Internet of Things

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Purnima Lala Mehta *Editors*

Smart Sensors for Industrial Internet of Things

Challenges, Solutions and Applications

Springer

Internet of Things

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Dr. Deepak Gupta would like to dedicate this book to his father Sh. R. K. Gupta and his mother Smt. Geeta Gupta for their constant encouragement, his family members including his wife, brothers, sisters, kids, and to his students close to his heart.

Dr. Ashish Khanna would like to dedicate this book to his mentors Dr. A. K. Singh and Dr. Abhishek Swaroop for their constant encouragement and guidance and his family members including his mother, wife, and kids. He would also like to dedicate this work to his (Late) father Sh. R. C. Khanna with folded hands for his constant blessings.

Dr. Purnima Lala Mehta would like to dedicate this book to the almighty, her teachers, family, and friends, and to her dear students.

Foreword

I am very much delighted to have been invited to write the foreword for this edited book on *Smart Sensors for Industrial Internet of Things*. The title of the book itself is self-explanatory and very interesting. This book highlights very important concepts related to the theory, design, and applications of the industrial smart sensor technology, which have advanced the fields of sensors and the industrial Internet of Things. This book is multidisciplinary in nature that includes different applications of the monitoring system.

With the rapid growth of connected technologies, the industrial world is transforming in a trend that conforms to several headlined names including the fourth industrial revolution, smart manufacturing, and industrial Internet of Things (IIoT). Industry 4.0 is a hot topic since it was first introduced, and which primarily focuses on the automation of factories and the implementation of IoT in industries. It enables industrial advancements with the help of advanced computing, analytics, low-cost sensing, and new levels of connectivity enabled through the Internet. Some of the technologies supporting this new form of industrial revolution are cloud services, big data analytics, and pervasive, intelligent, sensing technologies.

In modern industry, productivity, quality, reliability, and safety heavily depend upon the performance of the sensors employed. They form an interface between the production equipment and the surrounding environment providing feedback based on the results of the executed operations. The significant benefits of using intelligent sensing technology in industries are accuracy and consistency, which enable functions such as picking, placing, labeling, and printing to be performed at higher production rates, leading to low wastage, minimal downtime, and better quality control. These capabilities have made industrial smart sensors capable of more complex data processing enabled within the sensor unit while being independent of PLC. Given these abilities, it is quite certain that the manufacturing industry majorly depends on smart sensor devices in ensuring the accuracy and efficiency of the source data and eventually will hinge on the reliability of the information for the process chain. These days, two trends are extremely popular in researching and developing sensors. First is developing integrated sensors, which is inclined to supplying an advanced level of information by directly estimating the sensed data. Second is the augmentation of multi-sensor systems, which allows huge quantities of data to be acquired in the system.

This book provides a window to the research and development in the field of smart sensors and the industrial Internet of Things in a comprehensive way. The advances and challenges are discussed with a focus on successes, failures, and lessons learned, open issues, unmet challenges, and future directions. The contributions in this book cover a wide range of interdisciplinary areas including Internet of Things and its applications in smart sensors, industry 4.0, autonomous vehicles, future of mobility, intelligent transport systems, auto-braking accidental detection system, healthcare, artificial intelligence, cloud teleophthalmology, agriculture, monitoring systems, renewable energy, security, smart homes, real-time data collection, data management, systems design/analysis, web services, and other industrial applications. This book contribution emphasizes several topics in the area of smart sensors in industrial real-world applications.

I highly recommend this book to a variety of audiences, including numerous researchers working in the industrial smart sensor technology. This book is primarily intended for researchers from academia, and industry, who are working in the research areas such as sensor technology, system design, computer science, electronics engineering, wireless communication, IoT, big data, monitoring systems design, and information technology. It is my hope and expectation that this book will provide an effective learning experience, a contemporary update, and a practical reference for researchers, professionals, and students that are interested in the advances of sensor technology and its integration to the industrial Internet of Things.

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Preface

We are delighted to launch our book entitled *Smart Sensors for Industrial Internet of Things* that aims to attract a number of amateur researchers, engineering practitioners, academicians, scientists, scholars, and industry delegates with the respective book chapters. The book received plentiful abstracts from different parts of the world, and assured selection procedure was conducted to maintain the research standards. The book is composed of 18 full-length chapters in this volume. All the chapters submitted were peer reviewed by at least two independent reviewers, who were provided with a detailed review pro forma for evaluating each chapter. The valuable comments and suggestions from the reviewers were communicated to the authors and provided with their revised manuscripts. The exhaustiveness of the review process is evident, given the large number of articles received addressing a wide range of research areas. The stringent review process ensured that each published chapter met the rigorous academic and scientific standards.

We would also like to thank the authors of the published chapters for adhering to the time schedule and for incorporating the review comments. We wish to extend my heartfelt acknowledgment to the authors, peer reviewers, committee members, and production staff whose diligent work put shape to this volume. We especially want to thank our dedicated team of peer reviewers who volunteered for the arduous and tedious step of quality checking and critique on the submitted chapters.

Lastly, we would like to thank Springer for accepting our proposal for publishing the volume titled *Smart Sensors for Industrial Internet of Things*.

