Real-Life Applications of the Internet of Things

Challenges, Applications, and Advances

Monika Mangla | Ashok Kumar | Vaishali Mehta
Megha Bhushan | Sachi Nandan Mohanty
Editors

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Abbreviations

4G	fourth generation
ACHE	acetylcholinesterase
ACL	access control list
ACL	agent communication language
ADEPT	autonomous decentralized peer-to-peer telemetry
AI	artificial intelligence
AMQP	advanced message queuing protocol
ANNs	artificial neural networks
AoA	angle of arrival
API	application programming interface
BCoT	blockchain of things
BDA	big data analytics
BLE	Bluetooth
BP	blood pressure
C&C	command and control
CIS	cloud information service
CNN	convolutional neural network
CoAP	constrained application protocol
CPE	customer premises equipment
CRLB	Cramér-Rao lower bound
CTV	connected TV
DBN	deep belief networks
DDoS	disturbed denial of service
DES	discrete event simulations
DGA	domain generation algorithm
DICOM	digital imaging and communications in medicine
DLT	distributed ledger technology
DNS	domain name system
DOD	direction-of-departure
DoS	denial of service
dPBFT	developed delegated PBFT
DPI	deep packet inspection
DPOS	delegated proof of stake
DSD	data distribution service

DSNs	deep stacking networks
ECC	elliptic curve cryptography
ECG	electrocardiogram
ED	entity disambiguation
EDI	electronic data interchange
FAO	Food and Agriculture Organization
FCN	fully convolution network
FinTech	financial technology
GA	genetic algorithms
GBs	gigabits
GEO	geostationary satellite
G-IoT	green IoT
GPS	global positioning system
GPU	graphics processing units
GSM	global service for mobile
GUI	graphical user interface
HDFS	Hadoop distributed file system
HEO	highly elliptical orbit
HIPS	host-based intrusion prevention systems
HIS	hospital information system
HPC	high performance computing
IaaS	infrastructure as a service
IAM	identity and access management
ICT	information and communication technologies
IDS	intruder detection system
IIoT	industrial internet of things
IoE	internet of energy
IoMT	internet of medical things
IoT	internet of things
IoV	internet of vehicles
IPM	integrated pest management
ITU	international telecommunication units
K	potassium
KIF	knowledge interchange format
KQML	knowledge query and manipulation language
LDR	light dependent resistor
LED	light-emitting diode
LEO	low earth orbit
LI	laboratory interface
LIFS	localization information fusion system

LoS	line-of-sight
LPWA	low-power wireless access
LPWAN	low power wide area network
LSCSH	lattice-based secure cryptosystem
LSTM	long short-term memory
M2M	machine to machine
M2P	includes machine to people
MAC	message authentication code
MEMS	micro-electro-mechanical systems
ML	machine learning
MPA	microstrip patch antenna
MPI	message passing interface
MQTT	message queue telemetry transport
MTC	machine-type correspondence
MTL	multi-task learning
N	nitrogen
NDVI	normalized difference vegetation index
NE	named entity
NER	named entity recognition
NFC	near field communication
NLP	natural language processing
NPK	nitrogen-phosphorus potassium
NRC	National Research Council
OMA-DM	open mobile alliance device management
OTT	over-the-top
P	phosphorus
P2P	peer-to-peer
P2P	people-to-people
PaaS	platform as a service
PACS	picture archiving and communication system
PBFT	practical byzantine fault tolerance
PI	path lab interface
PIR	passive infrared
PN	personal network
PoET	proof of elapsed time
PoS	proof of stake
PoT	proof of trust
PoW	proof of work
QoS	quality of service
RDF	resource description framework

RFID	radio frequency identification
RFM	reference fingerprinting map
RI	radiology interface
RIS	radiology information system
RMS	remote monitoring system
RNNs	recurrent neural networks
RPi	raspberry Pi
RSS	received signal strength
RSSI	received signal strength indicator
SaaS	software as a service
SAR	synthetic aperture radar
SD	secure digital
SIM	subscriber identification module
SIoT	satellite IoT
SIT	secure IoT
SLAs	service level agreements
SMS	short message service
SSWE	sentiment-specific word embeddings
SVM	support vector machine
T&D	transmission and dissemination
TDOA	time difference of arrival
ToA	time of arrival
ToF	time of flight
UAVs	unmanned aerial vehicles
UGT	uses and gratification theory
UNFCCC	UN Framework Convention on Climate Change
USB	universal serial bus
UUID	universally unique identifier
V2G	vehicle-to-grid
VLC	visible light communication
VRI	variable rate irrigation
WAN	wide area network
WAP	wireless access point
WFC	weighted fingerprint construction
WHO	World Health Organization
WSN	wireless sensor network
WTFM	weighted text feature model
XMPP	extensible messaging and presence protocol

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We would like to acknowledge the assistance and contribution of all the people engaged in this project. We especially thank our authors for contributing their valuable work, without which it was impossible to complete this book. We express our special and most sincere thanks to the reviewers involved in the review process who contributed their time and expertise to improve the eminence, consistency, and arrangement of the chapters in the book. We also take the opportunity to express our thanks to personnel from the publishing house for giving it a final shape and presenting this book in this manner.

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—*Editors*

Preface

The internet of things (IoT) paradigm is on its way to making objects such as web cameras, wireless sensors, consumer electronic devices, mobile phones, home appliances, clinical support systems, etc., communicate with each other. Thus, it creates a networking environment comprising various objects. It has opened avenues to establish interaction among human and non-living things. Additionally, it enables to development of smart cities, infrastructures, and services so as to improve the lifestyle of mankind alongside the utilization of resources.

IoT is an emerging paradigm for new generation computing. The data that is produced by IoT devices, commonly known as smart devices or sensors, are integrated and analyzed efficiently with the help of IoT technology. The IoT is a new revolution of the networking world and is gaining the attraction of researchers and scientists due to its rapid advancements in technologies and smart devices. Analysts have predicted that there will be a total of 50 billion IoT devices/things by the year 2050.

This book covers many of the powerful features and applications of IoT, such as weather forecasting, agriculture, medical science, surveillance system, and many more. This book is a collection of chapters on diverse issues on the Internet of Things, written for educational programs at universities and institutes and also for experts from industry and for scientists and researchers.

The book structure consists of three divisions, with a total of 20 chapters. Part I covers the issues and challenges arising from the Internet of Things (IoT) and their characteristics. Taxonomy of security issues of IoT systems is presented comprising of various IoT levels of security in different domains. Part II introduces various application areas of IoT, including agriculture, healthcare, and finance. A depth study of various applications of IoT is provided so that readers can enhance their knowledge about smart devices and equipment and their use in agriculture, finance, medical industry, home automation systems, logistics, retail, etc. Part III introduces the readers to advanced topics on IoT, including the integration of IoT with blockchain, cloud, and big data. It is expected that diligent readers of this book can improve their knowledge and skills in order to develop their own IoT applications. We assume that readers of this book possess some basic knowledge about

IoT technology, the general idea of programming, awareness about wired/wireless technologies, and the concept of embedded systems. Our focus is on providing the reader a complete knowledge about different IoT domains for developing robust IoT applications.

We trust that the book will let readers find innovative ideas that are helpful for their educational research. Also, they can find an opportunity to setup some innovative business or develop their own smart application.

Organization of the Book

- **Chapter 1:** This chapter presents a detailed tutorial in the context of the IoT along with its description, merits, demerits, and challenges. This chapter elaborates on the main challenges faced by the field of IoT, such as unpredictable behavior, robustness, concurrency, coordination, and many more.
- **Chapter 2:** This chapter proposes an identification model that uses a random forest algorithm. This chapter also discusses the various botnet detection approaches in existence.
- **Chapter 3:** This chapter explores various challenges present in IDS over IoT. The authors also analyzed various types of available IDS Intrusion detection system techniques over IoT technology.
- **Chapter 4:** This chapter explains about empowering innovations of IoT, including distributed computing and various stages for information investigation.
- **Chapter 5:** This chapter explores IoT along with the emerging technologies and its implementation in the agriculture sector to achieve a greater result than traditional farming. SMART farming techniques along with the usage of various sensors, devices, and technologies are also elaborated section-wise.
- **Chapter 6:** This chapter discusses the capability of IoT in agribusiness, different periods of IoT in horticulture, and the challenges involved.
- **Chapter 7:** In this chapter, the authors present a weed monitoring system in crop production using various techniques, including manual surveys, sensors on land vehicles, or remote sensing. An optic mechanical system has been developed and installed with the reliability needed to operate the weed sensor under the outside area.
- **Chapter 8:** In this chapter, inset fed Microstrip Patch Antenna (MPA) is designed and analyzed for 7 GHz frequency for satellite communication which can be used to be mounted on IoT/OiE-based smart agriculture devices.
- **Chapter 9:** This chapter proposes a health monitoring system for cancer care using cloud-based IoT with wireless sensor network (WSN) to enhance the healthcare solution. The cloud services are used to achieve

transmission of data accurately, a good decision-making environment to enhance the cancer treatment facility.

- **Chapter 10:** The authors in this chapter propose a WSNs based system that collects data from different sensors deployed at various identified nodes in the field and communicates it through a wireless protocol. A solution has been provided for farmers which require less time and reduce the use of pesticides.
- **Chapter 11:** A lot of technological advancements were observed in financial sectors in the last decade. This chapter reviews various risks involved owing to the rapid increase in digitalization and mobilization of financial sectors.
- **Chapter 12:** In this chapter, a review on cloud computing as well as IoT with an attention on the need of the convergence of both innovations and security and privacy issues is presented.
- **Chapter 13:** This chapter proposes an effective summarization of surveillance videos by combining the advent of deep learning to IoT. Deep CNN is used for the selection of significant video features and LSTM is used for generation of video summary.
- **Chapter 14:** This chapter gives the complete insight of state of the art for blockchain and IoT. The chapter addresses research challenges, issues, and the concept of convergence of blockchain and IoT into BCoT. It also discusses the architecture, deployment, benefits, and challenges of BCoT.
- **Chapter 15:** This chapter presents the role of blockchain in IoT with respect to fault-tolerance, adaptability, security, and cost, etc.; additionally, it also discusses the associated challenges and issues.
- **Chapter 16:** In this chapter, the authors' emphasis is on the OTT platforms and their current market scenario. The authors also focus on understanding the theoretical perspective from the consumer viewpoint through cognitive dissonance theory.
- **Chapter 17:** The healthcare sector is always growing while technologies are updating and emerging. In this chapter, fog assisted IoT-based framework for the healthcare sector of a smart city is proposed that utilizes the concept of artificial intelligence by integrating with fog computing.
- **Chapter 18:** The authors in this chapter propose a novel activity recognition framework by the fusion of sensor technology with machine learning techniques. The framework is developed under real-time embedded implementation constraints and can be implemented in real-time sensor networks for accurate recognition of malicious wood logging activities.

- **Chapter 19:** The authors of this chapter propose a learning model system that takes IoT data from sensor devices, geographical locations, Twitter feeds, and SAR images. The authors propose a decision-making system for anomaly detection to minimize the risks.
- **Chapter 20:** This chapter focuses on the usage of Bluetooth Low Energy (BLE) devices beacons for indoor localization. Authors in this paper aim to present state-of-the-art for various developments in indoor localization.

PART I

Issues and Challenges in IoT

CHAPTER 1

Detailed Review on Security Challenges Associated with the Internet of Things

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ABSTRACT

Internet of things (IoT) is the trending technology in this 21st century that aims at the interconnection of all the things in our surroundings via the internet. This chapter presents a detailed tutorial in the context of the IoT along with its description, merits, demerits, and challenges. This chapter elaborates on the main challenges faced by the field of IoT, such as unpredictable behavior, robustness, concurrency, co-ordination, and many more. However, in today's world, one of the major challenges that IoT has to deal with is the extremely dangerous security attacks that even can destroy the entire network. So, maintaining a balance between security and privacy is a challenging task for the IoT field. Therefore, this chapter explores and reviews good journal articles that discuss the security problems in the domain of IoT also elaborate on the technology used, as well as a solution to overcome the discussed problems. Based on the knowledge gathered from all the reviewed articles, this chapter discussed the research gaps for the current going on research in the domain of IoT security that need to be addressed in the upcoming future. IoT application provides a lot of benefits to the user, but in the case, if the IoT could not be able to secure the user information as well as data from hackers, outbreaks, and vulnerabilities, then IoT would not be considered as a secure domain. Furthermore, a critical analysis has been presented

graphically for the evolution of the cybersecurity market in the domain of IoT. By reading this chapter, the readers will have a complete picture of the IoT domain as well as know the necessity for managing and controlling the security challenges faced by the field of IoT. Moreover, this chapter also allows the readers to understand and choose the research issues to carry out for their future research.

1.1 INTRODUCTION

The IoT (internet of things) is the novel technology in the present period that aims at the inter-connection of every single entity in a real-world scenario [1]. With the help of this technique, we can trail anything from a distant position using Internet set-up. Also, the IoT states the association of gadgets to the internet. Cars, kitchen machines as well as pulse rate all would be associated through IoT [2]. Furthermore, as the IoT progresses in a subsequent couple of ages, further new devices will connect that rundown. IoT is considered as a structure of interrelated substances ready to collect and skill data using embedded sensors. In order to deliver the entire systems intended for a service or product, IoT acts as advanced computerization as well as analytics systems that feats big data, networking, sensing, and artificial intelligence (AI) technology. These systems allow more notable straightforwardness, control, and performance when applied to any industry or framework [3]. The IoT is a framework of interconnected computing gadgets, motorized as well as digital machinery, articles, faunas, or humans that are equipped with the unique identifier as well as the capability of transferring information over a setup without requiring a human to PC or else human to human associations [4].

The word "thing," in the IoT things might be a human being with a heart screen implant, an animal with a bio-chip transponder, a car that has functioned in sensors to aware the car owner when tire weight is low or some other natural or man-made thing that can be allocated an IP address as well as outfitted with the capability to transfer above an internet. IoT has developed from the conjunction of wire-less skills, micro-electro-mechanical systems (MEMS), small-scale administrations as well as the web. Kevin Ashton, prime supporter as well as official chief of the Auto-ID focus at MIT, first whispered the IoT in an introduction he made in front of Procter and gamble in 1999 [5]. As per the novel research by Gartner, The IoT, which ignores PCs, tablets, and cell phones, will produce incremental income of more than $300 billion in amenities by 2020. The services involve equipment, embedded software, communications facilities as well as information amenities related to the things [6], [7]. Gartner predicted that 2.9 billion associated things will be in practice in the user area in the year 2015 and will spread over 13 billion in the year 2020. The motorized field will display the maximum progress rate at 96% in the year 2015.

Cryptography refers to the approaches and techniques which are developed and implemented for secured communication for specific channels [8, 9]. It is traditionally associated with the encryption approaches to secure the overall transmission. Security ideas can be executed simply by applying tools of cryptography for example message authentication outlines or encryption. Table 1.1 displays the evaluation of cryptography hash approaches applied in the network environment. Table 1.1 depicts different security-related algorithms with their description of various parameters. Also, Figure 1.1 shows the graphical illustration of traditional cryptography hash approaches using several parameters.

1.1.1 IoT: MERITS

The benefits of IoT navigate over each zone of lifespan as well as business. Here is a rundown of certain merits that IoT brings to the notice [7]:

1. **Enhanced Client Engagement:** In the current analysis, there occurs numerous flaws in the accuracy so involvement of the client becomes quite essential.
2. **Innovation Optimization:** The similar innovations that enhance client knowledge also improves gadget utilization, and help in more intense changes to advancement [8].
3. **A Decrease in Waste:** Current analysis provides us shallow understanding, but IoT provides real-world information provoking a more effective organization of assets.
4. **Improved Data Gathering:** Modern gathering of data encounters from its limitations and its design for passive use.

1.1.2 IoT: DEMERITS

Despite the way that IoT provides numerous benefits, it also offers a substantial number of challenges [9]. Here is a summary of a couple of its noteworthy issues:

1. **Security:** IoT presents an environment of frequently related devices communicating over the networks.
2. **Privacy:** IoT gives extensive individual data in extreme detail without the customer's active involvement.
3. **Complexity:** IoT systems are quite complicated regarding design as well as deployment.
4. **Flexibility:** Many are stressed over the flexibility of an IoT structure to facilitate quickly with another [10].
5. **Compliance:** IoT, like some other innovation in the area of business, must consent to guidelines.

TABLE 1.1 Evaluation of Cryptography Hash Approaches in Network Environment

Algorithm	Rounds	Word Size	Internal State Size	Block Size	Output Size (bits)
GOST	32	32	256	256	256
HAVAL	5	32	256	1,024	128
MD2	18	32	384	128	128
MD4	3	32	128	512	128
MD5	64	32	128	512	128
PANAMA	32	32	8,736	256	256
RIPEMD	48	32	128	512	128
RIPEMD-128/256	64	32	128/256	512	128/256
RIPEMD-160	80	32	160	512	160
RIPEMD-320	80	32	320	512	320
SHA-0	80	32	160	512	160
SHA-1	80	40	160	512	160
SHA-256	64	56	256	512	256
SHA-3	24	64	1,600	3,200	512
SHA3-224	24	64	1,600	1,152	224
SHA3-256	24	64	1,600	1,088	256
SHA3-384	24	64	1,600	832	384
SHA3-512	24	64	1,600	576	512
Tiger2	24	64	192	512	128
WHIRLPOOL	10	8	512	512	512
BLAKE2b	12	64	1,024	512	512
BLAKE2s	10	32	512	256	256

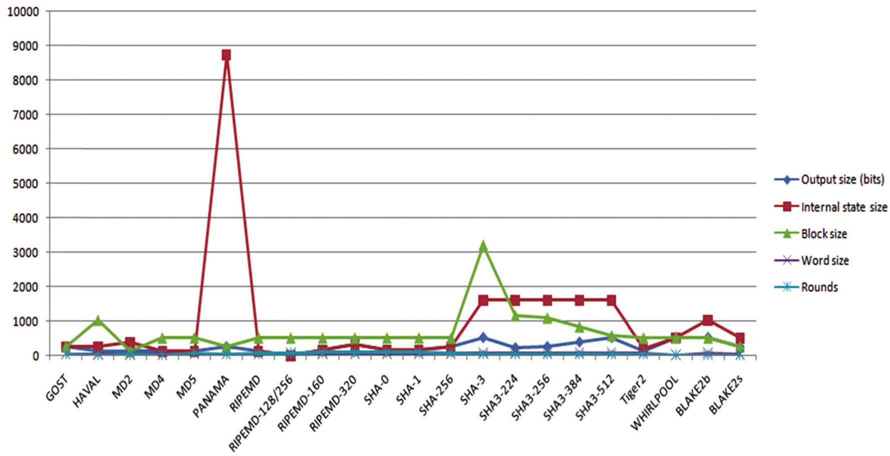

FIGURE 1.1 Graphical evaluation of traditional cryptography hash approaches.

1.2 CHALLENGES OF IoT

There are several challenges that IoT faces beyond costs and the ubiquity of devices such as [5]:

1. **Device Similarity:** IoT gadgets are genuinely uniform. They use a similar association innovation as well as modules [6]. In this, if one framework or gadget experiences powerlessness or suffers from a susceptibility then many more have a similar issue.
2. **Long Device Life and Expired Support:** One of the advantages of IoT gadgets is lifespan, although, that long life furthermore implies that they may outlast their gadget sustenance that is possible to some extent only.
3. **No Upgrade Support:** Many IoT gadgets acts in the same way as other portable and little gadgets do, which is not intended to permit redesigns or any alterations.
4. **Poor or No Transparency:** Many IoT gadgets neglects to furnish straightforwardness concerning their usefulness. Clients cannot watch or access their procedures and are left to accept how gadgets act. They have no influence over undesirable capacities or information accumulation; moreover, when a producer modernizes the device, it may bring more unwanted functions.
5. **No Alerts:** Another objective of IoT stays to give its unimaginable usefulness without being prominent. This presents the issue of client

mindfulness. Clients do not screen the gadgets or know when something turns out badly. Security breaches can persist over long periods without recognition.

6. **Mobility Induced Sensor Network Design:** The IoT gadgets think that it would be hard to interface with each other as well as any other components of IoT organizes in the existence of movability.
7. **Robustness:** The topology of the system in the case of IoT will be exceptionally unverifiable as well as may changes frequently [7]. In such cases keeping up of a long-lived and dynamic framework is dangerous. In this manner, there are challenges in gadget discoverability, control use, and communication protocols.
8. **Co-Ordination:** The real-time coordination among all the mobile device senses as well as actuation platforms is a crucial research challenge that needs to be addressed if IoT is to become fruitful.
9. **Concurrency:** For instance, a web associated auto traveling through more traffic could show variable portability patterns and travel times between its source and goal, managing communication and input/output tasks among various autos, every one of them is varying with their portability patterns and this would be additionally challenging.
10. **Optimal Data Capture and Processing:** A key issue in the IoT framework with more information is created and transmitted on the system. Since the greater part of the information is pointless for the client, methods for ideally filtering the information before storage, and this will rise as a critical research zone.
11. **Location-Based Data Representation and Storage:** Optimal representation, as well as storage of IoT information, is a vital subject, given the information volumes that may be put away from future examination and for review reason.
12. **Serve Implementation via Actuation:** Users need to roll out improvements in the IoT system through the actuation process.
13. **Integration with Opportunistic Computing:** The key research challenge is to decide the most ideal ways to deal with encourage decentralized resourceful directions among human clients and the IoT system [8].

1.3 BACKGROUND OF THE STUDY

IoT is highly susceptible as well as vulnerable to the assaults in assorted layers. There are many issues related to the field of IoT that have been revealed in

Figure 1.2. IoT integrates the low powered devices which communicate with the real-world objects in limited resources and thereby the need to associate the secured cryptography arises. In this research-based study, the need to integrate lightweight cryptography and secure authentication is required. A number of approaches that are devised and implemented here are in a need to integrate the high-performance approaches including quantum cryptography and effectual paradigms that can elevate the overall performance with the secured authorization and authentication in multiple channels.

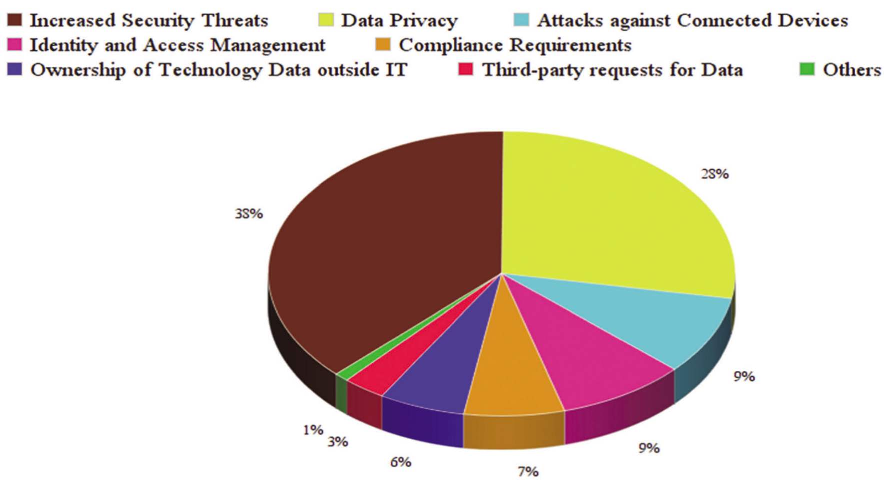

FIGURE 1.2 Top governance issues with the internet of things.

Following are the key assaults in the network environment of IoT:

1. **Sniffing:** In this type of attack, the secretly sniffing or intercepting the channel is done. The forceful evaluation of network channels is done in this type of assault to breach the security in a wireless network.
2. **Base Attack:** In this type of assault, the virtual work is created to intercept the network by hidden layers.
3. **Blackhole Attack:** In this attack, the hacker changes the data packets and the fake channel is used for the distribution of signals. The malicious nodes create a false route to send the fake data to damage the network.
4. **Convoluted Attack:** In this attack, the Convolutional path or complex path is allocated to the network for the damaging purpose. It is used

to exploit the network nodes with the fetching of data packets without permissions.

5. **Hastening Attack:** It energizes the resources so that a higher degree of energy can be consumed in an unethical way. The rushing attacks can damage the network environment to a huge extent with the luring factors by the non-genuine nodes in the environment.
6. **Choke Down Attack:** In this attack, the network channel, as well as bandwidth, are choked down with the evaluation and forcing the bandwidth to deplete a huge level. Using this way, the network bandwidth is consumed and heavily loaded to damage as well as stop the overall communication by the genuine or authenticated users in the network.

1.4 LITERATURE REVIEW

In this section, 23 reputed journal papers are considered, and an extract of each paper is mentioned below as well as the complete summary of all the reviewed papers is described in Table 1.2.

1.4.1 EXCERPTS FROM THE EXISTING WORK AND REVIEW OF LITERATURE

The approach of a certificate-less public key is presented whereby the industrial internet of things (IIoT) can be secured [10]. In this approach, the random public key is introduced rather than the public key of the user. The proposed SCF-MCLPEKS approach is found effective and executed in less time as compared to the approach by Peng et al.'s.

The work presents the lattice-based secure cryptosystem (LSCSH) for the implementation of higher security in the smart cities-based environment [11]. The proposed approach makes use of a lightweight key exchange mechanism with the secured authentication module having multiple layers so that the security can be enriched. The Access Right Verification Mechanism is used so that the permissions can be set for the nodes in the communication scenario.

The author of this chapter proposed the CP-ABE scheme to protect the user attributes values in contradiction of AA-based on the 1-out-of-n Oblivious transfer method [12]. Attributes Bloom Filter adopted to defend the attributes types of access strategy in the cipher-text. The outcome consequences proved that the planned model is much improved in terms of efficiency as well as security.

TABLE 1.2 Summary of Review

Year	Paper Title	Objective	Technology/ Technique	Problem	Solution	Advantages	Limitations
2018 [10]	Certificateless searchable public-key encryption scheme for industrial internet of things.	To elevate the security with dynamic encryption	SCF-MCLPEKS approach	Security, integrity, authentication, and authorization	Time	Execution time reduce	Cost factor
2018 [11]	LSCSH: Lattice-based secure cryptosystem for smart healthcare in smart cities environment	Lattice oriented cryptosystem development specifically for the smart cities and medical records	Lattice-based secure cryptosystem (LSCSH)	Security, integrity, authentication, and authorization	Security	Higher degree of security	Higher cost factor
2018 [12]	Efficient and robust attribute-based encryption supporting access policy hiding in internet of things.	Fault-tolerant and robust approach for security and integrity in the IoT	CP-ABE scheme	Security, integrity, authentication, and authorization	Security, efficiency, performance	Time and cost	Complexity may be compromised
2017 [13]	Privacy-preserving and lightweight key agreement protocol for V2G in the social internet of things.	Grid-based implementation of cryptography approach	Lightweight key agreement protocol	Security, integrity, authentication, and authorization	Communication complexity, functionality, and computational cost	Higher degree of security and reduce complexity	Time factor
2017 [14]	Secure data access control with cipher-text update and computation outsourcing in fog computing for internet of things.	Security aware IoT environment development with fog computing-based implementation for higher level of security	Secure data access control outline by using fog computing on CP-ABE as well as ABS is proposed	Security, integrity, authentication, and authorization	Encryption and decryption computational overhead	Overall computational overhead	May not be generic for multiple networks

TABLE 1.2 *(Continued)*

Year	Paper Title	Objective	Technology/ Technique	Problem	Solution	Advantages	Limitations
2017 [15]	Secure signature-based authenticated key establishment scheme for future IoT applications.	Secured key and signature associated authentication approach	Signature-based authenticated key establishment arrangement	Security, integrity, authentication, and authorization	Throughput as well as end-to-end delay	Throughput as well as end-to-end delay	Higher level of cost factor
2017 [16]	Lightweight three-factor authentication and key agreement protocol for internet-integrated wireless sensor networks.	Development of multi-level and multi-factor authentication approach for security in advanced wireless networks of IoT	Proposed lightweight and secure user authentication protocol based on Robin cryptosystem	Security, integrity, authentication, and authorization	Efficiency	Higher efficiency	Complexity factor
2017 [17]	Lightweight cybersecurity schemes using elliptic curve cryptography in publish-subscribe fog computing.	Association of ECC based approach for cryptography in IoT security	Fog computing based publish-subscribe lightweight protocol using elliptic curve cryptography (ECC)	Security, integrity, authentication, and authorization	Overall security	Higher degree of security	Cumulative performance on assorted networks
2017 [18]	Elliptic curve cryptography with efficiently computable endomorphisms and its hardware implementations for the internet of things.	Integration of ECC (elliptic curve cryptography) that is a prominent approach for security and its performance in IoT	Offer trade-off and optimization between resources and performance	Security, integrity, authentication, and authorization	Security and performance	Higher degree of security and performance	Greater value of complexity

TABLE 1.2 *(Continued)*

Year	Paper Title	Objective	Technology/ Technique	Problem	Solution	Advantages	Limitations
2017 [19]	Sit: A lightweight encryption algorithm for secure internet of things.	Analysis and implementation of Secured algorithm with lightweight resources in IoT	Secure IoT (SIT) a lightweight encryption algorithm	Security, integrity, authentication, and authorization	Correlation and entropy, histogram comparison	Correlation and entropy, histogram comparison and correlation comparison	Overall performance may be compromised
2016 [20]	An efficient user authentication and key agreement scheme for heterogeneous wireless sensor network tailored for the internet of things environment.	Implementation of security-based approach that can be integrated with assorted networks of IoT with heterogeneous properties	Improved the key agreement and user authentication for heterogeneous WSN	Security, integrity, authentication, and authorization	Storage, computational	Storage, computational, and commu-nication cost	Cost factor and complexity can be optimized further using high performance approaches
2016 [21]	S3K: scalable security with symmetric keys—DTLS key establishment for the internet of things.	Development of a framework with implementation using symmetric key-based approach	Symmetric key (S3K) for security in the IoT	Security, integrity, authentication, and authorization	Time as well as energy overhead	Time as well as energy overhead, memory-overhead	Complexity factor
2016 [22]	SecIoT: a security framework for the internet of things.	Development of an outline for effective safety in IoT	Prototype security framework with a transparent security feature.	Security, integrity, authentication, and authorization	Study results of access control model	Study results of access control model and study results of risk indicator	Complexity factor

TABLE 1.2 *(Continued)*

Year	Paper Title	Objective	Technology/ Technique	Problem	Solution	Advantages	Limitations
2016 [23]	FairAccess: a new blockchain-based access control framework for the internet of things.	Development of blockchain integrated approach for secured authentication and cumulative security in internet of things	Proposed a novel outline for access control in IoT using blockchain technology	Security, integrity, authentication, and authorization	Performance and security	Better performance and increased security	Complexity factor
2016 [24]	DCapBAC: embedding authorization logic into smart things through ECC optimizations	Usage of the embedded framework for authorization and secured authentication in IoT	This model proposed IP based technology for the IoT based scenario	Security, integrity, authentication, and authorization	AVISPA and authentication	Trade-off between security and performance is better	Cost factor and complexity can be optimized further using high performance approaches
2016 [25]	A lightweight message authentication scheme for smart grid communications in power sector.	Smart grid-based framework for energy optimization and security in power segment	Hybrid Diffie-Hellman based authentication scheme	Security, integrity, authentication, and authorization	Computational cost	Communication overhead and computational cost	Cost factor and complexity can be optimized further using high performance approaches
2015 [26]	OSCAR: Object security architecture for the internet of things.	Development of a new approach for security and secured framework	Address and overcome the issue of the E2E safety approach in the IoT	Security, integrity, authentication, and authorization	Computational overhead and scalability	Computational overhead and scalability	The generic performance on assorted topologies required

TABLE 1.2 *(Continued)*

Year	Paper Title	Objective	Technology/ Technique	Problem	Solution	Advantages	Limitations
2015 [27]	Optimized ECC implementation for secure communication between heterogeneous IoT devices, sensors.	Integration of ECC based cryptography approach for security and authorization with the key management	Elliptical curve cryptography algorithm	Security, integrity, authentication, and authorization	Usage of network	Network usage	Cumulative performance on assorted networks
2015 [28]	Triathlon of lightweight block ciphers for the internet of things.	Lightweight approach for security with minimum resource consumption	Framework in the embedded platform	Security, integrity, authentication, and authorization	Evaluate the memory parameters, resources	Evaluate the RAM, footprints, and binary code size.	Cost factor and complexity can be optimized further using high performance approaches
2015 [29]	SEA: a secure and efficient authentication and authorization architecture for IoT-based healthcare using smart gateways.	Smart healthcare integrated approach for overall performance in IoT	This proposed model adopted better key-management schemes between sensor nodes as well as a smart gateway	Security, integrity, authentication, and authorization	Transmission overhead and communication overhead	Better performance with Transmission overhead and communica-tion overhead parameters	Cumulative performance on assorted networks
2015 [30]	Talos: Encrypted query processing for the internet of things.	Data encryption-based model for increasing the privacy of the network	Encryption and key management approach	Security, integrity, authentication, and authorization	Time and energy	Reduced time and energy	Cumulative performance on assorted networks

TABLE 1.2 *(Continued)*

Year	Paper Title	Objective	Technology/ Technique	Problem	Solution	Advantages	Limitations
2015 [31]	IoT-OAS: An OAuth-based authorization service architecture for secure services in IoT scenarios.	Usage of open authentication for security and effectual services in cloud and IoT based environment	An innovative architecture for providing HTTP as well as CoAP service workers with an authorization sheet.	Security, integrity, authentication, and authorization	Energy consumption	Energy consumption and memory footprints	The generic performance on assorted topologies required
2014 [32]	Lightweight collaborative key establishment scheme for the internet of things.	An effectual approach integrating the collaborative key in IoT	Lightweight collaborative key exchange scheme	Security, integrity, authentication, and authorization	Overall energy consumption	Overall energy consumption reduced	Cost factor and complexity can be optimized further using high performance approaches

This chapter addresses the security as well as privacy problems in the V2G (vehicle-to-grid) network of the internet of thing and also proposed a lightweight key agreement protocol for making networks more secure and enhance the privacy [13]. The effectiveness of the proposed model is represented by comparison with the ECC based protocol.

In this, a secured data access control outline intended for IoT in the Fog-Computing on CP-ABE as well ABS is proposed [14]. The efficiency of the planned outline that is represented by the time taken by the proposed scheme for encryption, decryption as well as signing for the user is small and constrained. The simulation results proved that the planned outline is secure in contradiction to the attacks.

The Author of this chapter proposed a secure signature-based Genuine key establishment outline for an IoT which becomes more secure and reliable [15]. The planned structure of security is tested by using Burrows Adadi Needham logic, informal safety as well as formal safety verification by means of broadly accepted automated authentication of internet safety protocol and NS2 simulator.

The work presents a lightweight and secure user authentication protocol based on Robin cryptosystem with the characteristics of the computational asymmetry [16]. The proposed model support dynamic security features. The simulation results proved that the proposed model is suitable for providing security and higher efficiency in a more balanced way.

This chapter proposed a secure, fog computing-based publish-subscribe lightweight protocol using elliptic curve cryptography (ECC) for the IoT network [17]. Basically, ECC provides shorter key length, reduce message size, and lower the resources usage. This scheme provides better scalability and less overhead such as storage and communication.

This chapter offers trade-off and optimization between resources and performance because they both are important in the IoT network [18]. In this chapter, a twisted Edward curve with an efficient endomorphism is also used. The author also described how endomorphism exploited to speedup dual scalar multiplication. 100-bit security level trade-off offers between security and performance.

Author proposed secure IoT (SIT) a lightweight encryption algorithm [19]. This is a 64-bit cipher and always required a 64-bit key to perform a task and encrypt data. The simulation outcomes proved that the planned outline offers substantial safety only in five encryption rounds.

Author projected a new outline for improving the key agreement and user authentication for heterogeneous WSN [20]. This proposed model tackles and eliminates all security attacks. The security results proved that this model provides higher security.

The work presents Symmetric Key (S3K) for security in the IoT [21]. S3K is a lightweight as well as possible to use in the resource-constrained gadgets also at a similar time, it is scalable to numerous IoT gadgets.

The author of this chapter proposed a prototype security outline with a clear security feature [22]. The core aim of this chapter is to address the security matter as well as provide a real framework.

The author of this chapter proposed a novel framework for access control in the IoT using block-chain technology [23]. This new outline leverages and consistently provide block-chain based cryptography such as bit-coin to offer stronger as well as a transparent access control tool.

This work is dependent on a capability-based access control outline [24]. This model uses IP based technology for the IoT based scenario. The trade-off between security and performance is better.

A new approach named hybrid Diffie-Hellman based verification arrangement using AES as well as RSA for the session key creation is proposed in this chapter [25]. This communication overhead of this scheme is 23% that is much low than the existing schemes.

The author projected a new technique to overcome the problem of E2E security in IoT [26]. The application and security concepts are discussed in this chapter as well as Cooja simulator is used for simulating the work.

This chapter proposed the elliptical curve cryptography algorithm for dealing with the security issues in the IoT network [27]. Basically, ECC optimization is available for secure communication.

This chapter presents the framework for benchmarking of the lightweight block cipher on a multitude of embedded platforms [28]. This platform evaluates the RAM, footprints, and binary code size.

This model architecture was developed with a focus to make a network more secure than the existing systems [29]. This proposed model adopted better key-management schemes among sensor nodes as well as a smart gateway. The outcome proved that the communication overhead is reduced by 26%.

This chapter projected a data encryption-based technique for increasing the privacy of the network and reducing the encryption time [30]. The main emphasis of this chapter was to develop a more secure and higher privacy-based network scheme.

The author of this chapter planned an innovative architecture for providing HTTP and CoAP service workers with an authorization sheet [31]. The proposed approach is able to handle multiple smart objects with limited computational power.

This chapter represents a light-weight collaborative key exchange outline for increasing the security of the IoT network [32]. The proposed approach is better in terms of energy consumption as through this approach, the energy is saved by 80% as compared to existing strategies.

1.5 OVERVIEW OF CURRENT STATE OF THE FIELD AS WELL AS THEORETICAL UNDERPINNINGS OF THE RESEARCH

Today's era is encompassed by numerous devices and gadgets that are interlinked through technologies offering high performance. This technological communication is handled under the umbrella of the IoT. IoT based communication is being used at a rapid pace in the fields of defense, highway patrolling, smart cities, smart toll collections, satellite televisions, business communications, smart offices, traffic systems of interrelated webcams for the social security [33–35]. IoT is also linked with the terms like Pervasive Computing, Ubiquitous Computing (UbiComp), or Ambient Computing to provide virtual connections among devices for making decisions as well as remote monitoring. Because of the linking of enormous devices and objects through a virtual environment, severe challenge related to security and privacy arises. But with the advent of IoT, the risks to security and privacy are demolishing to a great extent.

There are numerous attacks that can harm the IoT environment at various layers [36, 37]. The hackers can damage as well as control the IoT system by distributing malicious packets and signals with the aim of practically destroying the structure [38, 39]. These attacks are in the list of the highest priority as they can affect the overall functionality of the system:

1. **DoS Attack:** In *the DoS attack*, the availability of the network is blocked by the attacker node or malicious packet by arresting the communication channel or bandwidth. In this case, genuine users will not be able to access the network facilities. This attack is treated as the main attack that occurs on the network layer of IoT based situation [40]. These kinds of attacks become much more dangerous when it turns out to be a Distributed Denial-of-Service (DDoS) attack. In this attack, the malicious node or hacker accomplish the attack through numerous as well as diverse locations.
2. **Sybil Attack:** In the *Sybil attack,* the network layer is greatly affected. This attack helps in manipulating the identity of the source. The malicious node fabricates the original source node to pretend

like it and then manipulates the identity of the source node. In a Sybil attack, with the help of replication, the attacker node creates dissimilar nodes and compels other nodes either to move quickly or leave the network path [41]. With the help of Resource testing, which is based on the assumption that vehicles have limited resources, these attacks can be detected. Moreover, Public-key cryptography may be used to diminish Sybil attacks through the means of public keys for authentication of vehicles.

3. **Application-Level Attack:** The *application-level attack* in the IoT environment, there is interference which results in the retransmission of messages to destination thus making it insecure. For instance, high traffic lanes can be relayed as Congestion Free Lane on the internet of vehicles (IoV), thus resulting in disasters. The main concerns in IoT based network environments are security and privacy which requires secure communication without any intrusion. To enforce a high level of security, IPv6 is implemented with dynamic hybrid cryptography for generating and authenticating key. The IPv6 based approach can be implemented with fully secured algorithms [42]. With the application of IoT in various scenarios, it becomes essential to handle the IoT security aspects by the secured routing of packets to ensure secure transmission without any interruption. IoT has an IPv6 Based Protocol named, RPL, which is combined with IPv6 over Low Power WPAN and works with DODAG (Destination-Oriented Directed Acyclic Graph) that supports unidirectional also with bi-directional communication. RPL permits each node to decide whether the packets are to be sent to the root or the child nodes.

1.5.1 IDENTIFICATION OF GAPS IN RESEARCH

- There is a need to integrate and associate the high-performance approaches of security in IoT including quantum cryptography;
- Quantum cryptography integrates Heisenberg's uncertainty principle and the no-cloning theorem which are effective and can give better results in the security as well as integrity;
- Quantum key distribution is required to be connected because of its current minimum usage and giving the better-predicted results;
- Lightweight cryptography is currently used that can be improved with the use of soft computing and meta-heuristic approaches.

1.6 CRITICAL ANALYSIS

An IoT involves the growing occurrence of objects as well as elements that are referred to in this setting as things-provided along with the capacity to naturally exchange data over the system [43]. A great portion of the development in IoT communication invents from computing gadgets as well as implanted sensor frameworks utilized in modern machine-to-machine (M2M) communication, a vehicle-to-vehicle communication, home, and building robotization, and also wearable computing gadgets.

Most of the time, IoT items are sold with previously used and improper working frameworks. Apart from this, customers either do not feel the need to change the default passwords or set new passwords. To improve security, IoT gadgets that directly open on the internet should be portioned into their system and should have constraints for accessing the network [44]. The statistic that demonstrates the IoT security spending worldwide from 2014 to 2022 (in million U.S. dollars) have been shown in Figure 1.3.

Following are the key points from the study which can be worked out for security and challenges with IoT:

- IoT API security;
- IoT tokens generation;
- IoT PKI;
- IoT encryption;
- IoT authentication.

Frameworks and libraries for implementation of IoT [45, 46]:

- *OpenIoT* (URL: http://www.openiot.eu/);
- *Zetta* (URL: http://www.zettajs.org/);
- *DSA* [Distributed Services Architecture] (URL: http://www.iot-dsa.org/);
- *Node-RED* (URL: http://nodered.org/);
- *IoTivity* (URL: https://www.iotivity.org/);
- *Cooja* (URL: http://www.contiki-os.org).

1.7 CONCLUSION

IoT applications are becoming vital in day-to-day routine for instance, smart home, smart parking, healthcare, smart grid, and many more. As we all know, IoT application provides a lot of benefits to the user, but in this case, if the IoT will not be able to secure the user information and data from hackers,

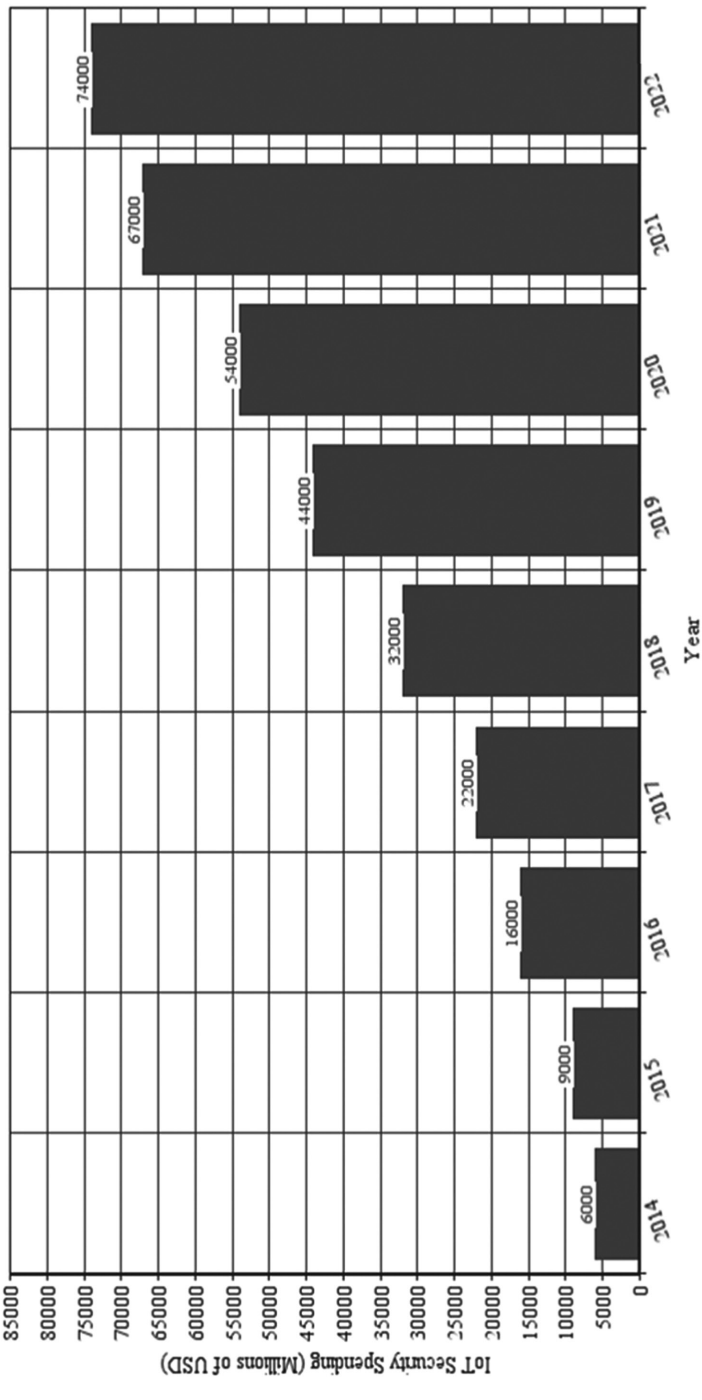

FIGURE 1.3 Internet of things cybersecurity market.

IoT will not have the future. Light-weight encryption is an area of traditional cryptographic algorithms that are relevant for resource-constrained gadgets in IoT. Using such integration, the overall escalation can be done in the IoT-based environment. This chapter covers the complete description of the security challenges linked with the IoT. Also, this chapter discusses the problems as well as the solutions faced by the domain IoT. Researchers will get a precise and clear idea for the problems that need to be addressed in the future to deal with the challenges of IoT after reading this chapter.

KEYWORDS

- **cryptography**
- **distributed denial-of-service**
- **internet of things**
- **networking attacks**
- **privacy**
- **security**

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