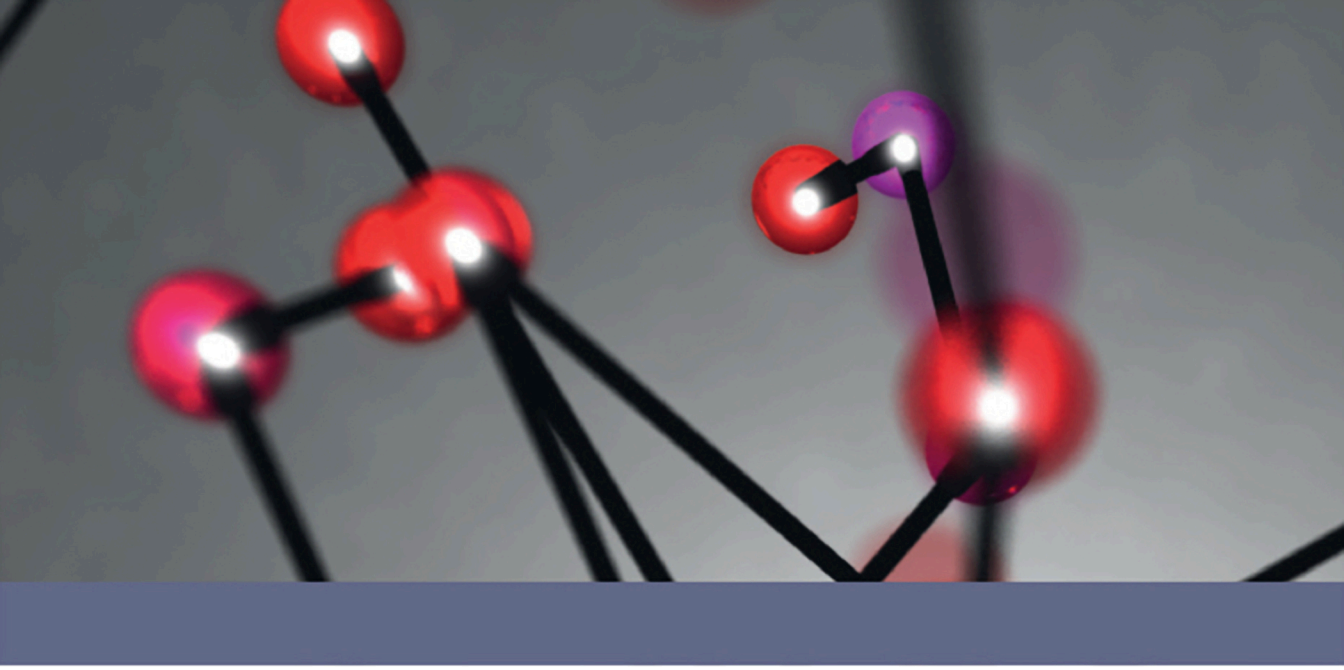
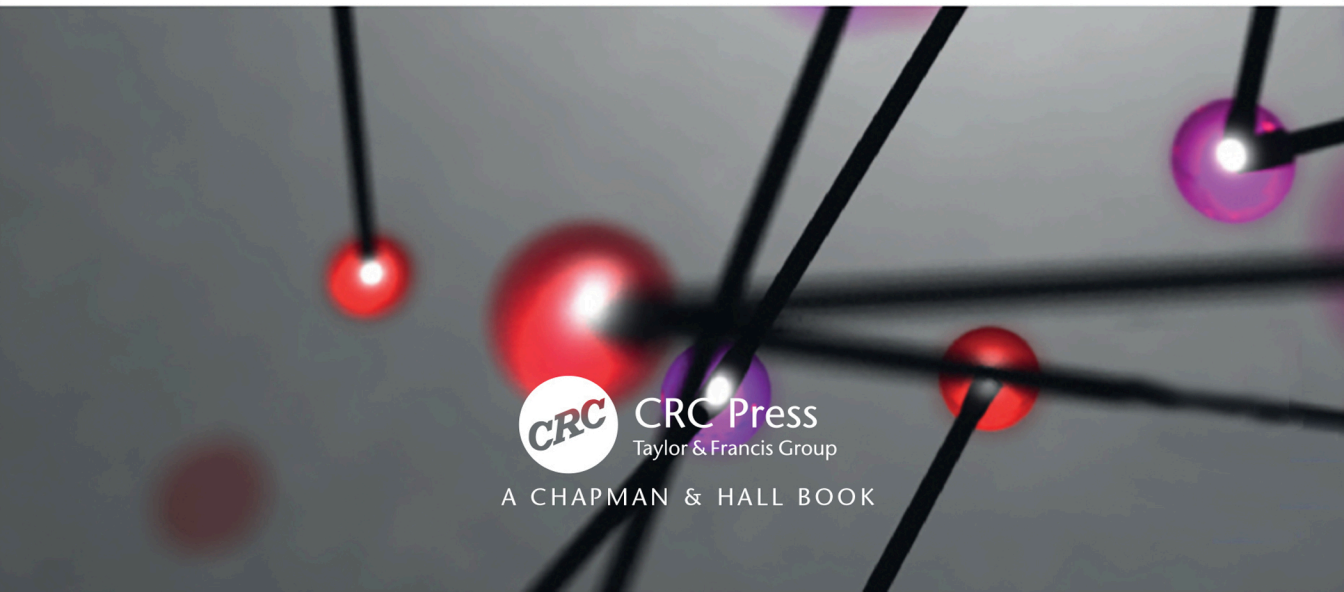


