

Internet of Things

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Artificial Intelligence-based Internet of Things Systems



Springer

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Artificial Intelligence-based Internet of Things Systems



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Preface

This book aims to bring together leading academic scientists, researchers, and research scholars to exchange and share their experiences and research results on all aspects of Internet of Things (IoT)-enabled artificial intelligence-based technologies. It also provides a premier interdisciplinary platform for researchers, practitioners, and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of AI-based IoT. This book aims to attract researchers and practitioners who are working in information technology and computer science. This book is about basics and high-level concepts regarding artificial intelligence paradigm in the context of Internet of Things. This book covers a wide range of AI-enabled IoT technologies. This book aims to explore the insight paradigm of the AI-based IoT technologies which will bring a smooth platform for the scope of industry-academia. The wide-range contents will differentiate this edited book from others. The contents include functional framework and protocols for IoT-based system, intelligent object identification, intelligent sensors, learning and analytics in intelligent IoT-enabled systems, CRISP-DM frame work, RFID technology, wearable sensors, IoT semantics, knowledge extraction, applications of linear regression, classification, vector machines and artificial neural networks for IoT devices, Bayesian learning, decision trees, deep learning frameworks, computational learning theory, multi-agent systems for IoT-based ecosystem, machine learning algorithms, nature-inspired algorithms, computational intelligence for cloud-based Internet of Things, and trustworthy machine learning for IoT-enabled system in IoT related topics. The above topics are likely to be embedded with the AI-enabled IoT technologies for future generation automation.

Chapter 1 explores IoT architecture; analyzes IoT network's technical details; and describes communication enabled technologies. Moreover, this chapter deals with various AI-based technologies integrated into IoT, edge computing, and trust models for IoT appliances. Recent AI-based projects and research challenges concludes this chapter.

Chapter 2 has formulated an overview of the IoT environment which illustrates IoT architecture, gateways, nodes, middleware, OSs, framework, protection,

storage and computation, communication or networking technologies of IoT, and interfaces for the efficient utilization of data in an ecosystem. This chapter moreover illustrates the hierarchy of the intelligence of the IoT ecosystem, which describes the process of generation of data, derivation of desired information from those raw data, processing, and manipulation.

Chapter 3 illustrates a detailed view of ML and DL applicability in WSN and IoT. This chapter also describes a complete view of various neural networks (NN) and support vector machine (SVM) types that incorporate frequent, deep neural networks, quarter and ellipsoidal SVMs, and subspace-SVM forms, which are relevant to wireless and IoT appliances. This chapter provides an in-depth summary of various communication issues in IoT that are addressed by neural networks and SVM, and application and motivation for using those techniques. Followed by intrusion detection in IoT with NN and SVM, a case study on outlier detection WSNs data and future research implementations is discussed.

Chapter 4 evaluates the different methods of machine learning that deal with the challenges posed in the handling of IoT data. Big data is generated through the communication of Internet of Things/smart devices, and this data stored at cloud. The taxonomy of machine learning algorithms is described in this chapter, explaining how different techniques are applied to data generated using IoT devices. It will also address the future problems of machine learning for IoT data analytics.

Chapter 5 aims to explore DL frameworks for IoT. The chapter begins with a discussion on the development and architecture of the DL framework. This chapter then discusses about various DL models associated with deep reinforcement learning approaches for IoT. The potential applications, including smart grid management, road traffic management, industrial sector, estimation of crop production, and detection of various plant diseases are discussed. Various design issues and challenges in implementing DL are also discussed. The findings reported in this chapter provide some insights into DL frameworks for IoT that can help network researchers and engineers to contribute further towards the development of next-generation IoT.

Chapter 6 addresses the technique that combines the capability to learn and evolve solutions for large-scale dynamic systems. The chapter deals with the extended classifier system (XCS) which is an amalgamation of reinforcement learning (RL) and genetic algorithms (GA). While RL learns the model-free problem environment, the nature-inspired GA evolves better decision-making rules and improves the existing ones. The motive is to provide intelligent computation for fog-cloud-based IoT systems through XCS. The chapter reveals how the XCS algorithm estimates the optimal number of IoT workload that is to be processed in fog, the remaining of which is transferred to the cloud. The optimal number of workloads estimated by the XCS algorithm balances the energy cost and delay in the fog-cloud based resource allocation (RA) system.

Chapter 7 integrates machine learning and IoT in a portable scale to perform high-accuracy verification system. This model uses a pre-trained convolutional neural network (CNN) on a Raspberry Pi. The CNN will analyze pixels from a signature image taken by the Pi camera to recognize abnormalities and differences and to

identify false signature. Other than requiring a secure digital authentication to operate, it also informs the user immediately on the app execution and image being scanned via a cloud-based system. The system is expected to provide on-the-spot signature verification and minimize any logistic issue that stems from faulty signature to an organization.

