysis of the sensed environment [7, 17].

The major challenge for data aggregation is the unreliable nature of sensor networks. The unavailability of required data, obtained from the deployed sensor, or an incomplete information, which is obtained from the responding sensors are a norm, rather than an occurrence. The protocol must be designed to consider the redundant data, which needs to be eliminated for reducing power consumption. The improved clustering techniques must be utilized to conserve the sensor power. On the other hand, the process of inserting and routing data, and other queries, across the network is data dissemination. Data dissemination is carried out in two steps. Initially, if some data is inserted in a node, it broadcasts the updating message into the network. In next step, the node that requires data will send request back to the source node [8, 9].

### 3.6 Summary

The advancement in wireless sensor networks has created next generation of open challenges, which still need addressing. They need to be addressed not only as a result of curiosity, but also for the development of the next generation of WSNs-based applications. In this section we have discussed some of the current design issues and challenges associated with the WSNs. It should be noted that WSNs are an emerging field which acts as the key tool for making the life more comfortable and safe. This is clearly visible when one considers WSNs applications in smart cities [12, 13]. Moreover, design of wireless sensor networks for Internet of Things (IoT) applications becomes another challenging area. Here, merging of existing IoT deployments into next generation of IoT ecosystems will bring about all kinds of scalability challenges. This, in turn, will require integration of WSNs with 5G technologies (and, later 6G) within community/city/state/country-wide deployments; resulting in challenges that we only start to envision. In this context, it has been identified that cross layer architectures must be designed, to integrate the IoT and WSNs, and to support the 5G technologies [10]. Adoption of WSNs to edge-fog-cloud continuum-based infrastructures is another area where a number of open research questions will have to be addressed. Again, some of these questions will become known only when such infrastructures will start to be deployed on large scale. Finally, we can conclude that in order to achieve the information centric networking, design of new security solutions is one the main challenging area for wireless IoT networks [11, 14, 16]. Already today, with relatively restricted use of WSNs the scale of security threats that will have to be addressed becomes visible, with steady stream of news of successful hacking attacks.

In summary, WSNs are the area where the research challenges that are already known, and that have been addressed in this book, are only a tip of the iceberg. We sincerely hope that reading this book, will bring more needed research efforts to the area.

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# Intelligent Applications of WSN in the World: A Technological and Literary Background

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**Abstract.** Where Wireless Sensor Networks (WSNs) have been widely considered to be an important technology in the 21st century, the group of specialized devices or sensors that are used to monitor different environmental conditions and collect and organize this data at some central location, detect and measure the number of physical conditions such as humidity, temperature, sound, pressure, speed and direction, chemical concentrations, vibrations, pollutant levels. As a tremendous application ranging from monitoring, surveillance, forest fire detection, and many other applications, it is, therefore, a promising technology for achieving energy-efficient, reliable and cost-effective flawless monitoring and control in smart grids. state-of-the-art infrastructure for greater efficiency, reliability, and security with harmonious integration of renewable energy and alternative energy sources through automation control and modern communication techniques. Advances in the field of communication networking are becoming a very interesting and challenging area of networking, with sensors deployed in everyday objects to capture everyday information such as humidity, temperature, heartbeat, motion, and others. With these sensors and microcomputers, the object for integrating the Internet set of things (IoT), becoming intelligent objects. Therefore, this chapter aims to provide an overview of the WSN application in the smart grid, in intelligent transportation, in smart homes, in the same way as Smart Agriculture, and the joint use with IoT and Smart Cities, showing and approaching its success relation, with a concise bibliographic background, categorizing and synthesizing the potential of both technologies.

**Keywords:** WSN · Smart homes · Smart Agriculture · Node · Sensor

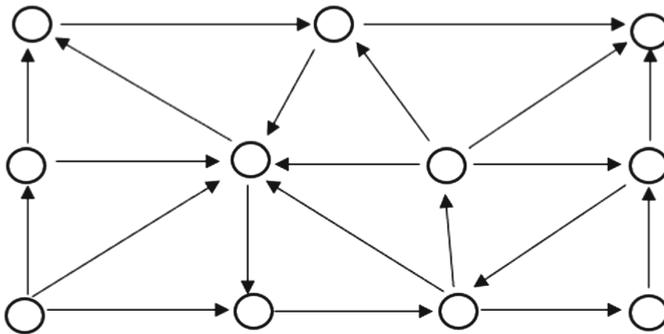
## 1 Introduction

Due to technological innovations in the fields of wireless communication, digital electronics, and micro-electro-mechanical systems, the world has seen a revolution in remote, focused and concentrated sensing for the development of wireless sensor networks (WSN). Wireless sensor networks (WSN) are a powerful monitoring tool in today's world, where this technology has been contributing from monitoring difficult-to-access locations to industrial process automation and is employed whenever network

cabling is complicated or difficult, high cost. Which can be characterized by the use of a large number of sensor nodes with the ability to communicate, where such nodes can be placed within or near the phenomenon to be analyzed, unlike traditional sensor networks, where the positions The relative values of each node are not predetermined or pre-calculated, they are random, since the deployment of sensor networks in hard-to-reach locations, and the nodes over the region to be analyzed [1].