# COMPUTATIONAL INTELLIGENCE FOR WIRELESS SENSOR NETWORKS

## PRINCIPLES AND APPLICATIONS

Edited by
Sandip K. Chaurasiya, Joydeep Dutta, Arindam Biswas,
Gorchand Dutta, and Mrinal Kanti Sarkar



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# Computational Intelligence for Wireless Sensor Networks

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## Principles and Applications

**Edited by**

Sandip Kumar Chaurasiya

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# *Preface*

Wireless Sensor Networks (WSNs) are networks of tiny electromechanical devices, more precisely called sensor nodes. These sensor nodes are equipped with the ability to sense and measure their surroundings. The popularity of such networks can easily be perceived through a wide variety of applications such as habitat monitoring, health monitoring, security and surveillance, civil structure monitoring, precision agriculture, animal tracking, and industrial applications. However, these networks suffer from several constraints such as storage and computational limitations, limited power resources, and limited transceiving capabilities. The limitations mentioned above result in many challenges such as deployment and localization, energy-efficient data gathering and routing, data fusion, security, task scheduling, etc.

Over the past few years, computational intelligence (CI) has emerged as an effective tool to address these challenges. Computational intelligence refers to a set of adaptive techniques facilitating intelligent behavior in complex and dynamically changing environments like wireless sensor networks (WSNs). The elements of learning, adaptation, and evolution are integrated to create an intelligent system via CI; thus, CI enables WSNs to exhibit autonomous behavior in a rapidly changing environment and provides robustness against the above-cited challenges.

This work attempts to bring the learning of technologies such as CI and WSN to foster strong collaboration between them. The following chapters thoroughly discuss WSNs and sensor-enabled technologies along with their respective properties and challenges. Furthermore, the present work will discuss various CI techniques such as fuzzy computing, evolutionary computing, reinforcement learning, artificial intelligence, swarm intelligence, and their respective applications in wireless sensor networks and sensor-enabled technologies in greater depth.

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**Sandip K. Chaurasiya** received his M.E. degree in Computer Science and Technology from the Indian Institute of Engineering Science and Technology Shibpur, Howrah, West Bengal, India, in June 2010. He is working as an Assistant Professor in the University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India. His research interests include mobile computing, wireless sensor networks, and the internet of things. He has authored a book, *A Complete Guide to Wireless Sensor Networks: From Inception to Current Trends* (2019), and contributed many technical papers in various journals and conferences. He has reviewed a number of research articles in several reputed international conferences/journals. He is an active member of the Institution of Electronics & Communication Engineers (India), New Delhi.

**Dr. Joydeep Dutta** completed his Ph.D. degree from the Department of Computer Science and Engineering, NIT Durgapur in 2020. He completed his M.E. in Computer Science and Engineering from the West Bengal University of Technology in 2008. Dr. Dutta was also awarded the bronze medal for his first-class 3rd position in the university. Dr. Dutta qualified with the UGC NET in Computer Science and Applications in 2013. He is currently working as an Assistant Professor in the Department of Computer Science of Kazi Nazrul University, Asansol, India. He has more than nine years of teaching experience in several reputed engineering colleges of West Bengal and two years of industrial experience in MNCs such as Wipro Technologies and Oracle Financial Services Software Ltd. His current research interests include network optimization problems, artificial intelligence, evolutionary algorithms, combinatorial optimization etc. He has several high-impact SCI-indexed publications like *Neural Computing and Applications, Transport,* etc. Dr. Dutta has acted as a reviewer of various reputed journals and conferences. He has chaired, organized, and presented papers at seminars and conferences of international repute.

**Dr. Arindam Biswas** was born in West Bengal, India, in 1984. He received his M-Tech degree in Radio Physics and Electronics from the University of Calcutta, India, in 2010 and his Ph.D. from NIT Durgapur in 2013. He was a Post-Doctoral Researcher at Pusan National University, South Korea, with prestigious the BK21PLUS Fellowship, Republic of Korea. He was Visiting Professor at the Research Institute of Electronics, Shizouka University, Japan. He has been selected for the IE(I) Young Engineer Award: 2019–20 in Electronics & Telecommunication Engineering, Institute of Engineers, India. Dr. Biswas has 11 years of experience in teaching research and administration. Presently Dr. Biswas is working as an Assistant Professor in the School of Mines and Metallurgy at Kazi Nazrul University, Asansol, WB, India. He has 48 technical papers in various journals and 30 conference proceedings and six books, one

edited volume and one book chapter with international repute. Dr. Biswas has received a research grant from the Science and Engineering Research Board, Government of India, under the Early Career Research Scheme for research in Terahertz-based GaN Source. He has also received a research grant from the Centre of Biomedical Engineering, Tokyo Medical and Dental University, in association with RIE, Shizouka University, Japan, for the study of biomedical Thz Imaging based on WBG semiconductor IMPATT Source. Presently Dr. Biswas is serving as an Associate Editor of Cluster Computing, Springer (SCI Indexed) and as a guest editor of *Nanoscience and Nanotechnology-Asia* (Scopus Indexed), *Recent Patents in Material Science* (Scopus Indexed), Bentham Science Publisher. Dr. Biswas has advised four Ph.D. students in different topics related to applied optics and high-frequency semiconductor devices. He has organized and chaired various international conferences in India and abroad. His research interests are in carrier transport in low-dimensional systems and electronic devices, non-linear optical communication, and THz semiconductor sources. Dr. Biswas has acted as reviewer for reputed journals and is a member of the Institute of Engineers (India) and Regular Fellow of Optical Society of India (India).