Chapter 8 illustrates the facilitators of Internet of Things like machine to machine (M2M), radio frequency identification (RFID), and software-defined networking (SDN). Machine to machine (M2M) is a communication system in IoT that endorses the group of devices to communicate with each other. The mobile communication system is optimized by M2M and standardized by 3GPP. The motivation of this chapter is that the communication system facilitated with IoT has performed their actions autonomously without the assistance of a human.

Chapter 9 discusses different types of framework, pros and cons of every framework, architecture, and different criteria to choose the better framework which will be useful for Internet of Things-based applications. Moreover, this chapter discusses architecture, generative models, and deep reinforcement learning for IoT applications.

Chapter 10 presents the active ongoing research in optimizing deep learning models for inference at the edge using connection-pruning, model quantization, and knowledge distillation. This chapter describes the techniques to train/retrain the deep learning models at the resource-constrained edge device using new learning paradigms such as federated learning, weight imprinting, and training smaller models on fewer data.

Chapter 11 presents a survey of techniques that have been introduced to exploit the pros and mitigate the cons of NVMs when used for designing IoT systems. This chapter classifies these techniques along several dimensions to highlight their similarities and differences. Keeping consideration that NVMs are rapidly growing in IoT systems, this chapter will encourage and motivate further researcher and scientists in the field of software technology for NVMs-based IoT.

Chapter 12 describes the digital abstraction of the physical aspects of a city using digital twin to simulate scenarios to understand behaviors of a particular event. This study analyzes the use of artificial intelligence techniques and IoT used in digital twin approaches to analyze cyber security risks in the smart city environment.

Chapter 13 discusses Cognitive Internet of Things (CIoT) which inherited numerous challenges from artificial intelligence, IoT, and cognitive systems. Therefore, the challenges of these fields should be studied to extract the challenges in designing CIoT. In the literature, there is no study on extracting the challenges considering associated technologies to CIoT. In this chapter, the challenges of the associated technologies are summarized. Then, some important challenges in designing CIoT are obtained.

Chapter 14 uses reinforcement learning techniques to find patterns of user dynamics and to determine the incentive prices. Specifically, the authors adapt the state-of-the-art reinforcement learning framework for dock-less BSS rebalancing. Different from existing research, the authors make full use of the benefits of destination incentives. In addition, they further extend the reinforcement learning

framework to docked BSSs by adding station capacities to the state space of the reinforcement learning agent. They have examined the performance of our schemes based on real-world datasets. An experiment result reveals that the hybrid incentive scheme outperforms the source-incentive-only scheme.

Chapter 15 discusses vital applications of IoT and Bayesian learning to the monitoring, messaging, and accident analysis on highways. The chapter adopts the case approach in presenting advances in IoT and cloud technologies and builds a concept around a scenario to demonstrate real-life applications and contextual relevance of Bayesian learning models.

Chapter 16 discusses the processes, challenges, and solutions concerning designing an airport smart parking system. IoT parking sensors, Open Automatic License Plate Recognition (OpenALPR) library, and the IBM cloud-based IoT platform are integrated to tackle technical challenges, including the automatic identification of plate numbers, models, and colors of vehicles in parking spaces, in both indoor and outdoor parking environments. The chapter also addresses several issues related to the system, that is, the system architecture design, the selection of sensing technologies, and hardware and software platforms, while taking into account specific characteristics of IoT and AI technologies.

Chapter 17 presents an overview of research on using end-to-end deep learning technologies for computer vision-based autonomous driving systems. It briefly discusses the ethics of autonomous driving; it also describes autonomous driving paradigms and the associated deep learning methodologies. Furthermore, it proposes an IoAT-compatible low-cost, low-latency, high-accuracy, and high-reliability CNN-LSTM based autonomous driving model that incorporates temporal information, transfer learning, and navigational command. It also provides a detailed analysis against existing models. Finally, the chapter draws its conclusions and discusses future research directions to further improve system performance.

In Chap. 18, the Bayesian learning and decision trees are presented in respect of their ability to entrench optimum intelligent prediction in IoT-enabled domain. Succinct elucidation of the potential application of an intelligent IoT-driven system is presented as a possible panacea to address some of the problems in food production cycle especially in post-harvest storage and wastage.

We are sincerely thankful to the Almighty for supporting and standing by us at all times, through thick and thin, and guiding us. Starting from the call for chapters till the finalization of chapters, all the editors have given their contributions amicably, which is a positive sign of significant teamwork. The editors are sincerely thankful to the series editors Prof. Giancarlo Fortino and Prof. Antonio Liotta for providing constructive inputs and allowing an opportunity to edit this important book. We are thankful to reviewers around the world who shared their support and stood firm toward quality chapter submission.

