Wireless Personal Communications (2020) 114:1687–1762
https://doi.org/10.1007/s11277-020-07446-4

Internet of Things (IoT), Applications and Challenges: A Comprehensive Review

Abhishek Khanna[1] · **Sanmeet Kaur**[1]

Published online: 28 May 2020
© Springer Science+Business Media, LLC, part of Springer Nature 2020

Abstract

During recent years, one of the most familiar names scaling new heights and creating a benchmark in the world is the Internet of Things (IoT). It is indeed the future of communication that has transformed things (objects) of the real-world into smart objects. The functional aspect of IoT is to unite every object of the world under one common infrastructure; in such a manner that humans not only have the ability to control those objects; but to provide regular and timely updates on the current status. IoT concepts were proposed a couple of years ago and it may not be incorrect to quote that this term has become a benchmark for establishing communication among objects. In context to the present standings of IoT, a comprehensive review of literature has been undertaken on various aspects of IoT, i.e., technologies, applications, challenges, etc. This paper evaluates various contributions of researchers in different areas of applications. These papers were investigated on various parameters identified in each application domain. Furthermore, existing challenges in these areas are highlighted. Future research directions in the field of IoT have also been highlighted in the study to equip novel researchers in this area to assess the current standings of IoT and to improve upon them with innovative ideas.

Keywords Internet of Things (IoT) · Wireless sensor networks (WSN) · Radio-frequency identification (RFID) · Near-field communication (NFC) · Internet of Energy (IoE) · Global Positioning System (GPS) · Representational State Transfer (REST) · Information and Communication Technology (ICT) · Service Oriented Architecture (SOA)

1 Introduction

During the past few years, the vision of the term Internet has been constantly expanding its wings in every aspect of life. It has become a challenging task for researches to identify the optimal potential of Internet usage. With time, the term of the Internet has been

✉ Abhishek Khanna
abhikhanna@hotmail.com

Sanmeet Kaur
sanmeet.bhatia@thapar.edu

[1] Computer Science and Engineering Department, Thapar Institute of Engineering and Technology, Patiala 147004, India

associated with things and is not being identified as IoT. As the name depicts, things are associated through the Internet via Wireless Sensor Networks (WSN), Radio-frequency identification (RFID), Wireless Sensor Networks (WSN), Bluetooth, Near-field communication (NFC), Long Term Evolution (LTE), and various other smart communication technologies. Hence, IoT can be defined as “things that are associated over the Internet.” This association helps in the transfer of information gathered from various devices to destined places over the Internet. Since IoT is the most reliable term of the technological world in today’s date, it still lacks the potential compliance that it is capable of. In such a complex scenario, this article aims to assist all those who want an easy and throughout the approach to understand the concept and further wishes to contribute towards its channelization to serve in the best optimal manner. This article depicts research articles related to the field of IoT, with the maximum number of citations, to extract the most valuable content and distinct researches over the years. The most relevant among them have been addressed and discussed by a length in this research article.

This article has been prorated in a total of five sections. Section 1 of the article is the introductory section which sheds light on the basics of IoT. Section 2 highlights the concept of IoT, its evolution, objectives and various communication technologies used for IoT. Various applications of IoT have been discussed by length in Sect. 3 based on extraction of research articles with highest number of citations over the years. All possible open issues, challenges and future research directions have been discussed in Sect. 4. Section 5 is the concluding portion of the research article, depicting the crux of the research article. Figure 1 depicts a pictorial representation of organizational structure for the research article.

```
Internet of Things (IoT), Applications and Challenges: A Comprehensive Review
├── Introduction
│   ├── Motivation for article
│   ├── Our Contributions to the research article
│   ├── Related Surveys
│   └── Research Methodology and Classification Method
├── Internet of Things (IoT): An overview
│   ├── Evolution of Internet to IoT
│   ├── Objectives of IoT
│   └── Communication technologies of IoT
├── Applications of IoT
│   ├── Smart Mobility
│   ├── Smart Grid
│   ├── Smart Home/Building
│   ├── Public Safety and Environment Monitoring
│   ├── Medical and Healthcare
│   ├── Industrial Processing
│   ├── Agriculture and Breeding
│   └── Independent Living
├── Open issues, Challenges, and Future Research Directions
│   ├── Open issues
│   ├── Challenges
│   └── Future research Directions
└── Conclusion
```

Fig. 1 Organizational structure for the research article

1.1 Motivation for Article

It is a fact that technology is never static. Constant advancements and ever enhancing expectations from existing terminology keep on motivating scientists and researchers to attain newer benchmarks. Moreover, during the last recent years, there have been ample of increase in several associated terminologies, i.e., cloud computing, big data, etc. to IoT. Therefore, keeping existing scenario of constant advancements in the field of IoT in mind, there was a dire need of revisiting the current standings and capabilities of the new age IoT concepts. There was a dire need of a study that highlighted modern-day requirements, its remedial alternatives, and lived precisely to the expectations based upon modern-day IoT concepts. Hence, it was therefore visioned to have a conceptual based methodical literature survey after considering changes that have come up within various applications of life while adopting the concept of IoT. The authors recognized the necessity of conducting a methodological literature survey after considering progressive research done in various applications by utilizing the concepts of IoT. Therefore, a summarized form of the most prized research in various applications on an existing database and to present the research standings has been carried out to identify key challenges, issues faced by various applications, and their immediate remedial solutions proposed by incorporating the concept of IoT over the years, has been presented in the study (Table 1).

1.2 Our Contributions to the Research Article

The research article has been framed in such a manner that:

- The study brings forward the concept of IoT from its origin, along with various upgradations from time to time.
- Various communication techniques used in IoT have been discussed by length.
- The study has been framed in a manner, that highlights the basics of the concept term and gradually covers the functional aspects of the domain and also highlights the limitations and challenges faced by various applications.

Table 1 Notations used in various tables for existing study

Symbol	Description	List of various tables where symbol notations have been used
L, ↓	Low	2, 26
M, ⟷	Medium	2, 26
H, ↑	High	2, 26
SB	Simulation based	2, 16, 18, 20, 22, 24, 26
RT	Real Time	2, 16, 18, 20, 22, 24, 26
LZ	Limited zone	2, 26
MZ	Moderate zone	2, 26
HZ	High zone	2, 26
PD	Pre-defined software	2, 26
D	Derived software	2, 26
N/A	Not-applicable	2, 26
A	Applicable	2, 26

Table 2 Keywords/symbols used in research article

Sr. no.	Parameters	Score	
		0	1
1	Observations	SB	RT
2	Impact of proposed methodology	↓, ⟷	↑
3	Costs involved to develop a framework	H	L, M
4	Area for experimentation	LZ, MZ	HZ
5	Software derived	–	D
6	Pre-existing software	PE	–
7	Possibility for implementation of proposed methodology on related platform	N/A	A
8	Future expansion of proposed methodology	N/A	A

Table 3 Parameters used in research article

Sr. no	Parameter name	Parameter description
1	P1	Impact of proposed methodology
2	P2	Costs involved to develop the framework
3	P3	Area of experimentation
4	P4	Pre-existing/derived software
5	P5	Observations
6	P6	Possibility for implementation of proposed methodology on related platform
7	P7	Future expansion of proposed methodology

- Comprehensive observations have been made to study various applications of IoT concerning the upward market keeping modern-day requirements in focus.
- Future research directions in the area of IoT have been presented based on forthcoming challenges.
- An evaluation has been done to all research articles discussed under various applications of IoT, based on various parameters, depicted in Table 3.
  - *Score evaluation for parameters*
    All parameters were evaluated to a corresponding score with static values 0, 1 as depicted in Table 2. Assigning of a score was based on the keyword/symbol corresponding to each parameter depicted in Table 26 (Table 3).

1.3 Related Surveys

Related surveys by Atzori et al. (2010), Agrawal et al. (2013), Gubbi et al. (2013), Said et al. (2013), Perera et al. (2014), Madakam et al. (2015), Fuqaha et al. (2015) and Whitmore et al. (2015) have been very innovative. Atzori et al. [1] has addressed the enabling technologies along with applications and open issues faced in the field of applications. Agrawal et al. [2] presented a paper in a wider context of IoT, mainly enabling the factors for integration in various technologies. Furthermore, key technologies involved in the implementation of IoT and its major application domain have been discussed. Gubbi et al. [3] highlighted the extension of presented the vision of IoT by enhancing the requirement for convergence of WSN, distributed computing, and Internet directed at the technological research community. Said et al. [4] highlighted architectures, new-age applications, and challenges faced by IoT. Perera et al. [5] discussed the significant growth of sensor deployments over the past decade in the field of IoT. Madakam et al. [6] highlighted the basic requirements, characteristics and aliases of IoT. The study also highlighted the usages of IoT in our daily life. Fuqaha et al. [7] emphasized on protocols, enabling technologies, and numerous application issues in the field of IoT. The study also depicts the architecture of IoT along with various elements and communication techniques. Lastly, the study also highlights the challenges faced in the field of IoT. Whitmore et al. [8] highlighted the identifying techniques, sensing technologies, networking and processing capabilities of IoT. The research activities and advancements have persistently enhanced in the field of IoT over the years. Identifying the dire necessity for a methodical literature a survey that evaluates based on parameters, updated with modern trends and integrated with existing research, has been presented in the study. This survey article highlights the key findings from previous surveys and presents a fresh methodical literature review that evaluates and discovers the possible potentials based on available research in the field of IoT. Table 5 depicts a comparative analysis of existing surveys and the current study.

1.4 Research Methodology and Classification Method

The objective of this survey article is to correctly identify the current standings of IoT. Research has been done thoroughly by examining the existing literature work done in this context. To give a firm foundation to this review article, the study depicts the origin of IoT, along with its current standings, its trends, and technologies. Furthermore, the objective was to identify how the concept came into existence and what are its current standings. The last objective of conducting extensive research was to correctly identify the future directions for IoT. This comprehensive reference acts as a benchmark that assists in understanding the basics of the domain. To attain the objective, a thorough comprehensive review of the literature has been done. The framework for the existing study is based on thorough visit to various journals, conference papers, articles, and edited volumes that have made a significant contribution. Vital literature was identified and information was extracted by querying scholarly databases. 194 pa

pers out of a total database of 925 papers have been thoroughly read. Each paper was discussed, analyzed and classified a specific domain category. The literature was distributed among the two readers based on interest towards domain and content among categories and subcategories. Figure 2 depicts the selection procedure of the extraction of research papers based on abstracts and keywords. Whereas Table 4 depicts the defined strategy of extracting a content-based database from various e-resources. A sincere effort has been made to extract the most relevant literature as possible for this research article (Table 5).

2 Internet of Things (IoT): An Overview

During mid 80’s, communication was either limited to voice over telephone lines or letters. With time, the term Internet came into existence and communication got a new platform. The possibility of Voice over Internet Protocol (VoIP) was achieved over the years. Today’s era has left the concept of the Internet far behind and has come up with a new term, “IoT”.

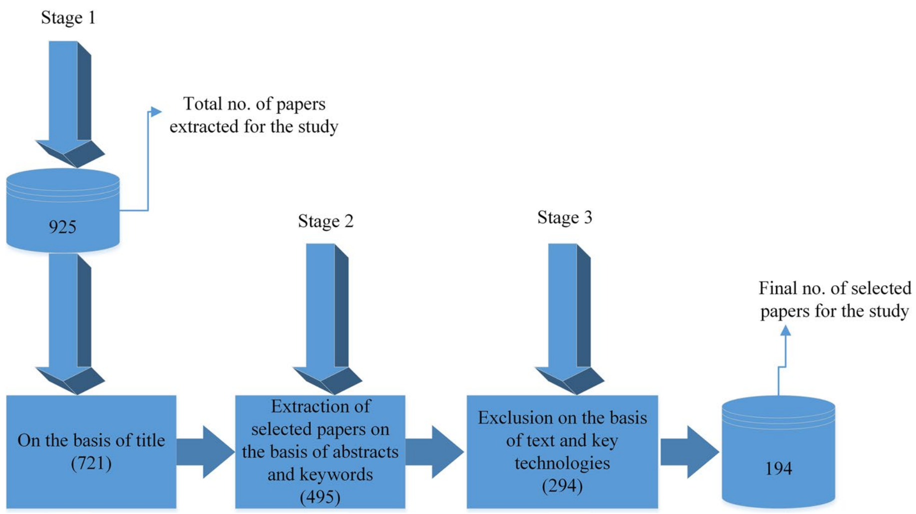


Fig. 2 Study selection procedure

IoT is a technique that combines existing resources over the Internet, that enables them to obtain control over these devices The introductory concept of IoT was proposed at Massachute Institute of Technology (MIT) Auto-ID Labs in the early 1990s [13]. Trojan Room coffee pot was the first IoT application that was developed and the term of IoT was coined [6, 14]. Over the years, numerous advancements have been made within the domain [15, 16]. There have been several definitions derived by various organizations working on this domain. Each organization has termed the definition of IoT in context to its functional capabilities. ITU-T has termed IoT as, "Global infrastructure for Information Society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving, interpolative information and communication technologies" [17]. Although IoT is all about synchronization of things (objects) over the Internet. A slight guidance from humans makes this concept a possibility. Figure 3 depicts the Tri-sectional relationship between the three aspects of IoT.

There have been many phases in transition for the term of Internet to IoT. The first phase was the Pre-Internet phase, where communication was possible over a fixed telephone line and via Short Message Service (SMS). Later the communication medium was upgraded with mobile telephony devices. The second phase was of Internet of Content phase. This phase was capable of sending large sized messages, i.e., e-mail that was capable of associating attachments. Information, Entertainment, etc. were the basic possibilities of this phase. The third phase was of Internet of services, that focused on electronic applications like E-productivity, E-commerce, etc. The fourth phase, i.e., Internet of people was the phase were people got associated with each other through social media and numerous other mediums like Facebook, Orkut, Skype, Youtube, etc. The functional aspect of IoT endures the capability of connecting numerous devices over the Internet. By virtue of this aspect the devices can communicate with each other and perform several directed activities according to the design and functional capabilities of those objects. However, the existing era might not be considered to be the end of the road for this concept. Researchers are trying to incorporate the concepts of Artificial Intelligence (AI) upon these interconnected devices so that they can take necessary decisions and act upon with 0% human intervention. It may not

Table 4 Summary of data of papers selected on the basis of search string

Sr. no	Domain	E-resource	Search domain	No. of papers
1	www.acm.org	Conference, Journals, Proceedings, Transactions, Databases, Magazines, White papers, Reports, etc.	IoT, Internet of Things, IoT Applications, Communication Techniques in IoT, Issues in IoT and Challenges	82
2	www.ieeexplore.ieee.org			272
3	www.sciencedirect.com			108
4	www.scholargoogle.com			125
5	www.onlinelibrary.wiley.com			75
6	www.springerlink.com			82
7	www.webofknowledge.com			127
8	www.elsevier.com			54
Total number of research papers under review				925

Table 5 Comparative analysis of existing surveys and current study

Citation reference	Year of publication	Literature Title	Topics focused by authors within the research article	Significant difference of the current research article
[1]	2010	The Internet of Things: A survey	Various enabling technologies of IoT	Discussion on various communication technologies and their commercial benefits based on various parameters
			Applications of IoT	Applications of IoT have been discussed based on maximum number of citations over the years
			Open issues related to IoT	Other vital references related to all applications within IoT domain have been cited, considering their valuable inputs within the field of research
			Issues highlighted in the study are not domain specific	
[2]	2013	Context aware computing for the Internet of Things: A survey	Various communication technologies	Communication technologies along with their comparative analysis
			Applications of IoT	Identification of communication technologies used in various applications
			Issues related to communication and privacy	Applications of IoT along with their proposed techniques along with identification of further scope of improvement enabling new researchers to clearly identify their area of interest and future course of action

Table 5 (continued)

Citation reference	Year of publication	Literature Title	Topics focused by authors within the research article	Significant difference of the current research article
[3]	2013	Internet of Things (IoT): A literature review	Various elements used in making IoT communication possible	Communication devices making IoT a possibility and their evaluation on various parameters
			Applications of IoT	Applications of IoT have been discussed highlighting the research being observed on the basis of simulation or real time, precise location of experimentation, and industrial adaptation
			Synchronization of Cloud server with IoT	Aspects of incorporating of the study with similar platform have been depicted in the study
			Challenges and future research directions	Challenges faced within each application domain, along with their remedial actions, and future scope of improvement
[4]	2013	Internet of things: A survey on enabling technologies, protocols, and applications	History of IoT has been presented	Evolution of IoT has been presented, year-wise
			Various applications of IoT	Applications of IoT
			Challenges faced while working on various IoT applications	Approach used to over come the challenges and future scope of improvement keeping modern day's vision and expectations
[5]	2014	The Internet of Things A survey of topics and trends	Application domains of IoT	Proposed study highlights:
			Components of IoT	Applications of IoT
			Possible usage of sensors and actuators within IoT	Components of IoT
				Identification of usage of sensors and actuators
[6]	2015	RFID technology and its applications in Internet of Things (IoT)	Architectures that supports IoT	Time series that helped IoT attain newer and newer benchmarks
			Communication technologies of IoT	Communication technologies

Table 5 (continued)

Citation reference	Year of publication	Literature Title	Topics focused by authors within the research article	Significant difference of the current research article
[7]	2015	Building the Internet of Things using RFID: the RFID ecosystem experience	IoT architecture and protocols	Identification of precise objectives for IoT, based on an architecture that can either be derived or developed
			Elements used in IoT	Identification and usage of elements in IoT
			Communication standards of IoT	IoT challenges and approach used to resolve the issues
			IoT challenges	
[8]	2015	Architecture of Internet of Things and its key technology integration based-on RFID	Applications of IoT	Various applications of IoT on the basis of numerous parameters
			Challenges in IoT	Challenges in IoT
[9]	2017	Challenges and Opportunities of Waste Management in IoT-enabled Smart Cities: A Survey	IoT approach for waste management	IoT based approach and implementations covering every possible application under smart smart city domain
[10]	2017	IoT middleware: A survey on issues and enabling technologies	Middle-wares of IoT	In-depth review of IoT in modern era
			Key challenges and issues while handling middle-wares	
[11]	2017	Advanced lightweight encryption algorithms for IoT devices: survey, challenges and solutions	Incorporating of various Symmetric and Asymmetric Cyphers for secure communication	Various aspects and challenges faced while performing communication among devices
[12]	2017	A Survey on Network Methodologies for Real-Time Analytics of Massive IoT Data and Open Research Issues	Requirements for Real-Time IoT analytics	Issues faced while handling Real-time data
			Methodologies handling Real-time IoT analytics	The study identifies RT/SB approach approach adopted within various applications discussed in the article
			Challenges faced while handling Realtime data	Challenges have been discussed and study is not just limited to Real-time analytics of IoT

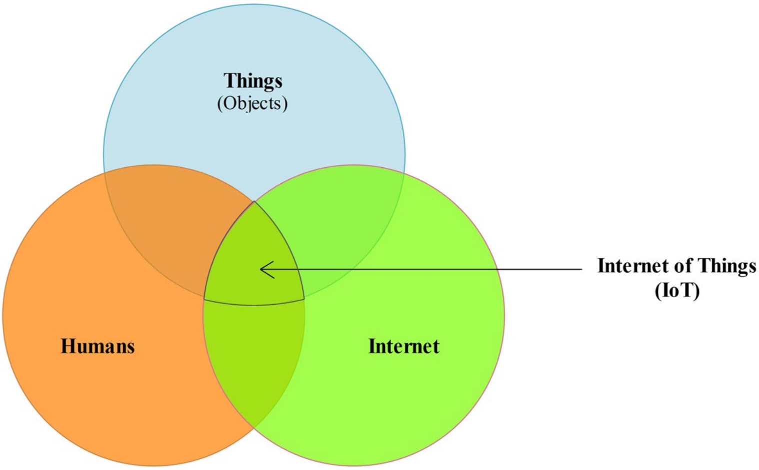


Fig. 3 Tri-sectional relationship among the three aspects of IoT

be incorrect to term the upcoming phase as the IoT will be powered by Internet of Things based Artificial Intelligence (IoTAI). The transformation phase(s) of IoT has been depicted in Fig. 4.