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# 1

# *Wireless Sensor Network (WSN) Vis-à-Vis Internet of Things (IoT) Foundation and Emergence*

**P. K. Paul**

**CONTENTS**



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## 1.1 Introduction

Wireless sensor networks are autonomous sensors that are responsible for the collection, cooperation, and monitoring of physical as well as environmental quantities and qualities and allied interests, viz. temperature, sound, vibration, pressure, pollutants and so on [1–3]. Initially wireless sensor networks were projected for defense and military applications; gradually they are becoming important tools for societal applications and civilian applications in diverse activities such as

- healthcare and monitoring
- transportation and traffic management
- environment and ecological monitoring and management
- industrial automation, and so on.

Two standard communication protocols have been proposed in past few years: Wireless HART and ISA100.11a; in this regard, the HCF consortium and ISA Association play a leading role. These tools are designed for process and monitoring as well as control. Each node in the wireless sensor network is equipped with a sensor, a small microcontroller responsible for analog-to-digital signal conversion, a computational unit, and storage systems [3–5]. The gradual development of the internet emerged as the internet of people (IoP), and in recent past the internet of things concept has become widely recognized and popular. It is further expected that IoT will add about 75 billion things and items through the internet by the end of 2025 [6].

The shift in electronics products includes radio frequency identification (RFID), mobile devices, and wireless sensors etc. Here IPv6, IPv6 over low power wireless personal area networks sensors standards are playing a leading role. Here M2M (machine-to-machine communication) is also an important concept. Integration and applications of wireless sensor networks in the IoT is worthy and important. In the internet of things, machines and electronic devices become more and more connected with other things or objects. To communicate autonomously with the help of internet, the emergence of IoT is noticeable and acceptable. In 2019 the total number of IoT devices reached 26.66 billion, and it is worthwhile to note that every second 127 new IoT devices are connected with the web. Billions of things are connected to the internet, and they are dedicated to data generation. In IoT, M2M is the main communication standard between the internet of things [7–9].

## 1.2 Objectives

The present work has the following (but not limited to) objectives:

- To know about the basics of wireless sensor networks with reference to their foundation, features, and characteristics.
- To learn about the role and importance of the wireless sensor network with reference to the present context.

- To know about the basics of cloud computing in relation to wireless sensor networks.
- To learn about the basics of the internet of things with reference to the foundations, features and characteristics.
- To learn about the growing applications of the internet of things in different sectors and areas.
- To know about the role and need of wireless sensor networks in the internet of things context.

## 1.3 Methods

This work is theoretical in nature and deals with various aims and objective as discussed. The topic of the work "Wireless Sensor Network and its utilizations in internet of things: *Foundation and Emerging Trends*" is theoretical in nature; therefore a review of literature played a leading role in the formation of the paper. Secondary sources were initially reviewed, and thereafter various primary sources were also exploited for doing the research work. Various websites of companies offering IoT and WSN services were also reviewed and analyzed to get a concise picture of the topic.

## 1.4 Wireless Sensor Networks: Foundations

Collection of nodes make up wireless sensor networks. Such nodes are individual small computers. WSNs form centralized network systems and enable multi-functionality while being wireless in nature. Wireless sensor networks may have a predefined goal; having a centralized and synchronized structure, they follow a certain topology like linear, star, mesh etc. Limited broadcast range in a wireless sensor network normally is 30 meters. Wireless sensor networks normally having following steps:

- collecting data
- processing data
- packaging data
- transferring data

Wireless sensor networks are similar to wireless ad hoc networks as they also collect the data with wireless support, and it is important to note that wireless sensor networks are the kind of sensors that are autonomous in nature and are responsible for the physical or environmental conditions including the temperature, sound pressure and so on [9–11]. Here data basically are moved by the cooperation of the network to the main location. Modern networks may be bi-directional, collecting data from the distributed sensors and also dedicated in controlling the sensor activities. Military applications like battlefield surveillance were the main reason for the development of the WSN, but today WSNs are widely used in many industrial as well as consumer applications that are built of "nodes;"

the number may be a few to hundreds or even thousands, where each node is connected to one sensor. Such sensor network nodes may have various types of parts, viz. internal antenna, external antenna, microcontroller, and an electronic circuit for the connectivity of the sensors and an energy source, battery, or other energy-harvesting system. It is worth noting that the sensor node size may be different, and further the cost of sensor nodes is also variable depending upon the brand and country. As far as the topology is concerned WSNs may be prepared with a simple star network or even a multi-hop wireless mesh-based network. The propagation technique of hops of the network may be routing or flooding [12–14]. As far as characteristics are concerned the following can be consider as important and valuable:

- Power consumption constraints can be noted for the nodes using batteries or energy harvesting systems.
- Ability to cope with node failures is important.
- In certain case the mobility of nodes can be noted.
- Heterogeneity and homogeneity of the nodes can be important.
- Scalability is an important feature, emphasizing large scale of deployment.
- WSNs are very effective to use.
- Cross-layer optimization is important and can be noted.