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Key Features

1. Addresses the complete functional framework workflow in AI-enabled IoT ecosystem.
2. Explores basic and high-level concepts, thus serving as a manual for those in the industry while also helping the beginners to understand both basic and advanced aspects in AI-enabled IoT ecosystem related technology.
3. Based on the latest technologies, and covering the major challenges, issues, and advances in AI-based IoT environment.
4. Explores intelligent object identification and object discovery through IoT ecosystem and its implications to the real world.
5. Explains concepts of IoT communication protocols, intelligent sensors, statistics and exploratory data analytics, nature-inspired algorithms, computational intelligence, and machine learning algorithms in IoT environment for betterment of the smarter humanity.
6. Explores intelligent data processing, deep learning frameworks, game theory, and multi-agent systems in IoT-enabled ecosystem.
7. Explores vector machines and artificial neural networks for IoT devices, and big data analytics in IoT-based environment.
8. Explores security and privacy issues and trustworthy machine learning related to data-intensive technologies in AI-based IoT ecosystem.

About the Book

The edited book *Artificial Intelligence-based Internet of Things Systems* is intended to discuss the evolution of future generation technologies through Internet of Things in the scope of artificial intelligence. The main focus of this volume is to bring all the related technologies in a single platform, so that undergraduate and postgraduate students, researchers, academicians, and industry people can easily understand the AI algorithms, machine learning algorithms, and learning analytics in IoT-enabled technologies.

This book uses data and network engineering and intelligent decision support system-by-design principles to design a reliable AI-enabled IoT ecosystem and to implement cyber-physical pervasive infrastructure solutions. This book will take the readers on a journey that begins with understanding the insight paradigm of AI-enabled IoT technologies and how it can be applied in various aspects. This proposed book will help researchers and practitioners to understand the design architecture and AI algorithms through IoT and the state-of-the-art in IoT countermeasures.

It provides a comprehensive discussion on functional framework and knowledge hierarchy for IoT, object identification, intelligent sensors, learning and analytics in intelligent IoT-enabled systems, CRISP-DM frame work, RFID technology, wearable sensors, IoT semantics, knowledge extraction, applications of linear regression, classification, vector machines and artificial neural networks for IoT devices, Bayesian learning, decision trees, deep learning frameworks, computational learning theory, multi-agent systems for IoT-based ecosystem, machine learning algorithms, nature-inspired algorithms, computational intelligence for cloud-based Internet of Things, and trustworthy machine learning for IoT-enabled systems. This book brings together some of the top IoT-enabled AI experts throughout the world who contribute their knowledge regarding different IoT-based technology aspects. This edited book aims to provide the concepts of related technologies and novel findings of the researchers through its chapter organization. The book explores AI-enabled IoT paradigms which will be utilized as a part of betterment of mankind in the future era. Specifically, the far-reaching references of various works and executions will be observed to be significant accumulations for engineers and

organizations. The primary audience for the book incorporates specialists, researchers, graduate understudies, designers, experts, and engineers who are occupied with research on Internet of Things, artificial intelligence, machine learning, and applications.

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Award” along with gold medals for his outstanding and extraordinary achievements in the field of information technology and services rendered to promote greater friendship and cooperation between India and the world. He served as the founding editor-in-chief of the *IEEE Transactions on Cloud Computing*. He is currently serving as co-editor-in-chief of the journal *Software: Practice and Experience*, which was established 50 years ago. For further information on Dr. Buyya, please visit his cyberhome: www.buyya.com

Part I
Architecture, Systems, and Services

Artificial Intelligence-based Internet of Things for Industry 5.0



Bhanu Chander, Souvik Pal, Debashis De, and Rajkumar Buyya

1 Introduction

Nowadays, wireless communications, IoT devices, intelligent sensors, industrial IoT, mobile edge computing, and communication protocol are the buzz words in industry-academia. In general, IoT works through implanting short-range moveable transceivers into an eclectic arrangement of devices and everyday objects, enabling novel communication procedures among people and things and things themselves. Therefore, IoT would add a new dimension to information and communication. IoT devices are interconnected devices through a piece of inventive communication machinery such as RFID, Wi-Fi, GSM, Bluetooth, and many more, which can help improve people's living standards [1–4]. The latest survey reports that the number of IoT devices like embedded devices, sensors, game consoles, laptops, and smart devices anticipated to reach more than 60 billion in 2025. In general, IoT expertise's evolution is very similar to the current society, where people and devices practically

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integrated into information systems over wireless sensors technology. IoT integration's main intention is information sharing, enabling smart surroundings to identify objects then retrieve information. Embedded devices play an essential part in IoT, which mainly connect with intelligent sensors for information gathering. In detail, embedded devices interact with the physical environment with these sensor nodes [3–5]. Nowadays, the IoT platform provides advanced control and monitoring services for novel appliances to expand their working efficiency.