Delhi, India — Deepak Gupta
Fortaleza, Brazil — Victor Hugo C. de Albuquerque
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About the Book

Smart Sensors for Industrial Internet of Things brings together the latest research in smart sensors technology and exposes the reader to myriad industrial applications that this technology has enabled. The book emphasizes several topics in the area of smart sensors in industrial real-world applications. The contributions in this book give a broader view on the usage of smart sensor devices covering a wide range of interdisciplinary areas like Intelligent Transport Systems, Healthcare, Agriculture, Drone communications, and Security. This book series will demonstrate that this new domain is an outstanding and significant domain that has a brilliant future.

The book reflects specific topics like smart sensors for industrial IoT, intelligent connected vehicles, green IoT, heart disease prediction, medical image classification, smart fitness diagnosis, Internet of drones, and so on.

By presenting an insight into smart sensors for industrial IoT, this book directs the reader to explore the utility and advancements in smart sensors and their applications into numerous research fields. Lastly, the book aims to reach through a mass number of amateur researchers, industry experts, researchers, scientists, engineers, and practitioners and help them guide and evolve to advance research practices.

Contents

About the Editors

Deepak Gupta is an eminent academician and plays versatile roles and responsibilities juggling between lectures, research, publications, consultancy, community service, PhD and postdoctorate supervision, etc. With 12 years of rich expertise in teaching and two years in industry, he focuses on rational and practical learning. He has contributed massive literature in the fields of Human-Computer Interaction, Intelligent Data Analysis, Nature-Inspired Computing, Machine Learning, and Soft Computing. He has served as Editor-in-Chief, Guest Editor, and Associate Editor in SCI and various other reputed journals. He has completed his postdoc from Inatel, Brazil, and PhD from Dr. APJ Abdul Kalam Technical University. He has authored/edited 33 books with national/international level publisher (Elsevier, Springer, Wiley, Katson). He has published 118 scientific research publications in reputed international journals and conferences including 56 SCI indexed journals of IEEE, Elsevier, Springer, Wiley, and many more. He is the convener and organizer of "ICICC" Springer conference series.

Victor Hugo C. de Albuquerque [M′17, SM′19] is a professor and senior researcher at the University of Fortaleza, UNIFOR, Brazil, and Data Science Director at the Superintendency for Research and Public Safety Strategy of Ceará State (SUPESP/CE), Brazil. He has a PhD in Mechanical Engineering from the Federal University of Paraíba, an MSc in Teleinformatics Engineering from the Federal University of Ceará, and graduated in Mechatronics Engineering at the Federal Center of Technological Education of Ceará. He is currently an Associate Professor of the Graduate Program in Applied Informatics of UNIFOR and leader of the Industrial Informatics, Electronics and Health Research Group (CNPq). He is a specialist, mainly, in IoT, Machine/Deep Learning, Pattern Recognition, and Robotics.

Ashish Khanna has 16 years of expertise in Teaching, Entrepreneurship, and Research and Development He received his PhD from National Institute of Technology, Kurukshetra. He has completed his M. Tech. and B. Tech. from GGSIPU, Delhi. He has completed his postdoc from Internet of Things Lab at

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Purnima Lala Mehta received her bachelor's degree and master's degree in the field of Electronics and Communications Engineering (ECE) from Bharati Vidyapeeth's College of Engineering for Women (BVCOEW), University of Pune, India, and Northcap University (formerly ITM University), Gurgaon, India, respectively. She has received her Doctor of Philosophy (PhD) degree in the field of "Wireless Cellular Communications through Aerial Drones" from Aarhus University, Denmark (ranked 141 by QS World Ranking). She has been working as an Assistant Professor since July 2012 and has around 8 years of teaching and research experience including international exposure at countries like Denmark, Germany, China, etc. Her research interests include the areas of Mobile Computing, Aerial Drone-Based Wireless Communications, Wireless Ad Hoc Networks, Millimeter Wave Communications, Future Generations of Communications, and Business Modeling. She has contributed her papers in multiple peer-reviewed conferences, journals, and books. For her astounding research work in Springer, she has been awarded "Franklin Quarterly Membership" by *London Journals Press*. She has been appointed as reviewer of SCI indexed journal *Wireless Personal Communications*, Springer, and has served as a Resource Person/Panel Speaker at a number of research events like IEEE 5G Summits, IEEE ANTS conference, etc. She has chaired and conducted multiple sessions in peer conferences including IEEE WPMC, Portugal.

Introduction

Deepak Gupta, Victor Hugo C. de Albuquerque, Ashish Khanna, and Purnima Lala Mehta

Abstract Sensors play a crucial role in capturing the measurements from the environment around and on computation produced results for further understanding and analysis of the environment. Sensors are vital for applications in a broad range of industrial operations. The book on *Smart Sensors for Industrial Internet of Things* brings together the latest research in smart sensors technology and exposes the reader to myriad industrial applications that this technology has enabled. The contributions in this book give a broader view of the usage of smart sensor devices covering a wide range of interdisciplinary areas like Intelligent Transport Systems, Healthcare, Agriculture, Drone Communications, and Security. By presenting an insight into smart sensors for industrial IoT, this book directs the reader to explore the utility and advancements in smart sensors and their applications into numerous research fields.