The sensor node are standalone devices equipped with sensing, processing and communication capabilities, which implements the physical monitoring of an environmental phenomenon, which varies greatly by application, which generates measurement reports via wireless communication; which produces a measurable response to changes in physical conditions such as brightness, temperature, motion, humidity, magnetic field, among others. They can be understood as small and extremely basic computers in terms of interface and components, consisting of a processing unit with limited capacity, reduced memory, one or more sensors that pick up and recognize certain signals, a communication device, generally radio and a source of energy. When these nodes are networked in an ad-hoc mode, they form sensor networks, collecting data via sensors, processing locally or coordinated between neighbors, and transmitting this information, with tasks such as environment sensing, information processing, and tasks associated with it. traffic, among others [2–4].

Ad hoc networks are wireless networks that do not require the use of a common access point to the device connected to it, so that all devices on the network function as if they were a router, routinely routing information that comes from neighboring devices, as shown in Fig. 1 [3, 4].



**Fig. 1.** Ad-hoc concept

Thus, each node consists of sensor devices that have some computational power - memory and processor, which will be responsible for the operation of applications and the retransmission of messages throughout the network. In addition, they communicate over a wireless interface and have a certain power range, usually powered by batteries [2–4].

Conceptually, a WSN is composed of three basic entities which are sensor, observer and phenomenon, where based on the monitoring problem can be solved

using sensors scattered in an area await the occurrence of a phenomenon whose alert will be sent to an observer (be Police, Firefighters, Hospital, among others.) [3, 5, 6].

The technology behind WSN nodes is basically ultra-low-power embedded systems with sensing and communication capabilities (RF, IR, Ultrasound, etc.), which form a communication network, usually independent of a usual infrastructure; with their elements scattered/thrown at the place of interest; where the number of elements can be tens, hundreds or thousands of sensors. Therefore, these positions in these particular places of interest should be addressed by the communication and network management protocols, making these protocols a vast field for research, and communication between these nodes is done through an ad-hoc wireless network, where one node is transmitting the sensing values to another node nearby. This next node should be in charge of passing the data to the next node, and so on. The idea is to take advantage of devices so small and relatively inexpensive that they can be used on a large scale [7, 8].

In addition to sensing, sensors perform data processing and communication between components. WSN features improvements over traditional sensors, which feature hardware with computational power, need and processing power; along with signal acquisition, digital-analog conversion; energy acquisition and management, still counting on low consumption; its sensors have communication and efficiency, spectrum use and low consumption; synchronous medium access; routing techniques; data collection and sending [3, 8, 9].

Sensors can be positioned away from the event to be monitored, leading to large and complex sensors. Where many sensors are placed close to the event to be monitored, only sending the values to a processing center, which requires a very careful study of the communication topology and proper methods for each application should be developed. In a common WSN architecture, measurement nodes are deployed to acquire measurements such as temperature, voltage, or even dissolved oxygen. Where nodes are part of a gateway-managed wireless network that governs aspects of the network such as client authentication and data security. This gateway collects the measured data on each node and sends it over a wired connection, typically Ethernet, to a host controller. The idea is to take advantage of devices that are so small and inexpensive that they can be used on such a large scale to enable many different types of applications [10–12].

A WSN is by nature data-centric, unlike traditional address-centric networks, but similar in this respect to faithful bus-type wired networks, such as a CAN, where a node broadcasts/requests attribute-based information (either temperature range, vibration levels, spatial location, speed limit, among others). Also having a feature that sensor nodes are expected to meet specific application requirements, it is common to meet a single attribute or, at most, a few combined attributes (detection of a vehicle on the street, or at an intersection, being attributes speed and direction), which will imply processing capacity within the network. Another feature, also derived from the low price per sensor and, consequently, its high availability, will certainly be the formation of dense and very large-scale networks, with little care and installation costs, generating a saturated distribution of nodes present in a given environment. monitor/analyze a particular aspect, taking advantage of a high degree of redundancy and availability [3, 13, 14].

Whereby linking high availability and data orientation it is possible to generate data aggregation on sensor nodes determined by interactions located between nodes sharing the same neighborhood and programmed to reduce traffic, resulting in energy savings, being possible to coordinate sensing and direct interests; data propagation by interest, restricting or directing data transmission according to rules and based on previously cached data; path reinforcement mechanisms, with rules for deciding when and how to enforce propagation messages [14, 15].