The *Internet of Things* (IoT) is defined and used by a well-known researcher Kevin Ashton in the early days of 2000. From Kevin Ashton's explanations, the IoT is a system/structure of material things in the real world to link to the Internet through intelligent sensors. Ashton also conceived the *RFID* technology, which heavily applied to transportation tracking services without any human interventions. Now there are different definitions available based on their specific idea in the real-world scenario. For instance, from IEEE, "IoT is a framework of connected devices thru the internet, for new appliances and services enable the interaction in the physical and virtual world in the form of M2M communication" [3]. From Internet Architecture Boards (IAB) definition, "IoT is the networking of smart objects, meaning many devices reasonably communicate in the presence of internet protocol that not directly operated by human beings but exist as components in buildings, vehicles or the environment" [6].

As discussed above, most IoT systems are becoming increasingly dynamic, mixed, and multifaceted; thus, the organization of such an IoT system/model is challenging. IoT System-oriented services need to enhance efficiency and variability to attract more abusers. In recent times, artificial intelligence (AI) reaches tremendous success in numerous domains by employing modifications in computing technologies [5]. Machine learning (ML) is another unique technology and a sub-part in AI applied on IoT for better services. Both AI and ML are recognized as the critical parts for IoT to make intelligent network management and operations. Many kinds of research work produced better results by applying AI and ML in pattern recognition, natural language processing, object detection, and network sharing. Hence, the IoT domain can also benefit from leveraging support from AI and ML. There are huge chances by employing AI- and ML-based models to IoT to make profound analytical and in-depth progress of well-organized smart real-world appliances [6, 7].

Before knowing the technical research trends of IoT, everyone needs to take a look and understand how an IoT works and impacts our everyday life. Every researcher and data scientist tries to import and understand IoT preliminaries according to their visualizations and then requirements. After all, there is no universal definition of IoT and its visualization requirements. Internet of Everything (IoE), Internet of Cloud Things (IoCT), and Web of Things (WoT) come from the IoT visualizations and have their respective definitions of working protocols. However, IoT is designed based on integrating various standards and enabling technologies with dissimilar sensing, computational capabilities, connectives, and storage capacities. Here in IoT systems, the integration standards in employed devices present high-rated challenges while authentic connections of everything. The challenges on

integration in IoT devices are considered significant IoT issues since those are fundamental to the further development of IoT projects [7–9]. Nowadays, numerous standardization administrations, associations, researchers, and manufacturing industries make an effort on IoT expansions, modernization, and setting things in the right way. However, there is still a lack of a broad context with combined ethics beneath one IoT.

2 Industry 5.0 Paradigm

When it comes to the twenty-first century, most of the domains turn into digitalization. However, we admit that companies struggle to digitalize their business by incorporating AI, IoT, and Industry 4.0 technologies. Apart from the mentioned technologies, the subsequent step of the Industrial Revolution seems in the upcoming days and is named Industry 5.0 [2–6, 10–14]. The term Industry 5.0 was familiarized in early 2015; however, it was called the Fifth Industrial Revolution, which built tremendous influence in different domains, especially day-to-day business, because of the velocity of added industrial, technical enhancement and shifting human process integration [15–18].

The First Industrial revolution or Industry 1.0 started at the end of the eighteenth century; it symbolized industrialized mechanical arrangements consuming coal, human, water, and stream power. The Second Industrial Revolution or Industry 2.0 commenced in the last quarter of the nineteenth century, and it represented mass manufacture through the use of electrical energy [19–22]. The discovery of the telephone, mass production, telegraph, introduction of assembly lines, and mechanization are few features of Industry 2.0. The Third Industrial Revolution or Industry 3.0 started in the early twentieth century. It established computerization and then micro-electronic skills into the industrialized field. A higher level of automation is accomplished using robots, information technology, and microprocessors – most of these twentieth-century initiatives are closely related to information and communication technology (ICT). Computer-integrated manufacturing, computer-aided processing planning, computer-aided design, and flexible manufacturing systems are some of the fields taking advantage of the third revolution. In recent times at the start of the twenty-first century, Fourth Industrial Revolution or Industry 4.0 started with the inclusion of cyber-physical systems (CPS), which makes revolutionary changes in manufacturing. Industry 4.0 was predominantly characterized by CPS, cloud computing, big data analytics, augmented reality, IoT, simulation, and intelligent devices. This means it entirely focuses on end-to-end digitalization and incorporating digital industrial ecosystems by seeking completely integrated solutions [20–24]. Besides, it highly focused on IoT objects that connect with the industrial plant.