Keywords Smart sensors · Industrial Internet of Things · Transportation · Healthcare · Agriculture · Industry

1 Smart Sensors for Industrial Internet of Things

Sensors play a crucial role in capturing the measurements from the environment around and on computation produced results for further understanding and analysis of the environment. Sensors form a bridge between the production equipment and

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the surrounding environment [1]. Sensors are vital for applications in a broad range of industrial operations. The Internet of Things (IoT) usually refers to a worldwide network of interconnected heterogeneous objects and recently a new definition of IoT seen as a loosely coupled, decentralized system of cooperating smart objects [2]. Modern industrial wireless sensor networks (IWSNs) integrate the two main networks, i.e., wired and wireless sensor networks using mobile intelligences in smart factories [3].

The book on *Smart Sensors for Industrial Internet of Things* brings together the latest research in smart sensors technology and exposes the reader to myriad industrial applications that this technology has enabled. The book emphasizes several topics in the area of smart sensors in industrial real-world applications. The contributions in this book give a broader view of the usage of smart sensor devices covering a wide range of interdisciplinary areas like Intelligent Transport Systems, Healthcare, Agriculture, Drone Communications, and Security. This book series will demonstrate that this new domain is an outstanding and significant domain that has a brilliant future.

The book reflects specific topics such as smart sensors for industrial IoT, intelligent connected vehicles, green IoT, heart disease prediction, medical image classification, smart fitness diagnosis, Internet of drones, and so on. By presenting an insight into smart sensors for industrial IoT, this book directs the reader to explore the utility and advancements in smart sensors and their applications into numerous research fields.

The book is divided into application-based sections. The first is the Introductory section comprising two chapters, the second session deals with Transportation and Automobile vehicles comprising four chapters, the third section deals with Healthcare covering five chapters, the fourth section focuses on Agriculture and covers four chapters, and lastly, we present some Case Study chapters on topics like the Internet of Drones, Energy Harvesting, and Secure and Smart Homes. The following sections shall walk through a brief introduction to the individual book chapters.

2 Introduction

The second chapter titled "Internet of Things Concept and Its Applications" is an introductory chapter that starts with the basic concept of the Internet of Things (IoT), talking about the network interface and communication of physical objects, devices, and peripherals that can interact and exchange data between one another without depending on human interactions. The chapter covers IoT applications in the domains of Smart Grid, Solid Waste Management, Healthcare, Marine Environment Monitoring, and Protected Agriculture.

The third chapter "Smart Sensors and Industrial IoT (IoT)—A Driver for the Growth of Industry 4.0" discusses smart sensors in the field of industrial Internet of things (IIoT) and presents an analysis of changes that were initiated by applying smart sensors and IIoT in industry to connect technologies in industries, factories, households, and workplaces. The authors further emphasize on the impact of smart sensors and IIoT on the working of the manufacturing industry or business organization and are able to answer about the smart sensor for better understanding with underlying reasons why producers and consumers both are resistant to smart products.

3 Research Solutions—Transportation and Automobile

The first section of chapters dissertates the integration of smart sensors with vehicles supporting the concept of intelligent transport systems. Roadside safety measures and traffic controlling can benefit from multiple sensors deployed intelligent transport systems [4]. The fourth chapter "Smart Sensors for IIoT in Autonomous Vehicles: A Review" focuses on smart sensors for autonomous vehicles and discusses signal conditioning methods such as RF module, BTS, TPMS, capacitive balancing of humidity sensor (in HVAC) used in an autonomous vehicle, and industrial IoT implementation. The fifth chapter "Connected Vehicles—Intelligent Transport Systems" covers the connected vehicle (CV) technology along with an intelligent traffic system to aid in increasing the safety of people on the road. With respect to CVs, the authors have emphasized its benefits, applications, and challenges in this chapter. The sixth chapter "Connected Vehicles—Intelligent Transport Systems" deals with Connected Vehicles in Intelligent Transport Systems (ITS), and the authors present a design of a secure long-range decentralized network of vehicles [5]. In their proposed work, all the vehicles within the range of a kilometer will be able to communicate with each other to solve all the specified problems. In the seventh chapter, "Design of Auto-braking System for Accident Prevention and Accident Detection System Using IoT," the authors focus on decreasing the impact of a collision and establishing communication with the nearby hospital for providing necessary support to the victims during road accidents. Their proposed work is supported by simulations and can be used in any type and size of the vehicle.

4 Research Solutions—Healthcare

Smart devices are a future in healthcare, and smart sensors are essential for smart fitness devices and medical care units. Our next section of the book focuses on smart sensors in healthcare [6]. In the eighth chapter "IoT in Healthcare Perspective and Green IoT," the author presents a new approach to the conjoining of green IoT and healthcare IoT. With the proper usage of green resources, the greenhouse effect can be prevented from occurring. The ninth chapter "IoMT with Cloud-Based Disease Diagnosis Healthcare Framework for Heart Disease" presents the Internet of Medical Things (IoMT) that interlinks a collection of intelligent sensors on the patient's body to observe and interpret multimodal health data, including the patient's physiological and psychological signals [7]. The chapter proposes a new IoMT-based disease diagnosis healthcare framework for heart disease prediction using the BBO-SVM model. In the tenth chapter "Hyperparameter Optimization of Deep Neural Network for Multimodality Fused Medical Image Classification," the authors present a hyperparameter optimization of deep neural networks in multimodality fused medical image classification for medical and industrial IoT. A Multimodality Image Fusion Classification (MMIFC) is proposed in the chapter by the incorporation of image fusion, feature extraction, and classification techniques. The eleventh chapter "Cognitive IoT-Based Smart Fitness Diagnosis and Recommendation System Using 3-Dimensional CNN with Hierarchical Particle Swarm Optimization" proposes a cognitive IoT-based smart fitness diagnosis and recommendation system using a three-dimensional convolutional neural network with a hierarchical particle swarm optimization (PSO) algorithm and has been applied to check the health statuses of exercisers. In the twelfth chapter "IIoT with Cloud Teleophthalmology Based Age-Related Macular Degeneration Disease Prediction Model," a scalable cloud-oriented teleophthalmology structure by an Internet of Medical Things (IoMT) to detect the AMD has projected examination. A projected Optimal Generative Adversarial Network (OGAN) helps to investigate the images to find as well as to compute AMD disease severity. The experimental outcome through their proposal showed the superior performance of the proposed model over the compared methods by attaining a maximum accuracy of 98.03%.