WSN has been attracting a lot of attention because of the challenges and the wide variety of possible applications, research and investments in the area are constantly growing, allowing the evolution of the technologies involved. Where the pursuit of ever smaller and lighter sensors draws studies to the search for technologies and protocols that allow sensors to communicate more and more efficiently, use less and less power and require less and less processing power [3, 14, 15].

Therefore, this chapter aims to provide an updated review of Wireless Sensor Network, showing and approaching its success relation, with a concise bibliographic background, categorizing and synthesizing the potential of both technologies.

## 2 Methodology

This study was based on the research of 66 scientific articles and books that address the theme of the present work, exploring mainly a historical review and applicability of techniques related to Wireless Sensor Network (WSN). These papers were analyzed based on the publication date of fewer than 5 years, with emphasis on publications with date greater than 2014 as well as publications and indexing in renowned databases, such as IEEE and Scholar Google.

## 3 Results

A Wireless Sensor Network is a wireless network consisting of spatially distributed standalone devices that use sensors to monitor physical or environmental conditions. These standalone devices, or nodes, are used with routers and a gateway to creating a typical WSN system where these distributed metering nodes communicate (wirelessly) with a central gateway which provides a wired world connection where you can measure, process, analyze and present your collected data. To increase the distance and reliability of a wireless sensor network, it is possible to use routers for an additional communication link between the end nodes and the gateway [3, 16].

WSN can be defined as a communication network formed by autonomous, spatially distributed sensing devices, cooperating in the monitoring of physical or environmental variables. Being the devices in this network presenting great memory, processing capacity and communication bandwidth constraint. The expansion of this technology was catalyzed by the cost reduction of microcontrollers, the miniaturization of RF transceivers, and the development of miniaturized sensors by MEMS (Micro Electro-Mechanical Systems) technology. Related to the battery life of network devices, being essential in home and building automation applications, having less importance in

industrial automation, and with features that the nodes are powered by the power grid. It has the benefit of cable elimination, which contributes to reduced installation cost while still considering fault tolerance characteristics and increased coverage when new nodes are inserted [17, 18].

The **communication** between two nodes is performed using radiofrequency, where a node sends a message in the middle and all nodes within range can receive it, we call this technique Broadcast. This type of communication is very influenced by the geography of the place, and messages may be lost. Sensor nodes can be configured to transmit information periodically or by exception and routers must always be active to forward messages. While sensor nodes must meet application-specific requirements, very often nodes focus on just one attribute, or a small set of attributes, and thus require processing within the network. The restrictions imposed on the wireless sensor network imply a series of requirements for communication protocols never before encountered at such a scale, and as a consequence of their characteristics, network management and communication protocols must have self-organizing capabilities promptly [15].

Sensor nodes must be inexpensive and small in size, which makes them unreliable, so the network must be fault-tolerant. Failures can occur for a variety of reasons: power outages, lack of visibility to another network node, or physical damage, and the network must be able to perform its tasks even with the loss of some nodes. Fault tolerance levels will determine different network control algorithms. Where your level of **fault tolerance** will depend on the environment and application, the network control algorithm also depends on these same factors [15, 19].

The fact that nodes have low cost and minimized size as their basic attributes contribute to the formation of dense networks and results in **scalability**, requiring little care and installation costs. With dense networks, a high degree of data redundancy and availability is achieved, which can be seen as a problem, but one that we should take advantage of. Thus, data aggregation on sensor nodes is of great importance for energy savings, through reduction of traffic, for example, coordination of sensing and targeting of interests, being determined by interactions located between nodes that share the same neighborhood. Some typical functions of sensor nodes are determining the value of a parameter at a given location; event detection and estimation parameter values as a function of the detected event; classification of a detected object; trace of an object. Thus, WSNs have obvious advantages over wired networks because they eliminate high cabling costs and can be deployed in hard-to-reach locations over the area to be analyzed [19–21].

WSN has a large number of nodes due to its related production cost to make installing such a network feasible and preferable over a traditional sensor network. **Energy** is seen as the crucial factor in a WSN, as power sources are limited, since sensors are microelectronic devices, sensor nodes must cooperate with each other in order to transport data efficiently in terms of spending power. Communication is the main energy consumer, with data transmission consuming even more than reception. Thus, one should also explore local adaptive algorithms that are not based on interaction or global information, avoiding energy expenditure by handling a very large information load [22].

Nodes should automatically adapt to the environment and can be dormant when not needed to save energy, as well as become operational and may need to automatically