Industry 5.0 emphasizes collaboration among humans and machinery types, which means the Fifth Industrial Revolution is more captivated by forward-thinking human-machine interfaces through human-machine interaction. Industry 5.0 main intention is to progress Industry 4.0 to an advanced level. For this, it brings the

concept of collaborative robots which are also known as cobots. With the successful integration, cobots will fulfil today's need for enterprises that produce personalized products [20–24]. Hence, with improved manufacturing, software tools, the Internet of Everything, and robotics using technical progressions, Industry 5.0 is familiarized in manufacturing and medicine than other allied areas.

It provides chances for a customer to experience mass customization in different groups' collaboration across the world. Technology innovations do not consider the foundation of revolution for the organization, and there is a need for customer goals. To fulfil the customer goals, Industry 5.0 follows some set of principles:

Mass customization – suggest actual price and comfortability of various product or service customization to customers.

Customer-centric – concentrate on customer goals and try to resolve hurdles in business expansion through reengineering

Green computing – also an emphasis on environmental conditions.

Cyber-physical systems – prepare an intelligent system from the human serving the customers by gaining maximum benefits from the human with machine intelligence [16–18, 20–24] (Table 1).

Reasons for Adopting Industry 5.0 in Manufacturing

Industry 5.0 will advise or solve the issues associated with removing human workers from dissimilar manufacturer procedures from the discussions mentioned above. However, there is a need for advanced technologies to boost the Industry 5.0 manufacturer [16–18, 20–24]:

Multiscale modeling and simulation – advances of digital twin with intelligent autonomous schemes arise difficulties in valuation monitoring of manufacturing sites. In this context, visualization tools play a crucial role in constructing the

Table 1 From Industry 1.0 to Industry 5.0

Phase	Period	Description	Identification by	Key point
Industry 1.0	1780	Industrial manufacture based on stream and water machines	Mechanization Water and stream	First mechanical loom
Industry 2.0	1870	Mass production with electrical energy	Electrification Division of labor Mass production	First assembly line
Industry 3.0	1970	Automation with electronic and IT system	Automation Electronics IT systems	The first programmable logic controller
Industry 4.0	2011	The connected device, data analytics, computerized machinery programs to automate the industry production	Globalization Digitalization IoT, robotics, big data, cloud computing	Cyber-physical systems
Industry 5.0	Future	Cooperation among human intelligence with a machine to improve products and services	Personalization Robotics and AI Sustainability	Human-robot co-working Bio-economy

policies for managing and personalizing genuine products and then product outlines.

Miniature sensor data interoperability – usage of sensor nodes highly increased from smart homes to autonomous manufacture cobots and distributed intelligent systems. These intelligent sensor nodes sense and collect real-world raw data, which is an unavoidable asset to the next Industrial Revolution. However, with the progress of energy optimization, fast and effective customization process, selection of a local agent for pre-processing data, and creating high modeled distributed intelligence in IoT, Industry 4.0 is still an open research issue.

Virtual reality with digital twin – with the result of continuous growth in big data and AI-based cobots, it is even more feasible to create more realistic digital twins. It properly allows industry experts to allow reduced wastage in the process flow and system design. Hence, the digital twin with advanced visualization techniques will tremendously increase the throughput of all the sectors.

Real-time trackers – will boost real-time production tracking, facilitating the customers' sales orders with manufacture orders and supplementary material. Virtual training will assist in some cases: when trainee or trainer on different locations but learns a specific job in a virtual/simulated atmosphere. This type of training pointedly decreases the costs than time for both parties.

Intelligent autonomous systems – artificial intelligence models have great deals in autonomously controlling production lines in the manufacturing industry. Up-to-date AI-related ML and DL models effectively make changes in intelligent systems and solutions that assist in decision-making scenarios.

Transfer learning – transfer learning policies guide the schemes mentioned earlier, securely and progressively in Industry 5.0.

Computer vision with DL and RL and GPU-based computation has shown great potential in reproducing primitive vision besides sensory abilities. However, for advanced performances of Industry 5.0, cobots proficiencies must be improved suggestively.

Problems and Limitations in Industry 5.0

Industry 5.0 resolves most of the manufacturing issues associated with removing human workers from different procedures. However, it must incorporate additional forward-thinking skills since humans may add innovative manufacturing skills in the coming days. There are numerous skills in the developing stage, some of them pointed in this section.