5 Research Solutions—Agriculture

Smart agriculture, precision agriculture [8], and vertical farming [9] are a new age thing in the agricultural market with multiple applications utilizing smart sensors. In the thirteenth chapter of this book titled "Significance of IoT in the Agricultural Sector," the authors emphasize the significance of IoT in the agriculture sector and discuss the evolution, benefit, and uses of IoT in agriculture. The authors have further developed and tested an IoT-based smart irrigation framework dependent on the moisture level of the soil. In the next chapter, i.e., the fourteenth chapter, "Soil Moisture Sensor Nodes in IoT-Based Drip Irrigation System for Water Conservation," the authors present a new sensor network-assisted irrigation system and a rule-based analysis model that has been developed in this research work to enhance the efficiency of water usage. A smart irrigation system can be built with smart sensor networks for collecting field values and can be analyzed using rules for effectively watering the plants. The fifteenth chapter "Precision Agriculture Using Advanced

Technology of IoT, Unmanned Aerial Vehicle" focuses on the illustration and utilization of those advanced technologies for smart farming. Precision agriculture (PA) uses site-specific crop management concept based on measured data using sensors and data analytics to find the root cause of yield reduction. The sixteenth chapter "IoT-Based Brinjal Crop Monitoring System" uses a remote crop monitoring mechanism using LORAWAN in the greenhouse. The motive of this chapter is to enhance the traditional way of agriculture in rural areas with the help of a wireless sensor network using LORAWAN protocol.

6 Research Solutions—Case Studies

The next three chapters are part of specific case studies. The seventeenth chapter "Internet of Drones: An Engaging Platform for IIoT-Oriented Airborne Sensors" introduces the Internet of Drones (IoD) paradigm, and this chapter takes a walk in describing IoD and proposes a state-of-the-art architecture, and its applications, especially that are oriented to industrial IoT. The eighteenth chapter "A Novel Approach on Renewable Energy Harvesting Using the Internet of Things (IoT)" presents renewable energy harvesting using the Internet of Things by proposing an IoT-based system to distribute energy among the solar board. The control methodology is to drive two little DC engines with the goal that the sun picture is kept at the focal point of the four-quadrant photograph indicator detecting the sun position. The final paper of this book titled "Security and Surveillance at Smart Homes in a Smart City Through the Internet of Things" focuses on how security and surveillance are achieved in smart homes. Smart homes provide efficient management with minimum lifetime costs of hardware and facilities. They optimize things such as structures, systems, and services and also manage the interrelationships between these three.

7 Conclusion

To conclude, this book comprises eighteen papers that were selected after a peer review. The main objective of this book is to explore research work involving smart sensors in IoT and industrial IoT applications. The book covers a broad range of applications and scenarios, where IoT and IIoT technologies can be well understood and open more research areas and paradigms for the audience to adapt and follow. Lastly, the book aims to reach through a mass number of amateur researchers, industry experts, researchers, scientists, engineers, and practitioners and help them guide and evolve to advance research practices. We thank our readers and we hope that each chapter in this book gives ideas and deeper understanding into a variety of concepts and research paradigms.

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Internet of Things Concept and Its Applications

Prashant Ahluwalia and Nitin Mittal

Abstract In the current era of digital communication and networking, the term Internet of Things abbreviated as IoT has become very famous. The Internet of Things relates essentially to the network interface and communication of physical objects, devices, and peripherals that can interact and exchange data between one another without depending on human interactions or computer interactions. IoT applications promise to add enormous value to our lives. With newer wireless networks, superior sensors, and revolutionary computing capabilities, for its wallet share, the Internet of Things could be the next frontier in the race.

Keywords Internet of Things · Smart grid · Solid waste management · Healthcare · Marine environment · Protected agriculture · Cloud computing · Transmission Control Protocol (TCP) · Internal Control Protocol (ICP) · Global positioning system (GPS)

1 Introduction

The IoT research is in the early stages, and it has been given separate definitions by researchers. IoT comprises of two sentences: "Internet" and "Thing." "Internet" can be defined as "TCP/IP protocol-based global computer interconnection" and "Thing" is "an unrecognizable object." Thus, "Internet of Things" implies semantically a global network of interconnected objects that are uniquely addressable, based on the Transmission Control Protocol (TCP) and the Internal Control Protocol (ICP) Therefore, it is suitable to define the IoT as "things with identities and virtual personalities operating in smart spaces using smart interfaces to link and interact in social, environmental, and user contexts" [1]. IoT can also be defined at anytime, anywhere, anything, and anyone using any path or service as a link between individuals and things [2, 3]. This means addressing aspects such as convergence,