The internet of things is an important technology that offers scalable and mobile computing services. Various technologies play an important role for the further development of IoT; among these are ubiquitous and pervasive computing. These technologies are helping in the development of wireless systems by producing, and consuming RFID and mobile computing-based services. RFID is a useful early example of IoT applications where WSNs are also effectively started a few years back; and among the examples are goods, cars, wearable sensors, etc. RFID basically uses less energy than mobile and handheld devices. With the support of cloud computing, the capabilities of these devices will be further boosted in respect of the storage and other infrastructure-based services [15–17].

## 1.5 Wireless Sensors Network: Emergence and Basic Applications

Wireless sensor networks run in a bi-directional fashion and it are wirelessly connected with networks of various kind of sensors. These sensors are dedicated to collection of data on different aspects, viz. temperature, humidity, speed, etc. Communication is done on a multi-hop basis, and each sensor is dedicated to perform the defined task. Wireless sensor networks follow OSI architecture and model and have five layers and three cross layers. For the active operation it is essential to have five layers:

- application layer
- transportation layer
- network layer
- data link layer
- physical layer

Wireless sensor networks are able to offer various advantages and benefits; these include the following:

- Network arrangements can be brought in without involvement of immovable infrastructure.
- WSNs are effective IN non-reachable places, viz. over the sea, rural areas, deep forests, hills, and mountain areas.
- They are very flexible in casual situations.
- The cost of the tools and technologies, especially the execution pricing, in wireless sensor network is inexpensive.
- Wireless sensor networks avoid wiring.
- Wireless sensor networks may also able accommodate many kind of devices at any time.
- With the help of centralized monitoring, wireless sensor networks become worthwhile.

Wireless sensor networks offer various types of applications that come with the comfortable, effective, and smart life. Energy saving and minimal noise are other benefits of WSNs [18–20]. Wireless sensor networks contribute effectively in the development of less costly atmospheric monitoring system while reducing the pollution, and hence, facilitating the healthcare benefits too. In wireless sensor networks application-based communication requires sensors and different kinds of server connectivity. Wireless sensor networks basically function by the use of three main access technology architectures. Various kinds of sensors are used, viz. low sampling rate, seismic, magnetic, thermal, visual, infrared, radar, and so on based on situation and usefulness. Sensor nodes are very useful in constant sensing, including in event ID, event detection, and so on. The application of wireless sensor networks initially was for military and defense-related purposes, and gradually it has been updated in other areas:

- medical and healthcare sectors and applications
- environmental and ecological applications
- home and living applications
- organizational and commercial applications
- area monitoring and management
- earthquake sensing and similar activities
- air pollution monitoring and management
- forest fire detection
- landslide detection and similar activities
- water quality and ocean monitoring with management

Wireless sensor networks have longer range than that of the basic sensor networks, and WSNs are based on communication in a peer-to-peer basis. The maximum number of wireless sensor networks is based on IEEE 802.15.4 standard and is connected with the physical and medium access control (MAC) layer of low rate-wireless personal area networks (LR-WPANs). In effective WSNs, data mining techniques are also used to extract

enormous amount of data. In WSNs the sensors are always active and reduce the energy consumption according to the need [21, 22]. The sensors of WSNs collect the data frequently and store them in the cloud or database accordingly.

## 1.6 Internet of Things: Foundation and Emergence

Entrepreneur Kevin Ashton initially coined the term internet of things, or IoT, in 1999, and gradually it has become an important field of practice in information technology. Though it is important to note that the technology rapidly emerged and grew in past decade. In 2011 Gartner reported that IoT was one of the latest technologies; thereafter the growth of the IoT was noticeable. In the recent past, the abbreviation IoT became popular as the emerging technology is applied to various kinds of objects. Industrial machines become wearable devices with the help of IoT. Ashton played a leading role in IoT development under the auspices of Auto-ID Center at Massachusetts Institute of Technology. Many experts initially called it "embedded internet," and today it is embedded in our daily lives. There is no universally accepted and perfect definition of the internet of things; various experts viz. scientist, academician, researchers, practitioners, engineers, developers and industry persons define it differently [23, 24].

The internet of things is an open and comprehensive network of objects that are capable of decision making, data and resource sharing, intelligent computing, and manufacturing, connecting intelligent devices with sensors and the internet. The internet of things is maturing and getting more sophisticated and it is making the world more completely a global village with various kind of connected objects. Further IoT provides services anytime and anywhere using the internet and sensors and it is considered a global network. This network further is responsible for the human-to-human, human-to-object or thing, and thing-to-thing communication. With the help of IoT unique identity for every object can become possible and may be connected and worked accordingly. With IoT more can be communicated in an intelligent fashion than ever before and "being connected" becomes possible. Various electronic devices can be connected, viz. servers, computers, smart phones etc. The internet of things is integrated with sensors and actuators embedded in physical objects, and it also linked by wired and wireless networks using IP. Due to the increasing components in IoT (refer to Figure 1.1) the services are changing and improving day by day.