1. Before incorporating advanced skills into industrial management, there is a need for how an autonomous system can incorporate ethical principles.
2. There is a need for proper verification and validation of ethical behavior inside the autonomous system model.
3. Implementation operation transparencies and fast and competent manufacturing might have significance in an overproduction phenomenon.

4. The outcome results must be understandable ethical behavior solutions in an autonomous scheme. In particular, industrial experts are facing adapting and implementation issues.
5. Tuning and validation will avert somewhat serious problems among technology, experts, stockholders, society, and businesses.

3 Elements of IoT

As we mentioned in the introduction, understanding IoT building blocks will give some visualization and a better perception of the IoT's actual meaning than functionality [23]. We listed six fundamental elements of IoT, which are noted in Fig. 1.

Identification

In any communication or data transmission network, the term identification plays a considerable role. The precise identification is key to the IoT structure to name and match services with their claim. However, it is tricky to addressing object ID and its corresponding IP address in the IoT system. An ID indicates a particular object or device's name, and an address indicates its present address inside the network territory. Differentiation among object identification then addresses authoritative since identification models are not inimitable; moreover, objects might practice with public IP addresses inside the network. Hence the designed models must overcome the hurdles mentioned above and identify every object inside the network correctly.

Sensing

IoT setup intends to gather information from a particular region/area, organized through sensing devices. Sensing devices/objects collect real-world data from the surrounding atmosphere and send it back to the database or cloud for additional

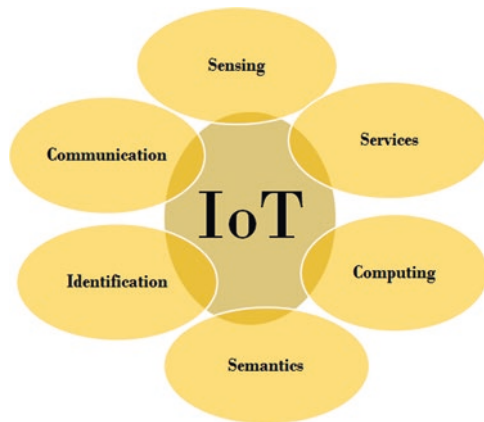


Fig. 1 Internet of Things elements

processing: sensors, wearable devices/sensors, and actuators utilized mainly for sensing purposes. For example, single-board computers (SBCs) like Arduino Yun and Raspberry PI combined with sensors and integral TCP/IP and safety functionalities are naturally used to grasp IoT products. Such devices characteristically attach to a central managing portal to deliver the essential data by clients.

Communication

In general, most IoT objects contain adequate resources; with these limited resources, objects connect with heterogeneous devices/objects in the company of lossy, noisy connotations. Wi-Fi, Bluetooth, NFC, RFID, and IEEE standards some IoT communications; in the next section, a brief description provided a better understanding.

Computing

The computing power of hardware devices is also an essential concern in IoT. The computation components like microprocessors, microcontrollers, and software-oriented appliances represent the brain to a particular appliance. Arduino, Raspberry PI, UDOO, MULLE, and Gadgeteer are hardware platforms designed for IoT appliances. Some other platforms are real-time-software operating systems (RTSOS), for real-time IoT functions; TinyOS, for lightweight operations; and cloud platforms, for too big data processing in real time. Still, some of the computing components have drawbacks, and research community is working on them to perform well.

Services

IoT offers a wide variety of services. Most of them are divided into identity-based services, in which most of the real-time appliances come in this category; information-aggregative services, which accumulate real-world raw sensor data connected with appropriate IoT applications; collaborative-aware services, which use the collected data to data analytics for decision-making; and ubiquitous-based services, aimed to represent collaborative systems to work anytime, anywhere when they are required by clients. Still, the above mentioned services are not reached or achievable to a comfortable stage; many complications besides challenges have to be answered.

Semantics

Semantic operation in IoT performs to useful abstract information smartly from different objects. It is similar to knowledge extraction, like finding resources that improve the model performances. Resource Description Framework (RDF), World Wide Web Consortium (W3C), Efficient XML Interchange (EXI), and Web Ontology Language (OWL) are some of the well-known semantic technologies adopted in IoT systems.

4 IoT Architecture

IoT and its variant inclusion into various domains and organizations will enhance the product or working performances. However, these proposals are severe and complicated to implement when it comes to real life since the number of devices, protocols, and working conditions is entirely dissimilar from one device to another. In other words, the problem of creating a consistent architecture of IoT unavoidably arrives in this phase. Before designing IoT architecture, it is better to understand the factors that affect IoT behavior, making it easier to find reliable IoT solutions. Moreover, it will reduce the various resources spent on IoT design. Before revealing the enigmas and providing an explicit construction of this creativity, it is vital to recognize what this idea means [23–28]. In essence, IoT architecture is the combination of great fundamentals network tools. It is measured as a global network setup collected of several allied devices that rely on communication, networking, sensory, and then information processing types of machinery. See Fig. 2.

4.1 Perception Layer

IoT is a kind of worldwide physical interrelated system in which things can couple and then be measured remotely. The perception layer is considered an initial stage for IoT schemes, and it is like a bridge between real and digital worlds. In some cases it is acknowledged as a sensing layer. Most of the perception layer deals with intelligent wireless devices like intelligent sensors, tags, and actuators. These wireless schemes with tags or sensors are now talented to inevitably sense and then exchange info among different devices. Devices may diverge in procedure and size

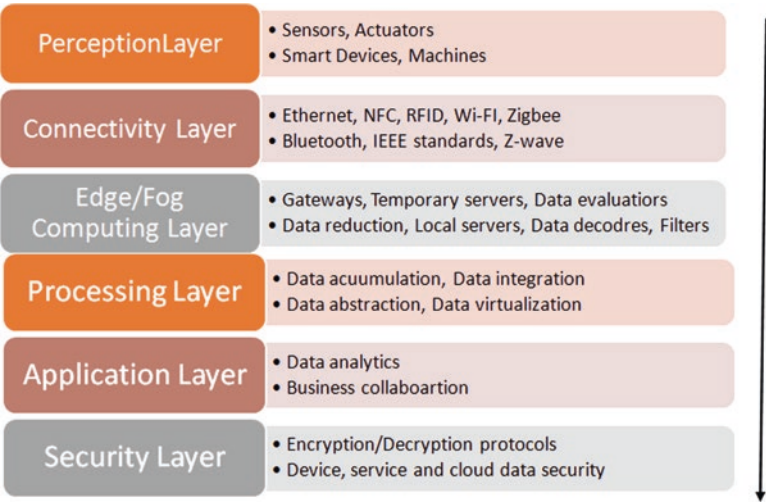


Fig. 2 Internet of Things architecture

from miniature to ad hoc vehicles. Sensors accumulate environmental conditions, transform them into electrical signals, and then forward them to IoT schemes. Actuators transform electrical signals collected from IoT scheme toward physical activities. It must note that IoT architecture does not make any limitations on elements and their deployed locations. It means objects/devices can lace in a small place to corners of the world.

4.2 Connectivity Layer

The connectivity layer is considered the second phase of the IoT scheme since it takes care of complete communications across devices, systems, and then cloud centers that made the perfect IoT scheme. The communication connectivity among physical layers to cloud centers can be achieved thru TCP/UDP or software/hardware modules. Ethernet connects fixed IoT devices; Wi-Fi are widespread wireless connectivity applied on home IoT setups; NFC is data transmission among two devices; Bluetooth is used to transfer small-size data, not applicable for large data files. In some unique scenarios, IoT uses message-oriented protocols depending on the application requirement for data connectivity. Advanced Message Queuing Protocol (AMQP), Constrained Application Protocol (CoAP), Data Distribution Service (DDS), and Message Queue Telemetry Transport (MQTT) are some of them.

4.3 Edge or Fog Computing Layer

Edge/fog computing is vital for IoT systems to satisfy the increasing volume of connected devices and real-world services. The intention of designing edge/fog computing is to store and pre-process the sensed data as fast as it sensed and adjacent to its sources as possible. So it can save time and resources for IoT devices; also, it will decrease the scheme latency time, which can improve performance accuracy. Usually, edge/fog computing takes place on gateways and local servers distributed over the network.

4.4 Processing Layer

The processing layer collects all the data across the IoT schemes. It applies pre-processing models to use abstract information for decision-making or make data available for any further operations. Real-time data is observed with API and used for non-real purposes, and it stands like a hub among event-based and query-based data ingesting. After collecting multidimensional data from various devices and applying data abstraction methods, at that moment, only other connected devices can understand the data.

4.5 *Application Layer*

Data analysis is done through software applications to bound with appropriate answers for main business questions/requirements in the application layer. In IoT, hundreds of IoT requests diverge in intricacy and function, using different expertise stacks than functioning schemes. In present days, various applications are constructed right on top of IoT stages that can suggest software-related advance setups through ready-to-use utensils for data mining, pattern, and forward-thinking analytical skills.

Business Layer

The information collected and pre-processed in IoT schemes can only help problem-solving/decision-making systems achieve excellent results. The business layer is well-defined as a distinct stage, advanced, and challenging to describe in a single application layer for this motive.

4.6 *Security Layer*

In any network-related application, the word security has its place. In IoT, the security layer plays a crucial part, covering all the services mentioned above/layers. It is tough to discuss the security topics of IoT in one single paragraph or a section. There are different security levels in IoT schemes: in *device security*, IoT-related devices need low-resourced authentication services, physical metal shields, and chips that can boost procedures to avoid unauthorized code. *Connection security* is mostly data transfer in IoT done through wireless channels, which is easy for attackers to steal or alter the data. Hence, when the data sent over a device or network, it must be in an encrypted format. In *cloud security*, sensed information kept in the cloud must be encoded to mitigate hazards of revealing delicate info to trespassers. Hence, always pay attention to security protocols to certify that security is high at all stages, from the smallest devices to multifaceted analytical schemes.

5 **Enabling Technologies**

5.1 *Radiofrequency Identification (RFID)*

RFID communication technology is specially designed for transportation tracking made of tags and readers. RFID is considered an automatic identification mechanism that involuntarily identifies the target tag signal with suitable data. Hence, it was employed extensively in various hazardous and impassive atmospheres. As we mentioned above, the RFID structure completes with tags and readers. The tag

consists of address bars attached to objects as a small microchip handled by the antenna. The electromagnetic pitch is applied to send and collect data records from an entity over a tag. The data records stored on a tag can only be read or abstracted by readers only when both tags and readers are placed at a specific angle or range. The reader forwards a signal to read the tag's information, and the antenna on the patch receives it, acknowledging the signal by sending appropriate data. In record, three tags are available in RFID communication: passive tag, which obtains signals from tags working on batteries; active tag, in which tags abstract energy from readers' signals, which means those do not have batteries; and, finally, active reader active tag, which works on both low and high frequencies. RFID tags are professionally applied on real-world appliances since they automatically monitor payments, goods or baggage tracking, inventory management, tracking of products, and product lifecycle supervision and then update the information without any third-party or human interference. RFID technologies can fit into different domains to design and enhance model/systems accessibility and then efficiency. However, there are some drawbacks for implementation of RFID because most IoT WSNs appliances are built in harsh environments, where the signals are disturbed and intercepted and there is a chance for the entire device to collapse.

5.2 Power-Line Communication (PLC)

In PLC, data records are forwarded through the attached cables. It means a sender modulates the data records into the transfer medium; when it reaches, receivers demodulate the data records and then read them. By doing this, data transfer with power cables, where one can both power it up and then at a similar time control/retrieve data from it in a half-duplex style. Hence, PLC attracts a communications model in intelligent meters (AMI), HEMS, BEMS, and solar panel-intensive care schemes that understand smart society. There are low-speed and then high-speed kinds of PLC, each of which uses a different communication procedure.

5.3 Electronic Product Code (EPC)

EPC was utilized to recognize RFID tags; it is in string type 96-bit long and placed on tag/patch. Out of these 96-bits, 8 bits represent header which aimed to identify the version of the protocol, 28 bits refer to the unique address of the system that manages the data on tags, 24 bits hold the type of product to be recognized, 36 bits mention the serial number of the tag. Finally, the last 2 bits are being hold the by the organization that created the tag.

5.4 *Wireless Sensor Network*

Wireless sensor networks collect small tiny sensor nodes employed to gather sensed data from surrounding atmospheres. Computer networks, micro-electro-devices, and wireless technology combinations made the formation of WSNs. In the past, wired sensor networks/nodes used for communication, which places very local amenities, overcome WSN technology developed and produce possible results with various appliances. It is a known fact that WSNs drive IoT systems and enhance performance precision. Due to the node's resource constraints, deployment topology, connection, detection of neighbors, and transmission paths are the essential tasks in WSN formation. WSN is a vital element of IoT as it combines mixed sensor data, systems, and appliances. Researchers designed various inclusion techniques for IoT, the Internet, and WSNs, but still face many challenges that need optimal solutions and research under study.

5.5 *Near-Field Communication*

NFC technology is applied for data transmission and small communication setup when two objects are near to each other. It is similar to radio communication but works by touching or two objects closer to the exact location. The communication range of the NFC depends on the scale of the object's antenna. Hence, NFC technology is mostly not recommended to isolated locations, and it also not safer due to its limitations easily vulnerable to attackers.

5.6 *Actuator*

Actuators apply to specialized appliances, and they work significantly when the objects are in motion. It creates various motions like rotary, spherical, linear, and oscillator; then, it creates power from using them into kinetic energy. Actuators consider three types: electrical-based, employed on motors; hydraulic-based, hydraulic fluids; and pneumatically based, which use compressed air.

5.7 *Machine to Machine (M2M)*

M2M communication is similar to LAN and WAN networks; devices gather data from various sources and sent it back to other devices within the network. In M2M, stored data records are monitored and automatically take some assigned tasks depending on the applications. Moreover, the performance of M2M depends on software-controlled communications among machines and devices.