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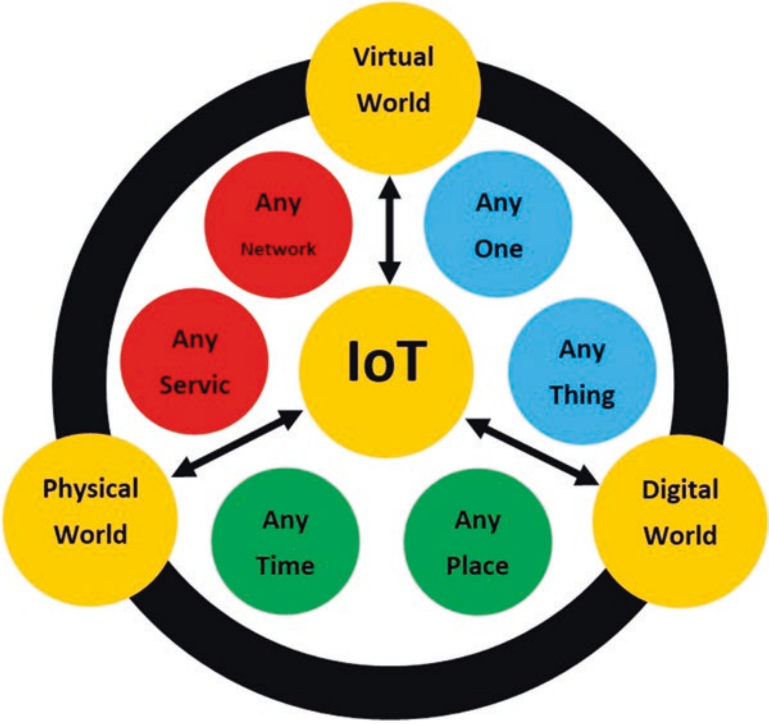

Fig. 1 Internet of Things (IoT) with its connections and related entities

content, collections (repositories), computing, interaction, and connectivity in a context where there is a seamless interconnection between people/humans and things and/or between things (see Fig. 1) [4]. Thus, IoT is a huge dynamic global network infrastructure of internet-enabled physical and virtual objects/entities with internet facilities that involves embedded systems and all sorts of information technologies such as global positioning system (GPS), infrared devices, scanners, RFID tags/devices, sensors, actuators, smartphones and the internet to be sensed, recognized, computing and so on. The International Telecom Union (ITU) published an IoT annual report [5], which extended the concept of IoT in 2005.

1.1 Vision

Today, IoT is used to indicate sophisticated device and service connectivity that extends beyond the traditional machine to include a range of protocols and apps.

There are three visions for IoT [6]:

1. Internet-oriented: it is necessary to create intelligent items in an internet-oriented vision.
2. Semantic-oriented: the amount of sensors accessible will be enormous in semantic-oriented vision and their collected information will be enormous. Thus, for better depictions and comprehension, the raw information must be managed and processed.
3. Things-oriented: in the vision of things, we can monitor any object using sensors and pervasive technology.

2 Characteristics

There are three important characteristics of IoT [7]:

1. Comprehensive sense: Using sensors to gather information from any object whenever and wherever.
2. Intelligent processing: Use cloud computing methods to evaluate enormous quantities of information for object control.
3. Reliable transmission: Accurate and real-time transmission of information via the Internet and communication networks.

3 Applications of IoT

The few applications of IoT are:

1. Smart Grid.
2. Solid Waste Management.
3. Healthcare.
4. Marine Environment Monitoring.
5. Protected Agriculture.

3.1 Smart Grid

The intelligent grid is proposed to tackle electricity grid problems (e.g., bad reliability, high power outages, high greenhouse gas and carbon emissions, economy, security, and energy security) [8]. One of the smart grid ideas is that the smart grid (SG) is a communication network at the top of the energy grid that collects and analyzes information from various energy grid parts to predict the supply and demand that can be used to manage energy [3].

Some of the required functionalities to deploy the smart grid are as follows [9]:

1. *Communication networks*: public, private, wired, and wireless communication networks that can be used as the communication infrastructure for smart grid [10].
2. *Cyber security*: policy-making to guarantee the availability, integrity, and confidentiality of communication and control systems required to manage, operate, and protect intelligent grid infrastructure [11].
3. *Distributed power resources*: use of different kinds of generation (e.g., renewable energy) and/or storage devices (batteries, bi-directional plug-in electric vehicles) connected to distributed systems [12].
4. *Management of distribution grids*: attempt to maximize the performance of parts in distribution systems such as feeders and transformers and integrate them with transmission systems, boost reliability, boost the effectiveness of distribution systems and enhance the management of distributed renewable energy sources [13].
5. *Electrical transport*: integration of large-scale plug-in electrical vehicles [14].
6. *Energy efficiency*: To provide processes for distinct types of clients to change their energy consumption during peak hours and to optimize the equilibrium between power supply and demand [15].
7. *Energy storage*: the use of techniques for direct or indirect energy storage such as pumped hydroelectric storage technology [16].
8. *Wide-range tracking*: monitoring parts of the energy scheme over a big geographic region to optimize their efficiency and avoid issues before they occur [17].
9. *Advanced metering infrastructure (AMI)*: AMI as one of SG's main parts provides a bidirectional communication network between intelligent meters (SMs) and utilities to collect, send, and evaluate information on the usage of energy [18–20].