IoT has become an important technology connecting physical and digital components. The components of the IoT are able to transmit data without human mediators and each component has a unique identifier (UID). IoT applications can be following types.


**FIGURE 1.1**
Major components of IoT.

### 1.6.1 Consumer IoT

Consumer-based IoT is dedicated to the consumer only, viz. light fixtures, home appliances, old-age services, nursing services, entertainment-related activities, and so on [25, 26].

### 1.6.2 Commercial IoT

Applications of the internet of things is very effective and important in different commercial activities, including healthcare, transportation, manufacturing devices, smart pacemakers, office- or establishment-based monitoring systems, and in the emerging vehicle-to-vehicle communication, and so on.

### 1.6.3 Industrial Internet of Things (IIoT)

IoT applications in industry launched the industrial internet of things, dedicated to making industries more advanced and smarter, viz. digital control systems, statistical evaluation, smart and digital agriculture, and design and development of industrial products.

### 1.6.4 Infrastructure IoT

Applications of the IoT are increasing day by day in the infrastructure sector, enabling the connectivity of smart cities and organizations in building of healthy and sophisticated infrastructure with the support of the sensors, management systems, and other intelligent electronic system support [27, 28].

### 1.6.5 Internet of Military Things (IoMT)

The utilization of the IoT technologies in the areas of defense as well as military sectors has also been increasing, viz. robots for surveillance and human-wearable biometrics for combat and so on.

These are the basic types of IoT, and such terminology is increasing. In 2018 about 7 billion IoT devices existed, and gradually the number has increased to 26.66 billion and it is expected to grow to about 75 billion by the end of 2025. IoT applications are noticeable in different sectors, viz. business, commercial ventures, and industries; agricultural, horticultural, and environmental sciences; education, teaching and research, government and other management-related organizations; healthcare and medical systems; transportation and tourism; manufacturing organization systems, etc. In diverse areas IoT applications are possible with wireless internet and embedded sensors with various technology. Due to the nature and uses of the IoT in different sectors, the IoT architecture (refer to Figure 1.2) is also changing gradually and thus IoT can be consider as additionally as follows:

- The Internet of things can be treated as valuable in the information technology age for the development of smarter information solutions with allied technologies.
- Cloud computing, data analytics, usability engineering, human computer interaction (HCI) can be considered a valuable technology in respect of IoT support.
- It is sensor dependent, and various grids are connected; further most of these are renewable [29, 30].
- Machine monitoring sensors are getting intelligent machine and systems development support for complete internet-based services and products.

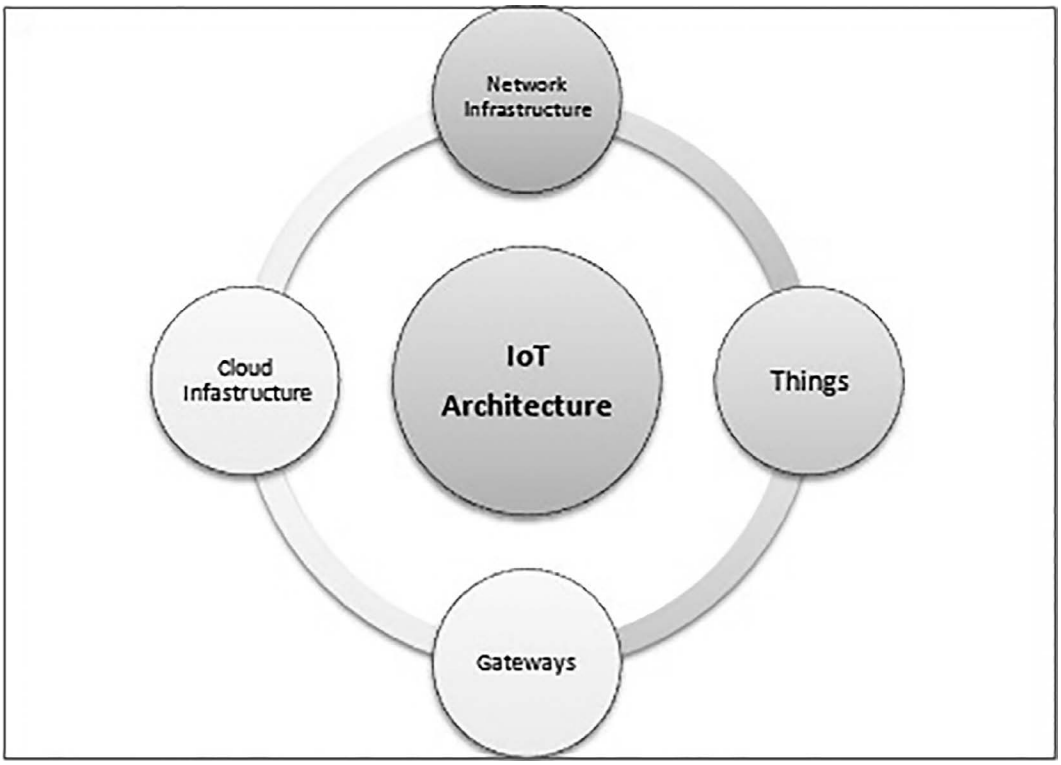


**FIGURE 1.2**
The IoT architecture at a glance.

## 1.7 IoT: Emerging Applications

The internet of things is an internet-based system, digitally connected and controlled; therefore it is applicable in wider areas, including in efficiency, safety, security, etc., in diverse areas such as oil and gas, education and training, manufacturing, transportation, tourism, agriculture, retail and hospitality sectors, etc.

The internet of things and its implementation is an important issue as high organizational cost can be applicable in the broad areas of IoT. In home automation, smart towns and cities, and other smart development, IoT is also very important and needed.

In developing the smart home, viz. air conditioning, lighting, heating, security etc., IoT plays a leading role. Smart devices such as iPhone or iOS are useful in this context, and the smart building is also an emerging concept and tool of IoT for reducing energy consumption. With the help of IoT, elderly individuals and people with disabilities can use assistive technology and voice control systems; therefore IoT applications are increasing.

Smarter healthcare is an integrated approach of IoT in healthcare and medical systems such as collection and analysis of data. Remote emergency services are a core part of IoT systems. The use of the pacemakers, smart beds, nursing informatics, medical facilities, and "m-health" (mobile health services) is very important [31, 32]. Different kinds of IoT-enabled social applications such as vehicle management, traffic control, electronic toll collection, and infrastructure development & management are very

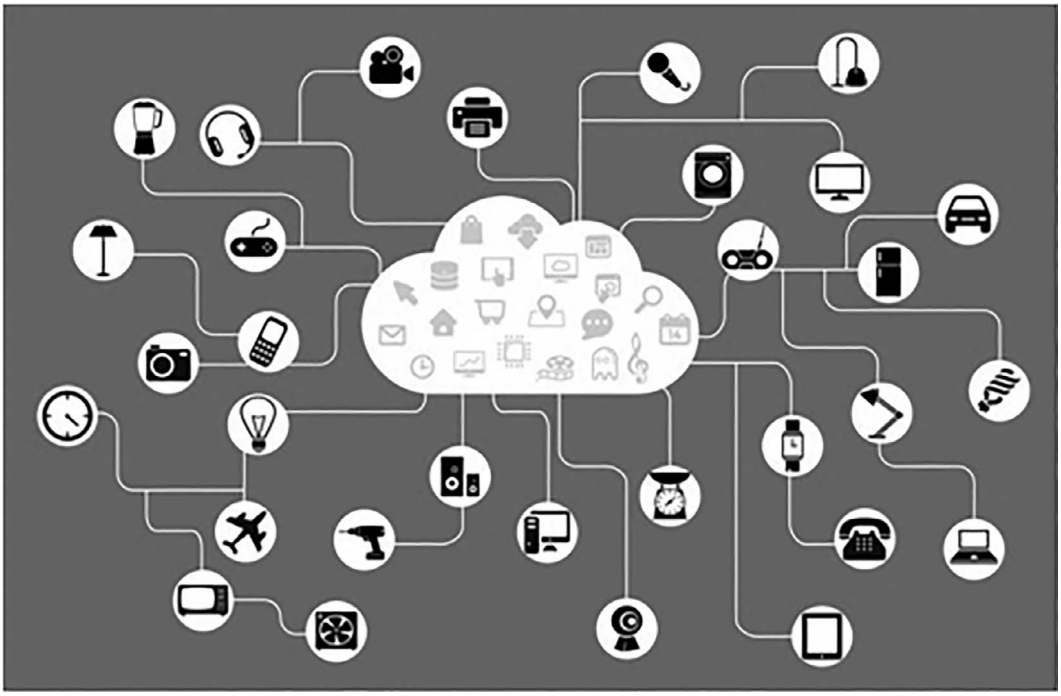

**FIGURE 1.3**
Major using devices of IoT.

important and growing. Thus, IoT has evolved as a need of the hour in almost every aspect of our life.

In manufacturing IoT is important in identification, processing, and communication. It is also important for better manufacturing equipment and rapid manufacturing, proper supply chain management, and smart grid-based systems. The concept of the industrial internet of things is important but is possible only with proper support from all the stakeholders and institutions. Day by day the use of electronic products is rising, including various items, viz. refrigerators, air conditioning, simple computing devices, cameras, or even a simple blender. Figure 1.3 provides details.

## 1.8 WSN, Cloud Computing and Internet of Things

Cloud computing is an important concern in modern information technological tools; it is responsible for the design and development of virtual information technology systems, including software, applications, information technology infrastructure, operating systems, platforms, and so on. There are different types of cloud computing:

- public
- private
- hybrid

Public cloud computing basically uses internet services, which helps in offering cloud-based tools, techniques, and services [33, 34]. Higher bandwidth and sophisticated internet connections are an important concern. Private cloud computing is similar to the public offering but services are normally designed and developed in-house. There are various cloud computing services based on service models; the major ones are software as a service, platform as a service, security as a service, storage as a service, infrastructure as a service, and so on. Cloud computing is highly connected with the wireless sensor network as both are responsible for making IT systems remote and wireless. Cloud computing is significant in a developing virtual world. Similar to cloud computing another concept is also significant: big data, or analytics. The combination of wireless sensor networks and the internet of things is important since both are dedicated in wireless IT support. The mixture of IoT and cloud with the WSN enables the provision of sensor data or sensor event as a service over the internet. Therefore sensor data can be easily analyzed locally and everywhere with a proper system that connects to the wireless systems [35, 36]. WSN architecture is also advantageous in respect of mode flexibility, viz. task management, mobility management, power management, and so on. Refer to Figure 1.4 to learn about more about WSN architecture and core benefits.

Due to the importance and role of the wireless sensor networks and cloud computing (and partially IoT), sensing as a service and sensor event as a service has emerged. Sensor data basically is made available to the clients across the cloud and similar type of infrastructure. These combined technologies are significant for a large number of different applications and are increasing. Among the basic and core uses few important are the following.

### 1.8.1 Transport and Tourism Monitoring

There are various places in which systems of traffic control can be supported by WSN-integrated IoT: license plate recognition, toll way management, normal as well as emergency vehicle management, smarter traffic lights, emergency road management, etc. WSN-integrated IoT-based devices can collect data and store them in the cloud and make

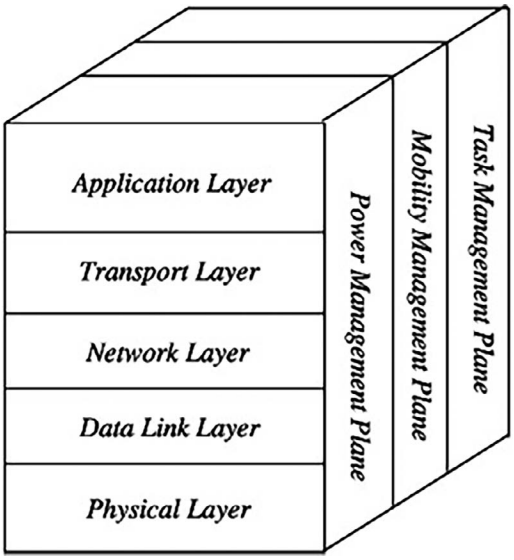


**FIGURE 1.4**
Layers vs. effectiveness of WSN.

transportation and traffic systems more effective and modern. In a variety of areas these collected data are useful, viz. in vehicle classification, collision avoidance systems, automatic toll gates, and others [37, 38].

### 1.8.2 Military Use

Wireless sensors networks initially were developed to solve problems of military and defense sector, and gradually it has been recognized as useful in other sectors. Initially it was for the smart dust concept. Since a wireless sensor network is internet based, therefore cloud computing uses are important to note.

### 1.8.3 Weather Forecasting

With the support of cloud computing and big data, wireless sensor network–based devices integrated with the IoT are able to make weather forecasting systems more useful and important. WSN-supported sensors basically collect numerous data that help in weather forecasting [17, 39, 40].

### 1.8.4 Healthcare

Sensors are effective and useful in data collection and highly important in healthcare and medical applications. Personal or individual devices, many of them portable, are increasing in healthcare sectors. These can be effective in collection of the data from the patient and helpful in decision-making. WSNs for real-time warnings for safer and more effective patient management are important. Furthermore, WSN and IoT are important in constant and remote and personalized patient care [18, 41, 42]. The following sections are noteworthy in respect of emerging and future applications of IoT, WSNs, and integrated approaches.

## 1.9 WSNs in Smarter IoT Systems: Emerging Applications and Trends

As far as technological scope is concerned a WSN is smaller than the internet of things. Wireless sensor networks are not directly connected with the internet but are mainly connected with the central node or a router. But the internet of things is directly connected with the internet or it is internet-based only. Therefore IoT can collect data from a wireless sensor network; a sensor can collect the data and can also store it in the cloud, where it can be utilized based on need and requirement. For example, the sensors are able to collect data viz. temperature, wind movement, etc., and data can be sent periodically to the internet, where a server can process the data and interpret accordingly. We are already aware that IoT is based on internet and sensor connections, but a WSN can be seen as a group of sensors, or in as sense, it is the big sensor. Therefore IoT exists at higher level then wireless sensor networks. Since a WSN may be considered as a part of IoT, therefore the function areas can be seen as similar. In a mesh network or similar, WSN can be used to gather data by a router. A wireless sensor network consists of a network of only wireless sensors, normally without any wired sensor.

The internet of things has unique identifiable embedded computing devices within the existing internet framework and offers sophisticated, advanced connectivity to the

devices, systems, and services, and that may be beyond traditional machine-to-machine communication and based on different kind of protocols, applications etc. This helps in automation and also enables advanced smart grid types of applications. Things basically communicate with each other without interaction with a human or system. IoT from core sense has three basic components:

- sensors
- actuators
- connectivity devices

There are broad agreements among the connectivity between the devices' security and privacy risks, and all these are major issues in WSN. Wireless sensor networks integrated with IoT may be helpful in the following areas:

- enabling authorized access
- preventing the misuse of personal information
- facilitating the reduction of attacks on a system
- mitigating the safety risks

Security is an important concern. In the information technology field there are tools, devices, and components that pose possible threats. Wireless sensor networks may have different kind of security-related issue. The internet of things also has various security-related issues, and organizations have to deal with such security-related concern very carefully [5, 43, 44]. All the components of the IoT should be considered of prime importance in this aspect of security. (Refer to Figure 1.5 for more details.)

Technologies like radio frequency identification and wireless sensor networks, which are integrated with the IoT, help in decision making and various applications. They are increasing in wide areas apart from the previously mentioned.

### 1.9.1 Smart Home and Residential

In home automation and advanced management of the home and residential complexes WSN and IoT-based tools and technologies are emerging rapidly for a wide range of areas, viz. utility meters, energy and power supply management, water supply and water leaks, lift and door systems, remote operation and monitoring using WSN/IoT based systems, and so on.

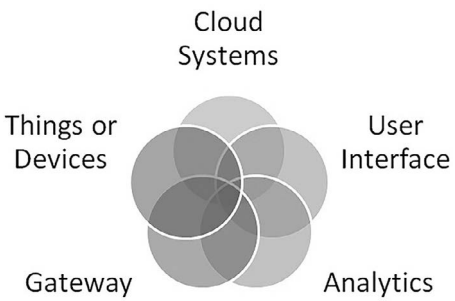


**FIGURE 1.5**
Major components of IoT where security aspects are important and connected.

### 1.9.2 Smart Environmental Management and Monitoring

In various environment and ecology related areas IoT and wireless sensor networks are useful, such as in flood management, fire management, earthquake management, disaster management, and air pollution management.

### 1.9.3 Smart Hospitals and Healthcare

In future hospitals and healthcare organizations there will be more automation and much technological involvement. There are numerous areas where wireless sensor networks, RFID, or IoT can be connected, viz. in managing heart rate, blood pressure, temperature of the patient, and the room. Apart from these uses in hospital management, IoT and WSN integrated technologies are highly important and required for remote operations, electronic device management, medical emergencies, and medical transportation. Drone ambulances can fly to the scene with the emergency kit and some specially designed assistance drones. IoT-based automated information system design and development are also noteworthy and very important [19, 45].

### 1.9.4 Smart Transportation and Tourism

In transportation and allied fields IoT and WSN-based tools and technologies are noteworthy and important. There are traditional and diverse areas where IoT and WSN are important to use, viz. real-time traffic and public transportation systems using information sharing, intelligent and automated traffic control systems, electric vehicle management, automated charging facilities, short-range communication.

a. *Proper navigation and safety of transportation*—In different types of vehicles, such as cars, buses, and trains, as well as routes and roads the use of sensors and actuators is valuable for the drivers as well passengers regarding better navigation and safety.
b. *Road planning and route optimization*—More accurate traffic information, including road patterns, planning, warning messages on climate conditions, and traffic jams, can be possible with IoT and WSN-based systems.

### 1.9.5 Real-Time Management and Decision Making

Time is an important aspect for all kinds of organizations, institutions, and individuals, and everywhere time is an important concern. IoT and wireless sensor network-based systems would be an important example in regard to time management. Sensors collect data and provide the same to the user, and based on this, real-time management and decision making become possible. Therefore in organizational support and development IoT and similar system such as WSN are noteworthy [37, 46].

### 1.9.6 Smart Gardening and Farming

IoT and WSN based systems are worthy and important in advanced and intelligent farming, including vertical farming also. Among the areas where IoT and integrated WSN are useful are automated lighting, humidity and temperature control, proper moisture identification and arrangements, etc.

### 1.9.7 Security and Privacy in Different Stakeholders

In proper and solid security privacy management of different products, organizations, and institutions IoT and WSN-based devices can be helpful in achieving security methods and in finding the existing trust relationship between the devices and server [2, 20, 47].

## 1.10 Future Potentialities

The internet of things and wireless sensor networks are very important and valuable for the development of organizations and institutions of different kind, including for profit and nonprofit, small and large. Proper planning and interest in this regard is important for different stakeholders, including government, institutions, policy makers, and so on. As the technology grows and it comes with aspects of cost; therefore proper funding is also important in the making of the intelligent world using different technologies, which include IoT, wireless sensor networks in association with allied technologies, viz. cloud computing, big data, and so on.

## 1.11 Conclusion

Wireless sensor networks (WSNs) are responsible for sensing, monitoring and controlling options of data. From the military applications it has now developed valuable environmental applications, lifestyle and citizen science, and industrial applications. Environmental applications, viz. forest management, disaster management, and air- and water-quality management can be considered important with WSNs. A wireless sensor network is combined with a network of nodes that collaborate and monitor the surrounding environment. An interaction between people and nodes is fundamental in wireless sensor networks. The connections, requirement, and affiliation of the internet of things can be considered important in developing a perfect combination of the IoT and WSN. The growing applications in diverse sectors regarding the WSN and IoT are a significant move in building an intelligent and digital society.

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## Computational Intelligence in Wireless Sensor and Actuator Networks: A Thorough Review

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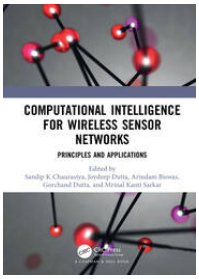
Show Path

Chapter




# Metaheuristic Clustering in Wireless Sensor Networks

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**ABSTRACT**

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