2.1 Evolution of Internet to IoT

The Internet has undoubtedly become a benchmark in terms of communication. During the last few years, there has been a steep inclination towards the adaptation of new-age communication technologies. To date, the world is deployed with around 5 billion smart devices. It has been predicted that over 50 billion devices will be connected over the Internet by the year 2020 [18]. It has been estimated that the incremental value of IoT would surpass $300 billion by the end of this decade. This boosts vision for the development of newer communication technologies and finding out new modes of getting synchronization of newer devices over the Internet. However, it may be incorrect to directly evaluate the functional capabilities of IoT, before understanding time to time changes and advancements in the field of IoT. Figure 5 depicts IoT's evolution and its achievements during the recent years. Whereas, Table 6 depicts references for Fig. 5.

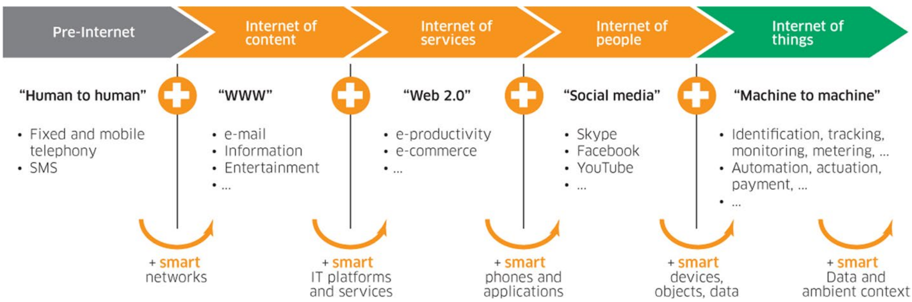


Fig. 4 Transformation of Internet from Pre-Internet to IoT

Since research on IoT is an area of interest for both academia and the industrial sector, the outcomes depict the urge for constantly finding new methodologies for associating various devices over the Internet. This concept is now being looked upon as a road map for development in many of the areas of concern towards society, e.g., Smart Mobility, Smart Grid, Smart Homes and Buildings, Public Safety and Environment Monitoring, Medical and Health care, Industrial Processing, Agriculture and Breeding, Independent Living, etc. Figure 6 depicts the constant increase of devices being associated over the Internet during the last few years.

Garter's Information Technology Hype Cycle for the year 2019 has also revealed that IoT platform tops the chart with respect to peak inflated expectations; that had initiated through an innovation trigger and has reached the maximum level of expectation, where the dependency rate and increased expectations persuade researches for newer developments. Figure 7 depicts the Emerging technologies for Gartner's Hype Cycle report for the year 2019.

2.2 Objectives of IoT

Since IoT is all about universal integration of the IoT through an IP based Service Oriented Architecture (SOA) enabling heterogeneous components and their interoperability. IoT aims to attain the following objectives:

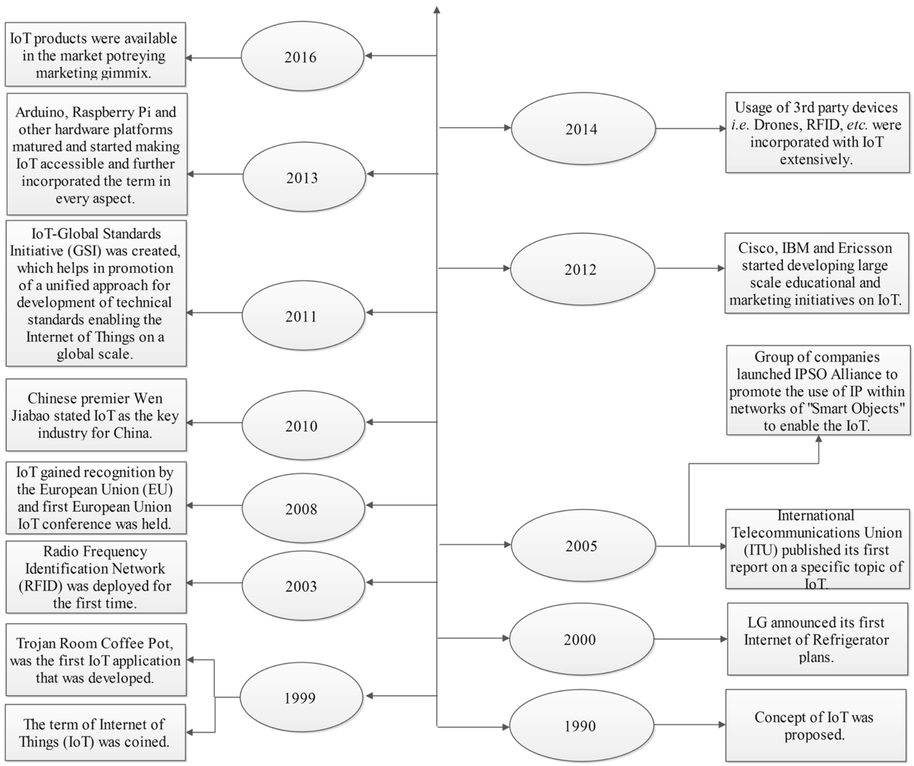


Fig. 5 Evolution in IoT

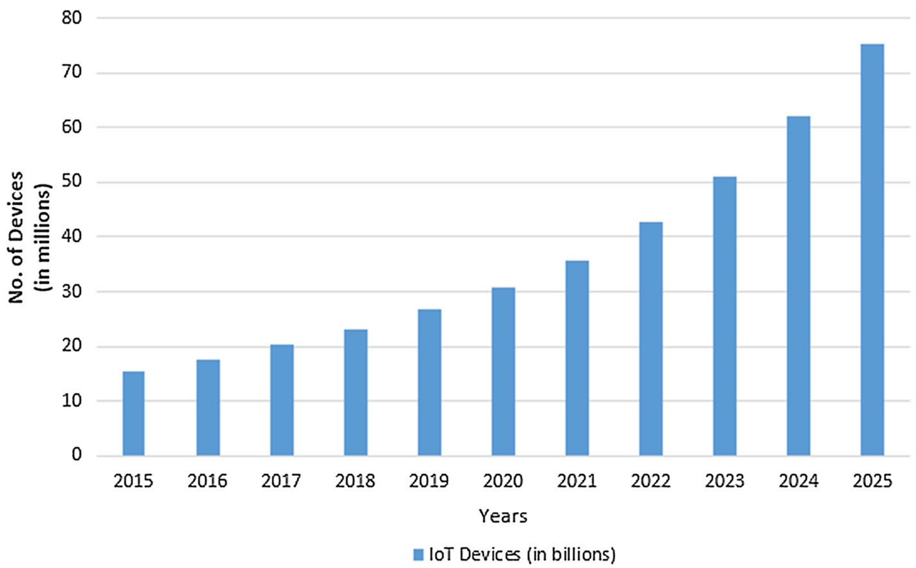


Fig. 6 Projection in number of devices being associated over the Internet (2015–2025) [19]

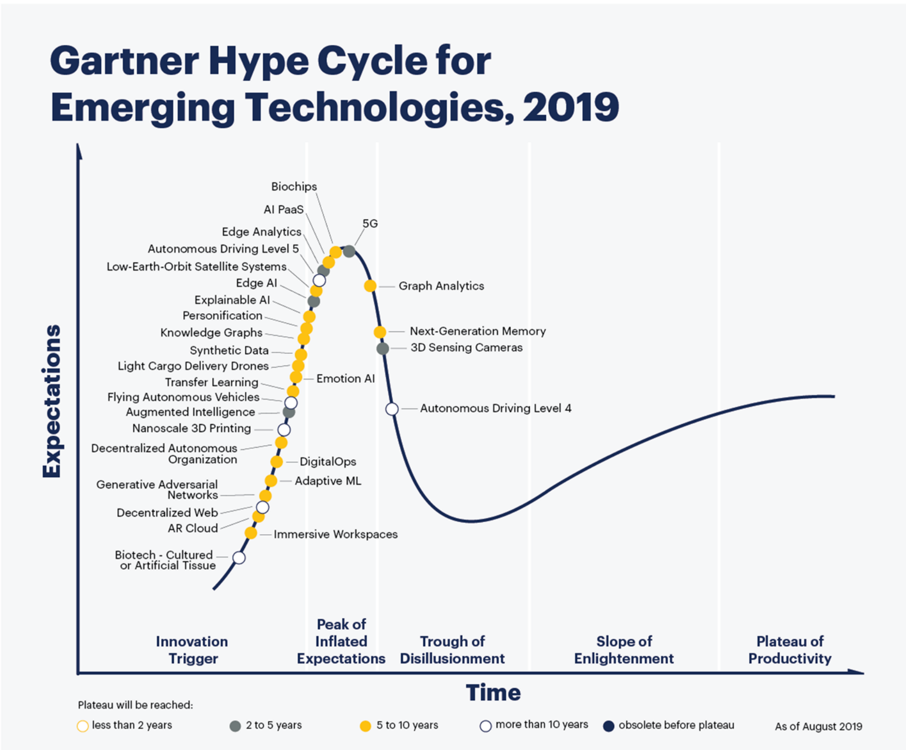


Fig. 7 Gartner's Hype Cycle-2019 [20]

Table 6 References for IoT's evolution for various years as depicted in Fig. 5

Year of evolution	Terminology derived	References
1990	Concept of IoT proposed	[13]
1999	IoT term coined	[6]
1999	First IoT application—Trojan Coffee Pot, 1999	[14]
2000	First Internet of Refrigeration by LG	[6]
2003	First time deployment of RFID commercially	[21]
2005	International Telecommunications Union (ITU)'s first report on IoT	[22]
2005	Group of companies launched IPSO Alliance to promote the use of IP within networks of "Smart Objects" to enable the IoT	[23]
2008	IoT gained recognition by the European Union (EU)	[24]
2010	Chinese premier Wen Jiabao stated IoT as the key industry for China	[25]
2011	IoT-Global Standards Initiative (IoT-GSI) was created	[26]
2012	Cisco, IBM and Ericsson started developing large scale educational and marketing initiatives on IoT	[27]
2013	Arduino, Raspberry Pi and other hardware platforms matured and started making IoT accessible and further incorporated the term in every aspect	[28–32]
2014	Usage of 3rd party devices i.e. Drones, RFID, etc., were incorporated with IoT extensively	[33]
2016	IoT products were available in the market potreying marketing gimmix	[34]

i. The research potentials are further aimed to extend the capabilities from IPv4 to IPv6 and other related standards that are competent enough to support the future of IoT and to overcome its existing fragmentation issues.
ii. To develop a highly scalable IPv6-based SOA that is capable to achieve on issues like mobility, interoperability, cloud computing integration, and intelligence distribution among heterogeneous smart components, applications, and their services.
iii. Self capable of exploring innovative forms of interactions with:

(a) Multi-protocol integration.
(b) Self interoperability with heterogeneous devices.
(c) Cloud Computing Services (IaaS, Paas, and SaaS).
(d) Self-identification of RFID tags and other related services.
(e) Intelligent distribution systems.

2.3 Communication Technologies of IoT

There exists an almost bewildering choice of connectivity options for modern-day applications.

These are based upon the products and systems associated with IoT. Major communication technologies of IoT have been depicted in Fig. 8.

2.3.1 Radio-Frequency Identification (RFID)

RFID system is composed of one or more reader(s) and several RFID tags. RFID tags are characterized by a specific address and applied upon objects. They make use radio-frequency electromagnetic fields to transfer data associated to an object as shown in Fig. 9.

These tags are embedded with electronically stored information which can be read by RFID reader when the object came in the proximity of the reader [35]. RFID allows monitoring objects in real-time, without the need of being in line-of-sight. An RFID tag comes in three configurations. The first one is the Passive Reader Active Tag (PRAT) in which the reader is passive and receives the signal from the battery-operated active tags, whereas the second one is the Active Reader Passive Tag (ARPT), which is most commonly used for communication purposes [36]. The third one is an Active Reader Active Tag (ARAT).

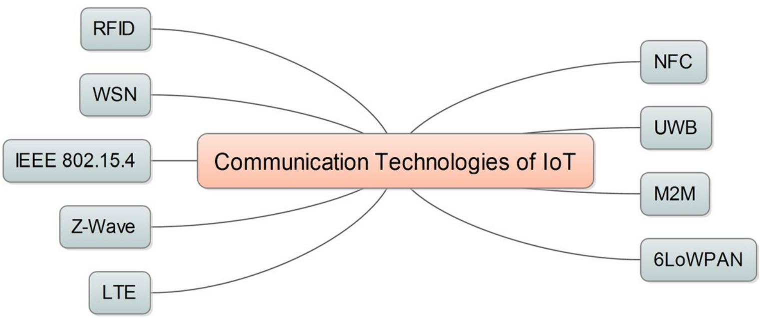


Fig. 8 Communication technologies of IoT

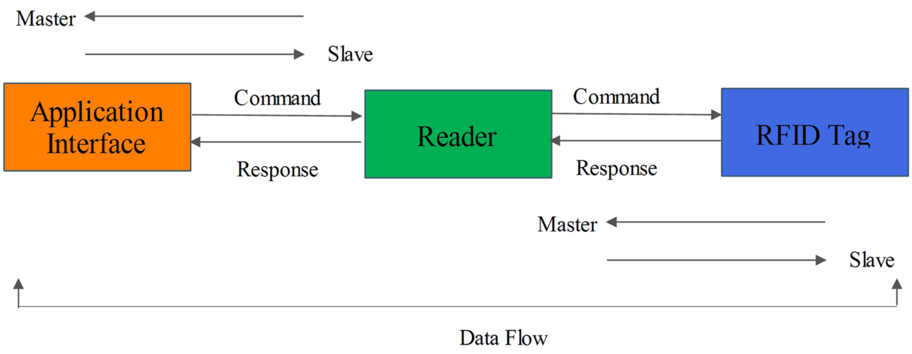


Fig. 9 Working of RFID

RFIDs are the most commonly used techniques of communication. RFID is categorized into 4 different segments as depicted in Table 7.

2.3.2 IEEE 802.15.4

It is a standard which specifies the physical layer and media access control for Low-Rate Wireless Personal Area Networks (LR-WPANs). The original version of IEEE 802.15.4 supported 826 and 915 MHz frequency bands, while the working model supports 2.4 GHz ISM band. The basic framework conceives a 10 m communications range with a transfer rate of 250 kbit/s [37].

2.3.3 Zensys Wave (Z-Wave)

Z-Wave is a low-power wireless communication protocol for Home Automation Networks (HAN). It is used widely in remote control applications for smart homes, as well as small-size commercial domains. In Europe, it operates at 868.42 MHz, whereas in Canada and the USA it uses 908.42 MHz bandwidth for communication. The distance between two nodes should not be exceeding 30 meters.

2.3.4 Long Term Evolution (LTE)

LTE is a standard wireless communication protocol for high-speed data transfer between mobile phones based on Global System for Mobile Communication (GSM) network technologies. It supports up to a maximum of 100 MHz. Data upload and download often encounter lower latency rate and higher throughput [38].

Table 7 RFID categories

RFID type	RFID operating frequency
Low frequency	125–134 kHz
High frequency	13.56 MHz
Ultra high frequency	860–960 MHz
Super high frequency	2.45 GHz

2.3.5 Near-Field Communication (NFC)

NFC is quite similar to RFID. It is overlooked as the integration of RFID readers onto a mobile phone. NFC is also be seen as a unique kind of a radio communication device that is enabled on mobile devices either by tracing inbuilt options that need to be activated or by them two devices close in the proximity [39]. NFC is a short-range, low power wireless link evolved from RFID that can transfer small amounts of data between two devices held in proximity. It enables the communication between two smart objects, that is safe, as this cannot be done from a remote location [40].

2.3.6 Ultra-wide Band (UWB)

UWB communication technology is designed to support communications within low range coverage areas, that are similar to NFC that uses low energy. However, high bandwidth is used for applications to connect sensors for communication. It is capable of a maximum of 500 MHz bandwidth. It was earlier known as radio pulse.

2.3.7 Machine to Machine (M2M)

M2M refers to the communications either between computers, embedded processors, smart sensors, actuators or with mobile devices. Usage of M2M communication has been increasing at a fast pace during the last recent years [41]. There are a total of five basic components for any M2M communication technique, i.e., sensing, heterogeneous access, information processing, applications, and services [42]. M2M is a five-part structure that constitutes of following parts:

i. M2M Device: A device capable of replying to request for data contained within that device.
ii. M2M Area Network (Device Domain): Provide connectivity between M2M Devices and M2M Gateways.
iii. M2M Gateway: Use M2M capabilities to ensure M2M Devices inter-working and interconnection to the communication network.
iv. M2M Communication Networks (Network Domain): Communications between the M2M Gateway(s) and M2M application.
v. M2M Applications: Contains the middleware layer where data goes through various application services and is used by the specific business-processing engines.

2.3.8 IPv6 Low-Power Wireless Personal Area Network (6LoWPAN)

Internet Protocol (IP) is based on technology of 6LowPAN. This network protocol defines encapsulation and header compression mechanisms. The standard has the freedom of frequency band and physical layer and can also be used across multiple communications platforms, including Ethernet, Wi-Fi, IEEE 802.15.4, and sub 1 GHz ISM.

Table 8 depicts an overview of various communication technologies used for IoT communication.

3 Applications of IoT

IoT has a lot of potential for social, environmental, and economic impact towards its adaptation. Mobility, Smart Grid, Smart Homes/Buildings, Public Safety and Environment Monitoring, Medical and Healthcare, Industrial Processing, Agriculture and Breeding, and Independent Living are some of the IoT based concepts. All these applications are associated with us in one way or another. Usage of these applications and vivid benefits have an important role and now there is a huge dependency on their existence. During recent years, their existence and usability have attained a visionary scale and have become of paramount importance. It may not be incorrect to state that the future of the Internet is purely based on the concept and vision of IoT, which drives us into the future practically. Various application areas of IoT have been depicted in Fig. 10. The research work is carried out on the basics of functional aspects of applications and prominent work done by various researchers over the years, has been explained in the upcoming part of the article.