3.1.1 Requirements for Using IoT in SG

Communication techniques for the use of IoT in SG: Communication techniques can be used to obtain and communicate obtained data on the state of the systems of SG. We have communication technology standards of short-range and long-range. Examples of short-range communication techniques are ZigBee, Bluetooth, and ultra-wideband systems. Power line communications [21], optical fiber, 3G and 4G wireless cellular networks and satellite communications can be used for long-range communications.

3.1.2 Future Research Directions

There are many difficulties that need to be resolved in future study directions in order to attain technical objectives in implementing IoT in SG. Since IoT systems must operate in distinct settings that may have difficult circumstances (e.g., elevated or low temperatures, high voltages, exposure to electromagnetic waves, water work, etc.), they must therefore meet criteria under such circumstances as reliability or compatibility.

3.2 Solid Waste Management

Waste management is a name given to a waste collection scheme, which includes transportation, disposal, or recycling. This word is ascribed to waste material generated by a human activity that must be managed to prevent its adverse effect on health and the environment. Most often, it is anticipated that waste will reuse the available resources. Methods of waste management can differ from developed to urban, rural, industrial, and residential. Metropolitan and rural waste management are a municipality's general responsibility, while industrial waste is their responsibility and is managed by themselves.

The different types of considered waste are as follows:

1. *Organic Waste*. It is the trash of organic waste [22].
2. *Recyclable Waste*. It is all the waste that can be used in the technique of conversion to other parts or in raw material production [23].
3. *Industrial Waste*. They are the mainly powerful residues that originate from the industrial production system. It usually consists of residues of raw materials designed for industrial process recycling or reuse [24].
4. *Hospital Waste*. It is the waste that comes from hospitals and medical centers and can contaminate and transmit diseases to people who come into contact with it [25].
5. *Commercial Waste*. Business organizations manufacture it, such as apparel stores, toys, and machinery [26].
6. *Green Waste*. It is the material that mainly results from the pruning of trees, branches, trunks, barks, and leaves in the highways. Because it is organic matter, it can be used to compost and generate organic fertilizer [27].
7. *Electronic Waste*. This is the waste generated by the disposal of consumer electronics products that have stopped operating or become outdated [28].
8. *Nuclear Waste*. It is the one mainly generated by nuclear power plants. It is a very dangerous waste because it is a radioactivity aspect [29].

3.2.1 Available IoT Architecture Reference Models for Waste Management Systems

The Web is powered by the Transmission Control Protocol/Internet Protocol (TCP/IP) architecture to allow network hosts to communicate as they are known. There is also a need for an IoT-based system architecture that always addresses issues such as scalability, interoperability, consistency, quality of service (QoS), etc. According to the author of [30], IoT has access to different models and reference architectures.

Some projects can be identified as one of the predominant reference models, such as RAMI 4.0, the reference architecture for intelligent factories applied to IoT standards. A consortium formed by AT&T, Cisco, General Electric, International Business Machines Corporation (IBM) and Intel, Industrial Internet Reference

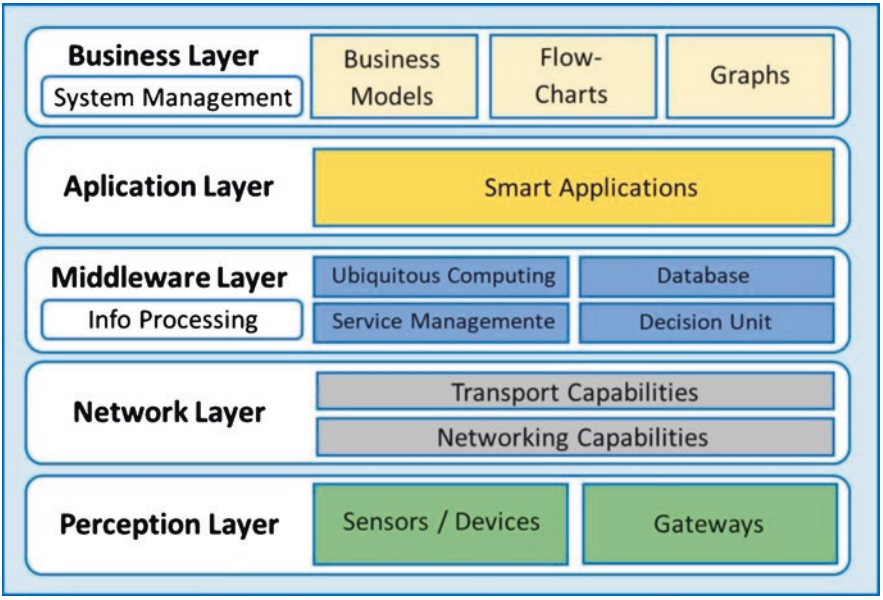

Fig. 2 Layered architecture for waste management systems

Architecture (IIRA), has also launched another venture, while the Internet of Things Architecture (IoT-A) is stimulating an architecture design involving comprehensive system requirements [31].

Most design models rely on a standard architecture based on a requirement assessment or on certain layers that form the basic model of a reference architecture. Figure 2 shows the basic layout architecture. The most basic approach is considered to be a three-layer architecture consisting of implementation, networking, and layers of perception [32]. Recent literature also includes some other models that contribute more to the abstraction of IoT architecture, such as the Service Oriented Architecture (SOA) model, the middleware [30, 33, 34] model, and the five-tier model [35–37].

First, there is a brief discussion of these layers, which, in effect, alternate between the models presented.

1. *Perception Layer*. The perception layer of the IoT architecture is similar to the physical layer of the Open Systems Interconnection (OSI) model as it is based on the hardware level and is responsible for the collection, processing, and transmission of physical information through secure channels to the upper layers. It applies techniques for detecting parameters of physical features through particular sensors such as weight, temperature, humidity, etc., and for collecting object recognition information such as Quick Response codes (QR codes) and RFID.

2. *Network Layer*. The network layer is responsible for moving the measured data in the perception layer to the upper layers where the processing devices are located. It uses ZigBee, Z-wire, GSM, UMTS, Wi-Fi, Infrared, and 6LoWPAN. Besides basic tasks, the network layer also performs data management operations.
3. *Middleware Layer*. The middleware layer is a software layer or even a set of sublayers interconnecting IoT parts otherwise unable to interact, i.e., an interpreter. It plays a significant part in developing fresh techniques and offers competitiveness so that the application layer can communicate with the perception layer and guarantee efficient communication.
4. *Application Layer*. The application layer does not make a significant contribution to the building of an IoT architecture, but it is in this layer that the different equipments are constructed to interact with customers, i.e., where the data is interpreted and available.
5. *Business layer*. This layer is accountable for coordinating the entire IoT scheme, including service-related apps such as supplying the underlying layers with a high-level analysis report and protecting users'privacy. This layer can be responsible for generating graphs and business models.

Since IoT connects everything together for information exchange, traffic and network stores tend to be exponentially improving. The development of IoT apps is thus based on advancing technology and design following a reference model for IoT architecture.

3.3 Healthcare

The Internet of Things (IoT) is certainly one of the study community, government sector, and industry's most interesting subjects. While traditional internet enables communication between a number of restricted devices and humans, IoT connects all kinds of linked "things" into an extensive network of computer-related intelligence without a human being's interference. IoT adoption and the development of wireless communication technologies enable the health conditions of patients to be streamed in real-time to caregivers [38, 39]. Furthermore, many available sensors and portable devices can measure specific human physiological parameters such as heart rate (HR), respiration rate (RR), and blood pressure (BP) through a single touch. Although it is still in the early development stage, businesses and industries have quickly adopted the power of IoT in their existing systems, and they have witnessed improvements in production as well as user experiences [40].

However, the integration of IoT technology in healthcare brings several challenges, including data storage, data management, exchange of data between devices, security and privacy, and unified and ubiquitous access.

One possible solution that can address these challenges is Cloud Computing technology. Figure 3 shows a typical healthcare system that integrates both IoT and

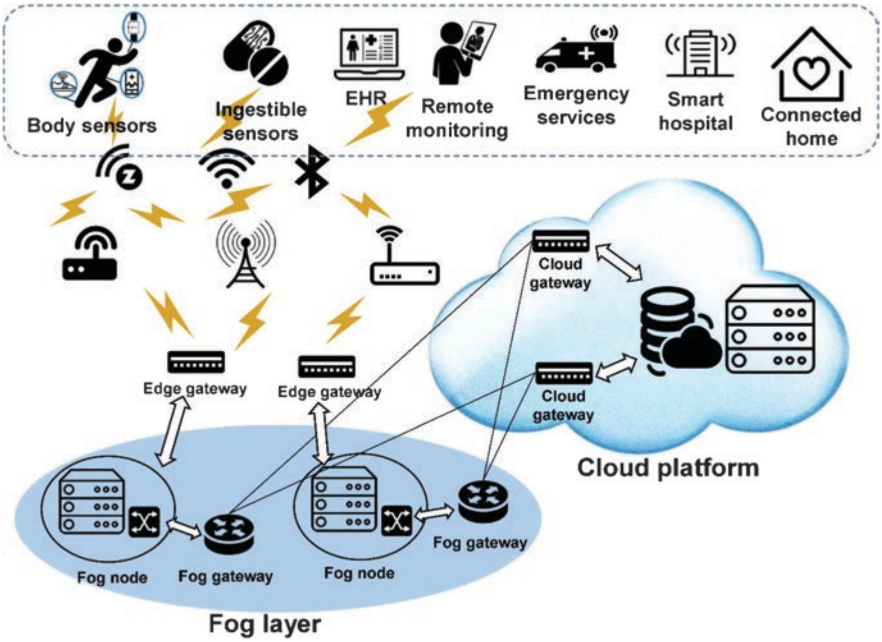

Fig. 3 An overview of a typical IoT and cloud computing-based healthcare system

cloud computing to provide the ability to access shared medical data and common infrastructure ubiquitously and transparently, offering on-demand services, over the network, and performing operations that meet growing needs [41].

IoT delivers proper solutions for various applications that cover all aspects of life such as smart cities [42], smart traffic management, waste management, structural health monitoring, security, emergency services, supply chain, retail, industrial management [43–46], and healthcare.

3.3.1 IoT Framework for Healthcare

The IoT in healthcare framework (IoTHeF) is considered the most fundamental aspect of IoT in healthcare because it helps healthcare applications to completely utilize the IoT and cloud computing. The framework also provides protocols to support the communication and broadcast of raw medical signals from various sensors and smart devices to a network of fog nodes.