3.1 Smart Mobility

Smart Mobility is the methodology that allows seamless, efficient, and flexible travel across various modes. With the change in time and constant increase in demands of the society, Vehicular Ad-hoc Network (VANETs) has been much in talks. Hence, it can be stated that it is a paradigm shift to a more flexible and multi-modal transport system. It is indeed the pillar for the Internet of Vehicles (IoV) that tends to improve road safety either by preventing or reducing road accidents, giving new solutions towards optimized transportation modes. There are numerous other issues related to traffic problems, commuting from one place to another which have been undertaken by various researchers for improvement. Based on existing resources, researchers have come up with newer techniques in the field of mobility. Some of the major contributions in this domain are as under:

Zorzi et al. highlighted the current standings of the IoT under smart mobility domain. Issues related to Smart Mobility and technical challenges related to wireless communications have been highlighted within the study [43].

Hank et al. proposed a novel communication network along with topologies and components that described an evolutionary path for bringing Ethernet specifically for automotive applications with a focus primarily on electric mobility. Ethernet has been broadly used for undertaking various experiments. The most conversed about is the Advanced Driver Assistant Systems (ADAS), which catered navigation and positioning, multimedia and connectivity issues systems have been studied [44].

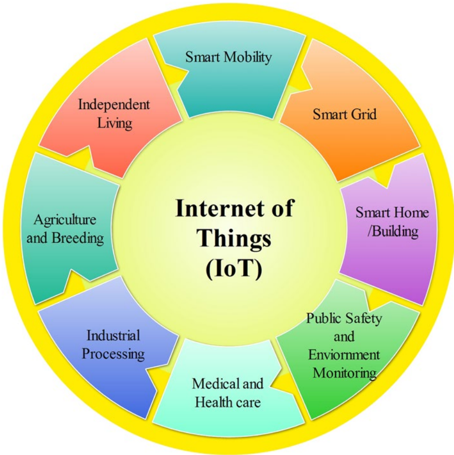
Kyriazis et al. highlighted impact of smart vehicles based on Smart City IoT and Eco-Consciouss Cruise Control for Public Transportation, that aimed at utilizing available resources within the framework that provided driving recommendations in an eco-friendly and efficient manner. The study revealed that the proposed framework was suitable for both Smart city as well as for Smart mobility within a network [45].

Somov et al. highlighted the advantages of using WSN in the field of smart transportation. The study depicted the creation and representation of virtual real objects, i.e., sensors that interacted with the Virtual Object (VO) model. Evaluations have been carried out using a real city-scale traffic monitoring sensor network deployed in the various parts of the network [46].

Table 8 Overview of various communication technologies used for IoT communication

Technology	Standard	Year of discovery	Downlink/uplink	Range (in metres)	Operating frequency (in MHz)
RFID	Wireless	1973	100 kbps	2	0.125–5876
WSN	Packet based communication	1970	1.37 Mbps	300	900
Bluetooth	Wireless	1994	720 Kbps	10	2450
IEEE 802.15.4	6loWPAN	2003	250 Kbps	30	826, and 915
Z-Wave	Wireless	2013	100 kbit/s	30	868.42, and 908.42
LTE	3GPP, LTE, and 4G	1991	100 Mbps	35	400–1900
NFC	ISO 18092	2004	106, 212 or 424 Kbits	< 0.2	13.56
UBW	IEEE 802.15.3	2002	11–55 Mbps	10–30	2400
M2M	Open for all communication protocols	1973	50–150 Mbps	5–20	1–20
6loWPAN	Wireless	2006	250 Kbps	30	915

Fig. 10 Applications of IoT



Vermesan et al. introduced the concept of connected Electric Vehicle (EV) within a defined network. Furthermore, the study depicted an utmost extent of electric mobility integration into the Internet of Energy (IoE), aiming Smart Grid infrastructure, that was programmed for providing energy management solutions for transforming the EVs from mere transportation mediums to an advanced transport connectivity platforms. The study proposed new energy source architecture to use several energy sources that were installed roadside within the proposed framework [47].

He et al. provided advancements that collaborated with the concepts of Cloud Computing and IoT. The collaboration of both terminologies provided an opportunity to resolve the challenges that were being faced. A novel multi-layered vehicular data cloud platform was incorporated within the study that hosted the concepts of Cloud Computing and IoT [48].

Jin proposed the requirement of automated services and remotely controlled infrastructure to meet the requirements of city inhabitants. Although usage of ICT based concepts are utilized to the maximum limit, the authors proposed a framework that consisted of a complete urban information system. The data could be managed through a Cloud-based integration [49].

Lee et al. proposed an efficient vehicle tracking system for tracking the movement of a vehicle within a specific domain network. The designed proposed an in-vehicle device that worked with on the fundamentals of Global Positioning System (GPS) and Global System for Mobile Communication for tracking the vehicle [50].

Ma et al. highlighted the need to undertake the issue of traffic congestion at one location that hampered the entire network. The study experimented on the concept of deep Restricted Boltzmann Machine and Recurrent Neural Network architecture that was able to predict the traffic congestion evolution based on GPS data acquired from a taxi. A methodological Graphical Processing Unit (GPU) based parallel computing environment framework had been proposed by in the study [51].

Posland et al. proposed a trip zoom system in his study. The main objective of the study was highlight the use of mobile sensors to classify various urban transportation modes, that could generate information which was later classified for understanding a level of behavioral shifts in traveling [52].

Table 9 depicts Evaluation of research article and Table 10 presents a Comparative assessment for Smart Mobility domain.

3.2 Smart Grid

Smart Grid is an electricity supply network that uses digital communications technology to detect and react to local changes in usage. It can also be referred to as a digital technology that allows two-way communication enabling the customers to put up the requirement of electricity after performing observations with the help of sensors and in reciprocation. The grid channelizes the energy as per the calculated requirement that has been put before. Some of the major contributions made by various researchers under this domain are as follows:

Karnouskos highlighted the future of a Smart Grid infrastructure. To boost the energy efficiency, a dynamic ecosystem such as the smart infrastructure was proposed in the study [53].

Bressan et al. explored the possibilities of implementing a smart monitoring system over the WSN. A Routing Protocol for Low-power and Lossy Networks (RPL) was proposed in the study. This framework was a lightweight implementation of the Representational State Transfer (REST) paradigm by utilizing a binary web service [54].

Farhangi in his study highlighted the comparative analysis of possible functional capabilities a smart grid. Furthermore, time to time evolution in the field of Smart Grid, i.e., Automatic Meter Reading (AMR) and Advanced Metering Infrastructure (AMI) have been discussed by length. Based on the existence of two generations of grid technology, emerging standards of the grid have been proposed, i.e., incorporation of Common Information Model (CIM), and possible support of TCP/IP among other protocol modules like fiber optics, 1.8 GHz flavor of WiMax and DLMS/COSEM standards [55].

Karnouskos emphasized a strong coupling among various ICT that was embedded with devices to provide a sophisticated dynamic echo system by using the sharing of energy consumption and by actively participating in a household or building energy management systems. Hence a Service Oriented Architecture (SOA) was proposed for the existing devices that enabling cooperation and control over the devices. Furthermore, resources of Information Technology (IT) have been considered specifically as it empowered the traditional processes and enables sophisticated cooperative services to answer numerous challenges [56].

Rad et al. in their study emphasized existing demand management between utility providers and their end customers. Game theory was proposed in the research article to formulate energy consumption scheduling where strategies were based upon daily schedules of household applications and their energy loads [57].

Yu et al. focused on researching the architecture and key technologies of IoT. The research work highlighted principal characteristics for a proper integration proposed architecture within a Smart Grid [58].

Bui et al. (2011) proposed a Constrained RESTful Environments (CoRE) framework that was programmed to obtain a web-oriented binary protocol which was simple enough in terms of handing and aimed at serving a limited number of devices. The basic aim of the framework was to channelize energy and traffic [59].

Yu et al. emphasized the importance of IoT for shaping a Smart Grid. The study also depicted the practical significance in the development of IoT based Smart Grid [60].

Yun et al. highlighted the concepts and technological advancements in the field of Smart Grid. The study emphasized the usage of Renewable Sources (RS), i.e., Hydro, Biomass, Solar and Geothermal energies instead of non-renewable resources like coal, gas, and oil as it has been estimated that there are few decades left for these resources

Table 9 Evaluation of research article for Smart Mobility domain

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[43]	Issues related to minimization of reading errors and calibration	ID splitting techniques	Readily adaptable	Contributions fall short from representing complete and definitive answers
[44]	Encountered issues related to Advanced Driver Assistant Systems (ADAS) and Precise navigation and positioning of vehicle	V2V and V2I or V2I+I communication systems proposed	Ethernet projected as the backbone in EV enabling V2V and V2I communication	Security issues not discussed
[45]	Issues related to the management of public transportation	Proposed Eco-conscious cruise control for public transportation	Suitable for both Smart City and Smart Transportation applications	Problems in decision-making and the functionality of the process was lacked transparency
[46]	Automatic data management was not possible on existing framework	Proposed Virtual Real Objects (VRO) framework for overcoming the issues faced	Potentials of the IoT paradigm demonstrated successful traffic monitoring	Security parameters were overlooked in the proposed framework
[47]	Existing framework had major issues related to the transfer of energy from the grid to vehicle	Proposed Energy Source Architecture (ESA) framework	On-going issue was resolved by introducing the framework	Numerous issues related to data transfer were still unanswered even after introducing a new framework
[48]	Management of vehicular data over cloud was a tedious and time-consuming task	Multi-layered Vehicular Cloud Data platform proposed	Management of vehicular activity within a network became easy	Complex and difficult to understand the new framework for a novice user
[49]	Issues related to Addressing scheme, Sensing paradigm, and connectivity among nodes	Noise mapping architecture proposed	Individual addressing scheme for nodes that helped in further identification for performing various computations	In actual scenario, implementation of the proposed framework required more promptness
[50]	Constant monitoring of vehicle	A micro-controller and GPS/GSM/GPRS was used for tracing of the vehicle on a real-time basis	Capable of tracking the vehicle and perform other related computations, i.e., obtaining vehicle's current whereabouts, choosing traveling directions, etc.	Probability of loss of GPS/GSM/GPRS network resulted in complete framework's failure
[51]	Issues related to traffic congestion and its management	Restricted Boltzmann Machine and Recurrent Neural network architecture	Reduced congestion within the observational environment	No concrete information on network congestion pattern and time limit for performing experiments

Table 9 (continued)

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[52]	Congestion, safety, and well-being while transit were main issues	Tripzoom system was proposed	Proposed framework resolved the on-going concerns	–

Table 10 Comparative assessment for Smart Mobility domain

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[43]	RT	TCP/UDP	Environmental and Traffic Sensors	Europe	–	Further improvement in Self management capabilities and Energy management techniques
[44]	SB	TCP/IP	High-resolution cameras, and VLAN	Belgium, Germany, and Norway	Public Authorities, and European Commission	Improvement in short/long range radar systems
[45]	RT	TCP/UDP	Sensors, Actuators, and Access points	Athens, Greece, Madrid, Spain, and London, United Kingdom	–	Future extension of ICT and calibration of proposed terminology
[46]	RT	–	WSN, Autonomous Sensors, RFID, and Cameras	The Netherlands	Municipality of Enschede, The Netherlands	Complete automation of Virtual Objects and further improvement on the traffic monitoring system
[47]	SB	–	Ethernet, Power Line Communication (PLC), GPRS/GSM, and LTE	Oslo, Norway, Hamburg and Munich, Germany and Milan , Italy	ARTEMIS JU Internet of Energy for Electric Mobility (IoE), Norway	–
[48]	SB	Next Generation Telematics Protocol (NGTP) communication system	GPS, RFID, and mobile devices	Evansville, Illinois, USA	Complex structure and Difficult to understand	–
[49]	RT	–	RFID, WSN, GIS, and Environmental sensors	Australia	Smart Santander and Internet of Things	Further improvement in GIS for tracing current location of vehicle
[50]	RT	TCP/IP	GPS/GSM/ GPRS module, Mobile phone, and Google Maps	Flint, MI, USA	–	Possibility of implementation of same experimentation with low cost
[51]	RT	–	GPS, and GIS	Ningbo, China	Beijing Key Laboratory for Cooperative Vehicle Infrastructure	Future scope of improvement in prediction performance and improvement on other related parameters

Table 10 (continued)

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[52]	SB	HTTP data transfer technique	Mobile sensors	London, England	Framework Research Program funded by the European Commission	Flexibility and cost-effectiveness in future models

supply. The aspect of pollution concerns and other aspects have also been touched. Terminologies like Wind Energy Conversion Systems (WECS), Flexible Alternating Current Transmission Systems (FACTS), have been suggested to be adopted [61].

Zhang et al. observations proposed M2M communications paradigm by the name of Cognitive Machine-to-Machine (CM2M) communication framework. The framework aimed at the energy-efficiency spectrum discovery scheme. Coordination based energy-efficient spectrum discovery scheme also been proposed in the study for the Smart Grid neighborhood area that was used for showing a significant decrease in energy consumption [62].

Table 11 depicts Evaluation of research article and Table 12 presents a Comparative assessment for Smart Grid domain.

3.3 Smart Home/Building

A Smart Home or a Building is a similar environment unlike any other living environment that is equipped with heating, lighting and other electronic devices. A significant difference is that they can be controlled remotely either by a smart phone or through a computer. During recent years, the concept of Smart homes/buildings have come up by incorporating various devices to the Internet. Some of the major researches and advancements are done in similar context are as under:

Darianian et al. suggested integration of homes by using the concept of RFID. The study proposed a novel Read-Out concept for having a hierarchical wireless Master-Slave reader architecture based on RFID technology for multi-standard Ultra High Frequency (UHF) and NFC technologies [64].

Chong et al. identified the rapid development of IoT and its integration for Smart homes. The study highlights the characteristics, advantages and disadvantages for a smart home. Browser/Server (B/S) module has been proposed in the study that provided a more convenient, flexible, and easy mode to control [65].

Li et al. proposed adaptation of smart community architecture whose functioning was considered to be robust and secure. The framework composed of a multi-hop network for smart homes, where the frequency was intercepted via RFID that followed 13 unique wireless communication standards such as IEEE 802.11 and the third generation mobile telephony i.e. 3G [66].

Ji et al. proposed usage of RFID tags. Objects were identified based on the tags. Researchers proposed a design considering the architecture, infrastructure, intercommunication, and realization of the smart home system [67].

Piyare proposed usage of a micro-web server, that could be connected via IP services. A smart home hateway application framework was proposed in the study that was flexible, easy to operate, and cost-effective [68].

Soliman et al. suggested an approach toward the development of Smart Home applications by integrating IoT with Cloud computing, and web services. The proposed framework had an Arduino device that controlled various sensors and actuators through wireless communication, i.e., Zigbee [69].

Wang et al. proposed a framework that could control home via a smart central controller. The device communicated through a 433 MHz radio frequency that was able to control a Wireless Sensor and Actuator Network (WSAN) [70].

Table 11 Evaluation of research article for Smart Grid domain

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[53]	Proper management of energy and its optimizing efficiency techniques	Multi-agent system based simulator was proposed for eliminating the ongoing issues	Test experiments were based on the simulated environment which is very close to real-world	Framework required update of data sets every year Correctness and robustness of software was not tested
[54]	Unmanaged multi-hop routing among variables	REST-based Web Services proposed	Framework was based on REST paradigm	Compatibility issues for a proposed protocol not discussed
[55]	Legacy issues to leap forward, without the need for backward compatibility	Automatic Meter Reading (AMR) and Automatic Metering Infrastructure (AMI)	Correct identification of network for the upstream utility of assets	Problems surfaced when disparate systems, functions, and components begin to be integrated as part of a distributed command-and-control system
[56]	Limited performance of existing simulators	Service Oriented Architecture (SOA)	Approach was based on heterogeneity behavior of devices abstraction and Focusing was done for specific implementations at device level	Robustness of the proposed system not been observed
[57]	Voltage problems, damage to utility and consumer equipments	Distributed demand-side energy management strategy	Proposed methodology was advantageous to define a based approach that can be implemented so that updates can autonomously accommodate the changes within the system	–
[58]	Distributed control among networks, Demand prediction for the requirement of energy, Energy generation, and Prediction forecast	Integration of proper function-able characteristics among all issues	Current standings of IoT applications for Smart Grid application have been highlighted	–
[59]	Proper management of distributed network	RESTful Environment (CoRE)	Approach aimed at reducing IPv6/UDP header for maintaining addressing space	Energy and traffic burden of the proposed framework was kept on standby while performing simulations
[60]	Issues related to high bandwidth and rate, non-line-transmission ability and large-scale management	Resetting of communication lines with higher bandwidth	The system was flexible, mobile and ensured that the supply of energy is reliable, secure and responsive	Framework was costly and difficult to maintain

Table 11 (continued)

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[61]	Key issues related to application layer for information sharing and its security	Highlighted principal aspects of effective sharing	–	–
[63]	Issues related to M2M communications	Multiple-QoS flow scheduling algorithm/CM2M communication technique	The proposed framework gave customers an advantage to decide on their load profile based on the electricity price	Simulations depicted an increase in customer payoff

Table 12 Comparative assessment for Smart Grid domain

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[53]	SB	Software agent paradigm	–	USA	AVTA, U.S. Department of Energy	Individual appliance to reflect different energy consumption
[54]	RT	6LowPAN	WSAN, and Actuators	Italy	Cariparo Foundation, Italy	Possibility of a generation of higher no of routing paths for energy management
[55]	RT	TCP/IP	–	North America	Electrical and Power Industry and British Columbia Institute of Technology, North America	To develop a transition system for next generation technologies required to realize Smart Grid
[56]	SB	IP-based infrastructure, and UDP	–	Karlsruhe, Germany	Cooperating Objects Network of Excellence Centre, Germany	Future possibility of devices to offer functionalities as a part of service
[57]	RT	Energy Consumption Scheduler (ECS) communication Network	–	British Columbia, Vancouver and Toronto, ON, Canada	–	Usage of similar techniques to aggregate profile of commercial load within industrial region
[58]	SB	Internet based communications, and Web of Things –based CPS architecture	–	Italy	Industrial Electronics and drives at the University of L'Aquila, Italy	Possibility of improving efficiency with less waste and better quality of service
[59]	RT	Independent Press Standards Organization (IPSO) based communication system	–	Padova PD, Italy	Office for Metropolitan Architecture (OMA) and IPSO alliance	Proposed terminology likely to be complex in near future, costly and may fall short due to limited capabilities

Table 12 (continued)

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[60]	RT	NLOS transmission	WSN, and Zigbee	Beejing, China	Implemented over all industries related to Smart Grid	Scope of improvement in energy efficiency to reduce environmental impact and improvement in safety and reliability of electricity supply
[61]	RT	Ubiquitous Identifier (uCode) using ubiquitous communication devices	RFID tag, Camera, GPS, Infrared sensors, and Laser scanner	Hubei, China	–	Possibility of high speed and two-way communication
[63]	SB	CM2M communication	Radio Frequency, Zigbee, and Sensors	Oslo, Sweeden, China, and UK	Natural Science Foundation of Guangdong Province, China	Further scope of improvement in connectivity

Kumar proposed a framework that consisted of an Arduino Ethernet shield and Arduino Mega 2560 device. The framework was of low cost, standalone, and a flexible smart home system that could be controlled via an android [71].

Hemant et al. proposed an efficient, reliable, economical, flexible, real-time, and realistic wellness sensor network for smart home systems. The system has been designed in such a manner that the study could be extended from a smart home system to smart buildings [72].

Rathore et al. proposed four-tier architecture that had the capabilities of data generation, collection, observation, and evaluations. Based on data filtration, aggregation, preprocessing, classification, computing, and decision making were performed. The throughput of the proposed system increased with the increase in data sets [73].

Table 13 depicts Evaluation of research article and Table 14 presents a Comparative assessment for Smart Homes/Building domain.

3.4 Public Safety and Environment Monitoring

Public Safety and Environmental monitoring is the process of making observations on weather conditions, endangered species protection, water quality monitoring, and various other parameters that are associated directly or indirectly to our environment. Applications are incorporated with various sensors and other observational devices to monitor timely changes in environmental parameters. Some of the most valuable contributions in this domain are:

Castellani et al. analyzed the requirement of a distributed network that has sensing capabilities that create an unprecedented market of opportunities for a variety of spurring new services. Hence the study focused on the implementation of similar communicational technologies by adopting the REST approach that relies on GET and POST terms for communication [74].

Oliveira et al. emphasized on highlighting the security protocols of in mobile WSN for observing environmental monitoring. The observations and later the communication of data are based on LoPAN, Mesh Networks, and IEEE 802.15.4 platforms [75].

Cheng et al. emphasized on lifelong learning units that need to understand whether the courses they provide are appropriate and their student's learning effectiveness just as advertisers need to understand the market and customers. The focus has been given to the learning strategies of the students. Environment for Lifelong Learning using Learning Analytics (ELLLA) has been used to make observations [76].

Jia et al. had proposed the usage of RFID technology for obtaining various environmental parameters. The study aimed at highlighting the usage of RFID technology for obtaining various environmental parameters [77].

Swan highlighted the rapid changes and their adaptation with the help of sensor platforms like fitness bands, smart watches, wearable sensors, and monitoring patches [78].

Kelly et al. proposed an integrated network architecture that had an interconnecting mechanism for evaluating various parameters through smart sensors. The framework proposed in the study consisted of a monitoring system and a combination of pervasive distributed sensing units for a concrete information system for environmental protection [79].

Lazarescu proposed a virtual view via IP considering WSN for environmental data collection. The study aimed to introduce a system that was low on cost. It had the capability of associating with several sensors, had a faster deployment, long lifetime, high quality and low maintenance [80].

Table 13 Evaluation of research article for Smart Home/Building domain

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[64]	Challenging of observational capabilities within an environment	Read out concept	Proposed system was of low cost, consumed less power and comparatively less complex	Multi Standard Readers and supporting tags were not incorporated
[65]	Proper identification of implementations of RFID within homes	B/S(Browse/Server) module	The proposed framework was first of a kind, but was dependent upon SQL statements	Requirement of complete knowledge for SQL statements was required to revive the framework in case of system failure
[66]	Improvement in inter home interconnectivity	Side Channel Monitoring (SCM) technique	The framework was secure and had a robust inter-networking capability	Focus only on Wi-fi (IEEE 802.11) standard
[67]	Creation of a smart home and its implementations phase	Creating communication through RFID keys	Every device was connected with a unique RFID tag	There were constraints on ontology
[68]	Issues related to function-ability and flexibility in usage of devices within a smart home	Web-Server based on Arduino	The proposed framework was of low cost, flexible and the proposed monitoring system using Android-based Smartphone	–
[69]	Synchronization of smart home devices on a cloud server	Various approaches to facilitate smart home implementations	The framework was Arduino enabled and Artificial Intelligence was embedded within the sensors	Sensors required additional memory space
[70]	Managing and control of sensors and actuators via Radio Frequency 433 MHz	IoT-based smart home control system	The framework was easily monitored, capable of controlling the associated devices	Focus was only on efficiency and lower energy costs
[71]	Creating a flexible, standalone, and a low-cost smart home system	Smart home application	Hardware proposed was cheaper in terms of cost and was capable of switching functionalities	No alert and notification system proposed in the framework
[72]	Issues related to the design of smart home/building environment	Proposed and implemented an integrated framework based on the basic needs of a smart home/building	Sensors were compatible with major home devices	There was difficulty in handling ISM band interference and the proposed system was less effective

Table 13 (continued)

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[73]	A requirement of addressing issues related provide a more secure environment among citizens of the proposed smart city	Four-tier architecture	Framework was easy to operate and had decision-making capabilities	Throughput of the system increased with the in-case in data

Table 14 Comparative assessment for Smart Home/Building domain

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[64]	SB	UHF, and NFC	RFID, and M-RFID	Helsinki, Finland	Nokia Corporation	Further improvement in Mobile-RFID (MRFID) reader devices
[65]	RT	IEEE 802.15.4 compliant RF transceiver, and USB communication with extensible interface module	Zigbee and Smart Sensors	China	Key Laboratory for Advanced Control, China	Scope for improvement in terms of flexibility and creating RFID devices more convenient for smart home system
[66]	RT	IEEE 802.11, and 3G	Wireless sensors	China	State Key Laboratory of Industrial Control Technology, China	Further scope for improvement in the proposed protocol's performance
[67]	RT	GSM, and Ethernet	RFID, Sensors, and Actuators	China	Department of High Technology and Academy of Inspection and Quarantine, Shenzhen, China	Scope for improvement in interoperability among each other, constraints of ontology and service-oriented language
[68]	SB	M2m, Simple Object Access Protocol, and Wi-fi	Sensors and Actuators	Mokpo, South Korea	NIPA, National IT Industry Promotion Agency, S Korea	Future enabling of proposed terminology on 4G and 5G
[69]	RT	I2C bus communication, GSM, and IEEE 80211	Zigbee, Moibles, Wearable sensors, and Actuators	Oulu, Finland	–	Implementations of other household devices over cloud infrastructure
[70]	RT	433 MHz Radio frequency, and Wi-fi (24 GHz)	Sensors, Actuators, and controllers	Beijing, China	–	Scope of improving building energy efficiency
[71]	RT	Radio frequency, and 3G/4G GSM	Sensors, Actuators, Tablets and mobile devices	Mokpo, South Korea	Department of Information Electronics Engineering, Mokpo National University	–

Table 14 (continued)

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[72]	RT	ZigBee end device (ZED), and Zigbee end device plus router (ZEDR)	Sensors, and Actuators	New Zealand	School of Engineering and Advanced Technology, New Zealand	Scope of Significant improvement while using the proposed technique with advanced wireless technologies
[73]	RT	ICT based communication techniques	RFID, Sensors, and Actuators	Anyang, Republic of Korea	SW Human Resource Development Dept, Anyang, Republic of Korea	Possibilities of further improvement in various functionalities including collection, aggregation, communication, processing, and interpretation

Zhao et al. had made observations concerning Environment Internet of Things (EIoT) highlighting the proposed framework and its main features. The study proposed monitoring of atmosphere, water, soil, and wind environmental indicators [81].

Fang et al. proposed a novel IIS model that combined services of Cloud Computing, IoT, Geoinformatics [Geographical Information System (GIS), Remote Sensing (RS) and GPS], and e-science for environmental monitoring and its management [82].

Kantarci et al. highlighted the IoT paradigm that was equipped with sensing, computing, and communication capabilities to enhance the capabilities of IoT [83].

Table 15 depicts the Evaluation of the research article and Table 16 presents a Comparative assessment for Public Safety and Environment Monitoring domain.

3.5 Medical and Healthcare

Often termed as the Internet of Medical Things (IoMT) is the systematic application mode that connects healthcare services to the IT system through on line various computer networks. Medical devices are equipped with in-built Wi-fi systems that further allow machine-to-machine communication based on the IoMT concept. Some of the most cited researches done under this domain are as under:

Bui et al. identified various communication requirements for various processes and their integration to the Internet as web services. The observations that depicted the requirement of typical IoT protocols [84].

Istepanian et al. highlighted the potential benefits of using M-IoT in non-invasive glucose level sensing and potential m-IoT architecture based on diabetes management has been proposed in the study. The observations from the framework were sent on mobile for information updates [85].

Doukas et al. proposed utilizing generated data for future reference and usage by uploading the data onto the cloud server. The study suggested a platform based on cloud computations for managing the data [86].

Sung et al. examined the possibilities of synchronizing real-time remote identification through WSN using the Android platform in the healthcare domain. Particle Swarm Optimization (PSO) method was proposed in the study [87].

Amendola et al. proposed the usage of RFID based applications for body-centric systems for gathering information on human behavior in compliance with power and sanitary regulations [88].

Fan et al. highlighted that IoT based smart rehabilitation systems were better techniques to mitigate problems associated with aging populations and a shortage of health professionals. Furthermore, the study proposed an Automating Design Methodology (ADM) for smart rehabilitation systems in IoT [89].

Xu et al. highlighted the rapid development of IoT and the possibility of connecting various smart objects via the Internet. The study further proposed possible potential applications of IoT in intensive information industrial sectors for healthcare services [90].

Yang et al. proposed an intelligent home-based platform, the iHome Health-IoT system that had an open-platform based on intelligent medicine box (iMedBox) [91].

Hassanalieragh et al. suggested networked sensors, either worn or embedded. The framework of these devices was capable of gathering rich information that indicated the physical and mental health of an individual [92].

Ukil et al. highlighted the significant importance of IoT in the field of healthcare. Proactive healthcare analytics for cardiac disease prevention has been the Usage of smartphone

Table 15 Evaluation of research article for Public Safety and Environment Monitoring domain

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[18]	Clearly identify a viable solution towards Internet-based SG system	Trickle probabilistic broadcasting algorithm	The proposed system suggested Real Time monitoring	Occupancy rate of memory was higher
[75]	Key management, and message authentication	Study proposed Lo-PAN, Mesh Networks that were powered by IEEE 802.15.4 platform(s)	Study provided an overview of security	–
[76]	Identify methodologies for learning effectiveness	Lifelong Learning using Learning Analytics (ELLLA)	Filtering was observed on data	No implementation and prediction module available in proposed framework
[77]	Security, and privacy of RFID tags	Study provided complete overview of RFID's working procedure	Study was incorporated of numerous parameters	Future advancements and updates of the same sector have not been discussed
[78]	Problematic aspects of making decisions	Cognitive engagement of IoT devices	The study provided a comprehensive review on IoT solutions	Real time monitoring of the parameters was not available
[79]	Security issues related to Zigbee	Architectural design based on standard Zigbee communications proposed	The framework had an integrated network, architecture and interconnecting mechanisms for the reliable measurement of parameters	There was no estimation or consideration for evaluating the entire city or demographic area
[80]	Identification of versatile, and low-cost data IoT applications	Virtual View via IP considering WSN for environmental data acquisition was proposed	Maintenance and cost of the framework were low It accommodated a high number of sensors and provided a faster deployment	-
[81]	Economic, Social, Urban construction, and management related issues	Observations with respect to Environment Internet of Things (EIoT) was proposed	Proposed framework monitored water, atmosphere, soil and wind properties	No scope for further improvement on EIoT platform suggested
[82]	Monitoring and management of environment	Proposed a framework based on IIS model	The study was vast, in depth and covered major aspects of IoT with respect to domain	–
[83]	Availability of built-in sensors within a mobile device	study proposed a sensing network service that was equipped with Smart phone over a Cloud Server	Framework Utilized S2aaS to assist disaster management	–

Table 16 Comparative assessment for Public Safety and Environment Monitoring domain

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[18]	RT	Constrained Application Protocol (CoAP)	Sensors, Actuators, Zigbee, and IEEE 802.15	Padova, Italy	SENSEI, CaRiPaRo Foundation, Italy	Further improvement in the usage of standardized protocols
[75]	RT	Application Programming Interface Module via IEEE 802.11	Sensors, Actuators, and Access points	Portugal	Instituto de Telecommunications, Next generation Networks and Applications Group (NetGNA)	Further possibility of node integration
[76]	SB	TCP/UDP	WSN, Autonomous Sensors, RFID, and Cameras	Taipei, Taiwan	Microsoft Taiwan and Chinese Computer Education Association in Taiwan	Further improvement in teaching and learning effectiveness
[77]	SB	TCP/IP	GPS, RFID, and mobile devices	China	National Natural Science Foundation of China	Further automation of devices and cost reduction
[78]	RT	HTTP data transfer technique	GPS/GSM/ GPRS module, Mobile phone, and Google Maps	Palo Alto, USA	Medical Device and Diagnostic Industry	–
[79]	RT	6LowPAN	GPS, and GIS	Palmerston North, New Zealand	–	Development of Low-cost smart sensor node development enabled devices
[80]	RT	NLOS transmission	WSN, Zigbee	Torino, Italy	Dipartimento di Elettronica, Dipartimento Elettronicae Telecomunicazioni, Politecnico di Torino	Improvement key WSN application parameters, such as cost, productivity, reliability, interoperability, and maintenance
[81]	SB	UHF and NFC	Zigbee, and Smart Sensors	China	Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen, China	Future scope of improvement for Ecology, Culture, Politics, Governance, Society, and Economy

Table 16 (continued)

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[82]	RT	GSM, and Ethernet	Sensors, Actuators, and controllers	China	–	Improving the integration and scientific laws of urban development and ecological processes for sustainable city construction
[83]	RT	Radio frequency, and 3G/4G GSM	Sensors and Actuators	Ottawa, Canada	–	Disinformation probability could be degraded

for an exemplary case has been depicted in the study. The proposed methodology only was able to detect the threat of heart attack and no alarm or notification framework was proposed in the study [93].

Table 17 depicts Evaluation of research article and Table 18 presents a Comparative assessment for Medical and Healthcare domain.

3.6 Industrial Processing

During recent years, the concept of IoT has also flourished in the field of industry. Modern-day industrial equipments and requirements are so intense that the functional capabilities of IoT are either molded or designed in specific to cater to the needs of the industry. Some of the recent advancements of IoT in the field of Industrial domain are as follows:

Kovatsch et al. proposed a common approach for the possibility of interconnecting of heterogeneous devices with diverse functionalities. A Californium (Cf) CoAP framework was proposed in the study. The goals were realized using the proposed framework [94].

Durkop et al. highlighted runtime mechanisms and other delivering tools to significantly simplify commissioning, operating, and maintaining complex production processes [95].

Palattella et al. proposed the use of a standardized IoT architecture as suggested by IETF. A data-centric scheduling algorithm, Traffic-Aware Scheduling Algorithm (TASA) has also been proposed in the study [96].

Bi et al. proposed an Enterprise Systems (ESs) in the study for communication, data acquisition, and all decision-making activities [97].

Chi et al. suggested solving the problem of several sampling rates and signal types because of restricted devices. A Complex Programmable Logic Device (CPLD) has been proposed through the main controller [98].

He et al. proposed the first of its kind architecture that was used to store the interpret IoT data. Then a resource-based data accessing method, i.e., Ubiquitous Data Accessing Internet of Things (UDA-IoT) acquired and processed IoT data ubiquitously to improve the accessibility to data resources. On successful evaluation, the proposed framework demonstrated the functioning of emergency medical services to integrate, collect and inter-operate IoT data at the time of emergency medical services [99].

Perera et al. evaluated various available resources and methodologies for the Industrial Market perspective. Evolution in terms of technology has been observed. Context-Aware computing theories, evaluation framework, and communication mediums have been discussed [100].

Yan et al. proposed a framework based on a super frame structure for slotted MAC. The framework designed by IWSN designers achieved the objective by minimizing the MAC access latency [101].

Qiu et al. in their study presented a deep knowledge on various public logistics services. A Supply Hub in Industrial Park (SHIP) application was proposed in the study to achieve the objective of information sharing and real-time visibility. This proposed framework had an efficiency of sharing physical assets and services along with effectiveness [102].

Reaidy et al. proposed an IoT infrastructure for collaborative warehouse. The study integrated a bottom-up approach with numerous mechanisms like Decision Support Systems (DSS), self-organizing, and negotiation protocols among agents based on “com-peration = competition + cooperation” concept [103].

Table 19 depicts the Evaluation of research article, whereas Table 20 presents a Comparative assessment for Industrial Processing domain respectively.

Table 17 Evaluation of research article for Medical and Healthcare domain

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[84]	Problems related to patient's health	IoT based paradigm	The proposed system had an easier integration on the Internet as web services	Observations recorded were for a single day
[85]	Identification of low glucose level within body	Intelligent Identification and Management technique was proposed for patients suffering from high sugar levels	M-IoT based non-invasive glucose level sensing framework was implemented	Authenticity of the framework has been evaluated only on one person
[86]	Data storage and management of patient's record	Medical sensor communication technique	The interface had easy uploading of data onto a cloud server and data was intact for future reference	Data was managed and utilized by an open hardware system
[87]	Node signal processing, WSN localization, and anti-collision information-aggregation	Particle Swarm Optimization (PSO)	The proposed framework's synchronization with WSN was easy	No practical implementation performed
[88]	Issues related to tissue's regrowth and prosthesis displacement	Feasibility of compounds classification based on RFID applications	Applications were based on body-centric systems	–
[89]	Problems associated with aging populations and shortage of health professionals	Ontology-based Automating Design Methodology (ADM) for smart rehabilitation the system in IoT	Study was based on the foundation for disease diagnosis and resource allocation only	–
[90]	Sharing of medical information during service processing	UDA-Io) method	The proposed framework could easily integrate the data and flexibility	Objects in IoT caused the heterogeneity problem
[91]	Advancement to develop user-friendly sensors	An intelligent home-based healthcare IoT system	The proposed framework had an ability to easily integrate the data and flexibility	Objects in IoT caused the heterogeneity problem
		iHome		
		Health-IoT		
[92]	Synchronization of data over Cloud server	Energy constrained WPAN devices to upload data onto cloud server	e-study highlighted various other opportunities for attaining the scope	No alert/notification system available

Table 17 (continued)

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[93]	Issues related to healthcare analytics for timely cardiac disease prevention	Proactive healthcare technique for cardiac disease prevention proposed	Able to detect the possibility of a cardiac arrest by observing the vitals The framework is also compatible with smart-phone	–

Table 18 Comparative assessment for Medical and Healthcare domain

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[84]	RT	Constrained Application Protocol (CoAP) based communication	Wireless Medical Sensors	Ferrara and Padova, Italy	Symbiotic Wireless Autonomous Powered system (SWAP), Italy	Further improvements improvements in e-Health pointed towards a fourth paradigm
[85]	RT	6LoWPAN, and emergin 4G networks	Sensors	London, UK	UKIERI Research Center	Possibility of further clinical analysis
[86]	RT	iDigi M2M communication	Sensors	Samos and Lamia, Greece	Greek General Secretariat of Research and Technology	Proper analysis, management and processing of acquired information
[87]	RT	ICT based communication	RFID, and ZigBee	Taichung, Taiwan	National Science Council of Taiwan	Deployment and implementation of framework among employees for body health check on individual basis
[88]	SB	433 MHz Radio frequency, and Wi-fi (2.4 GHz)	Wearable tags, Zigbee	Rome and Palermo, Italy	–	Possibility of synthesis of existing RFID research and technology for personal healthcare environment
[89]	RT	TCP/IP	Sensors, Actuators, and controllers	Shanghai and Hefei, China and Norfolk,VA, USA	–	Popularization of the smart rehabilitation systems in hospitals, rehabilitation centers, communities and homes
[90]	RT	I2C bus communication, GSM, and IEEE 802.11	Zigbee and Smart Sensors	Shanghai, China	–	Future scope of adaptation of UDA-IoT method for information-intensive industries
[91]	RT	ICT based communication techniques	RFID, Sensors, and Actuators	Shanghai, China	Fudan University, Shanghai, China	Plastic insulation layer over the patch to protect the conductive traces on iMeb-Box's GUI

Table 18 (continued)

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[92]	RT	6LoWPAN	RFID, M-RFID	Rochester and Postdam, NY, USA	Nvidia Corp	Integration of remote health monitoring technologies in clinical practice of medicine
[93]	SB	TCP/UDP	Sensors, Actuators, and Access points	–	–	–

3.7 Agriculture and Breeding

Climate-Smart Agriculture (CSA) is defined as an approach for transforming and reorienting agricultural development under the practical realities of climate change. There have been enormous changes in the techniques and methodologies for performing agricultural activities. The new-age farmer has now moved from the conceptual farming to modernized concepts. Researchers working under this domain have come up with theories and practices that incorporate smart devices to evaluate the parameters that contribute towards the growth of plants and according to the observations, the agricultural activities are performed. Some of the major contributions under this domain are as follows:

Zhao et al. projected the benefits of performing agricultural activities within a greenhouse technology. Furthermore, the process of automating the zone by incorporating the concepts of IoT technology. The authors highlighted incorporating control through information networks within the testbed. Hence, a framework that combined both Remote Monitoring System (RMS) with Internet and wireless communications were proposed [104].

Liqiang et al. suggested an agricultural application on the parameters of WSN. The framework had sensors that gathered data sets related to temperature and humidity within the testbed. The framework's application captured crop growth images from time to time [105].

Yae-e (2011) proposed the Intellegent Agricultural Management and Information Management (IAMIS) framework for identifying the untouched features of agricultural activities. Furthermore, the information stored in the proposed framework was accessible to all those who further wished to carry out the same process and for terminal customers through personal computers, tablets or via cell phones [106].

Bo et al. proposed the usage of Cloud Computing techniques and its significant importance for IoT. The study proposed collaboration of two techniques to analyze the feasibility and prospect of combination among both techniques. The experimentations carried out on the study proved that a combination of these two technologies could successfully resolve problems and could eliminate development bottlenecks [107].

Bandyopadhyay et al. highlighted a state-of-the-art framework for key technological drivers on IoT. The study also visionized the help farmers could obtain from IoT applications for acquiring information for delivering of crops directly to customers within small region [108].

Chen et al. proposed a framework named RPL that was compatible with COOJA simulator [109].

Li (2012) has focused towards modern agricultural cultivation and management perspective with the help of WSN. The study proposed Precision Agriculture Irrigation System with a focus was on hardware and network architecture along with software processes that controlled Precision Irrigation System [110].

Kaloxylos et al. in their study highlighted the importance of precision farming systems that played an important role in improving farming activities. A Farm Management System (FMS) has been proposed in the study [111].

Tongke et al. highlighted the issues concerning agriculture. The study depicted one solution to the problems encountered for agricultural modernization. The authors proposed the usage of IoT concepts and cloud computing techniques for performing agricultural activities [112].

Ojha et al. the study depicted the advent of WSN techniques that spurred a new direction of research in the field of farming domain. The study highlighted the potential

Table 19 Evaluation of research article for Industrial domain

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[94]	Diverse functionalities of heterogeneous devices	Californium (Cf) CoAP framework has been proposed	Separate application from logic had the added advantage	Error tendency was observed in the study and application developed was deployed without any knowledge of the embedded domain
[95]	Identification of required signals and real-time communication	Auto configuration technique proposed in the study	The framework was easy to operate and simple commissioning of the protocol was possible	Extension for a controller of a PN IO the network was not possible
[96]	Building of schedules depending on the topology and data traffic requirements	IETF architecture proposed in the study	The proposed network easily undertook serious engineering framework and strengthened the requirements	Network-side operations were not possible
[97]	Enterprise Systems (ES) applications and their issues	An integrated approach based on the sensor network for water resource management	Proposed framework highlighted requirements of DSS within a dynamic and distributed environment	Framework was unbalanced and no responsive while dealing with all types of changes
[98]	Multi-sensor data acquisition interface with good compatibility and normative interface	Complex Programmable Logic Device (CPLD) proposed	Framework was compatible for solving a number of problems on the basis of sampling rate and signal types	Framework was compatible only with IEEE 14512 intelligent sensors
[99]	Distributed enterprise applications and their communication	Integration of industrial applications, i.e., RFID, WSN, and IoT proposed for usage	The study identified the need to develop different applications for different business systems	Gap to identify the need of functional specific industrial applications and their development persisted
[100]	Identification of gesture based commands	Context-aware computing theories	Evaluation of various available resources and methodologies for Industrial Market perspective	–
[101]	Estimation of the average MAC access latency within a network	Mathematical and Simulation model	The proposed framework minimized the MAC access latency	Simulation tools were limited to the active part of a super-frame
[102]	Identification of current location, current available capacity, and route planning	SHIP	The framework provided deeper knowledge on public logistics services	Further scope for guiding theoretical perspectives untouched

Table 19 (continued)

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[103]	Identification of IoT standards and their performance	Proposed a sample data simulation of “comper-ation” negotiation protocol	Advancements in scheduling and planning	–

Table 20 Comparative assessment for Industrial domain

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[94]	RT	UDP-based communication	Sensors, Actuators, and Access points	Zurich, Switzerland	–	Extension of real-world deployment of IoT architecture
[95]	RT	TCP/IP based Real-time Ethernets (RTE) based configuration service	WSN, Autonomous Sensors, and RFID	Lemgo, Germany	Fraunhofer IOSB-INA Application Center Industrial Automation, Germany	Extension of the auto configuration capability to modular and IRT PN devices
[96]	RT	IEEE 802154e Time-slotted Channel Hopping (TSCH) protocol	Ethernet, Power Line Communication (PLC), GPRS/GSM, and LTE	Luxembourg City, Luxembourg and Bari, Italy	–	Development of procedures and algorithms for exchanging TASA signaling messages
[97]	RT	IT infrastructure for data acquisition	RFID, and WSN	Shanghai and Shenyang, China	–	Development of safe, reliable, and effective communication and decision-making
[98]	SB	M2M, and Person-to-Computer (P2C) communications	RFID tag, Camera, GPS, Infrared Sensors, and Laser scanner	Sweden and Norfolk, VA, USA	ABB, Corporate Research Center, Sweden	Possibility of developing a relevant interface protocol
[99]	SB	CM2M communication	Radio Frequency, Zigbee, and Sensors	Norfolk, VA, USA and Beijing, China	Institute of Computing Technology, Chinese Academy of Sciences, Beijing, China	Future development of enterprise architectures
[100]	RT	IoT based data communication	Zigbee, and Z-WAVE	Canberra, Australia Beijing and Wuhan, China	–	Research and development in context-aware computing domain
[101]	SB	Industrial wireless sensor network (IWSN) based MAC communication	IWSN sensors	Sweden, Shanghai, China and Norfolk, VA, USA	–	Refinement of interactive part of framework
[102]	RT	IP-based infrastructure, and UDP	RFID, and sensors	Hong Kong and Shenzhen,China	National Natural Science Foundation of China	Further development of analytical models

Table 20 (continued)

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[103]	SB	IoT based Collaborative Warehouse Management (CWM) protocol	Wi-fi, Bluetooth, and ZigBee	Grenoble,France and North Dartmouth, Miami, USA	–	Possibility of testing on real collaborative warehouse

WSN applications along with various challenges and issues associated with the deployment of WSN for improved farming [113].

Table 21 depicts Evaluation of research article and Table 22 presents a Comparative assessment for Agriculture and Breeding domain.

3.8 Independent Living

Independent living aims at supporting elderly people in the best possible manner in their daily routine to allowing them an independent and safe lifestyle. The concepts of IoT have been invoked with major research work and contributions in this domain are as under:

Lopez et al. proposed the usage of RFID tags that have significant data storage capacity. The usage of the NFC supported platform has also been proposed. Observed data were available 24 * 7 via CarTwitter [114].

Zhang et al. highlighted on streaming the Quality of Service (QoS). Therefore, a QoS model has been proposed that helped in improving and as well as streaming quality in a dynamic environment [115].

Domingo had proposed IoT based concepts that assisted disables. Further, they proposed IoT architecture from a technical perspective. Various application scenarios have been proposed in the study to depict the communication of various devices among associated components via IoT [116].

Jara et al. depicted diabetes therapy management techniques in AAL environments. There are many factors identified that are associated with the rise and fall in blood sugar levels. Since it is a very difficult task to maintain blood sugar level and often variations are often observed while taking recordings, i.e., a patient suffers from either hyperglycemia or hypoglycemia [117].

Memon et al. highlighted that most of the AAL systems remained confined due to a limited set of features that ignored essential aspects of the proposed system [118].

Kumar et al. depicted potentials of VLCs in the field of ambient assisted living that made use of radio and fiber communications. The proposed framework supported a high data rate connectivity [119].

Konstantinidis et al. suggested a Controller Application Communication (CAC) framework in the study. The proposed framework was independent of transmission and was based on the concept of distributed computing principles, delegating server duties onto use-site gateways that in return reducing the load on the main server [120].

Cubo et al. emphasized specifying and efficient implementation of device handling. It also verified their heterogeneity and composition of devices and standardizing along with managing data that helped in handling a large number of systems at one go. The framework helped in avoiding standalone applications on local servers. It took care of Device Profile Web Services (DPWS). The results were satisfying however, the number of applications associated with it was limited [121].

Parada et al. focused on parallel functioning of IoT concepts and Ubiquitous computing. The study proposed a weighted Information Gain (wIG) in its study as the empirical method that helped in detecting unassisted, device less and in real-time user-object interaction via RFID [122].

Li et al. sheds light on various ICT that provided numerous options to help aged people in improving the quality of living by being healthier and living independently at all times. A comparative description is given between wearable and non-wearable sensors [123].

Table 21 Evaluation of research article for Agriculture and Breeding domain

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[104]	Issues related to control and managing of IoT technology	RMS framewrk proposed	The proposed framework collected data that provided for agricultural research and management facilities	Study and its results are limited to greenhouse
[105]	Proper monitoring of protocols	Scalar Sensor Node technique has been proposed	TinyOS that supported an energy-saving algorithm within the software system and the a proposed framework capable of working for hours on testbed	There were issues in context to scalability and reliability of the framework
[106]	Management of agricultural information for proper decision making	Crop Tracking System (CTS) proposed in the study	The proposed framework had test bed laid down for tracking of crops health only	Lack of security issues within the proposed framework
[107]	Exploring the feasibility of synchronization of agricultural data on cloud server	Approach to streamline the concepts of Cloud Computing and IoT	Modern day concepts and equipments were used for developing the framework	The proposed framework required technical knowledge, that farmers lagged upon
[108]	Complete interoperability between interconnected devices within a test bed	The study proposed a state-of-the-art framework based on IoT concepts	Study highlighted a wider spectrum of challenges and opportunities	–
[109]	Development and maintenance of applications incorporated for data procurement	RPL framework proposed	Initial simulations were performed by RPL depicted that its compatibility with COOJA simulator	–
[110]	Hardware and Network architecture for Software process control in precision irrigation practices	Precision Agriculture Irrigation System (PAIS) proposed in the study	Study aimed towards modern agricultural cultivation and management perspective	–
[111]	Existing information management, and enhancement of existing functionalities	Farm Management System (FMS) model proposed	The proposed framework had easy access to data	Tedious task to implement the framework over a bigger horizon
[112]	Implementation of cloud services	The study proposed usage of IoT concepts along with Cloud Computing techniques	Massive data was generated for undertaking agricultural production. The framework achieved dynamic distribution	–

Table 21 (continued)

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[113]	Challenges and issues related to the deployment of WSNs (devices, sensors, and their communication techniques) for improved farming	The study suggested usage of WSN in agriculture	The study reviewed various applications and challenges of WSN. The framework was further extended to understand the shortcomings in the deployment of sensor devices and other communication techniques associated with farming activities	–

Table 22 Comparative assessment for Agriculture and Breeding domain

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[104]	RT	TCP/UDP	WSN, Autonomous Sensors, and RFID	China	–	Implementation of same technology over other varieties
[105]	RT	CPT Protocol using GPRS/CDMA based communication	Micro-controllers, RFID, Sensors, and Actuators	Beiging, China	–	Experiments to be conducted for further increase the stability and reliability of the work
[106]	RT	Transmission of network infrastructure through mobile communications network	Sensors, and Actuators	Beiging, China	Beijing Municipal Commission of Education	Further scope for improvement in improved in efficiency and analysis
[107]	RT	IP-based infrastructure, and UDP	WSN, and Zigbee	Beiging, China	Dingshan Professional Cooperation, Jiangsu Province, China	Scope for improvement in large scale farms, and increase in reliability, expandability, economical, practical and higher rate of efficiency
[108]	RT	IEEE 802154 protocol using IP infrastructure by adoption of 6LoWPAN	RFID tags, Sensors, and Embedded edge processors	Kolkata, India	Innovation Labs, Tata Consultancy Services Ltd, Kolkata	Further increase in efficiency and productivity
[109]	SB	UDP, ICMPv6, IP, and IPv6 based communication	Sensors, Actuators, Tablets, and mobile devices	Mokpo, South Korea	Department of Information Electronics Engineering, Mokpo National University	Further change in metering, monitoring, control and diagnosing
[110]	RT	DTPS05Ci—Siemens Industrial Mobile Module and TCP/IP Protocol	ZigBee, Sensors, Actuators, and GPRS based devices	Lishui, China	–	Future scope for proper utilization of water for requirement based irrigation

Table 22 (continued)

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[111]	RT	ICT based communication techniques	RFID, Sensors, and ZigBee	Greece, Germany, Finland, and The Neatherlands	–	Possibility of adaptation of newer characteristics in the field of agriculture
[112]	RT	6LoWPAN, and emergin 4G networks	Sensors, Actuators, and Zigbee	China	–	Further improvement in efficiency and resource usage
[113]	RT	6LoWPAN	RFID, M-RFID, Sensors, and Actuators	Kharagpur, India	Infomration Technology Research Academy (ITRA), India	Association of relative factors for improvement

Table 23 depicts Evaluation of research article and Table 24 presents a Comparative assessment for Independent Living domain.

Apart from the above-discussed research articles, some other relevant studies and unique researches in the field of IoT under various applications by eminent researchers and academicians have been cited separately along with references in Table 25. A brief description of various aspects, and application domains for the research article have been presented in Table 26.

4 Open Issues, Challenges, and Future Research Directions

IoT can mend the usage of the Internet the way it is required by its end-user. This feature also has to face some of the open issues that are directly or indirectly associated with the concept of IoT. Most common of them have been discussed as under:

4.1 Open Issues

Open challenges in IoT have been pictorially depicted in Fig. 11. All these issues can be related to the existing pitfalls of IoT. Constant advancements have always been incorporated from time to time to overcome these ongoing issues.

4.1.1 Availability

Realization of IoT must be based on existing hardware and software, so that they can provide anytime, anywhere access as well as services. Since IoT at times misunderstood just as software by many as an application that is capable of providing services. The hardware part is equally important and is indirectly associated that functions with the help of various protocols such as 6LoWPAN, IPv6, CoAP, RPL, etc. The entire setup is often understood as a different unit. Hence an awareness of association among hardware and software by its end users can contribute towards channelizing the vision in a much more effective way.

4.1.2 Reliability

The basic aim of having an enhanced reliability is to increase the success rate of IoT service, by virtue of its capability of delivering information. It becomes a critical aspect. Hence a series of checksums are required to be implemented over the hardware and the software part of the IoT framework. A shortcoming due to system failure or threats from intrusion always keeps the reliability of the framework as one of the major challenge in IoT.

4.1.3 Mobility

Mobility is another challenge for the smooth implementation of IoT as most of the applications are based on a mobile interface. Since connectivity also plays a vital in the mobility of data. Hence, a failure in connectivity among non -stationary devices are often taken as incapability on IoT for not being capable enough to transfer the data from origin to destination.

Table 23 Evaluation of research article for Independent Living domain

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[114]	Issues related to awareness of health	Data on tag approach using RFID tags	Data updated periodically and was available 24 * 7	There were security and privacy issues with respect to framework
[115]	Issues in PAN/LAN health devices, their communication and security modules	Electronic Health Record (EHR) proposed	The framework was flexible and secure	Interoperability was not possible in the proposed framework
[116]	Correct identification of disability among children	An RFID-tag based navigation system	The proposed framework specially designed for disables	–
[117]	Issues related to generate alert in case patient suffers from hyperglycemia and hypoglycemia	Proposed usage of RFID that provided a global connectivity for patient's health connected via 6LoWPAN	The framework alarmed on variations in sugar level, i.e., Hyperglycemia and Hypoglycemia. The framework also provided assistance and considered more factors for insulin therapy and dosage	–
[118]	Issues related to data quality issues in medical sensors activity sensors, location sensors and wireless communication sensors	PRISM model checking tool	The framework was platform oriented, standardized and focused on patient's health	–
[119]	Issues related to dense low and high data rate connectivity while enabling deployment of secure sensitive indoor applications, including indoor tracking and localization	Suggested usage of potentials of visible light communications (VLCs), jointly with radio and fiber	The proposed framework was capable of switching functionalities such as Automatic Environmental Control and Intrusion detection	–
[120]	Addressing multiple modern controllers concurrently communicating with multiple, device native, requesting applications, utilizing standard and Internet communication technologies	Controller Application Communication (CAC) framework	The framework facilitated numerous devices	Various devices within the framework played foul in terms of experiments and observations
[121]	Issues related to appropriate management of inter-connection among diverse devices	Usage of ThingML langugae proposed for handing the information sets	The proposed suggestion had easy handling, verification of devices	–

Table 23 (continued)

Citation reference	Issue faced	Technique/methodology proposed in research article	Strength	Weakness
[122]	Navigation or unassisted indications while shopping	weighted Information Gain (wIG) technique	Massive data was generated for undertaking agricultural production. The framework only interacted via RFID devices	The framework detected unassisted devices and no standard or empirical method suggested
[123]	Issues related to support for elderly people	An integrated lifestyle management system is proposed in the study	Easy to operate	A comparative description has been highlighted between wearable and non-wearable sensors

Table 24 Comparative assessment for Independent Living domain

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[114]	RT	NFC 6131 using 3G communication	Wi-fi, Bluetooth, and mobile phones	Spain	Industry, Commerce and Tourism Department of Basque Government, Spain	Future scope of improvement in data management
[115]	SB	Interactive, audio-visual, and data communication	Wi-fi	Changsha, China	General Electrical and Intel Corporation	Future improvement in inter-portability and adaptive streaming of proposed system
[116]	SB	Wireless embedded radio communications at 2.4GHz, 915 MHz, and 868MHz	WiMAX, Bluetooth, and UWB	Louisiana, USA	–	Future scope improving the design for specific interfaces that can be designed to manipulate the home devices for automation and control
[117]	RT	Serial communication based on RS232	RFID, and NFC	Intelligent Systems Group of the University of Murcia	–	Information could also to be shared on Hospital Information System (HIS)
[118]	SB	ICT based communication technique	Sensors, and Actuators	Aarhus, Denmark	–	Future scope of improvement on design, technology, quality-of-service and user experience perspectives
[119]	RT	M2M and Fibre optical based communication using VLC	Sensors, Filament based bulbs, and CFL	Aalborg, Denmark New Delhi, India	–	Factual real-time evaluations of the proposed framework
[120]	RT	GET and POST based polling methodology	Sensors, and Actuators	Greece	Industries participating in SOA	Further scope of improvement in the quality of life of people facing health problems

Table 24 (continued)

Citation reference	Observations conducted	Communication technology	Digital devices used for observations	Location of experimentation	Industries adopting the proposed technique	Future scope of improvement
[121]	SB	NFC and Universally Unique Identifier (UUID) technique	Zigbee, and Smart Sensors	Spain	–	Future scope of implementation by home health gateway communicated with the hospital and care centers
[122]	SB	RFID based self enabled interaction technique	RFID, Wireless sensors, and actuators	Denmark	–	Further scope of improvement in shopping experience
[123]	RT	Communication was performed through static embedded agent via wireless network	RFID tag, Camera, GPS, and Infrared	UK	–	The proposed application has further scope for potentially improving the quality of life of older people

Table 25 Empirical classification of unique researches in the field of IoT for various applications by eminent researchers and academicians

Area of research	Classification of review literature	Reference citations
Smart Agriculture	Agriculture and Breeding	[104–113, 124–128]
Smart City	Smart City, Aviation and Smart Tourism and Smart Homes	[129–131]
Smart Buildings	Building and Management, Construction Engg. and Management	[64–73, 132, 133]
Smart Grid	Energy Management	[18, 53, 54, 56, 58–63, 74, 134–138]
Food Processing	Food Management	[139, 140]
Ambient Assisted Living	Health, Smart Hospitals, Disabled Assistance	[114–120, 120–123, 141–151]
Smart Education	Library Services	[152–155]
Smart Business	Smart Logistics and SCM, Retailing	[156–163]
Environment Monitoring	Waste Management, Environment	[74–83, 164, 165]
Smart Mobility	Traffic Management	[43–52, 166–172]

Table 26 Comparative analysis for various aspects, and application domains for the research article

Reference Citation	Application Area	P1	P2	P3	P4	P5	P6	P7
[43]	1	↓	H	LZ	PE	RT	A	A
[44]	1	↑	M	MZ	D	SB	A	A
[45]	1	↓	M	HZ	PE	RT	A	A
[46]	1	↑	L	LZ	PE	RT	A	A
[47]	1	⟷	L	MZ	D	SB	A	A
[48]	1	↑	M	LZ	D	SB	A	A
[49]	1	↑	M	HZ	D	RT	A	N/A
[50]	1	↑	H	HZ	PE	RT	A	A
[51]	1	↑	L	HZ	D	RT	A	N/A
[52]	1	↑	H	HZ	D	SB	A	A
[53]	2	↑	H	HZ	D	SB	N/A	A
[54]	2	↑	M	LZ	PE	RT	A	A
[55]	2	↑	L	MZ	D	RT	N/A	A
[56]	2	↑	M	HZ	PE	SB	N/A	A
[57]	2	↑	M	MZ	D	RT	A	A
[58]	2	↓	L	MZ	D	SB	A	A
[59]	2	↓	M	LZ	D	RT	A	N/A
[60]	2	⟷	M	LZ	D	RT	N/A	A
[61]	2	⟷	M	HZ	PE	RT	A	A
[62]	2	↑	H	HZ	D	SB	A	A
[64]	3	⟷	M	HZ	D	SB	A	A
[65]	3	↑	H	MZ	PE	SB	A	N/A
[66]	3	⟷	M	HZ	D	RT	N/A	N/A
[67]	3	⟷	M	HZ	D	RT	N/A	A
[68]	3	↑	L	MZ	PE	SB	A	A
[69]	3	↑	M	MZ	D	RT	N/A	A
[70]	3	↓	H	MZ	D	RT	A	A
[71]	3	↑	M	MZ	PE	RT	A	A
[72]	3	⟷	M	HZ	D	RT	N/A	A
[73]	3	↓	M	HZ	D	RT	N/A	A
[74]	4	⟷	M	HZ	PE	RT	A	A
[75]	4	⟷	M	MZ	D	RT	N/A	A
[76]	4	↑	H	HZ	D	SB	A	A
[77]	4	↑	M	LZ	D	SB	A	A
[78]	4	↓	L	MZ	D	RT	N/A	A
[79]	4	⟷	M	MZ	PE	RT	A	A
[80]	4	↓	M	MZ	D	RT	A	N/A
[81]	4	⟷	L	MZ	D	SB	A	A
[82]	4	⟷	M	HZ	D	RT	A	A
[83]	4	↓	M	LZ	PE	RT	N/A	A
[84]	5	↑	L	MZ	D	RT	A	N/A
[85]	5	↑	H	MZ	D	RT	A	N/A
[86]	5	↑	M	LZ	D	RT	A	N/A
[87]	5	⟷	M	MZ	D	RT	A	N/A
[88]	5	↑	M	MZ	D	SB	A	N/A

Table 26 (continued)

Reference Citation	Application Area	P1	P2	P3	P4	P5	P6	P7
[89]	5	↑	M	MZ	D	RT	A	N/A
[90]	5	↓	L	MZ	D	RT	A	N/A
[91]	5	↑	M	HZ	D	RT	A	N/A
[92]	5	⟷	L	HZ	D	RT	A	N/A
[93]	5	↑	M	LZ	D	RT	A	N/A
[94]	6	⟷	M	MZ	D	RT	A	A
[95]	6	↑	M	MZ	D	RT	A	N/A
[96]	6	↓	L	MZ	D	RT	N/A	A
[97]	6	↑	H	HZ	PE	RT	A	A
[98]	6	↑	M	HZ	D	SB	N/A	N/A
[99]	6	↑	H	HZ	D	SB	A	N/A
[100]	6	⟷	M	MZ	PE	RT	A	A
[101]	6	↑	M	MZ	PE	SB	A	A
[102]	6	⟷	M	MZ	D	RT	A	N/A
[103]	6	↑	H	HZ	D	SB	N/A	A
[104]	7	↓	M	MZ	PE	RT	A	A
[105]	7	⟷	M	LZ	D	RT	A	A
[106]	7	↑	M	MZ	D	RT	N/A	A
[107]	7	↑	M	LZ	PE	RT	A	A
[108]	7	⟷	M	MZ	D	SB	A	A
[109]	7	↑	M	HZ	D	RT	A	A
[110]	7	⟷	H	HZ	D	RT	A	N/A
[111]	7	⟷	M	LZ	PE	RT	A	A
[112]	7	⟷	H	MZ	D	RT	A	A
[113]	7	↑	M	MZ	D	SB	N/A	A
[114]	8	⟷	M	MZ	D	RT	N/A	A
[115]	8	↓	M	LZ	D	SB	A	A
[116]	8	↑	H	HZ	PE	SB	A	A
[117]	8	⟷	M	MZ	D	RT	A	N/A
[118]	8	↑	H	HZ	D	SB	A	A
[119]	8	↑	M	MZ	D	RT	N/A	A
[120]	8	↑	M	MZ	PE	RT	A	A
[121]	8	⟷	M	HZ	D	SB	A	N/A
[122]	8	↓	M	MZ	D	SB	A	A
[123]	8	↑	M	LZ	D	RT	A	A

Table Notations: 1 = Smart Mobility, 2 = Smart Grid, 3 = Smart Home/Building, 4 = Public Safety and Environment, 5 = Medical and Health care, 6 = Industrial Processing, 7 = Agriculture and Breeding, 8 = Independent Living

4.1.4 Working Ability and Performance

Evaluation of the functional capability and performance of IoT services are considered to be a big challenge. Since performance is directly associated with the underlying

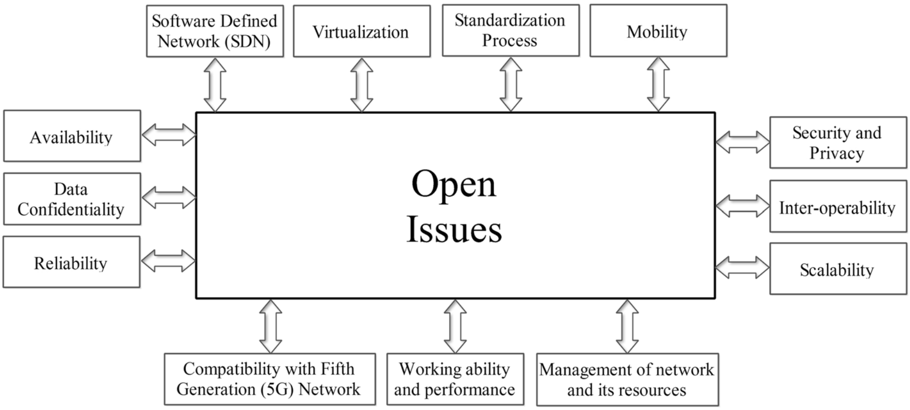


Fig. 11 Open issues of IoT

technologies, it is very much mandatory to keep services updated from time to time to meet the requirements of the end-users. Another factor is the evaluation of performance which is directly associated with the price and quality of underlying technology. However, the end-user does want the best of performance with less of investment, the issue of evaluation of the performance of any IoT application remains an open issue irrespective.

4.1.5 Data Confidentiality

It remains one of the most critical aspects in terms of challenges, because of constant change in terminologies and requirements of end-users, it is indeed hard to find a stable ground for data confidentiality.

4.1.6 Management of Network and Its Resources

Establishing a connection with trillion of devices the service provides are often face issues managing as well as addressing the issues like fault configuration, constantly managing the performance and security of devices and its channels.

4.1.7 Scalability

It refers to the concept of adding newer devices over the existing paradigm without affecting the existing services and functional capabilities of the existing framework. Hence, scalability always remains a challenging task to achieve collective consensus.

4.1.8 Interoperability

To handle a large number of heterogeneous devices it is indeed a difficult task. Moreover, issues also faced at the time of establishing synchronization among different platforms. Hence, interoperability often remains an issue concerning IoT.

4.1.9 Security and Privacy

Since the concept of IoT is designed to transmit information over the Internet, data privacy always holds a special significance. A lot of research works goes in making the data transmission completely secured, however, shortcomings do occur at times.

4.1.10 Software Defined Network (SDN)

Over the years, the concept of SDN has been incorporated into many aspects of life. It is an approach that allows network programmers to initialize, control, change and manage the work behavior dynamically via interfaces. These concepts work on simulation and or a real-time basis. SDN function-ability is based on responses from Data Center Networks (DCNs) and available IoT environments [62]. Although the network is effective, flexible and efficient, there persists some associated threats and challenges that cannot be overlooked.

4.1.11 *Visualization*

There are a lot of concerns related to the creation of a virtual version to eliminate the ongoing concerns of modern-day applications. Its development, proper deployment and adaptability to existing scenarios are one of the biggest challenges faced by IoT [173].

4.1.12 *Standardization Process*

Standards are incorporated so that they can support numerous range of applications. Even with the use of semantic ontologies, machine-readable codification does occur at times which initially results in differences and misinterpretation due to different scenarios encountered from time to time [108].

4.1.13 *Compatibility with Fifth Generation (5G) Communication*

Even though when the high-speed communication system is facing a rapid transformation, major innovations always rebuked by some of the commonly faced issues by 5G communication techniques for IoT based implementations. Some of the most commonly faced issues are enabling physical layer techniques of modulation, timely handling of multiple input multiple output and error control coding [174].

Although a lot of efforts have been carried out in the name of IoT. There are still several aspects on which IoT needs to mature. A constant increase of interest by various academia, industries and other related bodies associated directly or indirectly with the field of IoT keeps on adding expectations that often lead to enhancement of challenges without realizing the basic requirements and functional capabilities of IoT.

4.2 Challenges

During the recent years, it has been visionary clear that challenges of IoT will be the manifold and far-reaching as well. Majority of challenges have been identified by considering the following two perspectives

- Research
- Industry

Most of the IoT technologies in themselves allow identification of research and development challenges after outlining a road map for future research activities to attain a reliable as well as practical solutions. The road map is formed based on the correct identification of research priorities based on evaluation of the following identifiers:

- Identification Technology
  It's main challenge is to map a unique identifier (globally unique or unique within a particular scope), to an entity to make it without ambiguity identifiable and retrievable.
- Internet of Things Architecture Technology
  The biggest challenge in SOA is to become imperative for the providers and requesters to communicate meaningfully with each other irrespective of being heterogeneous nature.
- Establishment of communication technology
  Biggest challenges faced in establishing a well-oriented communication are:
  - Proper Deployment
  - Constraint free mobility of items
  - Cost
  - Heterogeneity
  - Communication modality
- Network Technology
  Correct implementation of the vision to reach out to objects of the physical world to bring them onto the Internet.
- Network Discovery
  Overcoming the existing network dynamically to change the continuous evolving of things, so that they can feature varying degrees of autonomy.
- Correct identification of data and further signal processing
  There is an enormous data generation when objects are synced over the Internet with the help of sensors, hence following issues are of paramount priority:
  - Semantic interoperability
  - Correct service discovery
  - Service composition
  - Data sharing and collaboration
  - Correct identification of autonomous agents
- Standardization
  Standards are to be designed so that they support a wide range of applications and address common requirements of all the possible applications that are inter-related to IoT.

Since IoT mainly evolves around synchronization of devices over the Internet, constant advancements from time to time in every domain indirectly invites some associated issues along with updates, which can neither be ignored nor can be overlooked [175]. Based on the road map of identification of correct technologies, most basic encountered challenges are:

- Uninterrupted network connectivity.
- Acquisition of complete informational service.
- Uninterrupted operational service.
- Security related issues.
- Proper management of on-going services.
- Correct identification of services.
- Standardization.
- Inter-portability.
- Information Privacy.
- Security and safety of objects.
- Data confidentiality.
- Data encryption.
- Dedicated spectrum.

some of them to name a few [176–178]. Based on the most commonly encountered issues, several challenges have been identified based on various application domains of IoT that have been precisely presented in Table 27.

4.3 Future Research Discussions

The concept of IoT as come a long way, over the years. Resources available under the hood of IoT have fallen short and the existing scenario gives rise to several queries that in one way or another, need to be addressed before we scale to a newer dimension. Keeping given ever-increasing spectrum of IoT, some of the future related queries have been presented that need to be addressed before we find ourselves enclosed in a new horizon.

- What would be the next big step to correctly identify and handle the huge range of devices that are being added over the Internet?
- How will the next generation of information systems work in synchronization with IoT, specifically when the technology is not constant?
- How will the newer concepts overcome the inherent complexity and data volume for providing a useful DSS?
- Which IoT business model will drive the next generation's global business and commerce?
- Will the objects (things) only rely upon only Internet services for communication, in the mere future?
- What is the next big thing post IoT era?

5 Conclusion

This research article presents a comprehensive literature survey on the concept of IoT. The term IoT has been broadly described keeping in view the current standings of IoT, its evolution from time to time along with various communication technologies used by various objects for interface and communications purposes. Furthermore, the study represents a detailed literature review of various application areas of IoT highlighting the author's viewpoint on the issue faced along with the proposed methodology along

Table 27 Challenges faced by various Applications of IoT

Applications	Challenges faced
Smart Mobility	Unawareness regarding concept
	Lot of investments required in bringing up the infrastructure
	Existing structure not equipped
	Compatibility issues
	High costs involved in installation
Smart Grid	Protocols vary according to locations
	Lacks on memory space
	Self computation is time consuming
	No proper data acquisition framework available
	Problems occur due to variations in tariff
Smart Home/Building	Requirements differ from environment to environment
	Higher costs involved in installation of devices
	Knowledge required to re-configure if dis-connectivity occurs
	Variations in protocols
Public Safety and Environment Monitoring	Requirements differ as per geographical locations
	Wear and Tear of devices with passage of time
	Sensors installed in open
	High costs involved in selection of devices
	Difficult to manage enormous data
	Variations in protocols
	Lacks in terms of memory space
	Knowledge required to re-configure if dis-connectivity occurs
	Required skilled technicians to retrieve the observed data
Medical and Health care	In adequate knowledge to end user
	Sensors are highly over priced
	Highly complex mechanism
	Requires time to time update according to patient's health
	Timely updates required
Industrial Processing	Sensors get outdated from time to time
	Chances of malfunction
Agriculture and Breeding	Sensor placement is at physical locations
	Lack of awareness among farmers
	Need to be cautious while performing agricultural activities
Independent Living	Issues difficult to resolve in case of malfunctioning
	No. of sensors increase as per requirements

with various other informative details related to the research article. Various parameters were identified to evaluate as to how a particular problem has been undertaken. Hence a static value of 0, 1 had been assigned to every parameter and evaluation of every research article has been done on a 7 giving each a specific weightage. Lastly, Open Issues, Challenges and Future Research Directions concerning IoT have also been discussed by length.

The following conclusions can be further drawn from the study:

- Since technology is not static, an existing era of IoT will soon be over and a newer dimension of IoT would be overtaken in the mere future.
- Proposed methodology for any research article would fall short at one time, keeping in view the ever-increasing demand and requirement of end-users.
- Data generated by various sensors is of paramount importance and needs to be managed and evaluated with a high level of precision.
- Sooner or later during the next few years, almost everything that exists physically would be connected over the Internet with the basic objective of interaction and precise evaluation.
- Extensive research in this field will take a giant leap with only one motive, i.e., to have 0% human intervention.

Acknowledgements The authors would like to acknowledge Council of Scientific and Industrial Research (CSIR) for funding grants vide No. 38(1464)/18/EMIR-II for carrying out research work.

References

1. Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, *54*(15), 2787–2805.
2. Agrawal, S., & Vieira, D. (2013). A survey on Internet of Things. *Abakós*, *1*(2), 78–95.
3. Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, *29*(7), 1645–1660.
4. Said, O., & Masud, M. (2013). Towards internet of things: Survey and future vision. *International Journal of Computer Networks*, *5*(1), 1–17.
5. Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D. (2014). Context aware computing for the internet of things: A survey. *IEEE Communications Surveys & Tutorials*, *16*(1), 414–454.
6. Madakam, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of Things (IoT): A literature review. *Journal of Computer and Communications*, *3*(05), 164.
7. Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys & Tutorials*, *17*(4), 2347–2376.
8. Whitmore, A., Agarwal, A., & Da Xu, L. (2015). The Internet of Things—A survey of topics and trends. *Information Systems Frontiers*, *17*(2), 261–274.
9. Anagnostopoulos, T., Zaslavsky, A., Kolomvatsos, K., Medvedev, A., Amirian, P., Morley, J., et al. (2017). Challenges and opportunities of waste management in IoT-enabled smart cities: A survey. *IEEE Transactions on Sustainable Computing*, *2*, 275–289.
10. Ngu, A. H., Gutierrez, M., Metsis, V., Nepal, S., & Sheng, Q. Z. (2017). Iot middleware: A survey on issues and enabling technologies. *IEEE Internet of Things Journal*, *4*(1), 1–20.
11. Singh, S., Sharma, P. K., Moon, S. Y., & Park, J. H. (2017). Advanced lightweight encryption algorithms for IoT devices: Survey, challenges and solutions. *Journal of Ambient Intelligence and Humanized Computing*, *4*, 59.
12. Verma, S., Kawamoto, Y., Fadlullah, Z., Nishiyama, H., & Kato, N. (2017). A survey on network methodologies for real-time analytics of massive IoT data and open research issues. *IEEE Communications Surveys & Tutorials*, *19*, 1457–1477.
13. Ma, H.-D. (2011). Internet of things: Objectives and scientific challenges. *Journal of Computer science and Technology*, *26*(6), 919–924.
14. Abou-Zahra, S., Brewer, J., & Cooper, M. (2017). Web standards to enable an accessible and inclusive internet of things (IoT). In *Proceedings of the 14th Web for All Conference on The Future of Accessible Work*, ser. W4A '17 (pp. 9:1–9:4). New York, NY: ACM.
15. Welbourne, E., Battle, L., Cole, G., Gould, K., Rector, K., Raymer, S., et al. (2009). Building the internet of things using RFID: The RFID ecosystem experience. *IEEE Internet Computing*, *13*(3), 48–55.

16. Zhang, M., Sun, F., & Cheng, X. (2012). Architecture of internet of things and its key technology integration based-on RFID. In *2012 Fifth International Symposium on Computational Intelligence and Design (ISCID)* (Vol. 1, pp. 294–297). IEEE.
17. Elkhodr, M., Shahrestani, S., & Cheung, H. (2013). The Internet of things: Vision & challenges. In *2013 IEEE TENCON Spring Conference* (pp. 218–222). IEEE.
18. Mainetti, L., Patrono, L., & Vilei, A. (2011). Evolution of wireless sensor networks towards the internet of things: A survey. In *2011 19th International Conference on Software, Telecommunications and Computer Networks (SoftCOM)* (pp. 1–6). IEEE.
19. Columbus, L. (2015). Roundup of Internet of things forecasts and market estimates. In *Forbes*, Vol. 27.
20. Linden, A., & Fenn, J. (2017). *Understanding Gartner's hype cycles*. Strategic Analysis Report № R-20-1971. Gartner, Inc.
21. Juels, A., Rivest, R.L., & Szydlo, M. (2003). The blocker tag: Selective blocking of RFID tags for consumer privacy. In *Proceedings of the 10th ACM conference on Computer and communications security* (pp. 103–111). ACM.
22. Gonzalez, G. R., Organero, M. M., & Kloos, C. D. (2008). Early infrastructure of an internet of things in spaces for learning. In *Eighth IEEE International Conference on Advanced Learning Technologies, 2008. ICALT'08* (pp. 381–383). IEEE.
23. Santucci, G. (2010). The internet of things: Between the revolution of the internet and the metamorphosis of objects. In *Vision and Challenges for Realising the Internet of Things*, pp. 11–24.
24. Weber, R. H., & Weber, R. (2010). *Internet of Things* (Vol. 12). Berlin: Springer.
25. Medeiros, E. S., & Fravel, M. T. (2003). China's new diplomacy. *Foreign Aff.*, *82*, 22.
26. Meddeb, A. (2016). Internet of things standards: Who stands out from the crowd? *IEEE Communications Magazine*, *54*(7), 40–47.
27. Kuyoro, S., Osisanwo, F., & Akinsowon, O. (2015). Internet of things (IoT): An overview. In *3rd International conference on advances in engineering sciences & applied mathematics*, pp. 53–58.
28. Bell, C. (2016). The Internet of things and data. In *MySQL for the Internet of Things* (pp. 1–28). Springer.
29. Hodges, S., Taylor, S., Villar, N., Scott, J., Bial, D., & Fischer, P. T. (2013). Prototyping connected devices for the Internet of things. *Computer*, *46*(2), 26–34.
30. Evans, M., Noble, J. J., & Hochenbaum, J. (2013). *Arduino in action*. Manning.
31. Shajahan, A. H., & Anand, A. (2013). Data acquisition and control using Arduino-Android platform: Smart plug. In *2013 International Conference on Energy Efficient Technologies for Sustainability (ICEETS)* (pp. 241–244). IEEE.
32. Tso, F. P., White, D. R., Jouet, S., Singer, J., & Pezaros, D. P. (2013). The glasgow raspberry pi cloud: A scale model for cloud computing infrastructures. In *2013 IEEE 33rd International Conference on Distributed Computing Systems Workshops (ICDCSW)* (pp. 108–112). IEEE.
33. Wilkinson, G. (2014). Digital terrestrial tracking: The future of surveillance. In *DEFCON*, Vol. 22.
34. Babin, B. J., & Zikmund, W. G. (2015). *Exploring marketing research*. Cengage Learning.
35. Dominikus, S., Aigner, M., & Kraxberger, S. (2010). Passive RFID technology for the internet of things. In *International Conference for Internet Technology and Secured Transactions (ICITST)* (pp. 1–8). IEEE.
36. Lapide, L. (2004). RFID: What's in it for the forecaster? *The Journal of Business Forecasting*, *23*(2), 16.
37. Jiang, W. (2015). *A diagnostic tool for the causes of packet corruption in wireless sensor networks*. Master's thesis, Mid Sweden University, Department of Information and Communication systems.
38. YangDacheng, W. C. Z. (2010). Device-to-device communication as an underlay to lte-advanced networks. *Modern Science & Technology of Telecommunications*, *7*, 005.
39. Bravo, J., Hervas, R., Nava, S. W., Chavira, G., & Sanchez, C. (2007). Towards natural interaction by enabling technologies: A near field communication approach. In *European Conference on Ambient Intelligence* (pp. 338–351). Springer.
40. He, D., Kumar, N., & Lee, J.-H. (2015). Secure pseudonym-based near field communication protocol for the consumer Internet of things. *IEEE Transactions on Consumer Electronics*, *61*(1), 56–62.
41. Wu, G., Talwar, S., Johnsson, K., Himayat, N., & Johnson, K. D. (2011). M2M: From mobile to embedded internet. *IEEE Communications Magazine*, *49*(4), 36–43.
42. Severi, S., Sottile, F., Abreu, G., Pastrone, C., Spirito, M., & Berens, F. (2014). M2M technologies: Enablers for a pervasive Internet of things. In *2014 European Conference on Networks and Communications (EuCNC)* (pp. 1–5). IEEE.
43. Zorzi, M., Gluhak, A., Lange, S., & Bassi, A. (2010). From today's intranet of things to a future internet of things: A wireless-and mobility-related view. *IEEE Wireless Communications*, *17*(6), 44–51.

44. Hank, P., Müller, S., Vermesan, O., & Van Den Keybus, J. (2013). Automotive ethernet: In-vehicle networking and smart mobility. In *Proceedings of the Conference on Design, Automation and Test in Europe* (pp. 1735–1739). EDA Consortium.
45. Kyriazis, D., Varvarigou, T., White, D., Rossi, A., & Cooper, J. (2013). Sustainable smart city IoT applications: Heat and electricity management & Eco-conscious cruise control for public transportation. In *2013 IEEE 14th International Symposium and Workshops on a World of Wireless, Mobile and Multimedia Networks (WoWMoM)* (pp. 1–5). IEEE.
46. Somov, A., Dupont, C., & Giaffreda, R. (2013). Supporting smart-city mobility with cognitive Internet of Things. In *Future Network and Mobile Summit (FutureNetworkSummit)* (pp. 1–10). IEEE.
47. Vermesan, O., Blystad, L.-C., John, R., Hank, P., Bahr, R., & Moscatelli, A. (2013). Smart, connected and mobile: Architecting future electric mobility ecosystems. In *Proceedings of the Conference on Design, Automation and Test in Europe* (pp. 1740–1744). EDA Consortium.
48. He, W., Yan, G., & Da Xu, L. (2014). Developing vehicular data cloud services in the IoT environment. *IEEE Transactions on Industrial Informatics*, *10*(2), 1587–1595.
49. Jin, J., Gubbi, J., Marusic, S., & Palaniswami, M. (2014). An information framework for creating a smart city through internet of things. *IEEE Internet of Things Journal*, *1*(2), 112–121.
50. Lee, S., Tewolde, G., & Kwon, J. (2014). Design and implementation of vehicle tracking system using GPS, GSM, GPRS technology and smartphone application. In *IEEE World Forum on Internet of Things (WF-IoT), 2014* (pp. 353–358). IEEE.
51. Ma, X., Yu, H., Wang, Y., & Wang, Y. (2015). Large-scale transportation network congestion evolution prediction using deep learning theory. *PLoS ONE*, *10*(3), e0119044.
52. Poslad, S., Ma, A., Wang, Z., & Mei, H. (2015). Using a smart city IoT to incentivise and target shifts in mobility behaviour—Is it a piece of pie? *Sensors*, *15*(6), 13069–13096.
53. Karnouskos, S., & De Holanda, T. N. (2009). Simulation of a smart grid city with software agents. In *Third UKSim European Symposium on Computer Modeling and Simulation, 2009. EMS'09* (pp. 424–429). IEEE.
54. Bressan, N., Bazzaco, L., Bui, N., Casari, P., Vangelista, L., & Zorzi, M. (2010). The deployment of a smart monitoring system using wireless sensor and actuator networks. In *2010 First IEEE International Conference on Smart Grid Communications (SmartGridComm)* (pp. 49–54). IEEE.
55. Farhangi, H. (2010). The path of the smart grid. *IEEE Power and Energy Magazine*, *8*(1), 18–28.
56. Karnouskos, S. (2010). The cooperative internet of things enabled smart grid. In *Proceedings of the 14th IEEE international symposium on consumer electronics (ISCE2010)*, June 2010, pp. 7–10.
57. Mohsenian-Rad, A.-H., Wong, V. W., Jatskevich, J., Schober, R., & Leon-Garcia, A. (2010). Autonomous demand-side management based on game-theoretic energy consumption scheduling for the future smart grid. *IEEE Transactions on Smart Grid*, *1*(3), 320–331.
58. Yu, X., Cecati, C., Dillon, T., & Simoes, M. G. (2011). The new frontier of smart grids. *IEEE Industrial Electronics Magazine*, *5*(3), 49–63.
59. Bui, N., Castellani, A. P., Casari, P., & Zorzi, M. (2012). The internet of energy: A web-enabled smart grid system. *IEEE Network*, *26*(4), 39–45.
60. Li, L., Xiaoguang, H., Ke, C., & Ketai, H. (2011). The applications of WiFi-based wireless sensor network in internet of things and smart grid. In *2011 6th IEEE Conference on Industrial Electronics and Applications (ICIEA)* (pp. 789–793). IEEE.
61. Yun, M., & Yuxin, B. (2010). Research on the architecture and key technology of Internet of Things (IoT) applied on smart grid. In *2010 International Conference on Advances in Energy Engineering (ICAEE)* (pp. 69–72). IEEE.
62. Qin, Z., Denker, G., Giannelli, C., Bellavista, P., & Venkatasubramanian, N. (2014). A software defined networking architecture for the internet-of-things. In *2014 IEEE Network Operations and Management Symposium (NOMS)* (pp. 1–9). IEEE.
63. Zhang, Y., Yu, R., Nekovee, M., Liu, Y., Xie, S., & Gjessing, S. (2012). Cognitive machine-to-machine communications: Visions and potentials for the smart grid. *IEEE Network*, *26*(3), 6–13.
64. Darianian, M., & Michael, M. P. (2008). Smart home mobile RFID-based Internet-of-Things systems and services. In *International Conference on Advanced Computer Theory and Engineering, 2008. ICACTE'08* (pp. 116–120). IEEE.
65. Chong, G., Zhihao, L., & Yifeng, Y. (2011). The research and implement of smart home system based on internet of things. In *2011 International Conference on Electronics, Communications and Control (ICECC)* (pp. 2944–2947). IEEE.
66. Li, X., Lu, R., Liang, X., Shen, X., Chen, J., & Lin, X. (2011). Smart community: An internet of things application. *IEEE Communications Magazine*, *49*(11), 68–75.

67. Jie, Y., Pei, J. Y., Jun, L., Yun, G., & Wei, X. (2013). Smart home system based on IoT technologies. In *2013 Fifth International Conference on Computational and Information Sciences (ICCIS)* (pp. 1789–1791). IEEE.
68. Piyare, R. (2013). Internet of things: Ubiquitous home control and monitoring system using android based smart phone. *International Journal of Internet of Things*, *2*(1), 5–11.
69. Soliman, M., Abiodun, T., Hamouda, T., Zhou, J., & Lung, C.-H. (2013). Smart home: Integrating internet of things with web services and cloud computing. In *2013 IEEE 5th International Conference on Cloud Computing Technology and Science (CloudCom)* (Vol. 2, pp. 317–320). IEEE.
70. Wang, M., Zhang, G., Zhang, C., Zhang, J., & Li, C. (2013). An IoT-based appliance control system for smart homes. In *2013 fourth International Conference on Intelligent Control and Information Processing (ICICIP)* (pp. 744–747). IEEE.
71. Kumar, S. (2014). Ubiquitous smart home system using android application. arXiv preprint arXiv:1402.2114.
72. Ghayvat, H., Mukhopadhyay, S., Gui, X., & Suryadevara, N. (2015). WSN-and IOT-based smart homes and their extension to smart buildings. *Sensors*, *15*(5), 10 350–10 379.
73. Rathore, M. M., Ahmad, A., Paul, A., & Rho, S. (2016). Urban planning and building smart cities based on the internet of things using big data analytics. *Computer Networks*, *101*, 63–80.
74. Castellani, A. P., Gheda, M., Bui, N., Rossi, M., & Zorzi, M. (2011). Web Services for the Internet of Things through CoAP and EXI. In *2011 IEEE International Conference on Communications Workshops (ICC)* (pp. 1–6). IEEE.
75. Oliveira, L. M., & Rodrigues, J. J. (2011). Wireless sensor networks: A survey on environmental monitoring. *JCM*, *6*(2), 143–151.
76. Cheng, H.-C., & Liao, W.-W. (2012). Establishing an lifelong learning environment using IOT and learning analytics. In *2012 14th International Conference on Advanced Communication Technology (ICACT)* (pp. 1178–1183). IEEE.
77. Jia, X., Feng, Q., Fan, T., & Lei, Q. (2012). RFID technology and its applications in Internet of Things (IoT). In *2012 2nd International Conference on Consumer Electronics, Communications and Networks (CECNet)* (pp. 1282–1285). IEEE.
78. Swan, M. (2012). Sensor mania! The internet of things, wearable computing, objective metrics, and the quantified self 2.0. *Journal of Sensor and Actuator Networks*, *1*(3), 217–253.
79. Kelly, S. D. T., Suryadevara, N. K., & Mukhopadhyay, S. C. (2013). Towards the implementation of IoT for environmental condition monitoring in homes. *IEEE Sensors Journal*, *13*(10), 3846–3853.
80. Lazarescu, M. T. (2013). Design of a WSN platform for long-term environmental monitoring for IoT applications. *IEEE Journal on Emerging and Selected Topics in Circuits and Systems*, *3*(1), 45–54.
81. Zhao, J., Zheng, X., Dong, R., & Shao, G. (2013). The planning, construction, and management toward sustainable cities in China needs the Environmental Internet of Things. *International Journal of Sustainable Development & World Ecology*, *20*(3), 195–198.
82. Fang, S., Da Xu, L., Zhu, Y., Ahati, J., Pei, H., Yan, J., et al. (2014). An integrated system for regional environmental monitoring and management based on internet of things. *IEEE Transactions on Industrial Informatics*, *10*(2), 1596–1605.
83. Kantarci, B., & Mouftah, H. T. (2014). Trustworthy sensing for public safety in cloud-centric internet of things. *IEEE Internet of Things Journal*, *1*(4), 360–368.
84. Bui, N., & Zorzi, M. (2011). Health care applications: a solution based on the internet of things. In *Proceedings of the 4th international symposium on applied sciences in biomedical and communication technologies* (p. 131). ACM.
85. Istepanian, R. S., Hu, S., Philip, N. Y., & Sungoor, A. (2011). The potential of Internet of m-health Things “m-IoT” for non-invasive glucose level sensing. In *Engineering in Medicine and Biology Society, EMBC, 2011, Annual International Conference of the IEEE* (pp. 5264–5266). IEEE.
86. Doukas, C., & Maglogiannis, I. (2012). Bringing IoT and cloud computing towards pervasive healthcare. In *2012 sixth international conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS)* (pp. 922–926). IEEE.
87. Sung, W.-T., & Chiang, Y.-C. (2012). Improved particle swarm optimization algorithm for android medical care IOT using modified parameters. *Journal of Medical Systems*, *36*(6), 3755–3763.
88. Amendola, S., Lodato, R., Manzari, S., Occhiuzzi, C., & Marrocco, G. (2014). RFID technology for IoT-based personal healthcare in smart spaces. *IEEE Internet of Things Journal*, *1*(2), 144–152.
89. Fan, Y. J., Yin, Y. H., Da Xu, L., Zeng, Y., & Wu, F. (2014). IoT-based smart rehabilitation system. *IEEE Transactions on Industrial Informatics*, *10*(2), 1568–1577.
90. Xu, B., Da Xu, L., Cai, H., Xie, C., Hu, J., & Bu, F. (2014). Ubiquitous data accessing method in IoT-based information system for emergency medical services. *IEEE Transactions on Industrial Informatics*, *10*(2), 1578–1586.

91. Yang, G., Xie, L., Mäntysalo, M., Zhou, X., Pang, Z., Da Xu, L., et al. (2014). A health-IoT platform based on the integration of intelligent packaging, unobtrusive bio-sensor, and intelligent medicine box. *IEEE Transactions on Industrial Informatics*, *10*(4), 2180–2191.
92. Hassanalieragh, M., Page, A., Soyata, T., Sharma, G., Aktas, M., Mateos, G., et al. (2015). Health monitoring and management using Internet-of-Things (IoT) sensing with cloud-based processing: Opportunities and challenges. In *2015 IEEE International Conference on Services Computing (SCC)* (pp. 285–292). IEEE.
93. Ukil, A., Bandyoapdhyay, S., Puri, C., & Pal, A. (2016). IoT healthcare analytics: The importance of anomaly detection. In *2016 IEEE 30th international conference on Advanced Information Networking and Applications (AINA)* (pp. 994–997). IEEE.
94. Kovatsch, M., Mayer, S., & Ostermaier, B. (2012). Moving application logic from the firmware to the cloud: Towards the thin server architecture for the internet of things. In *2012 sixth international conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS)* (pp. 751–756). IEEE.
95. Durkop, L., Trsek, H., Jasperneite, J., & Wisniewski, L. (2012). Towards autoconfiguration of industrial automation systems: A case study using Profinet IO. In *2012 IEEE 17th conference on Emerging Technologies & Factory Automation (ETFA)* (pp. 1–8). IEEE.
96. Palattella, M. R., Accettura, N., Grieco, L. A., Boggia, G., Dohler, M., & Engel, T. (2013). On optimal scheduling in duty-cycled industrial IoT applications using IEEE802. 15.4 e TSCH. *IEEE Sensors Journal*, *13*(10), 3655–3666.
97. Bi, Z., Da Xu, L., & Wang, C. (2014). Internet of things for enterprise systems of modern manufacturing. *IEEE Transactions on industrial informatics*, *10*(2), 1537–1546.
98. Chi, Q., Yan, H., Zhang, C., Pang, Z., & Da Xu, L. (2014). A reconfigurable smart sensor interface for industrial WSN in IoT environment. *IEEE Transactions on Industrial Informatics*, *10*(2), 1417–1425.
99. He, W., & Da Xu, L. (2014). Integration of distributed enterprise applications: A survey. *IEEE Transactions on Industrial Informatics*, *10*(1), 35–42.
100. Perera, C., Liu, C. H., Jayawardena, S., & Chen, M. (2014). A survey on internet of things from industrial market perspective. *IEEE Access*, *2*, 1660–1679.
101. Yan, H., Zhang, Y., Pang, Z., & Da Xu, L. (2014). Superframe planning and access latency of slotted MAC for industrial WSN in IoT environment. *IEEE Transactions on Industrial Informatics*, *10*(2), 1242–1251.
102. Qiu, X., Luo, H., Xu, G., Zhong, R., & Huang, G. Q. (2015). Physical assets and service sharing for IoT-enabled Supply Hub in Industrial Park (SHIP). *International Journal of Production Economics*, *159*, 4–15.
103. Reaidy, P. J., Gunasekaran, A., & Spalanzani, A. (2015). Bottom-up approach based on internet of things for order fulfillment in a collaborative warehousing environment. *International Journal of Production Economics*, *159*, 29–40.
104. Zhao, J., Zhang, J., Feng, Y., & Guo, J. (2010). The study and application of the IOT technology in agriculture. In *2010 3rd IEEE International Conference on Computer Science and Information Technology (ICCSIT)* (Vol. 2, pp. 462–465). IEEE.
105. Liqiang, Z., Shouyi, Y., Leibo, L., Zhen, Z., & Shaojun, W. (2011). A crop monitoring system based on wireless sensor network. *Procedia Environmental Sciences*, *11*, 558–565.
106. Yan-e, D. (2011). Design of intelligent agriculture management information system based on IoT. In *2011 International Conference on Intelligent Computation Technology and Automation (ICICTA)* (Vol. 1, pp. 1045–1049). IEEE.
107. Bo, Y., & Wang, H. (2011). The application of cloud computing and the internet of things in agriculture and forestry. In *2011 International Joint Conference on Service Sciences (IJCSS)* (pp. 168–172). IEEE.
108. Bandyopadhyay, D., & Sen, J. (2011). Internet of things: Applications and challenges in technology and standardization. *Wireless Personal Communications*, *58*(1), 49–69.
109. Chen, Y., Chanet, J.-P., & Hou, K. M. (2012). RPL Routing Protocol a case study: Precision agriculture. In *First China-France Workshop on Future Computing Technology (CF-WoFUCT 2012)*, p. 6-p.
110. Li, S. (2012). Application of the internet of things technology in precision agriculture irrigation systems. In *2012 international conference on Computer Science & Service System (CSSS)* (pp. 1009–1013). IEEE.
111. Kaloxylos, A., Eigenmann, R., Teye, F., Politopoulou, Z., Wolfert, S., Shrank, C., et al. (2012). Farm management systems and the Future Internet era. *Computers and Electronics in Agriculture*, *89*, 130–144.
112. TongKe, F. (2013). Smart agriculture based on cloud computing and IOT. *Journal of Convergence Information Technology*, *8*(2).

113. Ojha, T., Misra, S., & Raghuwanshi, N. S. (2015). Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges. *Computers and Electronics in Agriculture*, *118*, 66–84.
114. Lopez-de Ipiña, D., Díaz-de Sarralde, I., & Zubía, J. G. (2010). An ambient assisted living platform integrating RFID data-on-tag care annotations and Twitter. *Journal of UCS*, *16*(12), 1521–1538.
115. Zhang, X. M., & Zhang, N. (2011). An open, secure and flexible platform based on internet of things and cloud computing for ambient aiding living and telemedicine. In *2011 International Conference on Computer and Management (CAMAN)* (pp. 1–4). IEEE.
116. Domingo, M. C. (2012). An overview of the Internet of Things for people with disabilities. *Journal of Network and Computer Applications*, *35*(2), 584–596.
117. Jara, A. J., Zamora, M. A., & Skarmeta, A. F. (2011). An internet of things-based personal device for diabetes therapy management in ambient assisted living (AAL). *Personal and Ubiquitous Computing*, *15*(4), 431–440.
118. Memon, M., Wagner, S. R., Pedersen, C. F., Beevi, F. H. A., & Hansen, F. O. (2014). Ambient assisted living healthcare frameworks, platforms, standards, and quality attributes. *Sensors*, *14*(3), 4312–4341.
119. Kumar, A., Mihovska, A., Kyriazakos, S., & Prasad, R. (2014). Visible light communications (VLC) for ambient assisted living. *Wireless Personal Communications*, *78*(3), 1699–1717.
120. Konstantinidis, E. I., Antoniou, P. E., Bamparopoulos, G., & Bamidis, P. D. (2015). A lightweight framework for transparent cross platform communication of controller data in ambient assisted living environments. *Information Sciences*, *300*, 124–139.
121. Cubo, J., Nieto, A., & Pimentel, E. (2014). A cloud-based Internet of Things platform for ambient assisted living. *Sensors*, *14*(8), 14070–14105.
122. Parada, R., Melia-Segui, J., Morenza-Cinos, M., Carreras, A., & Pous, R. (2015). Using RFID to detect interactions in ambient assisted living environments. *IEEE Intelligent Systems*, *30*(4), 16–22.
123. Li, R., Lu, B., & McDonald-Maier, K. D. (2015). Cognitive assisted living ambient system: A survey. *Digital Communications and Networks*, *1*(4), 229–252.
124. Artmann, R. (1999). Electronic identification systems: State of the art and their further development. *Computers and Electronics in Agriculture*, *24*(1), 5–26.
125. Wismans, W. (1999). Identification and registration of animals in the European Union. *Computers and Electronics in Agriculture*, *24*(1), 99–108.
126. Streit, S., Bock, F., Pirk, C. W., & Tautz, J. (2003). Automatic life-long monitoring of individual insect behaviour now possible. *Zoology*, *106*(3), 169–171.
127. Stoces, M., Vanek, J., Masner, J., & Pavlík, J. (2016). Internet of Things (IoT) in agriculture-selected aspects. *AGRIS On-line Papers in Economics and Informatics*, *8*(1), 83.
128. Khanna, A., & Kaur, S. (2019). Evolution of Internet of Things (IoT) and its significant impact in the field of precision agriculture. *Computers and Electronics in Agriculture*, *157*, 218–231.
129. Wyld, D. C., Jones, M. A., & Totten, J. W. (2005). Where is my suitcase? RFID and airline customer service. *Marketing Intelligence & Planning*, *23*(4), 382–394.
130. Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of things for smart cities. *IEEE Internet of Things Journal*, *1*(1), 22–32.
131. Beyer, S. M., Mullins, B. E., Graham, S. R., & Bindewald, J. M. (2018). Pattern-of-life modeling in smart homes. *IEEE Internet of Things Journal*, *56*, 5317–5325.
132. Sommerville, J., & Craig, N. (2005). Intelligent buildings with radio frequency identification devices. *Structural Survey*, *23*(4), 282–290.
133. Jaselskis, E. J., & El-Misalami, T. (2003). Implementing radio frequency identification in the construction process. *Journal of Construction Engineering and Management*, *129*(6), 680–688.
134. Shrouf, F., Ordieres, J., & Miragliotta, G. (2014). Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm. In *2014 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 697–701). IEEE.
135. Li, Y. (2013). Design of a key establishment protocol for smart home energy management system. In *2013 fifth international Conference on Computational Intelligence, Communication Systems and Networks (CICSyN)* (pp. 88–93). IEEE.
136. Lai, C.-F., Lai, Y.-X., Yang, L. T., & Chao, H.-C. (2012). Integration of IoT energy management system with appliance and activity recognition. In *2012 IEEE international conference on Green Computing and Communications (GreenCom)* (pp. 66–71). IEEE.
137. Zheng, L., Chen, S., Xiang, S., & Hu, Y. (2012). Research of architecture and application of Internet of Things for smart grid. In *2012 International Conference on Computer Science & Service System (CSSS)* (pp. 938–941). IEEE.

138. Bekara, C. (2014). Security issues and challenges for the IoT-based smart grid. *Procedia Computer Science*, *34*, 532–537.
139. Hall, R., & Hampl, J. S. (2004). Radio frequency identification: Applications for dietetics professionals. *Journal of the American Dietetic Association*, *104*(10), 1521–1522.
140. Jones, P., Clarke-Hill, C., Comfort, D., Hillier, D., & Shears, P. (2005). Radio frequency identification and food retailing in the UK. *British Food Journal*, *107*(6), 356–360.
141. Venkatesan, M., & Grauer, Z. (2004). Leveraging radio frequency identification (RFID) technology to improve laboratory information management. *American Laboratory*, *36*(18), 11–14.
142. Yao, W., Chu, C.-H., & Li, Z. (2011). Leveraging complex event processing for smart hospitals using RFID. *Journal of Network and Computer Applications*, *34*(3), 799–810.
143. Coronato, A., Esposito, M., & De Pietro, G. (2009). A multimodal semantic location service for intelligent environments: An application for Smart Hospitals. *Personal and Ubiquitous Computing*, *13*(7), 527–538.
144. Catarinucci, L., De Donno, D., Mainetti, L., Palano, L., Patrono, L., Stefanizzi, M. L., et al. (2015). An IoT-aware architecture for smart healthcare systems. *IEEE Internet of Things Journal*, *2*(6), 515–526.
145. Yu, L., Lu, Y., & Zhu, X. (2012). Smart Hospital based on Internet of Things. *JNW*, *7*(10), 1654–1661.
146. Hautala, M., Keränen, N. S., Leinonen, E., Kangas, M., & Jämsä, T. (2017). ICT use in family caregiving of elderly and disabled subjects. In *eHealth*360° (pp. 42–48). Springer.
147. Kumar, D., Ravindra, S., et al. (2016). E-Assistance for elderly and disabled. *Journal of Embedded Systems and Processing*, *1*(2), 1–7.
148. Chaudhari, N., Gupta, A., & Raju, S. (2016). ALED system to provide mobile IoT assistance for elderly and disabled. *International Journal of Smart Home*, *10*(8), 35–50.
149. Agrawal, S., & Lal Das, M. (2011). Internet of things—A paradigm shift of future internet applications, pp. 1–7, 12.
150. Hussain, A., Wenbi, R., da Silva, A. L., Nadher, M., & Mudhish, M. (2015). Health and emergency-care platform for the elderly and disabled people in the Smart City. *Journal of Systems and Software*, *110*, 253–263.
151. Qushem, U. B., Dahlan, A. R. B. A., & Ghani, A. S. B. M. (2016). My emergency assistant device: A conceptual solution in enhancing the quality of life for the disabled and elderly. In *2016 6th International Conference on Information and Communication Technology for The Muslim World (ICT4M)* (pp. 82–87). IEEE.
152. Hicks, P. (1999). RFID and the book trade. *Publishing Research Quarterly*, *15*(2), 21–23.
153. Keskilammi, M., & Kivikoski, M. (2004). Using text as a meander line for RFID transponder antennas. *IEEE Antennas and Wireless Propagation Letters*, *3*(1), 372–374.
154. Coyle, K. (2005). Management of RFID in Libraries. *The Journal of Academic Librarianship*, *31*(5), 486–489.
155. Lee Eden, B., Fabbi, J. L., Watson, S. D., Marks, K. E., & Sylvis, Z. (2005). UNLV libraries and the digital identification frontier. *Library Hi Tech*, *23*(3), 313–322.
156. Jansen, R., & Krabs, A. (1999). Automatic identification in packaging—Radio frequency identification in multiway systems. *Packaging Technology and Science*, *12*(5), 229–234.
157. Angeles, R. (2005). RFID technologies: Supply-chain applications and implementation issues. *Information Systems Management*, *22*(1), 51–65.
158. Twist, D. C. (2005). The impact of radio frequency identification on supply chain facilities. *Journal of Facilities Management*, *3*(3), 226–239.
159. Kärkkäinen, M. (2003). Increasing efficiency in the supply chain for short shelf life goods using RFID tagging. *International Journal of Retail & Distribution Management*, *31*(10), 529–536.
160. Jones, P., Clarke-Hill, C., Comfort, D., Hillier, D., & Shears, P. (2004). Radio frequency identification in retailing and privacy and public policy issues. *Management Research News*, *27*(8/9), 46–56.
161. Eckfeldt, B. (2005). What does RFID do for the consumer? *Communications of the ACM*, *48*(9), 77–79.
162. Jones, P., Clarke-Hill, C., Hillier, D., & Comfort, D. (2005). The benefits, challenges and impacts of radio frequency identification technology (RFID) for retailers in the UK. *Marketing Intelligence & Planning*, *23*(4), 395–402.
163. Soliman, K. S., Janz, B. D., Prater, E., Frazier, G. V., & Reyes, P. M. (2005). Future impacts of rfid on e-supply chains in grocery retailing. *Supply Chain Management: An International Journal*, *10*(2), 134–142.
164. Wäger, P., Eugster, M., Hilty, L., & Som, C. (2005). Smart labels in municipal solid waste-a case for the Precautionary Principle? *Environmental Impact Assessment Review*, *25*(5), 567–586.

165. Moreno, M. V., Santa, J., Zamora, M. A., & Skarmeta, A. F. (2014). A holistic IoT-based management platform for smart environments. In *2014 IEEE International Conference on Communications (ICC)* (pp. 3823–3828). IEEE.
166. Yu, M., Zhang, D., Cheng, Y., & Wang, M. (2011). An RFID electronic tag based automatic vehicle identification system for traffic IOT applications. In *2011 Chinese Control and Decision Conference (CCDC)* (pp. 4192–4197). IEEE.
167. Misbahuddin, S., Zubairi, J. A., Saggaf, A., Basuni, J., Sulaiman, A., Al-Sofi, A., et al. (2015). IoT based dynamic road traffic management for smart cities. In *2015 12th international conference on High-Capacity Optical Networks and Enabling/Emerging Technologies (HONET)* (pp. 1–5). IEEE.
168. Foschini, L., Taleb, T., Corradi, A., & Bottazzi, D. (2011). M2M-based metropolitan platform for IMS-enabled road traffic management in IoT. *IEEE Communications Magazine*, *49*(11), 50–57.
169. Zhou, L., & Chao, H.-C. (2011). Multimedia traffic security architecture for the internet of things. *IEEE Network*, *25*(3), 35–40.
170. Djahel, S., Doolan, R., Muntean, G.-M., & Murphy, J. (2015). A communications-oriented perspective on traffic management systems for smart cities: Challenges and innovative approaches. *IEEE Communications Surveys & Tutorials*, *17*(1), 125–151.
171. Lee, W.-H., Tseng, S.-S., & Shieh, W.-Y. (2010). Collaborative real-time traffic information generation and sharing framework for the intelligent transportation system. *Information Sciences*, *180*(1), 62–70.
172. Figueiredo, L., Jesus, I., Machado, J. T., Ferreira, J. R., & De Carvalho, J. M. (2001). Towards the development of intelligent transportation systems. In *Intelligent Transportation Systems, 2001. Proceedings. 2001 IEEE* (pp. 1206–1211). IEEE.
173. Nastic, S., Sehic, S., Le, D.-H., Truong, H.-L., & Dustdar, S. (2014). Provisioning software-defined IoT cloud systems. In *2014 international conference on Future Internet of Things and Cloud (FiCloud)* (pp. 288–295). IEEE.
174. Yilmaz, T., Gokkoca, G., & Akan, O. B. (2016). Millimetre wave communication for 5G IoT applications. In *Internet of Things (IoT) in 5G Mobile Technologies* (pp. 37–53). Springer.
175. Wu, M., Lu, T.-J., Ling, F.-Y., Sun, J., & Du, H.-Y. (2010). Research on the architecture of Internet of things. In *2010 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE)* (Vol. 5, pp. V5–484). IEEE.
176. Khan, R., Khan, S. U., Zaheer, R., & Khan, S. (2012). Future internet: The internet of things architecture, possible applications and key challenges. In *2012 10th international conference on Frontiers of Information Technology (FIT)* (pp. 257–260). IEEE.
177. Gan, G., Lu, Z., & Jiang, J. (2011). Internet of things security analysis. In *2011 international conference on Internet Technology and Applications (iTAP)* (pp. 1–4). IEEE.
178. Yang, Y., Wu, L., Yin, G., Li, L., & Zhao, H. (2017). A survey on security and privacy issues in internet-of-things. *IEEE Internet of Things Journal*, *4*(5), 1250–1258.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abhishek Khanna is M.C.A. (2007), M.Tech in Computer Science and Applications (2014), & pursuing Ph.D. (CSE) from Thapar Institute of Engineering and Technology, Patiala, Punjab. He has several publications in reputed journals and conferences. His area of research includes Internet of Things (IoT), Wireless Sensor Networks (WSN), and Precision Agriculture.

Dr. Sanmeet Kaur is Assistant Professor in Computer Science and Engineering Department, Thapar University Patiala, Punjab, India. She has earned her ME (Software Engineering) in 2008 and Ph.D. in 2015 from Thapar University Patiala. Her Ph.D. is in intrusion detection and signature generation under the broader area of network Security. She is certified as Ethical Hacker (C|EH) by EC-Council USA. Her areas of interest are Network Security, Software Testing and Software Engineering. She has published more than 30 research papers and articles in Journals, Conferences and Magazines of repute.