As shown in Fig. 4, there are three essential components of IoTHeF, which include topology, structure, and platform. Each component serves a specific function in the IoT healthcare framework, all of which will be discussed in detail in the following sections. The readers are recommended to review proposed IoT architectures in [47, 48] to gain insights into the IoT architectures for healthcare. The systems can collect data about patient health status through multiple sensors. After that,

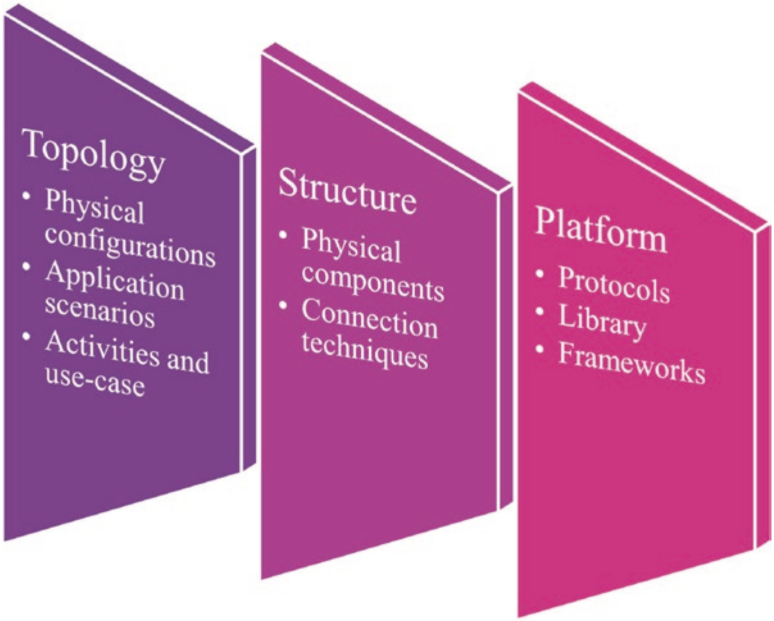

Fig. 4 Three basic components and their main functions in the IoT framework for healthcare

the collected data were transmitted to the remote server for analyzing, and the results were displayed in real time.

The IoTHeF topology handles the arrangement of general IoT components and outlines some standard setups for given application scenarios in the IoTHeF framework. Figure 3 presents a typical IoT and cloud computing in healthcare topology containing three main elements [49]. First of all, a publisher represents a network of connected sensors or hand-held devices in charge of recording patient's vital signs, and continuously sending a considerable amount of raw information such as electrocardiogram (ECG), electromyography (EMG), body temperature, blood glucose (BG), and the volume of air inspired and expired by lungs to a broker. Next, the broker analyzes and stores processed data on the cloud. Finally, a subscriber, who directly monitors patients can access the data from any location and responds immediately when unexpected incidents happen. The IoT HeF framework incorporates individual components into a hybrid computing grid where each component serves a specific purpose on IoT and cloud computing in the healthcare network.

3.4 Marine Environment Monitoring

IoT is a flexible global network architecture with self-configuring capabilities based on ordinary and interoperable communication protocols, where physical and virtual components have identities, physical and virtual features, and are seamlessly integrated into the data network [50]. IoT has recently been widely recognized as a groundbreaking paradigm that can transform our society and industry by seamlessly integrating various devices equipped with sensing, detection, storage, interaction, actuation, and networking capabilities [51]. The WSN (Wireless Sensor Network) plays a key role in IoT. This includes a large number of distributed sensors that are interconnected by wireless connections.

Wireless sensor networks (WSNs) have been widely used over the past few decades as an IoT subset for a variety of smart applications and services, including smart home [52], smart building [53, 54], smart transport [55, 56], smart industrial automation [57, 58], smart healthcare [59], smart grid [60], and smart cities [61]. Similar IoT-based methods of monitoring and protecting marine environments can certainly be used.

While our society and economy grow, the marine environment has received a great deal of attention from scientists and academics. It is very expensive to monitor traditional marine environmental networks such as oceanographic research vessels and hydrological research. Our methods of gathering and reviewing information are time consuming and the data collected are of low resolution. The Internet of Things (IoT) has developed wireless sensor networks (WSNs). IoT has a much higher capacity for data management than WSNs, which allows intelligent object control.

In a typical marine monitoring system based on IoT, various sensors are used to calculate and track precise physical and chemical parameters such as water temperature and pressure, wind direction and velocity, salinity, turbidity, pH, oxygen density, and chlorophyll rates.

Nonetheless, to solve some critical problems, including autonomy, adaptability, scalability, flexibility, and self-healing, it is important to model, build, and deploy an IoT-based marine environment monitoring and protection Scheme [62, 63], following specific requirements for extreme marine environments [64]:

1. High water resistance.
2. Strong robustness in hardware.
3. Low energy consumption and energy harvesting.
4. Stability of radio signal.

In particular, instruments and sensor nodes should be extremely reliable due to hard installation and maintenance; the need for boom and mooring systems; sensor coverage should be closely measured due to large areas [65]; equipment should be installed against potential vandalism behavior.

3.4.1 Overview of IoT in Marine Environment Monitoring

IoT-Based Marine Environment Monitoring Applications

IoT-based marine environment surveillance applications include: