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IoT and IoE Driven Smart Cities

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Preface

The introduction and advancement of the IoT/IoE make our society more instrumented and intelligently interconnected. The interconnected world makes the life of the human being easier, secure, and eco-friendlier. The integration of IoT and Information Communication Technologies (ICT) for city management observes an exponential growth of urbanization and population, thus significantly increasing people's quality of life. IoE brings people, process, data, and things all together to form a well and vastly connected network. This well-connected network will enable the main concept of smart city. To have efficient IoT/IoE-enabled smart cities, as researchers we have to move from traditional approaches to provide sustainable solutions for energy-intensive, waste-generating, efficient and open sharing and utilization of information and resources, etc. Energy efficient smart cities, smart buildings, smart homes, smart grids, etc. are essential for the environment and for global sustainability, and it need to have a continuous development. This book will provide an idea about the applicability of IoT/IoE for smart cities and its design aspect related to its physical and network layer model. It will also highlight the application of cloud computing/management and soft computing tools for the sustainable development of the IoT/IoE-based application for smart cities. It also includes some research challenges and future way forward for efficiently implementing and exploring the benefits of smart city.

Chapter 1 by Minh-Sang Van Nguyen et al. provides a comprehensive review of physical layer design for smart cities. It highlights the latest communication technology trends for smart cities and proposed a backscatter communication system-based solution method for applications in smart cities. The Security and Privacy aspect of the smart city-related technologies and the related challenges is extensively discussed in Chap. 2 by Navod Neranjan Thilakarathne et al. It highlights the key issues and practical strategies related to information security in smart cities and figures out some challenges that need to be addressed in order to improve the quality of service. Multiple antenna systems play an important role in the future generation communication technologies (5G and 6G). Chapter 3 by Mayank Kothari et al. discusses the advancement in multiple antenna technologies and its importance for the successful realization of smart cities.

It also discusses the importance of the use of artificial intelligence, machine learning, and reinforcement learning to make the multi-antenna system and communication technologies more intelligent and secure. From the successful implementation of the communication system for smart cities, energy harvesting and multiple accesses protocols play an important role. In Chap. 4, Minh-Sang Van Nguyen et al. provide a solution for smart cities by proposing a NOMA for a sustainable and energy-efficient wireless network. Chapter 5 by Sushma Malik et al**.** highlights the notion of the smart city by discussing the benefits, applications, and objections of using Internet-equipped smart devices. It also reviews numerous viable and available IoT technologies and their capacities to blend into and cover distinct elements of smart cities. In Chap. 6, P. Malini et al. provide a comprehensive survey on the idea of the smart city other than their various applications, advantages, and favorable circumstances and furthermore about IOT-based sensors and its applications. Chapter 7 by Idowu Dauda Oladipo et al. provides insights into the applicability of the state of the art of deep learning (DL) and machine learning (ML) in smart cities developments. It also addresses some key issues like frameworks, convergence of information, and protection of privacy, and future research directions to develop fully data analytics for smart cities. Today cloud computing becomes an integral part of the advanced networking system. In Chap. 8, Kazeem Moses Abiodun et al. highlight the potential of the Internet of Everything (IoE) alongside advanced networking technology and cloud computing for achieving smartness in every smart city system. The main idea of this chapter is to converge IoE/IoT with cloud computing for achieving the goal of implementation of IoT towards a green climate. With each passing day, it is clear that cloud computing is emerging as an important pillar for the realization of smart cities. Chapter 9 by N. Thillaiarasu et al. addresses the privacy and the security aspect of information based on the scattered storage provided by the progressively standard schemes of multi-clouds. Addressing the same cloud storage, in Chap. 10, Krishna Keerthi Chennam et al. discuss the various mechanisms to store data and its integration with artificial intelligence, deep learning techniques for retrieval of hidden patterns in real time, and IoT health care data in smart cites. In Chap. 11, Mahfuzuar Rahman Barbhuiya et al. address the net-zero cities concerned with the use of IoT technology in smart city development. It figures out three major factors that can help make a city a net-zero smart city, namely, planning factors and use of IoT; role of citizen engagement and community participation in net-zero city; and energy and transportation and use of IoT. In a smart city, water conservation and distribution is an important aspect and is discussed in Chap. 12 by A Christy Jeba Mala et al. Addressing the same, in Chap. 13, Mahfuzuar Rahman Barbhuiya et al. propose the Internet of Things (IoT) in better water management in cities and integrating traditional knowledge with advanced technologies. In Chap. 14, Sergey Patsko et al. highlight the smart city problems and provide solutions as well as technical implementation challenges, and further elaborate on the reference architecture of an integrated IoT platform that can support smart city developments.

The editors wish to thank all the authors who have contributed to this book and sincerely thank the Springer Nature Editorial and production team for the constant support. We send our best wishes to our readers!

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About the Editors

Samarendra Nath Sur (SMIEEE-20) was born in Hooghly, West Bengal, India, in 1984. He received his B.Sc. degree in Physics (Hons.) from the University of Burdwan in 2007. He received his M.Sc. degree in Electronics Science from Jadavpur University in 2007, his M.Tech. degree in Digital Electronics and Advanced Communication from Sikkim Manipal University in 2012, and his Ph.D. degree from National Institute of Technology (NIT), Durgapur, in 2019. Since 2008, he has been associated with the Sikkim Manipal Institute of Technology, India, where he is currently an assistant professor in the Department of Electronics & Communication Engineering. His current research interests include Broadband Wireless Communication (MIMO and Spread Spectrum Technology), Advanced Digital Signal Processing, and Remote Sensing, Radar Image/Signal Processing (Soft Computing). He is a member of the Institute of Electrical and Electronics Engineers (IEEE), IEEE-IoT, IEEE Signal Processing Society, Institution of Engineers (India) (IEI), and International Association of Engineers (IAENG). He has published more than 63 SCI/Scopus indexed international journal and conference papers. He is the recipient of the University Medal and Dr. S.C. Mukherjee Memorial Gold Centered Silver Medal from Jadavpur University in 2007. He is also a regular reviewer of reputed journals published by, namely, IEEE, Springer, Elsevier, Taylor and Francis, IET, Wiley, etc. He is currently editing several books with Springer Nature, Elsevier, and Routledge & CRC Press. He also serves as a guest editor for topical collection/special issues of journals from publishers like Springer Nature and Hindawi.

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Dr. Balas participated in many international conferences as Organizer, Honorary Chair, Session Chair, member in Steering, Advisory or International Program Committees and Keynote Speaker.

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Chapter 1
A Comprehensive Review on Physical Layer Design for Smart Cities

Minh-Sang Van Nguyen, Samarendra Nath Sur, and Dinh-Thuan Do

1.1 Introduction

5G communications become popular in the world; beyond 5G, 6G communications have attracted much attention from both the industry and the academia. In the perspective of applications for smart cities, high speed and massive connections are the main requirements. In particular, we study the main approaches of physical layer design that benefits to 5G and 6G wireless networks. The other main requirements need be addressed such as higher transmission rate, spectrum efficiency, wider frequency band, massive connections, reduced delay, larger coverage, and secure transmissions. By introducing advances in emerging techniques, critical technologies, challenges, and performance analysis, this survey presents an insightful understanding of 5G and 6G wireless communications. Therefore, the transmission techniques at physical layer are the necessary demand to deploy applications for smart cities. Table 1.1 shows abbreviations used in the whole book chapter.

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Table 1.1 List abbreviations

Abbreviation	Description
5G	Since fifth generation
6G	Sixth generation
AB	Ambient backscatter
ABEP	Average bit error probability
AmBC	Ambient backscatter communication
AN	Artificial noise
AF	Amplify and forward
BackCom	Backscatter communication
BDs	Backscatter devices
BER	Bit error rate
CBN	Cognitive backscatter network
co-NOMA	Cooperative NOMA
CRN	Cognitive radio network
DF	Decode and forward
EE	Energy efficiency
EH	Energy harvesting
IM	Index modulation
IoT	Internet of things
LIS	Large intelligent surface
mmWave	Millimeter wave
MIMO	Multi-input multi-output
NOMA	Non-orthogonal multiple access
NOMAD	NOMA using directional modulation
NJS-UNT	Non-jammer selection-aided uplink NOMA transmission
NU	Near-end user
OFDM	Orthogonal frequency division multiplexing
OJS-UNT	Optimal jammer selection-aided uplink NOMA transmission
OP	Outage probability
PBIT	Passive beamforming and information transfer
PS	Power splitting
QoS	Quality of service
RF	Radio frequency
RHI	Residual hardware impairment
RIS	Reconfigurable intelligent surface
RIS-SM	RIS spatial modulation
RIS-SSK	RIS space shift keying
RJS-UNT	Random jammer selection-aided uplink NOMA transmission
RSMA	Rate-splitting multiple access
SE	Spectrum efficiency
SER	Symbol error probability

(continued)

Table 1.1 (continued)

Abbreviation	Description
SIC	Successive interference cancellation
SINR	Signal-to-interference-plus-noise ratio
SNR	Signal-to-noise ratio
SOP	Secrecy outage probability
SR	Symbiotic radio
SSR	Secrecy sum rate
SU	Strong user
TDMA	Time division multiple access
TS	Time switching
WU	Weak user
ZFBF	Zero-forcing beamformation

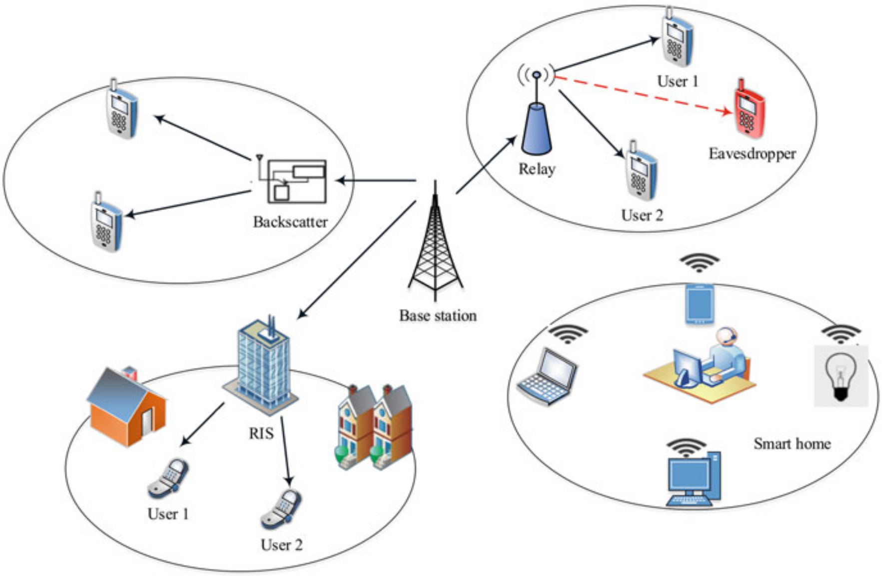


Fig. 1.1 Typical RIS, backscatter, physical layer security applications in wireless network

More specifically, we focus on main transmission techniques to implement applications for smart cities. In particular, this book chapter aims to introduce key transmission techniques such as AmBC, backscatter communication, and RIS, and these approaches need to be further facilitated ability of physical layer security, shown in Fig. 1.1.

1.2 Backscatter Communication Systems

One of the major constraints for the massive deployment of IoT-enabled devices is power consumption and emerged as a significant challenge for battery-constrained wireless devices. BackCom is the way forward to harvest energy and emerged as one of the possible solutions to fulfill the goal of the future generation communication system. In Figs. 1.2 and 1.3, AmBC system has the IoT devices that are known as BDs. The main idea, here, is to exploit the RF signal of the primary system to transfer the messages by utilizing backscatter modulation without the involvement of any active RF components. In other words, the passive backscatter transmission shares the same spectrum and also exploits the same RF source as for the active primary transmission.

Lots of efforts have been imparted toward the study of cooperative ambient backscatter systems. And based on the features of the AmBC, the relationships between the primary and backscatter transmissions can be categorized as commensal, parasitic, and competitive. Systematic approaches have been taken to explore

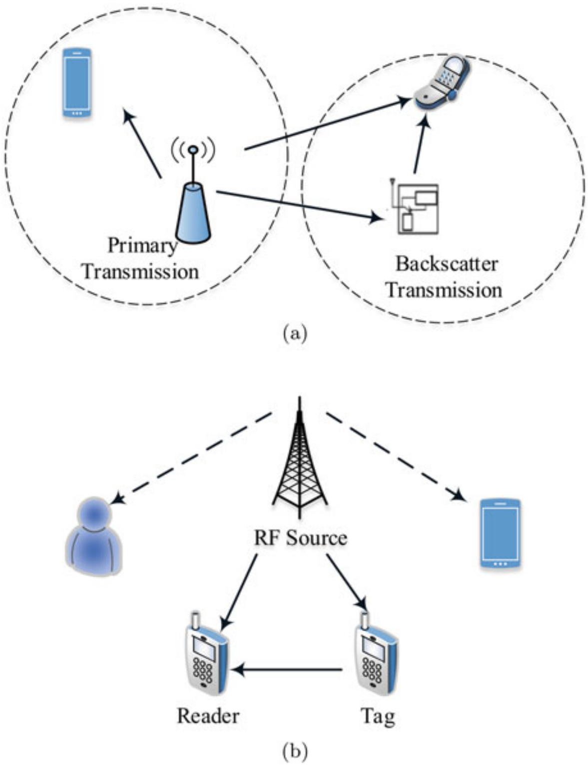


Fig. 1.2 Typical applications of backscatter in wireless network with (**a**) a symbiotic radio paradigm for passive IoT; (**b**) an ambient backscatter communication system

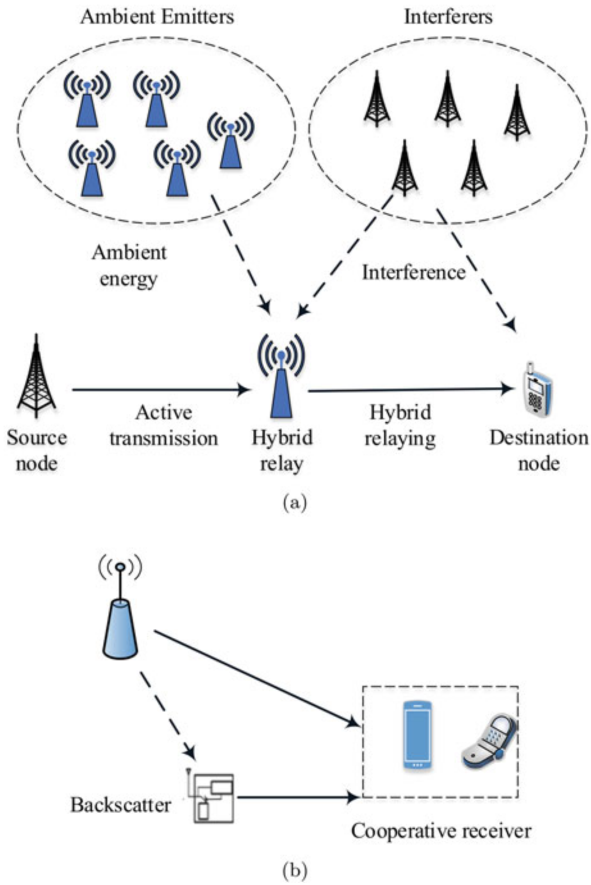


Fig. 1.3 Typical applications of backscatter in wireless network with (**a**) a dual-hop relaying system in an α-GPP field of ambient emitters and interferers; (**b**) the proposed cognitive backscatter network

the nature of those schemes. Particularly, to provide effective transmission, the outage probability is computed at the backscatter system. Each of these schemes is characterized based on the mechanisms for cooperative spectrum sharing and also based on the parameters choice for the primary and backscatter communications.

As in [1, 2], they studied the BackCom scheme that is suitable to transmit signals for applications in smart cities. As main results, the same outage performance in comparison to others under the condition of high transmit SNR can be obtained [1, 2]. Similarly, to characterize those schemes, the authors, in [3–5], have studied the achievable rates for both primary and backscatter transmissions under fading conditions and suggested optimal power allocation frameworks for each transmission scheme. It is the well-established fact that RF signals can be utilized for both information transmission and energy harvesting. RF-based energy harvesting can be integrated with the existing communication technologies to improve the QoS but at the same time maintain the rate–energy tradeoff. That motivates the researchers to have a hybrid strategy by combining wireless-powered communication and AmBC.

The proposed strategy not only improves the data transfer performance but also enhances its applicability. The proposed scheme is also a perfect candidate for energy harvesting, and the hybrid relay can perform ambient backscattering [6]. Basically, the RF-based energy-harvesting relaying network improves the overall diversity gain and extends the network coverage along with additional energy for data transmission. Extending the backscatter-enabled relay-network-related works, the authors in [7] have proposed AmBC-assisted DF cognitive relay network to improve the energy-harvesting capabilities. Here, the authors have demonstrated that the proposed ambient backscatter-assisted network is more energy efficient and improves the overall throughput performance of the network. In [8, 9], the authors have analyzed the outage probability of the AmBC system along with the effective channel distribution in order to have a better understanding.

Here, AmBC enables RF-powered backscatter devices to modulate the information bits over the ambient RF carriers, and this technology has emerged as a promising solution to achieve the goal of a green communications society. In [10], the authors have analyzed the AmBC system by exploiting the ambient OFDM-modulated signals. The goal of this chapter is to explore the error performance of the AmBC system under higher modulation and also provide an intuitive analysis of error probability in the case of the M-ary modulation. Extending further, researchers also engage themselves to come up with a suitable transceiver design. As in [11, 12], the authors have come up with a model AmBC system that is proposed from the perceptive of spread-spectrum communication to improve the system BER performance, operating range, and the data rate of the system.

With the growing demand for IoT-enabled devices, the role of the green communication system becomes more significant, and here, the backscatter communication system can play a major role. Extending the support toward the IoT, the researchers are proposing a CBN for efficient spectrum sharing for IoT. The goal of the CBN is to maximize the data rate of the IoT transmission subject by exploiting the joint optimization of the time sharing and power allocation. As in [13], the authors have demonstrated the potential of CBN and established its supremacy over the conventional TDMA scheme. Addressing the issue of the connectivity between ultra-low-power devices in an AmBC-enabled IoT network, the authors in [14, 15] have proposed new receiver architectures based on the TS and PS mechanism. The proposed architectures not only aim to enable energy harvesting and ambient backscattering at the AB transmitter but also achieve near-optimal outage capacities. Further extending the support toward the IoT application and data hungry applications, researchers are proposing hybrid architecture by combining multi-antenna system along with the ambient backscatter communication system. The authors in [16] have proved the fact that the hybrid system can improve the ergodic capacity of the system significantly.

1.3 RIS

RISs are emerging as a promising solution to enhance the performance of future generation wireless networks in terms of SE and EE, shown in Figs. 1.4 and 1.5. The main idea of RISs is to control the propagation path and turn it into a favorable condition. Researchers are trying to integrate RISs with the existing technology to enhance system performance. As in [17–19], the authors have proposed to combine power-domain NOMA with RISs to enhance the system performance. It demonstrated that the intercluster interference can be eliminated by exploiting a large number of RIS elements [20]. In [21], the authors have exploited the potential of the RISs to enhance the performance of backscatter communication by integrating it with a RIS. It shows that with a proper and optimized number of reflectors the channel gain of the backscatter link can be made stronger than that of the direct one.

The advancement of the reconfigurable surface encourages researchers to engage in developing hybrid architecture. The authors in [22] proposed a joint PBIT technique to enhance the system performance. It also shows that with the spatial modulation of the LIS and optimized passive beamforming, the proposed PBIT improves the system performance significantly and outperforms the conventional system without LIS. In RIS, optimization of the phase plays an important role

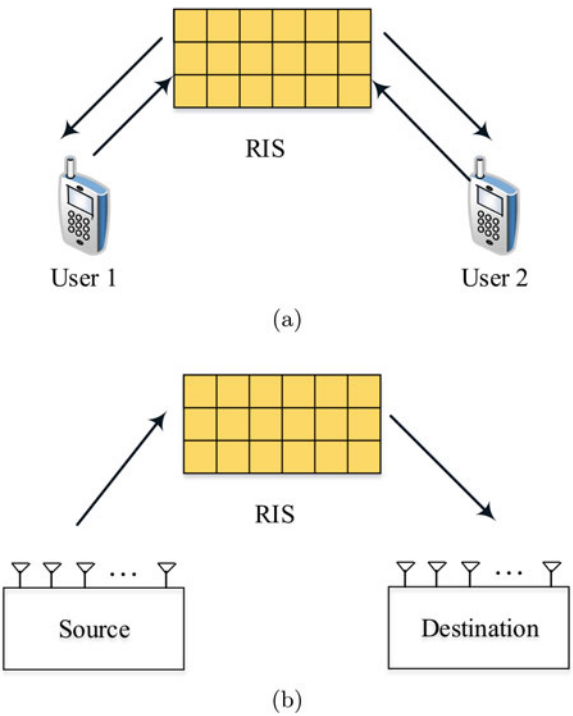


Fig. 1.4 Typical RIS applications in wireless network with (**a**). Two transmission schemes for two-way communications. (**b**) RIS-aided MIMO systems

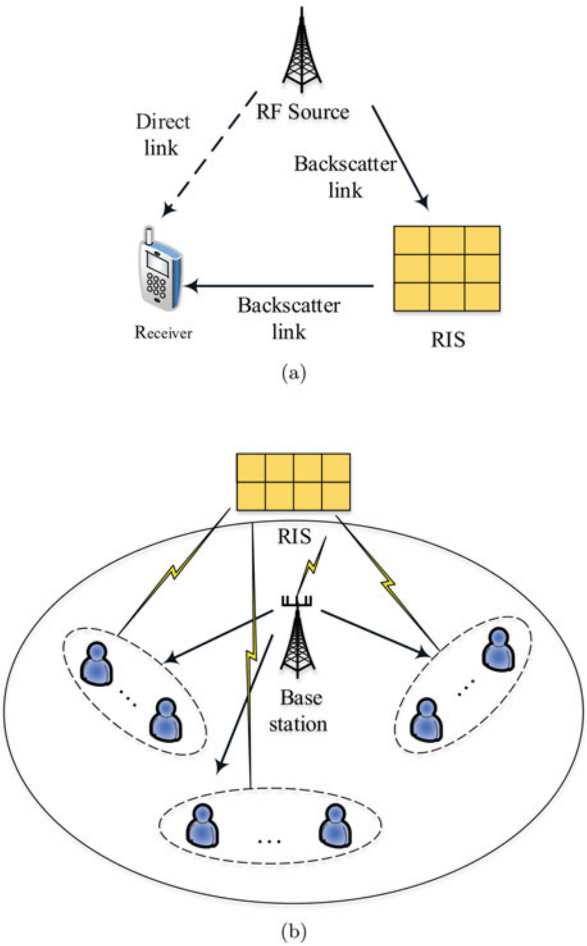


Fig. 1.5 Typical RIS applications in wireless network with (**a**). Integrated RIS and backscatter technology. (**b**) The RIS-based downlink multi-user communication system

as it configures the channel environment. The authors in [23] show that with the proper choice of phase shifts of a RIS-assisted MIMO system, the ABEP of the system improves significantly. Similarly, in [24, 25], the authors have exploited the RIS-assisted multi-antenna system for a downlink multi-user system. It shows that RIS-assisted system can improve the sum-rate performance of the system by utilizing a reasonable size of RIS and in addition to a small number of discrete phase shifts.

Further extending to the work related to the IM, the authors in [26] proposed RIS-SSK and RIS-SM schemes for the RIS-assisted communication system. It also demonstrated that RIS with IM improves the data rate significantly with considerably low error. The concept of RIS-SSK is further extended and studied in [28]. In [28, 29], the authors established the fact that the RIS-based SSK system can able to provide a highly reliable transmission system with high energy efficiency but in addition with the considerable increase in receiver complexity. The proposed scheme has the potential to fulfill the goal of the future generation of wireless communication systems and can be considered as the potential solution beyond MIMO. Advantages of the RIS open up lots of possibilities and researchers are continuously exploring new ways to improve the communication system performance. In [27], the authors investigate RIS-aided two-way communication link between two users. And the authors have a proposed greedy-iterative method to achieve higher performance with lower complex algorithms. Similarly, in [30, 31], the authors have utilized RIS-based communication system to a point-to-point multi-data-stream MIMO wireless communications. It shows that the optimized reflection coefficients and precoder can improve the system performance in terms of SER in comparison to a full-duplex AF relay system.

1.4 Physical Layer Security

Physical layer security is an important aspect of future generation communication systems, shown in Figs. 1.6 and 1.7. Particularly, in the case of massive deployment of IoT devices and their application for smart cities, health care, it becomes a much more important factor to discuss.

From the perspective of the realization of a smart city, 5G is going to play an important role, and mmWave communication and NOMA are considered to be the key ingredients for the development of 5G networks. Lots of efforts are imparted to discuss the security aspect of NOMA in 5G networks. In the case of a 5G NOMA system, the authors in [32, 33] discussed the physical layer design aspect considering a stronger NU internal eavesdropper. To get insight into the design aspect, the authors have analyzed the proposed system performance considering the two-user case and a multi-user case in terms of secrecy rate. Extending further, the authors in [34–36] have analyzed the physical layer security of mmWave NOMA in terms of SOP. To be more practical, the proposed framework address the security issue for mmWave channels with a limited scattering environment along with imperfect SIC at receivers. It successfully demonstrated the utility of the proposed framework by providing the analytical expression for the optimal radius of network coverage ranges and transmit power to minimize the SOP of the user pair. But in the MU scenario, it is the weak users who suffer most in a conventional network and the concept of NOMA drastically changes the scenario. The work in [37, 38] addressed and analyzed the physical layer security of the data from the WU against interception by the SU in NOMA systems. It proposes a new framework NOMAD to improve the secrecy rate performance. It also demonstrated that the proposed NOMAD performs better than orthogonal multiple access, such as a zero-forcing beamformer, and achieves sufficient gain in spectral efficiency and BER performances.

In [39], the authors investigated the security performance of RJS-UNT and OJS-UNT schemes in comparison to NJS-UNT scheme. It demonstrated that the

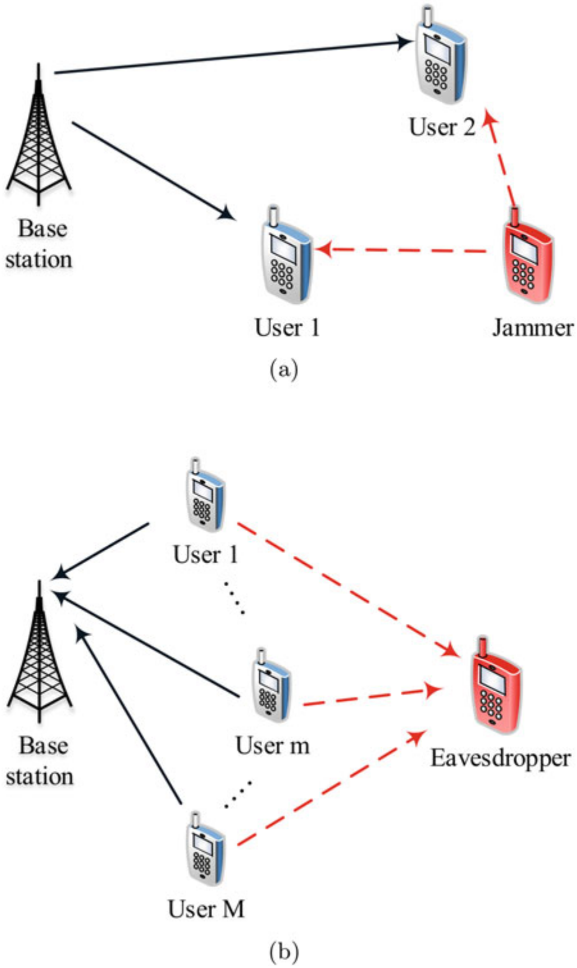
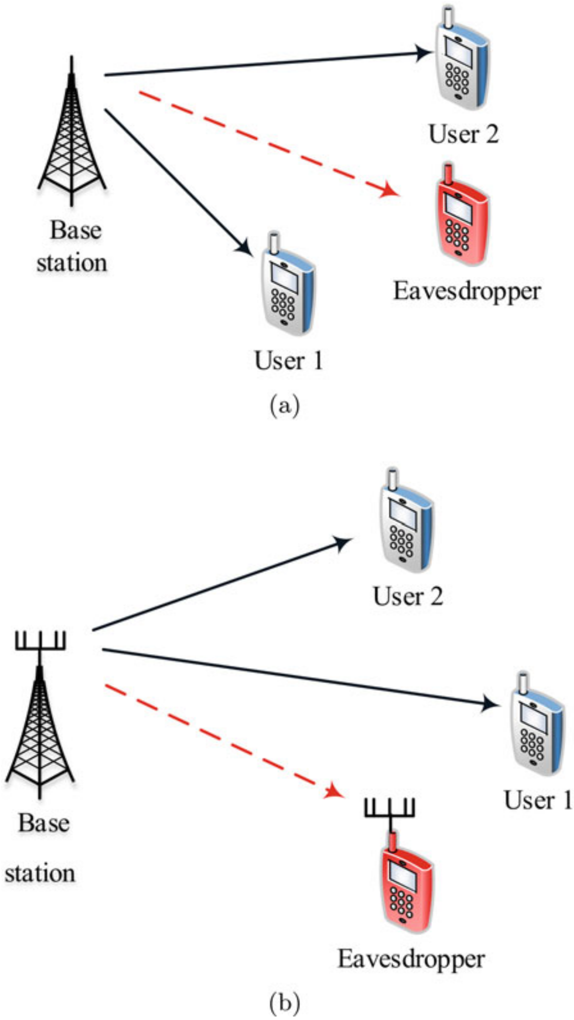


Fig. 1.6 Typical physical layer security applications with relay link in wireless network with (**a**) NOMA model with jamming; (**b**) security enhancement of uplink NOMA systems

proposed scheme is advantageous in terms of security improvement. There are lots of works related to NOMA and its coexistence with AF and DF protocols. In [40], the authors analyzed the secrecy performance of the NOMA systems and come out with the conclusion that the secrecy performance is independent of the channel conditions between the relay and the WUs.

CRN and NOMA play crucial roles in the 5G communication systems. The security performance of a CRN can be increased, and its reliability and security performance have been thoroughly investigated in [41–44]. The proposed co-NOMA improves the security performance in comparison to non-cooperative NOMA and achieves a performance tradeoff between the security and reliability of the network. The security of the CRN-NOMA system can be further improved by utilizing suitable beamformation techniques. In [45], the authors analyzed the secrecy rate performance of the MIMO-NOMA-based CRNs with ZFBF-based transmission.

Fig. 1.7 Typical physical layer security applications with direct link in wireless network: (**a**) traditional NOMA model with an eavesdropper; (**b**) illustration of a downlink MIMO NOMA system



The proposed scheme is proven to be beneficial for maximizing the total secrecy rate. Extending further, the study in [46] proposed a novel beamforming design to improve the physical layer security of a NOMA system with the help of AN. With the help of the optimal power allocation, the proposed scheme maximizes the SSR. The recent work in [47–50] provided survey of the security issues, applications, techniques, and challenges corresponding to the wireless networks for EH technologies. In the context of EH wireless networks, emerging technologies like NOMA and RSMA schemes, and RIS play an important role. Similarly, in [51], the authors have exploited AN to improve the security of the downlink legitimate communications link corresponding to non-cooperative NOMA nodes.

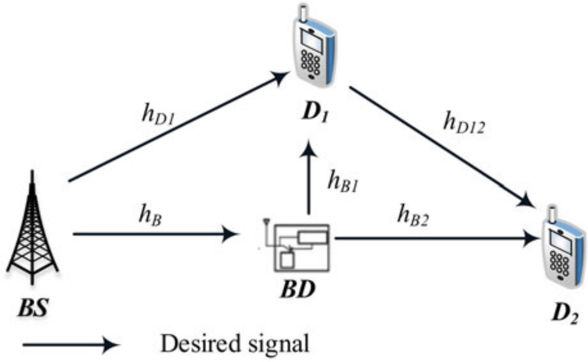


Fig. 1.8 Typical backscatter applications in wireless network

The proposed physical layer security scheme improves and ensures security while transferring energy and meeting outage probability constraints.

1.5 A Case Study of Backscatter System

In Fig. 1.8, a downlink from the base station to two destinations is considered. In this case, the base station needs assistance of backscatter to communicate with destinations. A flat slow Rayleigh fading is adopted for all channels, i.e., the links $BS \to D_1$, $BS \to BD$, $D_1 \to D_2$, $BD \to D_1$, and $BD \to D_2$ are denoted as h_{D1}, h_B, h_{D12}, h_{B1}, and h_{B2}, respectively. The channel gains are determined as $h_{D1} \sim CN(0, \lambda_{d1})$, $h_B \sim CN(0, \lambda_b)$, $h_{D12} \sim CN(0, \lambda_{d12})$, $h_{B1} \sim CN(0, \lambda_{b1})$, and $h_{B2} \sim CN(0, \lambda_{b2})$, respectively [52].

As a main role of a backscatter, the base station's signal is processed at user D_1. The signal in this case is $q(t)$, and we assume that $\mathrm{E}\left[|q(t)|^2\right] = 1$.

In the context of backscatter communication, D_1 receives two components related to two specific links. Those are the direct link signal from the base station to user D_1, and the backscatter BD is able to get signal from the backscatter link.

We can determine the received signals at D_1 as [52, 53]

$$y_{b-d1} = h_{D1}\left(\sqrt{\partial_1 P}x_1 + \sqrt{\partial_2 P}x_2 + \eta_{b,d1}\right) + \psi h_B h_{B1}\sqrt{P}x_1 q(t) + \sigma_1, \tag{1.1}$$

where x_i, $(i = 1, 2)$ are the signals dedicated to D_i, the base station transmit power level as P, power allocation factors are ∂_i with $0 < \partial_i < 1$, and $\eta_{b,d1} \sim CN\left(0, k_{b,d1}^2 P\right)$ is the residual hardware impairment (RHI) that is distortion noise of the link from the base station to D_1.

To characterize RHI levels, $k_{b,d1} = \sqrt{k_b^2 + k_{d1}^2}$. In this case, we denote k_b and k_{d1} as the levels of hardware impairments in the base station and D_1, respectively [54]. The complex reflection coefficient is ψ related to normalize signal $q(t)$, the complex Gaussian noise at D_1 is σ_1, and its distribution is $\sigma_1 \sim CN(0, N_0)$.

To conduct NOMA, D_1 needs to detect signal x_2 and then decodes x_1 and $q(t)$ by enabling SIC technique. We can compute SINR to detect x_2 as

$$\gamma_{d1\leftarrow 2} = \frac{\partial_2 \mu |h_{D1}|^2}{\partial_1 \mu |h_{D1}|^2 + k_{b,d1}^2 \mu |h_{D1}|^2 + \mu |\psi|^2 |h_B|^2 |h_{B1}|^2 + 1}, \tag{1.2}$$

where $\mu = \frac{P}{N_0}$ is transmit signal-to-noise ratio (SNR) at the base station.

By assuming that x_2 is able to be detected, y_{b-d1} and then x_1 is also detected, we can obtain SINR as

$$\gamma_{d1} = \frac{\partial_1 \mu |h_{D1}|^2}{k_{b,d1}^2 \mu |h_{D1}|^2 + \mu |\psi|^2 |h_B|^2 |h_{B1}|^2 + 1}. \tag{1.3}$$

In case of successful detection of x_1, the backscatter device sends to user D_1 a signal $q(t)$, and SNR can be obtained at user D_1 corresponding to signal $q(t)$ as

$$\gamma_q = \frac{\mu |\psi|^2 |h_B|^2 |h_{B1}|^2}{k_{b,d1}^2 \mu |h_{D1}|^2 + 1}. \tag{1.4}$$

Similarly, user D_2 can receive signal as [52, 54]

$$y_{d1-d2} = h_{D2} \left(\sqrt{\partial_2 P} x_2 + \eta_{d1,d2} \right) + \psi h_B h_{B2} x_2 q(t) + \sigma_2, \tag{1.5}$$

where σ_2 represents the complex Gaussian noise term at user D_2, i.e., $\sigma_2 \sim CN(0, N_0)$. Regarding RHI, $\eta_{d1,d2} \sim CN\left(0, k_{d1,d2}^2 P\right)$ is the RHI related to link $D_1 \to D_2$.

It is worth noting that the levels of hardware impairments in D_2 [54] are represented as $k_{d1,d2} = \sqrt{k_{d1}^2 + k_{d2}^2}$, k_{d2} as the levels of hardware impairments in D_2.

Interestingly, user D_2 wants to detect only x_2 directly and the corresponding SINR is computed by

$$\gamma_{d2} = \frac{\partial_2 \mu |h_{D2}|^2}{k_{d1,d2}^2 \mu |h_{D2}|^2 + \mu |\psi|^2 |h_B|^2 |h_{B2}|^2 + 1}. \tag{1.6}$$

1.5.1 Outage Probability Analysis

1.5.2 OP of D_1

For a SR circumstance, x_1 is not detected at D_1 successfully, and it leads to the outage event. In fact, the outage probability with RHI awareness at D_1 and such metric is given by [52, 53]

$$\begin{aligned} OP_{d1} &= \Pr\left(\gamma_{d1} < \gamma_{th,d1}\right) \\ &= 1 - \Pr\left(\gamma_{d1} \geq \gamma_{th,d1}\right). \end{aligned} \tag{1.7}$$

To evaluate system performance, the outage event is expressed at D_1 as

$$\begin{aligned} OP_{d1} = 1 + \frac{\left(\partial_1 - \gamma_{th,d1} k_{b,d1}^2\right)\lambda_{d1}}{\gamma_{th,d1}|\psi|^2\lambda_b\lambda_{b1}} \exp\left(\frac{\left(\partial_1 - \gamma_{th,d1} k_{b,d1}^2\right)\lambda_{d1}}{\gamma_{th,d1}|\psi|^2\lambda_b\lambda_{b1}}\right. \\ \left. - \frac{\gamma_{th,d1}}{\left(\partial_1 - \gamma_{th,d1} k_{b,d1}^2\right)\mu\lambda_{d1}}\right) \mathrm{Ei}\left(-\frac{\left(\partial_1 - \gamma_{th,d1} k_{b,d1}^2\right)\lambda_{d1}}{\gamma_{th,d1}|\psi|^2\lambda_b\lambda_{b1}}\right), \end{aligned} \tag{1.8}$$

where $\gamma_{th,d1} = 2^{2R_{d1}} - 1$, R_{d1} is the target rate for D_1.

1.5.3 OP of BD

If signal x_1 or $q(t)$ is not detected successfully at user D_1, the backscatter devices exhibit an outage event and such outage probability at backscatter is formulated by [52, 53]

$$\begin{aligned} OP_b &= 1 - \Pr\left(\gamma_{d1} \geq \gamma_{th,d1}, \gamma_q \geq \gamma_{th,b}\right) \\ &= 1 - \Pr\left(\gamma_{d1} \geq \gamma_{th,d1}\right)\Pr\left(\gamma_q \geq \gamma_{th,b}\right). \end{aligned} \tag{1.9}$$

At backscatter, we achieve an outage probability as

$$\begin{aligned} OP_b = 1 + \tfrac{\left(\partial_1 - \gamma_{th,d1} k_{b,d1}^2\right)\lambda_{d1}}{\gamma_{th,d1}|\psi|^2\lambda_b\lambda_{b1}} \exp\left(\tfrac{\left(\partial_1 - \gamma_{th,d1} k_{b,d1}^2\right)\lambda_{d1}}{\gamma_{th,d1}|\psi|^2\lambda_b\lambda_{b1}} - \tfrac{\gamma_{th,d1}}{\left(\partial_1 - \gamma_{th,d1} k_{b,d1}^2\right)\mu\lambda_{d1}}\right) \\ \times \mathrm{Ei}\left(-\tfrac{\left(\partial_1 - \gamma_{th,d1} k_{b,d1}^2\right)\lambda_{d1}}{\gamma_{th,d1}|\psi|^2\lambda_b\lambda_{b1}}\right) \tfrac{1}{\lambda_{b1}} \int_0^\infty \tfrac{\mu|\psi|^2\lambda_b y}{\gamma_{th,b} k_{b,d1}^2 \mu\lambda_{d1} + \mu|\psi|^2\lambda_b y} \\ \times \exp\left(-\tfrac{\gamma_{th,b}}{\mu|\psi|^2\lambda_b y} - \tfrac{y}{\lambda_{b1}}\right) dy, \end{aligned} \tag{1.10}$$

where $\gamma_{th,b} = 2^{2R_b} - 1$, R_b is the target rate for BD.

1.5.4 OP of D_2

If x_2 cannot be detected successfully at D_2, D_2 exhibits an outage event as [52, 53]

$$\begin{aligned} OP_{d2} &= \Pr\left(\gamma_{d2} < \gamma_{th,d2}\right) \\ &= 1 - \Pr\left(\gamma_{d2} \geq \gamma_{th,d2}\right). \end{aligned} \tag{1.11}$$

At D_2, the outage probability is expressed as

$$OP_{d2} = 1 + \frac{\left(\partial_2 - \gamma_{th,d2}k_{d1,d2}^2\right)\lambda_{d12}}{\gamma_{th,d2}|\psi|^2\lambda_b\lambda_{b2}} \exp\left(\frac{\left(\partial_2 - \gamma_{th,d2}k_{d1,d2}^2\right)\lambda_{d12}}{\gamma_{th,d2}|\psi|^2\lambda_b\lambda_{b2}} - \frac{\gamma_{th,d2}}{\left(\partial_2 - \gamma_{th,d2}k_{d1,d2}^2\right)\mu\lambda_{d12}}\right) \mathrm{Ei}\left(-\frac{\left(\partial_2 - \gamma_{th,d2}k_{d1,d2}^2\right)\lambda_{d12}}{\gamma_{th,d2}|\psi|^2\lambda_b\lambda_{b2}}\right), \tag{1.12}$$

where the target rate R_{d2} for D_2 is $\gamma_{th,d2} = 2^{2R_{d2}} - 1$.

1.5.5 Numerical Results

To verify our analytical results, we conduct Monte Carlo simulations with 10^6 iterations to compare with exact expressions. In these figures, we evaluate outage behavior of devices in the backscatter system.

In Fig. 1.9, we can see the outage probabilities of two destinations and backscatter device versus the transmit SNR at the base station. When we increase the SNR,

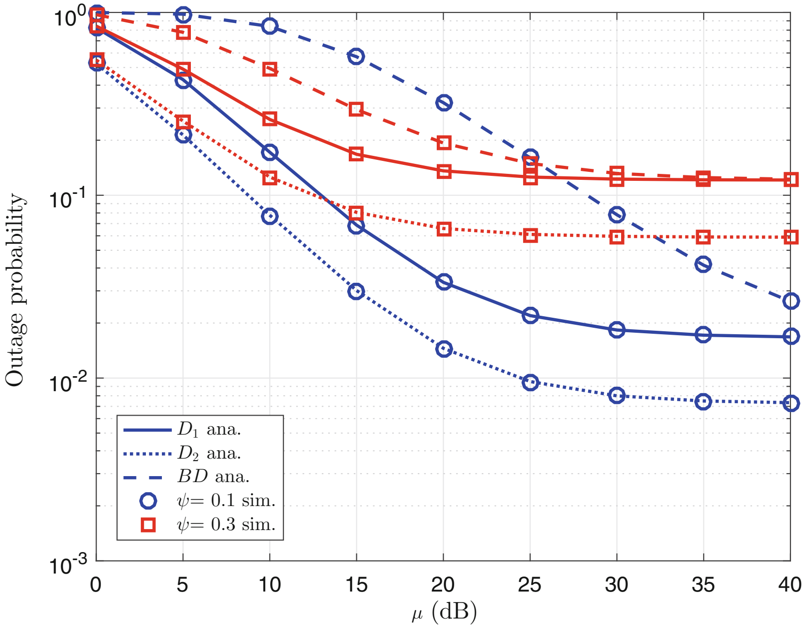


Fig. 1.9 OP for D_1, D_2, and BD versus μ as changing ψ with $\partial_1 = 0.3$, $R_{d1} = R_{d2} = 0.3$ (bps/Hz), $R_b = 0.1$ (bps/Hz), $k_b = k_{d1} = k_{d2} = 0.001$, $\lambda_{d1} = \lambda_{d2} = \lambda_b = \lambda_{b1} = \lambda_{b2} = 1$

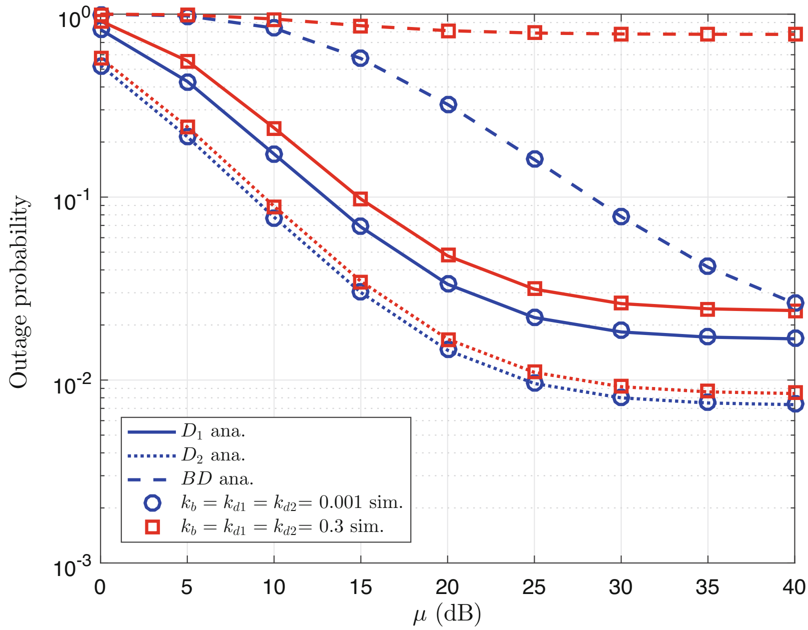


Fig. 1.10 OP for D_1, D_2, and BD versus μ as changing $k_b = k_{d1} = k_{d2}$ with $\partial_1 = 0.3$, $R_{d1} = R_{d2} = 0.3$ (bps/Hz), $R_b = 0.1$ (bps/Hz), $\psi = 0.1$, $\lambda_{d1} = \lambda_{d2} = \lambda_b = \lambda_{b1} = \lambda_{b2} = 1$

the significant improvement of outage probability can be observed. Two users D_1, D_2 show difference in terms of outage probability due to different power allocation factors ∂_i.

The impact of hardware impairment on the outage performance can be reported in Fig. 1.10. $k_b = k_{d1} = k_{d2} = 0.3$ leads to the backscatter device meets outage event.

1.6 Conclusion

This book chapter has considered an interesting survey on several transmission techniques along with the design and analytical results that can be applied to wireless communication networks. We provided main results achieved in recent studies to realize the vision of 5G and 6G wireless systems. Then, we have focused on its applications in backscatter communication system and calculated closed-form expressions of outage probability for typical users in that system. We indicated different performances among devices that can benefit from their advances. A case study of backscatter wireless networks under hardware impairment is detailed considered. We examine some numerical simulation to demonstrate the outage probability versus transmit SNR at base station. We further consider the impact of hardware impairments on outage performance. This survey covers a broad set of research topics that range from its physical characterization to research problems in performance analysis, mainly focusing on possible transmissions for smart cities. The current literature has identified basic problem models and solution methods for applications in smart cities.

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Chapter 2
An Overview of Security and Privacy in Smart Cities

Navod Neranjan Thilakarathne and W. D. Madhuka Priyashan

2.1 Introduction

Recent estimations indicate that five billion people worldwide, that is, almost 60% of the world's population, would live in crowded urban areas by 2030. With this rapid urbanization economies of countries would be challenged, public safety would be challenged, energy consumption would be increased, healthcare resources might not be adequate, education might require new innovative approaches, and the environment would also be challenged. Thus this continuous increase in urban areas has led to the need for advanced management approaches [1], which use various ICT-powered technologies for smartening the pertained ecosystem of cities which had led to the emergence of modern smart cities [1–12]. With rapid population growth and boost in the field of ICT [1, 3], smart cities have become an emerging phenomenon, which provides new economic and social opportunities for people living in such cities.

Rapid urbanization creates a lot of confusion when it comes to the management of cities, due to the increasingly rising demands of people in urban areas. Also, this unplanned and extremely rapid urban development puts an extreme strain on the climate, resources, environment, and even living conditions. As a result, these challenges are delaying the sustainable growth of urban cities. In order to address and solve all these challenges, the smart city concept can be widely used for improving governance and service delivery, providing easy access to public services,

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and facilitating affordable housing, quality healthcare, and education in urban areas [1–3, 10–15]. While these cities get bigger, they do not necessarily get better. A modern idea of a smart city was born with the goal of providing people with a better place to live. The key goal of these smart cities is to tackle many local issues, like local economies and infrastructure, to ensure the quality of life in the city [5].

Even though this smart city concept is still an evolving concept, it leverages numerous promising techniques such as IoT, big data analysis, and cyber-physical systems (CPS) for providing convenient lives for citizens. Basically, smart cities are able to track and integrate the conditions and status of all their essential infrastructure, including subways, highways, bridges, buildings, railways, airports, parking places, public places, water, and electricity, to optimize the city resources, to schedule maintenance activities, and to monitor all aspects of the city infrastructure [14]. In addition, it enables these massive systems and structures to monitor their own problems and carry out self-repairs whenever needed.

This futuristic smart city is made up of vast underlying IoT infrastructure to interconnect any object in the city and features pervasive sensing, heterogeneous networks, and smart information processing and control systems, and it enables to track the physical world in real time and provide people with smart services in terms of healthcare, education, entertainment, surveillance, agriculture, transport, and so on [2, 15–21]. This IoT represents a worldwide network of interconnected objects which are uniquely addressable and have the ability to exchange information over the World Wide Web forming a massive communication network. In a smart city, the advantages of IoT technologies are immense. As of now, new integrated systems for monitoring, control, and automation are transforming the infrastructure and services of smart cities. Most of the governments and private organizations such as IBM and Cisco are designing and implementing innovative solutions to enhance the management of city operations in many fields, including e-governance, transport, electricity, sustainability, and so on [21–37], thanks to this underlying ICT and IoT-powered technologies [2, 5]. Although this notion of a smart city is still novel, there are many examples of cities that have embraced it for the time being. The City of Amsterdam, for example [5], has identified four areas (e.g.: sustainable living, working, mobility, and public space) around the definition of sustainability in which smart projects are carried out with the goal of improving the city and transforming it into a real smart city in the near future [2]. Dubai, Rio de Janeiro, New York, Stockholm, London, Tokyo, Copenhagen, Vienna, Toronto, Paris, Singapore, Hong Kong, and Barcelona [5, 16] are some other examples of cities operating along the "smart" axis [38].

The smart city is all about having a tight cooperation between public and private sector organizations and government institutes to implement and deploy sustainable and durable computerized platforms that are built and implemented using modern technologies, including IoT, mobile computing, cloud computing, and heterogeneous data analysis technologies [1]. In general, smart cities around the world strive to cope with the key problems that the world faces today, such as scarce resources, rapid urbanization, high population growth, and climate change. In general smart economy, smart governance, smart living, smart people, smart

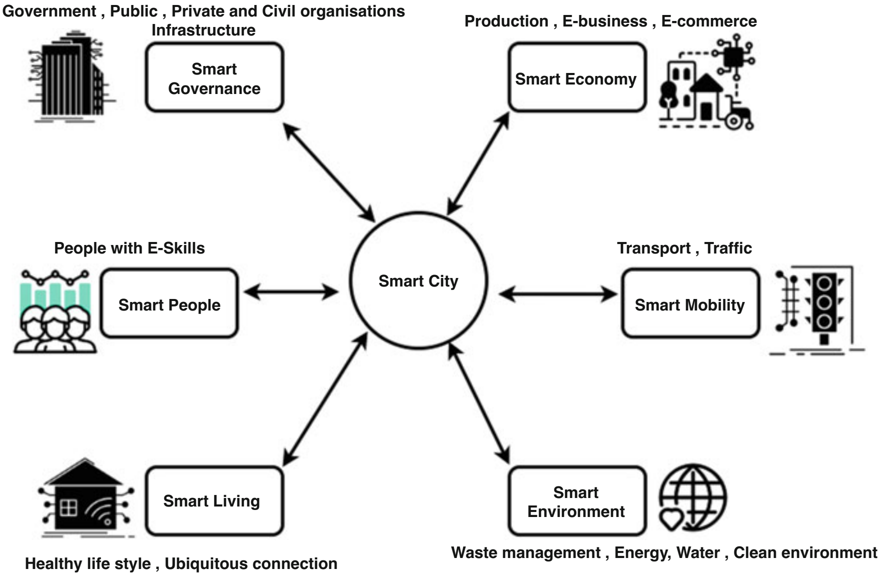

Fig. 2.1 Dimensions of smart city

mobility, and smart environment are six dimensions or areas in which cities can become smarter [1–5], as shown in Fig. 2.1.

In summary, a smart city consists of numerous physical devices that connect and communicate through wired and wireless networks. It can also be used as a synthesis of many computer-related sciences that are used in the entire smartening process, such as cloud computing, embedded computing, artificial intelligence, mobile computing, and biometrics. Radio-frequency identification (RFID) systems, smart mobility devices (e.g., laptops, tablets, smartwatches, and mobile phones), and surveillance systems are also included in addition to these main set of technologies [1, 4, 5]. Obviously smart cities are big, complex, and interdependent structures, leading to a variety of social, economic, political, and technological problems. As of now, funding, rapidly evolving population needs, stakeholder collaboration, interoperability, security, and privacy are major challenges in the context of smart cities. In this study, we concentrate primarily on the security and privacy aspect of smart cities since they can cause real damage to the lives of citizens and the entire city, if not well considered and treated.

While underlying technologies help to solve many of the associated problems with smart cities their ability to collect massive quantities of information could jeopardize citizens' privacy [5]. Since most of the smart city applications are used to collect data from citizens, for controlling city facilities, jeopardizing this data may affect the entire city and the lives of citizens [8, 21]. On the other hand, the ubiquitous nature of underlying IoT-powered smart city services allows citizens in the city to become a digital part of the city, making them an integral part of the smart city environment [39–50]. Therefore the effective functioning of a smart city is subject to the pivotal creation and development of effective safety mechanisms [3]. In general citizens in the city communicate with these smart city services through a wealth of devices that are linked using heterogeneous networks, which will be an ideal target for attackers. As a result, to avert such problems, citizens may refrain from using smart city services [5]. Inspired by achieving a sustainable, secure, and trustworthy smart city environment, in this study we provide an extensive overview of security-related issues that are seen as a massive problem around the world. To do so, in the next section we provide an overview of smart city architecture. In the third section, we discuss several applications of smart cities. In the fourth section, we present a brief discussion about native smart city characteristics. In the fifth section, we discuss privacy and security challenges in smart cities with the countermeasures we can take. Next, we highlight the related work done by others. After that, we discuss the challenges and future directions that we can anticipate in the context of smart cities and finally we conclude our chapter with the conclusion.

2.2 Smart City Architecture

When it comes to smart city architecture urban infrastructure is essentially a mixture of CPSs which are integrated into physical independent components. CPSs are made up of interconnected physical objects, such as various sensing devices, networking devices, and so on. In smart cities, CPSs have to conduct three main activities, which are data collection, deciding which procedures need to be carried out, and handling physical components [1, 4]. The core of the smart city is made out of various IoT technologies [4]. Among these IoT technologies which made out the core, part of them consists of very sophisticated embedded systems such as smart devices like smart TVs, smart mobile devices, refrigerators, medical devices, and SCADA (supervisory control and data acquisition) systems [3].

When it comes to smartening the city, the underlying technologies connect the physical city with the data processing units through the Internet. The smart city manipulates the data sensed from the real world in order to have a smooth, pervasive environment [21]. The sensed data is distributed over vast networks and analyzed to provide and offer advanced intelligent smart services for its citizens and all the stakeholders. Based on the literature we have reviewed there is no unique architecture for smart cities. But to the best of our knowledge, here we discuss the well-known three-layer architecture for smart cities. Based on that, the architecture of the smart city can be apportioned mainly into three layers, that is, the physical layer, the network or the communication layer, and the processing or the application layer. A holistic view of smart city architecture is presented in Fig. 2.2.

The physical layer mainly includes physical sensing devices. These devices include smart sensing devices, wearable devices, and industrial sensors for gathering data from the physical world and transmitting the gathered data to the processing units in the application layer for intelligent decision-making. These physical sensing

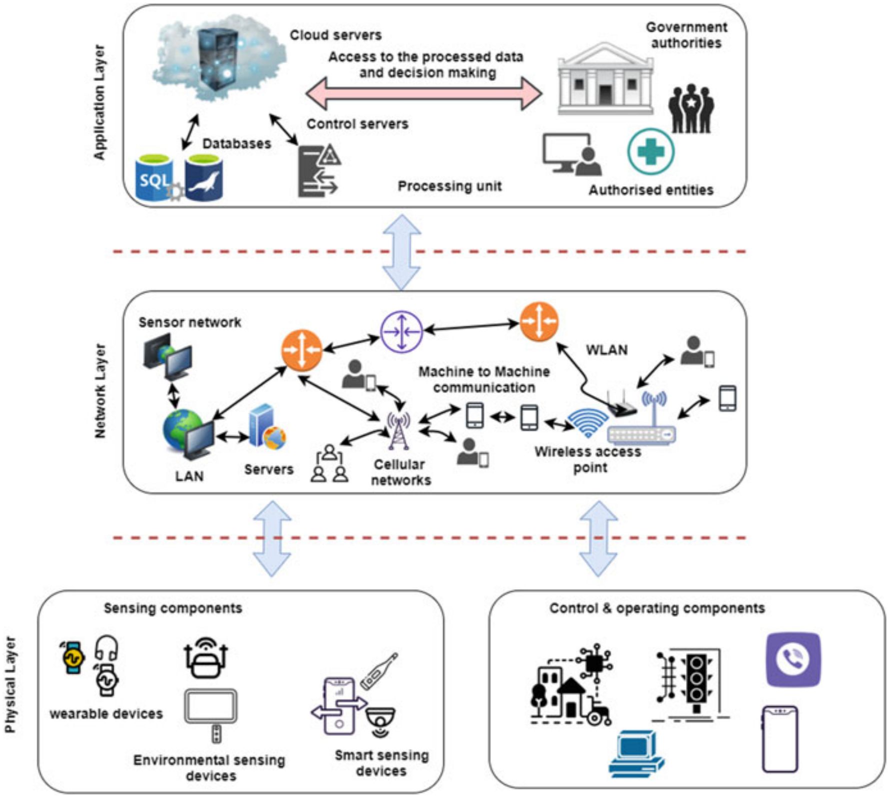

Fig. 2.2 Smart city architecture

devices are either installed or held by the government, private organizations, or individual users [5]. The network layer is responsible for transmitting sensing data via the heterogeneous network infrastructure in various ways; machine-to-machine (M2M) communications, cellular networks, wide area networks (WAN), and short-range communication media such as Bluetooth are incorporated into these heterogeneous networks and facilitate seamless switching between different types of networks. The processing layer utilizes powerful cloud storage servers, ample databases, and dedicated control systems [1, 3], to analyze and process the gathered sensing data from the physical devices for effective decision-making. Approved and authorized bodies, such as the government institutes, factories, hospitals, military, and consumers, have certain rights and permits to view the information gathered for services to be performed. Based on those insights they will decide citywide policies and regulations. Also based on the decisions taken from the processing units, a smart city feeds back to affect the physical world through the control and operating components, such as through smartphones. These control and operational components optimize the physical environments and make improvements such that it is possible to have a decent quality of life in a smart city [1, 3, 9].

By doing so, each system or feature in a smart city can also be controlled and managed to make it work properly [4]. As being constituting a major core part of the smart city architecture, in the next subsection, we also discuss the IoT in smart cities.

2.2.1 The IoT in Smart City

As being the main enabler of a smart city, the IoT has the ability to track, manage, monitor, and operate equipment remotely and to create new information and valuable insights from massive real-time data sources, as it forms a significant part of the smart city. On the other hand, in order to achieve intelligent identification, location, monitoring, and control, the IoT in smart cities employs various physical sensing devices for linking the physical environment to the Internet via unique network protocols for information sharing and communications [37, 42, 46]. Several architectures have been proposed in relation to the IoT architecture for smart cities. Yet there is no standardized architecture that is agreed upon by everyone [29, 51–53]. However, we concentrate primarily on the well-known four-layer architecture for IoT [29], as shown in Fig. 2.3. The IoT architecture in smart cities can be split into four layers [29, 53]. A brief introduction about this IoT architecture is provided in the following.

- Perception layer

  This is often referred to as the sensing layer or the edge layer which constitutes the architecture's lowest layer. In this layer, physical sensors such as sensing

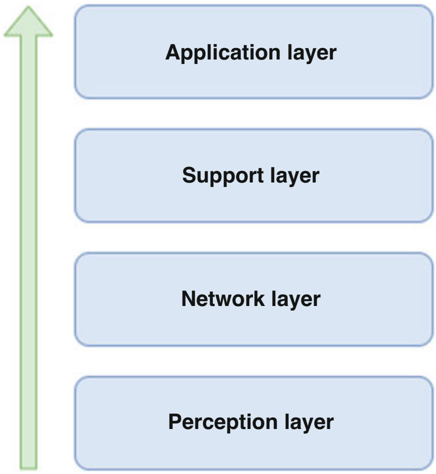

Fig. 2.3 The IoT architecture in a smart city

devices are responsible for gathering data about the different environmental variables that are sent to the network layer [9].

- Network layer

  This can also be viewed as the core of IoT architecture and consists of Internet links, basic networks, and communication networks for transmitting the collected data from the perception layer to the smart applications, cloud servers, database servers, and so on [1, 9].
- Support layer

  This layer interacts very closely with the topmost application layer in the architecture, offering support for the diversified applications by various computing techniques such as edge computing, fog computing, and cloud computing [28, 29].
- Application layer

  As the topmost layer in the architecture, this layer is responsible for providing users with smart services and applications based on their tailored requirements [1, 9, 28].

2.3 Smart City Applications

In order to offer seamless, smooth service to its users, smart city provides many applications as depicted in Fig. 2.4. These applications are highly beneficial for people and the functions of the city in a variety of aspects. In the following we introduce several important applications in the smart city [7, 21, 24, 25]. To provide a better overview, we apportioned these applications into several categories as smart living, smart services, smart environment, smart industries, smart energy, smart utilities, smart government, and smart transportation, and next, we discuss each of the example applications in detail.

- Smart living

  In order to build comfortable cozy homes, smart living offers intelligent monitoring of multiple equipment and utilities in homes and simultaneously facilitates maximization of energy efficiency in homes. This enables homeowners to remotely control appliances, change the house climate, save energy, and incorporate security, entertainment, and education into living environments. Making your home environment into a such kind of smart living environment is also known as the adoption of smart homes [8, 12, 13, 19, 20, 24, 25]. Smart living applications in the larger communities often facilitate social networking, crowdsourcing, waste management, intelligent parking, navigation, and so on.
- Smart services

  Smart services offer various services for the benefit of the citizen in the city. Such services include traffic surveillance, security surveillance, smart healthcare, smart agriculture, and so on [9, 30].

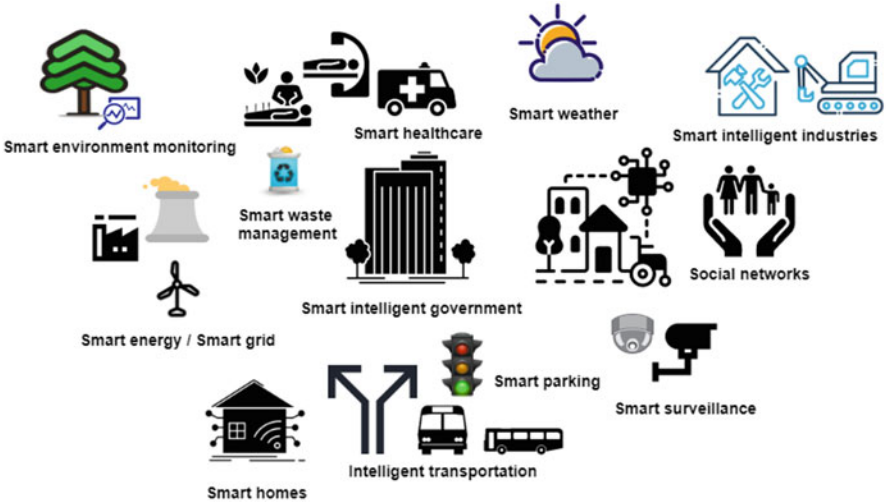

Fig. 2.4 Smart city applications

- Smart environment

  In order to support a comfortable atmosphere and a safe ecosystem for a smarter community, the smart environment is introduced. Pervasive sensing and intelligent climate control are jointly implemented in a typical smart environmental setting. Air and water contamination, forest coverage, greenhouse gas, urban noise, and so on [9, 31] would be tracked to provide a smart and sustainable environment.
- Smart industry

  The key aim of smart industries is to improve the efficiency of manufacturing and to improve product quality while achieving high productivity and robustness. Also it decreases the use of excessive resources (e.g., time and labor) during the manufacturing process and avoids unnecessary industrial pollutions [31].
- Smart energy

  This mainly facilitates for the effective use of energy. By adopting various smart energy practices [31, 32], this facilitates to track the energy supply, storage, delivery, and usage. Also this helps to reduce power supply blackouts and human energy consumption failures. A key example includes smart grid which is used to replace traditional error-prone power systems in the twenty-first century [32].
- Smart utilities

  This allows smart cities to reduce the consumption of resources such as energy and water, and to fuel economic activities and contribute to the conservation of the environment. As an example smart metering is commonly applied in smart grids to track distributed electricity supplies [5, 9, 32].

- Smart government

  In a smart city, smart governance plays a key role. By interconnecting data, institutions, processes, and physical environments, it servers and facilitates for people and communities in the city. In addition, smart governance encourages people to engage in public decisions and community planning, which will increase the performance of policy making while increasing the transparency of information at the same time [9].

  For example e-government encourages users to access online government services, such as paying bills and applying for passports [9].
- Smart transportation

  Smart transportation seeks to make the use of transport networks more intuitive. Specifically, by improving safety and reliability, intelligent transport networks can better serve the public. This makes it easier for people to prepare their schedules while seeking the most affordable and quickest routes [9].

After providing categorization details of smart city applications, next in the following we discuss examples of smart city applications [1, 5, 9].

- Smart parking services

  Here, separate intelligent sensing systems monitor the accessible parking spaces. Drivers are directed to the closest parking spot available and pay for the time they have parked in the space [1, 5].
- Electric car recharging

  Electric cars may use recharging sockets at smart parking locations to charge their vehicles. Users will pay the fee based on the consumed energy for charging [9].
- Smart buildings

  This enables the use of building energy relevant to lighting, air-conditioning, and so on to be regulated based on the climate and user requirements [5].
- Smart location-based services

  This service enables information to be queried depending on the position of the requestor [9, 30] (e.g.: people looking for nearby restaurants).
- Smart medical centers

  Most of the time patient pathological data are obtained from the local medical centers. Medical center staff also ask other hospitals to retrieve information on the patients they are in care of [30]. Also this facilitates to monitor the condition of patients remotely and generate emergency alerts based on the patient condition [30, 35].
- Smart garbage containers

  When the containers are full, these containers will give alerts to local responsible authorities to empty the containers. Moreover, they can only be accessed by people living in the local city [1, 5, 9].

2.4 Smart City Characteristics

Before discussing the security and privacy issues that are pertained to the smart city ecosystem, it is essential to learn about the intrinsic characteristics of smart cities, as most of the time it influences the security and privacy aspect of smart cities [5, 9]. Thereby in the following, we highlight the key characteristics of a smart city as shown in Fig. 2.5.

- High mobility

  High mobility has been seen as an important driver for the development and progression of smart cities. Mobility in smart cities applies not only to the movements inside a city and the delivery of goods from one location to another destination, but also to technology such as wireless citywide communication and monitoring the real-time traffic flow in the city, as well as quick, adaptive responses to issues happening. Moreover, through the well-developed connectivity networks, mobility in smart cities can be highly improved [9, 30].
- Heterogeneity and complexity

  The most distinguishing characteristic of IoT-based systems is high heterogeneity, meaning that the systems are independent, distributed, or used by multiple users [1, 5]. This applies to the broad range of IoT nodes, technologies, and protocols present in the smart city. In addition based on the device manufacturers, underlying technologies, and protocols, the material will also be changed leading to high complexity within the ecosystem.
- Resource constraint nature

  Most of the smart city IoT devices are resource constrained by nature. The devices may possess limited memory, processing capacities, and battery capacity [1, 5, 9, 30].
- Connectivity and scalability

  Connectivity allows the interconnection of any device with other devices in a smart setting. It is the most fundamental feature of a successful smart city. On the other hand, scalability is an apparent element of the smart city environment.

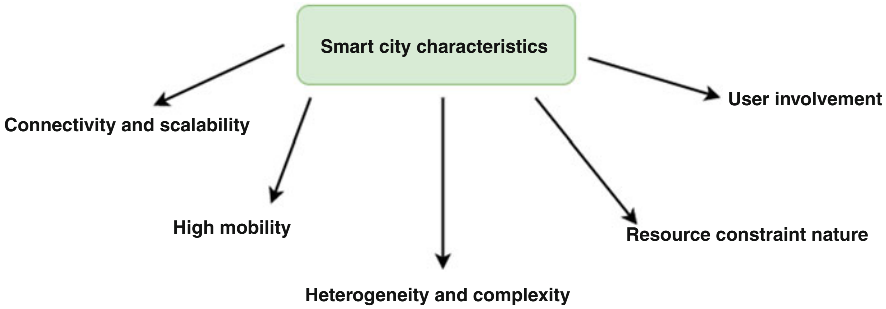

Fig. 2.5 Smart city characteristics

From small to big, smart cities are rapidly developing and growing, resulting in exponential growth in both data and network traffic [9, 30].

- User involvement

  The standard of most of the smart city applications can often be increased by the participation of citizens [9] (e.g.: participation of citizens in decision-making processes through e-government applications).

2.5 Security and Privacy Challenges

Protecting underlying information and infrastructure against any threat and malicious activity requires maintaining adequate security mechanisms in smart cities. When it comes to smart city security, there are a lot of security challenges that pertain to the underlying smart city ecosystem. Especially the physical hardware and software that are implemented in smart cities are made by manufacturers without proper cybersecurity testing. Using such unsafe products will lead to many security vulnerabilities and eventually it will lead to the compromise of the entire city ecosystem. Sometimes it will also lead to shutting down of the vital city services endangering of citizens' lives.

While cities are trying to become smarter, many of the smart city applications pose a range of security and privacy issues and challenges. Thereby smart city should also be able to protect the information involved against unwanted entry, dissemination, destruction, alteration, and annihilation in compliance with the basic information security fundamentals. The key information security fundamentals confidentiality, integrity, and availability should all be satisfied in every aspect of the smart city.

Also, smart cities face issues with vulnerability assessment and response and recovery plans [1, 4, 8]. The IoT as the main enabler of the smart city consists of various devices that produce, process, and share large quantities of essential security-critical information, as well as sensitive private information, and is becoming a tempting target for various cyberattacks [13, 17, 19–21]. Nevertheless, most of the IoT devices would be part of a wider network, which may be the weakest connection without the requisite security design. Any of the devices that are linked to the Internet through wired or wireless connection may lead to a variety of attacks (e.g.: attackers can use Shodan IoT search engine and Google Dorks to easily find such kind of vulnerable devices) [1, 6, 54].

The functioning and operation of a smart city are thus subject to the pivotal development of smart security solutions. The important thing is whatever the solution is used, it should not jeopardize the three major pillars of security, that is, confidentiality, integrity, and availability [43]. Before diving deep in to talk about security and privacy challenges, in the next subsection we discuss the security requirements of smart cities. In the context of smart cities, security requirements need to be satisfied in order to guarantee security even at a minimum level. When deploying devices, services, and critical infrastructure these requirements need to be met always.

- Confidentiality

  This applies to the prevention of information being revealed to unauthorized individuals, groups, or programs. By prohibiting unauthorized parties from accessing the generated data, confidentiality secures the underlying infrastructure [29, 30].
- Integrity

  This refers to the prevention of falsification, alteration of underlying transmitting network data by unauthorized individuals or devices, and protection against the modification of information by injecting messages, replaying messages, and delaying messages on the network [29, 30].
- Freshness

  This concerns whether the data produced or measured in the system is recent and guarantees that old messages are not generated by adversaries [29, 30].
- Availability

  This ensures that when required, only approved entities can access data, services, and other available resources [29, 30].
- Authenticity

  This security measure is intended to determine the validity of a transmission, a message or an originator, or a means of verifying the permission of a person to obtain particular information [29, 30].

Having discussed these key security requirements, in the next section we discuss key security and privacy challenges that may occur in the context of the smart city followed by countermeasures we can devise to secure the smart city ecosystem. As this smart city is an amalgamation of cyber-physical systems, various cyber-physical components, and systems in the city that can be targeted by attackers. In the following we highlight such kinds of examples [1, 3–5].

- Underlying communication network

  In the pervasive cyber-physical systems various components are interconnected through heterogeneous communication technologies (e.g.: 3G, 4G, Bluetooth, and Wi-Fi). These communication technologies may have various intrinsic vulnerabilities and may pose various security issues when the system is in active mode [1, 4].
- Surveillance cameras

  In general cities are equipped with various cameras that are deployed for security surveillance or private use. Most of the time these cameras are not secured with adequate authentication methods where an attacker can easily compromise such devices [3].
- Transport management systems

  Most of the time, these systems face the most important hacks; especially when this happens to air traffic systems or train control systems, it may cause catastrophic consequences. In addition, by hacking traffic light control systems and their sequencing, road signals, and speed limit signs, hackers can create massive traffic delays that can last for hours [1, 3, 4].

Such kinds of real-world examples include the following: In 2011, at a hacking conference Jay Radcliffe demonstrated that hacking of a smart medical insulin pump is possible and even it can endanger the lives of patients [3]; in 2014, January Proofpoint announced the first proven cyberattack involving IoT devices imitating a spam email campaign that targets smart home appliances [55]. Next, in the following we highlight the main threats that can target the smart city ecosystem [1, 33, 34, 36, 46, 47].

- Denial-of-service (DOS) attack
  In a typical DOS attack, it overflows connections until services and devices that depend on that connection are interrupted. So the legitimate authorized users may not have the chance to access services. The availability of networks and underlying systems are influenced by this [29].
- Eavesdropping
  Here, in a particular network, the intruder implants eavesdropping tools to spy on communication networks, capture the behavior of network traffic, and obtain the network map so gathered data can be used to compromise the system completely. Eavesdropping is a dangerous threat that leads to the breakdown of integrity and privacy of the information systems [47].
- Theft
  Theft might cause huge damages as financial issues and loss of reputation if there are no adequate security measures placed [47]. This mainly breaks down the confidentiality and availability of systems in the city. This can be performed by stealing tangible items such as mobile devices, physical IoT devices, and personal computers and stealing intangible assets such as user credentials, software, and cryptographic information [29, 30].
- Unpatched vulnerabilities
  Hackers can gain access and manipulate critical data if most of the smart devices and software are left unpatched. Nowadays this is becoming a huge risk to the smart city [5, 47, 56]. So regular updating of software and hardware is highly required [30].
- Software bugs
  Software bugs present a major threat to smart cities in terms of security. They open up vulnerabilities that can be used by hackers to access smart city networks and infrastructure. Bugs can allow malicious software commands to be inserted by attackers so that they can gain unauthorized access [9, 30].
- Internet openness
  Internet transparency or openness, which all smart cities use, is another security issue. If it is not properly protected, the Internet will pose risks to everything linked to it [46, 47].
- Weak authentication
  This attack helps hackers to circumvent authentication to get into the smart city's internal administrative areas that should not be open to them without entering a password [29, 30, 46, 47].

- SQL injection

  The attackers submit data between the application and the database in the SQL injection attack. With this, hackers force the system to carry out acts that undermine the smart city's security [29, 46, 47].
- Social engineering attacks

  Social engineering attacks are a significant threat to smart cities. Here the attackers mislead a user to perform an operation that will cause a violation in the security of systems. The consequences of attacks from social engineering can also lead to physical impacts, such as causing accidents, damage to the water supply that causes water waste, damage to nuclear power plants, and destruction of manufacturing plants. In smart cities, phishing attacks have also increased as a key social engineering attack methodology. The key goal of phishing attacks is to seize the credentials of the user by targeting email users. The information obtained can be used by hackers to access smart city networks [46, 47].
- Advanced persistent threats (APT)

  In particular, most of the wide range of smart city networks are highly vulnerable to these APT attacks, which are dynamic attacks involving a mix of techniques. An APT campaign, for instance, can combine multiple access points with zero-day vulnerabilities and malware [46, 47].
- Data and identity theft

  This involves stealing personally identifiable information (PII) by exploiting data sources [29, 30] (e.g.: by compromising medical servers or networks, the attacker can access the patient medical history records).
- Man-in-the-middle (MITM)

  The attacker exploits the real-time processing of transactions, conversations, or transfer of other data in the MITM attack. By doing so, the attacker can perform various malicious activities [1, 29, 30].
- Side-channel attacks

  This attack involves the use of some knowledge about the physical execution of computing tasks, such as power consumption and execution time to perform the attack [1]. A successful side-channel attack may lead to exposure of underlining confidential data and revealing of highly sensitive cryptographic information [29].
- Spoofing

  The act of disguising a message from an unknown source as being from a known, trusted source is spoofing. Spoofing may apply to emails, phone calls, and websites, or may be more technical, such as spoofing an IP address from a device [1, 9].
- Brute force attack

  As most of the IoT sensing devices in the smart city contain weaker computational power, brute force attack can easily compromise the access control of the devices allowing attackers to easily exploit the device data [29].
- Hardware jamming

  Here the attacker can damage the physical devices by replacing the parts of the device hardware [29].

- Credential theft

  An attacker can obtain confidential user credentials from critical systems and use them to compromise the system further [29, 30, 46, 47].

Hardware failures, software crashes, environmental and natural behaviors, and end of supplier and manufacturer support may trigger other threats accidentally. These threats affect the availability and integrity of infrastructure networks, resulting in service provision deficiencies [1, 9, 46, 47]. Most of the attacks that target IoT devices often cause harm to the point of non-recovery. In the next subsection we discuss privacy challenges in smart cities.

2.5.1 Privacy Challenges in Smart Cities

Smart cities deal with large volumes of real-time data and data-driven systems linked to it and have many resources that generate numerous forms of data. These systems comprise systems that continuously produce fine-scaled and exclusive data. In smart cities, these systems are common and the data they generate are called big data. Many of these urban data are used to operate the smart city, so keeping it safe and securing these large quantities of data are important. In addition, it is important to protect the privacy of confidential data and personal data, to ensure that they are not reached or accessed deliberately or accidentally by unauthorized parties.

The heart of smart cities is the data obtained from the smart stuff. The issue is that this sensitive information is often obtained without citizen's explicit consent. For example, in our smartphones, messages, personal photos, bank account data, and contact details are stored with our full awareness. But a typical smartphone comes with various sensors like proximity sensor, accelerometer, geomagnetic sensor, barometer, and hall sensors [3, 4]. The important thing is place, gestures, time stamps, even private discussions, and background noises can be recorded by such sensors present in the smartphone without our awareness and consent [3]. These privacy-related issues can mainly be grouped into three categories such as communication privacy, individual privacy, and business privacy [1, 3–5]. In the following we provide more details about this.

- Communication privacy

  Communication privacy in a smart city can be challenged by DOS attacks, eavesdropping attacks, MITM attacks, and side-channel attacks as these attacks lead the attacker to access confidential information that is transmitted over various communication networks [1, 3]. This information may include various citizens' information and M2M communication information.
- Business privacy

  Business privacy can be challenged by various social engineering attacks especially phishing attacks, spoofing attacks, eavesdropping attacks, and so on [1, 3, 4]. Violation of this business privacy is now becoming a huge challenge for the banking sector, e-commerce sector, and most of the government services in a typical smart city.

- Individual privacy

  Personal data is a valuable resource in the smart data-driven economy. The data generated by citizens holds an enormous importance in a smart city. If information is not properly protected and privacy is not assured, smart cities will evolve from user-centered initiatives into societies that pose a significant danger [1, 3–5].

As privacy-related issues are becoming a huge problem, city management and government authorities have a huge responsibility to work for consensual solutions that respect the privacy of people in a smart city. In the next section, we discuss countermeasures that we can take for protecting the smart city from such kind of security and privacy issues.

2.5.2 Countermeasures and Solutions for Securing Smart City

Securing a smart city faces serious challenges. The introduction of effective measures can, however, successfully mitigate most of these risks [1, 9, 20, 29, 30, 46–48, 50].

- Data encryption

  Both at rest and in transit, data should be encrypted. Basically encryption scrambles the data so it cannot be recognized. In order to decode this data, an encryption password needs to be used. There are two types of encryption mechanisms, that is, public and private key encryption. This encryption is really essential since sensitive information such as personal identifiable information is normally managed by smart city systems [1, 9, 46, 47]. In the event of a hack, encrypting prevents attackers from misusing the data. Also securing and encrypting data from the outset is easier than doing it later.
- Perform software updates on time

  In a smart city, all the technologies used should be kept up to date. A system administrator should be responsible for ensuring that all software and hardware are well updated to prevent hackers from exploiting known vulnerabilities. As an example both firewalls and antiviruses can be updated periodically [1, 50].
- Proper security framework

  Due to the sophistication and complexity, keeping track of all aspects of a smart city is difficult. There could be thousands of connected devices deployed that are geographically dispersed all around the city. To take care of the security aspect of all these devices will be a tedious task. But using a proper security framework, this tedious task can be simplified and thus security can be enhanced [1, 9, 30].

- Adopting best security practices

  When it comes to smart city security, implementing best security practices is important. Good security practices require the use of enhanced network security guidelines to restrict entry to confidential networks and safe password procedures. In addition providing sound access control mechanisms, removing all unwanted or unused systems or something that is not actually being used, disabling remote control functions and ports to prevent hackers from accessing, using security incident and event management software (SIEM) to scan network operations and detect abnormal security incidents, having proper patch management guidelines, and having proper controls and standard operating procedures for when a security breach happens are also counted as best security practices we can adopt in terms of smart city security [46–48].
- Citywide security operation centers (SOC)

  To track security issues, mitigate vulnerabilities, and respond to attacks fast and efficient establishment of security operation centers is really needed in smart cities. This involves deploying citywide network monitoring systems, intrusion detection systems, intrusion prevention systems, firewalls, and so on [46–48].
- Regular penetration testing using ethical hackers

  In protecting the smart city, an ethical hacker will play a significant role. To ensure that everything is intact, and make sure that there are no security loop holes and no intruder can access, ethical hackers can be used to test the security of smart city systems. They will use the same tools that dangerous hackers are using to access. Further ethical hackers will also test all of the latest new city technologies to ensure that the smart city is well updated for unexpected cyberattacks. This also involves hiring third-party security firms to test the underlying security [46–48, 50].
- Biometrics

  In IoT-based applications, biometrics is widely used for authentication. This technology can be used to automatically identify an individual based on their particular behavioral and biological characteristics. To recognize individuals, fingerprints, faces, voices, handwritten signatures, and other biodata are collected [9, 46–48].
- Endpoint solutions

  Endpoint solutions can be used to prevent attackers from accessing systems and identify any malware on the workstations and servers [29, 30, 46, 47].
- Blockchain

  The blockchain's decentralized function allows applications to work in a distributed way and this blockchain security solution provides decentralized security and privacy, making it really tedious to break into systems and underlying data [1, 6, 46].
- Introducing cybercrime laws

  To discourage attacks on the smart city, heavy penalties should be placed. There are currently limited and loosely defined consequences for cybercrimes. To represent the ramifications for rule breakers in a smart interconnected environment, penalties, fines, and jail sentences need to be introduced and existing laws must be updated for discouraging such attack attempts [46, 47, 50].

2.6 Related Work

In this section we summarize various surveys, experiments, and prototypes that have been done by others towards researching the security and privacy of smart cities, as depicted in Table 2.1.

Table 2.1 Related work

Reference	Year	Description
[2]	2014	The authors concentrate here on two key challenges, security and privacy. They present a mathematical model representing the interaction between individuals, IoT, and servers which are vulnerable to information security threats in the context of smart cities
[3]	2016	This study introduces a four-layer framework for approaching data security requirements and solutions in smart cities. The four layers include smart things, smart spaces, smart systems, and smart citizens
[5]	2013	A number of privacy violations linked to smart cities have been found in this study. Further authors have also described the concept of privacy in smart cities as a five-dimensional model
[17]	2013	This study assesses the security and privacy problems that come up with smart software
[18]	2019	The authors identified five types of vulnerabilities with regard to smart city technologies in this study and provide a number of illustrative examples of such smart city-related vulnerabilities
[22]	2014	Here the authors propose a comprehensive security framework to deal with smart city security issues
[26]	2017	Here the authors propose three new approaches using fog computing to meet the necessary privacy of mobile devices in smart cities
[31]	2020	The idea of reducing the energy consumption of IoT devices and keeping the environment safe and clean is reviewed in this study
[32]	2020	In this study, authors have performed an extensive review about smart grid data analysis using machine and deep learning techniques; in addition it also presents security requirements in the context of smart grid
[44]	2020	In this study, the authors suggest three categories to categorize smart city security interventions
[57]	2013	In order to resolve the problem of security problems in sensing and querying, an encryption scheme is proposed to deal with such problems
[58]	2013	In this study, the authors suggest a data protection framework that can be handled automatically by distributed cloud computing services in the smart city environment
[59]	2013	In this study, the authors describe the smart solutions and elaborate on the security issues regarding the implementation of such solutions in smart cities

2.6.1 Summary

Engineers, architects, and city management must start enforcing security policies at the strategic planning stage in order to protect the smart city in terms of security and privacy. Protection is critical at any stage of the development process. Vulnerabilities must be addressed at all times in order to avoid serious repercussions that could jeopardize the smart city as a whole. When appropriate security measures are in place, the systems that the smart city supports will normally function properly, and residents will continue to benefit from the smart city's services. Anyhow at some point, attackers can cause significant harm and can even go up to loss of lives. It would cause irreparable harm to traffic surveillance systems, food distribution networks, smart healthcare systems, and smart transportation systems if such attacks happen. So the security must be an integral part of smart city development, and city management and responsible authorities should always keep an eye on the security aspect of the smart city at all times.

2.7 Challenges and Future Directions

Every year, smart cities invest more towards ensuring the security of cities. But the number of security threats they face is also rising with time. Attacks targeting smart cities are evolving day by day and so do the security measures. In the following we discuss such kinds of security challenges and future directions of such security measures that we can anticipate in the coming years.

- Integration of blockchain

  When it comes to the security of smart cities, IoT security becomes a huge challenge as it is being the main enabler of the smart city. Most of the related IoT security issues can be solved using blockchain-based approaches which provide decentralized security and privacy [13, 23, 39]. As of now, most cities are offering blockchain-based security solutions for their citizens. Blockchain also offers the opportunity to abandon the current technologies used in third-party ledgers for information storage. With the absence of a third party, the resources required are substantially reduced and the transaction speed with protection also increases [6].
- Fog computing

  Fog computing is a new computing model that operates closer to the peripherals and is an extension of cloud computing [22, 28, 45]. It is designed with smaller capacity and lower processing power, and it works closer to the peripherals to process data until it enters the cloud. As the operating environments of dispersed fog systems are more sensitive to attacks than centralized cloud, fog-based networks may present new security challenges. But as the fog nodes are close to end users, they provide useful opportunities to protect consumers' privacy before leaving the edge network with personal sensitive data. Therefore, much more attention should be paid to smart device security in fog-based smart systems and as per the time being various research activities are being carried out with regard to improving fog security [9].

- Lightweight security solutions

  In recent years even though different novel security mechanisms have been developed, the direct application of any of these mechanisms is impractical due to the resource-constrained nature of IoT. The restricted processing and memory capacities and limited energy capacities of sensors and equipment make it possible only to implement simple and poor cryptographic algorithms (e.g.: most IoT devices possess very limited processing capacity, memory, and battery capacity by default). As a result, more research is needed for developing lightweight security solutions [1, 9, 29, 30].
- Citywide cybersecurity strategies

  Cities should match their plan for cybersecurity with the overall city strategy. To define and minimize threats involves reviewing their data and processes. These cybersecurity strategies should be an integral part of the smart city strategic plan (Singapore has recently passed a bill indicating cybersecurity as a nationwide strategy [9]).
- Encouraging innovations

  New solutions to security problems can be created by attracting innovators by offering reasonable prizes for their efforts (e.g.: encourage citizen participation for hackathons). In recent years this has become a trend for coming up with innovative security solutions [9, 30].
- User-focused and personalized security

  In user-centric smart cities, consumers should have the ability to delete or switch data from one service provider to another at any time. Furthermore, since people's behaviors and conditions vary, people's preferences for protection and privacy must also be considered at any given time. Furthermore, the growing number of configurable privacy settings makes it impossible for users to adapt their settings to their actual preferences. As a result, in the coming years, the invention of user-friendly security assistants that can improve both security and comfort would be a boom [9, 29, 30].
- Ontology

  Ontology has been identified as a promising method for dealing with heterogeneous problems, especially those involving unstructured data and information. The key aim is to better clarify, describe, and reuse some formally represented information, as well as to search for new knowledge and eliminate contradictions. In this case, artificial intelligence methods such as machine learning and deep learning are used. Machine learning and deep learning algorithms, for example, have been used to improve the effectiveness of intrusion detection systems and next-generation firewalls, two of the most commonly used defense infrastructure for defending smart city networks from attacks [9].

2.8 Conclusion

In conclusion, smart cities are designed to address significant global issues such as climate change, urbanization, resource scarcity, and rapid population increase. The definition of the smart city is characterized by the fact that embedded networks, IoT, and smart technologies are completely used. In terms of smart city challenges, smart city security is a very critical topic as it can even jeopardize the lives of citizens in the city. The evolving convergence of technology and the resulting intense connectivity, high sophistication, and high interdependence nature of underlying smart city technologies may lead to infinite attack surfaces and thus make a sound target for attackers. As a result, community administrators or officials should pay special attention towards ensuring the security and privacy of network protocols, underlying technologies, and resident identities, among other things. For the time being, security risks are becoming greater as the environment continues to be more interconnected. Criminals and hackers are finding new ways to access confidential citizen information. As a result, smart city security should still be a top priority, and security consultants and experts should be brought in early on in the design and development phase. Finally, it is difficult to take care of all aspects of smart security and it takes a long time to get an adequate budget to fulfill all security needs. Most of the time for mitigating most of the novel advanced smart city security issues international cooperation is required. Therefore this will always be a time-consuming task if this security and privacy have not been addressed in the early stages. So security measures should always be an integral part of smart city design. The aim of this chapter is to review key issues and practical strategies related to information security in smart cities, and we hope that our findings would be extremely useful to researchers, educators, and scholars working to make smart cities a safer place to live.

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Chapter 3
Multi-antenna-Enabled Technologies for IoT-Driven Smart Cities

Mayank Kothari, Zerksis Mistry, Aniket Kamat, and U. Ragavendran

3.1 Introduction

A few years back, the advent of the Internet of Things (IoT) was greeted with some cynicism. Those days, thankfully, are no more. A string of announcements, ranging from Google's purchase of Nest Labs for approximately $3.2 billion to Samsung Gear and other wearables related to health, to the development of Amazon Alexa for smart home appliances, have greatly expanded market prospects in IoT. IoT technologies are certain to play a significant role in our day-to-day lives. With newer cellular networks, prevalent sensors, and advanced computing capabilities, the IoT could be the next frontier in the quest for a piece of the pocket. IoT systems are supposed to provide sophisticated knowledge and access to billions of everyday objects [1].

One of the most influential tech developments to surface in recent years is the IoT. In basic terms, it refers to the fact that, although the term "Internet" is originally applied to large-scale electronic networking, today, machines of all sizes and shapes—from vehicles to kitchen appliances to heavy equipment—are linked and transmitting knowledge online on a global scale. The global coronavirus pandemic, like any other part of our lives, has undeniably influenced how this trend

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is evolving and affecting our lives. In a world where human-to-human interaction is currently minimal, contact between computers, tools, and toys will help us stay connected.

About the hype surrounding American and Asian mobile device makers, European IoT science and technology remains very solid. Not only this but also there are several examples of successful European companies. European market leaders like Bosch and STMicroelectronics have excelled in providing a full ecosystem on smart sensors, while market leaders like ARM, Infineon (embedded systems), SAP, and Atos (software) to name a few have also contributed significantly to the European markets. The "European Research Cluster" has played a decisive role in the application of IoT not only in Europe but also internationally. Wearable technologies are a pillar of IoT innovations, and healthcare was unquestionably one of the first businesses to put IoT to use. When we think about the IoT, we probably think about smart homes first. Livestock control is concerned with livestock farming and cost cutting. According to Amitai Etzioni, the IoT helps merchants to communicate with consumers and enhance the in-store experience. According to him, the IoT is supposed to offer access and knowledge to billions of everyday objects [2].

A smart city is defined as the city that monitors and controls the infrastructure and the needs of the city such as the transport facilities. It is made in such a way that natural and artificial emergencies can be focused quickly and necessary actions can be taken on it. The world is confronting a clean city with facilities of controlling and monitoring different services smartly in an effective manner. By utilizing different sorts of sensors like dampness sensors, temperature sensors, air quality measurement sensors, soil dampness sensors and other numerous sensors can be used in DES. While executing this thought we require a completely computerized water system framework that is associated with a remote correspondence framework and sensors with legitimate calculation. The data gathered by these sensors should be shipped to the cloud for dynamic utilizing of different web administrations. This would bolster the mechanized water system framework by investigating past in-formation put away at the cloud. Fast developments in remote correspondence arrangement have revealed new challenges [3].

The 5G remote correspondence framework raises prerequisites on vitality effectiveness and unearthly productivity. Multiple input multiple output (MIMO) is the future remote framework that will be substantially more effective to satisfy the need for remote correspondence in a restricted recurrence range. Right now, we have learned about the reasonable issues which are experienced in the MIMO correspondence framework. Likewise, future challenges and research bearing for MIMO channel estimations are distinguished [4].

The main objective of this chapter is to give brief information about multi-antenna-enabled communication technologies more suitable in connecting different objects of the city which helps citizens in improving the lifestyle. In this chapter, the authors explain multi-antenna systems with their types, benefits of the multi-antenna system in IoT, and advancement in communications technologies like LTE, 5G, WiMAX, Wi-Fi, and VANET due to multi-antennas. How these multi-antenna-enabled technologies are very much helpful is described in the case study of smart cities.

The remainder of this chapter is organized as follows. Section 3.2 presents the multi-antenna system with its classification. Section 3.3 presents the benefits of multi-antenna system in IoT. Multi-antenna-enabled wireless communication technologies that are helpful in designing IoT applications are discussed in Sect. 3.4. Section 3.5 presents the case study of smart cities Toronto and Santiago. Conclusion and future scope is provided in Sects. 3.6 and 3.7.

3.2 Multi-antenna Systems

There are four correspondence models in remote correspondence. These are depicted as below.

3.2.1 SISO

SISO stands for single input single output. Figure 3.1 shows the block diagram of SISO system in which only one antenna at transmitter and receiver is attached for communication purpose. This system gives limited performance due to single communication link between transmitter and receiver.

3.2.2 SIMO

SIMO stands for single input multiple outputs. Figure 3.2 shows the block diagram of SIMO system in which single antenna is used at transmitter side and multiple antennas are used at receiver end. Multiple links at receiver end reduce the effect of shadowing, fading, and other channel losses. This system has high receiving diversity. This system is efficient where receiver has enough source of power [5].

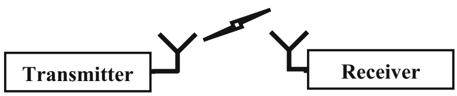

Fig. 3.1 Block diagram of SISO systems

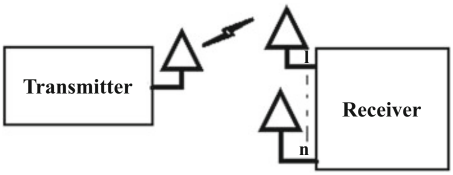

Fig. 3.2 Block diagram of SIMO systems

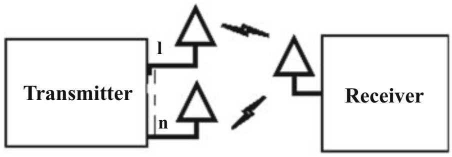

Fig. 3.3 Block diagram of MISO systems

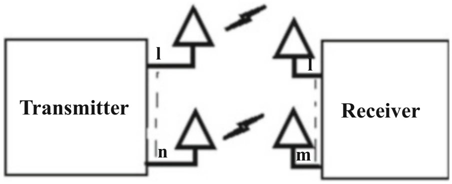

Fig. 3.4 Block diagram of MIMO systems

3.2.3 MISO

MISO stands for multiple input single outputs. Figure 3.3 shows block diagram of MISO system in which MISO various communication links are associated with the transmitter and just a single radio link is there on the recipient side. It is one of a few types of savvy receiving wire innovation to limit mistakes and upgrade information speed.

3.2.4 MIMO

MIMO represents numerous info various yield. Figure 3.4 shows the block diagram of MIMO system in which multiple radio links are associated with the transmitter as well as the receiver. Due to multiple links at both ends, this system gets high signal improvement with better reliability and high data rate. This system improves reliability by transmitting same signal with multiple links at the same time, known as spatial reliability. By transmitting multiple data stream simultaneously using space time block code known as spatial multiplexing high data can be achieved in MIMO system. This system has an assortment of significant ways that convey information, picking separate ways for every receiving wire to empower various sign ways to be utilized. It has numerous receiving wires situated at various focuses [6].

3.2.5 Massive MIMO

Massive MIMO may be a key enabler of 5G’s extremely fast information speeds, potentially elevating the technology’s ability to a replacement stage. The following are the benefits of this to the network and end users:

- Increased network capacity—Network capability is defined as the total amount of information available to a user, as well as the widest range of users who can access a given level of expected service. This technology contributes to enhanced capability by allocation of same frequency resources to multiple users at the same time in spatial domain and by allowing 5G NR readying inside the higher frequency home in Sub-6 rate (e.g., 3.5 GHz).
- Better coverage—With broad MIMO, consumers get a more consistent experience across the network, right at the cell's edge, so they can expect high-speed service almost anywhere. Furthermore, 3D beamforming allows for dynamic coverage for moving users (e.g., users in cars or connected cars) and changes coverage to accommodate user location, including in areas where network coverage is restricted [7].
- Spectral potency—As increasing spectrum is used for various communication protocols, this is becoming an increasingly important issue. Governments have set aside a wide band of frequencies for 5G, but those frequencies are not infinite. The antenna array of a 5G broad MIMO system can be used to direct beams down to individual users.
- Energy potential—Since the United States will not be producing oil indefinitely, it is time to start thinking about energy potency for electronic systems as well. It is used in combination with massive MIMO antennas to increase the gain of transmitted signals. This means that they radiate less power after receiving transmission information, resulting in a more energy-efficient device [7].
- User trailing—A similar problem that results in significant MIMO energy savings allows it to monitor individual users accurately. The antenna beam widths narrow as the antenna beams are aimed to provide high gain. As a result, the tower must use a thin signal beam to monitor each consumer [8].

3.2.6 Smart Antenna

The wireless and other mobile technologies in addition to newer and improved telecommunication services have grown rapidly at an extremely formidable and exponential rate. As we know, in recent years, technology has advanced significantly over the last decade and there have been significant modifications in the telecommunication networks and multiple-access systems. The spatial processing approaches and methodologies become very important as it is considered as the core idea behind the application of adaptive and smart antennas, beamforming algorithms, interference cancellation, direction of arrival estimation scheme, and antenna arrays, to name a few. Smart antenna system framework procedure can be acquired by executing various ways like null steering and beamforming. Also called as adaptive antenna systems, it is a design in which the channels follow straightforwardly toward the client and away from the obstructions [9].

A smart antenna system integrates several antenna components with signal processing capability to automatically optimize radiation and transmission patterns

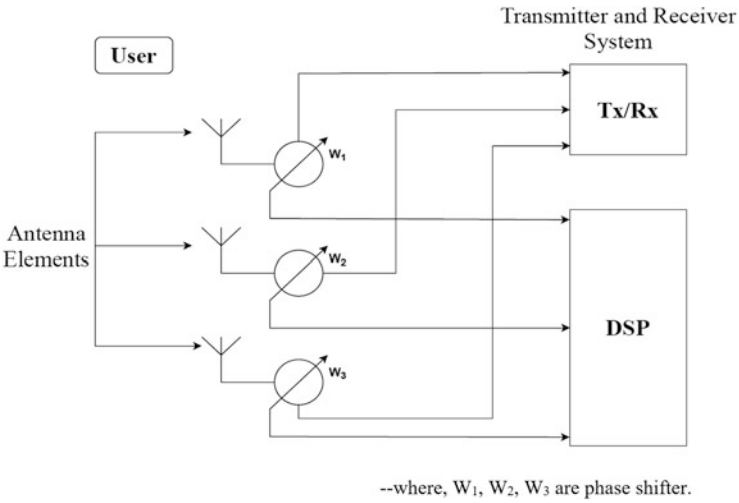

Fig. 3.5 Smart antenna system structure. W_1, W_2, and W_3 are phase shifters.

depending on the signal environment. As per Fig. 3.5, the phase of the phase shifter is controlled by the digital signal processing (DSP) processor. By controlling the phase of the phase shifter, the antenna beam gets steered. By changing the magnitude via DSP, the antenna beam may steer in some other direction if required. Consider a user as shown in the diagram. When a user sends a signal through any means to the antenna elements, then based on signal reception, the smart antenna DSP processor will vindicate the direction of arrival, which will be calculated by the DSP processor based on the magnitude of the phase shifter. The smart antenna elements shall in turn send back the signals to the user and back to the antenna elements, forming the main lobe, in the direction of the antenna elements, and that is based on the direction of arrival. To summarize, based on the user direction, the signal radiates and the system will identify the direction of arrival and once the system validates the direction of arrival, it will send signals in the same direction only and hence radiates in the desired direction only, because of which the interference will be minimum and have higher diversity and array gain in the desired direction. This will significantly improve the wireless system's performance characteristics (such as capacity).

To comprehend smart antennas, switched-beam or fully adaptive array antennas are commonly used. Two or more antennas (the array's elements) together make an array that is joined electrically and spatially to deliver a directional radiation pattern. The phases of the thrilling currents in each array element antenna are adjusted in a phased array to modify the array's pattern. Even though existing amplitudes could be changed, the phase shift is just what determines the beam's steering. In wireless communication networks, smart or adaptive antennas are being considered. Smart antennas can boost a system's coverage and capacity. They will increase the overall data rate in multipath channels while also mitigating fading caused by multipath portion cancellation. Adaptive antennas may also be used for navigation, with uses ranging from rescue services to vehicle traffic control. In a simple RF environment, a simple antenna will suffice. Smart antenna solutions are needed as the number of users, interruption, and propagation complexity increase. Their expertise is held in their optical signal-processing laboratories. Like other modern advances in electronics, the multimedia format for editing RF files provides various advantages in terms of precision and simplicity of the operations. Smart antenna devices, on the other hand, track, decode, and modulate analog signals for digital transmission and reconvert them to analog information at the other end. In adaptive antenna systems, advanced techniques (algorithms) are used to control operation in the face of complicated variations of operating conditions, which complement the fundamental signal-processing power. Maintaining a more focused and efficient use of the system's resources and bandwidth allocation can yield significant benefits.

3.2.7 Signal Processing in Multi-antenna Systems

To improve the channel limit and upgrade the range usage, streamlining of the framework is compulsory. Smart antennas are another innovation for remote frameworks that utilize a fixed arrangement of antenna elements in a cluster. The signals from these are joined with a complex signal processor to improve the presentation of the framework. To the much-expanded traffic, keeping standard with every one of the boundaries of the telecommunication framework is a genuine test. A smart antenna has the property of spatial filtering which can get energy from a specific direction, at the same time obstructing from the wide range of various directions [10].

Out of the two sorts, adaptive smart antenna is equipped for shaft guiding toward any path as per the direction of arrival (DOA) and producing an invalid interferer's way when contrasted with the witched beam smart antenna having a few fixed bar designs. Beamforming is very much dependent on the adaptive signal-processing algorithms and must utilize large, directive antenna arrays, e.g., massive MIMO, to defeat the propagation losses innate at high frequencies. As these exhibits become bigger, nonetheless, energy utilization turns into a basic issue, and the framework execution should be offset with the power use. Besides, the expected exists for a yield information rate more noteworthy than the application layer can oblige, in which case specifically choking the quantity of samples per test can be cultivated in the physical layer or in the application layer. This rate limitation, regardless of whether because of power or information prerequisites, makes a bottleneck at the yield of the receiver. Mutual data determination can be cultivated through two distinct techniques: antenna domain and digital domain.

In the analog domain through antenna subset selection using a switch as shown in Fig. 3.6 in the computerized area through subset determination of pieces after quantization as shown, the main strategy utilizes a simple change to choose a subset of radio wires preceding quantization. This empowers the receiver to fix the quantity

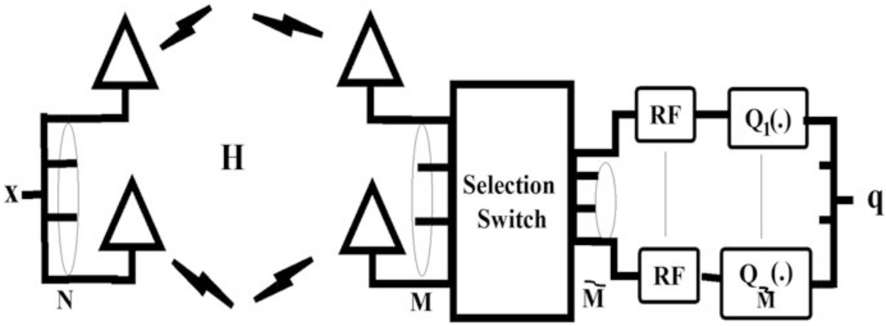

Fig. 3.6 Analog domain mutual information selection

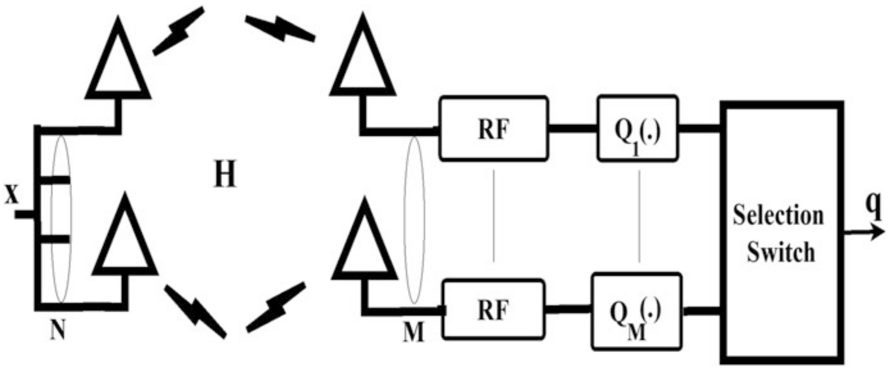

Fig. 3.7 Digital domain mutual information selection

of required radio frequency (RF) and quantizer chains to some number M , dictated by the rate imperative. Denoting the total number of antennas by M, for M < M the cost and power consumption of the receiver are reduced. Analog switch selects a fixed number of ADCs before quantization.

Notwithstanding, the receiver requires either delay in or capacity of the signal before quantization or potentially a committed choice-preparing stage to figure out which antennas to go on to expand the shared data between transmitted signal x and the receiver output q. Bits are generated using one ADC per antenna and then selected after quantization. In the subsequent technique, we accept that every receiving wire has a devoted RF chain and quantizer. We note that though this assumption disregards combination plans with a couple of antennas for each, a RF chain, for example, utilized in expansions can be made to join these more perplexing plans. The common data [11] determination is advanced, occurring after quantization, and depends on the quantized signals. Postponement or capacity of the quantized signal is expected to be worthy. Utilizing this strategy takes into consideration constant quantization of the approaching signal (Fig. 3.7).

Notwithstanding, generally substances of the brilliant receiving wire array preparation are centered around the utilization of customary narrowband and wideband system. With the quick advancement of the arising UWB impulse technology the standards of these space-time array processing are applied on UWB frameworks to improve their possibilities. Dissimilar to narrowband frameworks, UWB signal provides a wide scope of range. A large portion of narrowband array-processing strategies tend to be incapable at times where an array gets signals with huge transfer speed. It is on grounds that the signals created at diverse array components are not totally correlated because of the inter element propagation delay. Recurrence reaction coordinating for various antenna components is likewise troublesome because of huge transfer speed of the signal. Subsequently for handling UWB signals tapped defer line (TDL) is utilized on each branch of the exhibit. UWB beamforming has extra advantages instead of the narrowband beamforming. In narrowband for antenna dispersing of more noteworthy than half wavelength ($\lambda/2$) of the highest frequency of the signal, grating lobes happen and lead to vagueness in course of appearance of the signal. Anyway, for UWB, the array spacing can be expanded further with no equivocalness since grating lobes are found in the middle value of out, empowering high goal with a few array components [12].

3.3 Benefits of Multi-antenna System in IoT

Smart cities have gone on to become brilliant with the most recent setup of IoT innovation, fueled by multiple antenna-based networks associated completely with the IoT. The next era of smart antenna system-enabled IoT solutions removes the obstacles formed by the earlier infrastructure to deliver affordable, user-friendly, plug-and-play connectivity [13]. From air quality monitoring to connected fire hydrants, and to smart trash dumpsters, the system of the IoT delivers a group of affordable arrangements to give the users an easier, more cost-effective municipality.

Applications that need a resolute multi-antenna system have an excellent indoor and outdoor reach that minimizes the number of gateways needed to serve an area. A multiple-antenna system having low power operation coupled with a high-performance sensor can increase the lifetime of a sensor and allow it to work for prolonged times. The low-power operation also allows an easy data connection. Also due to this operating labor costs are reduced because several sensor test and maintenance operations are performed remotely. The multiple-antenna system can also establish a system for sensor communication allowing the user to initiate remote maintenance functions like a reset and self-test [14]. A multiple-antenna system can also use public infrastructure making it cost efficient. A multiple-antenna system is also very secure in functioning as it secures all its end-to-end communications keeping the systems protected from cyberattacks and data. Many of the multiple-antenna systems are approved worldwide for example the LoRaWAN Protocol which allows companies to sell their products and services which have assurance in global interoperability. Multiple-antenna systems offer the ability to distinguish transmission over multiple paths. It is feasible to encode the signal even more adequately if the impact of those ways is thought of. Although an arbitrary number of spatial channels is not practical, the capacity to build information rate by half, or maybe twofold, inside a similar data transmission use is a significant benefit. Impedance in a smart antenna system can be decreased by utilizing the invalid guiding through direct interferers [15]. Variety can be accomplished by carrying out different ways of sending information between transmitter and receiver per channel at the base station. Array gain can be increased by using a technique that joins two signals together [16].

3.4 Multi-antenna-Enabled Technologies

3.4.1 5G

5G is the latest global generation mobile network standard after 4G. This technology delivers the data at a very high speed and provides ultralow latency. The 5G technology is more reliable compared to other standards and has a vast network capacity. The 5G makes the use of World Wide Wireless Web (WWW) popular as it causes mixed media web systems in mobile allowing restriction-free access [17]. 5G incorporates the technologies from 4G LTE. The web systems in 5G support LAS-CDMA (large area synchronized code-division multiple access), IPv6, UWB (ultra-wideband), MC-CDMA (multi-carrier code division multiple access), OFDM (orthogonal recurrence-division multiplexing), and Network-LMDS (local multi-point distribution service). 5G enables information abilities providing unhindered and unbound access within the structure. IoT is a system of interrelated computing devices or any other thing that is attached by a unique identifier that can transfer data over a network without requiring a human to various devices or things virtually with each other by providing high-speed data rates at cheap rates, etc. and making it work efficiently [18].

Millimeter-Wave Radio Access Technology in 5G

The next generation of mobile applications are powered by 5G, also known as mm Wave or millimeter-wave 5G. 5G will carry portability to mm Wave interchanges as the innovative remote organization endeavors to serve more individuals and even things with a significant extension of versatile administrations. Indeed, even with the advances of 4G LTE, the organization is running out of transmission capacity. The arrangement is to add more data transmission by utilizing the recurrence range in the millimeter-wave recurrence range. The term mm Wave alludes to a particular piece of the radio recurrence range somewhere in the range of 24 and 100 GHz situated among microwaves and infrared, which have an extremely short frequency. This segment of the range is essentially unused which is represented by the diagram, so mm Wave innovation is expected to extraordinarily build the measure of transmission capacity accessible. The target of mm Wave is to expand the information data transmission accessible over more modest, thickly populated zones. It will be a critical piece of 5G in numerous urban communities, controlling information in sports arenas, shopping centers, and assembly halls, just as essentially anyplace information clog may be an issue. Out in rustic towns and towns, sub-6 GHz and low groups beneath 2 GHz will presumably assume a more vital part in guaranteeing reliable inclusion [19].

Another potential gain of this short frequency is that it can move information considerably quicker; however, its exchange distance is more limited. Also, the utilization of mm Wave in 5G innovation turns the bothersome attributes of mm Wave because it relies upon the utilization of miniature foundations, for example, little cells spotted around thick city areas. This, combined with high reach frequencies, will be a critical quality of 5G organizations. Along these lines, mm Wave is just required across a restricted reach and the tight frequencies limit the danger of obstruction from different cells—upgrading the proficiency of the range. With many megahertz of remote transmission transfer speed accessible at focus frequencies like 24, 28, and 38 GHz, 5G remote organizations will be able to do just about zero-idleness calls and incredibly high information speeds [20].

In any case, there are numerous reasons why mm Wave gear has stayed inside space science, military, and examination applications for such countless years, past the significant expense of the parts and the overall shortage of test hardware for adjusting and assessing the equipment. Electromagnetic (EM) energy at those higher frequencies endures a lot of way misfortune through the air (particularly through the air with high stickiness) contrasted with lower recurrence signals with longer frequencies. Signals at 24 GHz or more can be consumed by any articles in their engendering way, like structures, trees, and even the hand of somebody holding the cell phone that is imparting the mm Wave signs to a phone site to associate with an audience. Nevertheless, mm Wave frequencies additionally have benefits, notwithstanding the liberal data transmissions they offer, like their utilization of a lot more modest receiving wires (to fit those more modest frequencies) contrasted with lower frequencies. The little size of these reception apparatuses makes it conceivable to pack large numbers of them together into little structure elements to profit from radio wire clusters [21].

The mechanical 5G use cases for mm Wave 5G are solid, with the innovation ready to give a dependable, elite network anyplace on the planet. Savvy port innovation is perhaps the most evolved modern application for 5G, promising to drive effectiveness and decrease costs through robotization and far off the activity of hardware. Coordination, mining, and different ventures will likewise be changed through the digitization of cycles and the upgraded profitability of the labor force. The genuine utilization of mm Wave recurrence groups in 5G remote organizations still cannot seem to be resolved, albeit the extra data transmission they offer is crucial to the improved exhibition guarantees of 5G organizations. The mm

Wave frequencies, for instance, may just be for open-air use, with indoor cell destinations working at under-6 GHz frequencies and giving indoor and open-air to indoor inclusion. The arrangement for the development of the 5G new radio (NR) framework is not to forsake 4G LTE, yet to add to the limit and inclusion previously given by 4G LTE organizations [22].

Forward-looking organizations, for example, Qualcomm, Skyworks, and Ericsson, have been grinding away on 5G parts and subsystems for quite a while. Qualcomm has worked intimately with the 3GPP on building up its 5G NR standard as a method for cost-successfully joining mm Wave innovation into reduced 5G base stations and versatile handsets. It will do so utilizing 3D beamforming and numerous info various yield (MIMO) receiving wire strategies [23].

5G Architecture

5G framework consists of a client terminal and improvises in various free independent radio access. The terminal consists of radio access known as IP which allows the user to connect to the world of the Internet. Each versatile terminal should have one radio access technology (RAT). The early two OSI levels describe advances in radio access using which we could access the Internet, which further depends upon the entrance innovation. The first two layers are the system layer and the above-described layer is the IP layer, of the OSI model. Currently, either IPv4 or IPv6 is used that pays little attention to the radio access innovation. IP offers sufficient control information for routing of IP bundles with an appropriate address according to their application. Web attachments are endpoints for information correspondence streams. Every attachment of the web is given a unique IP address. If there is a need for heterogeneous systems the nearby IP address and goal IP address must be fixed which will also support vertical handovers. The best possible design of the parcels and directing to the objective goal and the other way around must be extraordinary and should utilize a similar approach. A fitting IP interface is assigned to every radio access which can be accessed by the client. All these interfaces have their own IP address. At that point, changes in any of the parameters of the attachment means changing the attachment, i.e., shutting the attachment and opening another one. This methodology is not flexible, and it depends on the present Internet communication. So, to unravel this insufficiency a new layer is added that gives high system capacities and directing of parcels dependent on characterized approaches for direct routing of bundles.

3.4.2 Beyond 5G

The use of artificial intelligence (AI) with the nanotechnology will provide a boom in modern world technology. The robots can be controlled using mobile applications. Your mobile can consequently note the information about what you are

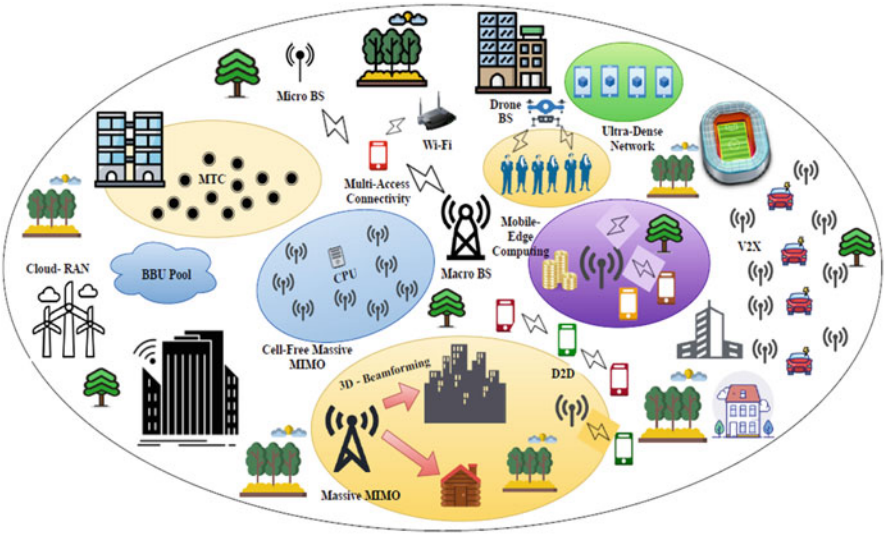

Fig. 3.8 Next-generation communication system [24]

thinking. There may be a situation where there is no need of any correspondence. The newly designed configurations provided by the Google will make 6G the most chased technology. The 6G in iPod comes in seven various hues and has a solid aluminum body to withstand a day-to-day use. 6G innovation has not been completely uncovered at this point yet search queries in the fields of portability, innovation, versatility, and arrangement have to be developed (Fig. 3.8).

AI and ML in Telecom Networks

In a service-driven next-generation network, a single infrastructure will need to deliver dynamic networks safely and efficiently like advanced mobile broadband, super-reliable and high speed with minimal latency communications, and vast computer-style communications. It can promote coexistence with various norms, such as 5G, LTE, and Wi-Fi. It should also coordinate an ambiguous network of numerous base station (BS) types, such as macro, nano, femto, and pico BS, as well as numerous consumer devices and applications. The task of a network provider is to effectively run a network capable of enabling versatility while fulfilling requirements of varied networks. Furthermore, network operators face major difficulties in widening their reach and addressing ever-increasing bandwidth demands with a small pool of capital and finite resources such as spectrum [23, 24]. Manual setup for network planning, tracking, and optimization might complicate matters to a greater extent. Operators have often optimized their networks, but even now, the prevalent strategy is to individually optimize single main success metrics, or an aspect within the network, using a limited range of data sources. Network analysis and optimization are also mostly based on old or even recorded data, greatly limiting their capabilities. Besides, network providers can ingress large volume of information from their subscribers and networks. Big data, when analyzed properly, can reflect greater intuitiveness and comprehension since it draws from various sources to expose previously unseen trends and associations [24]. It is advantageous to gain a better understanding of various uncertain principles and to deliver new steps for improving the efficiency of various stages of wireless networks. Analytics adds value to efficiency by broadening the spectrum of data sources and adopting a customer-centric, QoE-based approach for improving end-to-end network output. Network data analytics has already been launched as part of the third-generation collaboration initiative to seamlessly provide slice and traffic steering and slicing-based analytics. The European Telecommunications Standards Institute has developed an industry specification community named Experimental Network Intelligence, which defines a cognitive network management architecture focused on AI techniques and context-aware policies. The ENI model aids network administrators in automating the network setup and control procedures. In terms of operating costs, the system must be smart, self-aware, and self-adaptive, and it must be able to run network systems economically as well as maintain and operate networks autonomously. Traditional reactive maintenance is no longer effective. The predictive and constructive management of network components is feasible with big data analytics [25, 26].

AI methods, formed by Turing machine theory in the 1930s and rekindled by the invention of deep neural networks (DNN), have been widely applied in a variety of research areas, including computer vision and natural language processing (NLP), just to name a few. One of the earliest ways of creating AI is the artificial neural network. It is analogous to the brain in terms of computation, vast parallelism, and distributed representation. Recurrent neural networks (RNN) are a type of neural network that allows neurons to build and process memories of sequences of input patterns which are random, with the connectivity in between layers forming a loop. A deep neural network (DNN), also known as a deep belief network (DBN), has a hierarchical structure with several restricted Boltzmann machines and operates through a layer-by-layer learning mechanism. DBN's benefits stem from its multilayer structure, which allows for unsupervised learning, rapid inference, and versatility. A convolutional neural network is composed of layers of combining adaptable filters, resulting in growing attribute complexities [27]. A CNN differs significantly from a DBN wherein the DBN is a generative model which describes the joint data distribution and the resultant targets, while the CNN is an exclusionary model which describes the distribution of targets conditional on the distribution of information [28].

As illustrated in Fig. 3.9, recent developments in computing and AI have allowed wireless communications researchers to use AI, particularly in the perspective of 5G. By separating, collecting, and analyzing operational data, an AI-defined 5G network allows base stations (BSs)/cloud to establish a cognitive and secure data repository. Massive quantities of real-time data are produced by a diverse set of

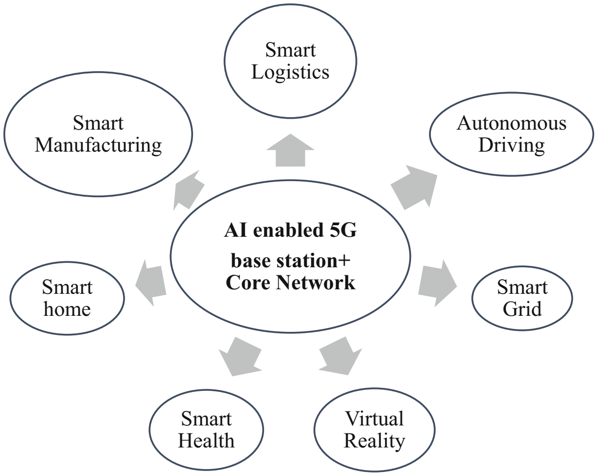

Fig. 3.9 Artificial intelligence 5G network's applications [27]

users, varying from channel-state information (CSI) to IoT system observations [29]. The collected data and geolocation databases are merged to offer a comprehensive view of the region. From the standpoint of person-centric connectivity, the reconfigurable AI-defined wireless network learns and adapts human activities to develop functionalities of the network and build services that are typically people oriented. In the telecommunications sector, AI technologies are rapidly assisting communications service providers (CSPs) in handling, improving, and sustaining not only networks but also customer service activities. Network management, automated maintenance, robotic assistants, and robotic process automation (RPA) are all examples of how AI has changed the telecom market, providing better consumer service, and added value to companies [30].

One of the most promising AI approaches is machine learning, which was developed to support smart radio terminals. Intelligent 5G cell terminals are required to independently monitor transmission capabilities while concentrating on energy consumption learning or intuition and concurrently modifying transmission protocols leveraging quality of the service learning or inference soon. ML may be applied to a broad range of technological challenges in next-generation systems, like large-scale MIMOs, heterogeneous networks made up of small cells and femtocells, and device-to-device (D2D) networks.

Basically, there are three types of machine learning techniques, all of which are used in wireless communication techniques and are shown in the tables below along with their subsections. Machine learning can be used in a number of applications such as fault detection, anomaly detection, cell or channel selection association, user behavior analysis, channel detection, or estimation spectrum sensing, just to name a few. Each teaching example, along with its name, must be fed into supervised learning. The intention is to train a learning algorithm on known optimal models of the problem and then use the approach to simulate optimal solutions from new in-formation. LTE small cells are increasingly being deployed to satisfy the high traffic needs of 5G networks [31]. These small-scale cells experience dynamic and complex interference patterns, necessitating the development of self-optimized technologies capable of resulting in smaller declines, faster data rates, and lower operator costs. Self-organizing networks (SON) should be able to grasp and adjust to changing conditions [32] and assess machine learning and statistical regression approaches (e.g., bagging tree, boosted tree, SVM, linear regressors). They began by gathering radio output measurements from the cells, such as path loss and throughput for various frequencies and bandwidth configurations. They then used learning-based approaches to modify the parameters to determine how a person would experience in the future. Artificial neural networks (ANNs) are a type of machine learning architecture that is commonly used to portray or estimate objective functions for current replicas or to create accurate replicas which are traditionally hard to decipher without the aid of machine language. ANNs have been proposed for next-generation wireless networks to address propagation loss approximation in diverse conditions, where the input parameters can indeed be chosen from knowledge about the transmitter, receiver, houses, frequency, and so on, and the learning network can learn to estimate the function that approximates the propagational loss to its best [33]. The learning model for supervised learning along with its application in mobile and wireless communication is shown in Table 3.1.

The data used to train the ML algorithms in unsupervised learning is a set of unlabeled features x1; x2;$\cdots$; xn, and the method looks for subgroups with identical characteristics without any instruction, characteristics of the variables. This approach is especially useful when searching for trends and associations in a dataset. The algorithm is never instructed to detect classes with similar attributes because the algorithm solves this relation on its own. However, in some situations, we will specify how many clusters we want the algorithm to generate. Clustering is a popular machine learning technology that has shown outstanding results when grouping edge devices in a mobile network [33]. The learning model for unsupervised learning along with its application in mobile and wireless communication is shown in Table 3.1.

Reinforcement learning is the process of teaching machine learning models to make a series of decisions. In an unpredictable, inherently difficult world, the agent learns to accomplish an objective. An AI is placed in a gamelike scenario in reinforcement learning. The machine uses trial and error to find a solution to the problem. For finding the right policy, an RL-based algorithm is used. Nkenyereye et al. [43] investigated the use of machine learning in CRNs. LTE-Unlicensed (LTE-U) has arisen as a solution to bandwidth shortages by using unlicensed spectrum. Maglogiannis et al. [44] investigated the learning method that accounts for the coexistence of "LTE and LTE-U" in order to model the resource distribution dilemma in "LTE-U" small stations (SBS). Authors in [43] proposed an RL algorithm focused on long short-term memory (RL-LSTM) cells to proactively distribute LTE-U services over the unlicensed spectrum. The dilemma is envisioned

Table 3.1 A compilation of plans for 5G mobile and wireless networking technologies focused on machine learning techniques

Machine learning techniques	Learning model	Application in mobile and wireless communication
Supervised learning	Statistical logistics regression	In the creation of self-organized LTE dense small cells, hierarchical frequency and bandwidth allocation are used [32]
	Deep neural networks (DNN)	Prediction and alignment of beamforming vectors at base stations using uplink pilot signals and learning mapping functions specific to the environment configuration [34]. MIMO channel estimation and DOA estimation [35]
Unsupervised learning	Hierarchical clustering	Detection of anomalies, faults, and intrusions in wireless mobile networks [36]
	Auto-encoders (AE)	Channel characterization is accomplished by seeing a communication system architecture as an end-to-end reconstruction mission, allowing transmitter and receiver components to be optimized in tandem in a single phase [37]
Reinforcement learning (RL)	Multi-armed bandit	HetNets power optimizer handover decision dilemma [38]. The UE partnership process's prejudice judgment for CRE, allocation of shared resources for LTE pico cells for interference control [39]
	Deep RL	Secondary consumers can use an anti-jamming technique to choose their contact platform and mobility [40] Secondary consumer anti-jamming approach to accelerate learning rate [41] Determine the sets of potentially linking neighboring vehicles and customize the capturing parameters in shared V2V networks [42]

as a noncooperative game between the SBSs, in which an RL-LSTM scheme enables the SBSs to efficiently understand which of the unauthorized channels to use based on the probability of potential changes in WLAN service and LTE-U traffic loads of the unauthorized channels. This work considers the utility of LTE-U for offloading certain LTE data flow, as well as the implications of AI in the context of RL-LSTM for long-term dependencies on learning, sequence, and time-series problems. Q-learning is used in [34] to ensure that "LTE and Wi-Fi" coexist in the unauthorized band in the spectrum. RL is used in wireless sensor [45].

3.4.3 New Wi-Fi, WiMAX Versions

Wireless technologies are utilized for assignments as straightforward as turning off the TV or as unpredictable as providing the business power with data from

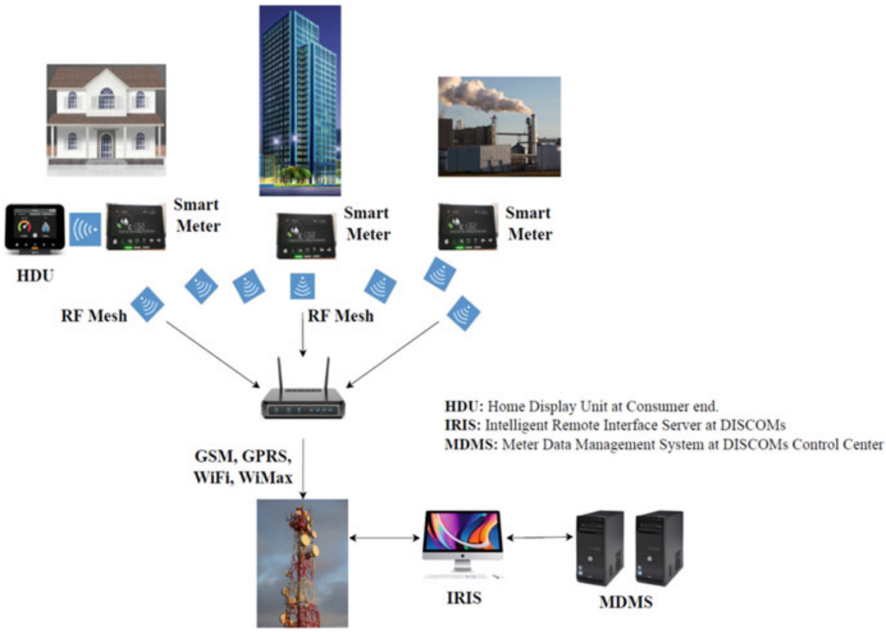

Fig. 3.10 An example of a system using Wi-Fi and WiMAX in smart cities and IOT

a mechanized endeavor application while in the field. Introductory arrangement cost could be somewhat high yet different benefits beat that significant expense. Fundamentally there are three different ways of arranging a wireless setup like point-to-point (or multipoint) and mesh or ad hoc network [46] (Fig. 3.10).

WiMAX offers the capability reach (up to 50 miles) and high data transmission (up to 50 Mb/s). This new radio innovation tremendously surpasses the abilities of generally utilized technologies like Wi-Fi, providing highlights which are not upheld in the present remote frameworks. The new WiMAX standard gives the chance for utilizing versatile reception apparatus framework (AAS); however, this usefulness has not been broadly executed. Not at all like a traditional omnidirectional antenna that squanders a large portion of its energy in headings without clients, a smart antenna can frame at least one beam toward fixed or versatile clients and make nulls toward impedances, hence extraordinarily improving framework execution. Smart antennas come in two types: switched beam and adaptive array. For a switched-beam system, a set of specific, sometimes predetermined, beam patterns are formed with the main lobe toward the mobile node. The antenna setup looks at the signal strength and switches among the lobes periodically to update beam selection. This antenna configuration improves execution by expanding signal strength and smothering obstructions that are not a similar way as the signal. Nevertheless, if impedance is inside a similar lobe as the signal, the obstruction will not be stifled, a significant hindrance of the switched-beam framework. An adaptive array uses refined signal-preparing calculations which constantly recognize among ideal signals and obstructions and which shape up a limitless number of beam patterns to ideally better the signal gain while smothering impedances [13, 47].

The adaptive array provides higher gain due to exact pointing capacity than the switched-beam array and more noteworthy obstruction dismissal. Adaptive arrays could need longer computational opportunity for merging ideal patterns; consequently it might not be appropriate to ongoing high information rate correspondences in areas which have an enormous number of profoundly portable nodes and obstructions [48]. Additionally, they will burn through a more prominent measure of force than a switched-beam array framework. In a framework where there is low impedance, a switched-beam system might be sufficient because it is less exorbitant and it can deliver a signal like an adaptive array. In a framework where there is impressive impedance, following the specific area of the nodes is a necessary piece of expanding framework execution and accordingly the adaptive array might be a superior decision. Various measures are of interest while dissecting a framework and regularly utilized measures are outage, for example likelihood of no connection, and furthermore bit error rate. Utilizing packet switched communication, measures as throughput and packet delay are substantial. Wireless methods communicate signals utilizing radio waves as the medium rather than wires. Wireless framework is simple and quick to convey in correlations of cabled network [49].

The IEEE 802.11b works in the 2.4 GHz band; there are obstruction issues with the numerous other principles that work in this band. Additionally, consistently an ever-increasing number of advances that utilize the 2.4 GHz band show up, which can be the reason for some working troubles. Nonetheless, it permits more prominent reach and more noteworthy ability to navigate hindrances than the 5 GHz band. IEEE 802.11b gadgets can arrive at a hypothetical information pace of 11 Mbps; however on the off chance that the obstructions increment or the signal force is decreased, second rate transmission speeds are embraced to have the option to limit the mistake rate. The transmission velocities will steadily diminish to 5.5, 2, and 1 Mbps. This usefulness is called adaptive rate selection (ARS). The IEEE 802.11g standard was endorsed in 2003 as the advancement of the standard IEEE 802.11b. Gadgets that satisfy the guideline are viable with those that follow IEEE 802.11b. Albeit the hypothetical transmission rate is 54 Mbps, the genuine transmission rate is roughly 24 Mbps. Besides, if an IEEE 802.11b-consistent gadget is brought into an IEEE 802.11g organization, the speed is altogether diminished, to oblige IEEE 802.11b transmission rates each time that gadget partakes in the transmission. The IEEE 802.16 standard is an advanced arrangement of norms to help broadband to be fixed and furthermore versatile remote interchanges [50]. WiMAX is a term contrived as a shortened form for Worldwide Interoperability for Microwave Access. The WiMAX association speed is utilized to control the smart grid. WiMAX is prepared to do conveying of information to cell phones at rates a few times quicker than current third-age (3G) cell speeds, despite the fact that WiMAX offers huge region inclusion supporting class QoS prerequisites. Then again, WiMAX is by and large utilized in an authorized range [51].

3.4.4 Vehicular Networks

Wireless systems are used in vehicular networks to increase road security and conveyance quality, particularly advantageous for an efficient driving aid. A wide variety of players are involved, including car manufacturers, wireless regulation regulators, and highway authorities. A broad variety of vehicle technologies, such as automated self-driving systems, toll collection systems, and information-provisioning systems, are being considered. Self-directed driving systems can detect changes in their environment by combining sensor information with signal-image processing to alert the driver of potentially hazardous street conditions. “Real-time wet road condition monitoring” and “anti-collision detection,” for example, are needed to improve not only vehicle protection but also vehicle performance [46].

Recent advancements in 5G networks and AI improve vehicular networks by enabling secure, effective, high-speed, and mutual communications. Vehicle-centric information (for example, pace, global positioning, system configuration, and performance), path-centric information (for example, road surface state, routing, collision), and passenger-centric information (for example, drowsiness, duration of incessant driving) are collected by autonomous vehicles and sent to the AI-defined 5G base station. The base station can analyze the actions of automated automobiles on street, forecasting vehicle speeds, driving conditions, hazards, and lane-changing behaviors to provide processed knowledge to highway networks and enhance road dynamics. The VANET allows automobiles to avoid problems by considering their desired behaviors or by monitoring the drivers; for example, during snafus in roads and highways or main roads, a distress warning can be transmitted to alert all other automobiles [52].

The importance of VANETs has grown because of the emergence of innovative ideas such as smart vehicle commuting, roadside advertising, and video games. Wireless nodes in a VANET may be categorized as handheld units or roadside units. Roadside units are fixed wireless nodes located adjacent to roads that have Internet access. Sensors offered by “Internet service providers (ISPs)” are usually roadside systems. In VANETs, this results in two forms of wireless communications: V2V communications and V2I correspondence. In V2V interaction, interaction between vehicles happens ad hoc, and critical situations are efficiently communicated [53]. VANETs have excellent network characteristics that set them apart from the rest of the autonomous networks, such as massively autonomous topology. The foreseen characteristics demonstrate that the current MANET-based routing principles face disagreements when locating clear paths for guiding messages in VANETs. Preliminary route recognition operations are performed in topology-based routing standards, and maximal bandwidth is used for episodic topology-based revisions [54]. Furthermore, major drawbacks to geography-based routing include network

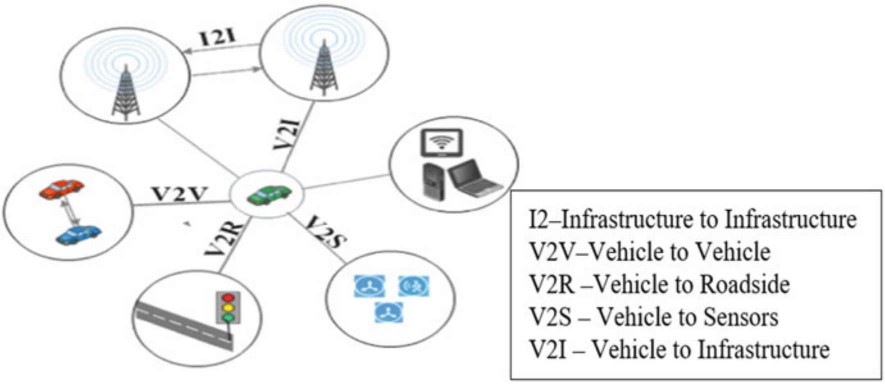

Fig. 3.11 VANET in smart cities and IOT [53]

segmentation and weak neighboring nodes, which can obstruct sufficient knowledge transfer, rendering them unsuitable for authentication-based implementations in VANETs (Fig. 3.11).

In VANET, routing standards are divided into many groups, including topology-based routing standards, location-based routing standards, group-based routing standards, geo cast routing standards, and relay-based routing standards. In order to route traffic, topology-based routing principles allow data use that exists in the network itself. There are three types of standards: reactive, constructive, and hybrid. The constructive protocol strategy enables a self-directed node to maintain routes to other nodes and rewrite its routing table [55]. The Reactive Protocol does not need to validate or revise its routing table, because the routes kept are just the same. The Hybrid Routing Standards (HRS) seek the best possible collaboration between constructive and reactive routing principles.

The above classification systems do not address the problems associated with VANETs and route intelligence. Moreover, the desired path choice is not only answered by vehicle displacement, focus, and paths. Since node relocations occur in VANETs, the spine must be reconstructed chronologically in order to assess the importance of fragmented, dynamic, and excellence. This is the primary explanation why the mediator is becoming a more appealing element of VANETs. The mediator-based analysis is used to analyze activity by considering various criteria like node exchange, association ratio, group head events, association security, and communication of message. The VANET structure is built on categories grouped by automatic mediators by forming a new category with the help of autonomous mediators common in VANETs. As a result, the analysis focuses on cars, and the group considers all the other vehicle options while topology modification-related options are unavailable. Both inspirations, which were studied based on the drawbacks obtained from the proposed scheme, are centered on mediator-based schemes, with an aim of designing a relatively flawless, minimum overhead, and customizable routing scheme in VANETs [56].

3.5 Smart Cities' Case Studies

A smart city is a platform, primarily made up of information and communication technologies (ICT), which are used to design, execute, and encourage sustainability activities to provide solutions to issues and hurdles caused by the increasing urbanization. A significant part of this ICT architecture is a smart network of linked objects and machines (also known as a smart city) that exchange data using wireless technologies and the cloud. Cloud-based IoT applications accumulate, process, and handle data in real time to assist businesses, municipalities, and inhabitants in making informed decisions that increase the quality of life. Citizens can interact smart city ecosystems in many ways which include laptops, mobile devices, wired cars, and houses. Combining sensors and data with physical technology and services in a community has the potential to minimize costs while enhancing sustainability. Local communities can use IoT to improve power provision, increase efficiency of garbage collection, reduce vehicular congestion, and enhance the standard of air [57, 58].

3.5.1 Smart City of Toronto

The consideration of the worldwide foundation market has fallen decisively on the Canadian city as it pondered the role it could play in the introduction of another age of PPPs that are becoming the overwhelming focus in the development of this area. In October 2017 Waterfront Toronto (a three-sided organization set up by the Government of Canada, Province of Ontario, and the City of Toronto) reported that it had chosen Sidewalk Labs as their advancement and financing accomplice to plan and build up another sort of mixed-use, complete local area on Toronto's Eastern Waterfront. Sidewalk Labs offered an exceptional vision of a brilliant local area at Quayside, in which they called their city as a stage. Key to this vison was an advanced layer of profoundly complex advanced foundation and frameworks that empowered the creation and the board of carefully empowered administrations [59].

A critical part of Sidewalk Labs city as a platform proposition was their arrangement to construct an advanced layer that empowers network, access, and information reconciliation across the segments of the city's actual layer. Deep data interlinking, in view of interoperable information principles and conventions, empowered the trading of smart city information between framework parts inside the computerized layer. Information interlinking of the computerized and actual layers raised a few concerns in regard to the part of information in the computerized layer, especially around information assortment, sharing, use, security, and protection. Computerized framework was a bunch of metropolitan innovation advancements that upheld the carefully empowered administrations. This included new normalized open-air mounts that gave admittance to power and interchange availability, software-defined networks that empowered a safer and versatile orga-

Fig. 3.12 Toronto smart city

nization foundation, super-passive optical network (Super-PON) that empowered adaptable rapid web access, and distributed verifiable credentials, a security saving innovation that gave people control and straightforwardness over the individual data they share [60] (Fig. 3.12).

Carefully empowered administrations involved a bunch of center computerized frameworks and subsystems addressing a cross-segment of shrewd city administrations needed for a complete local area at Quayside. These included center frameworks for the administration of versatility, cargo transportation, stopping, public domain, energy, squander, and what's more, stormwater. An aggregate of 18 significant administrations/frameworks and furthermore 52 subsystems were proposed and depicted in detail as the Quayside Digitally Enabled Services List. A central point of contention was the capacity of Sidewalk Labs to furnish Quayside with a variety of interconnected gadgets and sensors that were implanted in the advanced framework. This "Array of Things" (AoT) can gather and also screen a wide scope of metropolitan information and action from the metropolitan climate. Sidewalk Labs city as a platform vision for Quayside was an illustration of a change of a piece of Toronto's Eastern Waterfront toward a keen local area [61].

It featured the likely significant degrees of intricacy in the manner of interlinked frameworks and information streams associated inside the computerized layer, the likely startling results in the actual layer, and the different worries about advanced administration. Sidewalk Labs addressed an arising metropolitan innovation area utilizing computerized advancement to address the difficulties of smart networks and urban communities. The key inquiry was the degree of private area investment in zones, generally the obligation of public works and urban government. The

Quayside project offered a significant contextual analysis of the critical role the digital layer will play in future smart city arrangement and also advancement.

3.5.2 Smart City of Santiago

In Chile, smart city projects are only in their infancy, with "Chilectra," now "Enel Distribution," taking on the task of creating the "1st Smart City Model." The Santiago project launched at the end of 2011, as a first pilot, is comparable to projects produced by the Enel Endesa company in Spain, in particular, the popular smart city concept introduced in Málaga. That is how Smart City Santiago is being built in the Ciudad Empresarial business park, in the monastery of Huechuraba, in which every detail is intended to enhance people's quality of life [62].

The prototype is comprised of 15 organizations that invest in and contribute to the concept. Project model envisions the implementation of approximately 100 smart meters in client homes, development of an infrastructure integration showroom, integration of delivery network automated systems in medium-voltage networks, optimized and reliable lighting systems, electric transportation scheme with very little or no emission, and connections to information technology facilities. The aim of this experimental project is to put the smart grid idea to the test in different dimensions in a real network setting in Chile, and to research its implementation and prediction at larger scales in the urban environment.

Smart City Santiago is an initiative that aims to develop the environmental effects of human settlements and is Chile's first ecological urban center. One of the most important facets of designing an interconnected urban project is the introduction of a smart grid or smart network. Electric power can be controlled remotely and more effectively with smart grids. With real-time details and online communication along with the service provider, the operator can make fast decisions. The key argument and axis of what Smart City Santiago promotes are the effective and safe use of electricity, a model intended to improve people's quality of living by allowing users to encounter innovative approaches that maintain a harmonious relationship with the natural environment. The foregoing is due to the use of various useful and attractive instruments that contribute to conserving energy and, thus, to environmental stewardship. The model's goals are to enhance network energy management, improve demand balances, and include all agents in the electricity sector from production to utilization [63, 64].

3.6 Conclusion

IoT can be applied in agribusiness to expand the benefit and productivity of cultivating. It fills in as a superior path for actualizing horticulture and its related exercises. Right now, we have looked into different strategies, which will improve the present state of ranchers. The 5G wireless communication technology will provide much more applications to wireless network in mobile communication. More powerful and advanced features of these technologies will increase its future demands to a great extent. Though there is much more work that needs to be done and tested before the implementation of this technology as it is in a developing state, it beholds a bright future and will revolutionize mobile communication system. The smart cities of santiago and Toronto discussed in this chapter is real example where few components of cities are connected using IoT.

3.7 Future Scope

Multi-antenna systems are matured technology used in 4G and 5G wireless communication systems. Due to its high reliability, capability of high channel capacity, and better throughput, it is being implemented in other wireless communication technologies. Communication technologies are one of the essential components required at the physical layer in IoT applications. The use of artificial intelligence, machine learning, and reinforcement learning will make multi-antenna system and communication technologies more intelligent. This will give more benefits in improving the performance of IoT applications like smart cities, smart heath, and smart grid.

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Chapter 4
Design of Multiple Access Network by Enabling User Grouping and Energy Harvesting in Relaying System for Smart Cities

Minh-Sang Van Nguyen, Samarendra Nath Sur, and Dinh-Thuan Do

4.1 Introduction

This book chapter investigates multiple accesses protocols for smart city applications by enabling energy harvesting (EH) scheme. We focus on the system model that combines EH, and a cooperative NOMA system is introduced. In the proposed scheme, the relay harvests energy from the base station to serve some user groups including the near and far users. Later, SWIPT technique is exploited to determine performance improvement at least amount of harvested energy. The other parameters need to investigate the impact of imperfect power allocation factors on system performance. It is proved that introducing SWIPT does not harm system performance. Furthermore, the outage probability of both near and far users is derived and indicated in closed-form expressions. Numerical simulations are conducted to examine the outage probability of the proposed scheme and to verify the derived formulas. The proposed scheme has the potential to solve the problem of EH in the context of the smart city.

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Internet of things (IoT) is an emerging technique that enabled efficient information exchange between massively deployed smart devices and considered to be an integral part of future communication systems and the beyond 5G networks [1, 2]. Apart from the deployment strategies, energy efficiency and spectrum efficiency (SE) are two major thrust areas for achieving the goal of smart city, and it becomes much more convenient with the growing deployment and the demand of data hungry application [3, 4]. Therefore, it is required that researchers should put more focus on the areas like radio resource management, cognitive network architectures, energy consumption aspect of the networks, etc.

Now to have a sustainable solution for the smart cities, deployment of IoT devices and their integration with future generation communication systems are very much needed. But from the point of view of the sustainability of the networks, EH is considered to be one of the best solutions to realize an energy efficient network [5, 6]. EH is envisioned as a suitable technique for providing required energy for cooperative communication, information transfer, and for a vast application of wireless communication systems [7]. Lots of works have been carried out to address the issue of EH for the future generation communication system. In [8], the authors have investigated an EH cooperative communication protocol, and in this protocol, users can collect energy from the ambient environment for successful information transmission. In [9], the authors have demonstrated that relay nodes can harvest energy from wireless signals and also provide insight into the outage probability of the system.

The next-generation networks (5G and beyond) are aiming for providing high data rate, massive connections, ultralow latency, and along with reliable link under high mobility condition. Considering as a promising wireless access approach for the coming 5G era, NOMA has great attentions [10–19]. NOMA is proven to be beneficial for extending the coverage of network, improving the performance in terms of SE, EH, and also supporting dense networks. In the principle of NOMA, at the transmitter side, non-orthogonal transmission is required and users' signals are differentiated in the power domain. As a result, higher SE can be achieved. More advances compared with traditional orthogonal multiple access (OMA), NOMA-aided transmitter can send signals to multiple terminals over the same resource block, and effective improvement can be obtained in terms of sum rate. The NOMA systems adopt successive interference cancellation (SIC) to decode the users' signal at the receiver. In terms of decoding order, systems have a higher priority to decode the user with the best channel condition, while other users are considered as noise terms. In [20], the authors gave the review on NOMA and the authors compared traditional multiple access techniques with NOMA. Specifically, NOMA is recommended to apply to the 5G communication system. Due to non-orthogonal transmission and SIC, NOMA can enhance SE.

The normal energy supply is limited for the users in NOMA-aided systems; for example, it is difficult to replace the battery in some places and/or limits the system performance improvement. To overcome this difficulty, EH architecture is studied to harvest energy from the surrounding environments. To provide a flexible, sustainable, and stable energy supply, radio frequency (RF) energy harvesting [21–

23] allows users to harvest the energy from the RF signals. For example, SWIPT has been widely explored in emerging systems [24–29]. In [27], the authors have proposed an optimal wireless power method to improve the outage probability by utilizing the harvested RF energy. As in [28], the RF energy harvesting approach can be utilized for the benefit of cognitive networks and a detailed study has been presented.

The authors in [30] studied the resource optimization problem of NOMA heterogeneous small cell networks with SWIPT. The authors in [31] considered an EH-based incremental relaying cooperative NOMA (IR-EH-NOMA) approach, with a two-user downlink network model. They derived analytical formulas for the system throughput of the IR-EH-NOMA network. They evaluated the performance of conventional cooperative relaying NOMA network with EH (CR-EH-NOMA) in the delay-limited transmission mode; two real situations are examined such as maximal ratio combining (MRC) and imperfect successive interference cancellation. Motivated by Zhang et al. [30], Reshma and Babu [31], this book chapter studies EH for NOMA relaying system by considering outage performance of two users. With the aim of providing the solution for smart city, in this book chapter, we present the system performance analysis of relaying network to serve a specific group of users.

The rest of this chapter is organized as follows. The system model is described in Sect. 4.2. Section 4.3 presents the mathematical calculation for outage probability, and Sect. 4.4 shows the simulation results along with analysis. Finally, Sect. 4.5 concludes the paper.

4.2 System Model

We consider the relaying system containing the base station (BS) intends to serve the near (U_1) and far users (U_2) in the context of NOMA, shown as Fig. 4.1. The BS communicates with U_2 through relay (R) that is able to harvest energy from the BS. In the first phase of communication, the received signal regarding link BS-U_1 is given by Dang et al. [32]

$$x_{SU_1} = \sqrt{P_B} f_1 \left(\sqrt{\phi_1} s_1 + \sqrt{\phi_2} s_2 \right) + \varpi_{U1}, \tag{4.1}$$

where $\phi_1 + \phi_2 = 1$ and $\phi_1 < \phi_2$. We can see the main parameters in Table 4.1.

The received signal-to-interference-plus-noise ratio (SINR) at BS-U_1 to detect U_2's message s_2 is given by

$$\gamma_{SU_1}^{(s_2 \to 1)} = \frac{P_B \phi_2 |f_1|^2}{P_B \phi_1 |f_1|^2 + N_0}. \tag{4.2}$$

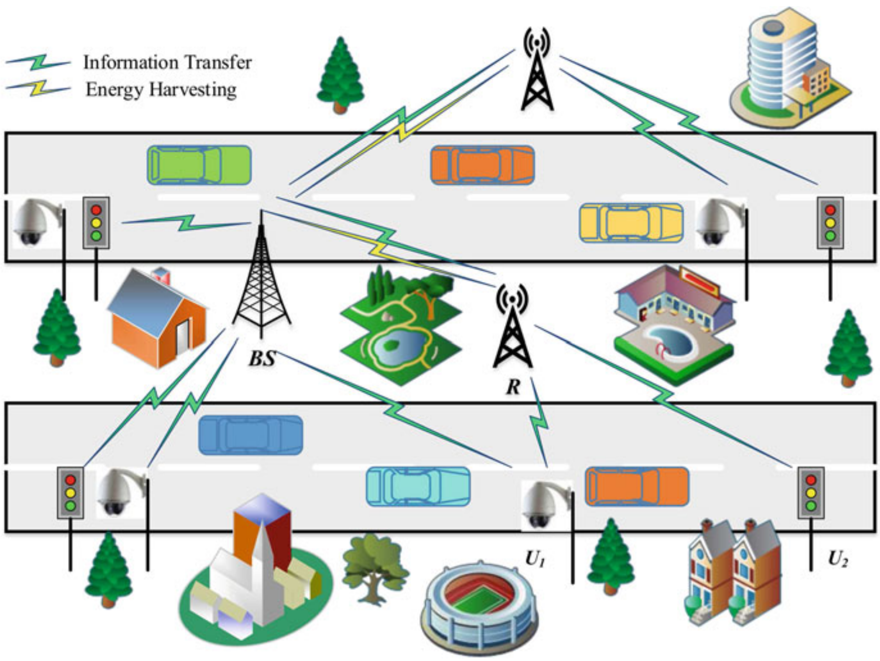

Fig. 4.1 System model (a typical scenario for smart city)

After SIC, the received SINR at BS-U_1 to detect its own message s_1 is given by

$$\gamma_{SU_1}^{(s_1)} = \frac{P_B\phi_1|f_1|^2}{N_0}. \tag{4.3}$$

R harvests energy from the BS in the first phase and uses such energy to transmit the signal to U_1 and U_2 in the second phase. Therefore, by employing power-splitting protocol (PS) [31, 33], the received signal at R in the first phase is expressed as

$$x_{SR} = (1-\alpha)\sqrt{P_B}f_2\left(\sqrt{\phi_1}s_1 + \sqrt{\phi_2}s_2\right) + \varpi_R. \tag{4.4}$$

The received SINR at BS-R to detect U_2's message s_2 is computed by

$$\gamma_{SR}^{(s_2)} = \frac{(1-\alpha)\,P_B\phi_2|f_2|^2}{(1-\alpha)\,P_B\phi_1|f_2|^2 + N_0}. \tag{4.5}$$

Using SIC, the received SINR at BS-U_1 to detect its own message s_1 is formulated by

Table 4.1 Definitions of Notations

Notation	Meaning
Pr (.)	Probability operator
$CN(u, v)$	A complex Gaussian distribution with mean u and variance v
f_X (.)	The probability density function (PDF)
F_X (.)	The cumulative distribution function (CDF)
K_1(.)	The modified first-order Bessel function of the second kind
P_B	The transmit power of BS
P_R	The power of the R
s_1	The information symbol to U_1
s_2	The information symbol to U_2
ϕ_1	The power allocation coefficients of U_1
ϕ_2	The power allocation coefficients of U_2
ϖ_{U1}	The additive white Gaussian noise (AWGN) at U_1 with $\varpi_{U1} \sim CN\,(0, N_0)$
ϖ_{U2}	The additive white Gaussian noise (AWGN) at U_2 with $\varpi_{U2} \sim CN\,(0, N_0)$
ϖ_R	The additive white Gaussian noise (AWGN) at R with $\varpi_R \sim CN\,(0, N_0)$
N_0	The normalized noise variance
α	The power-splitting coefficient
ρ	Energy conversion efficiency
R_1	The target rate to decode s_1
R_2	The target rate to decode s_2
f_1	The channel coefficient between the BS-U_1 with $f_1 \sim CN\,(0, \varphi_1)$
f_2	The channel coefficient between the BS–R with $f_2 \sim CN\,(0, \varphi_2)$
f_3	The channel coefficient between the R-U_1 with $f_3 \sim CN\,(0, \varphi_3)$
f_4	The channel coefficient between the R-U_2 with $f_4 \sim CN\,(0, \varphi_4)$

$$\gamma_{SR}^{(s_1)} = \frac{(1-\alpha)\, P_B \phi_1 |f_2|^2}{N_0}. \tag{4.6}$$

In the second phase of communication, the received signal at R-U_1 is given by Dang et al. [32]

$$x_{RU1} = \sqrt{P_R} f_3 \left(\sqrt{\phi_1} s_1 + \sqrt{\phi_2} s_2\right) + \varpi_{U1}. \tag{4.7}$$

The received SINR at R-U_1 to detect U_2's message s_2 is calculated by

$$\gamma_{RU_1}^{(s_2 \to 1)} = \frac{P_R \phi_2 |f_3|^2}{P_R \phi_1 |f_3|^2 + N_0}. \tag{4.8}$$

After SIC, the received SINR at R-U_1 to detect its own message s_1 is given by

$$\gamma_{RU_1}^{(s_1)} = \frac{P_R \phi_1 |f_3|^2}{N_0}. \tag{4.9}$$

The received signal at R-U_2 is given by Dang et al. [32]

$$x_{RU2} = \sqrt{P_R} f_4 \left(\sqrt{\phi_1} s_1 + \sqrt{\phi_2} s_2 \right) + \varpi_{U2}. \tag{4.10}$$

The received SINR at U_2 to detect its own message s_2 is given by

$$\gamma_{RU_2}^{(s_2)} = \frac{P_R \phi_2 |f_4|^2}{P_R \phi_1 |f_4|^2 + N_0}. \tag{4.11}$$

We assume U_1 regarding two associated links and hence, the decision rule for selecting one of the links at U_1 in the case of the full selection combining (SC) [34, 35]. Therefore, the instantaneous SINR at user U_1 is written as

$$\gamma_{U_1} = \max \left(\min \left(\gamma_{SU_1}^{(s_2 \to 1)}, \gamma_{SU_1}^{(s_1)} \right), \min \left(\gamma_{SR}^{(s_1)}, \gamma_{RU_1}^{(s_2 \to 1)}, \gamma_{RU_1}^{(s_1)} \right) \right). \tag{4.12}$$

The instantaneous SINR at user U_2 is written as

$$\gamma_{U_2} = \min \left(\gamma_{SR}^{(s_2)}, \gamma_{RU_2}^{(s_2)} \right). \tag{4.13}$$

The energy harvested at relay R is given by Nasir et al. [33], Yang et al. [36]

$$P_R = \alpha \rho P_B |f_2|^2. \tag{4.14}$$

4.3 Outage Probability

When U_1 and U_2 transmit at fixed target rates R_1 and R_2, the outage probability, which is defined as the probability of the instantaneous SINR falls below a predefined threshold, becomes an appropriate performance metric. We define:

4.3.1 Outage Probability of U_1

In this section, we explore the situation where R harvests energy from the RF signal that is sent from BS and U_1 receives the signal s_1 from either BS or the best relay, an outage event at U_1 happens if R cannot successfully detect s_1 or U_1 cannot successfully decode s_1 from BS if the link is selected. Otherwise, the outage event occurs if the best relay cannot decode s_1 or U_1 cannot successfully decode the signal forwarded from BS. The outage probability (OP) for U_1 can therefore be obtained as [32]

$$\begin{aligned} OP_1 &= \Pr\left(\max\left(\min\left(\gamma_{SU_1}^{(s_2\to 1)}, \gamma_{SU_1}^{(s_1)}\right), \min\left(\gamma_{SR}^{(s_1)}, \gamma_{RU_1}^{(s_2\to 1)}, \gamma_{RU_1}^{(s_1)}\right)\right) < \beta_1\right) \\ &= \underbrace{\Pr\left(\min\left(\gamma_{SU_1}^{(s_2\to 1)}, \gamma_{SU_1}^{(s_1)}\right) < \beta_1\right)}_{\Theta_1} \underbrace{\Pr\left(\min\left(\gamma_{SR}^{(s_1)}, \gamma_{RU_1}^{(s_2\to 1)}, \gamma_{RU_1}^{(s_1)}\right) < \beta_1\right)}_{\Theta_2}. \end{aligned} \tag{4.15}$$

Proposition 1 *The exact OP of U_1 can be written as*

$$\begin{aligned} OP_1 &= \left[1 - \exp\left(-\frac{\Omega}{\varphi_1}\right)\right] \\ &\quad \times \left[1 - \exp\left(-\frac{N_0\beta_1}{(1-\alpha)\, P_B\phi_1\varphi_2}\right)\sqrt{\frac{4\Omega}{\alpha\rho\varphi_2\varphi_3}} K_1\left(\sqrt{\frac{4\Omega}{\alpha\rho\varphi_2\varphi_3}}\right)\right], \end{aligned} \tag{4.16}$$

where $\beta_1 = 2^{2R_1} - 1$, $\Omega = \max\left(\frac{N_0\beta_1}{P_B(\phi_2-\beta_1\phi_1)}, \frac{N_0\beta_1}{P_B\phi_1}\right)$.

Proof See Appendix A.

4.3.2 *Outage Probability of U_2*

In this case, according to the principle of NOMA, an outage event at U_2 will occur when U_2 and R cannot detect s_2 as [35]

$$\begin{aligned} OP_2 &= \Pr\left(\min\left(\gamma_{SR}^{(s_2)}, \gamma_{RU_2}^{(s_2)}\right) < \beta_2\right) \\ &= 1 - \underbrace{\Pr\left(\gamma_{SR}^{(s_2)} \geq \beta_2\right)}_{Z_1} \underbrace{\Pr\left(\gamma_{RU_2}^{(s_2)} \geq \beta_2\right)}_{Z_2}. \end{aligned} \tag{4.17}$$

Proposition 2 *The exact OP of U_2 can be written as*

$$\begin{aligned} OP_2 &= 1 - \exp\left(-\frac{\beta_2 N_0}{((1-\alpha)\,\phi_2 - \beta_2\,(1-\alpha)\,\phi_1)\, P_B\varphi_2}\right) \\ &\quad \times \sqrt{\frac{4\beta_2 N_0}{(\phi_2 - \beta_2\phi_1)\,\alpha\rho P_B\varphi_2\varphi_4}} K_1\left(\sqrt{\frac{4\beta_2 N_0}{(\phi_2 - \beta_2\phi_1)\,\alpha\rho P_B\varphi_2\varphi_4}}\right), \end{aligned} \tag{4.18}$$

where $\beta_2 = 2^{2R_2} - 1$.

Proof See Appendix B.

4.3.3 The Imperfect SIC at U_1

We consider SINR at the link BS-U_1 to detect its own message s_1 as [37]

$$\gamma_{SU_1}^{(ip,s_1)} = \frac{P_B\phi_1|f_1|^2}{P_B\phi_2\left|\widetilde{f_1}\right|^2 + N_0}, \tag{4.19}$$

where $\widetilde{f_1} \sim CN(0, k_1\varphi_1)$, k_1 $(0 \le k_1 \le 1)$ is the level of residual interference at BS-U_1 due to SIC imperfection. With regard to specific case, $k_1 = 0$ and $k_1 = 1$ represent perfect SIC and no SIC, respectively [37, 38].

Similarly, we compute the received SINR at the link BS-R to detect its own message s_1 as

$$\gamma_{SR}^{(ip,s_1)} = \frac{(1-\alpha)\,P_B\phi_1|f_2|^2}{(1-\alpha)\,P_B\phi_2\left|\widetilde{f_2}\right|^2 + N_0}, \tag{4.20}$$

where $\widetilde{f_2} \sim CN(0, k_2\varphi_2)$, and the level of residual interference at R because of SIC imperfection is denoted by k_2 [37, 38].

Considering the link R-U_1, we calculate the received SINR to detect its own message s_1 as

$$\gamma_{RU_1}^{(ip,s_1)} = \frac{P_R\phi_1|f_3|^2}{P_R\phi_2\left|\widetilde{f_3}\right|^2 + N_0}, \tag{4.21}$$

where $\widetilde{f_3} \sim CN(0, k_3\varphi_3)$, and the level of residual interference at R-U_1 associated with SIC imperfection is denoted by k_3 [37, 38].

The outage probability of user U_1 with imperfect SIC is formulated by Do et al. [37]

$$\begin{aligned} OP_{ip,1} &= \Pr\left(\max\left(\gamma_{SU_1}^{(ip,s_1)}, \min\left(\gamma_{SR}^{(ip,s_1)}, \gamma_{RU_1}^{(ip,s_1)}\right)\right) < \beta_1\right) \\ &= \underbrace{\Pr\left(\gamma_{SU_1}^{(ip,s_1)} < \beta_1\right)}_{\Lambda_1}\underbrace{\Pr\left(\min\left(\gamma_{SR}^{(ip,s_1)}, \gamma_{RU_1}^{(ip,s_1)}\right) < \beta_1\right)}_{\Lambda_2}. \end{aligned} \tag{4.22}$$

Proposition 3 *The exact OP of U_1 for imperfect SIC can be written as*

$$\begin{aligned} OP_{ip,1} = &\left[1 - \frac{\phi_1}{\beta_1\phi_2 k_1 + \phi_1}\exp\left(-\frac{\beta_1 N_0}{P_B\phi_1\varphi_1}\right)\right] \\ &\times\left[1 - \frac{\phi_1}{\beta_1\phi_2 k_2 + \phi_1}\frac{\phi_1}{\beta_1\phi_2 k_3 + \phi_1}\exp\left(-\frac{\beta_1 N_0}{(1-\alpha)\,P_B\phi_1\varphi_2}\right)\right]. \end{aligned} \tag{4.23}$$

Proof See Appendix C.

4.3.4 The Benchmark: OMA

In the first phase, the received signal for the link BS-U_1 is given by Do et al. [37]

$$x_{SU_1}^{O} = \sqrt{P_B} f_1 s_1 + \varpi_{U1}. \tag{4.24}$$

We formulate SINR at link BS-U_1 to detect its own message s_1 as

$$\gamma_{SU_1}^{(O,s_1)} = \frac{P_B |f_1|^2}{N_0}. \tag{4.25}$$

The receiving signal at the link BS-R is expressed as [37]

$$x_{SR}^{O} = (1-\alpha)\sqrt{P_B} f_2 s_i + \varpi_R. \tag{4.26}$$

As a result, the received SINR at BS-R to detect s_i is formulated by

$$\gamma_{SR}^{(O,s_i)} = \frac{(1-\alpha) P_B |f_2|^2}{N_0}. \tag{4.27}$$

In the second phase, the received signal at R-U_i is computed by Do et al. [37]

$$x_{RU_i}^{O} = \sqrt{P_R} f_X s_i + \varpi_{Ui}, (X = 3, 4). \tag{4.28}$$

To detect signal s_i, the received SINR at R-U_i is written by

$$\gamma_{RU_i}^{(O,s_i)} = \frac{P_R |f_X|^2}{N_0}. \tag{4.29}$$

Therefore, we achieve the instantaneous SINR at user U_1 as

$$\gamma_{U_1}^{O} = \max\left(\gamma_{SU_1}^{(O,s_1)}, \min\left(\gamma_{SR}^{(O,s_1)}, \gamma_{RU_1}^{(O,s_1)}\right)\right). \tag{4.30}$$

Then, at U_2 the instantaneous SINR U_2 is computed by

$$\gamma_{U_2}^{O} = \min\left(\gamma_{SR}^{(O,s_2)}, \gamma_{RU_2}^{(O,s_2)}\right). \tag{4.31}$$

The OP (in OMA mode) for U_1 can be obtained as [37]

$$\begin{aligned} OP_1^{O} &= \Pr\left(\max\left(\gamma_{SU_1}^{(O,s_1)}, \min\left(\gamma_{SR}^{(O,s_1)}, \gamma_{RU_1}^{(O,s_1)}\right)\right) < \beta_1^{O}\right) \\ &= \underbrace{\Pr\left(\gamma_{SU_1}^{(O,s_1)} < \beta_1^{O}\right)}_{\Upsilon_1} \underbrace{\Pr\left(\min\left(\gamma_{SR}^{(O,s_1)}, \gamma_{RU_1}^{(O,s_1)}\right) < \beta_1^{O}\right)}_{\Upsilon_2}. \end{aligned} \tag{4.32}$$

Proposition 4 *The closed-form OP of* U_1 *is given by*

$$OP_1^O = \left[1 - \exp\left(-\frac{\beta_1^O N_0}{P_B \varphi_1}\right)\right] \times \left[1 - \exp\left(-\frac{\beta_1^O N_0}{(1-\alpha) P_B \varphi_2}\right) \sqrt{\frac{4\beta_1^O N_0}{\alpha\rho P_B \varphi_3 \varphi_2}} K_1\left(\sqrt{\frac{4\beta_1^O N_0}{\alpha\rho P_B \varphi_3 \varphi_2}}\right)\right], \tag{4.33}$$

where $\beta_1^O = 2^{5R_1} - 1$.

Proof See Appendix D.

The outage probability of U_2 can be expressed as [37]

$$\begin{aligned} OP_2^O &= \Pr\left(\min\left(\gamma_{SR}^{(O,s_2)}, \gamma_{RU_2}^{(O,s_2)}\right) < \beta_2^O\right) \\ &= 1 - \underbrace{\Pr\left(\gamma_{SR}^{(O,s_2)} \geq \beta_2^O\right)}_{Z_1^O} \underbrace{\Pr\left(\gamma_{RU_2}^{(O,s_2)} \geq \beta_2^O\right)}_{Z_2^O}. \end{aligned} \tag{4.34}$$

Proposition 5 *The closed-form OP of* U_2 *is calculated by*

$$OP_2^O = 1 - \exp\left(-\frac{\beta_2^O N_0}{(1-\alpha) P_B \varphi_2}\right) \sqrt{\frac{4\beta_2^O N_0}{\alpha\rho P_B \varphi_4 \varphi_2}} K_1\left(\sqrt{\frac{4\beta_2^O N_0}{\alpha\rho P_B \varphi_4 \varphi_2}}\right), \tag{4.35}$$

where $\beta_2^O = 2^{4R_2} - 1$.

Proof From (4.34), Z_1^O can be first calculated as

$$\begin{aligned} Z_1^O &= \Pr\left(\gamma_{SR}^{(O,s_2)} \geq \beta_2^O\right) \\ &= \Pr\left(\frac{(1-\alpha) P_B |f_2|^2}{N_0} \geq \beta_2^O\right) \\ &= \Pr\left(|f_2|^2 \geq \frac{\beta_2^O N_0}{(1-\alpha) P_B}\right) \\ &= \exp\left(-\frac{\beta_2^O N_0}{(1-\alpha) P_B \varphi_2}\right). \end{aligned} \tag{4.36}$$

Then, Z_2^O can be further computed as

$$
\begin{aligned}
Z_2^O &= \Pr\left(\gamma_{RU_2}^{(O,s_2)} \geq \beta_2^O\right) \\
&= \Pr\left(\frac{\alpha\rho P_B |f_2|^2 |f_4|^2}{N_0} \geq \beta_2^O\right) \\
&= \Pr\left(|f_4|^2 \geq \frac{\beta_2^O N_0}{\alpha\rho P_B |f_2|^2}\right) \\
&= \int_0^\infty \left(1 - F_{|f_4|^2}\left(\frac{\beta_2^O N_0}{\alpha\rho P_B x}\right)\right) f_{|f_2|^2}(x)\, dx \\
&= \int_0^\infty \exp\left(-\frac{\beta_2^O N_0}{\alpha\rho P_B \varphi_4 x}\right) \frac{1}{\varphi_2} \exp\left(-\frac{x}{\varphi_2}\right) dx \\
&= \frac{1}{\varphi_2} \int_0^\infty \exp\left(-\frac{\beta_2^O N_0}{\alpha\rho P_B \varphi_4 x} - \frac{x}{\varphi_2}\right) dx \\
&= \sqrt{\frac{4\beta_2^O N_0}{\alpha\rho P_B \varphi_4 \varphi_2}} K_1\left(\sqrt{\frac{4\beta_2^O N_0}{\alpha\rho P_B \varphi_4 \varphi_2}}\right).
\end{aligned}
\tag{4.37}
$$

Finally, replacing (4.36) and (4.37) into (4.34), the outage probability for U_2 OMA in this mode can be computed. It completes the proof.

4.4 Numerical and Simulation Results

In this section, simulation results are provided to demonstrate the performance of the proposed cooperative NOMA systems. The simulation parameters, unless otherwise specified, are summarized in Table 4.2.

Table 4.2 Main parameters for numerical results [38]

Parameter	Value
The power allocation coefficients of U_1	$\phi_1 = 0.3$
The power allocation coefficients of U_2	$\phi_2 = 0.7$
The power-splitting coefficient	$\alpha = 0.6$
Energy conversion efficiency	$\rho = 0.6$
The target rate to decode s_1	$R_1 = 0.5$ (bps/Hz)
The target rate to decode s_2	$R_2 = 0.5$ (bps/Hz)
Transmit SNR	$P_B/N_0 = 10$ (dB)
Residual interference	$k_1 = k_2 = k_3 = 0.1$
Channel gains	$\varphi_1 = \varphi_2 = \varphi_3 = \varphi_4 = 1$

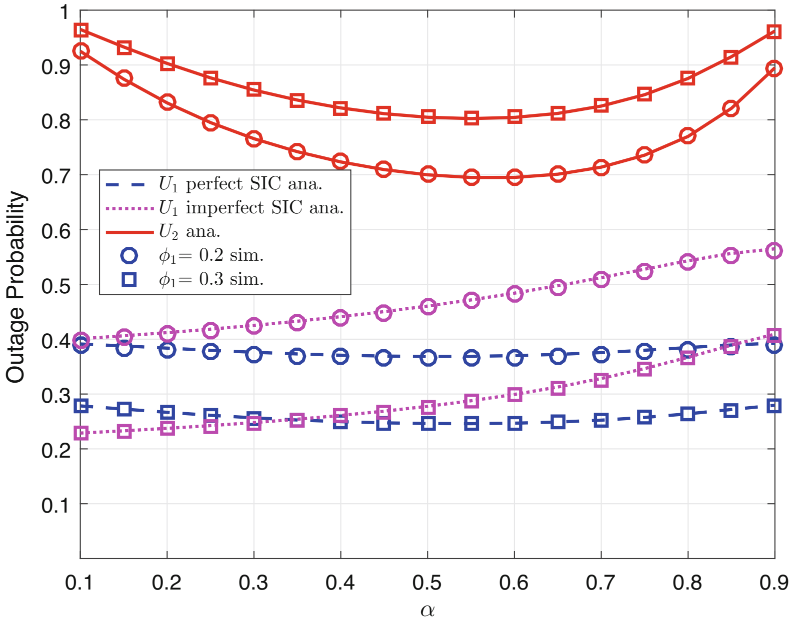

Fig. 4.2 Outage performance of U_1 (perfect SIC, imperfect SIC) and U_2 versus α as varying ϕ_1

In Figs. 4.2 and 4.3, we can see outage probabilities of two users depend on amount of harvested energy. As can be seen in Fig. 4.2, user U_2 benefits from energy harvesting since the optimal point is about 0.65. In these figures, the OP for imperfect SIC is worse than that with perfect SIC.

The target rate limits performance of two users, as shown in Fig. 4.4. The higher target rates lead to worse performance. The main reason is that the OP performance depends on SINR, while SINR depends on target rates.

Interestingly, we can find OP performance for two users U_1, U_2 as in Fig. 4.5. It can be explained that these OPs rely on power allocation factors. Fortunately, we can find optimal OP for user U_2.

As conditioning on power allocation factor, OP performance will be adjusted by the transmit SNR at the source. It can be seen clearly that the outage performance of user U_1 is better than that of user U_2 at whole range of transmit SNR at source, as shown in Fig. 4.6.

4.5 Conclusion

In this chapter, we have explored the possibilities of energy harvesting and NOMA from the point of view of smart cities. We have studied the impact of the energy harvesting on system performance metric of NOMA system. We focus on outage

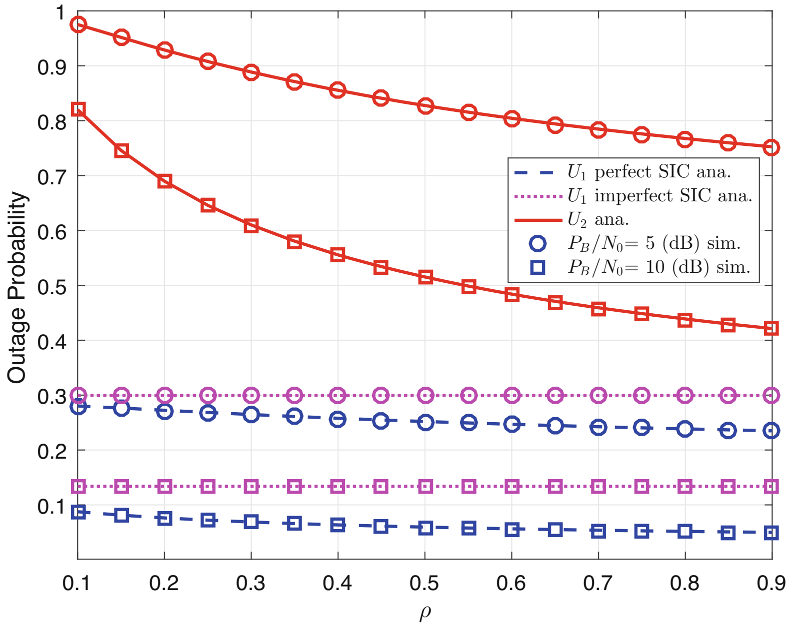

Fig. 4.3 Outage performance of U_1 (perfect SIC, imperfect SIC) and U_2 versus ρ as varying P_B/N_0

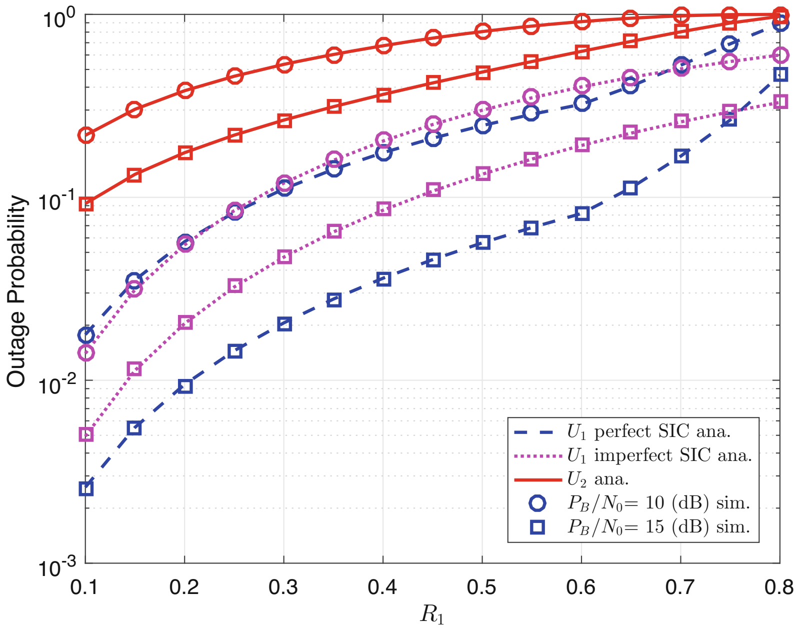

Fig. 4.4 Outage performance of U_1 (perfect SIC, imperfect SIC) and U_2 versus $R_1 = R_2$ as varying P_B/N_0

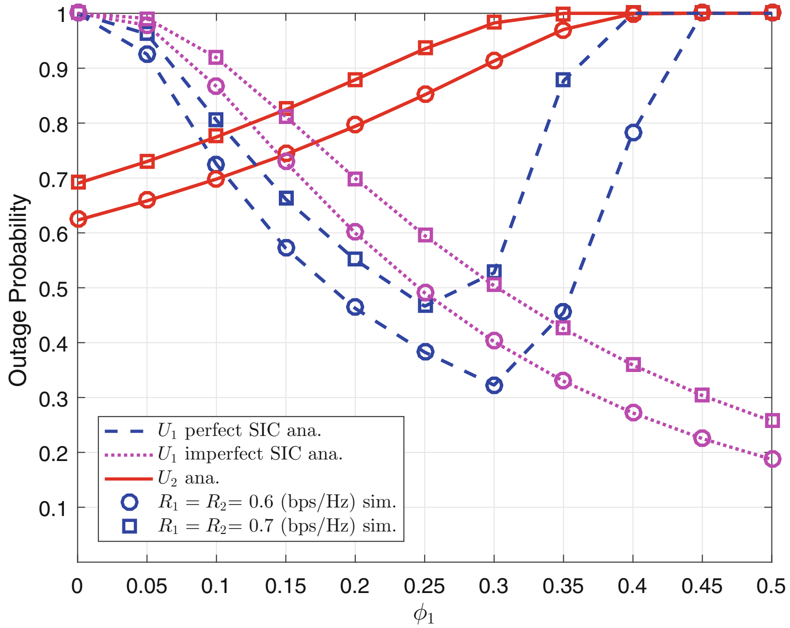

Fig. 4.5 Outage performance of U_1 (perfect SIC, imperfect SIC) and U_2 versus ϕ_1 as varying $R_1 = R_2$

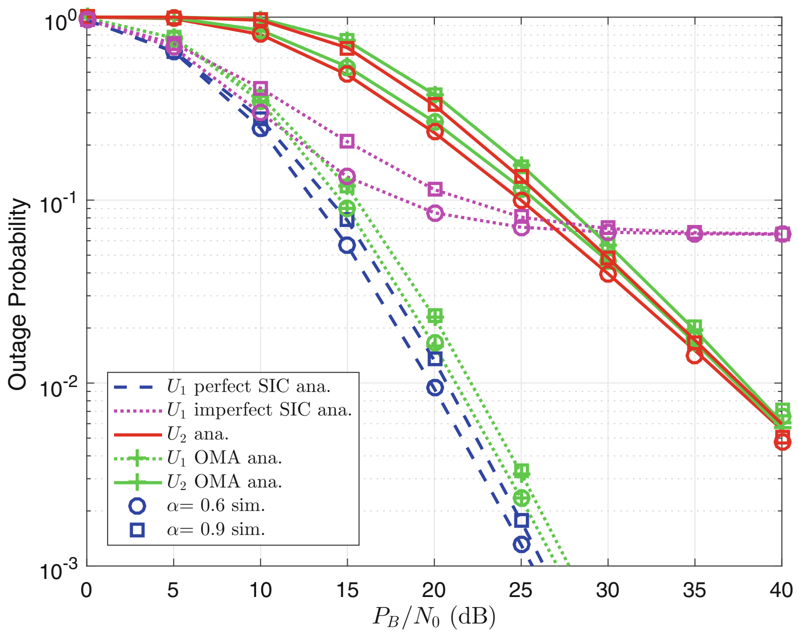

Fig. 4.6 Outage performance of U_1 (perfect SIC, imperfect SIC), U_2 and OMA versus P_B/N_0 as varying α

probability for two users with fixed power allocation factors adopted to make differences among two users. When the relay is able to harvest a larger amount of harvested energy, the system performance can be improved significantly. Further, we have obtained optimal outage probability for specific user with given power allocation factor. Therefore, one can conclude that the proposed system can provide a good solution to a sustainable and energy efficient wireless network. It is expected that the proposed solution can be beneficial for the deployment of communication system and the smart city planning.

Finally, more antennas equipped at the source benefit to outage performance of the considered system, and this topic is expected in our future work.

Appendix A

Proof of Proposition 1

By definition, Θ_1 and Θ_2 denote the complementary events at U_1, and Θ_1 can be written as

$$\begin{aligned}\Theta_1 &= 1 - \Pr\left(\gamma_{SU_1}^{(s_2\to 1)} \geq \beta_1, \gamma_{SU_1}^{(s_1)} \geq \beta_1\right)\\ &= 1 - \Pr\left(\frac{P_B\phi_2|f_1|^2}{P_B\phi_1|f_1|^2 + N_0} \geq \beta_1, \frac{P_B\phi_1|f_1|^2}{N_0} \geq \beta_1\right)\\ &= 1 - \Pr\left(|f_1|^2 \geq \frac{N_0\beta_1}{P_B\left(\phi_2 - \beta_1\phi_1\right)}, |f_1|^2 \geq \frac{N_0\beta_1}{P_B\phi_1}\right)\\ &= 1 - \Pr\left(|f_1|^2 \geq \max\left(\frac{N_0\beta_1}{P_B\left(\phi_2 - \beta_1\phi_1\right)}, \frac{N_0\beta_1}{P_B\phi_1}\right)\right).\end{aligned} \tag{A.1}$$

We let $\Omega = \max\left(\frac{N_0\beta_1}{P_B(\phi_2-\beta_1\phi_1)}, \frac{N_0\beta_1}{P_B\phi_1}\right)$. We adopt all channels as the Rayleigh distribution with PDF and CDF $f_{|X|^2}(x) = \frac{1}{\varphi_X}\exp\left(-\frac{x}{\varphi_X}\right)$, $F_{|X|^2}(x) = 1 - \exp\left(-\frac{x}{\varphi_X}\right)$, respectively [32]. We can compute Θ_1 as

$$\begin{aligned}\Theta_1 &= 1 - \Pr\left(|f_1|^2 \geq \Omega\right)\\ &= 1 - \exp\left(-\frac{\Omega}{\varphi_1}\right).\end{aligned} \tag{A.2}$$

Based on (4.15), Θ_2 can be expressed as

$$\begin{aligned}\Theta_2 &= 1 - \Pr\left(\gamma_{SR}^{(s_1)} \geq \beta_1, \min\left(\gamma_{RU_1}^{(s_{2\to 1})}, \gamma_{RU_1}^{(s_1)}\right) \geq \beta_1\right) \\ &= 1 - \underbrace{\Pr\left(\gamma_{SR}^{(s_1)} \geq \beta_1\right)}_{\Theta_{2a}} \underbrace{\Pr\left(\min\left(\gamma_{RU_1}^{(s_{2\to 1})}, \gamma_{RU_1}^{(s_1)}\right) \geq \beta_1\right)}_{\Theta_{2b}}.\end{aligned} \tag{A.3}$$

Then, Θ_{2a} can be calculated as

$$\begin{aligned}\Theta_{2a} &= \Pr\left(\gamma_{SR}^{(s_1)} \geq \beta_1\right) \\ &= \Pr\left(\frac{(1-\alpha)\, P_B \phi_1 |f_2|^2}{N_0} \geq \beta_1\right) \\ &= \Pr\left(|f_2|^2 \geq \frac{N_0 \beta_1}{(1-\alpha)\, P_B \phi_1}\right) \\ &= \exp\left(-\frac{N_0 \beta_1}{(1-\alpha)\, P_B \phi_1 \varphi_2}\right).\end{aligned} \tag{A.4}$$

Next, Θ_{2b} is calculated as

$$\begin{aligned}\Theta_{2b} &= \Pr\left(\gamma_{RU_1}^{(s_{2\to 1})} \geq \beta_1, \gamma_{RU_1}^{(s_1)} \geq \beta_1\right) \\ &= \Pr\left(\frac{\alpha\rho P_B |f_2|^2 \phi_2 |f_3|^2}{\alpha\rho P_B |f_2|^2 \phi_1 |f_3|^2 + N_0} \geq \beta_1, \frac{\alpha\rho P_B |f_2|^2 \phi_1 |f_3|^2}{N_0} \geq \beta_1\right) \\ &= \Pr\left(|f_3|^2 \geq \frac{N_0 \beta_1}{|f_2|^2 P_B \alpha\rho\,(\phi_2 - \beta_1 \phi_1)}, |f_3|^2 \geq \frac{N_0 \beta_1}{|f_2|^2 \alpha\rho P_B \phi_1}\right) \\ &= \Pr\left(|f_3|^2 \geq \frac{\max\left(\frac{N_0 \beta_1}{P_B(\phi_2 - \beta_1 \phi_1)}, \frac{N_0 \beta_1}{P_B \phi_1}\right)}{|f_2|^2 \alpha\rho}\right) \\ &= \Pr\left(|f_3|^2 \geq \frac{\Omega}{|f_2|^2 \alpha\rho}\right) \\ &= \int_0^\infty \left(1 - F_{|f_3|^2}\left(\frac{\Omega}{\alpha\rho x}\right)\right) f_{|f_2|^2}(x)\, dx.\end{aligned} \tag{A.5}$$

Based on the result $\int_0^\infty \exp\left(-\frac{\partial}{4x} - \lambda x\right) dx = \sqrt{\frac{\partial}{\lambda}} K_1\left(\sqrt{\partial\lambda}\right)$ in [39, eq. (3.324)], Θ_{2b} is given by

$$\begin{aligned}\Theta_{2b} &= \frac{1}{\varphi_2} \int_0^\infty \exp\left(-\frac{4\Omega}{4\alpha\rho\varphi_3 x} - \frac{x}{\varphi_2}\right) dx \\ &= \sqrt{\frac{4\Omega}{\alpha\rho\varphi_2\varphi_3}} K_1\left(\sqrt{\frac{4\Omega}{\alpha\rho\varphi_2\varphi_3}}\right).\end{aligned} \tag{A.6}$$

Substituting (A.4), (A.6) into (A.3), Θ_2 is written as

$$\Theta_2 = 1 - \exp\left(-\frac{N_0\beta_1}{(1-\alpha)\, P_B\phi_1\varphi_2}\right)\sqrt{\frac{4\Omega}{\alpha\rho\varphi_2\varphi_3}}K_1\left(\sqrt{\frac{4\Omega}{\alpha\rho\varphi_2\varphi_3}}\right). \tag{A.7}$$

Combining (A.2) and (A.7) into (4.15) can be obtained and the proof is completed.

Appendix B

Proof of Proposition 2

By definition, Z_1 and Z_2 denote the first and second outage events, respectively. The first term is given by

$$\begin{aligned} Z_1 &= \Pr\left(\gamma_{SR}^{(s_2)} \geq \beta_2\right) \\ &= \Pr\left(\frac{(1-\alpha)\, P_B\phi_2|f_2|^2}{(1-\alpha)\, P_B\phi_1|f_2|^2 + N_0} \geq \beta_2\right) \\ &= \Pr\left(|f_2|^2 \geq \frac{\beta_2 N_0}{((1-\alpha)\,\phi_2 - \beta_2\,(1-\alpha)\,\phi_1)\, P_B}\right) \\ &= \exp\left(-\frac{\beta_2 N_0}{((1-\alpha)\,\phi_2 - \beta_2\,(1-\alpha)\,\phi_1)\, P_B\varphi_2}\right). \end{aligned} \tag{B.1}$$

Then, Z_2 is calculated as follows:

$$\begin{aligned} Z_2 &= \Pr\left(\gamma_{RU_2}^{(s_2)} \geq \beta_2\right) \\ &= \Pr\left(\frac{\alpha\rho P_B|f_2|^2\phi_2|f_4|^2}{\alpha\rho P_B|f_2|^2\phi_1|f_4|^2 + N_0} \geq \beta_2\right) \\ &= \Pr\left(|f_4|^2 \geq \frac{\beta_2 N_0}{(\phi_2 - \beta_2\phi_1)\,\alpha\rho P_B|f_2|^2}\right) \\ &= \int_0^\infty \left(1 - F_{|f_4|^2}\left(\frac{\beta_2 N_0}{(\phi_2 - \beta_2\phi_1)\,\alpha\rho P_B x}\right)\right) f_{|f_2|^2}(x)\, dx. \end{aligned} \tag{B.2}$$

By using $\int_0^\infty \exp\left(-\frac{\partial}{4x} - \lambda x\right) dx = \sqrt{\frac{\partial}{\lambda}}K_1\left(\sqrt{\partial\lambda}\right)$ in [39, eq. (3.324)], Z_2 is given by

$$Z_2 = \frac{1}{\varphi_2}\int_0^\infty \exp\left(-\frac{\beta_2 N_0}{(\phi_2-\beta_2\phi_1)\,\alpha\rho P_B\varphi_4 x} - \frac{x}{\varphi_2}\right)dx$$
$$= \sqrt{\frac{4\beta_2 N_0}{(\phi_2-\beta_2\phi_1)\,\alpha\rho P_B\varphi_2\varphi_4}}K_1\left(\sqrt{\frac{4\beta_2 N_0}{(\phi_2-\beta_2\phi_1)\,\alpha\rho P_B\varphi_2\varphi_4}}\right). \quad \text{(B.3)}$$

Combining (B.1) and (B.3) into (4.17) we can obtain the final result and the proof is completed.

Appendix C

Proof of Proposition 3

By definition, Λ_1 and Λ_2 denote the first and second outage events, respectively. The first term is given by

$$\begin{aligned}\Lambda_1 &= 1 - \Pr\left(\gamma_{SU_1}^{(ip,s_1)} \geq \beta_1\right)\\
&= 1 - \Pr\left(\frac{P_B\phi_1|f_1|^2}{P_B\phi_2\left|\widetilde{f}_1\right|^2 + N_0} \geq \beta_1\right)\\
&= 1 - \Pr\left(|f_1|^2 \geq \frac{\beta_1\left(P_B\phi_2\left|\widetilde{f}_1\right|^2 + N_0\right)}{P_B\phi_1}\right)\\
&= 1 - \int_0^\infty \left(1 - F_{|f_1|^2}\left(\frac{\beta_1\left(P_B\phi_2 x + N_0\right)}{P_B\phi_1}\right)\right) f_{\left|\widetilde{f}_1\right|^2}(x)\,dx\\
&= 1 - \frac{1}{k_1\varphi_1}\exp\left(-\frac{\beta_1 N_0}{P_B\phi_1\varphi_1}\right)\int_0^\infty \exp\left(-\left(\frac{\beta_1\phi_2}{\phi_1\varphi_1} + \frac{1}{k_1\varphi_1}\right)x\right)dx\\
&= 1 - \frac{\phi_1}{\beta_1\phi_2 k_1 + \phi_1}\exp\left(-\frac{\beta_1 N_0}{P_B\phi_1\varphi_1}\right).\end{aligned} \quad \text{(C.1)}$$

Then, Λ_2 can be written by

$$\begin{aligned}\Lambda_2 &= 1 - \Pr\left(\min\left(\gamma_{SR}^{(ip,s_1)}, \gamma_{RU_1}^{(ip,s_1)}\right) \geq \beta_1\right)\\
&= 1 - \underbrace{\Pr\left(\gamma_{SR}^{(ip,s_1)} \geq \beta_1\right)}_{\Lambda_{2a}}\underbrace{\Pr\left(\gamma_{RU_1}^{(ip,s_1)} \geq \beta_1\right)}_{\Lambda_{2b}}.\end{aligned} \quad \text{(C.2)}$$

Base on (C.2), Λ_{2a} is calculated as follows:

$$\begin{aligned}
\Lambda_{2a} &= \Pr\left(\gamma_{SR}^{(ip,s_1)} \geq \beta_1\right) \\
&= \Pr\left(\frac{(1-\alpha)\,P_B\phi_1|f_2|^2}{(1-\alpha)\,P_B\phi_2\left|\widetilde{f}_2\right|^2+N_0} \geq \beta_1\right) \\
&= \Pr\left(|f_2|^2 \geq \frac{\beta_1\left((1-\alpha)\,P_B\phi_2\left|\widetilde{f}_2\right|^2+N_0\right)}{(1-\alpha)\,P_B\phi_1}\right) \\
&= \int_0^\infty \left(1-F_{|f_2|^2}\left(\frac{\beta_1\left((1-\alpha)\,P_B\phi_2 x+N_0\right)}{(1-\alpha)\,P_B\phi_1}\right)\right) f_{\left|\widetilde{f}_2\right|^2}(x)\,dx \\
&= \exp\left(-\frac{\beta_1 N_0}{(1-\alpha)\,P_B\phi_1\varphi_2}\right)\int_0^\infty \exp\left(-\left(\frac{\beta_1\phi_2}{\phi_1\varphi_2}+\frac{1}{k_2\varphi_2}\right)x\right)dx \\
&= \frac{\phi_1}{\beta_1\phi_2 k_2+\phi_1}\exp\left(-\frac{\beta_1 N_0}{(1-\alpha)\,P_B\phi_1\varphi_2}\right).
\end{aligned} \tag{C.3}$$

Base on (C.2), we focus on the high SNR approximation of Λ_{2b}, which is given by

$$\begin{aligned}
\Lambda_{2b} &= \Pr\left(\gamma_{RU_1}^{(ip,s_1)} \geq \beta_1\right) \\
&\approx \Pr\left(\frac{\phi_1|f_3|^2}{\phi_2\left|\widetilde{f}_3\right|^2} \geq \beta_1\right) \\
&\approx \Pr\left(|f_3|^2 \geq \frac{\beta_1\phi_2\left|\widetilde{f}_3\right|^2}{\phi_1}\right) \\
&\approx \int_0^\infty \left(1-F_{|f_3|^2}\left(\frac{\beta_1\phi_2 x}{\phi_1}\right)\right) f_{\left|\widetilde{f}_3\right|^2}(x)\,dx \\
&\approx \frac{1}{k_3\varphi_3}\int_0^\infty \exp\left(-\left(\frac{\beta_1\phi_2}{\phi_1\varphi_3}+\frac{1}{k_3\varphi_3}\right)x\right)dx \\
&\approx \frac{\phi_1}{\beta_1\phi_2 k_3+\phi_1}.
\end{aligned} \tag{C.4}$$

Substituting (C.3) and (C.4) into (C.2), Λ_2 is written as

$$\Lambda_2 = 1-\frac{\phi_1}{\beta_1\phi_2 k_2+\phi_1}\frac{\phi_1}{\beta_1\phi_2 k_3+\phi_1}\exp\left(-\frac{\beta_1 N_0}{(1-\alpha)\,P_B\phi_1\varphi_2}\right). \tag{C.5}$$

Combining (C.1) and (C.5) into (4.22), we can obtain the final result and the proof is completed.

Appendix D

Proof of Proposition 4

From (4.32), Υ_1 can be first calculated as

$$\begin{aligned}\Upsilon_1 &= 1 - \Pr\left(\gamma_{SU_1}^{(O,s_1)} \geq \beta_1^O\right)\\ &= 1 - \Pr\left(\frac{P_B|f_1|^2}{N_0} \geq \beta_1^O\right)\\ &= 1 - \Pr\left(|f_1|^2 \geq \frac{\beta_1^O N_0}{P_B}\right)\\ &= 1 - \exp\left(-\frac{\beta_1^O N_0}{P_B\varphi_1}\right).\end{aligned} \tag{D.1}$$

Next, Υ_2 will be processed as

$$\begin{aligned}\Upsilon_2 &= 1 - \Pr\left(\min\left(\gamma_{SR}^{(O,s_1)}, \gamma_{RU_1}^{(O,s_1)}\right) \geq \beta_1^O\right)\\ &= 1 - \underbrace{\Pr\left(\gamma_{SR}^{(O,s_1)} \geq \beta_1^O\right)}_{\Upsilon_{2a}}\underbrace{\Pr\left(\gamma_{RU_1}^{(O,s_1)} \geq \beta_1^O\right)}_{\Upsilon_{2b}}.\end{aligned} \tag{D.2}$$

Υ_{2a} is given as

$$\begin{aligned}\Upsilon_{2a} &= \Pr\left(\gamma_{SR}^{(O,s_1)} \geq \beta_1^O\right)\\ &= \Pr\left(\frac{(1-\alpha)\,P_B|f_2|^2}{N_0} \geq \beta_1^O\right)\\ &= \Pr\left(|f_2|^2 \geq \frac{\beta_1^O N_0}{(1-\alpha)\,P_B}\right)\\ &= \exp\left(-\frac{\beta_1^O N_0}{(1-\alpha)\,P_B\varphi_2}\right).\end{aligned} \tag{D.3}$$

Υ_{2b} is given as

$$\begin{aligned}
\Upsilon_{2b} &= \Pr\left(\gamma_{RU_1}^{(O,s_1)} \geq \beta_1^O\right) \\
&= \Pr\left(\frac{\alpha\rho P_B |f_2|^2 |f_3|^2}{N_0} \geq \beta_1^O\right) \\
&= \Pr\left(|f_3|^2 \geq \frac{\beta_1^O N_0}{\alpha\rho P_B |f_2|^2}\right) \\
&= \int_0^\infty \left(1 - F_{|f_3|^2}\left(\frac{\beta_1^O N_0}{\alpha\rho P_B x}\right)\right) f_{|f_2|^2}(x)\, dx \\
&= \frac{1}{\varphi_2}\int_0^\infty \exp\left(-\frac{\beta_1^O N_0}{\alpha\rho P_B \varphi_3 x} - \frac{x}{\varphi_2}\right) dx \\
&= \sqrt{\frac{4\beta_1^O N_0}{\alpha\rho P_B \varphi_3 \varphi_2}} K_1\left(\sqrt{\frac{4\beta_1^O N_0}{\alpha\rho P_B \varphi_3 \varphi_2}}\right).
\end{aligned} \tag{D.4}$$

Substituting (D.3) and (D.4) into (D.2), Υ_2 is written as

$$\Upsilon_2 = 1 - \exp\left(-\frac{\beta_1^O N_0}{(1-\alpha) P_B \varphi_2}\right)\sqrt{\frac{4\beta_1^O N_0}{\alpha\rho P_B \varphi_3 \varphi_2}} K_1\left(\sqrt{\frac{4\beta_1^O N_0}{\alpha\rho P_B \varphi_3 \varphi_2}}\right). \tag{D.5}$$

Combining (D.1) and (D.5) into (4.32), we can obtain (4.33). The proof is completed.

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Chapter 5
Examining the Adoption and Application of Internet of Things for Smart Cities

Sushma Malik and Deepti Gupta

5.1 Introduction

The Internet of Things (IoT) concept initiated with communication devices which are tracked, controlled, and observed by remotely connected computers through Internet [1]. The IoT is a radical communication technology whose main motive is to create the inventive framework to connect the binary devices through Internet [2]. IoT is an industrial and information wave after the invention of computers, Internet, and mobile communication network [3]. The two well-known words in IoT are "Internet" and "Things." Internet stands for a network of networks of digital devices where servers, computers, and portable mobile phones are connected together globally by using protocols which enables communication of information. On the other hand things have a number of definitions and explanations. In dictionary meaning, things are a term which is used for physical objects. IoT technology basically consists of inter-network of devices in which multiple digital objects can remotely collect the data and communicate it to other devices to acquire, manage, and analyze the data. This technology provides the vision to the things which become smarter and behave alive with sensing, computing, and communicating with each other through embedded sensors which interact remotely to objects or persons with the help of Internet [4, 5].

IoT can be divided into three parts:

- Internet
- Things (sensors, vehicles, buildings, home appliances, and other devices)
- Software (the programs to instruct the things)

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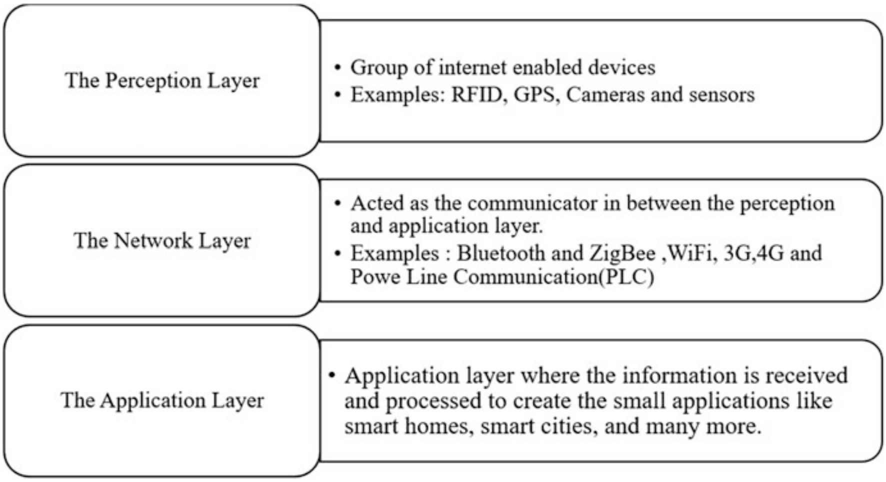

Fig. 5.1 IoT layers [7]

IoT can be defined as the global network of linked together things through communication protocols. This technology provides a prospect to connect the people to things all around the world anytime. IoT is called with different names by a number of companies like IBM calls it "Smarter Planet," GE uses "Industrial Internet," and Cisco calls it "Internet of Everything." The main motive of these companies is to better the production time, reduce consumption of energy, and shorten the count of accidents and downtime by using sensors [5, 6]. IoT consists of three layers [7] as mentioned in Fig. 5.1:

- The perception layer: This layer is basically an arrangement of Internet-empowered devices that are able to recognize the objects, gather the data, and share information through Internet with other devices. RFID, GPS, cameras, and sensors are some examples which are used in the perception layer.
- The network layer: Network layer basically acts as the communicator between the perception and application layer. The responsibility of this layer is to exchange the data in between the application and the perception layer under the limitations of network and taking into consideration the constraints of devices. Bluetooth and ZigBee are used for the short-range communication and Wi-Fi, 3G, 4G, and power-line communication (PLC) are used for long-distance communication in between things or objects.
- The application layer: Application layer is actually the layer where the data is collected and goes under analysis process to generate information to create the small applications like smart homes, smart cities, and many more.

A smart city is a new perception for the urban evolution by integrating various components of ICT to deal with city components like departments of data centers, transportation, educational institutes, healthcare facilities, powerhouses, waste

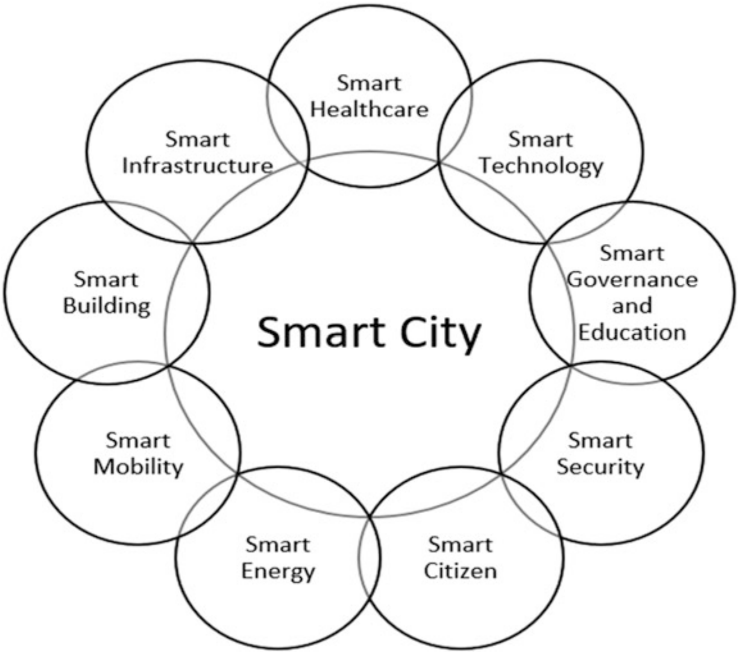

Fig. 5.2 The main aspects of a smart city [1]

management, law enforcement, and many other services [5]. Smart cities become smarter with the recent development of digital technologies like IoT. Smart city is furnished with disparate electronic devices implemented by several applications like street observation systems using smart cameras, smart transportation systems through sensors, and interconnectivity of medical equipment. In a smart city, live weather forecasting can be performed through IoT-based weather monitoring systems [8]. IoT devices can be easily controlled by the mobile devices [1]. Figure 5.2 shows the main aspects of a smart city.

5.1.1 IoT Technologies for Smart Cities

In the IoT platform, communication can be done through a number of sensors. Wireless communication is preferred among connected sensors to minimize connection cabling cost. This section includes some technologies which are used in IoT technology.

- Radio-frequency identification (RFID): This technology basically uses the readers and tags which play a crucial role in IoT. By applying this on the objects, it accomplishes the automatic identification and provides the identity to the objects which are used in the network to provide information and services. Each tag can be treated as a sensor because tags, apart from storing the manually written data, are capable of capturing the data. RFID is used in the designing of some smart applications including smart power grids, tracking the motion of objects, healthcare and medical applications, smart parking systems, and many more [1, 7].

- Near-field communication (NFC): It is a bidirectional communication technology that covers short distances that can span up to few centimeters and is especially used in smartphones. After implementing NFC, a smartphone can be used as a wallet which can store the personal identification information of the user [7].
- Low-rate wireless personal area network (LWPAN): It is the short-range radio technology which can help to communicate with the objects up to 10–15 km. This technology is widely used because of less energy consumption and has a battery lifetime of up to 10 years. According to the IEEE 802.15.4 standard, LWPAN is a low-cost and low-bandwidth communication protocol for sensor networks. It includes ZigBee and 6LoWPAN [7].
- ZigBee: It is the wireless communication protocol in the sensor nodes with low cost and power. It is based on IEEE 802.15.4 standard and is appropriate for creating wireless personal network such as automating homes and collection of data through connected smart medical devices.
- 6LoWPAN: It is specified to adopt IPv6 communication. Due to the exhaustion of address block of IPv4, Internet hosts have been replaced by IPv6 because it provides 128-bit addresses for IoT networks [9].
- Wireless sensor networks (WSNs): This network is composed of wireless sensors like radio interface, memory, power supply, and analog-to-digital converter. WSNs when integrated with RFIDs can be used to achieve several targets like collection of data regarding the position of people and objects, and their movement and temperature. It includes the number of sensors which collect the data in analog format and convert the data in digital format through an ADC and finally data are transmitted by a radio interface [7, 10].
- Dash7: This standard protocol is capable of covering long-distance applications having low power requirements like building automation. It is mainly used in military applications especially in the construction of substations. It is also used in the designing of smart applications for monitoring the hazardous materials, optimizing warehouses, and manufacturing units [7].
- 3G and long-term evolution (LTE): It is a wireless communication standard protocol which basically found its application in smartphones and data terminals. It has high data cost because it requires service providers [7].
- Addressing: Internet service provides the interconnectivity of the persons and in the similar way, IoT provides the interconnection of things to provide the smart environments. To implement this, the identification of devices and things is essential. Unique addressing methods are used for controlling and monitoring the large-scale combination of objects through Internet [1, 7].
- Middleware: The middleware plays an important role in the association of the things to the application layer because of the heterogeneity nature of objects

or things. The main objective of middleware is integrating the communication capabilities and functionalities of all interconnected devices or things in the IoT platform [1].

5.2 Concepts of Smart City

- Traffic Congestion
  In urban city, IoT technology can be utilized to monitor the traffic congestion. In many urban cities, the traffic is already monitored by camera-based traffic monitoring systems. Nowadays, GPS-installed vehicles are used for getting the information and position of vehicles. IoT technology is very helpful in the traffic domain by sending the officers where needed and also helpful for the public to identify the route to follow when going outside [11].
- Air Quality Management
  The quality of city air is polluted because of crowded areas and number of vehicles. But the IoT technology is playing a vital role to curb the quality of air in urban cities. To achieve this, air quality and pollution sensors are installed across the city to measure the quality of air and also provide the information to the citizens of urban cities [11].
- Smart Health
  With the usage of IoT technology, health system in the urban cities becomes the smart health system. Various critical parameters of patients like changes in heart condition, temperature, and pulse rate and respiration problem are easily monitored by the doctors with the usage of sensors remotely. Without any movement, patients are easily diagnosed by the doctors and it also helps to provide the alert message in critical conditions [11].
- Smart Energy
  IoT technology helps to monitor the energy consumption of the city which is very helpful for the empowering authorities and citizens to get the detailed view of the used electric energy. This helps to identify the main energy consumption sources and also helps to set priorities accordingly [11].

5.3 Motivations for Smart City Development in the Developing Countries

The main agenda of developing countries' governments is to convert the cities into the smart cities by the implementation of IoT technology. The main objectives are the following:

- Improve the efficiency of government to provide public services: The main motive to develop the smart city is to enhance the efficiency of government to provide public services. By implementing IoT technology, the government will provide public services to the citizens by reducing the transaction cost. IoT technology is facilitating the government to connect with the citizens in a more effective manner, improving the production of organizations and also improving the forecasting demand by using the collected data from the IoT system and also detecting the essential public services [12].

- Improving the quality of life: Another objective of smart city development is working towards the betterment of citizens' life. This technology has significantly improved the speed of travel ensuring better safety and the ultimate goal is minimizing the traffic congestion and vehicle pollution and enhancing the health security in turn improving the living status of citizens [12].
- Promoting inclusive governance: Smart city development encourages sharing the information among numerous stakeholders such as governments, organizations, and citizens for joint decision-making. Joint decision builds trust and confidence among citizens [12].
- Inclusion of vulnerable and disadvantaged populations: Smart city development can be made successful by including the susceptible and deprived population of the city by integrating their basic needs [12].

5.4 Requirements of IoT Platform for Smart City

IoT technology plays an essential role in the growth of smart cities. IoT devices are embedded with sensors to collect and analyze data from the connected devices. This collected data is then used to improve the infrastructure of the city, public services, and utilities. Collected data from IoT devices are in heterogeneous form and the size of data is huge since it is real-time data. At that time IoT technology will face big data domain challenges. The following requirements need to be addressed for smart city development:

- Interoperability: The main requirement among heterogeneous devices is interoperability which enables communication and data transmission in between IoT devices. Software infrastructure is needed to integrate the different systems and technologies in the same environment for the IoT platform. Middleware of IoT provides the interoperability among the heterogeneous devices and helps to perform their functionalities [13].
- Storage: IoT platform collects the real-time data from multiple sensors to present definite information about the events or behaviors of objects in a smart city. Storage systems should automatically scale themselves horizontally to store the large volumes of data generated by IoT devices on a real-time basis [13] (Fig. 5.3).
- Real-time data transmission: For the asynchronous communication on the IoT platform real-time data transmission is needed. Publish/subscribe communica-

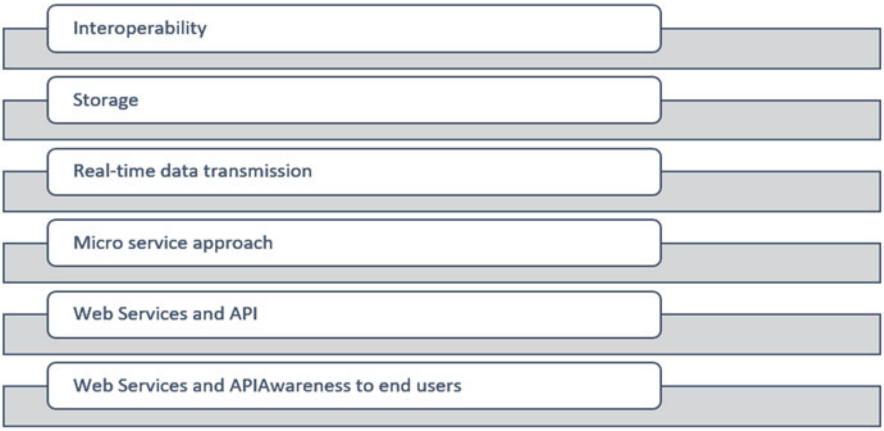

Fig. 5.3 Requirements of IoT platform for a smart city [13]

tion paradigm is used for this purpose because it removes the interdependencies between the sender and receiver of data [13].

- Microservice approach: IoT platform uses microservice approach to increase the flexibility and maintainability of devices because this approach is used to design and develop a single application as a set of small services, where each of them is running its own process and also interacting with lightweight mechanisms [13].
- Web services and API: The data can be accessed by IoT platform through web services and API either in processed or in unprocessed form. REST architectural principles are promoted as easy-to-use interfaces that are loosely coupled components.
- Awareness to end users: Smart city is basically designed for the citizens who are the end users. So it is necessary to provide the awareness of smart city applications to the end users. User-friendly applications are designed for the end users who facilitate the interaction between users and things [13].

5.5 Taxonomy of IoT-Based Smart City

- Communication protocols: Various communication protocols like ZigBee, Bluetooth, and Wi-Fi are used for short-range communication applications like smart metering. On the other hand, GSM, GPRS, and LTE are used for long-range communication in applications like e-healthcare and vehicle-to-vehicle communication [2]. Service providers: In the implementation of a smart city, Internet plays an essential role. The well-known service providers have already started introducing new communication protocols. Service providers like Jio, Airtel, and Vodafone provide a number of services and platforms for the implementation of

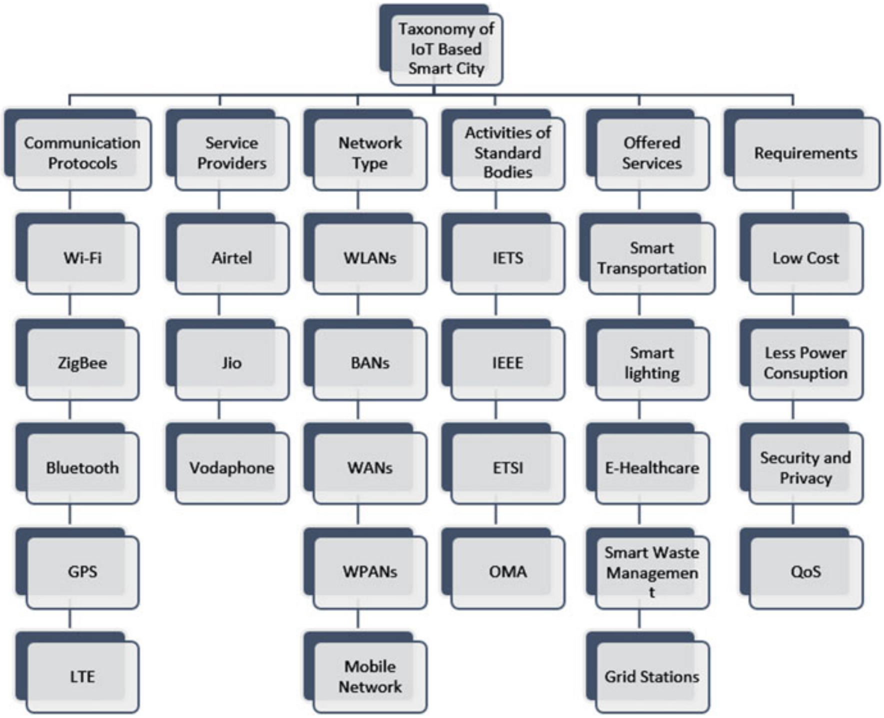

Fig. 5.4 Taxonomy of IoT-based smart city [2]

smart city applications like logistics, smart metering, home automation, and e-health [2] (Fig. 5.4).

- Network type: A number of network topologies are used for the implementation of a smart city which provide fully autonomous environment. Wireless local area network (WLAN), WAN, and wireless local personal area network (WPAN) are some examples which are used to design applications like home automation and indoor e-healthcare services. Other IoT applications like ITS and waste management use the wide area network (WAN), metropolitan area network (MAN), and mobile communication networks [2].
- Activities of standard bodies: Device interoperability among IoT devices used in smart city applications is equally important. For the development of standards which support smart city applications a number of prominent governing bodies like IETS, IEEE, ETSI (European Telecommunications Standards Institute), and OMA (Open Mobile Alliance) are actively involved.
- Offered services: IoT technology provides a number of services which improve the standard of citizens and also help the administration by reducing the operational cost. Smart lighting, waste management, grid stations, and distribution of energy in an efficient manner to home and workplace are some of the services

offered by the IoT platform. By using GPS, the traffic congestion is easily controlled in smart cities [2].

- Requirements: IoT technology gives a number of applications to transform the city into the smart city and thus needs a number of requirements. Such applications should be inexpensive that consume less energy and provide high quality of services (QoS) and wide coverage area, with better flexibility and immense security and privacy [2].

5.6 IoT Platform for Smart Cities

Managing energy is one of the applications of IoT in smart cities for which various platforms have been proposed. These platforms should be scalable and flexible in nature in order to adapt large amount of data reception from heterogeneous sources and its management.

5.6.1 DIMMER

The author in [13] presented two software-based distributed IoT platforms to support energy efficiency in smart cities. DIMMER described as District Information Modeling and Management is a three-layered infrastructure based on publish/subscribe and request/response approach. It aims at reducing the emission levels of CO_2 by implementing better policies. It works by collecting the data from numerous sensors and other IoT devices set up in building, then processing it, and correlating it with parametric models like GIS. This platform is flexible enough to allow different databases to work together. It also simulates various strategies for controlling energy in electrical systems with the use of renewable resources. Different hardware technologies like ZigBee can be integrated with software technologies like GIS through device connector in the data source integration layer so that information can be accessed from heterogeneous sources. The second layer of this platform schema consists of middleware components to provide services at district level. As it can be seen in the figure, service catalog maintains an index of all the available services in this platform. Similarly the resource catalog maintains the list of available resources and newly added IoT devices through device connector. Message broker communicates data through MQTT asynchronous communication protocol. Data storage as the name suggests is used to store all types of schedules, user feedbacks, and data sent by devices. Semantic metastore acts like a metadata file to hold all descriptions related to entities in the platform. The simulation engine keeps on replicating the policies to optimize energy and analyze their impact at district level. At the end, the application layer presents and provides various tools and application programming interfaces to stakeholders to observe and analyze the data from bottom layers (Fig. 5.5).

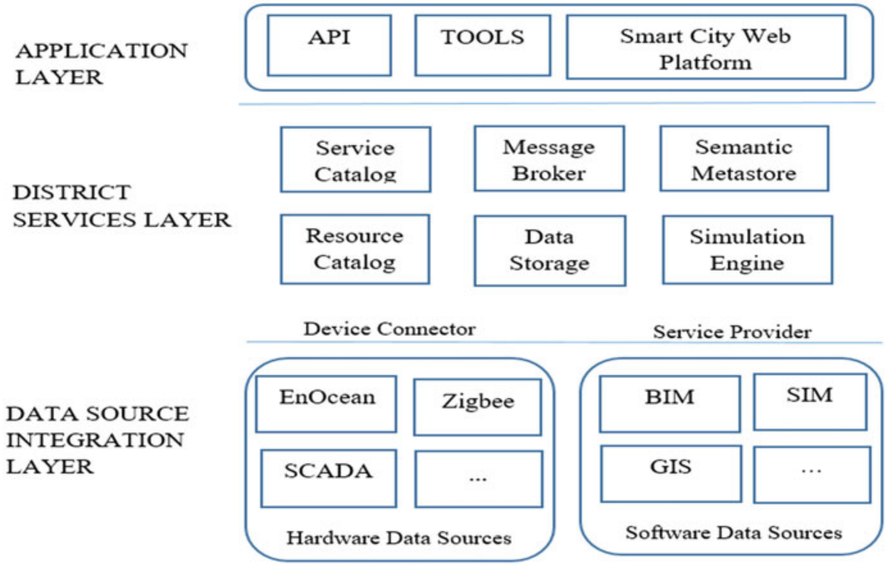

Fig. 5.5 Architecture of DIMMER platform [13]

5.6.2 FLEXIMETER

Another platform described by the author [13] is a four-layered architecture for flexible reading and management of data from smart meters installed for different utilities like electricity and water in buildings. It is another distributed platform to provide customers with real-time information through suitable interfaces. It helps in detecting faults at user and grid levels and also optimizes the alarming systems in meters. The first layer is the IoT device layer which uses MQTT protocol to send data captured by certain IoT devices through message broker to middleware layer. This layer actually contains the scalable NoSQL or MongoDB database which stores the collected information accessed through REST API. A new device in the system can automatically self-register through this layer only. The third layer, that is, business layer, is responsible for managing the user authentication and processing the data at different granular levels according to business requirements. Algorithms to detect fault and handle fluctuating demand in energy distribution network are implemented in services layer. It is at this layer that data can be seen and visualized using user interface (Fig. 5.6).

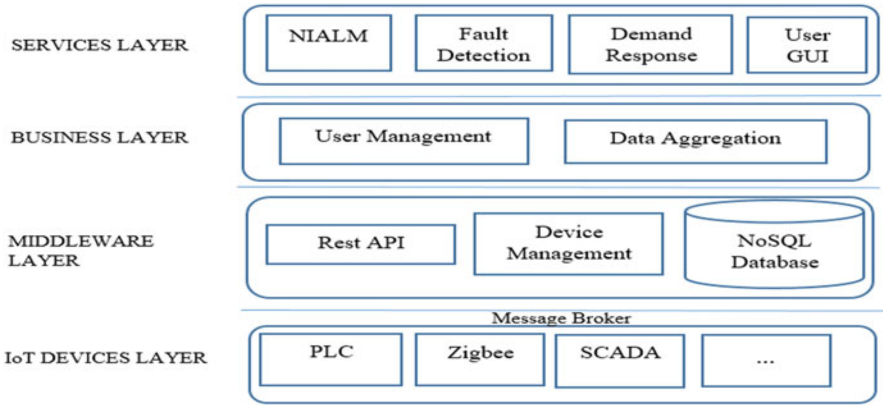

Fig. 5.6 Architecture of FLEXIMETER platform [13]

5.7 Issues and Challenges

The phenomenon of Fourth Industrial Revolution, that is, the evolution of IoT, has generated unprecedented opportunities for research. The complicated and collective type of smart cities causes serious political, social, economic, and technical challenges for developers, integrators, and organizations involved in carrying out these new concepts. The incrementing count of the studies target the security- and privacy-related issues within smart cities, concentrating the threats and challenges that can occur in managing the infrastructure of smart cities and privacy of data [14] (Fig. 5.7).

- Security and privacy—To ensure the trust of citizens in the government's decision of making any city or country smart, it is essential to make them believe that all their personal data is private and secure from unauthorized access. As all information is stored and assessed in a common IoT platform, it may face cross-site and side-channel attacks. Also the system may be vulnerable and subjected to certain other attacks. Therefore for successful application of IoT for smart cities, it is utmost crucial to adopt attack-resistant smart systems and focus on usage of techniques and controls to ensure privacy of information collected from sensors [7].
- Heterogeneity—The IoT system is a solution made up of several subcomponents which are knitted together depending upon the type of application. It is the responsibility of several authorities involved to understand the objective of smart system and then determine the hardware devices and software needed to be integrated together to work as a heterogeneous system. Building and deploying such infrastructure is a big challenge [7].
- Reliability—Reliability, generally defined as the ability to recover from failures, is also a very important challenge for system developers as infrastructure fault

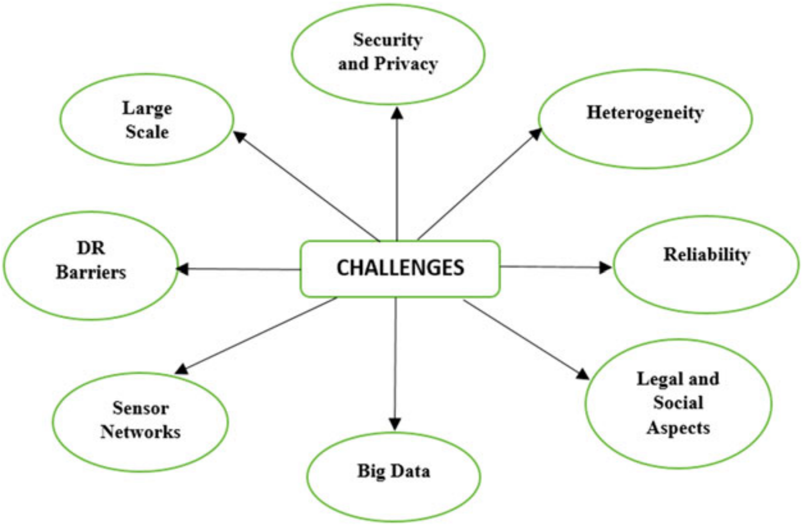

Fig. 5.7 Challenges with IoT-based smart systems [7]

or system failure can halt the entire system and may cause data leakage. It sometimes becomes difficult to measure and ensure the reliability of smart systems particularly when large number of mobile devices like moving cars are involved [7].

- Large scale—The large-scale amount of data collected from interactions among the multiple sensor and other Internet-equipped devices needs appropriate storage and computational capabilities as the high data generation rate is a major challenge faced which should be resolved. The physical and geographical distribution of IoT devices affects the monitoring of data as well due to distanced connectivity and delays [7].
- Legal and social aspects—The service providers of the IoT systems work according to local and international laws to provide user information-based services. The users should participate in the process of data elicitation and submission [15]. Some issues may arise if humans are treated as data resource [16].
- Big data—IoT infrastructure, where millions of devices consisting of sensors and actuators communicate and interact by sending and receiving messages, is generating large volumes of variety data at an exponential rate every second making data more big day by day. It is posing a challenge and needs attention regarding storage, transmission, and analysis of such enormous amount of data.
- Sensor networks—They are one of the principal technologies that can be used to implement and deploy IoT infrastructure. This technology is shaping the world around by understanding the environmental parameters and incorporating drawn inferences. The improving technologies of sensor networks are making them

more advanced and are capable of employing cheap and efficient devices in remote sensing applications [1].

- DR barriers—IoT is also bringing challenges in three different categories of demand response barriers. The first set of framework barriers can be the regulations and policies that need to be obeyed and some communication limits may also occur. The IoT service providers also face issues in convincing the customers and making profits over investments. The third category of barriers is with the customers who do not possess enough knowledge to work with latest equipment and technology [17].

5.8 Applications of IoT in Smart Cities

The evolution of IoT has made the dream of smart city come true. Internet of Things has made it possible to install sensor networks at different locations in the city, collecting and analyzing the data generated and hence monitoring their functioning. Smart cities basically means connecting every device through Internet so that these devices can communicate and thus reducing the need of human intervention. Below are listed some of the applications of IoT (Fig. 5.8):

- Smart homes—Smart homes are continuously gaining popularity due to the comfort and quality of life they provide. Smart homes can be defined as automating the residence where all the appliances including lighting, air conditioners, televisions, gas stoves, refrigerators, and security systems are made to interact with each other. The basic building blocks that need to be integrated to convert a

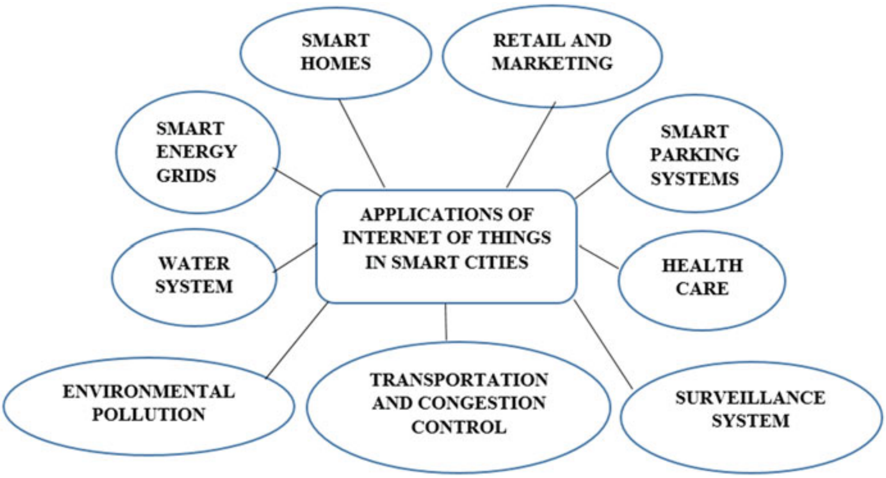

Fig. 5.8 Applications of Internet of Things in smart cities [1]

classic home to smart are the smart devices or home appliances having embedded sensors and intelligence to facilitate interactions among appliances, IoT services, and cloud computing to increase their computation power, storage capacity, and data exchange efficiency and the rule-based event processing [18]. The sensors communicate with each other through messages and data generated through each interaction is sent to the database stored on server connected through LAN. The server is responsible for controlling the device and logging their activities and performs the required action on the basis of rules or events triggered. Various systems at home which can be made smart are smoke detection, temperature controller, alarming system, humidity control, motion server, and gate locking system.

- Smart energy grids—The rise in the utilization of power appliances is a growing concern for researchers to find out solutions to minimize the risks from environmental hazards and to come out with alternative renewable sources. Consumers are facing problems like power cutoffs and low voltages especially during peak hours in developed countries. Therefore they have to spend on purchasing generators [19]. Efficient utilization of energy is important for any power system which can be achieved through IoT-based smart energy grids. Smart grids have transformed the energy sector as they quickly respond to power faults and outages. IoT improves the reliability of energy grids, makes it easy to collect and process the data, and then uses the output generated to plan the future requirements accordingly. Looking forward to promoting Digital India, a wireless system for meter reading and monitoring energy was proposed [20]. The functional units of this system include a ESP8266 12E Wi-Fi module with microcontroller, an OLED display, an analog energy meter, an optocoupler to sense data from meter, a sensor measuring AC and DC signals, a relay driver, power supply, and bulbs. The reading of energy meter is performed at regular intervals and is stored through Wi-Fi on open IoT platform ThingSpeak. The limitation of the system as discussed by the author is the requirement of good Internet speed to upload data to cloud space.
- Smart parking system—With the increasing count of private vehicle users, it is becoming essential to find a way out which can provide real-time information to the users regarding the availability of parking space through a mobile application. Several infrared and ultrasonic sensors need to be deployed in parking areas to sense the activities in parking area and other information of vacant slot can be stored on cloud. The mobile application may take several inputs like total time for which parking space needs to be booked, vehicle number, and user ID. The application may compute the parking charges accordingly and store other information on cloud for reference. The driver may need to pay the fine if parking time exceeds. The use of Internet of Things for smart parking can help to manage traffic in a more efficient manner and helps control congestion [4].
- Healthcare—Due to advanced medical facilities and more and more involvement of technologies in the healthcare sector, the life expectancy rate has increased [21]. Thus the demand of resources for aging population is giving stress to the hospitals [22]. Hence many of them have come out with a solution as they have started maintaining the health records of patients, their medical history,

and laboratory tests electronically on cloud. Medical advice by doctors is also provided through certain applications through which noncritical patients can be treated at home itself [22]. Cloud structure being scalable and flexible allows excessive amount of data that is captured using sensors to be stored and computed. Many researchers are diverting their attention towards smart rehabilitation systems which are cost effective and provide quite effective treatment. An automated ontology-based smart rehabilitation system methodology was proposed in [23] where the medical treatment is recommended to the patient automatically by analyzing and comparing his or her symptoms with the past data. Healthcare systems use sensors and devices connected in an IoT network through wireless technology to monitor captured data of patients so that they can be quickly diagnosed and rehabilitation strategy and resources can be created and reconfigured accordingly. Automatic data collection saves times required for data processing and also prevents human errors [1].

- Water system—The declining water environment and increasing waste and water pollution are appealing for the need of smart water systems and usage of better technologies to address this problem [24]. Apart from this, efficient ways over conventional methods need to be explored for water distribution so that pipeline leakage can easily be diagnosed and resolved. Deployment of sound and pressure sensors at proper locations in water distribution system can detect the leakage easily. Also ultrasonic sensors can be installed in storage water tanks to check the level of water and can avoid overflow. Monitoring the quality of water is equally important which can be ensured by placing glass electrode which can curb the pH of water at strategic locations [1]. Presence of nitrate in water especially in agricultural fields is one of the major components that contribute towards water contamination. An IoT-based analytical device is developed in [24] for monitoring the quality of water. This device analyzes the nitrate content level in the water when deployed in certain water treatment plants and provides real-time data for decision-making. The data obtained can then be worked upon towards the improvement of quality of water. Wireless sensor networks have been used to develop certain innovative methods to manage the requirement of water for irrigation purpose, improve water conservation techniques, and manage sewage overflows [1].
- Transportation and congestion control—The increased count of vehicles on road has raised traffic congestion and has become a major issue for transportation systems in many countries. This is negatively impacting the productivity and economic growth of the countries. It is important to control congestion for reducing not only the consumption of fuel but also various diseases like heart attacks and asthma caused by traffic pollution. Thus the study and use of IoT-based traffic congestion control systems have been attracting researchers over the past few decades. One of the solutions that came out is vehicle-to-vehicle communication which however failed to accurately compute the traffic density in an area. The researcher [25] proposed an architecture consisting of two modules, that is, TDMM and TMM. Traffic density monitoring module is placed at each cross point to assess the density of traffic and traffic management module adjusts timings of the traffic signals given the density detected at cross points.

TDMM consists of an ultrasonic sensor to collect data like the length of vehicle queue which is then processed by the microcontroller. The output information is then sent to TMM through Wi-Fi module if in accessible range or through other TDMM. TMM software module is installed on a workstation with Wi-Fi connected to microcontroller through a serial port which is further linked with signal LED through a relay module, an electromagnetic switch. TMM is responsible for labeling the traffic density as low, medium, and high and setting the operating time of traffic signals accordingly.

- Environmental pollution—Millions of people died every year due to exposure to air pollutants and fine particles resulting in respiratory diseases, lung infections, and heart attack. Taking into consideration the high health risks that air pollution is causing to the residents of big cities, many of them have decided to adopt ICT and IoT-based innovative strategies and technologies to control and treat environmental emissions to mitigate the risks. IoT devices with in-built sensors can be used to monitor levels of pollution present in multiple cities [26]. The author [27] recommended an inexpensive architecture of system for monitoring air pollution through the use of gas sensors, sound, and temperature sensors connected to a microcontroller. The gas sensor was used to measure the density of harmful gases like carbon dioxide in the air. The dust sensor was also used to detect cigarette smoke and dust in homes. The microcontroller processes the signals received from sensors. The software was implemented in Visual Basic programming language. The server receives and displays the data from sensors through microcontroller, stores it in database, and then sends it to experts for analysis. The collected data from sensors is stored in Google Spreadsheet and is represented through Environment Monitoring application developed using AppSheet platform. It was a compact and portable gadget which can be placed in an area to monitor certain environmental parameters.
- Surveillance system—Security is one of the very crucial elements for smart cities from a citizen's perspective. To ensure security, continuous motion monitoring is required so that criminal activities can be tracked and action can be taken immediately and accordingly. Initially the infrastructure of video surveillance system was built using the CCTV which records the video but does not have intelligent processing. The user can check the recorded video later. Surveillance systems built using smart devices are having the capability of triggering an alarm and tracking a person's activity at night using infrared cameras and even can detect the objects that the unapproved person is carrying [1]. The proposed system in [28] can be activated by entering a password by the owner of the system. The system sends an SMS along with an email if any motion is detected in the area. It is also capable of finding the count of people and ringing an alarm so that neighbors can be notified. The hardware of the framework is implemented using Raspberry Pi, Arduino Board, and GSM module. Whenever human presence is detected, two SMS are sent. The storage requirement of this system is quite low as video is recorded only when motion is detected. MOG2 algorithm is used to detect motion through the use of OpenCV. A video having up to 100 frames can be shared in a single email. It can be installed at crowded places like shopping malls, banks, and airports to detect unauthorized movement.

- Retail and marketing—Managing a healthy relationship with the customers and understanding the needs of consumers are critical for the economic growth of every retail or wholesale or customer-centered organization. The researcher [29] used smart mirrors as devices for analyzing and predicting the consumer purchase behavior and patterns in a shopping mall. Smart mirrors are two-sided mirrors fitted with LED and LCD to adjust the lighting in the background. A Raspberry Pi chip with Wi-Fi and RFID tag was also used to capture the RFID of the clothes tried by the customer to group apparels with similar tags. All the captured data can then be used to provide suggestions to the customers of similar age groups. IoT can be used to improve the logistic infrastructure and manage the store in a better fashion. The proposed intelligent model [29, 30] can track and monitor and manage things. It was proposed to validate the efficiency of an application developed in 2015 to understand shopping behavior of targeted audience by Coca Cola Company. The application is a combination of business practices and technology-based solutions which connects the manufacturers, retailers, and shoppers. It also measures the economic and technological effects.

5.9 Case Studies

See Table 5.1.

Table 5.1 Case studies of smart cities [31, 32]

S. No.	Country	IoT device/name of initiative	Use of IoT
1	Dubai, UAE	Smart Dubai happiness meter	A sentiment measurement tool that captures happiness data of citizens in a city aimed at making Dubai the delighted city in the world
2	Russia	Urban Environment Quality Index	An assessment tool launched under 3-year housing and urban environment program to evaluate the quality of infrastructure in the city, analyzing the citizen's response towards streets and parks. This tool also aims to find places in the country that need improvement
3	Maputo, Mozambique	Open Data Roadmap	Launched in the city of Maputo, the objective of this initiative is to make governance in the city more data driven, transparent, and accountable to resolve issues of land entitlement in order to promote private investments in urban services. SISCod and Imp+ apps have been developed and used to minimize land disputes and collect taxes electronically

(continued)

Table 5.1 (continued)

S. No.	Country	IoT device/name of initiative	Use of IoT
4	Paris, France	Reinventing Paris	This project was launched in two rounds in 2016 and 2017, respectively, focusing on modernizing the urban infrastructure of Paris keeping in mind the heritage preservation of the city
5	Boston, USA	New Urban Mechanics	It is an innovative group formed with the objective of improving the education and housing sector in the city. DiscoverBPS tool was built to provide digital experience to the parents by making the school registration process online
6	Quito, Ecuador	Bajale Al Acaso (Turn Down Harassment)	This project was launched and implemented to fight against women sexual harassment in municipal buses and other public transport. It works on the principle of instant messaging and response from a team of layers and social workers and resulting into a legal punishment
7	Buenos Aires, Argentina	Estaciones Saludables (Health Stations)	Launched in 2012 by the health department of the city, this program aims at reducing the risk of chronic diseases like high BP, diabetes, kidney and lung disease, and malnutrition by promoting the importance of healthy diet among the residents of city through health stations and consultancy
8	Singapore	Harnessing City Data	The objective behind harnessing the data from the public and private sectors through ConnectedLife is providing an insight to healthcare providers and insurance companies with the real-time information to improve the living of aged citizens in the city
9	Berlin, Germany	Hush City Mobile Lab	This mobile lab developed a mobile application to help the citizens to find quiet places in the city to get relieved from the traffic stress of Europe
10	Fukuoka, Japan	CareTech	An initiative was started under which CareTech solutions provide door-to-door services through IoT and ICT monitoring solutions to elderly people specially suffering from dementia with the use of GPS
11	Copenhagen, Denmark	Copenhagen Cycling Infrastructure	Keeping in mind the advantages of cycling like physical activity, reduced accidents, and better air quality, Copenhagen focused on the increasing use of cycling to commute to workplaces and colleges. They improved their cycling infrastructure in the city and adopted strategies like CycleChic blog to make cycling convenient for all ages

(continued)

Table 5.1 (continued)

S. No.	Country	IoT device/name of initiative	Use of IoT
12	California, USA	Santa Monica's Wellbeing project	This project aims at understanding and analyzing the needs and strengths of the community through a large collection of data. A tool named Wellbeing index measures the factors needed to improve the community
13	Singapore	Urban Solar	Singapore is continuously working on using solar energy as its largest renewable source to generate electricity. They have also installed the largest floating solar panel bed in Tengeh reservoir. SERIS, PUB, and Singapore water agency are investigating into the impacts of this solar bed and EDB is called for investments in these types of projects
14	Melbourne, Australia	1200 Buildings Program	To make commercial building owners aware of advantages of power and water efficiency, several seminars and workshops were conducted by industry experts under this program. This city also developed a Sustainable Melbourne Fund to provide funds for projects and administer the financing mechanism. An agreement was also signed among the local government, the bank, and the building owner named as Environmental Upgrade agreement aimed at lending money at a low rate for upgradation of commercial buildings
15	South Korea	Smart Seoul	It is an ICT framework-based infrastructure built with the objective of using IoT for improving the quality of life by maintaining the infrastructure including transport, water pipes, and power lines. Free Wi-Fi is also provided to push citizens towards more use of smart devices
16	Fukuoka, Japan	Hydrogen from Sewage	Due to the challenges involved with electric cars, that is, lengthy charging time and short distance covered, this city has come out with an alternative to use hydrogen produced from processed household sewage to fuel cars, logistic trucks, and bikes
17	India	Ahmedabad Heat Action Plan	Under the Heat Action Plan, the city designed a warning system to study the climate change and its factors so that death toll in the city can be reduced. It works on the basis of four different key strategies including creating awareness among people regarding the risk of heat waves, communicating to residents about weather forecasts, identifying heat-related issues, and putting efforts towards minimizing the heat exposure

(continued)

Table 5.1 (continued)

S. No.	Country	IoT device/name of initiative	Use of IoT
18	Fukuoka, Japan	Tenjin Big Bang Project	As countless earthquakes have destroyed the structure of the buildings in the city, there is a need to reconstruct earthquake-prone buildings. Fukuoka started this project to promote urban development through investment from private sectors
19	Fukuoka, Japan	Water Conscious Urban Development	Using the data collected from sensors, this city has very smartly developed the water distribution system to curb water shortage issues. It works by monitoring and controlling the flow of water and its pressure in different areas of the city. They are also educating people about the criticality of water
20	Amsterdam, The Netherlands	EDGE Olympic	A smart and sustainable building which connects everything with everyone in the building through single cloud platform. It uses smart apps which help users to locate their colleagues and find vacant rooms for meeting; in fact the room temperature and noise level can be customized and controlled
21	Amsterdam, The Netherlands	The Platform Economy	With the increased use of platform economy, to ensure the belief of people in this economy, this city developed certain standards to assess the algorithms used for auditing the private sector contracts and permits
22	Dubai, UAE	Dubai Blockchain Strategy	With the objective of creating stronger economic sector, making transaction ledgers more transparent, and solving other issues of multi-sector parties, blockchain strategy was adopted through prototyping
23	Amsterdam, The Netherlands	Repair Cafes	It is a meeting place in the city where many objects like furniture, bicycle, and toys can be fixed and mended free of cost to avoid wastage. They also have a website where a starter kit can be downloaded to learn how to repair objects
24	The United Kingdom	Circular Glasgow	It is an online platform based on the circular economy approach designed with the objective of adopting strategies for waste management and reducing the negative effects of billions of solid waste from industries and moving towards sustainability
25	London, UK	The Mayor's Civic Innovation Challenge	An initiative with the approach to solve technology-related issues of the city. It provides an innovative platform for areas like aging people and climate change

5.10 Conclusion

The objective behind writing this chapter is to present the recent trends of Internet of Things for smart cities. Through this chapter, we have explained and expressed the important concepts of IoT starting with defining its three layers; its technologies, that is, RFID and ZigBee; and how they are implemented to build smart cities, two different platforms for smart metering of daily home utilities like electricity and water. The prerequisites of IoT platform needed for smart cities are also discussed. As communication of IoT-based smart devices connected together in a network has created remarkable and new hopes for cities around the world to find solutions to their infrastructure, health, and traffic congestion issues, it is mandatory to make readers aware of the applications where IoT can be used and how daily activities can be improved by employing IoT devices. Thus multiple case studies are also considered and reviewed. Moreover, coming up with methods and procedures to cope with some crucial IoT objections, such as the security of the user's data and storage and computation of large-scale data, still needs further research.

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Chapter 6
Internet of Everything (IoE) in Smart City Paradigm Using Advanced Sensors for Handheld Devices and Equipment

P. Malini, Naveenbalaji Gowthaman, A. Gautami, and N. Thillaiarasu

6.1 Introduction

The size and the number of inhabitants in urban areas are consistently expanding as demonstrated in overall reports of forecast [1]. Thus, regular daily existence in metropolitan regions size and the number of inhabitants in urban areas are consistently expanding as demonstrated in overall reports of forecast [1]. Thus, regular daily existence in metropolitan regions will additionally be challenging because of restricted assets and administrations, for example medication, training, climate, and transportation. To hold the supportability of these administrations in metropolitan territories, new techniques for effective information for the executives ought to be organized. The smart city is a term that is selected from the selection and utilization of versatile registering frameworks through viable information from the executives' networks among all parts and layers of the city [1]. Urban communities are more centered around their endeavors on getting more astute with the utilization of information from the board organizations, for example the IoT, enormous information, and distributed computing advancements. This information of board frameworks gives enhancements about smart cities in various parts of tasks

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and associations, for example traffic light, feasible asset of the executives, personal satisfaction, and foundation [2].

The Internet of Things framework alludes to developing organization of computerized sensors, keen gadgets, and brilliant home machines. The Internet of Things innovation regards the consideration of residents, and the quick thoughtfulness regarding these frameworks will increase the personal satisfaction of individuals. For instance, creating suffering batteries will accomplish a lot of work, and they will have the option to control themselves by exploiting sunlight, warmth, or vibrations sooner rather than later [1]. This is a careful illustration of the area of applications that are being developed for the use of future smart cities. Be that as it may, every city contrasts as far as brilliant city needs and essential usage, and these sorts of shrewd gadgets and frameworks will be utilized later on.

6.1.1 Need for Smart City

In spite of the fact that the smart city is an inventive answer for metropolitan zones, as of late, all the more living areas can be investigated, and the idea of a smart city might be lifted to these elective spaces. City organizers, specialists, and analysts are also looking for these elective living areas for quite a long time. Consequently, because of the rising ocean levels, catastrophic events, and hurtful human exercises, drifting settlements or urban communities have arisen as another answer for people who are looking for discretionary territories for individuals. There are a few favorable circumstances and advantages of these discretionary territories, i.e., drifting urban communities, for example giving an eco-accommodating climate, simple and quick development on the ocean level, effortlessly eliminated and extended development modules, sturdiness against seismic stuns, and financially savvy arrangements [3].

Additionally, savvy city arrangements and subjects could be considered inside the idea of coasting settlements or urban areas. In this way, in view of the aftereffects of our review, we propose another methodology, specifically “smart floating cities,” which is a coordination of smart city subjects with the plan of floating settlements. As smart city ideas have arisen as novel answers for the restricted natural assets and human prerequisites across the world, these ideas can be incorporated into the idea of gliding urban areas, which gets fundamental because of the rising ocean levels. Likewise, since the rising ocean levels are exceptionally causing catastrophic events across the world because of an earth-wide temperature boost, the idea of “smart floating cities” can be considered as a profoundly significant safety measure to the rising ocean levels and restricted ecological assets.

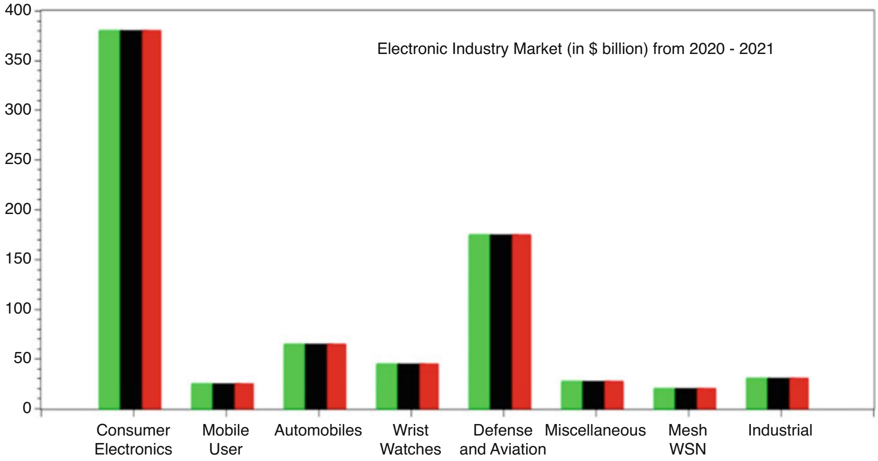

Fig. 6.1 Impact of various electronic components/gadgets in the electronic industry

6.1.2 IoE and the Smart City

The Internet of Energy (IoE) is characterized as a coordinated powerful organization foundation that interconnects the energy network with the Internet, in this way permitting units of energy (privately produced, put away, and sent) to be dispatched when and where they are required. IoE gives a constant interface between the smart matrix (privately appropriated sustainable power assets) and a haze of gadgets (electric vehicles, business and private structures, workplaces, electrical gadgets, apparatuses, and so on) that can be connected and stacked from any wellspring of electrical energy [1, 3]. The Internet of Things is propelling another type of smart city. A smart city exploits feasible data and correspondence advancements to improve personal satisfaction, well-being, training, and furthermore presentation of metropolitan administrations for residents (Fig. 6.1).

A smart city can be considered as the overall umbrella class, in which different undertakings like smart structures, savvy homes, shrewd matrices, brilliant automotives, and traffic by the board frameworks are additionally included. Energy-effective brilliant structures, smart homes, smart grid, and other shrewd items are principal for the climate and for worldwide supportability, which thusly requires the improvement of an IoE in the energy area, and we are on the edge of what will be the following mechanical transformation. The quickened improvement of sustainable power sources will achieve totally better approaches for living and will probably likewise prompt a change of industry. The key here is the Industrial Internet of Things (IIoT) where the presentation of intelligent sensors, crucial interchanges, mechanization, man-made brainpower, and mechanical technology will streamline ventures going from mining and transportation to assembling, brilliant cultivating, 3D printing, and petrochemical activities. Enterprises have just begun to investigate the usage of IIoT, and the IoE will assume an incredible part in improving the network of gadgets and the exhibition of administrations regarding social, natural, and worldwide supportability [4].

Information and communication technologies have been utilized to encourage associations between machines, among people, and among machines and people. As IoE-empowered shrewd structures, brilliant matrices, savvy homes, and traffic by the executives' frameworks are actualized, ICT for energy area should be re-evaluated to meet the changing necessities of things to come. All parts of things to come in the energy framework like matrices, makers, shoppers, and stockpiling can be associated based on normalized open engineering.

6.1.3 Organization

The organization of this work has been as follows: Sect. 6.2 states the areas of the smart city application and its services; Sect. 6.3 tells about the big data analytics, Internet of Things (IoT), and application of cloud computing; Sect. 6.4 describes about the smart city infrastructure; Sect. 6.5 gives an in-depth description about the blockchain technology in smart city implementation; Sect. 6.6 models the efficient energy utilization in the smart devices; Sect. 6.7 describes the wireless sensor network implementation in a smart city; Sect. 6.8 describes the application areas of wireless sensor networks; and Sect. 6.9 concludes the work with future consideration.

6.2 Areas of Smart City Applications and Services

The arrangement of ongoing data about metropolitan conditions is significant for running distinctive accommodating applications and administrations. A concise outline of different territories of keen city applications is given. As indicated by the current world situation, Tokyo is the city with the world's biggest populace thickness that continues developing and bragging the biggest number of individuals of the relative multitude of urban areas on the planet. The world's biggest metropolitan territory with a population in excess of 38 million individuals is the capital of Japan. What's more, an excess of 31 million live in Jakarta, Indonesia, and almost 26 million in Delhi, India. As per conjectures, 60% of the total population will stay in significant urban communities by the year 2030. The outcomes will be water shortage, heap of trash, lack of traffic management, and air contamination. How might we adapt to the above difficulties? One of the ways is smart city—the organized and wise city. It represents best personal satisfaction and low utilization of availability [5].

Here are some important factors of the smart city and their effect on the IoT era.

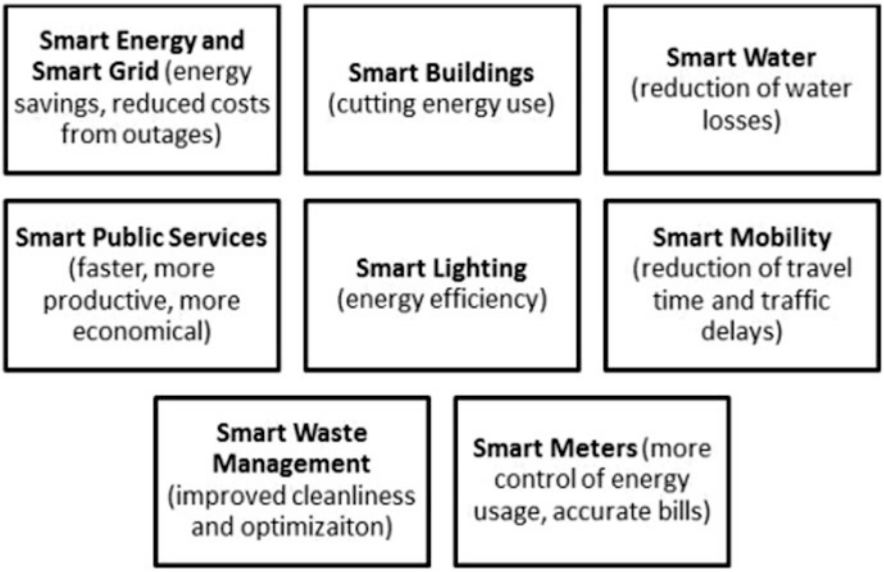

Fig. 6.2 Various elements of smart city based on Internet of Everything (IoE)

6.2.1 Smart Buildings

Cities should make the rules for constant turn of events: advanced innovations are turning out to be progressively significant, and metropolitan frameworks and structures should be arranged all the more productively and reasonably. CO_2 emanations ought to be kept as low as feasible for instance putting resources into electric vehicles and self-impelled vehicles (Fig. 6.2).

Smart city networks use new headways to achieve an energy-capable and unharmful biological system structure. Smart lighting ought to perhaps give guidance when somebody truly walks around them and adjust brightness levels by following step by step as a way to lessen power consumption [3, 5, 6].

6.2.2 City Air Management Tool (CyAM)

Siemens has built up a total, cloud-based programming called "The City Air Management Tool": it says about the contamination information continuously and conjectures outflows. Predictions about 90% precision are conceivable to acquire the emanations for the following 3–5 days. This forecast of air contamination with the estimation and the advances that are utilized makes the City Air Management instrument exceptional. The expectation depends upon the calculation that is a fake neural organization.

Consequences

The cloud-based programming suite called City Air Management Tool with a dashboard shows constant data about the contaminations present in the air all over the city and forecasts the values for 3–5 days. The cities can look over 17 different parameters to achieve the following in 3–5 days: speed cutoff points or open vehicle city air management that depends on MindSphere, Siemens' cloud-based, open working framework for IoT [3, 4, 6].

6.2.3 Traffic Management

Challenges for huge smart cities are to enhance this management system. Los Angeles is one of the busiest cities in the world; it follows one of the fine ways to control the traffic. Pavement-incorporated sensors will leave a message update about the traffic stream to the local traffic board and then they will investigate the information and automatically make changes in the traffic signals immediately. It utilizes chronicled information to look forward where traffic can go—all information without the help of human interaction [6, 7].

6.2.4 Smart Parking

This technique recognizes when a vehicle has left from home or any other place; the sensors which are placed on ground report through mobile to the driver where they can identify the free parking area. Others, uses vehicle input to express exactly about where the open areas are and the areas that are holding up vehicles which leads to the easiest course of action. Smart parking is a reality today and does not need convoluted foundation and also large venture to make a smart city [4, 6].

6.2.5 Smart Waste Management

This arrangement helps to enhance the productivity of waste assortment and to lessen new expenses and new location of the natural problem related with a waste assortment. Waste holder will have the level sensor. The user will get the information or notification on the mobile when it has reached a particular limit. The message looks to purge a whole compartment, which despises half-empty drains [8].

6.3 Big Data, IoT, and Cloud Computing

The Internet of Things plays an important role in several areas which include the conversation between more objects that include smart gadgets, mobile gadgets, sensors, and others. The elements of the IoT enable more conversation between all the structural types. The elements are objects, gates, network infrastructure, and cloud architecture. The Internet of Things and cloud computing combinedly play a very important role in all areas. The cloud framework can send different application zones to break down and measure the information in a quick way and settle on a significant choice at the earliest opportunity. It is surveyed that 4.4 trillion GB data will be processed in 2020. This has become difficulty that it will put a huge strain on its system. Accordingly, there is a need to restrict this high-pressure factor and find a response for moving the data.

Circulated figuring, of course, gives good execution and adaptability to store and work on especially gigantic volume of information. Internet of Things and distributed computing have a correlative relationship. While IoT makes a ton of data, many cloud providers grant data travel through the Web that infers and urges a way to deal with and investigate the data.

Cloud computing assists with teaming up in IoT advancement in the smart city paradigm. Utilizing cloud stage, Internet of Things engineers can store the data distantly and access without any problem. For monitoring of the IoT devices and advance analytics, cloud computing helps a lot. Internet of Things gadgets which utilize the basic application programming interfaces and back-end foundation can get significant security refreshes quickly through cloud when any security alert occurs in the framework. This Internet of Things and cloud processing joined element is an indispensable boundary for client security and protection. Consequently, from the above portrayals, we can locate the reliance between the three fundamentally unrelated advancements. Here cloud computing plays the part of a typical work environment for Internet of Things and large information where Internet of Things is the wellspring of information and enormous information as an innovation is the scientific foundation of the information (Fig. 6.3).

As per IDC, an excess of 90% of IoT information will be facilitated on the cloud stage within the following 5 years. A huge measure of Internet of Things information data will take care of the enormous information frameworks. To diminish the difficult nature of information mixing in IoT which is one of its standards to augment its advantages? The idea driving it is if the Internet of Things applications and information work in storehouses we will not receive the maximum capacity in return [5, 7].

Thus, to improve bits of knowledge and to decide, mixing data (information) from different sources is the most ideal way. Consequently, for the previously mentioned two focuses, we can see an unmistakable requirement for grasping cloud-based frameworks for both Internet of Things and big data. This coordinates in view of data-based result direction from product orientation.

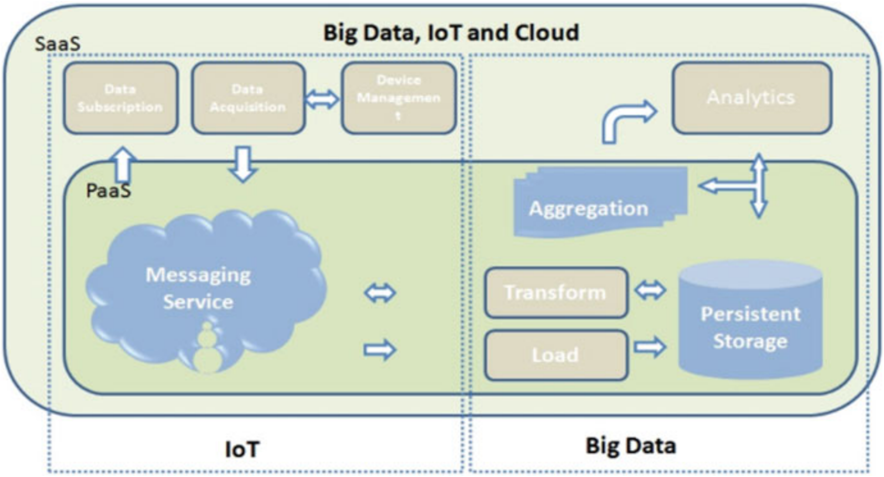

Fig. 6.3 Components of big data analytics in building smart cities

6.4 Smart City Smart Infrastructure (2010–2023*)

From 2010 to 2023, absolute interest in smart city framework is relied upon reaching $108 billion. It incorporates the arrangements that make more intelligent structures, utilities, transportation, and government (think public works, well-being, and crisis administrations) conceivable. Figure 6.4 is a graph from Pike that shows the extended development in those zones across the decade.

From the above chart we are able to view the development of smart cities in different fields. As per the analysis of our work in the year of 2010, the industry invested an amount of about $1468 million in the field of utilities. In the field of smart transportation the growth industry has invested nearly about $1720 million. For the new smart building structures, as per the study the industrial persons invested an amount of about $2685 million to see the growth of the country and also for their individual industry profit. As mentioned above the industrial persons also invested their money for the development of government (smart government). The invested amount was about nearly $3104 million. In the year of 2011, the industry invested an amount of about $1804 million in the field of utilities. In the field of smart transportation the growth industry has invested nearly about $2475 million. For the new smart building structures, the invested amount is about $3482 million. As mentioned above the industrial persons also invested their money for the development of government (smart government). The invested amount was about nearly $4069 million [8, 9].

In the year of 2012, the industry invested an amount of about $2517 million in the field of utilities. In the field of smart transportation the growth industry has invested nearly about $3440 million. For the new smart building structures, as per the study the industrial persons invested an amount of about $4825 million.

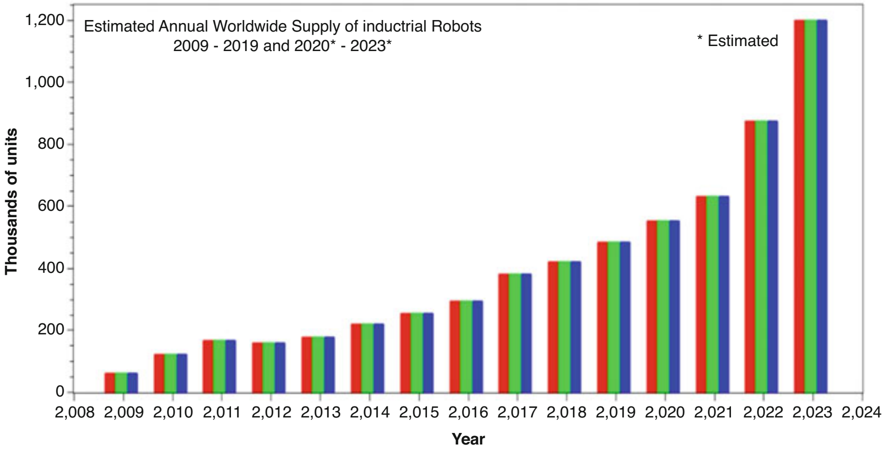

Fig. 6.4 Worldwide supply of industrial robots for a range of 2010–2023

As mentioned above the industrial persons also invested their money for the development of government (smart government). The invested amount was about nearly $5286 million. In the year of 2013, the industry invested an amount of about $3104 million in the field of utilities. In the field of smart transportation the growth industry has invested nearly about $4405 million. For the new smart building structures, as per the study the industrial persons invested an amount of about $6167 million to see the growth of the country and also for their individual industry profit. For the development of government (smart government) the invested amount was about nearly $6881 million.

In the year of 2014, the industry invested an amount of about $3608 million in the field of utilities. In the field of smart transportation the growth industry has invested nearly about $5328 million. For the new smart building structures, the invested amount was about $7342 million. As mentioned above the industrial persons also invested their money for the development of government (smart government). The invested amount was about nearly $8265 million. In the year of 2015, in the field of utilities, smart transportation, smart building structures, and smart government the growth was about $4195, $6209, $8643, and $9650 million. In the year of 2016, in the field of utilities, smart transportation, smart building structures, and smart government the growth was about $4531, $6839, $10,069, and $11,412 million.

In the year of 2017, the industry invested an amount of about $4741 million in the field of utilities. In the field of smart transportation the growth industry has invested nearly about $7552 million. For the new smart building structures, the invested amount was about $11,118 million. As mentioned above the industrial persons also invested their money for the development of government (smart government). The invested amount was about nearly $12,755 million. In the year of 2018, in the field of utilities, smart transportation, smart building structures, and smart government the growth was about $4783, $7903, $11,664, and $13,846 million [3–8].

In the year of 2019, in the area of utilities, smart transportation, smart building structures, and smart government the growth was about (in millions) $4793, $8265, $12,965, and $15,818. Finally, in the year of 2020, in the field of utilities, smart transportation, smart building structures, and smart government the growth was about $4825, $8601, $12,965, and $15,818 million. So these are the growth trends of a smart city region that was concentrated by the industry in the period of 2010–2020.

6.5 Blockchain Technology in IoT

Blockchain is an arising conveyed innovation that empowers P2P exchanges, arrangements, and organizations in a decentralized system administration climate, setting up trust among obscure individuals or peers, and then accounts the exchanges in a changeless disseminated record. Bitcoin is an agreement network which bolsters totally computerized cash, additionally called digital money, in a P2P decentralized installment framework. Blockchain gives information straightforwardness, unchanging nature, and cryptographic security.

In an IoE climate setting, different applications communicate to one another and give a lot of information; also, the innovation called blockchain is suitable to make sure about the information. Since there are different likely utilizations of the IoE, a few varieties of blockchain are outstanding, which lie on an agreement calculation. The agreement system is characterized as a cycle by which an appropriated blockchain record is refreshed in a request that each friend hub has an indistinguishable duplicate. Numerous agreement calculations are also presented and implemented, for example, POW, POS, and PBFT [7, 8].

This technology is also classified into three segments: (a) particular blockchain technology which works among a well-known, recognized, and frequently checked members; (b) common blockchain in which the members are mysterious or not trusted; and (c) half-and-half blockchain in which there is a pre-characterized gathering of hubs on the technology network that already exists and that is not doled out to a solitary gathering. Besides, it underpins security problems that are acquired by the permissionless technology. To evaluate the public block provided in Fig. 6.5 the author has explained about the flowchart of the format of public, private, or hybrid in the blockchain.

The reproduction has been performed over the public blockchain situation. Essentially, one can do the blockchain reenactment for different instances of private and crossbreed block chains [9–11]. The quantity of companion hubs in the P2P cloud worker (CS) network is taken as 10. A haze worker (FS) safely sends the information to the related cloud worker in type of exchanges. CS at that point accumulates the exchanges and puts them into an exchange pool [10]. In the event that the quantity of exchanges in the exchange pool spans to a pre-characterized exchange edge (i.e., the base number of exchanges needs to be stored in a square), a pioneer is chosen from the organization for creating a square and adding that

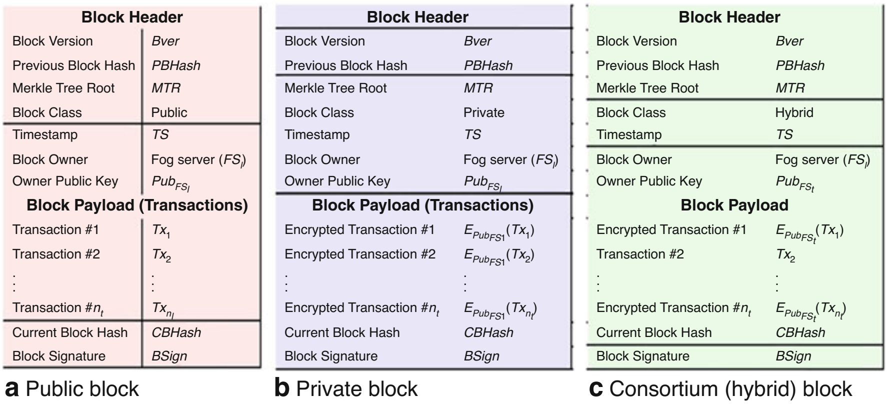

Fig. 6.5 Development of three types of blockchain technology

block into the blockchain. Subsequent to executing the agreement calculation (for our situation, Practical Byzantine Fault Tolerance (PBFT) agreement calculation), the made square is added into the blockchain. The recreation is finished under the accompanying two situations:

6.5.1 Scenario 1

The quantity of exchanges for each square is taken as 35 for the consideration. The reproduction outcome that appears in Fig. 6.6 shows the quantity of squares mined in blockchain to the aggregate computational time (in a moment or two) for the squares. From this we are able to know that if the quantity of squares mined is expanded, then the calculation time additionally increments straightly.

6.5.2 Scenario 2

In this scenario, the quantity of mined squares in each chain is assumed as 25. The reproduction outcome given in Fig. 6.7 depicts the quantity of exchanges put away in each block to the complete computational time for mining the squares. Comparable pattern depicts that the calculation period increments straightly when the quantity of exchanges for each block is additionally expanded.

From the above examination we could know the blockchain-based recreation to show the common sense of the new system and its great exhibition attributes.

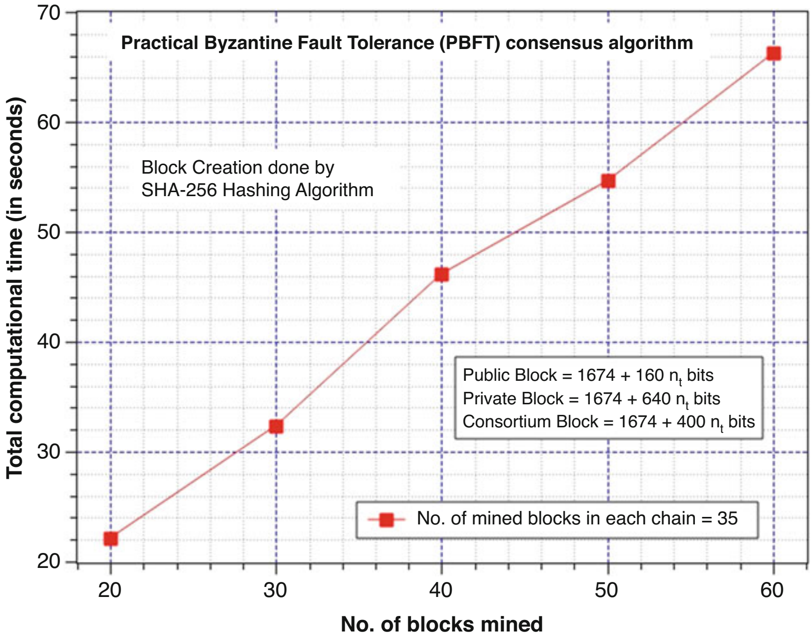

Fig. 6.6 Demonstration that shows the number of blocks mined into the blockchain to the total calculation time (in seconds) for the blocks

6.6 Energy-Efficient Wireless Network

Energy harvesting is one of the useful green communications for next-generation wireless networks. Wireless networks can also be divided depending on the performance network and the expenditure of energy as energy efficient or not. In the past investigations on the energy productivity of WN, it was additionally grouped depending on the accompanying boundaries.

Maximizing of bits/joule given by

$$\frac{\text{Bit}}{\text{Joule}} = \frac{\text{Network capacity}}{\text{Throughput (per unit of energy)}} \tag{6.1}$$

concentrates on these two exhibitions of the organization and the power consumption. This improvement on this boundary leads to arrangement into some classes under the power-productive WN. Think about the obtained image in an added AWGN channel as

$$y = \hat{s} + n \tag{6.2}$$

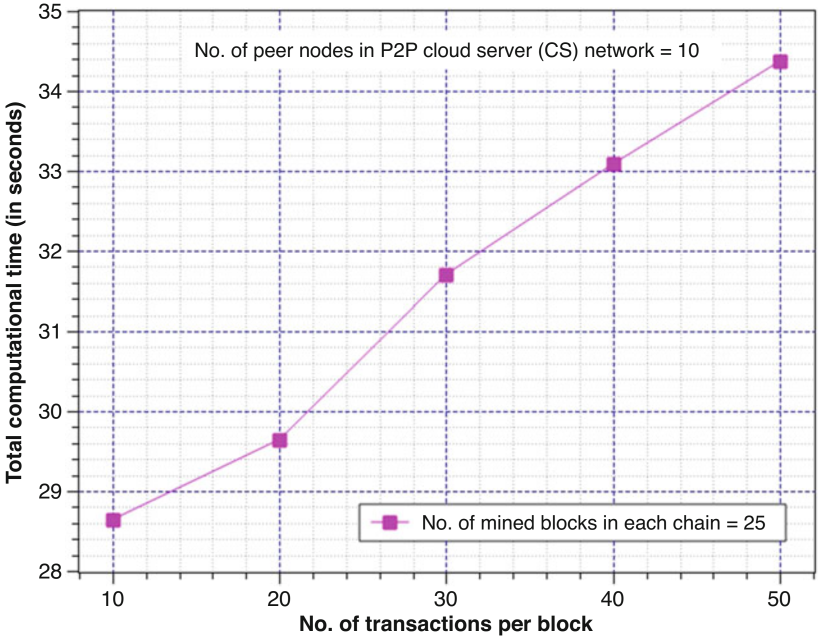

Fig. 6.7 The number of records stored for each block to the total calculation period (in seconds)

in which $\hat{s}$ indicates the communicated signal and n signifies AWGN and unit change. As indicated by Shannon, the force imperative on the code word for enormous value of code word m is written by

$$\frac{1}{m}\sum_{k=1}^{m} {s_k}^2 \leq P^{'} \tag{6.3}$$

in which P indicates the force. In each channel, the causal limitation should be fulfilled by

$$\sum_{k=1}^{n} {s_k}^2 < \sum_{k=1}^{n} E_k, \qquad n = 1, 2, \ldots, m \tag{6.4}$$

in which E_k indicates the fixed irregular cycle followed by the power that is collected at the sender side, the extent to which is $E[E_k] = p$, with $E[.]$ being the assumption administrator [11–13]. This condition guarantees that the code word is communicated with no blackouts in power. Furthermore, to save power which is collected for some other applications, on the off chance that battery is not accessible, the imperative for the code word is given as

$$s_k{}^2 < E_k, \quad k = 1, 2, \ldots, m \tag{6.5}$$

On the off chance that the battery is accessible for a limited size, with a most extreme size given as $B_{\max}$, at that point we can say that

$$E_{B_{k+1}} = \min\left(E_{B_k} - s_k^2 + E_k, B_{\max}\right) \tag{6.6}$$

which indicates that from the start s_k^2 amount of energy is scattered and afterward Ek measure is the power in the battery. The limit of the added AWSN with the imperative as given by Eq. (6.5) is communicated as

$$C = \lim_{m\to\infty} \frac{1}{m} \max I\left(S^m, Y^m\right) \tag{6.7}$$

Furthermore, the upper bound on the limit can be communicated as

$$C \le \frac{1}{2}\log\left(1 + \overset{,}{P}\right) \tag{6.8}$$

Energy limit of the frameworks having node with cradle ability to store the energy collected is bigger, as demonstrated in [3]. The channel limit of a framework under ideal conditions and having an endless support is given as

$$C = \frac{1}{2}\log\left(\frac{\mathbb{E}\left[E_p\right]}{\sigma^2}\right) \tag{6.9}$$

where E_{p} is the fixed random value and indicates that the point is recharged by E_{p} at time p and σ^2 means the commotion change. From the above equations it is clear that the wireless sensor network is an energy-harvesting system and also the spectrum-harvesting system. So the future generation is dependent on the wireless networks and IoT [14].

6.7 WSN in Smart Cities

In metropolitan regions, the coordination of the "product-characterized sensor organizations" and "detecting as an assistance" ideas with wireless sensor network (WSN)-based frameworks is prompting the change of traditional city administrations toward shrewd urban areas. Smart energy, smart driving, brilliant homes,

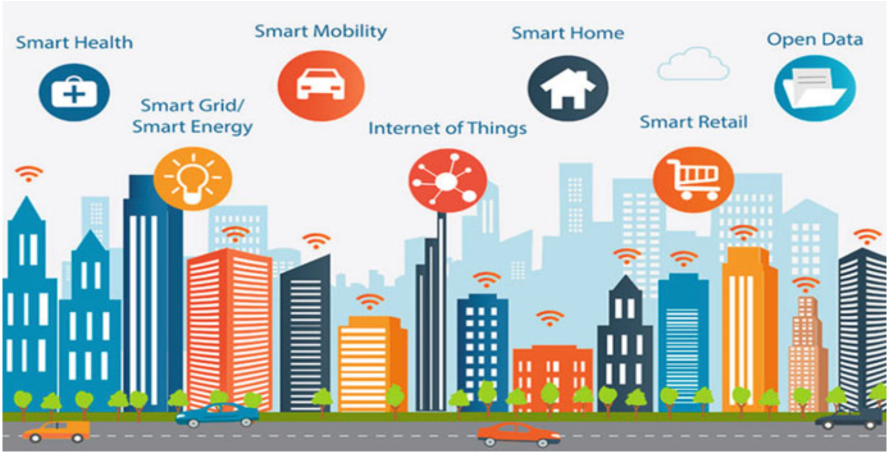

Fig. 6.8 WSN application area

smart living, smart administration, and keen well-being are only a couple of benefits that can be offered by keen urban areas. Moreover, while these ideas are significant application zones, smart residents close the circle by partaking in detecting, impelling, and dynamic cycles. In shrewd urban communities, inheritance WSN-based administrations are stretched out by having residents that go about as sensors. Artful or participatory detecting models empower gatherings of people to cooperatively pursue a similar objective with solid connection joints, despite the fact that this does not generally need solid social connections between them. Hence, nondedicated remote sensor structure networks, and teaming up network structure informal organizations where cooperation can happen as programming characterized detecting has been designed. This change in WSNs presents remarkable answers for the correspondence plane of keen urban communities. Figure 6.8 depicts the recent application areas of wireless sensor in smart cities [15–19].

Smart driving is a significant application in metropolitan brilliant city administrations. Evans [4] presents a brilliant stopping framework by misusing the advantages of WSNs. The WSN-based shrewd stopping framework calls for a versatile and mixture self-association calculation for the WSN so it runs under both straight and mass stopping cases while giving a superior energy to the executives' administration for sensors so the battery lifetime of each sensor can be drawn out, which would therefore drag out the lifetime of the whole WSN. Moreover, other than the correspondence and energy-related issues, the framework likewise helps a driver through a powerful quest instrument for accessible parking spaces in the region [16].

6.8 Areas of WSN Application

Smart gadget sensors have been implanted in some gadgets in view of improving their use, act of control, and also the board. For example, the type of sensor called proximity is also included to increase the ability of gadget power; that is, in case the gadget is close to the client's ear, it automatically turns off the screen immediately. Another model is an accelerometer that detects screen situating and turns its substance as indicated by clients' positions. What's more, the last model is called a battery sensor that controls the charge cycle and battery temperature [18].

According to the survey, the information detected in the abovementioned sensors can be used and deciphered to say about the information in the accompanying areas. Smart gadgets can also be utilized for the unknown information in the sensors that is used for harvesting. This prompts the arrangement of smart gadget sensors as indicated by its performance as two types of sensors: active sensor and passive sensor. Any sensor may go about as an active or a passive sensor as per its utilization. At the end of the day, if the information received from a sensor is utilized similarly as the smart gadget creators or engineers planned it, it is considered to be functioning as an active device. In any case, if the gathered information has been deciphered recently, the above types are working in a passive way. In the event that the sensors are utilized along these lines, hidden data issue happens. In the following sections, a lot of smart gadget sensors are presented [1, 7, 11].

6.8.1 Touchscreen

The new type of gadgets called touchscreen is very useful for the essential information and yield activities. The three basic principal connection methods are characterized for this one. To start with, contacting: it is characterized as the way toward tapping upon the display in any area to do the process like open or close, or for character typing. This is the basic fundamental movement of the display screen. Secondly, multitouch is also explained in the way toward knocking the screen by multiple fingers simultaneously. This capacity is vigorously utilized in the gaming world [5]. Thirdly, signal is characterized in the way toward sketching a specific example on the display screen. Signals might be actualized with a single finger as intuitive or more than one finger as during the time spent editing photographs and changing camera zoom. Heat map is one of the representation techniques for touchscreen information [19].

1. **Heat Maps.** It is the new information perception strategy where more than a single touch or motion on a cell phone display is called as the heat maps [6]. Designers have built up different techniques to produce these guides [7].
2. **Touchscreen as a Passive Sensor.** All the models that use the display screen in a functioning manner: contacting speed, delay, composing time, and motions. Nonetheless, specialists found another technique to acquire valuable information

from the display screen that can also be used with some new cell phone sensors to contemplate dozing practices of the clients by checking how often the display screen reacts to that [8]. Also, it tends to be used with the alert implementation to concentrate on how quickly clients react to cautions [9].

6.8.2 Motion Sensors

Three fundamental sensors are mainly used in present-day smart gadgets for movement identification: accelerometer, spinner, and magnetometer. The accelerometer identifies changes in the gadget removal, direction, and slant around three tomahawks by estimating increasing speed powers. Its operational hypothesis relies upon the worth variations of capacitance when a portable mass openly shifts in between the plates in the MEMS. The changes that occur everything from plates can be monitored and used for further process. Then again, the gyroscope measures how quickly the gadget turns according to the three axes [10]. Its inner design is like the construction of the accelerometer. Nonetheless, the rotational force moves the weight to vary the capacitance estimations of the interior fixed plates.

1. A new type of sensor called magnetometer quantifies the ability of the attractive field around the telephone from which the telephone can acquire its total bearing identified with the world's geomagnetic field [11]. Magnetometers rely upon the voltage measurement that is distinguished among metallic components when an attractive area is available. Subsequently, magnetometers are chiefly utilized in e-compass work area [3, 12, 20–21].
2. Movement sensors are also analog sensors. The yield of this sensor is in different voltage levels. The voltage variety is changed by utilizing analog-to-digital converter into an advanced number that can be perused and that appears in the computerized world. Movement sensors have various frequencies, which characterize the number of new estimations required each second. To separate valuable data of movement sensor information, highlights are removed. To remove these highlights, the recurrence of perusing is set. The windows will help to determine the many highlights. These highlights are ordered in three fundamental categories: time, recurrence, and wavelets. The meanings of these highlights and their conditions can be found in ref. [13].

6.8.3 Multimedia Sensors

Two primary media sensors are installed in brilliant gadgets: digital camera and finger impression and amplifier. From the next segments, we will be able to know about the camera picture securing cycle and finger impression sensors [23].

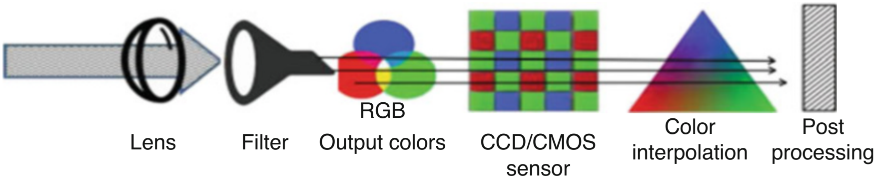

Fig. 6.9 Pipelining methodology of camera

1. **Camera.** Capturing a photograph by using a smart gadget camera gives five different difficult stages. This cycle begins by capturing the brightness through the camera focal point and shining the picture on the inward channel. Along these lines, the yield RGB tones travel through the principal camera, the charge couple devices/complementary metal oxide semiconductor sensor. At this stage, every tone is controlled as isolated segments. To see the last picture, shading introduction and picture post-working step are required. Every last stage of a level gives different marks above the acquired picture. The abovementioned marks might be used to follow any photograph behind the sensor that accepts it as an accompanying segment. Figure 6.9 depicts the pipelining methodology of a cell phone camera [24].
2. **Thumbprint**. Thumbprint is also a sort of biometric acknowledgment framework. The personality of the client setup is done by ID or confirmation with the help of biometric acknowledgment [14]. It acquires prevalence since its cycle relies upon the clients as what their identity is and not something they convey or recollect like other conventional security frameworks. The biometric acknowledgment highlight vigorously relies upon the physical, substance, and conduct attributes of the clients' body like the finger impression, eyeball, face, vocal, or personal stench or body temperature [15]. D.G. directed a pleasant overview of biometric acknowledgment strategies concentrating on the vast majority of them [16]. Among those characterizing attributes, finger impression is the most normally utilized in client-distinguishing proof frameworks since clients have particular finger impression designs for each finger [17]. Henceforth, unique mark frameworks are fundamentally design acknowledgment frameworks for the thumbnail [9] which sensor gauges the gap to identify the examples in the knocks and notches that modify the thumb impression [18]. Then, the framework further contrasts the outcome and also the biometric information that from the client—check cycle—contrasts it and a data set of finger impression information from various clients—ID measure [14].

6.8.4 Barometer

It is also a sensor type added to the cell phones. It estimates any variations occurring in the environmental pressing factor of the telephone. This is extremely delicate since it can quantify variations in air pressure inside a similar structure or design. It may very well be used to anticipate climate. Also, it can quantify the gadget elevation [19]. Wu et al. have indicated that cell phone indicators can also be used to distinguish the structures' entryway inaugurating/shutting occasions anyplace below the structure depending on abrupt variations in air pressure measurements [20, 25–28].

6.8.5 Ambient Light Sensor

An ambient light sensor is a photodetector sensor that detects the surrounding or ambient light of the smart device and reconfigures the brightness of the smart device screen. It is also utilized to dim the screen to reduce power consumption of the battery. In [21], it has been utilized to study the mental health of smart watch users.

6.9 Conclusion

As ocean levels are expanding each day, urban areas beneath ocean level (for example, most urban areas in the Netherlands) are confronting a critical test, and they are attempting to locate an elective arrangement that could beat the issue of moving toward ocean flows. Gliding urban communities or settlements have arisen as a novel idea because of environmental variations, increasing ocean levels, and land deficiency. This idea could likewise be taken into account as a chance for sociopolitical modification. Seas are not heavily influenced by any administration, and every human has the option to utilize these elective living areas. Along these lines, seas are our keep-going opportunities to get by on earth. Populated areas around the world, particularly the seafront territories, are getting progressively swarmed because of substantial traffic and awkward natural offices.

Smart and feasible city ideas ought to contain a few watchwords as referenced in the starter segments of this examination, and this part incorporates transportation, land use, climate, and their connection to one another. This smart city design ought to be adjusted. Besides, there is no single response for making the ideal mix of angles that comprise a shrewd metropolitan city. These viewpoints rely upon the size of the city, openness to different urban areas, and availability to support focuses. In this manner, the part of the creator is to total these elements by taking populace size and reasonable capacities into thought. In the writing, specialists contemplated the connection between transportation and land use in a point-by-point way. For example, in the investigation by Hall, the association between transportation and land use was examined, and the assessment of this association ought to be made.

The principal objective of this exploration was to bring issues to the knowledge of established researchers about the present status of the shrewd city ideas uncovering its key future patterns, including coasting urban communities misusing IoT advancements and applications. We likewise introduced the new advances of past examinations and the conceivable execution of past techniques in future investigations on various brilliant city ideas. In this examination, we investigated these smart city key subjects by auditing a few articles to comprehend the primary connections among them by showing application models. We presumed that depending on current advancements in logical examinations, there is as yet an absence of logical reports on brilliant gliding urban areas, which is by all accounts a great contender for future smart urban areas.

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Chapter 7
Machine Learning and Deep Learning Algorithms for Smart Cities: A Start-of-the-Art Review

Idowu Dauda Oladipo, Muyideen AbdulRaheem, Joseph Bamidele Awotunde, Akash Kumar Bhoi, Emmanuel Abidemi Adeniyi, and Moses Kazeem Abiodun

7.1 Introduction

The word "smart" refers to a computerized process that is adopted within a domain to conduct the desired operation. For example, all devices and electrical appliances like ovens, tube glows, fans, laundry engines, and HVAC systems among others are embedded in a smart home with miniature sensing devices. The devices can be used to collect information, sense environment, and move information to process hubs for making decisions using dynamic rules and regulations. Deep learning is also a rapidly growing machine learning technology. In recent years ML and DL methods have been used in smart cities to achieve remarkable breakthroughs in developing various models. There are currently machine learning systems implemented in many fields. DL nowadays is a new and dynamic field of ML. It is a computational intelligence paradigm, has attracted substantial interest from the academic community, and has shown greater promise over traditional techniques [1].

DL is the most efficient, monitored, time-consuming, and cost-effective technique than ML technique. DL is not a specific approach to knowledge, but it conforms to different methods and topographies that could be useful to a wide-ranging complicated problems. The method learns the illustrative and differential

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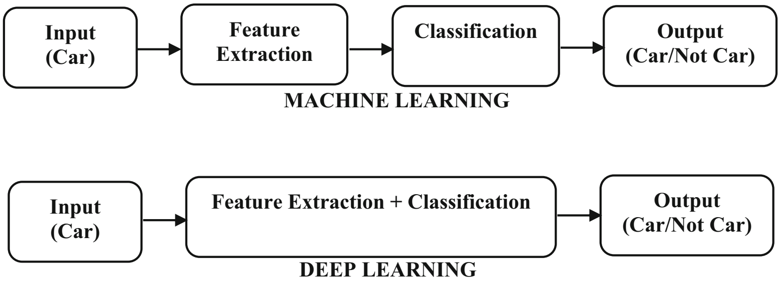

Fig. 7.1 The process of machine learning and deep learning

characteristics in a rather heterogeneous method [2, 3]. Robotics is the branch of artificial intelligence (AI) that automatically, without being explicitly programmed, provides the system with the benefits of learning from concepts and ideas. These produce better results and make future decisions using observations like direct experiences to prepare for information characteristics and patterns [4].

To have high-level abstractions with multiple nonlinear transformations, DL is based on a series of ML techniques used to model data. The artificial neural network (ANN) system runs on a deep learning technology. The algorithms follow learning efficacy and are enhanced by continuous increase in the amount of data. Efficiency depends on large amounts of data. The training process is referred to as intense as the amount of neural network layers grows with time [5, 6]. Figure 7.1 shows the machine learning vs. deep learning.

The efficacy of machine learning algorithms has historically depended heavily on the consistency of input data representation. As opposed to a good data representation, a poor data interpretation may also result in worse outcomes. As a result, for a long time, feature engineering has been a significant study direction in machine learning, concentrating on creating features from raw data and contributing to a vast number of research studies [5]. The execution of the deep learning experience is strictly dependent on two stages, known as the training phase and the assumption phase. The training phase entails labeling and evaluating the matching features of massive amounts of data, while the assumption phase entails making conclusions and using prior knowledge to mark new unexposed data [7, 8].

It is difficult to overemphasize the role of smart cities in the transformation of various areas of human life, impacting sectors such as transport, health, energy, and education. The data on weather information, for example, is growing dramatically at a rapid rate. It can be extremely helpful in terms of agricultural production to recognize and obtain useful information from large volumes of weather data [9, 10]. Figure 7.1 displays the processing of ML and DL algorithms.

Usually, the smart city idea is restricted to sensing and manipulating data in order to obtain sustainability and productivity in a city service. The amenities in the cities are turned to smart equipment like smart energy, smart water, and smart lighting among others. The cognitive cities were used to accomplish the same objectives

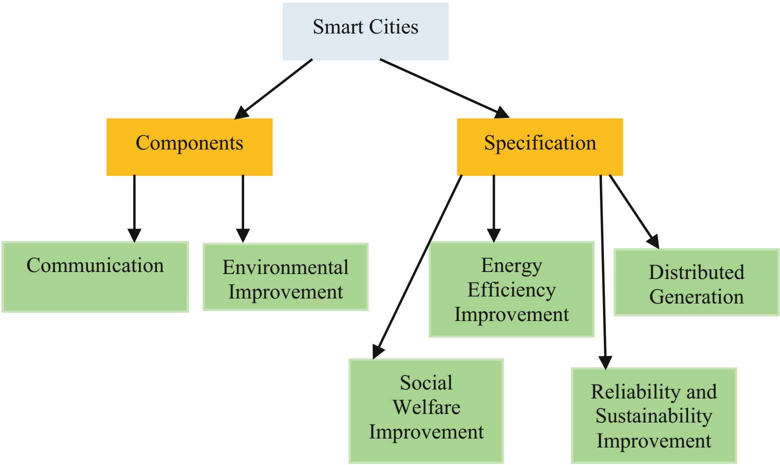

Fig. 7.2 Basic features of smart cities

with resilience in the services provided. Also, a cognitive city takes into account the technical sources, and other sources like economic, political, and geographical information and education in the smart and urban development [11, 12]. Figure 7.2 depicts the basic features of smart cities.

The expectation of today's digital era has been to merge cities with new technology solutions. Companies cater to the Internet of Things and big data solutions for their daily activities in order to put the city into the age of the "Fourth Industrial Revolution." This is the idea of a smart city, a promise to integrate the physical infrastructure and facilities of a city with the new technological offerings. As the IoT in daily life has become increasingly popular, the idea of the smart city has begun to evolve. The IoT is the key to intelligent cities being created [13, 14].

To control the resources of megacity populations, any device that is part of a smart city must collaborate with others. If the city is to be genuinely "intelligent," these machines must interact with each other. This is where the IoT comes in, offering the ideal model of a body of communicating devices that provide daily challenges with smart solutions [15]. For learning purposes, applications of IoT can stand to benefit from the decision process. Even in case of location-aware services, for example, location estimation may be described as a decision-making procedure wherein the exact or nearest value to a given goal is determined by a software agent. In this respect, to formulate and solve the issue, reinforcement learning can be used. A virtual machine communicates with its surroundings in a reinforcement learning solution and alters through carrying out certain operations, to improve the condition of the world [16, 17]. Figure 7.3 shows the relationship between the various objects based on IoT.

To improve productivity and mobility smart cities are funding and implementing Internet of Things (IoT) technology all over the globe. The Internet of Things (IoT) is an extension of Internet connectivity into physical objects (wireless detectors,

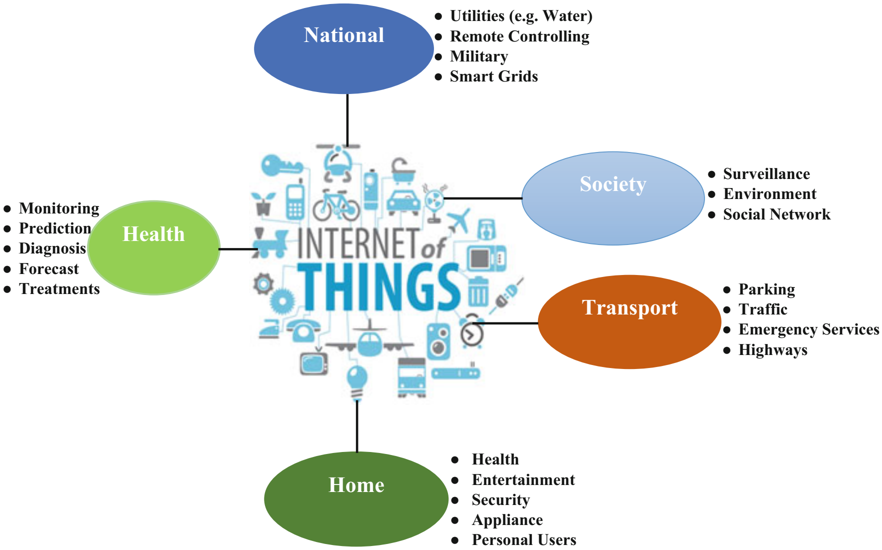

Fig. 7.3 The areas of Internet of Things applications and relationship

actuators, meters, and so on), systems, and ecosystems beyond computers and smartphones. These devices can communicate and interact over the Internet with each other, and they can be monitored and controlled remotely. This network-connected system integration is useful in a variety of areas, including community security, facility control, operations, and traffic management analytics [18, 19].

7.2 Application of Internet of Things (IoT) in Smart Cities

The IoT application is still emerging in the smart framework, smart city, and other areas of human activity, and thus many aspects of conceptualizing and leveraging it remain a work in progress. From industrial applications to emergency services, mass transit and mobility, public safety, city lighting, and other smart city applications, the Internet of Things is in every business and government field today. Cities are becoming increasingly connected as IoT technology advances, in an effort to improve the performance of infrastructure installations. As a result, the emergency services' dependability and awareness are improved at a lower cost. And there is continuing innovation. In the years to come, we expect to see many smarter city ideas using IoT technologies for this market. Nevertheless, there are many reasons for municipalities to switch to the methods of wireless communication given by IoT technologies. The following are some of the reasons:

1. **Performance:** One of the significant factors is performance. Service personnel must physically go to the construction site for the audit and service of the communications system in most wired solutions. These "truck rolls" are costly and inefficient because, whether or not a problem occurs, they usually occur on a timetable. Wireless connectivity, on the other hand, allows for remote control and management of IoT deployments. This helps administrators to conduct firmware updates and security fixes during the entire deployment and, in the case of any problems, get timely notifications.
2. **Cost:** In the decision to switch from wired solutions to wireless, cost is a key factor, as installing and maintaining landlines are massively expensive. In addition, the price of cellular data plans is declining and the robustness and reliability of wireless communications are also allowing new use cases that would have been cost-prohibitive before.
3. **Reducing resources:** Reduction of resources is often also a driver, particularly in instances of uses such as smart street lighting and asset monitoring. These IoT applications allow sensors to be used to collect data and wireless modules to monitor the use of resources, which can result in a significant decline in the use of energy.

7.2.1 IoT Technologies in Smart Cities

A plethora of issues, such as air pollution, freshwater shortages, mountains of waste, and an increase in traffic, will occur when cities face problems caused by population growth. How do we handle these difficulties? According to Al-Turjman [20], IoT and intelligent systems can be influenced by smart cities in the following ways:

1. **Smart foundation**

   For cities to have the requirements for steady growth, digital technologies are increasingly becoming essential; buildings and infrastructure in the cities must be built in a more effective and sustainable manner. Cities should also invest in hybrid cars and self-propelled engines to minimize CO_2 emissions. In practice, smart technologies are required to build a system that is both energy and environmentally compatible.

   Smart lighting, for example, just switches on as someone walks by it, minimizing the amount of energy used; setting brightness levels and monitoring everyday usage are also essential components of smart lights.
2. **Control of air quality**

   Smart cities are now introducing instruments that can collect pollution data and forecast emissions in real time. Being able to predict carbon emissions allows cities to get to the bottom of their pollution problems and brainstorm strategic solutions to minimize the amount of pollution they produce and put out.

3. **Traffic control**

   In the quest of means to grow, traffic is one of the biggest problems facing big cities. Yet, it is not difficult to find a solution. Los Angeles, for example, is one of the world's busiest cities and has introduced an intelligent transportation solution to handle traffic flow. Embedded street sensors send real-time traffic flow information to a centralized signalized intersection platform, which analyzes the data and dynamically adjusts the traffic signals in seconds to show the current traffic conditions. Simultaneously, historical evidence is used to predict where traffic will go, and human intervention is not needed in any of these processes.
4. **Smart parking**

   Communities that acknowledge whenever a car has entered the parking area often exploit intelligent parking strategies. Sensors are installed into the ground and, through a smartphone app that the driver downloads, report the location of free parking spaces. Others depend on vehicle input to accurately classify openings and lead pending cars along the lowest possible path. Smart parking is becoming a reality, requiring no complex infrastructure or major financial implications, making this smart city software suitable for a midsized smart city initiative.
5. **Control of smart waste**

   Sewage treatment techniques help to improve waste management performance while lowering maintenance costs and successfully resolving any and all environmental challenges created by inadequate waste disposal. In these solutions, the waste container receives a level sensor; a truck driver's management platform receives a notification through their smartphone when a certain threshold is reached. By pretending to empty a complete container, the message helps them prevent half-empty drains.

   The combined cloud and IoT-based application works well over ordinary cloud-based applications. The cloud-IoT-based system can be used for emergency and real-time applications like military, banking, and medical systems. In particular, the cloud-based IoT approach would help provide medical applications with effective resources for tracking and accessing information from any remote location. The IoT-based data-centric application can be used to collect data for a real-time update for a predefined period. Besides, this can be used to record relevant medical data for effective disease diagnosis, and monitoring, especially before the illness reaches a serious level.

   In big data analytics ML models can be used for intelligent decision-making due to the huge data generation by the IoT-based devices. The method of implementing data-processing techniques for particular fields requires specifying the data involved like the velocity, variety, and volume of such data. Normal data analysis modeling involves the model of the neural network, the model of classification, the process of clustering, and the implementation of efficient algorithms as well. The IoT devices can be used to generate various data formats from several sources; hence, it is very important to describe the features of the data generated for proper data handling. These help in handling the various characteristics of capture data for scalability, and velocity, and thus help in finding the best model that can provide the best results in real time globally without any challenges. These are all known to be one of the IoT's big problems. However, in the latest technologies, these are all problems that generate a large number of possibilities. Such information can be accessed using the latest healthcare applications, and the data is securely stored on the cloud server.

In the field of healthcare, IoT devices such as satellites could have diverse technologies, for instance the monitoring of various diseases like blood glucose, heart rate, and endoscopic capsules [21, 22]. The healthcare industry can be more relevant and operates in real time in remote areas during disease outbreaks if mobile technologies, sensors, and actuators are combined [23, 24]. The structure of smart healthcare devices helps in receiving information offered through Web communications systems for a better medical system [25, 26]. Approximately, 3.7 million biomedical devices are now in use, and then connected to and tracked by various sections of the body to record clinical remedies [27]. The IoT-based system can be used for monitoring patients with infectious diseases remotely and for a long time. It also provides real-time diagnostic and monitoring to know the status of any patient living in remote areas, hospitals, and clinics using wearable devices, and hence sends the results to the caregiver or medical experts for further examinations and decision-making. The wearable devices connected to the human body to monitor physiological signs can be incorporated or implemented as IoT technologies.

This showed that the IoT-based system operates with a massive deployment of resources for diagnosis and monitoring in real time. The Internet of Things (IoT) is characterized as a major artery of machine-to-machine communication equipment that performs sensing and actuation functions with minimal human interference. The number of infrastructure objects connected is predicted to outnumber humans in the near future. This is because IoT is focused on the reasonableness of networking specific physical gadgets via the connected networks; for instance, the majority of health gadgets linked to the Internet are growing exponentially every day [28]. Furthermore, healthcare facilities are believed to be the main potential market for connected devices, with pulse rate monitoring being the most important advantage. The IoT-based devices like glucose pulse rate tracking sensor has been used to urgently warn patient, and remote surveillance systems becomes easier with the use of more advanced technologies.

7.3 Machine Learning and Deep Learning Algorithm Technology for Smart Cities

The cloud computing is the most critical and key component of many of these smart city applications, producing data in huge quantity [20, 29]. The most accurate and productive activities are impossible to decide exactly in the existence of such

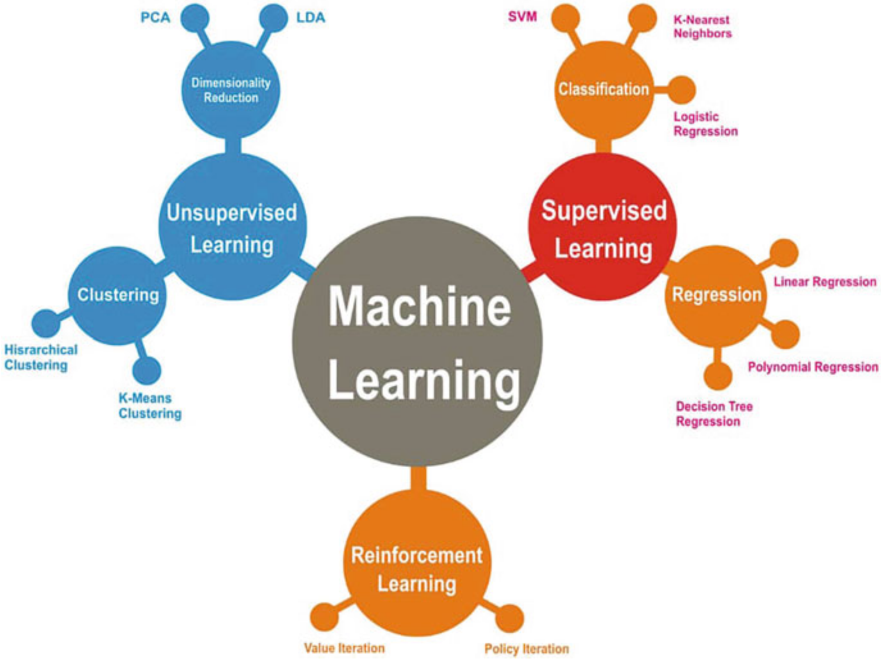

Fig. 7.4 Classification methods for machine learning

massive and diverse data volumes. Using advanced techniques such as AI, ML, and DL, the big data processing should be taken out to the greatest extent possible to achieve an optimal decision [10, 30]. The above strategies take into account a long-term approach and can result in either the optimum or close relatively to likely control decisions [31]. To further improve the abovementioned methods' precision and accuracy, an increased amount of training data is necessary to improve the learning competence of the techniques and therefore advance the efficiency of the automatic decision-making [32, 33].

There are three forms of machine learning strategies: supervised, unsupervised, and reinforced learning (RL). In the various scenarios, the RL employs methodologies across all fields as given in Fig. 7.4 by Ullah et al. [34]. With examples, we concisely describe supervised and unsupervised learning, in addition to addressing RL and its key algorithms. A dataset of input and output is used in supervised learning and its subsequent results are used to direct the AI system in its quest for a learning algorithm that transforms raw data to output.

In addition, regression and classification are split into classifier. Some instances include regression analysis, support vector machines, and random forest classifiers. Unsupervised learning has little guidance; the AI network is trained using a non-labeled and unclassified input dataset to detect distributions, responses, and hidden patterns. Unsupervised learning problems may be categorized as clustering or association with auto-encoder algorithm and k-means as some of the few examples of the categories.

The major ML and DL approaches that have been most commonly used in different areas of smart cities are support vector machines, decision trees, artificial neural networks, Bayesian, ensembles, neuro-fuzzy, and their hybrids.

1. **Support Vector Machine (SVM)**
   One of the most used and dependable classifier models is the support vector machines (SVMs). This is based on the principle of systemic risk optimization to perform classification methodology from computational learning theory [35]. The theory's main aim is the identification of hypothesis with the smallest true error. On the other hand, it is well founded and open to theoretical research and knowledge [36]. Like other classification methods, the SVM also involves both productive and bad training datasets. To locate the hyperplane, or verdict surface, this positive and negative training set is essential for the SVM in n-dimensional spaces that better distinguishes true and false data. The supporting report is the nearest report depiction to the decision vector. The classification output of the SVM remains the same even if documents that do not fit in are excluded from the training data collection [37].
2. **Artificial Neural Networks**
   Elements of large magnitudes greater than computational elements of traditional architectures with an input fan order are constructed from artificial neural networks [38, 39]. For information processing, a mathematical model based on a connectionist framework is used to connect certain components, namely artificial neurons, into categories. The neurons in neural networks are capable of interpreting objects. It can be used to store high-dimensional vectors that are distortion tolerant in a variety of situations.

   In order to record classification tasks, different forms of neural network approaches have been introduced. The use of input and output layers due to ease of execution employs a single-layer perceptron in ANN [40]. A sequence of weights are used as the inputs and fed directly to the output layers. The simplest form of feedforward network can be regarded in this way. The multilayer perceptron is more complex, and contains at least one hidden layer, and an input layer that is used for classification purposes [41, 42].

   The capacity to handle records with high-dimensional features remains the focal strength of the ANN in classification, and the power to handle noisy data and inconsistent data. A fundamentally parallel computational architecture, on the other hand, offers linear speed with respect to the vast number of computational components in the matching phase. Also, the value of the stored instances can be compared independently with each input value [43, 44]. The disadvantages of ANN are high computing costs, which require a lot of processor and memory power, and its exceeding difficulty for normal users to grasp. This may have a negative influence on the adoption of the methodology.

   ANN has been used to achieve better results in classification problems in a smart city model. For document classification, back-propagation NNs (BPNN) and improved back-propagation NN (MBPNN)-based sentiment extraction models are proposed [45]. To decrease the dimensionality as well as advance the competence, an effective feature selection methodology is employed. A new method of document classification based on the neural network [46, 47] has been implemented, which is beneficial for businesses to handle documents more efficiently.

The neuron's output is a dimensionless quantity f of its input layer, and the ANN possesses inputs x_i from presynaptic interactions. Neuronal performance is estimated with true weights w_i, and synaptic performance is optimized with true weights w_i. For sequence p, O_{pj} is the output of neuron j, where

$$O_{pj}\left(\text{net}_j\right) = \frac{1}{1 + \mathrm{e}^{-\lambda \text{net}_j}} \tag{7.1}$$

and

$$\text{net}_j = \text{bias} * W_{\text{bias}} + \sum_k O_{pk} W_{jk} \tag{7.2}$$

In complex domains, neural document classification networks lead to increased efficiency and are appropriate both for the discrete and continuous data classification (especially better for the continuous domain). Empirical risk minimization (ERM) allows ANN to attempt to reduce training error, which can lead to overfitting (compared to decision tree), and it is difficult for users to perceive learned results as learned rules (compared to decision tree).

3. **Decision Trees**

The decision tree recreates the process of manually categorizing training materials using the form of a tree structure with best true/false queries. Leaves denote the corresponding group of documents in a decision tree structure, and the branches reflect the intersections of features that correspond to particular categories. The well-organized decision tree can effectively identify a documentation by putting it in the root level of the tree and allowing it to run through the query structure before it reaches a particular leaf, which is the document's classification goal.

The decision tree classification methodology stands out from other decision support approaches due to its various advantages. The primary benefit of the decision tree is its simplicity, particularly for nonexpert users, in understanding and interpreting. In addition, it is easy to reproduce the description of a given result by providing a consolidated view of the logic using basic mathematical algorithms of classification, which constitutes valuable classification knowledge. Text classification tasks, as has been demonstrated experimentally, require a huge number of related features [36].

The tendency of using a decision tree to make classifications based on as few tests as possible will lead to bad text classification performance. However, decision trees' content-based prototypes, on the other hand, deliver performance, effortlessness, and ease of understanding when there are a limited number of standardized attributes. Kim et al. [48], Arivoli et al. [49], and Ansari and Riasi [50] explain the use of decision trees to personalize web page advertising.

The biggest drawback of using a random forest is that it over-fits the training data due to the impact of an alternate tree that identifies the training data wrongly but classifies the documents better [49, 51]. This is as a result of the decision tree classification algorithm designed to effectively classify training data while disregarding classification of other documents. In general, a dataset with a huge quantity of items is used to build a massive and extremely intricate tree structure.

4. **Bayesian**

   The naive Bayes technique, also identified as the Bayes of Idiots, basic Bayes, or Bayes of Freedom, is a very essential probability-band classifier. Given the class variable, it is assumed that the existence or nonexistence of a specific feature of a class has no bearing on the presence or absence of any other feature. This method has a wide range of applications. It is simple to construct because no complex recursive parameter estimation schemes are required. As a result, it may be helpful for massive datasets. The naive Bayes classifier has the advantage of requiring little training data to evaluate the constraints (training data means and variances) required for classification. Since independent variables are presumed rather than the entire covariance matrix, only the variances of the variables within each class must be calculated. In a variety of applications, such as health analysis [52], data mining [53], and musical style recognition [54], this classifier can be employed.

5. **Ensembles**

   Learning computer ensembles are one of the most recent developments of machine learning that is used to solve a number of real-world problems. Despite the lack of a specific concept on ensembles, there are several hypothetical explanations for merging several students, as well as practical evidence of the approach effectiveness. Significant amount of hybrid systems and collective approaches have been proposed in the literature. Mixture processes can be classified and evaluated in a number of methods, reliant on the key taxonomy criteria used. If we take as the primary criterion the representation of input patterns, we can define dual separate huge classes, one that uses the same input depictions as the other and one that does not [55–57].

   Using the ensemble's framework as a basis, we can discern among serial, parallel, and hierarchical systems [58], as well as a range of choice and combiner-oriented ensemble approaches, depending on whether the base learners are chosen by the ensemble algorithm or not [59, 60].

   Differentiation between non-generative and generative approaches for the ensemble: In order to incorporate a set of simple learners that may be well planned, non-generative ensemble strategies restrict their selves: They do not really actively create new base learners, but aim to incorporate in an effective manner a set of preexisting classification algorithms. Convolutional neural ensemble approaches create a collection of simple learners based on the foundation learning algorithm or dataset layout, with the goal of increasing the heterogeneity and precision of the base learners.

6. **Neuro-Fuzzy**

   A neuro-fuzzy model proposed by Ichihashi et al. [61] implemented a systematic method of inducing fuzzy tree structure utilizing linear programming for maximizing entropy.

   Altilio et al. [62] used Bayesian techniques with fuzzy technique to create thin models in another recent work. A comprehensive learning approach for fuzzy neural networks found in the brain of humans was created in a paper by Zamirpour and Mosleh [63], and was called the fuzzy emotional neural network. Qaddoum [64] has developed a reinforced offspring algorithm utilizing fuzzy C-means, principal component analysis, and a classification problem of evolutionary algorithm. In the work of Tagliaferri et al. [65], a fuzzy neural network uses the principles of fuzzy relationships with true values in an effective structure of algebraic to perform its principal activities.

   Reinforcement learning is used in intelligent hybrid models by combining two models that can produce a fuzzy control system using a reward/penalty signal [66]. In contrast to strong neural network training models, hybrid models have the advantage of producing fuzzy concepts that could be viewed as problem linguistic variables [67]. It should be noted, however, that, because of the significance and complexity of this subject, the study may not address these aspects in depth. The surveys of Oladele et al. [68], Adadi and Berrada [69], and Guillaume [70] are therefore recommended for consultation on the self-adaptive nature of hybrid classification.

7.4 The Relevance of Machine Learning and Deep Learning in Urban Sustainability and Smart Cities

Smart city is an example of a promising project which has been introduced around the world with the goal of making citizens' lives both comfortable and welcoming [71, 72]. The conventional city turned to the modern technology and the autonomous object without the need for substantial external help. All routine processes, such as governance, policies, facilities, and feedback, are automated and accessible to users through smart devices from anywhere on the planet.

7.4.1 Smart City-Supporting Technologies

The idea of the adoption of technology to ensure a simple and successful lifestyle is not new. Mankind has been incorporating technology into everyday processes since ages to achieve a certain degree of automation and decision-making. Many emerging innovations are also being used to achieve a lifestyle that is smart and sustainable as the society changes more towards Business 4.0 and Industry 4.0. The notion of

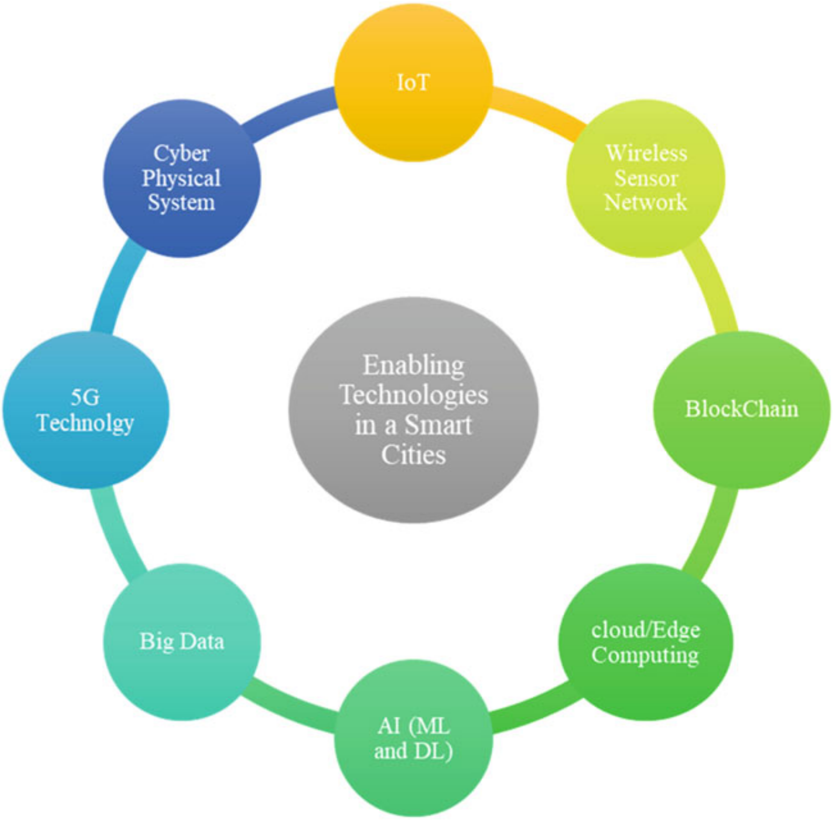

Fig. 7.5 Key smart city-supporting technologies

smart cities is a route in this direction. The smart cities were realized with the use of modern technological interventions and utilization. In order to facilitate the creation of linked virtual communities and organization in a smart city, many current and new technologies are incorporated. Figure 7.5 discusses the key supporting machineries in a smart city.

It is necessary for a smart city to be projected in order to provide seamless connectivity within technological organizations of the smart cities. To provide seamless connection within the network, the use of the cloud/edge computing model with constantly changing network configuration management, and software-defined networking (SDN), is very significant [73, 74]. The collection, analysis, and presentation of data can be done by big data analytics tools such as Hadoop, Cassandra, and Quantcast [73–75].

Some software are useful for real-time analysis, and some are suitable for historical data analysis; hence both software have advantages and disadvantages. The systems employed in smart cities are embedded with sensors that are self-sustaining and automated. The use of cyber-physical systems can help in achieving the integration of physical equipment, services, and management. The security and privacy of the smart city ecosystem of the users and devices are very important. New security mechanisms are needed in providing robust security and privacy for devices since the classical security protocols do not complement the heterogeneous nature of the smart city network and devices within participating organizations in the smart city ecosystem.

7.5 The Research Challenges of Machine Learning and Deep Learning in Urban Sustainability and Smart Cities

Deep learning is quickly evolving the way communities run, fund, and handle all foreseeable utilities such as transit, electricity, healthcare, networking, and many others, as shown by the aforementioned discussions. However, choosing the right technologies to integrate with smart city services successfully and efficiently remains a significant challenge. The administrative bodies' ability to implement these innovations and integrate them into their daily services and divisions is also a major challenge. There is a preconceived idea regarding the initial expenditure in such developments, which will result in a budget rise. However, the fact that once introduced it will result in a higher economic performance is also a fact that is underappreciated. In the smart city climate, time-sensitive applications necessitate both real-time and non-real-time data streaming. It is also difficult to build applications that incorporate big data and fast data analytics. Machine learning systems are developed into smart devices in a number of ways; however most of them are hard [76]. Another issue to focus towards is the need for flexible ML algorithms for resource-constrained applications that ensure protection and privacy [77]. The databases used for deep learning implementations are often not easily accessible and of sufficient scale to validate outcomes by simulations.

Another big problem with smart cities is the ever-changing technical progress; as technology develops, so does the principle of smart cities [78, 79]. Deep learning models will face difficulties as smart cities begin to develop as it may present difficulties in managing the current paradigm of smart city data analytics from future generations of smart cities. This is particularly true if deep learning technology is not updated to keep up with the evolving smart city concept [80–82]. It is, therefore, recommended that researchers continue to change deep learning models as the smart city paradigm evolves in order to respond to the evolving existence of the smart city in the future. Deep learning will thus remain important in the age of technological development by doing so.

Despite the smart city's deep learning penetration and impressive accomplishments, other facets of deep learning in smart cities have largely gone untapped. The feedforward neural model, neural abstract machine, memory-enhanced neural network, communication-guided deep network, sensitive network, and deep intense network are all examples of deep network machine learning; some examples of deep learning concepts are not used in smart cities. Exploiting these deep learning features in the smart city would be important to see how successful they are at solving problems in the smart city. The efficiency of the scope of learning varies according to the object model. It is important for researchers to understand the right deep learning algorithm for a specific area in order to prevent expensive and time-consuming trial and error.

The preeminent deep learning design for each smart city area is still a work in progress [83, 84]. Researchers should conduct a thorough performance review of various deep learning architectures in various domains of application in order to determine the paramount deep learning method for each smart city field.

Although there is a comprehensive method for obtaining the optimum objective functions, the adjustment of several inputs demanded by deep learning is still an open research problem. Moreover, the deep learning algorithm output is contingent on the optimum parameter configurations. Another unresolved issue is the computing time required by deep learning techniques; deep learning training typically takes a while before reaching convergence. Conversely, there are certain concerns where the passage of time is crucial in making a decision. For example, in a smart city, in case of crime notification to protection authorities, accident notification to the appropriate authority if an accident occurs, fire outbreaks, and health-related concerns, time is important, as any delay will lead to death. Scientists should focus on optimizing the convergence pace of deep learning techniques in the future used to solve smart city problems.

7.5.1 The Futuristic Solutions in Using Machine Learning and Deep Learning in Smart City Implementations

There are a variety of promising potential directions in the use of deep learning and machine learning technologies in smart cities. When the feature sets and delivery structures of the training and testing data are identical, it is assumed that the training process delivers accurate outcomes. Transfer learning is a research field in which the delivery of training and testing are adjusted or moved from one framework to another. Scientists can also concentrate on incorporating semantic technology into smart city applications in order to enhance the interaction between smart devices and their users. The use of virtual objects in combination with DRL algorithms will facilitate the development of virtual representations of real objects that could be run automatically. Finally, the usability of smart devices is very critical.

Smart city applications and devices are frequently mobile and wearable, requiring users to touch screens in small spaces, which can be difficult for less technically savvy users and senior citizens. Integration of speech recognition technologies into smart devices to enable natural language comprehension is also a promising research field. It is critical to recognize that in the procedure of developing such smart devices, we must avoid creating islands in which applications are developed solely for the purpose of lagging non-integration with one another.

7.6 Conclusion and Future Directions

The ML and DL have demonstrated great performance and adaptability in various fields for big data processing. These are accomplished with an increased accuracy rate and have clearly demonstrated usefulness and value in smart city technologies. The algorithm advancement and the trend for future progress and research have significantly differentiated it from other algorithms. Furthermore, the layer hierarchy and learning supervision are the important factors for making successful ML and DL applications. The hierarchy is very useful for proper classification and oversight means of maintaining the database in an application. The DL is also used for optimization of the existing ML framework and processing of hierarchical layer. In applications like digital image processing and speech recognition, the DL has the ability to deliver successful results. Both algorithms are very useful as safety tools both in the present and future use due to the hybridization of facial recognition and speech recognition. Therefore, the chapter reviews the applicability of ML and DL in urban development and for various aspects of smart city. The most used algorithms among many other available algorithms are support vector machine, ANN, fuzzy logic, Bayesian, ensembles, and hybrid of more than one of these algorithms. The applications of ML and DL have greatly increased the accuracy aspect of decision-making in smart cities, especially in the analysis of the capture data using IoT-based devices and sensors. The process of digital image processing has also been enhanced by the use of ML and DL models. Hence, ML and DL have become a hot research topic in AI techniques in recent years, and are proving to be a real optimization technique in smart cities. Finally, with the availability of huge data and computing resources, it can be concluded that the use of ML and DL in various applications has begun to gain acceptance. Though the technologies are very young, and ephebic, they are very unique, and it is expected that there will be a rapid growth in the nearest future. The algorithms have seen a great boom and prosperity in various fields like natural language processing, healthcare, remote sensing, and speech recognitions and will inevitably achieve goals and levels of triumph and satisfaction.

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Chapter 8
A Framework for the Actualization of Green Cloud-Based Design for Smart Cities

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8.1 Introduction

One of the basic requirements for a smart city is the software and hardware infrastructure. Data can be collected in real time with smart sensors with advanced monitoring systems that can be used for data analysis and decision-making. The smart city, for instance, has been described as a metropolis which can make full use of interconnectedness in physical substructure in 2008 by IBM. Also, the smart city can be interconnected by social infrastructure, business organization, and IT setup to produce collective intellect. This highlights the interconnectivity of the practical infrastructure of a metropolis. Most especially, the hardware infrastructure like network facilities and sensors in smart cities are of importance. Hall et al. [1] proposed a system that integrates and monitors cities with their critical infrastructure using network connections and decision-making algorithms to monitor target security and optimize resources.

Schaffers et al. [2] see smart cities' model city development using modern information technology and ubiquitous connectivity to improve urban residents' quality of life and achieve sustainable development and urban competitiveness. A smart city's mission is to create autonomous environments that are independent

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or less depending on people, and to combine and optimize environments centered on availability. Giffinger et al. [3] described smart cities as having smart infrastructure, smart citizens, smart government, smart transport, smart climate, and social upliftment [4]. A smart metropolis was defined by Giffinger et al. [3] as having a smart infrastructure, smarter individuals, sustainable cities, smart transport, smart buildings, and smart living. In their observations on the climate, rights, and development, Lazaroiu and Roscia [5] are much prescriptive and indicated that a smart municipality ought to provide a smooth budget, sustainable cities, an intelligent transportation, remote monitoring, and intelligent mobility.

In recognizing its essential nature and influencing the creation of its structure, a thoughtfulness of the fundamental of smart metropolises is of utmost importance. For example, the work on smart city assessment by the British Standards Institution (BSI) develops mostly on smart urban model, on the Publicly Available Specifications (PAS) 181 standards [6], as well as on the practice of the International Standards Organization (ISO) shared framework for the implementation of smart city by city leaders around the world [7]. As a modern paradigm of urban planning, the smart city has large technological branches. While several researchers and institutions have studied it, stakeholders following many different viewpoints have addressed different concepts [1, 8–10]. There has been no study from multiple backgrounds to carry out a clear grouping of smart municipal concepts. This chapter carried out and studied the concepts of the smart metropolis on the basis of a thorough study of the conceptual connotations and implementations of the smart metropolis, allowing for four phases: software and hardware infrastructure, spatiotemporal data and exploration, methods, and applications for cloud platforms.

Cloud computing and the Internet of Things (IoT) are two major ICT ideas which have emphasized the scientific society's relevance in recent times. The cloud computing concept [11] integrates and promotes the on-demand delivery of technology and information resources over the Internet functional description. Depending on the form of processing capabilities provided across the Web, cloud providers take a variety of forms like Network as a Service (NaaS), Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS), Storage as a Service (STaaS), and many more services that are accessible. These services provide higher efficiency, stability, broad supply, and improved QoS at a small asset average cost of ownership (TCO). The European Commission (EC) has already worked on a host of projects (e.g., RESERVOIR [12], VISION-CLOUD [13], OPTIMIS [14], CONTRAIL [15]) that have established Pan-European prototypic cloud resources while also improving specific cloud technology (e.g., power controlling, protection) and software.

Simultaneously, the IoT paradigm focuses on the identification and utilization of a complex set of physical and virtual objects (i.e., traditional and cyber viewpoints) connected to the Internet [16]. IoT enables communication among different items as well as in-context activation of their resources (infrastructure) for value-added implementations. Radio-frequency identification (RFID) and wire-free sensor networks became the roots of earlier Internet of Things technology and provide practical benefits in a variety of fields, like production, transportation, exchange, retail, environmentally friendly systems, as well as other industries.

Cloud computing and IoT are thus two main innovations for achieving the ubiquitous concept of connectivity. The cloud will offer vast and long-term computing and processing services for tailored ubiquitous applications distributed by IoT as well as essential back-end facilities. Internet of Everything (IoE) refers to a global, interconnected network of physical objects that are designed to detect or interact with other objects, devices, or personal computer. IoE is a core component of the future clever environment which can be defined as a Web system with personalized capabilities generated from specialized standards where digital and physical entities can interact effortlessly.

IoE links entities and individuals that can interact through different sensors and devices, radio-wave recognition via Bluetooth communication, etc. These “smart” items come in a wide range of measurements and capacities, combining basic objects with integrated sensors, household equipment, autonomous machines, cars, trains, and wearable items such as clocks, arm necklaces, or shirts [14]. Their value lies in the infinite amount of knowledge they can collect and their potential for interaction, cultivating continual control or review of information that reveals unique ideas and encourages new behaviors. With IoE, the universe is getting technologically more sophisticated, and an intelligent user can interact with items, and entities can interact with new particles devoid of user involvement.

Yet IoT can affect our environment in a few different ways. Any item of IoT, from its development through its use to its depletion, poses pollution risks. Production of sensitive devices, personal computers, laptops, and their countless sections absorbs fuel, resources, chemicals, and water and generates hazardous leftover. Both of these items and processes would increase atmospheric carbon discharges and impact the environment. In addition, the gross energy usage of servers, personal computers (PCs), displays, knowledge conversion facilities, and ventilation towers for data centers is increasing. Emissions of greenhouse gases will rise exponentially with rising energy usage. Each PC being used regularly emits an immense amount of pollution. Digital devices, sensors, and PC components used in IoT will enclose radioactive substances. Also consumers have a huge amount of outdated devices, electronic appliances 2 or 3 years postdelivery, and most of them in dump sites are also contaminating the earth. It is indicated that roughly 20–50 million, a huge range, computer components as well as cell phones are discarded each year, which is the biggest shortage. There is also tremendous strain on the IoT similar companies, enterprises, and people who develop IoT-associated artifacts and structures to create IoT schemes that are environmentally sustainable and renewable during its life span, i.e., from delivery to passing away to reawakening [17].

As IoT is embedded with several sensual components, it allows data to be detected and transmitted using innovative connectivity technology that eventually improves energy efficiency. Yet just telecommunications and information systems account for around 2% of carbon (IV) oxide discharges. The planet nowadays is absorbing eco, and it is our collective duty to protect our climate. It is not green with jealousy, but green as if it were being more mindful, energy saving, conforms to global norms, and environmentally friendly. The effective use of computational tools such as Energy Star, prohibition of dangerous chemicals, etc., might be helpful to handle them further effectively during their life span and also at the point of removal. Information systems that are environmentally friendly (IT) are an ecologically friendly computing activity. It intends to minimize the harmful environmental effect of the IT scheme by developing, producing, running, and positioning devices, sensors, goods, etc. in an ecologically sustainable way. Green IoT's real goals are to reduce the use of hazardous radioactive chemicals. It does have the potential to boost power consumption over its life span and to encourage the biodegradability and reusability of outdated goods and surplus plant material. Green IoT practices energy-efficient techniques employing sophisticated hardware and software that minimize the greenhouse effect of current implementations and limit the level of the conservatory outcome on the IoT system [18].

Sustainable IoT-based smart cities focus on sustainable buildings, green construction, green systems, green deployment, green recycling, and even ecological transformation with minimal environmental impact. Green modern aviation and engineering processes, green smart buildings, green sophisticated housing, green smart e-health, green smart logistics, green smart retail, supply chain performance, green smart packaging, green intelligent waste, green intelligent environment monitoring, and so on are all part of these innovative smart cities. Smart urban IoT provinces and items such as cell phones, servers, tablets, vehicles, and electronic gadgets can connect with each other with recognizable power addresses. These sensing instruments can interact smartly through the network technology and also provide green assistance for the management of various activities for people. Numerous technologies [19], i.e., recognition, connectivity, data, and data transmission innovations with lower energy consumption, can be assisted. When planning and creating smart cities focusing on green IoT, energy-efficient protocols are expected to be implemented.

The purpose of this chapter is to suggest an architecture for smart green cloud cities. In addition, the chapter analyzes the functionality of cloud and IoE frameworks in the sense of intelligent metropolis application. The remainder of the chapter is arranged as follows. Section 8.2 outlines the prospects and challenges of smart cities. Section 8.3 lays out the analysis methods and structure adopted. Information on the application of proposed method is seen in Sect. 8.4. Ultimately, the results drawn so far are outlined in Sect. 8.5.

8.2 The Prospect and Challenges of the Smart Cities

The smart city concept has already been popular for almost two decades, and its popularity has steadily increased owing to current technical developments, such as digitized sensors and data structures, expanding its skills to maintain sustainable growth and enhancing the living conditions of local populations. Early literature on smart cities was mainly focused on sustainability, new infrastructure, or information in the early 1990s. It was not until the 2010s that the term "smart city" became a common idea and accepted as an independent study area of its own. Since 2008, the volume of study on smart cities has been increasing enormously [20].

The smart city framework is related to current smart infrastructure, technologies, and knowledge, along with responsible, interactive, and participative principles. In addition, broad and available data play a crucial part in converting metropolis processes into intelligent schemes to improve the value of scarce assets [21] and make healthier choice possible. Open actual facts will increase clearness and offer resources for developers to build applications and services. The contemporary smart city was already characterized in a multidimensional manner, based on its basic elements, varying from technological infrastructure to societal investment.

As IBM's smart city concept emphasized the use of all relevant knowledge accessible to promote scarce capital, its smart city plan centered on developing interconnected data and analytical systems to enhance productivity and cooperation between government agencies [21]. In line with IBM's opinion, the prevalence of research in this field concentrated on the elements of interrelated infrastructure, pointing to smart metropolises as sensor networks, smart sensors, concurrent facts, or convergence of information technology and communications (ICTs) [22–24]. Conversely, these market-driven concepts of smart city strategies were attacked for applying technology to empower people, not vice versa [25].

Examples of smart city programs have been introduced in different states. Barcelona's sophisticated smart city project was built to create a safe, greener city, transform trade, and boost living standards [26]. As in the situation of Barcelona, the Vienna smart city initiative also concentrated on living conditions, resources, and creativity in accordance with clear objectives [27]. The Vienna case highlighted the engagement of team members in demand to minimize the distance between execution and perception of the investors. In the architecture of the smart city system, the main elements are evaluated accordingly, based on the preferences of the cities. Smart metropolises are constantly, and widely, reachable, information rich, collaborative, safe, and transparent; their advancement can be tailored to empower people and societies generally.

8.2.1 The Features of Smart Cities

In a realistic situation, smart cities combine three components, including infrastructure, citizens, and organizations; most researchers have defined these aspects as the primary features of a smart city [28–30]. The technology factor incorporates intelligent, digital, universal, and information standards [28], so the efficiency of ICTs and added infrastructure facilities is vital to the promotion of improved smart urban habits. It is necessary to strive towards a digital community.

ICT areas like computer science, engineering, electronics, and communication technology are the prevailing study fields for smart cities. These technical definitions correlate with the interpretations of the word "wise," described as intelligent or educated [24, 31]. Through the progression of ICT, smart city networking and incorporation of large amounts of records produced by physical and configured app [29] have been the subjects of current efforts to describe smart cities. Smart cities' knowledge including big data processing, modeling, and analysis enhances organizational and structural systems for better decision-making [24] and IoT incorporation [32].

The human perspective of smart municipalities intersects with innovative, human, training, and intellect urban models [33], and a smart city wishes to support residents through supplying a respectable quality of living [34]. The previous study suggested that population progress and wealth creation were connected to the emergence of smart societies, as provided by the professional group of people with awareness and expertise on all facets of their lives [35]. Interconnected cities cultivate productive partnerships between people and other innovative and structural elements to enhance the standard of human resources. Since innovation is a key feature of smart cities, an environment for literacy, training, and awareness is required to build community asset [36].

Smart cities can be characterized as intelligent people's analytical skills. Recent debates highlighted concerns of social isolation, some of which discussed the inaccessibility to smart city initiatives for some residents [36]. The structural viewpoint of smart metropolises requires public authority and development to exchange values and include a larger spectrum of citizens in the course of reaching a choice [26]. The design of emerging technologies has both policy and socio-technical consequences; as such, strategic partnerships between all participants are crucial in evaluating the progress or inability of smart city projects [37].

Investor positions in smart city initiatives have also been explored to make use of the triple helix philosophical paradigm [38–40]. A digitally integrated community embraces a citizen-centered mindset that enables people to address their needs in decision-making mechanisms. While smart city initiatives offer preference to relational and participative attributes, their activities are largely focused on the viewpoints of the stakeholders. Concentrating on smart city programs from a resident's perspective [41–43] is required to improve smart city activities.

A smart city strives to change the feature of community life cycle and to maximize its spatial, economic, and environmental capabilities. Smart cities are offering various benefits:

1. Security and safety: which entails security cameras, expanded emergency management systems, and electronic resident warning signals; real-time city data should be accessible.
2. Climate and transport: this includes a regulated level of emissions, smart street lighting, traffic laws, and modern public transport options to minimize the use of vehicles.
3. Home control of electricity: tools involve prompt power pricing and efficient power management, potentially saving 30–40% of energy costs; the European Commission predicted that about 72% of European energy users will possess smart meters by 2020 [44].

4. Learning infrastructure: more funding is anticipated to spur scholastic access for everyone, lifelong education, distance education, and smart classroom technology.
5. Tourist industry: protecting the mineral resources of a community encourages the development of tourism; in relation, smart devices have direct and personalized access to data.
6. Health of individuals: adopting emerging technologies will enhance human health; individuals need complete access to better, accessible telemedicine and wireless wearable data transmission sensors fastened on clothing and implanted underneath the skin that may capture clinical records (such as temperatures, glucose, and pulse rate) and transmit in a timely or in real-time, and off-line through wireless networks. Alongside this opportunity, several factors need to be recognized and weighed before cities will reap the rewards. Here we describe most of the key concepts and design features of emerging technologies, like energy efficiency (ISO 50001), smart homes, vehicle networks, smart grids, energy storage, and standard of living (ISO 37120). We then look at latest smart city developments all over the place, highlighting some of the obstacles and possibilities for potential study. We also illustrate some of the threats presented by information management in the urban setting [44].

8.2.2 Green Smart IoT-Cloud-Based Smart Cities

One of the main objectives of the electronic age is to develop these intelligent machines and sustainable metropolises. Green IoT is an emerging component for building smart green cities. Over the next decade, houses will be the primary energy customers to release greenhouse gases to the planet. The easiest way to make the building smarter is by encouraging holders and administrators to gather energy and functional data in a fixed, unified position and incorporate predictive and automation skills around the organization to derive knowledge from that data. There seems to be a range of equipment/software solutions that can help you with crucial data on electrical demand and power use.

Through leveraging real-time data collection, building administrators may conduct an audit to address service-related issues proactively before they emerge. They can also imagine energy use, atmosphere, floor size, portfolio efficiency, etc. There is also a need to make smart green sustainable cities commercially feasible. This may involve ICT-based smart routing to reduce the expense of transmitting of vitality and increase the flexibility of these functionality schemes [45]. In IoT-based smart cities, entities or items are prepared through individual analysis to help by using a special means of recognition where those smart substances relay information such as position, status, type, meaning, or other sensitive indicators to other gadgets.

In certain capacities, these aspects are also heterogeneous. Green smart cities contain green smart houses, heaths, forestry, education, water networks, transport, and merchants, among others, which work effectively as well as keep the world

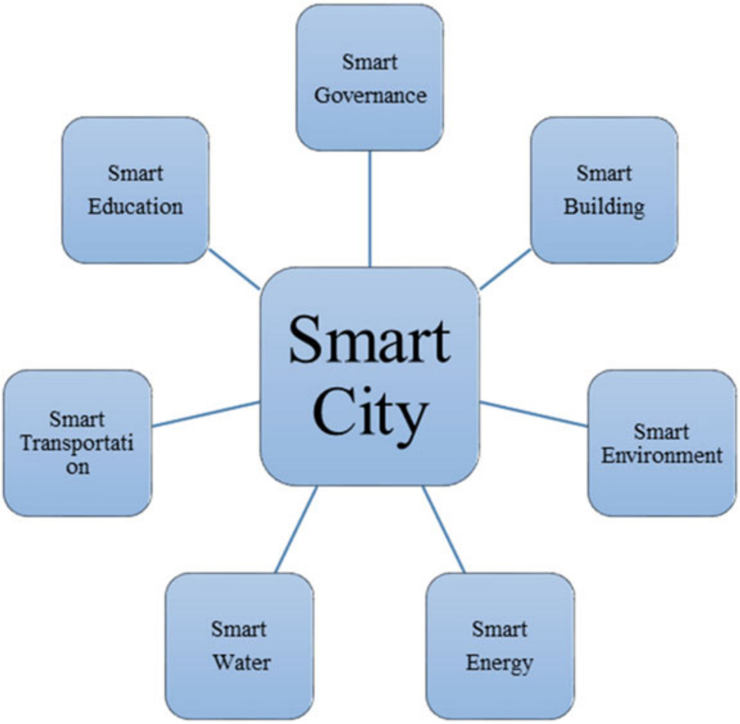

Fig. 8.1 The smart city components

clean and green [46]. The primary characteristics of a smart city can be seen in Fig. 8.1.

Some criteria have been created for these smart cities. There are international metropolis norms for community living, e-health, recreation, protection, schooling, transport, water, finances, etc. for the architecture of these smart cities. Smart authority, smart world, smart transport, smart individuals, smart budget, and smart life are core aspects of smart cities. Environmentally friendly smart cities include several essential characteristics, such as replanting regions, conservatories, green floors and roofs, towers, metropolitan centers, renewable energy conservation, fishing rivers, flood control, agriculture, and woodland regions, which have the benefits of evolution strategies.

A community is not smart because the different processes that constitute it are not able to share and operate together in systems. Contact relies primarily on e-mails, calls, teleconferences, optic fiber connections, online forums, wireless and various simulations, etc. Several smart procedures in the country, which are the key development sections of the region facilities, rely on the strong base of transmitting capability, i.e., connectivity, so this would enable to relay essential information by, e.g., vacant parking spaces, usage of vitality, car crashes, and weather patterns, among others. This information can be processed by the metropolis via cell devices or other digital equipment or sensors, and the platform can recommend other smart options for going all over the place. In order for the smart city method to operate seamlessly, both people and machines must have the power to interact with one another. ICT is thus a large part of the reliability of the abovementioned method [47].

8.2.3 Prospect and Challenges of Smart Cities

The challenges faced by smart cities and the prospects or opportunities that are there are explored in this section. Smart cities need attention for development and adoption.

Challenges of Investment: Lack of investment from potential investors is the major challenge that smart cities are facing, especially the green smart cities that require lots of investment into building low-energy equipment. The definition of smart cities represents a high investment opportunity and economic opportunities, but only a few rise up to the challenge.

High Power Utilization: According to the US International Energy Agency, clean energy accounted for approximately 21% of international power supply resources in 2011, with a predicted growth to almost 25% by 2040. The shortage of renewable capital in predicting energy demand for the remainder of the modern era shows a destructive part in investing in smart cities. The prospect of power prices and availability is unclear mainly in line with their reliance on the expected geopolitical, socioeconomic, and demographic perspectives [44].

Smart Residents: Social facets must also be taken into justification. The quality of a city relies heavily on residents' involvement in smart city initiatives, through various networking channels (such as the urban web site, social networks, and mobile applications). Smart cities require people to be constantly linked—in open spaces, in unrestricted transit, and at home to exchange their expertise and experience. The goal is efficient use of ecosystem services and a greater standard of living for community members; for instance, they may evaluate their domestic consumption of voltage, gas, and water from their devices. Appropriately managing this societal component is a difficulty, as it is a critical element of the smart city's technology that, when properly exploited, offers benefits for both people and the environment.

Protection: Privacy would play a vital role in every smart city plan. People communicate with smart city facilities via smartphones and laptops linked through diverse networks and systems. Smart cities, focused on the use of ICT, are also crucial to be skilled at dealing with essential concerns about privacy (such as spying and disclosure). Privacy can be divided into three components: respondent, consumer, and host. Another author suggested a definition of residents' safety focused on the regulation of predictive disclosure, including mechanisms for protecting the anonymity of information about people while revealing their results

[48]. Instances of such approaches are the extraction of personal data (procuring and covering someone's records), security of protection of data mining (relationship among organizations to extract outcomes without disclosing all data), position of privacy, secrecy and pseudonyms, secrecy in RFID, and data protection in surveillance cameras.

Cyberattacks: As for other technologies, smart cities are vulnerable to cyber threats, and the latest urban area under threat is wide open. IOActive Laboratories reported numerous sources of cyber threats: absence of cyber security monitoring, inadequate or nonexistent security features in embedded computers, poor security measure application, cryptography (obsolete and unreliable cryptographic algorithms), lack of network emergency services, large and complicated assault areas, patch deployment problems, unsafe legacy networks, and lack of cyberattack emergency management (DoS).

The 2015 conference described many problems, such as data transmission limitations, physical implications for cyber threats, processing and storing of vast volumes of information in the cloud, and manipulation of city data by hackers. As daunting as these challenges are, several opportunities that smart cities possess are making relevant authorities and even nations to start investing in it.

The development of a robust IoT/cloud integration is a huge prospect for smart cities' development. These activities are in transition as well as in the United States (Free Software IoT Cloud) and even in the European Union (OpenIoT Model) with a view to developing middleware infrastructure for cloud sensors that will allow the on-demand provisioning of IoT services. In addition to research into open software sensing devices, there is a broad array of market online cloud-like innovations that motivate end users to connect their devices to the Internet while also facilitating the development of initiatives that use those devices and similar sensor platforms. COSM, ThingSpeak, and Sensor-Cloud are examples of commercial devices [49].

Another prospect of a smart city that is driving its emergence in most countries now is the safety and peace of living offered by smart cities. Once you have an environment that is devoid of crime, everybody will live in peace. It goes a long way to prolong the life span of its citizens. In addition, the green smart city will allow people to live a healthy life that will reduce mortality rate. All these and many more are what is driving the establishment of smart cities that can be seen all around the globe.

8.3 Literature Review

The smart city, as the most innovative urban type, has come to be the planned superior for metropolises that aspire to accomplish growth. Scientists are currently conducting studies of functional applications focused on the conceptual context of smart cities using emerging information technologies like smart healthcare [50, 51], smart transportation [52, 53], smart tourism [54–56], and smart management [57]. Record preceding studies, however, have concentrated on exploration and smart city building in a distinct capacity of study. There are likewise scarce smart projects that focus on different subject areas, like Modern Matsushima New Town in Korea and Intelligent Island in Singapore, but due to the government's impetus, they continue to only consider a community as the research object and perform intelligent urban growth in those fundamental areas, such as smart transit, living, and leisure environs.

A statement by the United Nations states that almost two-thirds of the global populace will be settled in urban regions by 2050, increasing their population densities to much more than their saturation rates [58]. The development of goods, services, and infrastructure by then will not be capable to meet the requirements of the urban residents [59]. In such a situation the role that will be played by IoT will become unmatched due to its ability to allow objects to interconnect and to interact with humans in their service in a smart and effective way [60]. The basic aim of IoT will be to measure, understand, and analyze the residence of objects for the betterment of the environment. As per this, many communication science and objects like appliances, monuments and parks, heritage sites, cultural works, and art [61] will be embedded with IoT. One of the most essential features of IoT is its influence on human life [62].

Apache Storm introduced a scalable structure for home automation [63] and such scalability depends on local reasoning. A number of different designs for smart cities have been introduced till now such as the one by Vlacheas et al. [64] that proposes a framework for strengthening IoT for its deployment in smart cities; another design by Adeniyi et al. [65] talks of an experimental architecture of IoT that has been currently implemented at Santander city; another design named as Lea and Blackstock [66] marks smart city as a network of IoT hubs. On the other hand, economic policies, pricing methods, and their relationship with IoT along with communication and collection of data were studied by Zanella et al. [67]. Survey of smart city architecture was conducted by Da Siva et al. while the security parameters were focused on by Schaffers et al. [68]. Applications for specific smart cities (logistic mobile application) were proposed by El-Baz and Bourgeois [69].

A brief about the global deployment of smart cities was lined by Pellicer et al. [70]. Another survey that tells about sensors and their use of semantics in the cloud for IoT to cut the odds of separation between CoT and IoT was provided by Petrolo et al. [71]. A review of the electric vehicle changing application was given by Shuai et al. [72], whereas Wang and Sng [73] presented an in-depth learning survey of algorithms that included video analytics too. The application of wireless sensor network was the work of Rashid and Rehmani [74]. The investigation is highly different due to the data-centric views of the components of smart cities. A summary of the study on the data life cycle for traffic management system deployment in a smart city was given by Djahel et al. [75]. Various requirements of a smart city have been briefly discussed by the author and a smart and organized generic reference of the framework for designing an urban Internet of Things has been revealed. The experimental study of PADOVA was revealed by Cenedese et al. [76]. Services, policies, platforms, connectivity models, IoT infrastructure, and related aspects have been discussed by Lea and Blackstock [77]. The conception throughout the shape of a structure, smart city, and all the important requirements is presented by Zanella et al. [67].

Cities can be made smart by the application of IoT and this level of smartness may be further increased by combining IoT with cloud computing making a new computing paradigm, that is, CoT [14]. The author has dug deep into the evolution of smart cities and has made a detailed study on it in the last 20 years. Comparisons of smart cities with digital cities and their definitions, which could support all aspects of performance evaluation of a framework and city development strategy, have been made [78]. A very clear and unambiguous plus a comprehensive and verified description of a smart city has been presented by the author. The definition has been based on studies of concepts and surveys related to smart cities around the globe.

Along with it, discussions of numerous resources that the smart city will provide have also been included [79]. A structure for the design of intelligent metropolis which includes the utilization of IoT and cloud along with design requirements has also been proposed in Sheng et al. [80]. It is notable that Malaysia and Australia are at the top for cloud computing, the UK is leading in smart homes, and India is at the top in smart cities. Major advances in smart homes and cities in the forthcoming years are expected as the former technologies mature. A dual smart city approach and how they give rise to peculiarly diverse consequences were studied by Myeong et al. [81]. It was found out that reinforcing a culture of creativity by educating government officials and staff members is a crucial way to attain a comprehensive and viable smart city transition that can withstand changes in management.

8.4 Framework for Green Smart Cities

The IoT provides computing tools as extremely flexible as Web services. With the exponential advancement of IoT and cloud technology, a growing number of individuals, organizations, and businesses prefer IoT and cloud platforms for storing and manipulating their data. Cloud computing has major benefits including cloud storage, connectivity, data sharing, hardware and software cost savings, etc. Many security challenges attributed to the IoT environment, however, have not yet been addressed, especially in traditional computer environments [7, 42]. Moreover, protection and privacy concerns have been observed to seriously limit the practical implementations of IoT technologies [7]. To tackle these major problems, it is essential to propose and develop new algorithms and methods to secure the IoT platform and infrastructure (Fig. 8.2).

8.4.1 Green IoT/IoE Devices

At the bottom of the framework is the green IoT/IoE sensors which can help various types of sensors that run with lower energy consumption and are mounted in different networks in smart cities. Figure 8.3 explains how to save power by

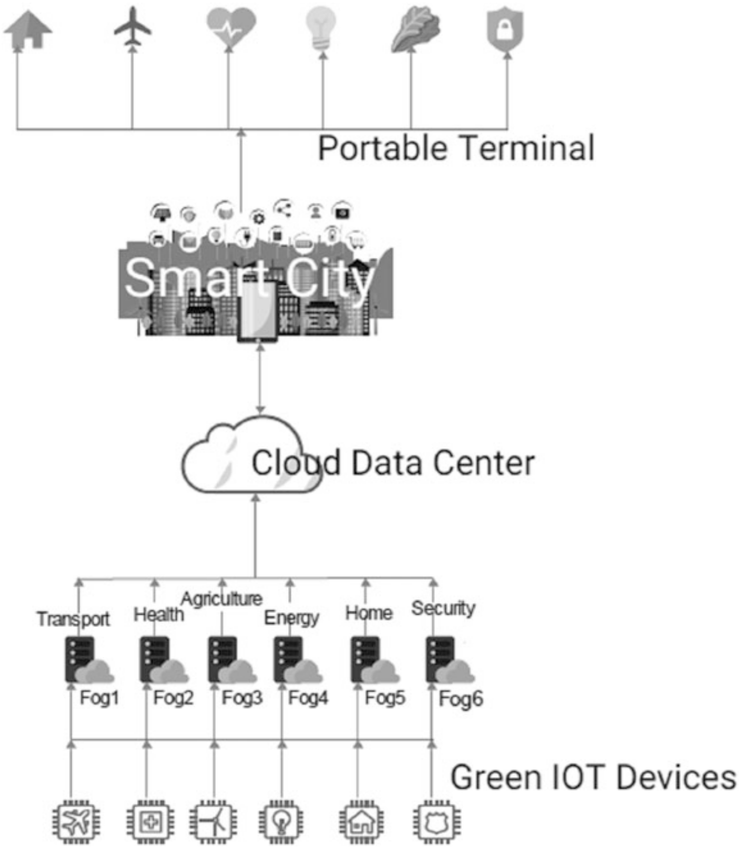

Fig. 8.2 Framework for green smart cities

using automated pause to awake the device once it is needed. Different categories of sensory models are available, such as RFID, networks with remote monitoring, and public tracing. RFID is an electronic recognition tool used to identify branded materials. These passive RFID tags do not use batteries and can use energy from the reader's detection impulses to transmit the code to the RFID scanner.

These structures may be effective for a range of uses, for instance marketing and quantity chain control for emerging technologies. Wireless sensor network (WSN) has a vital role to play in digital detecting claims. It is a viable option for applications pertaining to transporting and resource sharing that can capture, store, and interpret essential information obtained from a number of environs. Wireless networks are smaller in size, less expensive, smarter, and more commonly used (e.g., enclosed camera). The IoT/IoE proposed here will be energy. Figure 8.3 displays the green IoT/IoE devices in green cities.

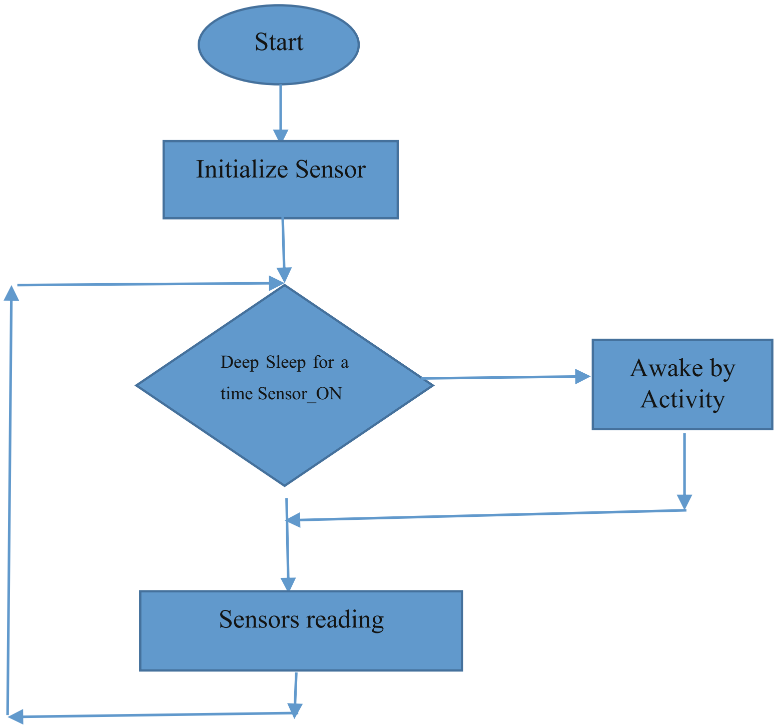

Fig. 8.3 Flowchart of a green IoT/IoE device

8.4.2 Fog Infrastructure

Fog computing is a decentralized computation technology that uses a single or a combined grouping of end-user clients or an edge computer to deliver a large quantity of storage. Some user services are managed on the edge devices of a smart computer and some application services are addressed in a data center—cloud [82]. The purpose of fog is to increase performance and lessen the volume of data that needs to be moved to the Internet for data collection, storing, and processing. This is done for purposes of productivity and defense and enforcement [83].

The fundamental principle of fog computing is that much of the operations occur on a mobile computer or on the edge devices on a smart router or other connectivity devices. Fog computing will be used in virtually any aspect of the smart city project—critical data can be submitted to the highest level of power, while the majority of data can only be used in nearby regions. IoT produces a lot of information and it is necessary to isolate it at the closest point in order to save the pace of computation, throughput, reliability, and decentralization.

8.4.3 The Cloud Services

Cloud storage services have been an integral part of these new innovations, and serve as an intermediary interface between IoT and consumer applications. Cloud computing provides a medium for data collection, post-processing, and modeling. The data stored on the fog server is stored on the server. The fog server links to the network using a regular Ethernet link to upload data locally. The cloud provides access to large volumes of computing resources and data analysis capacities that are not usable in either the edge sensor network or the fog servers. When a new data line is processed by the fog server, it schedules and reports multiple messages to the predefined region of the cloud IoT service. Each channel carries a basic time stamp data sensor and client choices. The cloud IoT program transfers messages sent to the data center service for storing and processing.

8.4.4 Smart City

In recent times, a major growth in global electricity usage and the amount of computation appliances and other items has driven government and commercial organizations to adopt the smart city model. The socioeconomic, fiscal, social, and environmental dynamics in cities are the key factors for the drastic rise in emissions, traffic, disturbance, violence, terrorism threats, oil production, road crashes, and global warming. Nowadays, communities are the main causes for the global warming. They occupy below 2% of the earth's crust, absorb 78% of the total energy production, and account for more than 60% of all carbon pollution (http://unhabitat.org/). Innovative methods are being created essential for the solution of social, economic, and environmental problem impacts on communities.

The smart city that will come out of this framework will boost energy performance and reduces greenhouse gas emissions. This smart city will become an incredibly metropolitan environment that meets the needs of businesses and organizations, health, agriculture, transportation, and especially citizens. The central administration policy will allow the city to be run in an effective way and at reduced cost. All portable devices will have the opportunity to be connected in a secured environment with authentication system that will be hard to break in.

8.5 Conclusion and Future Directions

There has been strong interest in the potential use of smart cities globally for the enhancement of everyone health. Countless smart city models have been presented based on various network technologies, with multiple attributes. Every smart city application is based on a certain architecture; therefore issues like interoperability, transparency, and convergence arise. In order to overcome these challenging conditions, the emerging smart city architecture suggests to use the cloud-IoT smart networks to produce power-efficient and sustainable cities. This makes it easy to set up smart metropolises that are clean, sustainable, and naturally aware. Sensor level includes all green IoT across wireless sensor networks allowing consumers to use various applications across cloud services and processes. In the future, smart city planners, engineers, and builders should have modular, budget solutions to the problems they face. Another specific field of study is the expectation of how to develop the most current developments that can be used to enlarge current smart city systems and technologies by incorporating new components.

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Chapter 9
Design of a Confidentiality Model Using Semantic-Based Information Segmentation (SBIS) and Scattered Storage in Cloud Computing

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9.1 Introduction

For imposing a vibrant safety concern the intention is to design a confidentiality prototype that provides a pre-planned confidentiality assurance for assuring its probability for which the proposal of empirical schemes reduces the number of cloud storage positions for depicting their abilities and precisely they are used for the least designed and most exciting information varieties.

9.1.1 Organization

This work has been organized as follows: Sect. 9.2 prefaces the work carried out; Sect. 9.3 has details about the general information about the work; Sect. 9.4 describes the contributions carried out to implement the new idea proposed in this work; Sect. 9.5 tells about the safety protocols used in the extensive design of this work; Sect. 9.6 describes the method of safeguarding the data collected without compromising the confidentiality in the cloud framework; Sect. 9.7 tells about the subcontracting of information with confidentiality assurance using background refinement and semantic data segmentation; Sect. 9.8 tells about the experimental

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analysis carried out; Sect. 9.10 discusses about the result with comparisons; Sect. 9.11 summarizes the work carried out; and Sect. 9.11 concludes the work with future establishments.

9.2 Preface

Cloud computing provides several profits to firms, public sectors, and people interested to store and process their information into the cloud such as vigorously expendable supplies, enhanced quickness, and administered, expandable, accessible, and global information available freely without bothering the topographical positions which offers estimation supremacy and elasticity [1]. Precisely cloud computing commonly makes use of cost cutdowns because it minimizes the prototypes and cost for preservation which thereby offers inexpensive storage abilities and analysis [2]. Precisely the intention is to design a semantic-based information segmentation that is capable of mechanically identifying information chunks that might create danger and divides them from the restricted principles so that every segment does not face any possible threats followed by which the segments of the flawless information are freely stored into individual positions of a multi-cloud so no peripheral objects can gain access to the comprehensive private information [3–5].

It is to be noted that the fractional information is stored in vibrant cloud environments; the outsourced characteristics are effortlessly and effectively aided by distributing the requests to several cloud positions. For imposing a vibrant safety concern the intention is to design a confidentiality prototype that provides a preplanned confidentiality assurance for assuring its probability for which the proposal of empirical schemes reduces the number of cloud storage positions for depicting their abilities and precisely they are used for the least designed and most exciting information varieties [4].

Since the safety-related issues regarding information outflow is focused due to the missing straightforward mechanism over the storage and administration of the subcontracted information which experiences diverse risks retarding several users from transfer their data to the cloud environment. In the European Union, nearly 40% of firms are making use of the cloud which conveys the threats in safety-related breaks as the key restricting feature in making use of cloud-related services. Precisely in the article released by the cloud safety association over nearly 170 IT and security experts in the United States several defendants measured cloud storage as an immense hazard. The European Network and the information safety assistance recognized missing control over the information subcontracted to the cloud as an unsympathetically significant feature.

For instance, *Dropbox* is meant to be an encoder for the user information by making use of dense cryptographic schemes where the private keys are generated and administered by the *Dropbox* themselves and not by the creator of the information [5]. Furthermore, the present safety-related issues negotiate information of users to store their information in the cloud. Several reputed illustrations comprise Sony Play Station outages due to the peripheral invasions where the private information from nearly 77 million user accounts was taken where the multiday outages in *Dropbox* momentarily permit the guests to gain access into desired files of their 25 million user accounts which might create malformation disputes or outflow of confidential pictures stored into the storage services of cloud.

Moreover, the use of the cloud might have disquieted the cloud service supplier's focus on processing their information. Cloud computing offered service providers the chance for examining and making use of the immense volume of secret information; for instance, the current confidentiality-related rule in Google states all the prevailing data which the user desires to distribute by Google to enhance or advertise its services. Likewise, Yahoo also attempts to gather precise user information and make use of them by aggregating them with the data acquired from the corporate companions. The information gathered by the service suppliers could be employed to aid the users but in parallel, it might create disputes related to confidentiality [6, 7]. Based on the documents provided by the Federal Commerce Directives it is postulated that the service providers often gather and examine the users' information without the awareness of the users and some references to these study can be profound; for instance the service suppliers can locate the data regarding diabetes since their attention is towards the gluten-free products and then distribute this data with the insurance firm which could make use of this data for categorizing the individual to be in an immense danger. In the financial concept the automated information is often regarded as the fresh input where the intention of the users is regarded as the information-processing activities accomplished by the service suppliers which are comprehensible and logical [8].

To overcome the issues and to recoup the user mechanism over the safety employed to the private and subcontracted data over-the-cloud diverse schemes are designed. The intention was to make use of precise sort of information safeguarding on the user side so that only safe results are subcontracted to the cloud which thereby permits only the creator of the information to precisely rebuild the information acquired from the cloud.

9.3 Genesis

Encoding is a normal solution for imposing information safety in cloud computing. Diverse solution mechanism is based on public and linear key cryptographic schemes are designed for storing information in the cloud where information safety is offered using encoding. The encoding is accomplished before the information is communicated and stored in the cloud and it is decoded only after that information is reverted to the creator of the information. These solutions are normally imposed as a belief-based encoding process; for instance, the cipher cloud offers a safe entry positioned in a belief environment besieged by diverse prevalent *SaaS* service suppliers [9–11]. It makes use of encoding to precise user-related information very before storing this information in the cloud. The cloud service is duplicated in the safe entry to offer logical outcomes to the processes such as investigation or categorization. The encoded keys are arranged and stored nearby under the influence of the user. The viewpoint system makes use of the identical mechanism which holds a server and a rear proxy that executes information encoding schemes. The safe cloud is a perfect solution for *IaaS* which is a cloud-based implementation platform where the application data are stored and encoded within the cloud, thus departing the initial governance and the description of access rules to the users.

Though the aforementioned system provides confidentiality safeguarding information storage for the users they experience diverse issues either mechanically or in the user base. The transmission between the service suppliers and the client device is seized and back processed for improving its safety aspects which are translucent to both the service suppliers and the users. However the transmission standards might frequently alter which thereby needs a consistent revision of the offered safety aspects which is a complex process that can extremely damage the dependability and accessibility of the services. Moreover, the service suppliers may execute precise countermeasures to avert these schemes in rough situations where the users analytically upload encoded contexts to their servers. It is precisely applicable to the service suppliers which offer services without involving costs since they anticipate acquiring turnover based on the user's information which might prohibit users from providing only encoded and unusable information [11].

The delicate data are analytically encoded and stored by the service providers which are intended to be conscious about the features provided by the service suppliers which could produce drivel results. Here only a minimized set of features are safeguarded or encoding could only be applied to that information that is not operated by the cloud or the cloud services that might be duplicated are the reliable entry. Lastly, the entry is enforced to excessively store plain information and to re-execute along with the back processing of several cloud services, thereby overcoming the comprehensive intention of information and evaluation subcontracting [12]. Though presently the cryptographic-based solutions are designed with restricted aids for several processes over the encoded information, the intricate process will need addressing mechanisms from identical encoding which are quite effectively used for real-time applications. There are more effective locatable encoded solutions which need appending of a substantial volume of information to the subcontracted information accomplishing diverse requests for reviving the harmonized information and provide restricted help for intricate and linked requests comprising rational and relation-based operators along with the value extremes.

The encoding of comprehensive information uploaded to the service suppliers at the client side suggests the forfeiture of diverse levels of direction effectively in terms of both the storage and processing which in the context of cloud computing depicts crushing its individual goal since one of the key intentions for migrating to the cloud is to cut down the cost. Furthermore, the supervision of encoded key might append fresh safety-related threats at the user side [12, 13].

The immense ranges of users are not aware of the basic conception of the cryptographic schemes and several of them cannot correctly govern the keys which thereby negotiates the efficiency and safety due to the inattentive administration of cryptographic schemes. For addressing these issues the intention is to design confidentiality safeguarding schemes alternate to the information encoding which governs the information more precisely [14]. To impose it becomes mandatory to be dependent on the immensely progressing context of multi-clouds, i.e., the usage of diverse cloud computing services in a unique individual framework. The multi-cloud appends diverse merits like minimized dependencies on any particular seller, thus escalating the suppleness or justifying the tragedies, but the focus is upon the scattered and independent nature of multi-cloud services. It paves the way for alternate information safeguarding schemes based on the information segmentation or divisions.

With information segmentation, the delicate information within a document or prevailing within the repository is divided into segments and stored in individual places so that every distinct segment does not reveal their individualities or any private data. Particularly the scattered storage of segments minimizes the volume of data acquired by the third party who adapts the data gathered from the information examination or user summarization becomes partial and unclear which also reduces the concerns of possible breaks. Likewise, the intention is that the information is stored in a precise manner which makes it probable to effortlessly recollect the number of cloud features by distributing the user requests since they are made use in fractional information segments which makes it probable for the information creator with the knowledge of position related to every segment for rebuilding the comprehensive outcomes by aggregating and uniting the fractional outcomes in a process with more efficient information decoding [15].

Thus on evaluation with information encoding and aiding an immense diversity of features the information segmentation does not face immense overheads linked with processing the requests. Lastly, in conditions where the service suppliers anticipate non-encoded information about the unique segments, it might be helpful since the service suppliers could still accomplish information examination and revive fractional inferences [7, 15, 16].

Diverse segmentation mechanisms are designed over decades which intend to perform information segmentation in a binary fashion. For instance, the users are segmented into bytes which are transferred and rejoined into a static set of segments which are lastly stored in different positions. Each of the subcontracted files is linked to an initial level which is selected by the users based on the compassion of their contexts. Then the segments are generated based on the RAID protocol storage schemes and those with utmost levels of confidentiality are stored in positions where the user relies on. These schemes where the information is segmented are performed following the static conditions and bytes are chosen in alternate and rejoined and are employed for comprehensive binary or even hypermedia files where the contexts are normally stored but not operated by the cloud schemes [8, 9, 13, 16].

Therefore files with contexts shall be operated by the cloud schemes for offering the features where the created outcomes provide neither confidentiality nor service assurance. Moreover, it is not probable to assure that segments of bytes do not hold adequate information to create exposure in case if it is too huge and not probable to assure cloud features or retains fractional information used for the service suppliers in case the segments are too minimal or partially joined. It makes it too complex for the users to comprehend safety and service conservation for which a precise scheme is made use of which naturally is dependent on the semantics of the information to be safeguarded [15–17].

At the elementary level, all the information segmentation schemes are intended on the planned repositories. In these situations, the information segmentation could be flat or upright. Therefore as per the statement, the flat segmentation is of restricted use in allowing confidentiality safeguarding and breakdowns since the revealing is often created from the synchronization among the entities instead of diverse documents which are normally autonomous. The upright segmentation is designed for assuring privacy at the documentation level by locating the entities of the repository which are encoded; meanwhile the quasi-identifiers are segmented and stored in diverse places [17]. Both the schemes restrict the number of positions since they consider that there is an individual set of quasi-identifier-based entities. Likewise, the exposure is sidestepped along with the preservation of information utilization at the entity level. Furthermore, the intention is to design diverse schemes for deciding the best breakdown for reducing the expenses of the following SQL requests which require being scattered and their outcomes are combined.

Though these schemes provide more vigorous assurances and improved features than the binary schemes they firmly depend on the modeling of information and on a set of physically described policies that state the groups of entities that might create breakdowns and segmentation [18]. Consequently, it could be operated to the unplanned information like documents and might not expand with immense information sets since human involvement is required to describe the uncertain mixture of entities for every information set. Furthermore, it is recognized by describing these dangerous mixtures which are an expensive and intricate process even for professionals.

9.4 Contributions

For addressing the restrictions of afore-detailed issues the intention is to design semantic-based information segmentation and safeguarding schemes for the sub-contracted information prevailing over the cloud. The designed scheme aims to evaluate the original semantics of the information to be safeguarded and the confidentiality prerequisites of the users for mechanically identifying the information segments which might create breakdowns and mechanical organization of segmented information to assure confidentiality to the user. In contrast to the schemes of information segmentation at the binary level the designed schemes segment the information along with the scattering of information contexts and the confidentiality prerequisites of the user. Thus the context of the resulting segments is not linear and is assured that it does not create any breaks in terms of confidentiality

[18, 19]. It is also compared with the schemes where the concern is on entailing privacy of user precise information.

The prevailing solution might be impractical for several conditions for the immense volume of documents that are subcontracted to the cloud system and the missing data of several users regarding the confidentiality hazards bothers their possessed information. Lastly, the comparison of methods based on the planned repositories in the designed scheme is uniquely based on the information semantics and it can make use of any variety of information irrespective of not focusing on their frameworks. To state the abilities and overview of the designed scheme, the intention is on the storage of fresh text-based documents where the most intricate task is to safeguard their absence of framework where similarly they comprise the most mutual manner to interchange possibly delicate data among the human players [20].

The goal of the designed scheme is stimulated from the conventional document purification schemes which endeavor at mechanically locating and safeguarding delicate elements in the input documents. To offer a pre-planned confidentiality assurance, the designed scheme satisfies an integral semantic-based confidentiality prototype for safeguarding documents. Based on the statement and imposing of confidentiality prototypes the information creators could innately describe their confidentiality prerequisites based on the semantics of the information which they do not wish to reveal to the cloud and possible intruders.

9.5 Safety Prototypes and System Framework

The designed safety prototype in which the user does not have belief in any service suppliers to safeguard their data. It is also regarded that all the service suppliers are truthful but could be probing; that is, it might assemble, process, and examine the information stored along with the requests they acquire from the users. It anticipates acquiring extra user information or breach any safety extents that the users might have executed over the information preceding subcontracted them. For any service supplier as a profitable supplier of services, it would not perform malevolently against the users and would precede the standards as anticipated, i.e., being truthful. It is also regarded that the accessibility of diverse service providers offering individual services, i.e., multi-cloud and providing a group of places where the information is possibly stored. It is also noted that the diverse service providers are autonomous from one another which does not allow to combine the fractional information that is stored to break down the user confidentiality [17–21].

Lastly, it is regarded that the user side is comprehensively believed and safe since it is the location where the information is stored preliminarily. Since it could be made use in a limited application or as a proxy on the user side it could safely process the flawless information preceding subcontracting them to the cloud and stores this metadata required to process the following requests on that information and rebuild the outcomes. For some situations, these safe applications or proxies can

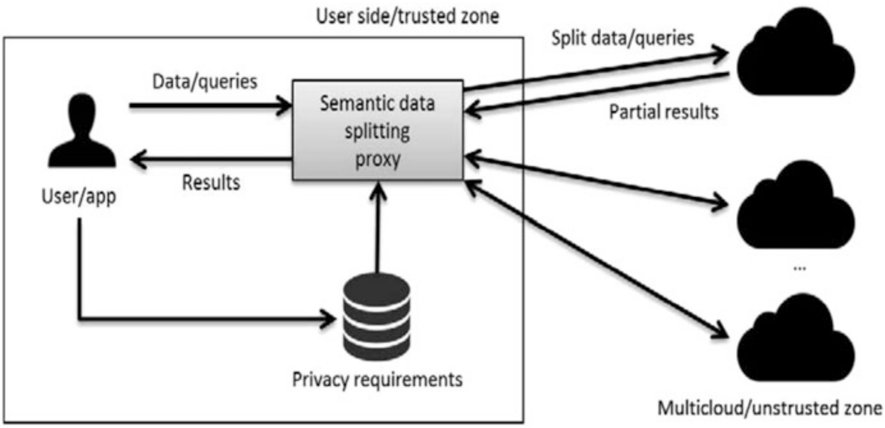

Fig. 9.1 General framework of the system

be distributed among diverse users. Here the cloud storage places will be distributed among diverse users. The application-level proxies would preserve the group of prevailing cloud places visible to the users [19, 21].

Furthermore, the users might state a set of confidentiality prerequisites that describe the theme which shall be safeguarded in any subcontracted information over the cloud, i.e., the utmost level of semantic exposure the user is permitting for every context. The prerequisites might be linked to the individualities needing safety against the revealing of uniqueness or private information, i.e., the entity revealing. In comparison to the prevailing schemes, these prerequisites are described at the abstract level instead of at the planning level. Based on the conditions entailed above, the framework is depicted in Fig. 9.1.

In semantic-based information segmentation, the proxy accomplishes two key activities, namely storage of information within the cloud and retrieval of information from the cloud as the outcome of the user request. The logic prevailing on the initial activity is portrayed in Fig. 9.2. Initially, the proxy acquires the information to be stored and makes use of discovery possibilities of the context. Performing these is dependent on the safety prerequisites entailed by the user so that the existence or synchronization of the input information might disrupt the confidentiality of the users which are spontaneously labeled as hazardous. This labeled information is then conceded to the segmentation component which consequently is hazardous and the limitations described in the confidentiality prerequisites make choices on the mechanism that the information is segmented and storage place required so that every chunk of information could be securely hoarded and compositely termed as information segments. It also stores the segmentation conditions within the local repositories as metadata so that the system could function flawlessly and processes the future requests over the information and combines the fractional outcomes followed by which they transmit every information segment to discrete service suppliers [22].

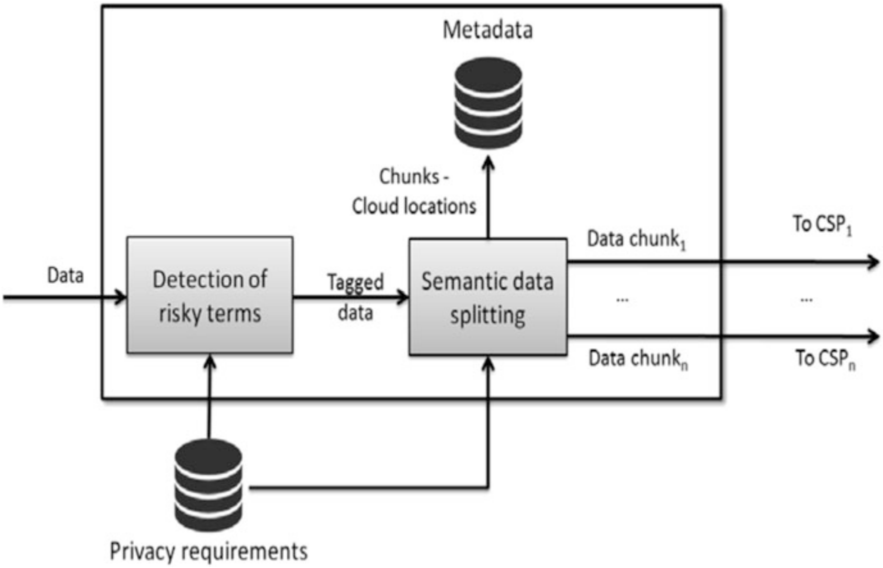

Fig. 9.2 Information subcontraction workflow to the multi-cloud through semantic-based information segmentation

Likewise, it is assured that the segmentation process is away from losses; that is, it offers a chance for rebuilding the actual outcomes in case if there is no need to store the comprehensive information within the local locations and the confidentiality-safeguarded contexts are stored in every isolated service suppliers that do not experience risks about safety prerequisites of the users [22]. In case if diverse users make use of identical proxy and distribute an identical group of cloud positions each position might hoard segments of flawless information from diverse users; that is, the segmented information of diverse users is multipart at each cloud location.

Since the proxy is the only probable understanding of segments related to the users offering an extent of safety against the approval of diverse service suppliers, the latter might limit the attempts to combine the fractional information they hoard which in turn are nosedived since they cannot differentiate the users to the matching information segments. Likewise, the reasoning linked to the implementation of user requests over the subcontracted information and the combination of concluding outcomes is portrayed in Fig. 9.3. Initially, the request is processed in the order that the storage positions of the information and the requests infer to the retrieval from the local metadata repository. Following this the requests are duplicated sometimes as the information segments are divided and the requests are transmitted to the resultant service suppliers. Consequently, the service suppliers offer a set of outcomes that depict a fractional vision of the comprehensive outcomes [20–23]. Lastly, the proxy combines these outcomes with the conditions employed to segment

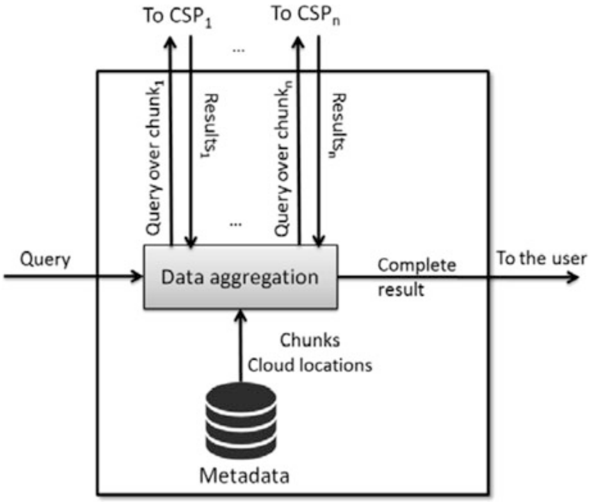

Fig. 9.3 Request-reply workflow with the segmented information

them and also stores them as metadata and offers comprehensive outcomes to the user.

9.6 Safeguarding Information Without Negotiating Confidentiality

There are diverse confidentiality schemes designed by several scholars to provide rigorous confidentiality assurances for safeguarding information. Many of these schemes like k-secrecy schemes along with their addition to plain text-based documents achieve the standard arrangement of the information for describing the confidentiality possibly as re-recognition of an individual within the information set to be unconfined [23]. Confidentiality is thus imposed by making the person vaguely recognize the information within the information set; that is, it primarily safeguards the information against self-exposure.

The other prevailing frameworks like differential confidentiality deal with the planned information sets and needs elements with restricted areas. Therefore the documents are created freely by every user and they shall be safeguarded exclusively based on the semantics they expose where open texts are also unplanned and limitless. Furthermore, the illustration of confidentiality prototypes is natural so that it could be used by the users to precisely describe their confidentiality prerequisites, and diverse confidentiality prototypes are created based on intangible numerical which several users feel too intricate to understand [24]. Lastly effortless aids are offered for safeguarding against self or entity exposures.

The only confidentiality prototypes which are suitable for these circumstances and prerequisites are background refinement which is a common confidentiality prototype for text-based refinement. The background refinement describes the preferred level of confidentiality in terms of a set of contexts in a manner that the confidentiality assurances are satisfied if the safeguarded results do not hold any of these terms which uniquely or jointly exist within the same documents, thus revealing the semantics of the delicate elements [25]. For instance in medical documents the HIV and AIDS refined form shall not hold these terms because the illegal information stealer might gain access to the safeguarded documents relating to AIDS and HIV. The prototype is described below.

9.6.1 Illustration 1 (Background Refinement)

For an input document id, the contextual information i_c prevails for the possible intruders where a set of delicate information d_i has to be safeguarded. It is depicted that id' is the background refined version of id if and only if id' does not hold any of the word w or set of words w_s which individually or in combination could expose any of the units within background refinement by negotiating i_c. For precisely arranging the transaction in between the extent of safety and information utilization it is possible to describe a fixed value of extreme expose by mentioning a set of overviews $O(d_i)$ for the delicate objects. For instance, the (HIV, sickness) and (HIV) refined document will not only retard exposure of AIDS but also expose those contexts related to an ailment and virus correspondingly.

9.6.2 Illustration 2 ((d_i, $O(d_i)$)) Refinement

For a given input document id the background data i_c is a well-ordered set of delicate objects d_i to be safeguarded along with the arranged set of their related overviews $O(d_i)$. It is inferred that id' is the ((d_i, $O(d_i)$)) refined version of id if and only if i_d' does not hold any word w or set of words w_s which solely or jointly exposes more semantics in all i_c offered by their particular $O(d_i)$ by negotiating d_i. Based on the illustration in the background refinement prototype, the users could describe their confidentiality prerequisites due to the metrics d_i in terms of semantic tags which is a set of delicate contexts that the safeguarded documents will not expose. Another key merit of the prototype is that it could be simply depicted to impose the confidentiality prerequisites of the prevailing regulation and principles on the confidential information whose descriptions related to the delicate information are also semantic.

Lastly, the utilization of overviews $O(d_i)$ as exposed fixed values for d_i authorizes to the minimal volume of semantics that could be exposed related to d_i which imposes the system to execute a sterner refinement. In terms of semantics, the utilization of overviews in the model depiction is to excellently tune the confidentiality assurances naturally and to offer a clear insight on the volume of data that the peripheral objects could acquire from the safeguarded document.

9.7 Subcontracting of Information with Confidentiality Assurance Using Background Refinement and Semantic Data Segmentation

The intention is to describe the semantic-based information segmentation scheme which is linked with information segmentation for mechanically coordinating the segmentation process and the forthcoming requests along with information revival based on the semantics and threats related to confidentiality of the information [26, 27]. To provide confidentiality assurance the safety is provided by the designed schemes which satisfy the background refinement process similar to the segmentation and scattered storage of segments in isolated service suppliers which are accomplished based on the semantics and sensitivity of the document contexts and confidentiality prerequisites of the user in a manner in which the segments that are stored individually in the cloud do not face any issues related to confidentiality negotiation.

The comprehensive process is accomplished in two ways as identification of words within the input document creating exposure threats based on the confidentiality prerequisites and segmentation along with transmitted storage of words for retarding exposures.

9.7.1 *Identification of Precarious Words*

The dynamic identification of precarious words happening within the input document is motivated by the concept of exposure entailed by the depiction of background repetition prototype which entails the confidentiality prerequisites. The semantic exposure that the words w/w_s created concerning the elements to be safeguarded d_i could be certainly imposed with data in terms of the hypothesis by calculating the volume of data given by w/w_s about d_i. The semantics covered by the element d_i could be refined based on its data context d_i similar to the semantics that a term w or a set of words w_s reveals regarding the object d_i which is measured based on the point-based synchronized data PSD (d_i,w). Therefore it is possible to recommunicate the common description 1 as entailed below.

9.7.2 Illustration 3 (Data Hypothesis for Background Refinement)

For the input document id, the contextual information i_c and a set of delicate information d_i have to be safeguarded for which it is portrayed that i_d' is the background refined version of i_d if and only if for all d_i, i_d' does not hold any words w or set of words w_s based on i_c as PSD (d_i,w) = d_i (or) PSD (d_i,w_s) = d_i correspondingly.

Based on the condition the words w or a set of words w_s within the input document where PSD (d_i,w) = d_i (or) PSD (d_i,w_s) = d_i for any d_i in d_i' will create threats related to exposure. The d_i of an object d_i estimates the data/semantics which should be concealed due to their delicate nature where the PSD estimates the volume of data/semantics that a word w or set of words w_s should disclose about d_i. Figure 9.3 depicts the association between d_i and PSD where cancer is considered to be objected d_i to be safeguarded and operation is the term w happening within the document which is semantically associated with d_i. The figure portrayed in grey exposes the data/semantics in which w creates d_i [24, 28].

The threats related to exposure and its estimation can be elaborated if the overviews of the delicate objects $O(d_i)$ are described as the fixed value of utmost exposures. Based on the changes performed in description 2 in the data hypothesis the threats related to exposure occur for those words w or a set of words w_s within the input document where PSD (d_i,w) > d_i (or) PSD (d_i,w_s) > d_i for any d_i in d_i'.

For real time d_i is evaluated as the reciprocal of the likelihood of its existence:

$$d_i = -\log 1\,(d_i) \tag{9.1}$$

The likelihood required to estimate the data related to the text is normally evaluated which generates minimal data than the precise ones since the likelihood of arrival in the exposure of proceeding is higher [3, 11, 21–23, 27, 28].

Similarly, the PSD (d_i,w_s) is estimated as the normalized likelihood of synchronized d_i and $w = \{w_1, \ldots.., w_n\}$ given their combined and border likelihoods:

$$\text{PSD}\,(d_i, w_s) = \log\left(\frac{l\,(d_i, w_1, \ldots, w_n)}{l\,(d_i)\cdot l\,(w_1, \ldots, w_n)}\right) \tag{9.2}$$

To seize the accurate perception of exposure, the likelihood of its existence shall be estimated from a quantity that openly symbolizes the information i_c prevailing to the probable intruders to accomplish their interfaces [29]. Therefore in worst-case conditions, the quantity shall be huge and is varied enough to shield and seize the data broadcasting at a common balance. The Internet is well matched for serving the purpose because it provides an immense volume of straightforwardly reachable data/awareness sources and it is immense that it is varied for a real-time proxy for social information. Furthermore, the scheme likelihoods could be estimated effectively by requesting words and a set in openly prevailing Internet-based search engines and estimating the resultant page calculations:

$$l(w) = \frac{Web\_Page\_Calculation}{Overall\_Webs} \tag{9.3}$$

Here the overall Webs are the number of prevailing Web resources filed by the Internet-based search engines. The design of Internet-based data and evaluation of exposed threats for identifying the precarious words at the proxy connected at the user side is carried out [29]. The below-entailed routine executes the operation.

9.7.3 Algorithm: Identification of Precarious Words

```
id = id'
di = acquire suspicious grouping
if (di = = 1)
substitute (di, id')
hd = acquire most helpful data
while (di!=0)
position_identification = false
data_chunk = initial
while (not (position_identification) && (data_chunk ≠ null))
hd = data_chunk + hd
if (not (verify exposure (safe ordered elements, helpful data)))
position_identification = True
append (hd, data_chunk)
eradicate (hd, di)
di = create rest of the terms
else
data_chunk = next (data_chunk)
end if
end while
```

9.7.4 Semantic-Based Information Segmentation and Scattered Storage

For the concept of document refinement, the input documents in its safeguarded form shall be unrestricted based on packets where the words are identified as threats that are normally detached so that the extent of exposure it create; is minimized below the confidentiality prerequisites [30]. It creates a loss of usage because some of the actual words are not prevailing within the detailed procedure within the safeguarded results.

Within the multi-cloud storage conditions conversely, it is possible to gain merits of the prevailing diverse cloud storage positions to divide and store precise information within the confidentiality-safeguarded manner while recalling most of the subcontracted features. Due to diverse cloud storage positions, it is not conscious about one another nor segmented conditions executed by the local proxy as the service suppliers will not be able to rebuild the comprehensive information in a clear manner that retards the exposure [30, 31]. Furthermore, because single-cloud positions are accessed by diverse users due to their scattered nature it is governed by the proxies; the segmented chunks of each user are combined which appends the arbitrariness of the subcontracted information stored at each position and provides an improved safety against conspiracy threats of diverse service suppliers that might attempt to combine incomplete information segments.

For some conditions and inconsistency with the background refinement, the confidentiality prototype on which we are dependent for the segmentation process shall assure that every individually stored information segment satisfies the descriptions 1 to 2 hypothetically using their data. Based on the uncertain words the precarious words identified within the preceding phase might vary in two cases. Initially, the location of separate words w for unique existence within the document creates exposure threats based on the confidentiality conditions [11, 24, 30]. For instance, for acquiring a medical record to be cancer refined the individual existence within the document of replacements of cancer such as malevolent neoplasm or the specialties like breast cancer comprehensively reveals the semantics of the word cancer.

Furthermore, in the usage of overviews of cancer to set severer confidentiality conditions for the model illustration other discrete words might also create exposure. For illustration within a refined document, any knowledge of ailments is also an overview of cancer such as a tumor which might also cause exposures [31]. These unique words could also be regarded as recognizers to the units to be safeguarded and they shall be stored in a precise form within any cloud location. These words as entailed lastly symbolize a minimal volume of data that should be safeguarded and stored locally by the proxy.

It is possible to recognize the mixture of words PWs $= \{w_1, \ldots, w_j, \ldots w_n\}$ happening within the document where each w_j does not create adequate exposures to be measured precarious their combination achieved could be regarded as quasi-recognizers to be safeguarded. Here the concrete exposure created by PWs is the combination of separate exposures created by each w_j in terms of d_i estimated using Eq. (9.2). The medical record has to be cancer refined; the existence of the set of terms PWs = {urine blood level, cancer, tiredness} might be dangerous since the combination in immense correction with cancer through every discrete word creates an incomplete exposure [31].

To safeguard the mixture of precarious words, the autonomous and scattered storage produced by the multi-cloud by individually storing w_j or set of PWs is utilized. Likewise, the retarding of combined interfaces and eliminating the exposure the recollection of features of incomplete information is stored precisely [32]. The information segments shall be generated independently which satisfies the situations specified by the illustrations of the background refinement prototype after which they shall be stored individually to continue unpleasant to the service suppliers. It is also able to safeguard against unintentional disclosure by the service suppliers or peripheral attacks since they are incomplete data. The rest of the words within the documents that are not regarded as precarious shall be composed in an individual segment and stored in several cloud locations.

To rebuild the comprehensive document and to offer intelligible and comprehensive outcomes to the user-related requests, the proxy would store them on a local basis based on which there is metadata for each subcontracted document [32]. The list of words that are not subcontracted to the cloud are arranged separately because of their autonomous understanding they are organized based on their presence within the document. There is a list of cloud locations of the quasi-locating word PWs based on their balance within the information segments where they are held. The lists are organized based on the precedence of quasi—the location of words within the document.

The cloud location of the refined document is produced based on the elimination and location of quasi-located words. The positions they acquired within the document are labeled with custodian; likewise the proxy would be capable of rebuilding the document by simply substituting them with the elements in the locally organized list of locators and the subcontracted quasi-locators acquired from the precise service suppliers based on the locally organized list of cloud locations and their counterbalance to each location [32].

The key disputes of the subcontracting process are that the number of needed positions is also an immense number of positions; that is, an immense number of requests shall be accomplished to acquire the entire context for the document [33]. Two features have key effects on the needed positions. The depiction of the confidentiality prototypes allows arranging the interchange among the extent of safety and number of diverse cloud locations needed to satisfy the confidentiality assurances; that is, precisely the more the fixed values the severer is the safety along with the immense number of positions required to satisfy confidentiality conditions [17, 25, 32]. For larger documents, the exposures are constricted and the confidentiality prerequisites are severe as the number of quasi-locators that are stored individually might be huge. For minimizing the expenses and reducing the solution the intention is to design a desirous segmentation and distribution scheme which integrates diverse experiments to reduce the number of cloud positions *cPos* needed to store the documents which assures that each information segment satisfies the confidentiality prototypes [34]. The scheme intends to make use of several words w_j for every segment, s, where the combination still satisfies the confidentiality conditions and only when the condition is not satisfied a fresh segment is generated and the process is reiterated till no more is remaining to be distributed.

9.7.5 Data Segmentation and Scattered Storage

```
id // Input Document
PWs // Precarious Words
di // Arranged set of objects to be safeguarded
o(di) // Arranged a set of overviews related to di
id' = id // id' is the refined version of id
while ((not(null PWs))) do
PWs = acquire delicate mixture (PWs)
if (|PWs|==1) then
substitute (PWs, id')
append (PWs, List_id)
else
substitute (PWs, id')
ic = acquire informative words (PWs)
while ((not(null PWs)))
position_located = false
segment= initial (set of segments)
while (not(position_located) && segment ≠ null)) do
ws = segment + ic
if(not(verifedexposure (di, o(di), ws))) then
position_located = true
append (segment, ic)
discard (ic, PWs)
ic = acquire rest of the words (PWs)
else
segment = next (set of segments)
endif
end while
if (not (position_located)) then
if (|ic |==1) then
segment= fresh segment (ic)
append organized (segment, set of segments)
discard (ic, PWs)
ic = acquire rest of the words (PWs)
else
PWs = acquire delicate mixture (PWs)
endif
endif
end while
endif
end while
for each segment in the set of segments do
cPos=hoard individual cloud position (segments)
append(cPos, list of cPos segments)
endfor
doc_cPos=hoard individual cloud position (id')
hoard locally (id_cPos)
(organizeList_id, organize List_cPos) = acquire organized list

(List_id, set of segments, List_cPos, segments, id)
store metadata locally (organize List_id, organize List_cPos)
```

9.8 Performance Analysis

There are two features of the designed system which could be analyzed: the precision of the identified precarious words and the efficiency of the segmentation process. The results of the preceding are previously described and assessed which reveals that the execution of the background refinement with discreetly common fixed values accomplishes similar performance. The outcomes of the analysis and the efficiency of the segmentation process along with the designed schemes were recorded. The number of cloud positions with the quantity identical to the employed analysis on the document refinement has been carried out.

For analysis, a similar document quantity was employed to calculate the precision of the identification of precarious words. It holds a set of recitation documents entailing some objects that are delicate based on the prevailing legal contexts on the confidentiality of the information and extremely delicate individuals [35]. About the previous, the policies on the medical information confidentiality instruct hospitals and healthcare firms to safeguard the situations made to transmitted ailments for persistent medical documents before freeing them for instance insurance firms in reply to the employee reimbursement or motor automobile chance entitlement. These words openly mention that these are ailments and these are semantically associated with indications that shall be safeguarded. Similarly, the European Union Information Safety Instructions state that safety should evade probable discernment. For all these cases the feature exposure along with safety has to be offered. Wikipedia is employed based on the literature since they organize stimulating information safety conditions due to their snug and semantically opulent exposures [36] (Fig. 9.4).

To provide these sorts of information safety for every document, it is essential to make use of a diverse variety of illustrations of the background refinement framework. Initially, the basic HIV refinement is performed uniquely for the

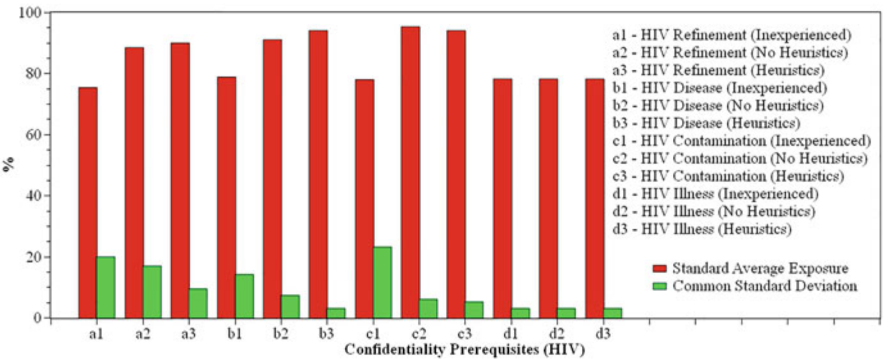

Fig. 9.4 Various confidentiality requisites for different heuristics schemes for the data collection of human immunodeficiency virus and its illness

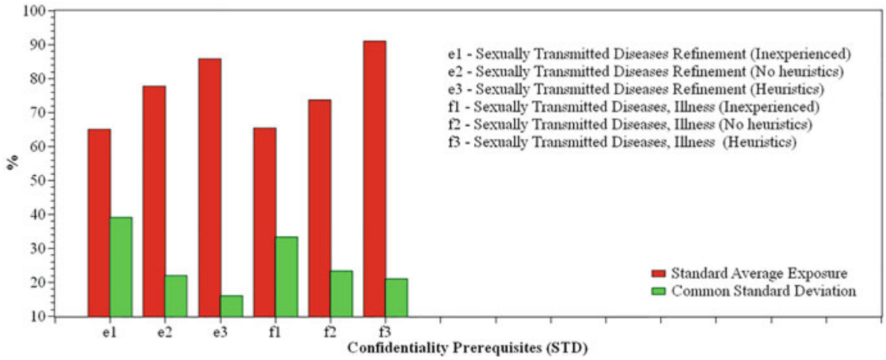

Fig. 9.5 Various confidentiality requisites for different heuristics schemes for the data collection of sexually transmitted disease and its illness

corresponding documents where the independent words or group of words that disclose the elements to be safeguarded are regarded as precarious. Following this semantically logical overviews are employed as fixed values to demonstrate the utmost extent of permitted exposures [37]. Disease, contamination, and illness were employed as overviews of HIV which is diagnosed as the sexually transmitted disease (Fig. 9.5). These case analyses are employed to demonstrate the mechanism of background refinement which could be naturally illustrated to the unit where the confidentiality statements are represented in the prevailing rules on information safety and for diverse confidentiality prerequisites.

9.8.1 Evaluation Parameters

To estimate the advantages designed based on the semantic information segmentation schemes the entailed segmentation policies are designed and used for the assessment. The inexperienced schemes for every delicate word are stored in a unique position. The comprehensive unfamiliar policies slightly satisfy the confidentiality prerequisites though it will probably need an immense number of positions. Routine 2 without the heuristics arranges the words and segments for increasing the unintended location of lawful provision [38]. Here the words are arranged identically as they are prevailing within the document and segments are assessed based on the conception. Scheme 2 based on the designed heuristics is entailed in data segmentation and scattered storage scheme. To estimate the efficiency of each segmentation policy, the below-entailed quality parameters are enumerated.

A number of cloud positions are required to assure that all the information segments are stored in precise format satisfying the confidentiality prerequisites [7, 15, 38, 39]. It is a vital feature that commonly states that with increased cloud positions immense is the expense of storage experienced by the users of the service suppliers. Furthermore more positions indicate more requests scattered for satisfying the input request and more outcomes shall be combined to offer comprehensive outcomes to the users. More positions are required to store the rest of the non-precarious words from the input document [8, 40, 41].

The exposure equalization among the cloud positions is estimated since the group of words is stored collectively based on the combined volume of data they expose where an improved distribution will be in combination exposed at every position where the closest exposure fixed value is entailed by the framework illustration [42]. Furthermore, the improved exposure-based equalization will be imitated based on a minimal difference among the extent of exposure of the words stored at every position; in the same manner identical extent of exposure is accomplished where several positions reveal meaningful data whereas others reveal crucially fewer data. Precisely, the heuristics method arranges the position of words to distribute the uniform equalization. To estimate the efficiency of the heuristics estimation of numerical average and the standard devotion of the combined exposure of the group of words stored in segments at every location has been recorded & analyzed. To provide numerals that could be straightforwardly estimated for diverse documents and framework illustrations normalization of every parameter based on the information exposure fixed value $o(d_i)$ is represented for the framework as below:

$$\text{normalized\_parameter} = \left(\frac{\text{parameter}}{d_i \; (\text{exposure\_fixed\_value})} \right) * 100 \tag{9.4}$$

Here the parameter relates to either the numerical average or the standard deviation of the combined exposure of the positions employed [43]. An improved and normalized average will be closer to 100% while an improved standard deviation will be 0%.

9.9 Results and Discussion

The assessment parameters for diverse documents, framework illustrations, segmentation processes, and heuristics employed are depicted in Tables 9.1, 9.2, 9.3, and 9.4. It is also depicted that these tables reveal the proportion of words from the entire document that were labeled as locators and quasi-locators.

Initially, it is perceived that the proportion of recognizing words escalates as per the refinement threshold. It is logical to fix common value, where the most common words are linked to the elements to be safeguarded could be missing words from data. An overview of the exposure threshold remains as locator that could not be stored precisely without negotiating the confidentiality prerequisites [44]. It is because of the requirement to locally hoard them within the proxies which guzzle

Table 9.1 Assessment parameters for the document regarding HIV with diverse segmentation policies and confidentiality prerequisites

Confidentiality prerequisite illustration	Locators (%)	Quasi-locators (%)	Segmentation policies	Standard average exposure (%)	Common standard deviation (%)
HIV refinement	6.5	15.0	Inexperienced	75.4	20.0
			No heuristics	88.5	16.89
			Heuristics based	90.01	9.52
HIV, disease refinement	9.8	13.5	Inexperienced	78.89	14.05
			No heuristics	90.99	7.23
			Heuristics based	94.00	3.02
HIV, contamination refinement	6.0	10.5	Inexperienced	78.02	23.23
			No heuristics	95.22	6.02
			Heuristics based	94.02	5.05
HIV, illness refinement	23.1	1.1	Inexperienced	78.21	2.99
			No heuristics	78.21	2.99
			Heuristics based	78.21	2.99

Table 9.2 Assessment parameters for the document regarding sexually transmitted diseases with diverse segmentation policies and confidentiality prerequisites

Confidentiality prerequisite illustration	Locators (%)	Quasi-locators (%)	Segmentation policies	Standard average exposure (%)	Common standard deviation (%)
Sexually transmitted disease refinement	5.5	10.2	Inexperienced	65.02	38.99
			No heuristics	77.75	22.0
			Heuristics based	85.85	16.02
Sexually transmitted disease, illness refinement	4.2	11.1	Inexperienced	65.4	33.3
			No heuristics	73.7	23.3
			Heuristics based	90.9	20.99

Table 9.3 Assessment parameters for the document regarding religions with diverse segmentation policies and confidentiality prerequisites

Confidentiality prerequisite illustration	Locators (%)	Quasi-locators (%)	Segmentation policies	Standard average exposure (%)	Common standard deviation (%)
Religion refinement	4.5	13.2	Inexperienced	76.75	25.55
			No heuristics	84.02	24.5
			Heuristics based	86.87	15.5
Religion, caste refinement	9.5	9.5	Inexperienced	79.00	21.1
			No heuristics	80.02	12.2
			Heuristics based	85.6	6.98

Table 9.4 Assessment parameters for the document regarding homosexuality with diverse segmentation policies and confidentiality prerequisites

Confidentiality prerequisite illustration	Locators (%)	Quasi-locators (%)	Segmentation policies	Standard average exposure (%)	Common standard deviation (%)
Homosexuality refinement	1.8	12.5	Inexperienced	62.98	50.98
			No heuristics	77.1	28.02
			Heuristics based	80.99	15.25
Homosexuality, illness) refinement	2.0	13.1	Inexperienced	63.23	39.98
			No heuristics	75.24	21.21
			Heuristics based	88.88	17.03

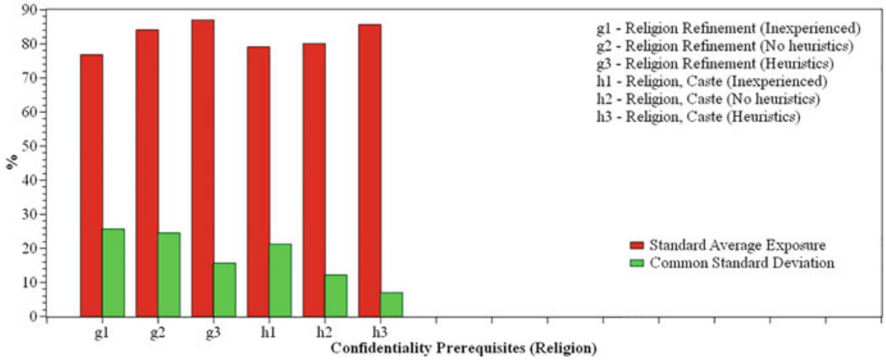

Fig. 9.6 Various confidentiality requisites for different heuristics schemes for the data collection of religion and caste

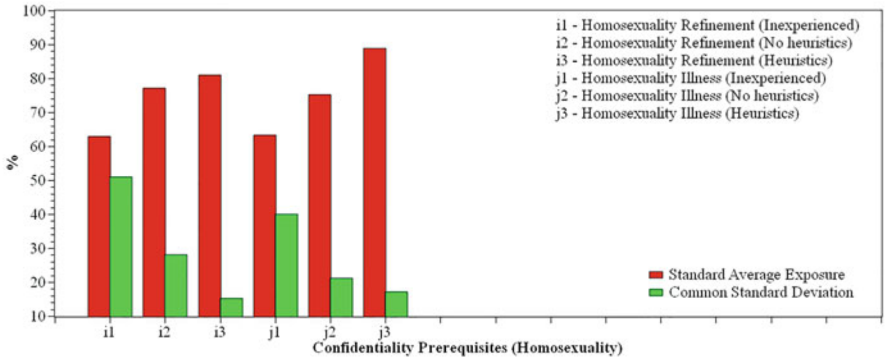

Fig. 9.7 Various confidentiality requisites for different heuristics schemes for the data collection of homosexuality and its illness

all the local storage supplies. Therefore it is perceived from the table that the locally stored locators experience minimal proportion of the overall volume of information to be subcontracted; furthermore it is crucial to recollect that these sort of documents are employed in worst-case conditions for information safety. It is also regarded as the number of positions required to store the quasi-locators for safeguarding confidentiality in a manner that it escalates the fixed values irrespective of the segmentation policies. The common fixed value entails increasing synchronization within the document which could expose in combination more data that could be entailed based on the fixed values (Figs. 9.6 and 9.7).

Therefore the firmest confidentiality conditions executed based on the common fixed value restrict the number of words stored together and escalate the number of required positions. The only exclusion is HIV documents (Fig. 9.4) for which many quasi-locators act as locators which could be employed for storing in one position but encoded form while creating a common fixed value. Based on the evaluation of diverse segmentation policies it is precise that the raw scheme offers the nastiest outcomes because it demands the principal number of positions [45]. Routing 2 crucially minimizes the number of required positions because it attempts to appropriate as many words as probable in each position till the confidentiality prerequisites are satisfied. The heuristics combined based on the routines also aids in enhancing the effectiveness of the distribution. Based on the arrangement of words in minimizing the demand for the information it attempts to assign initial words that execute the firmest limitations and will, therefore, be more intricate for distribution [46]. Based on the arrangement positions, the escalating demands of the combined exposures where the attempt is to make use of these segments has been more possible to fit a fresh word since there will be an exposure before negotiating the confidentiality prerequisites. It not only offers more effective employment of the prevailing resources but also minimizes the number of ineffective distribution tries in assessment based on the non-heuristic policy [47]. The heuristic scheme offers immensely related enhancements over the prevailing policies during the minimally firm confidentiality conditions mentioned, i.e., since no overviews are employed as exposure fixed values. Certainly, these configurations offer more extents of liberty to assign words without satisfying the confidentiality frameworks which the routines regard as merits.

The efficiency of the distribution process is demonstrated based on the equalization of exposure extents based on diverse positions employed. Based on the heuristics schemes the normalized average remains maximum and it is closer to 100% which represents that the exposure budget provided by every position in terms of fixed values is frequently used. Similarly, the standard deviation among the locations remains minimal which permits that the exposure extents of several positions are consistently equalized [47].

In the case of immobilizing the heuristics, the outcomes are somewhat inferior which much more gets inferior with the simple scheme. Here the distribution is nearly arbitrarily which means that the immense distribution budget is unexploited [48]. The outcomes are logical for all the documents irrespective of the confidentiality prerequisites inferring the private information like illness or recognition of information like name of the individuals [49, 50]. It is regarded that the heuristic-based segmentation policies briskly attempt to store the words which provide terminated data due to their synchronization which does not crucially escalate the levels of exposure of the segments while the split-balancing words with least shared data are stored independently.

9.10 Summary

Mostly the encoding serves as the key scheme for safeguarding confidentiality used to safeguard the subcontracted information over the cloud though it normally obstructs effectiveness both on the cloud and local sides for storage and location/recovery process which is not apparent for cloud suppliers which provide restricted services for the subcontracted features and append several problems like local managing of keys and the requirement to organize individually designed software components in the cloud to aid precisely subcontracted features. In comparison to the semantic-based information segmentation scheme, the intention is to design a curious alternate since all the subcontracted information is stored in precise form; the information organization is expandable and effective particularly during the location and revival process since it is fully translucent for cloud service suppliers that are not conscious about the information safety which preserves their services completely where the subcontracted features are directly safeguarded even for immense mobile exploration requests [14, 45].

Furthermore, the scheme creates a pre-planned confidentiality assurance provided by the background refinement framework which in contrast to estimation with other confidentiality frameworks is based on the algebraic and planned information which could be innately illustrated at an abstract level based on the semantic labeling. It permits the users to easily describe their confidentiality prerequisites without requiring them to be conscious of the procedures regarding information safety and also protects a unified implementation of prevailing semantics on qualitative information safety [48]. The framework permits describing the extent of safety made use of the information as a function of the volume of semantics that could be exposed. It is revealed that based on the simulation it also permits the equalization of the transaction among the extent of confidentiality and the volume of supplies required for implementing them.

Based on the comparison of the other safety schemes based on the information segmentation the essential semantic scheme for the designed approach makes it probable to mechanically estimate the threats prevailing on the safety of information based on the semantics they expose. It discharges the users from the liability of physically recognizing the delicate chunks of information as required based on the analysis and provides natural services for unplanned text-based information that could be barely organized by most of the prevailing confidentiality safeguarded solutions [27]. The intention is to design a semantic-based information segmentation that is capable of mechanically identifying information chunks that might create danger and divides them from the restricted principles so that every segment does not face any possible threats followed by which the segments of the flawless information are freely stored into individual positions of a multi-cloud, so no peripheral objects can gain access to the comprehensive private information. The forthcoming section portrays the conclusion of the designed works and future scopes.

9.11 Conclusion

With the aid of safe multiparty estimation, diverse individuals could estimate processes based on their input values without disclosing any data regarding their personnel input during the estimation. Here multiparty estimation is implemented among diverse clouds. By using safe multiparty estimation a better safety could be offered for the user's information for online-based services prevailing and employed nowadays but also has the perspective to perform fresh likelihood services which do not subsist currently due to the secrecy of user's prerequisites and lack of faithful third parties.

The forthcoming intention is to analyze the requirements for a standard confidentiality safeguarding prototype which intends in performing a choice in safeguarding the consumer's private information deposited into the cloud depository service suppliers. The growing improvements might cause the consumers of the cloud to miss their authority over the depositories. But the intention is to please the long-lasting distress of the consumer's prerequisite and the anticipated support and their precious information are of the system consumption which investigates the boundless support. The consumers of the cloud are forced to distribute their comprehensive facts and the data to the suppliers by tolerating the suppliers of the cloud tenure and provisions. It is noted that only up to 10% of the cloud consumers are conscious of the truth that the suppliers hold the entry to their private data. This becomes a significant problem in the rising cloud depository. The intention is to resolve the problems and to design a fresh common scheme with prototypes in safeguarding and maintaining the confidentiality of the consumers.

Though cloud computing offers several essential advantages such as cost cut-downs, accessibility, and expandability there arise issues related to the safety of information due to the missing of controls over the storage and administration of the outsourced information which still retards several users from transferring to the cloud environment. There is a diverse confidentiality safeguarding scheme based on the pre-planned encoding of outsourced information. The information encoding provides vigorous safety but the expenses in obstructing the effectiveness of the services and feature restrictions are employed over the encoded information onto the cloud environment. Since effectiveness and features are significant merits of cloud computing particularly in SaaS it is essential in designing a confidentiality safeguarding scheme that is dependent on dividing the information and based on the scattered storage provided by the progressively standard schemes of multi-clouds.

Precisely the intention is to design a semantic-based information segmentation that is capable of mechanically identifying information chunks that might create danger and divides them from the restricted principles so that every segment does not face any possible threats followed by which the segments of the flawless information are freely stored into individual positions of a multi-cloud so no peripheral objects can gain access to the comprehensive private information. It is to be noted that the fractional information is stored in vibrant cloud environments; the outsourced characteristics are effortlessly and effectively aided by distributing the requests to several cloud positions.

9.12 Future Scope

For imposing a vibrant safety concern the intention is to design a confidentiality prototype that provides a pre-planned confidentiality assurance for assuring its probability for which the proposal of empirical schemes reduces the number of cloud storage positions for depicting their abilities and precisely they are used for the least designed and most exciting information varieties. The future work is focused on enhancing the schemes, strategy, and authentication policies in active real-time cloud environments for adjusting its viability without completing the behavior of cloud computing.

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Chapter 10
Maintaining IoT Healthcare Records Using Cloud Storage

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10.1 Introduction to Healthcare Records

Recently medical organizations' important task has been to secure the healthcare records like personal details of patients, electronic health records, payment details of patients, lab records, diagnostic reports, treatments, therapies, pharmacy records, authentication of patients, doctors, and legal permissions. It includes storing healthcare records for every individual patient's ambition to backtrack completely with utmost care for research, education, and development of records. Directly, the secured data should handle all types of healthcare records with a feasible system. Various types involved in the database table, structured or unstructured database records like digital hard copies, are difficult to maintain in traditional ways. The purpose of the computer system shows highly effective and efficient healthcare records by aiding the renewal process of clinical trials data collected from various places like sites, lab records, pharmacies, researches, and service providers. It also alters healthcare records accordingly among delivery speed and minimizes the redundancy data or records as prescribed. Importantly, huge research on healthcare records needs the genomics data and improves the health and processes of prevention, treatment of diseases, and personal healthcare. As per healthcare records [1, 2] discussed in this research for analysis, by observing the latest designs with new ways [3], recently a new era of healthcare records has arisen, with great strength by modernizing the new and proposed concepts. Mostly this model is identified by the Web from the world of O'reilly (2015), where the concepts are open sources and

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distribution of knowledge and actions. Handling of healthcare records and storing of the data to access control management are proposed in this chapter. It also represents the privacy methods used for privacy homomorphism and considers the scheme of rural and urban healthcare records and storing in cloud areas to establish the flexible model of medical healthcare records. Storing healthcare records with high security requires multilevel security by producing encryption methods before sending data or storing data in the cloud. Medical organizations are adopting medical service providers (MSP) along with public, private, and government services. They are managing healthcare records by storing data in electronic record or digital record format. This helps patients to easily retrieve diagnosis reports, history of medical records, medicines used, reports of laboratories, and demographic information. Fast analysis is achieved by using electronic healthcare records with utmost care.

Internet of Things (IoT) and cloud computing (CC) are new growing revolutionary technologies that complement various capabilities integrated as flexible, scalable, and efficient patient healthcare systems. Various advantages when compared with conventional neural networks are advanced security information, easy record retrievals, and increased intensity of established system. IoT-cloud-based healthcare is built on services about healthcare and advertises daily processes. In IoT-cloud-based healthcare, the users, services, and servers using health data use cloud to store data with the help of IoT networks. This preserves healthcare records with minimum cost, scalability, high efficiency, and less maintenance of the system. CC automatically increases the demand in various organizations, businesses, service providers of servers, and hosting applications mainly because the cost is based on organizational usage, 24/7, infinite usage, and scalability of CC services. Accordingly, representing healthcare record storage on cloud-added services reduces overhead by handling healthcare records efficiently and securely. Sharing medical resources by various cloud services requires privacy and security for healthcare records in the cloud. Multi-tenant is an additional service provided by cloud for sharing resources among customers in storing healthcare records. Customers cannot compromise on security and privacy issues on healthcare records especially. Related to healthcare records of patients, legal issues involve security in countries like the USA, the UK, and Canada like Health Insurance Portability and Accountability (HIPAA), Health Information Technology for Economic and Clinical Health (HITECH), Federal Trade Commission (FTC), Red Flag Rules, Data Protection Act, Freedom of Information (FOI) Act, and Data Privacy Directives in the European Union. These legal acts are concentrated on privacy and confidentiality of patient's healthcare records based on access controls.

Sect. 10.1 discusses healthcare records' introduction. Sect. 10.2 gives cloud storage introduction. Challenges of healthcare records on cloud are discussed in Sect. 10.3. Provision of security to healthcare records by access control models and CryptDB is discussed in Sect. 10.4. Integration with AI for identification of hidden patterns and its characteristics is discussed in Sect. 10.5. Finally, Sect. 10.6 ends with the conclusion of maintaining healthcare records using cloud storage.

10.2 Introduction to Cloud Storage

The most popular way is to store data or maintain data needed for emerging technologies like CC. To store healthcare records in the cloud involves security and privacy issue of patient personal records and healthcare records. Storing healthcare records in the cloud reduces the expenditure of the organization and provides security for the records. Based on the cost, security, and privacy of healthcare records, cloud storage has become a popular process. The development and storage of large data enlarged extremely with the last decades of CC, called a computing paradigm. The computing paradigm is a huge model connected with private, public, or hybrid systems and produces dynamically scalable infrastructure for resources. CC characteristics are on-demand, self-service, networking, resource pooling, scalability, and elasticity. On-demand computing is to organize, access, and administer all computing resources. Wide area networks grant major services like private or public networks in CC. Service models are Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). In the SaaS model, clients are required to use software and pay for use on CC. PaaS provides services of operating systems, networks, and hardware based on client requirements. IaaS provides the hardware and network services and applications [4]. Simple illustrations of SaaS, PaaS, and IaaS are shown in Table 10.1. Generally cloud services are provided by private, public, or hybrid clouds in CC [5]. Nowadays most of the organizations are migrating to cloud and storing data in cloud. Public cloud is provided by third-party cloud services over the Internet. A private cloud is maintained by an organization, single or a group. Hybrid cloud is a combination of private and public cloud as shown in Fig. 10.1. Infrastructure owner is a third-party service provider like cloud and is operated by the organizations. Another important service offered by cloud providers is storage of cloud data maintained and managed by cloud providers. Relationship between service models and delivery models is shown in Fig. 10.2. The storage cloud service is accessible to users by Internet and pay-as-you-use and users can access the data from any location remotely through the Internet. Purchasing the storage is not necessary physically. The payment is based on data stored, data access, software used, and infrastructure used [4]. This chapter discusses the cloud storage models, use of the cloud storage models, and

Table 10.1 Illustrations of SaaS, PaaS, and IaaS

Name	SaaS	PaaS	IaaS
Features	Email CRM Collaborative ERP	Application development Decision support Web Streaming	Caching Networking Security System management
Philosophy	CONSUME IT	BUILD ON IT	MIGRATE TO IT

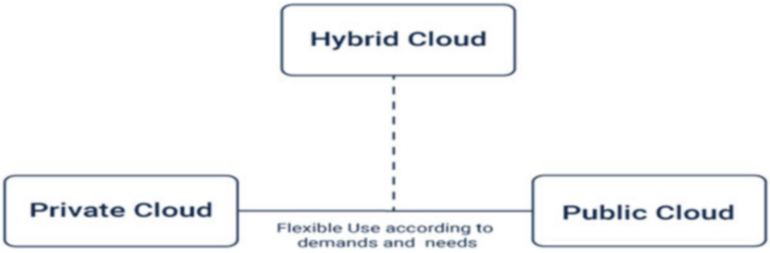

Fig. 10.1 Hybrid cloud architecture

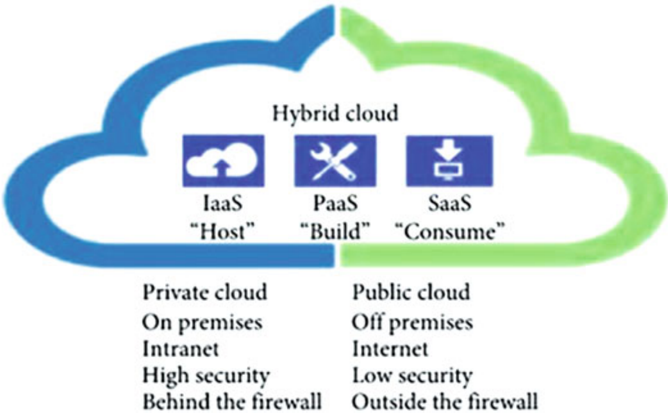

Fig. 10.2 Cloud service models and delivery models

their disadvantages. Managing data and data retrieval from cloud storage is another important service provided by the cloud provider and application for cloud storage.

Storage methods in CC are discussed one by one. The scheme of eliminating data redundancy in cloud storage upgrades efficiency of storage and reduces fault tolerance by eliminating data redundancy. This scheme is needed for minimizing the memory space and bandwidth in networks. This method identifies the data blocks to eliminate redundancy and store the duplicate data in storage and implements the new replicas without storing data redundancy. In the current model redundant parts of data are established, one duplicate data is saved in storage, and relevant pointers are created for many copies in place of data redundancy.

Models of duplicate storage avoid fault tolerances with various data and the same data parts that were missing when the system failed. Implementation of recent technologies in the medical organization is the critical approach required for various medical organizations to build up medical services and minimize costs [6–9]. Researchers, doctors, patients, nurses, pharmacy persons from the medical suppliers (Young 2003) required major improvement in medical services for improving many challenges. Along with this, illnesses are becoming highly difficult and new improvements in methodologies and research promote the growth of recent and highly effective examination and medications [10]. The strategies in the background to handle various methods are difficult and costly. Additionally, comparison between the medical organizations has improved [11]. Various medical organizations give various services to suit the requirement of diverse economic and disease levels. The forum is an appropriate rival to the weak efforts of regular authorities and medical organizations that left the business soon if they cannot perform well.

Based on previous experience the medical organizations surrounded by various solutions at the organization level by enhancing the methods to produce stable and bounded answers which provides huge and combined answers [12]. Generally the medical organizations involved in the last and present methods to make more active and proactive by taking high care in quality as discusses in [13, 14]. Medical organizations gained with the latest research technologies like databases and maximum redundancy for demanding systems, along with a new CC model to produce reliable and efficient solutions to suggest medical services. In [15], CC shows performance improvement like scalability, power storage, durability, dynamic, and visualization as well. Medical organizations provide huge connections to medical services. Owners of third-party providers like cloud provide facilities to compute storage space for data, hardware, and software. Further, it shows the operations on medical services in an elastic and expandable way through effective service-level agreements (SLAs), means pay for use. A few medical services identify connections to transfer the maintenance which is difficult for cloud providers. Normally, eliminating the operation costs from the medical organizations is important to minimize the operational and observation cost. CC provides another chance to medical organizations to handle the data with various organizations which are dependent on the medical organizations like government, pharmaceuticals, research industry, and medical insurance organizations. Sharing the patients' data by maintaining the privacy of their personal data is mandatory. To handle such data [16] with privacy and shared data involves threats by anonymous users, who easily and finally obtains the personal information of patients. Another hazard by Web analytics with third parties involves data on the Internet by composing and aiming advertisements. Few privacy problems rise like discovering entities and listing user's actions with Internet network traffics which violates privacy. By storing healthcare records in cloud, challenges are faced by regular CC along with special merits and basic medical services. Major challenges facing CC in the medical industry are privacy and security. Security techniques discussed in the model are still in high vision. Privacy is common and very sensitive in healthcare record data that highlights and analyzes the security and privacy solutions in healthcare records.

10.3 Challenges in Storing Healthcare Records on Cloud

Huge advantageous of medical services on cloud in medical industry which acquire maximum challenges from the medical industry and CC industry with additional advantage for these challenges to save and access personal data.

Summary of technical [17–19] and nontechnical [17, 20] challenges in dealing with healthcare records in cloud is given.

10.3.1 Technical Challenges

Particularly MSP needs huge opportunities for medical cloud services (MCS). Offering service and data is important for MSP who sometimes may not do this completely until the forms and data are in access. MCS must be available every time without any access problems or minimized performance. Cloud may fail with the hardware and software issues, network issues, malicious users, and disasters for many reasons. Instead of permanent infrastructure, using resources in the cloud is a better way to work in a distributed and open network. MCS provides fast and quick services continuously to handle medical services among various industries, along with hardware and software updates, new configurations, and installations for MSP. Usage of cloud for data reliability is an exceptional service of MSP to handle good reliability for MCP. Totally MSP and data must be error free. Crucial arrangements from one human or medical society related to data are featured by the medical cloud. Many features in cloud services to identify errors in data or redundant data or misplace data. The data in medical cloud should not change frequently and constantly in valid state for network, hardware, or software. Totally medical cloud produces services without errors for medical providers. Medical cloud stores high data records and images for millions of data from medical people. Data replications are used for correct access and reliability to various locations across a region. Various medical organizations need secure, scalable, efficient, and reliable access to data records. Services like fault tolerance, cloud storage, and queries produce efficiency and scalability approaches to the application data. Millions of healthcare records stored in the medical cloud provided by various medical services achieve scalable targets. The scalability capacity is the most required feature in MCS to enable the scalability feature in CC by improving the vertical to horizontal scaling of resources like instances, networks, regions, and volumes and producing relevant facilities in operations and management systems. Scalability means nothing but dynamic scaling or descaling in hardware or software resources [21]. MCS is accomplished by handling multiple services for various requirements like operations, clients, customers, auditing, and management quality of services. The medical cloud infrastructure and services are appropriately adjusted for various medical service requirements. MCP varies by counting up urgent services to carry out medical processes. MCS is flexible to reach various medical requirements, apparently constructed with different demands. The shape of CC services to reach various prerequisites is gained with less effort and cost. Interoperability can be achieved from various cloud service providers for MCS. The important task about interoperability is allowed on a framework with protocols to enable the servers and integrated data from various clouds [21]. Frequent schemes or protocols must involve techniques for protecting data exchanges and services. The interoperability task involved with MCS implements for local and external clouds. For example medical features progressed by integrating few services like local and outside services. Transferring data among old and local data for new medical clouds simplifies the provided protocols and APIs. Another reach is to exploit the model for service-oriented architecture (SOA) [22] for achieving medical cloud. To reach the services easily and reach out through basic schemes and protocols without reaching infrastructure, new models and implementations are the main aim of SOA. Interoperability is reached with loose connections with medical cloud factors from users of medical cloud. The MCS is contributed by various service providers of cloud used for medical services. The services offered by various cloud resources are gathered from the pool virtually to use medical services. Various services are commonly shared with different consumer services offered by open environments with high security. Identity and access controls managed by own infrastructure offered by medical organizations can secure data and monitor policies. From open circumstances, I need to offer suitable access controls and authentication techniques to add the data security from customers and service providers. It is mandatory to secure data in multi-tenant clouds when stored in other medical organizations. Service providers cannot access other healthcare records while using the service. For high security reasons, other ways to demand high estimation and transmission cost analysis are not efficient in assigned environments in the cloud. Alternatively huge security issues in medical organizations, where policies and requirements are not completely shown, impact cloud data services [23]. After security, privacy plays an important role in CC avoiding maximum usage of facilities with various organization types and applications [24, 25]. To secure patients' data from other customers or other medical organizations or other service providers is important. By protecting their own data records, organizations try for other healthcare records from other medical organizations. Reducing concerns in interconnected data and items is another big issue. Without having a medical organization for every independent MSP, a medical cloud is used for various medical services. Difficulty increases when maintaining a system of cloud medicine correlated to a separate medical system. Improvement reasons for various medical services and customers need to consider requirements and features. These features may vary in infrastructure, hardware, and software maintenance without influence on services for customers. Various features of different services in the cloud do not have a negative impact on suggestions for customers. Observing simple procedures, various cloud services are easy and reliable. It includes developed models for simplification of process to minimize the time for maintenance.

10.3.2 Nontechnical Challenges

Migrating to the medical cloud requires few necessary alterations to the clinical and system process by organizing certain boundaries in medical organizations. Creating new policies and procedures in service requires changes in clinical process and data. There is no clear legislation and rules for medical organizations in this industry are not consistent. This is another disadvantage for policies, interoperability, and medical organizations in medical cloud. More problems are identified due to change in technical and ethical interest. As discussed in the International Classification of Diseases, tech revision by Goldman and Hudson [26] shows about medical features of abnormal complaints, identifying diseases, social conditions, and complaints. The Systematized Nomenclature of Medicine is to store or access the data of healthcare records as shown in ref. [27]. Medical organization is normal with data owners with authorized policies and guidelines. Healthcare records for data owners of patients are an important challenge and create boundaries. Personal data involved in risk due to attacks or losing control on data or data causes reputation loss and patients may not trust the organization some times. The view of MSP shows maximum risk of accountability when losing data or leakage in data causes reputation loss and patients may not trust the organization. It is mandatory for medical organizations to adopt the technology and services of CC based on usability of customers, patients, doctors, and researchers. Requirement of relevant training sessions and advertisement to migrate the data to cloud is another important challenge in addition to the problems listed above like privacy, security, and trust. However, hard achievements in medical cloud are to handle these issues and improve privacy and security in medical cloud.

10.4 Challenges in IoT-Cloud-Based Healthcare Innovations

IoT systems ease the association of two small and wide spread systems. Clients are assured in safety for IoT devices. structures to identify firms for privacy in records. IoT structures are liable to outdoor assault or manipulation because IoT gadgets apply networks to connect definitely everything wireless. Publishers attempt to seek out for possible answers to safety and secrecy problems; these two components are generally researched in isolation, as discrete variables. Trust, security, and privacy may break the point when compromised on confidentiality, integrity, and availability (CIA). IoT based problems are spoofing, eavesdropping, crypto-analysis, middle attacks from various systems. The protection necessities of IoT-based structures are captivated with the traits of the surroundings at some point of which the gadget is carried out, and therefore the devices required for users' unique packages. Researchers like [2, 7, 10, 11, 16, 17, 24, 26, 28] created the traditional security and privacy related to IoT applications and provided safety necessities for IoT-based structures making use of widespread CIA with additional custom protection variables, like authentications which can be tested by using traditional safety risk evaluation. Such a gadget must contain robust protection to avoid assaults, especially on wireless communications between the IoT-based totally home equipment. The structure of IoT-based totally domestic automation is proposed to defend and prevent any assaults on Wi-Fi conversation, which include guy inside the center attack (MITM). Recently, an algorithm for IoT-based structures was established with a purpose to cozy all transmissions and manipulate assets within a heterogeneous community. The algorithm makes use of lightweight encryption and useful resource control structure to extend device overall performance, efficiency, and accuracy. By observing the evaluation and comparison of new protocols which are intended to exchange. A protocol evaluation device can measure and compare parameters like overall performance, aid usage, and deal with security with robustness, as utilized in references. Fan implemented an RFID system to a scientific machine to unravel the matter of privacy. They additionally offered a mild-weight mutual authentication scheme for use at some point of a scientific context supported by a completely specific protocol. The method shows fewer computing assets to meet the protection requirements like anonymity, assault resistance, and synchronization. This method supports the performance of the clinical device and can protect private affected person statistics securely. They supplied an analysis of varied security in opportunistic routing. The standards are often defined with the protocol and capabilities hired by means of sensor nodes to interface distinctive pretty networks. Moreover, Garcia incorporated IoT and WSN technology as a good way to be carried out inside the improvement of those structures. They presented a survey to summarize the existing smart irrigation machine by way of the usage of IoT-based irrigation gadget concerning water quantity and first rate, soil, and climate. They indicated that the use nodes and wireless technologies are practices for the implementation of sensor-based total irrigation system. Therefore, IoT-based total and cloud computing is that the pleasant implementation broadly changes in different areas.

10.4.1 Smart Cities' Healthcare Using IoT

Instead of patient care, IoT devices improve the healthcare data operations. Smart city environment provides smart buildings, smart metros, and many more to operate IoT devices for healthcare data. IoT eliminates the administrative dependency on medical staff. Using the data that these connected devices generate, staff can get real-time insights to feed into future business decisions and maintenance plans. Huge population in cities stresses the medical organizations in providing instant services. IoT provides new changes in the health monitoring system for the city's population while giving alert to emergency services with the help of smart cities and giving healthcare instructions to act immediately. Recently, medical providers have adopted various approaches to reduce the cost and improve efficiency using smart city healthcare using IoT.

10.5 Providing Security to Cloud-Stored Healthcare Records

The essential and basic requirement is authentication for required attributes. This creates or requests the basic fact of authentication. In view of man-in-the-middle attacks authentication is one of the important identities. The protocols are used for digital signatures, data encryption, authentication and approvals in different transactions. Figure 10.3 describes various data models in healthcare like lab data, survey data, pharmacy data, hospital data, disease data, wearable, electronic data or digital data, and claims data.

Patients accept or reject the common data with other medical people by changing the medical authorizations with the medical system. A patient may accept the rights to users depending on the attributes with the respective customers. Integrity is protecting the efficiency and stability of data. It is important that medical organization assigns the data without any leakage to others. The International Organization for Standardization (ISO) established that the data can be accessed only by authorized users. Access control and encrypting data in medical organizations reached confidentiality. Medical organizations have to serve the purpose that the data is in accessibility when it is required. The medical system needs to store and process the data and protect the controls and networks required to access it properly. The importance of systems is due to the avoiding of errors in services because of power problems, failures in hardware or software, or unavailability of upgrades in software. Even though the data is available, it is important to avoid attacks like denial service attacks and failure in healthcare record preservation.

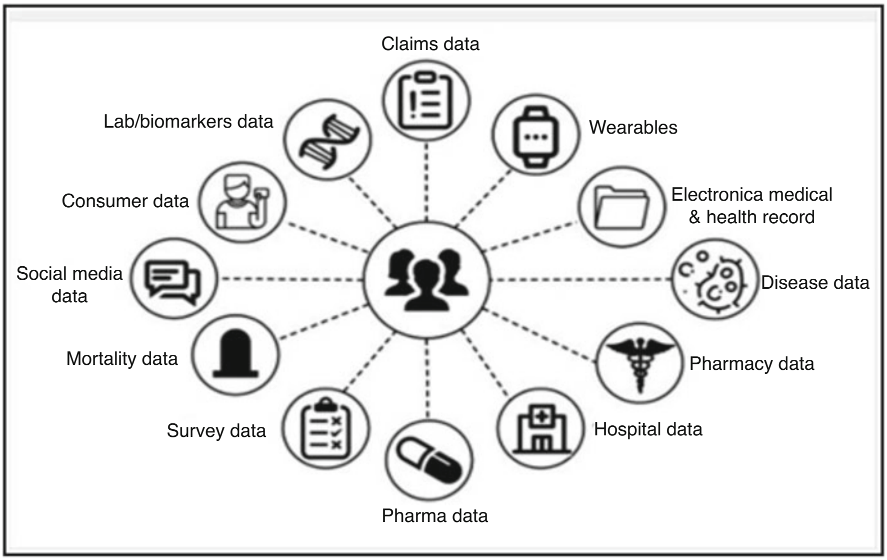

Fig. 10.3 Healthcare data model

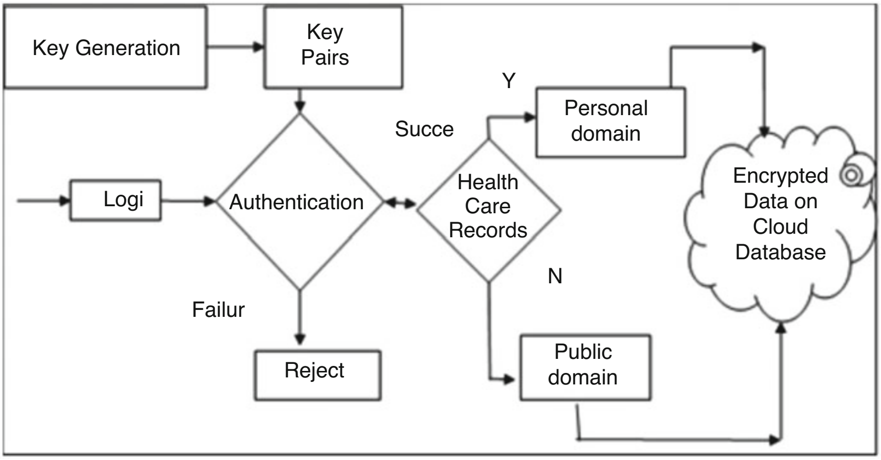

Fig. 10.4 Healthcare records on cloud database

Data records are stored with high security and privacy protection with HIPAA alliance. Retrieving and auditing are not mandatory services to establish security in the medical system. Auditing is nothing but maintaining a record for customer and user movements in the medical system in a sequential order like every access and changes or update in data. Auditing implements the previous data stages and is organized accordingly. Figure 10.4 shows the overview structure of storing healthcare records on a cloud database. Authentic user logs in and generates key pairs by key generation techniques. Users store the healthcare records in a cloud database after encrypting the records using two different domains like personal and public domains.

The patient data and medical organization are not connected and the doctors are unaware of the medical history of patients, leading to allegations. Allegations may be raised by family members also when the patient is not in a position to defend. Generally, government surveys regarding the health of people scrutinize the data. Authorized people from the government may have high levels of queries and may be transferred at the server. Alternatively the government can access the authorized data and analyze the statistics of the medical system by maintaining the privacy and security of customers with their personal data. The queries within a range can be easy for data processing and persevering in encryption algorithms.

10.5.1 Access Control Model

Access control can be defined as “The prevention of unauthorized use of a resource, including the prevention of use of a resource in an unauthorized manner.” The main base for any access control model is a matrix. An access control matrix

Table 10.2 Sample health records for a medical organization

	Medical record	Admin record	Prescription
Alice	W, R	R	R
Bob	–	R	–
Charly	W, R	W, R	R
David	R	R	–

is a straightforward representation of passage [*i*, *j*] of the matrix that determines the operations acknowledged to subject *i* on resource *j*. An example from the medical field is shown in Table 10.2. Representing client (more decisively forms summoned by client Charly) is agreed compose, read/access to both administrative and medical record questions, and read/access to medicines. Rows: In this manner it is deciphered as capabilities list, characterizing what is acceptable for the user; for example, “Bob: read access on medical and administrative records.” Columns: In this way it is translated as access control list (ACL), characterizing the authorizations acceptable for every query; for example, “remedies: read and write access is given by Alice and Charly.” An access control display characterizes relationships among authorizations, operations, protests, and subjects. We recognize here the contrast between clients, the general population who utilize the PC framework, and subjects, with PC forms acting on behalf of clients. Basically there are two widespread access control models: W: write and R: read.

Access control restricts the entry of use for data security and grants permissions depending on the type of access. The main three controls are administration, logical, and physical. Administrator creates the security policies for administration, monitoring audits with the limits and policies according to organization rules. The access is blocked to use software or hardware in logical control. Physical control is minimizing the hardware access with the objects, codes, and combination locks. The users are authorized to access the computational system from access control models. Initially access control starts with authentication to give user identification. Next the user grants the permission to access data according to user policies or group policies created by the data owner from healthcare records. Three areas majorly subjected in access control are permission for data, access objects, and finally access rights who can access read, write, delete, and update access control. These three play important roles in access control security. This can be considered as a basic or granule concept while developing a medical organization. According to researchers many models in access control satisfy healthcare record security in a controlled environment like electronic records and digital records in healthcare. Many various types of access control are discussed in the next section.

Discretionary access control (DAC) model: This is similar to other models which relates in matrix form and receives items. Rule is actualized in the different operating frameworks to regulate access to documents. This mechanism licenses granting and revocations for consents to the watchfulness of clients, deviating framework administrator control. A simple DAC model is shown in Fig. 10.5.

Mandatory access control (MAC) model: This model helps to reduce the disadvantages in DAC model and helps to produce confidentiality in difficult situations.

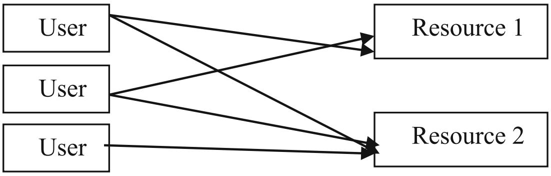

Fig. 10.5 DAC model

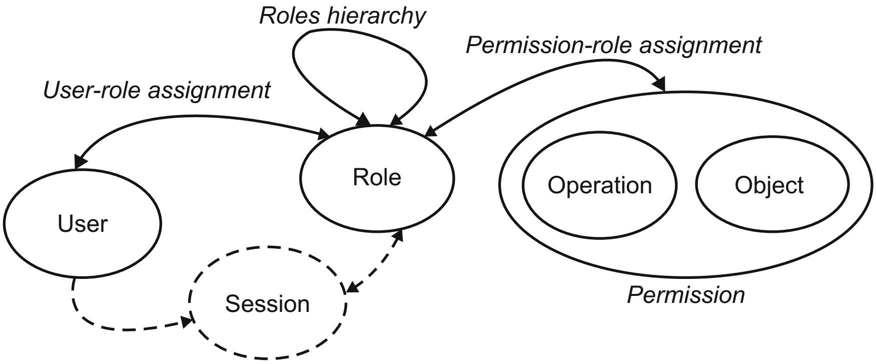

Fig. 10.6 RBAC access control model

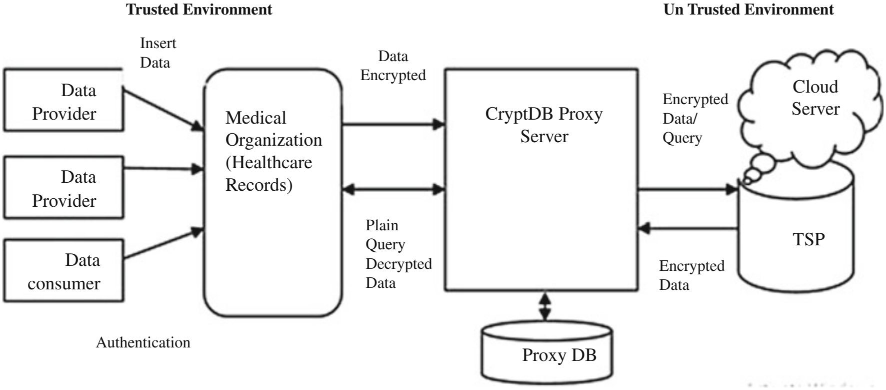

Fig. 10.7 CryptDB architecture

The primary rule of MAC is to reduce contact allowing client's approval and classify questions like security level, higher level, and major private-level data.

Role-based access control (RBAC): Permissions are provided based on the role of the user. A group of users are assigned roles and responsibilities and users are assigned to groups. Users must be in only one group. Users cannot be added to multiple groups as shown in Figs. 10.6 and 10.7. Based on the roles and access, privileges are allowed to read data as discussed in [29].

Attribute-based access control (ABAC): This model is an access control with the user policies and admitted to the user rights based on the policies created by users [29]. The properties are related to attributes with various descriptions like surroundings, constraints, objects, subjects, and requested actions that are described before an owner assigns the authorities or administrations.

Key policy attribute-based encryption (KP-ABE): Attribute-based encryption (ABE) is the classical method for encryption related to attributes. KP-ABE is the modified version of ABE. Customers create access structures based on attributes. Users' secret key is related to access structures. Encrypted data is created with the combinations of secret keys and attributes related to monotonic access structure can check the users who are decrypting the data [30].

Ciphertext policy attribute-based encryption (CP-ABE): This ABE is exactly the reverse of KP-ABE, data encrypted based on access policy by access structures. Secret keys are produced based on attribute set. The related key with attributes must match with the policy created and then the data can be decrypted [31].

Multi-authority attribute-based encryption (MA-ABE): This ABE method adopts various methods to assign attributes for customers. This method creates K authorities and one chief authority. Every attribute is assigned a value. To assure the delicate data security, access control scheme plays an important role in avoiding unauthorized users to enter into organization data.

Identity-based access control (IBAC): This method is not quick in CC where cloud users are high in number. ABE is a suggestible technique for scalability, flexibility, and accessibility [32].

10.5.2 Crypt Databases

Introducing healthcare records to cloud extends patients' worry about their healthcare records' security. The majority of researchers are confirming the privacy of healthcare records in the cloud by storing them in a digital way. Fully homomorphic encryption (FHE) is one way to store healthcare records with high security; the data is encrypted before storing in the cloud. The efficiency of FHE is better when compared with partial homomorphic encryption in providing security to healthcare records in the cloud. Alternative approach of data confidentiality is de-identification; this method eliminates the identity of individuals to relate the data with them for providing security for every individual. This method stores data for analytic reasons and may not be useful in operations. Additionally, these methods reduce the efficiency of applications implemented in CC. To store healthcare records in the cloud these applications required the relational databases for supporting Web applications. Storing and retrieving highly affect the efficiency of databases from the cloud. To reduce these disadvantages, CryptDB is the popular approach introduced by MIT [33]. CryptDB assures data confidentiality and security by using relational databases without decreasing the efficiency of retrieval and storing of healthcare records from the cloud. CryptDB provides security for the customer queries by encrypting the queries and applying the encrypted queries on encrypted data. CryptDB is the multi-tire application supported for Web applications to produce dynamic content in the back end. The data is encrypted before storing in the cloud, and the administrator cannot access original data or queries. The users can be data providers or data consumers who want to insert or retrieve data from the medical organization. Healthcare records are in medical organizations. The CryptDB proxy server stores the encrypted data in cloud and accesses the encrypted queries on encrypted data in cloud. The results retrieved from cloud data base is in encrypted form. The encrypted results are transferred to client then client decrypts the data.

Executing implementing queries and encrypting queries on encrypted data, decrypting data, and sending to the Web server are the important features in CryptDB. CryptDB is majorly powerful in executing queries on encrypted databases with high security and maximum speed. CryptDB reduces the maximum overhead of encryption by providing layers of security. CryptDB ensures high security for patients' healthcare records stored in the cloud.

10.6 IoT and Cloud Integration in Medical Healthcare

The IoT and CC have emerged as revolutionary technologies complementing each other's competencies and capabilities. The convergence of IoT and cloud computing has emerged as Cloud of Things (CoT). CoT easily builds the relation with people, systems, or devices interacting with one another through the Web. The executions of CC and IoT generations in healthcare systems result in improved results of the affected person because of elegant health diagnostics and coverings, offer satisfaction, and minimize fees by not losing the redundancy. The mixing and usage of IoT with CC technology for healthcare systems are handy due to the truth that customers can get entry to contribution via cloud servers anytime, everywhere, and in any circumstances. These various blessings imply that security and privacy issues are frequently not noted at some point of a change off for comfort and proficiency. CC technology integrates IoT devices and stores and strategizes the acts for the duration of an allotted nonpublic community of cloud servers in healthcare structures. CC permits legal clients to authenticate themselves and securely get admission to records from anywhere thru strong authentication. Niraja et al. [34] supplied a completely unique IoT-based method which may also additionally have interaction with technologies like cell health, CC, massive statistics, and smart environments. Chow et al. [35] and Zhang and Liu [36] provided the significance of IoT and benefits of IT and the way management is frequently contributing to the lifestyle technological expertise. The clinical data accrued from one-of-a-kind establishments are frequently mined and analyzed by means of the usage of large facts via net. This gives the improvement of IoT technology in medical healthcare which is fast growing to maintain relationships by connecting via clever devices or items with competencies of amassing and sharing in diverse sorts like human to machine, human being to human, or device to device.

10.7 Integration with AI for Identification of Hidden Patterns

Pattern recognition is one of the most popular applications of artificial intelligence in maintaining healthcare records using the cloud. AI helps us in designing the computer applications that will learn and relearn from data and support/take decisions. AI applications are capable of finding similarities in data as they are capable of learning from existing data in healthcare records. To get more appropriate results, AI engines become efficient with learning from more and more healthcare data. Huge storage space is required to store the huge amount of healthcare data used by AI engines for making decisions. AI engines also require fast I/O and processing power for learning from the healthcare data. This pushes the need of integrating AI with cloud technology. AI engines will get the leverage of infrastructural support from cloud technology's fast and efficient processing. Various cloud service providers have come up with services to support AI applications in storing healthcare records in the cloud. Integration of AI with cloud will convert the cloud into intelligent cloud. CC and AI together will provide optimized solutions to various industrial applications. Learning capability of AI and cloud resources together will make this happen. AI tools are effective in data management and identifying hidden patterns from the healthcare data. Use of cloud technology for storage and processing of this healthcare data will further strengthen the power of AI. AI applications are capable of finding similarities in healthcare data as they are capable of learning from existing data with machine learning algorithms. Pattern recognition is applied for text recognition and computer vision. Convolution neural network algorithms in machine learning are used to classify images. To get more appropriate results, AI engines become efficient with learning from more and more healthcare data. CC supports in overcoming the above issues like processing power and storage constraints. This pushes the need of integrating AI with cloud technology to support computations on large amounts of healthcare data. Various cloud service providers have come up with services to support AI applications. Cloud service providers like Amazon web services, Microsoft Azure, and Google cloud are providing various services to support storage, processing, and analytics on cloud. These cloud service providers integrated with AI techniques and applications support various medical healthcare organizations to store patients' healthcare records in cloud database.

10.8 Conclusion

Cloud computing is adopting and inheriting new technologies like medical organizations, banking, and telecommunications sectors. All these sectors' important aspect is providing security for personal information. Storing data in the cloud minimizes the dangerous threats from outsiders, attacks from networks, etc. By maintain healthcare records, security features and efficiency will be increased, and this reduces overhead in CC. Manpower, maintenance, and cost everything can be reduced by migrating healthcare records to the cloud and it will be easy for medical practitioners and doctors to provide diagnosis. In this chapter solutions are not holistic in nature and it provides solutions in security and confidentiality. Majority of solutions address these problems and balance the security analysis. In the future, we propose holistic solutions to solve all contradiction features. Migrating of healthcare data to the cloud by a medical organization is a critical and compounded opinion. IoT healthcare data storing in cloud provides security and reduces security challenges before migrating medical organization data and IoT devices data to cloud. Medical cloud service providers frequently check the healthcare records' life cycle. According to HIPAA and other policies, security measures are considered before migrating the healthcare records to cloud, like by considering firewalls, detection of intrusions, encryption types, CryptDB, authentication, and authorization checking. Because of minimum cost cloud is scalable rather than infrastructure for medical organizations. This counts the huge security for patients' healthcare records stored in the cloud. The chapter is concluded by discussing healthcare records, cloud technologies, healthcare records in cloud, and challenges and solutions in maintaining healthcare records using cloud storage.

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Chapter 11
Use of IoT in Net-Zero Smart City Concept in the Indian Context: A Bibliographic Analysis of Literature

Mahfuzuar Rahman Barbhuiya and Ketki Kulkarni

11.1 Introduction

India has a GDP of US$ 2.87 trillion and is home to 1.4 billion people [1]. Census data as available in 2015 displayed a total of 475 cities/urban agglomerations that housed 70% of India"s population [2]. The country has also been involved in global climate agreements since the Rio Earth Summit in 1992—moving from the fringes to playing an active part in combating climate change [3]. Given the rapid rate of urbanization, India"s emissions and energy usage proportionate to its population, and its active involvement in global climate politics [4], it is only prudent for India to have established an advanced body of literature in the fields of net-zero smart cities. The Government of India announced the Smart Cities Mission in 2015, intending to achieve better living condition and economic growth across 100 cities allotting US$ 1 billion for the purpose [2]. The Smart Cities Mission understood the lack of a universal definition for smart cities and defined two components of Indian smart cities, namely area-based development and pan-city development. It emphasized its projects based on the themes of smart environment, infrastructure, citizenship, governance, and economy [5]. The undertaking of such a massive mission demands an equally massive research body relevant to smart cities that is specific to the Indian context as well as updated with the latest technologies.

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This study will analyze the current status of and the existing gaps in Indian research relevant to net-zero smart cities involving IoT technologies. The main research questions can be stated as follows:

RQ1: What factors are considered most important in making a city net zero?
RQ2: How does the Indian research pertaining to "the use of IoT in making a city net zero using urban planning methods" compare with the status of research in the rest of the world?

The study focuses on literature available with the Scopus database and, among them, on those that match the criteria set by a subset of smart city-related keywords. Keywords vary across themes of net-zero concept, IoT, big data, urban planning, energy, transportation, citizen engagement, and community participation.

The answers to these questions have been attempted through a literature review constrained by keywords and a bibliographic study that analyzes themes, keywords, word frequency, authorship, and collaboration of authors between countries. Bibliographic analyses provide an understanding regarding the growth trajectory of research literature and knowledge within a particular field of research [6]. These analyses often use quantifiable data and are therefore considered useful for researchers to study the trends and synergies of literature in their respective fields. This study has used publication counts, use of keywords over time, articles per author, frequency of keywords, frequency of keywords over time, and collaboration between countries as metrics to analyze the body of literature for this study.

The main contribution of this study is the keyword-specific bibliographic literature study performed using the bibliometrix software package in RStudio. This study points out the three primary factors required to make a city net zero: (i) planning factors and use of IoT; (ii) role of citizen engagement and community participation; and (iii) use of IoT in energy and transportation. Additionally, it also sheds light on the evident gaps in research using factorial and thematic analysis (Figs. 11.2, 11.3, 11.4, 11.5, 11.6, and 11.7). Figure 11.8 shows the collaboration of researchers between various countries in the world while suggesting that in order to achieve the level required in Indian research for attaining a stronghold in net-zero smart cities, higher international collaboration is needed.

The structure for the chapter is as follows. Section 11.2 elaborates on the methodology used for the bibliographic analysis. It lists out the nine steps used to shortlist literature for the study and specifies the keywords and combinations used to search articles on the Scopus database. Section 11.3 is the literature review and reads about the three primary factors required to make a city net zero. Section 11.4 discusses the findings of the analysis using the following tests: (i) factorial analysis, (ii) thematic evolution, (iii) three-field plot, (iv) tree mapping analysis, (v) word growth analysis, and (vi) country collaboration statistics. Finally, Sect. 11.5 provides the conclusion.

11.2 Methodology: Bibliographic Analysis of Literature

A bibliographic analysis of relevant literature available under the broad thematic umbrella of “use of IoT in net-zero cities using urban planning approaches” was performed to understand the state of current research being carried out in the field of the net-zero city concerning the use of the Internet of Things in making a city smart using urban planning approaches. The Scopus database was used for the bibliographic analysis, and the keyword-specific article search was carried out in September and October 2020. The same search command was rerun on January 27th, 2021, to add recently published articles. Articles were only considered if they included a particular keyword(s) or combination of keywords in the title, abstract, or keyword section of the articles. The literature search followed ten crucial steps (Fig. 11.1) listed below:

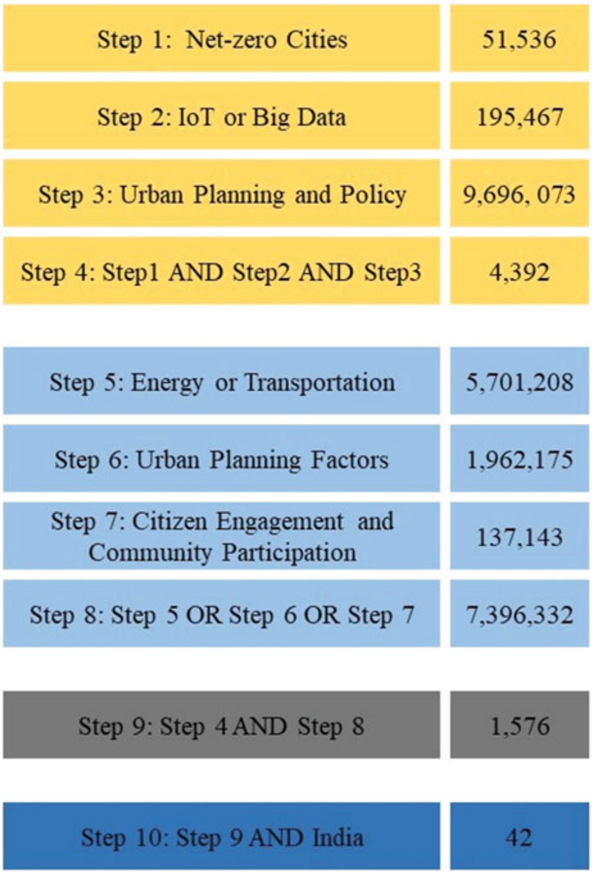

Fig. 11.1 The ten steps followed in the methodology

1. Literature published with the net-zero concept was searched in this step. Articles that had any of the following keywords in their title, abstract, or keyword section were considered: “net-zero city” OR “net-zero city” OR “net-zero energy” OR “zero-energy city” OR “smart city” OR “carbon footprint” OR “zero-carbon city” OR “net zero.” The search produced 51,536 articles.
2. The second step in the bibliographic analysis used the second theme of this chapter: IoT or big data. For this purpose, “big data” OR “bigdata” OR “IoT” OR “Internet of Things” were used as keywords and 195,467 articles came forth.
3. “Urban planning” OR “framework” OR “strategy” OR “solution” OR “policy” were the keywords used to identify the research articles published in the urban planning and policy area. 9,696,073 research articles were found in this area.
4. In the fourth step, only articles that discussed net-zero cities, the Internet of Things or big data, and urban planning and policy were sorted, while the rest of the articles were discarded. In short, the fourth step was the intersection of the results in steps one, two, and three, and 4392 relevant articles were found.
5. Articles that were published with keyword combinations of “energy” OR “urban energy” OR “energy management” OR “sustainable energy” OR “energy consumption” OR “renewable energy” OR “exergy” OR “smart grid” OR “transportation” OR “smart transportation” OR “recycling” OR “resource conservation” OR “sustainable transportation” OR “walk” OR “cycling” OR “public transportation” OR “electric vehicles” were considered for this step and a total of 5,701,208 articles were found to have been available in the Scopus database.
6. “Land use” OR “bye laws” OR “property tax” OR “housing” OR “green” OR “open space” OR “mixed use” OR “recreation” OR “restoration” OR “retrofitting” OR “better housing” OR “conservation” were used to identify the research articles that were published with urban planning factors. 1,962,175 relevant research articles were found in this step.
7. Citizen engagement and community participation factors, namely “local agricultural” OR “agricultural produce” OR “community gardens” OR “deforestation” OR “less meat” OR “open space” OR “food waste” OR “green approaches” OR “green approach” OR “sustainable business” OR “increase awareness” OR “local environment” OR “community engagements” OR “better society” OR “social justice” OR “equal opportunities” OR “equal opportunity” were used to identify 137,143 articles.
8. In this step, any articles that mentioned energy or transportation, urban planning factors, citizen engagement, or community participation were considered. In short, this step was the union of the results identified in steps five, six, and seven. This union of all the articles gave 7,396,332 results.
9. This step is the intersection of the results in steps four and eight. “AND” command was used to identify the articles that talked about net-zero cities, the Internet of Things or big data, and urban planning and policy as well as energy or transportation, urban planning, or citizen engagement or community

participation. 1567 articles were shortlisted for analysis based on keyword-specific criteria.

10. In this final step, among the 1576 articles, only those articles that had “India” in the keyword section, title, or abstract were selected. This step gave 42 articles. This step is essential to understand the level of progress made by Indian researchers in the field of using IoT using urban planning practices to achieve net-zero city in India. This step is essential in developing an understanding of research available in the aforementioned fields established within the contextual constraints of India.

The articles selected in this step were then analyzed in the RStudio software. “Bibliometrix” package in R was used for the bibliometric analysis. The command “biblioshiny()” was used, and then the raw BibTeX data was used for further research. The results of this bibliometric analysis are further discussed in detail in the Sect. 11.4 of this chapter.

11.3 Literature Review

A review of the literature was carried out to identify the main factors that can help a city to achieve net-zero goals. The three broad categories identified under which the factors can be divided are urban planning factors, citizen engagement and community participation, and energy and transportation.

11.3.1 Planning Factors and Use of IoT

Studies have shown that many factors that govern the shape and future of a city such as property tax, land use of a locality in a city, disaster management, solving housing-related issues, and retrofitting and restoration of existing structures can be used efficiently and in a planned manner with the help of IoT-based technology [7, 8]. IoT-based technology in urban planning factors makes the cities across the globe net zero, sustainable, and resilient [7, 9, 10]. Boeing et al. [11] identified that the proper use of technology could help find affordable and livable housing facilities in a town and investment support in real estate, and capture the behavior of landlords or rules imposed on tenants by a particular housing society. IoT technology and the big data generated can help solve housing issues and remove probable human biases by suggesting minimal changes or modifications in the policies rather than significant changes or introducing a completely new policy [11, 12]. Further, IoT sensors and proper planning strategies can help avoid disasters related to city planning by monitoring and surveying the old infrastructure and suggesting renovation and retrofitting works [7, 12–14].

Every element in a city, such as the housing options, rents, commercial values, vehicles, new registrations, educational institutes, religious institutes, and number and type of tourists the city attracts, generates a considerable amount of data; most of the data is unused but using advanced technology will not only help in using the data, but the city administrators can use the data in making a particular city net-zero smart city [14–17]. Thus, the literature review gives three important urban planning-related areas where IoT can help in making a city net zero:

1. Land-use planning and taxes.
2. Affordable and livable housing.
3. Restoration and retrofitting of existing infrastructure.

11.3.2 Role of Citizen Engagement and Community Participation in Net-Zero City

It is imperative to engage citizens in the net-zero city goal and seek their active participation. Staletić et al. [8] observed Serbian citizens' willingness to crowdfunding for incorporating new technology for making their city smart. The study highlights that a project can be successful if it has positive responses from citizens. Moreover, it becomes quite likely that the citizens will accept the new rules and regulations that may be imposed on them, along with the proposed changes [8]. Building information systems widely and popularly used by architects, building system engineers, and urban planners are based on IoT technology and need citizens' support for its successful operation [18–20].

Kristjansdottir et al. [21] observed that the buildings or housing societies with greater community participation had lower net carbon emissions. Encouraging food from local farms, encouraging responsible meat consumption, reducing food wastages, and deforestation can reduce carbon emissions to a great extent [22, 23]. A vital area that is mostly neglected by city authorities and the public is the need to set up local businesses and encourage their consistent survival. These businesses can reduce emissions by reducing the fuel consumption of transporting employees and materials [24, 25]. A city with awareness programs can help make the citizen aware of the benefits of generating less waste, reducing emissions [21, 26]. Based on the above review of literature, the following areas need to be given special care to generate greater citizen engagement and community participation and better use of data:

1. Encourage local agricultural activities, reduce wastage of food, and discourage deforestation.
2. Promote local businesses.
3. Awareness and community engagement and participation programs.
4. Societies with equity, justice, and sufficient growth opportunities.

11.3.3 Energy and Transportation and Use of IoT

Using IoT-based sensors can help design better transportation network and infrastructure in a city, as identified by Barbhuiya et al. [27], and help reduce net carbon emissions as observed by Chuai and Feng [17]. Many cities and transportation departments also use IoT sensors worldwide to check emission levels and propose policy recommendations based on the findings [28]. Vehicular emissions are significant sources of carbon pollution, and to achieve net-zero cities electric vehicles need to be introduced along with stricter emission laws [29]. Bouman et al. [30] demonstrated the need to have modern technologies and regulatory measures to reduce greenhouse gas emissions towards sustainability.

Regular performance analysis of the energy and related systems needs to be carried out to optimize and look for ways to improve performance as carried out by Ascione et al. [28] in Greece. With the world moving towards zero emissions during electricity productions, the city administrators need to find suitable ways to shift to green methods of energy production and carbon emissions [10, 22, 31, 32]. The IoT technology can help save energy from loss during transmission and predict the perfect tilt angles for solar and wind energy production systems during a particular season or point of time in a day [33, 34]. Thus, the areas under energy and transportation, specific to the use of IoT, which can help in reducing the emissions and can be a more significant influence in shaping a city towards a net-zero city are:

1. Use of renewable sources of energy, recycling, and resource conservation.
2. Better transportation facilities like walkability, cycling public transportation, and electric vehicles.

11.4 Findings and Discussions

The bibliometric analysis was carried out to observe the emerging areas in "use of IoT in net-zero smart city concept" and understand the recent trends and gaps in research. Seven necessary checks carried out in RStudio software are the factorial analysis, thematic evolution, thematic map, three-field plot, tree map, word growth, and country collaboration map of the 1576 research articles and 42 Indian specific research articles. Finally, a word cloud was generated to check the most used keywords in this particular field of research.

11.4.1 Factorial Analysis

The multiple correspondence analysis (MCA) was carried out to understand the underlying data set and the significant factors involved in this field of research

[35]. The MCA is represented in two-dimensional Euclidian planes and helps in understanding the present trends in a particular research field [36]. From the top graph of Fig. 11.2, it can be observed that four factors are evident, namely, energy, transportation, automation, and a red cluster covering almost all the elements of a smart city. It can be noted that while three clusters are covering multiple aspects of a technologically smart city, factors like governance, planning, strategy, and policy are still entirely missing. This can be thought of as a massive gap in the research area and needs to be given more attention so that cities with technology are planned and governed in an elegant manner. The bottom graph of Fig. 11.2 also has four factors and accommodates the missing items discussed above. The items are placed in one factor, and it can be mind-boggling for researchers to find specialization-specific research gaps. This could be a reason for having only 42 India-specific articles out of 1576 articles focusing on the use of IoT in a net-zero smart city, even though the Government of India had planned to develop hundreds of smart cities in India [37].

11.4.2 Three-Field Plot

The three-field plot of the "biblioshiny()" command of RStudio software using bibliotex library shows linkages between the important matrix used in a research article such as authors, keywords, sources, country, affiliations, funding and number of authors [38]. Since the objective of this study is to understand the critical study areas in the field of "use of IoT in net-zero smart city concept," the three-field plot of authors, keywords used, and sources for all the articles published were carried out (Fig. 11.3). The main keywords used are smart city or smart cities, IoT or Internet of Things, big data, security, and cloud computing. The three-field plot shows that though the keywords used are very relevant, researchers have not yet wholly directed their focus towards urban planning solutions for achieving net-zero smart cities.

11.4.3 Thematic Evolution and Thematic Map

A thematic evolution helps understand the factors used at the start of the research in a particular research field and the emerging factors that are used recently [39]. The top graph of Fig. 11.4 shows that the factors that were used in early research between 2012 and 2019 are energy efficiency, smart city, intelligent systems, and the Internet of Things, whereas the India-specific articles (bottom graph of Fig. 11.4) that were published between 2015 and 2019 used only two main factors, namely, energy efficiency and Internet of Things. Since January 2020, while India-specific research has been using the Internet of Things and smart city as the two main factors, global articles have started using deep learning, energy utilization, and intelligent systems, and the Internet of Things and smart city. It is worth noting that the research in areas of smart city and Internet of Things has merged into the other fields, thus

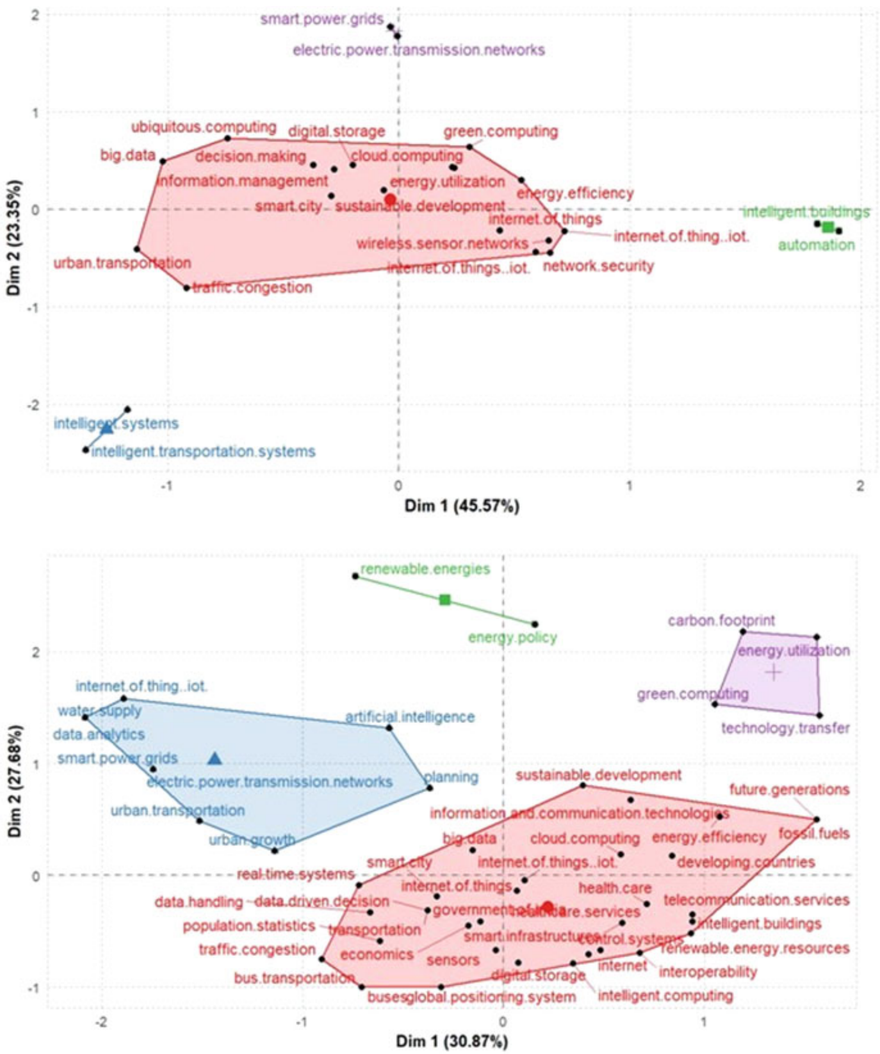

Fig. 11.2 Factor analysis using multiple correspondence analysis. Top: Analysis of all articles. Bottom: India specific

giving a direction for Indian researchers to upgrade and follow the lead. This could greatly help in moving forward in this new and much-needed field of research.

The thematic mapping of factors helps understand the niche along with basic, emerging, and major themes in a research area [40]. Research specific to India uses factors like urban transportation planning and healthcare, which, although relevant in the Indian context, needs to be supplemented with a focus on intelligent systems and automation. Researchers should work with problems specific to

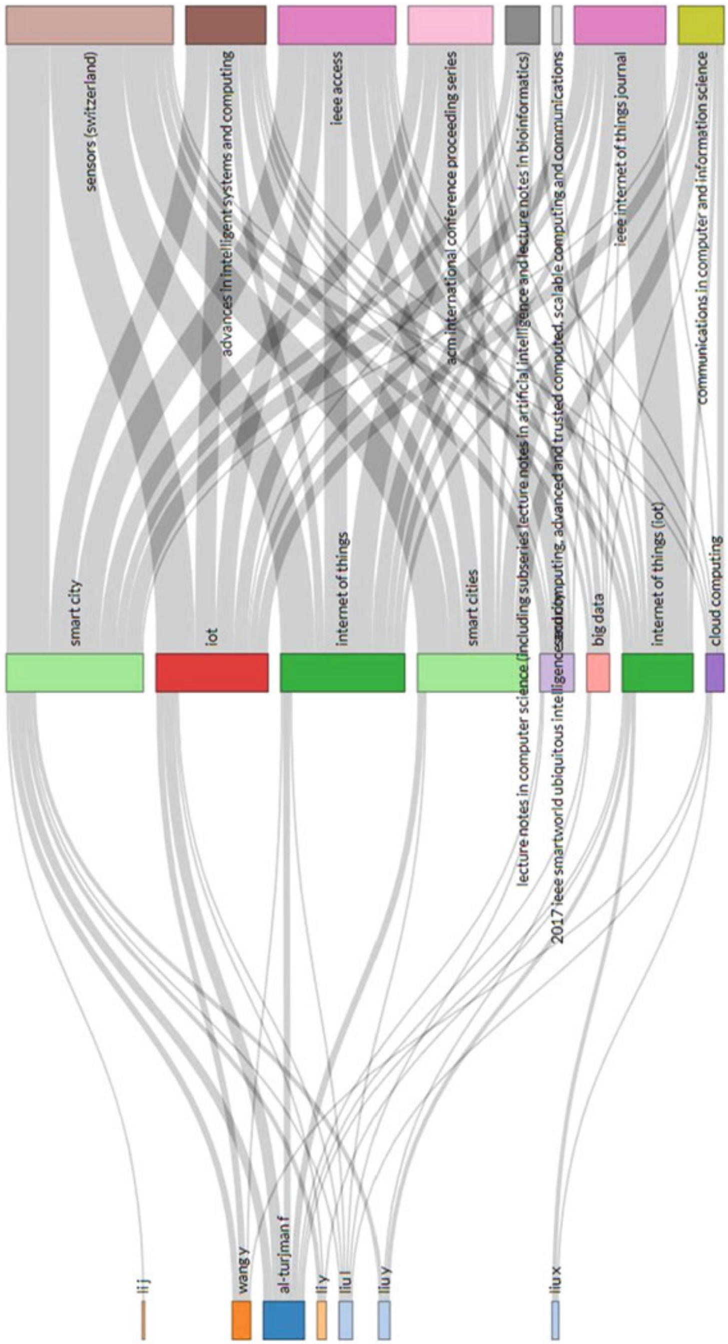

Fig. 11.3 Three field plot of authors, keywords used and sources for all the articles published in "use of IoT in net-zero smart city concept"

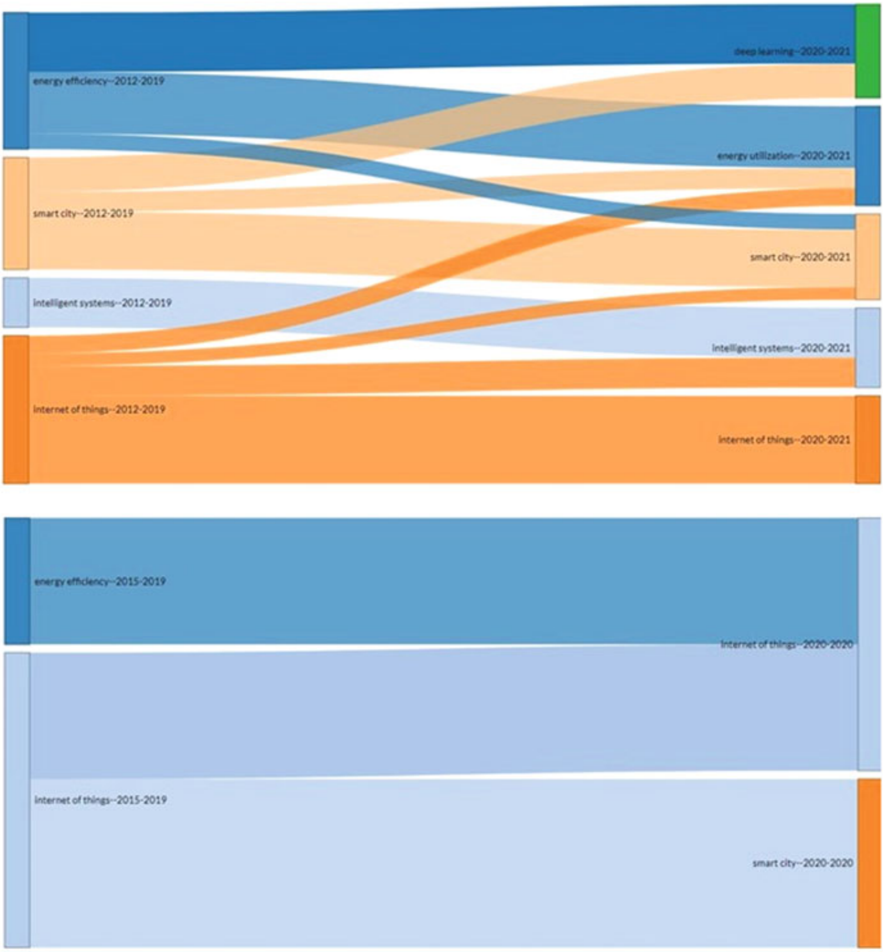

Fig. 11.4 Thematic evolution of factors. Top: analysis of all articles, bottom: India specific

systems (transportation, healthcare, energy, etc.) in India and provide solutions specific to the Indian context without generalizing Western solutions (Fig. 11.5). Yet another notable area in which Indian research is lagging is the "Internet of Things" and "smart city," which are still at a primary level. In contrast, researchers internationally are extensively researching at an advanced level already.

Fig. 11.5 Thematic map of factors showing niche, emerging, major, and basic themes. Top: Analysis of all articles. Bottom: India specific

11.4.4 Tree Mapping Analysis and Word Growth Analysis

Tree mapping analysis is a popular data visualization method in which the data is presented in a hierarchal manner in the form of rectangles [41, 42]. This analysis is used in the present study to understand the objective and relative frequency of keywords used and the existing volume of research. It was observed that apart from the critical areas in which research is already being heavily undertaken, such as energy efficiency, smart city, intelligent systems, and the Internet of Things, a few other exciting areas came into the picture, like intelligent systems, sustainable

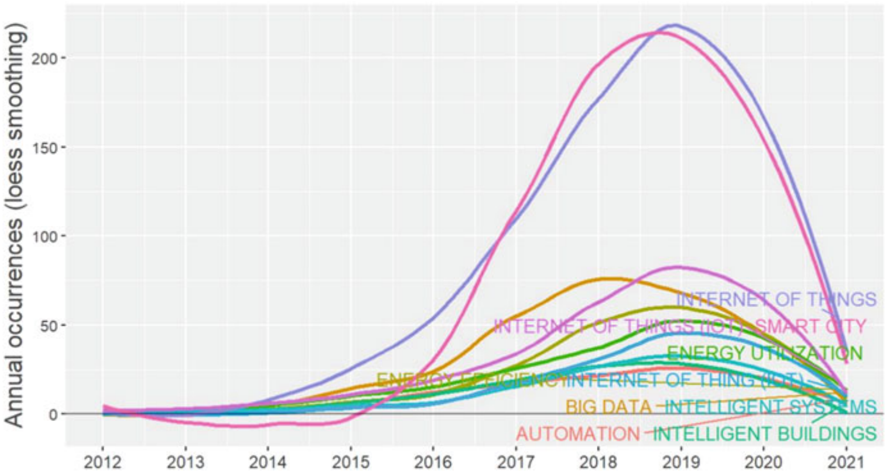

Fig. 11.6 Word growth analysis from 2012 to 2019

development, network security, decision-making, computing, digital storage, and information management.

It should be noted that the graph shown in Fig. 11.6 should be read till 2019, and the "biblioshiny()" tool of RStudio software automatically shows new keyword trends for the last years. It can be easily noted that though all the keywords were almost equally used until 2015, the smart city and IoT outpaced every other research area since 2015.

Figure 11.7 shows that 52% of the research works since 2012 in IoT in the net-zero smart city field have used IoT and smart city as keywords. However, data, security, sensors, intelligence, and storage, which are also essential, were mentioned in a mere 19% of the total research works. Word growth analysis further validates the tree mapping analysis results.

11.4.5 Country Collaboration Map

The country collaboration map (Fig. 11.8) shows how authors from different regions collaborate and participate in collaborative research in IoT in a net-zero smart city. While it is interesting to note that Indian researchers are collaborating with researchers from other nations, the Indian researcher needs to be more focused to come up with policy-level solutions. Only 42 out of 1576 articles were published by Indian authors, which is merely 2.67% of the total publications. Consequently, a significant number of additional researchers need to work in this field. Also, it can be observed from Fig. 11.8 that quite a few countries from Africa, Middle East, and South America, along with Russia, lack international collaboration.

Fig. 11.7 Tree mapping analysis of the published studies. Top: Analysis of all articles. Bottom: India specific

11.5 Conclusion

The literature review gives a clear picture of the three major factors that can help make a city a net-zero smart city, namely, planning factors and use of IoT, role of citizen engagement and community participation in net-zero city, and energy and transportation and use of IoT. This implies that while the focus should be on reducing the overall carbon emissions, city administrators and designers should also give due importance to stakeholders' participation, resilience and vulnerability, safety, and citizens' well-being. The bibliographic analysis showed that while research carried out in the Indian context had only 2.67% of the total

Fig. 11.8 Country collaboration map

publications, the research is heading in the right direction. There is a massive scope for improvement, and as established by thematic mapping, thematic evolution, and factor analysis, research in the Indian field lags behind by 4–5 years. Areas such as intelligent systems, data security, and deep learning in urban planning have not been explored much in the city context. Research in India should collectively try to see sectors such as energy, transportation, and housing as systems and develop policy recommendations and planning strategies rather than trying to solve small issues related to these areas. The three-field plot analysis showed that apart from the keywords Internet of Things and smart city, big data, sensors, and cloud computing are the new emerging topics in this field and should be taken up by urban planning researchers. Tree mapping analysis and word growth analysis indicated that the Internet of Things and smart cities are being used as the keywords in 52% of the articles. Still, only 5% of the selected articles were also using the keyword "net-zero." Thus there is immense scope for exploring this area for all the researchers. Another important observation is the lack of collaborative work with researchers from most of African and many Asian and South American countries. Collaborative works must be encouraged to make the net-zero world as soon as possible.

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Chapter 12
Smart and Innovative Water Conservation and Distribution System for Smart Cities

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12.1 Introduction

In the developing countries, water scarcity is a fact due to population and industrial growth. According to current statistics, per capita water supply in India's class 1 cities is 145 L per day. According to the WHO, the recommended minimum water intake per day is 45 gallons or 200 L; however, for low-income groups and economically vulnerable sectors, this can be reduced to 135 L. Most smart cities of India are provided with inadequate water supply. Domestic water consumption has increased as the population has grown, but non-domestic uses have seen a rise in demand due to increased industrial growth and transportation. Still in slum areas, which are a place known for water scarcity, they are provided with 30 l of water per day, which they feel as insufficient for their regular use. River water has been brought into the city as a result of groundwater shortages, affecting farmers who rely on river water for agriculture. People often utilize the traditional tap method,

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which allows water use to be lowered but not controlled. Almost 62 percent of the water delivered to a single home is squandered as drainage water that is never used. This is the fundamental source of water shortages that are occurring all across the world. Water supply in cities is in high demand. There appears to be a supply and demand imbalance, which is also perpetual in nature. Water pipeline network nature and development at all needed levels have been examined at all periods in various places of the world. Our system is attempting to provide a better solution to this challenge.

Both urban and rural areas are becoming more conscious of the value of water conservation. People, on the other hand, struggle to keep track of their water use because they are uncertain when to stop. As a result, water is wasted without the user's knowledge. Our system assists users in keeping track of their water use and reducing their water supply when consumption levels are excessive automatically. Moreover, our device incorporates Internet of Things and mobile application technology to keep users connected and provide real-time control and monitoring, making it user friendly. The prime aim of this chapter is to conserve water at the terminal ends of the distribution system. In order to understand the water conservation system rest of the chapter is formulated as follows.

Section 12.2, about existing water management techniques, investigates a specific area's water supply and water distribution pattern, and gives better understanding of the water storage facilities, how water is transported from treatment plant to homes, and recycling methods like automated water tapes and sensor-controlled mechanical valves. Section 12.3 discusses on different water tank types, valve types, and designs of smart water tap.

12.2 Literature Review

Kaushik Gupta [1] presented a system using a smartphone application, using which monitoring of water level can be done from anywhere continuously. It is possible to accomplish full smart automation and have the motor operated automatically. This system is durable, simple to set up, and small. Residents may monitor and regulate the water management system remotely using their smartphones, according to the work provided. Even if water-level monitoring is possible, there is a lack of long-term management.

Lalith Mohan and Kavin Prabhu L [2] suggested that their technology allows a user to control a faucet from anywhere over the Internet. Users may preheat the water and have it ready to use in the shower or at the faucet for a bath. It cuts down on waiting time while also ensuring that no water is wasted while drawing hot water from the solar water heater since any wasted cold water in the hot water pipeline is immediately sent to the storage tank for reuse. It will become a smart gadget that will save water and monitor consumption in all households and commercial buildings.

Mohapatra and Rath [3] proposed an information and communication technology-based water distribution network which aids in monitoring extreme water supply and preventing water from being wasted. They designed a smart tap with heterogeneous architecture instead of normal flow. With intelligence it senses the object in front of the tap and decides to flow the water or not; thereby water wastage can be avoided and also it proves that the smart tap saves water wastage by 14.04%. It was designed for the developing countries like India only and is not applied globally.

Suresh and Muthukumar [4] described an automated water meter reading for the usage by customers from the distribution center. It was accomplished using low-cost IoT hardware and a mobile app, and it also lowers the cost of managing meter readings for water distribution in both urban and rural locations. This work was unaccounted for water issues faced in smart infrastructure.

Sithole and Rimer [5] designed a low-cost smart water meter device composed of a flow meter sensor fitted into the water pipes which was used to determine the leakages in water usage in household consumption. Even though the device managing the water supply and maintenance there was no mobile application to intimate the user.

Mutchek and Williams [6] raised awareness of smart water networks and the issues associated with their integration, by examining the technical aspects. It includes leak detection, drought management, and energy conservation; however there is a cost distribution issue.

Karray et al. [7] suggested a method for detecting and locating pipeline breaches over large distances. The modified time difference of arrival approach based on pressure measurements is linked with leak detection and localization algorithms. Many authors [8–12] analyzed and proposed many methodologies to avoid water wastage and leakage in long-distance pipelines.

Sandesh Subedar Singh [13] suggested a technique for monitoring and managing the usage of coolant in industrial machines. This system was low cost, simple to use, sturdy, and resource efficient, and it could be employed in industrial machines like CNCs and SMEDs. This method operates in two modes: automatic and manual, based on priority. It reduces coolant wastage and removes the need for an operator or manpower. This system used an ATMEGA microcontroller and radio-frequency communication. Using master and slave modules, it properly monitors and controls the level of a succession of machines. The final result implies that a low-cost solution for coolant-level management will be achieved under a variety of industrial operating circumstances.

According to Dadan Nur Ramadan [9], the system employs a Raspberry Pi as the main controller unit, and it was fitted with a camera as well as GPS module for real-time monitoring, which involves collecting photographs of the surrounding area and then sending the image to a cloud real-time database. This system can be operated via applications on an Android smartphone connected to a 4G network, and users can examine the obtained image as well as the system's position coordinates on the app's screen. Results of data transmission speeds for sending commands from an

Android smartphone to manage the system have an average speed of 1.84 s in the open environment. The program took 5.68 s to display photos with a file size of roughly 4 Mb.

According to Sayali Wadekar [14], the approach aids in the management and planning of water consumption. This method is simple to set up in residential communities and locations. A sensor in the tank continually reports the water level at the present moment. This information may be updated on the cloud, and users may view the water level on their smartphone anywhere they have an Internet connection using an Android application. The motor's operation will be controlled automatically based on the amount of water in the tank; when the water level is low, the water motor will switch on automatically, and when the tank is about to fill up, it will switch off automatically. Ramos et al. [15] analyzed the benefits of smart water grids and revealed the technical developments in water and energy use with a case study. This system monitored water loss and improved water sustainability with innovative technologies in smart cities. The deteriorating water system leads to the integration of IoT and wireless sensor network in wastewater treatment [16]. It shows the effective way of managing wastewater quality parameters, but it needs massive sensor deployments in urban areas. Nardo Di et al. [17] discussed many solutions in smart water management in urban areas with challenges and issues faced in water distribution networks with the involvement of information communication technologies.

12.2.1 Source of Groundwater

Despite the fact that static water levels range from 4 to 25 meters, groundwater in shallow aquifers (weathered zone) is almost depleted or dried up, and the aquifer in deep-seated fractures or lineaments at depths of 100 to 200 meters is now being tapped for various purposes. Groundwater has become unsuitable to drink as a result of excessive extraction and contamination. In every household, a mixture of water sources is used (water supply from municipal corporation and groundwater). The major sources of supply of drinking water are usually rivers and lakes which are present either near or within the particular municipal corporation. The pickup dams are usually present close to major resources which act as primary reservoirs. Water from the pickup dams is then diverted to the tunnels which extend up to the treatment plants. The water from the main reservoirs is treated at the treatment plants before entering the distribution system. Water treatment involves removing undesirable components and other contaminants or reducing the concentration of water, so that it is best suited for use. This treatment is crucial for human health as it allows humans to drink and irrigate.

12.2.2 Community Water Treatment

Coagulation and flocculation are the first phases in water treatment. Water is mixed with chemicals that have a positive charge, which neutralizes the negative particles in the water. The particles combine with the chemicals and form floc, which are larger particles, as a result of this. Small particles of size 1 μm are called as colloids. Coagulation is a chemical process that neutralizes charges and combines particles through chemical interactions between the coagulant and colloids which form a mass of large particle. During flocculation fine particulates are clumped together to form a floc. This floc may float above water or settle down at the bottom, so that it can be removed by filtration. The settling process, also known as sedimentation, occurs when the floc settles to the bottom of the water. After sedimentation filtration will be performed to filter out the clear water from the top of the supply. During sedimentation dissolved particles are removed. During disinfection chlorine or chloramine can be added to remove parasites and bacteria from water. Filtration comes after sedimentation. The clear water will pass through a series of filters with varying compositions (sand, gravel, and charcoal) and pore sizes to flush out dissolved particles like dust, bacteria, viruses, parasites, and chemicals before the floc sinks to the bottom of the water source. After filtering the water, in order to destroy the pathogens and microbes in the water a disinfectant is added before distributing it for the users.

12.2.3 Water Distribution Pattern

The water from the main reservoirs is stored in the smaller reservoirs (overhead and ground level) present in various places. Water is then distributed through the distributive system from the reservoirs. Based on the population density and the size of the city, required number of water supply distribution zones is established. The water supply connections may be domestic, commercial, and industrial. Figure 12.1 represents the water distribution system in cities. Water storage facilities: The storage facilities at the consumer level may be underground water tanks or overhead water tanks. The water which is obtained from the distribution system is collected in the tanks. From the overhead tanks water is then distributed to residents of that particular apartment or building. For civilization to exist, there are two prerequisites. One is a sewage system for disposing of wastewater, and the other is a consistent and reliable water supply system for drinking, bathing, and irrigation, among other things for household purpose. There is facility to treat the water so as to remove impurities and make it portable before use. Every city and town need ready source of water and a means to store this water for future use.

Water treatment plants at household level: These water treatments can be done at home using dilute bleach solution, Aqua tabs, solar disinfection (SOLIDS), cloth filters, ceramic filters, biosand filter, PURE, etc. Here are some advantages of

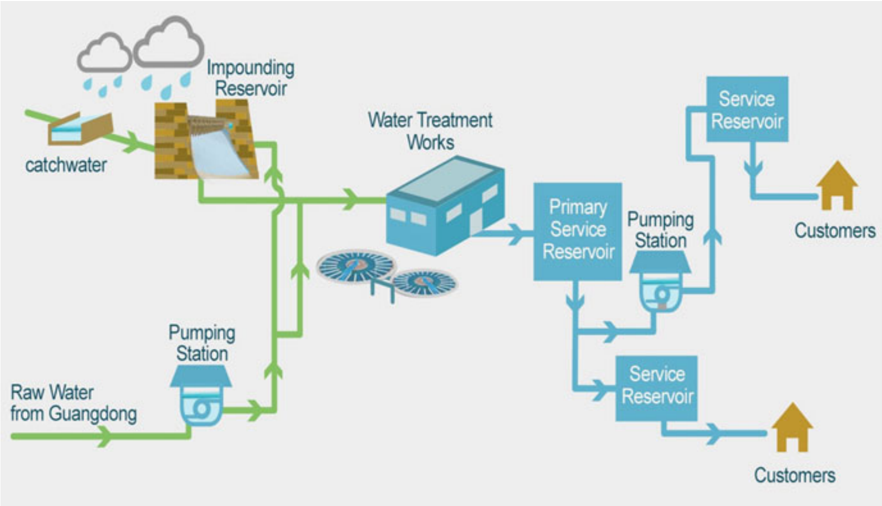


Fig. 12.1 Water distribution system in smart cities

household level. They are low cost and cost effective, and they are not dependent on an institutional setup or centralized systems. It can be installed more quickly than community/centralized drinking water treatment and distribution systems. It improves microbial water quality and lowers the risk of contamination between treatment and use, and it makes low-cost and simple technologies available. This allows people to choose the appropriate technology.

Reservoirs: Factories and homes are supplied with water. Reservoirs are built to store rain that falls during the wettest seasons of the year, ensuring a steady supply of water throughout the dry months. Water is treated before use. Addition of chemicals is done to remove unwanted particles along with bacteria. Dirt is removed by filtering through sand bids and gravel. Chemicals can also be added, which enables the sticking of particles together, in order to separate them from water. Once the treatment is done, we transfer it to a storage reservoir and make it ready to be distributed. Every day, billions of liters of clean water are delivered to homes, workplaces, schools, companies, and hospitals in the United Kingdom via a network of tens of thousands of kilometers of subterranean pipes.

12.2.4 Water Tanks

To satisfy the household needs of drinking, washing, bathing, and cleaning, all households require a constant supply of water. To store water, we construct water tanks. It is designed according to the location, where the tank is kept, i.e., underground or overhead. Tanks are made in various shapes, mostly in circular

Fig. 12.2 Image of chemical contact tank

and rectangular shapes. Overhead tanks are elevated through column from rooftops. Underground tanks lay upon the foundation. There is a drain provided to empty the tank which is present at the bottom. Water tanks are used to hold water for drinking, irrigation, agriculture (plants and cattle), chemical processing, food preparation, and a variety of other applications. Plastics such as polyethylene, polypropylene, concrete, stone, and welded or bolted carbon or stainless steel are among the materials used to construct the water tank. In South Asia, alternatives such as clay containers are employed for water storage. Water tanks can be used to store cleansed water in developing areas.

Types of Tanks

Chemical contact tank: This tank enables chemicals to be retained for a period of time before being chemically treated with product water. This is achieved by making the chemical to be in contact with the water. The commonly used chemical for disinfection of water is chlorine. Figure 12.2 depicts the image of chemical contact tank.

Groundwater tank: These are constructed of lined carbon steel. It collects water from a well or from surface water, enabling for a huge amount of water to be stored and utilized during high-demand periods. These tanks can be placed above the ground or underground. Figure 12.3 depicts the image of groundwater tank.

Fig. 12.3 Image of the groundwater tank

Fig. 12.4 Image of elevated water tank

Elevated water tank: It is sometimes referred to as a water tower since it generates pressure at the ground-level exit. It is sufficient for most domestic and industrial requirements. An elevated tank makes use of natural gravity to distribute the water using consistent water pressure. Therefore no other additional pump systems are required to distribute water. Figure 12.4 depicts the elevated tank.

Fig. 12.5 Image of vertical cylindrical dome top tanks

Fig. 12.6 Image of hydropneumatic tank

Vertical cylindrical dome top tanks: It may contain anything from 200 L (50 gallons) to several million gallons of water. Horizontal cylindrical tanks are utilized for transportation because their center of gravity is low, allowing them to maintain balance with the vehicle. Vertical cylindrical dome top tank is represented in Fig. 12.5.

Hydropneumatic tank: They are pressurized horizontal tanks for storage. Surge-free delivery is possible by pressurizing the water for distribution. This system can work automatically and it does not require any manpower. Hydropneumatic tanks provide efficient water supply by controlling system pressures to rapidly satisfy system demand. Figure 12.6 represents hydropneumatic tank.

12.2.5 Water Stress in Smart Cities

India's smart cities program was intended to have water as an important factor. Around 160 million Indians are estimated to live in water-stressed cities by 2030, which is less than a decade away. As per the Central Water Commission, levels in the country's 90 or so major reservoirs that feed our cities have not exceeded half their total capacity in the last five years. As per the Smart Cities Council, in order to improve its livability, workability, and sustainability a smart city should use information and communication technology. A "Smart Water Network" (SWN) inside a smart city helps cities to better predict and respond to various water network problems, such as detecting leakage, water quality accidents, and theft, as well as monitoring residential water use and conserving energy. There is a lack of data on water, both as a resource and in relation to other aspects of urban management. Our cities' future will be in jeopardy unless better methods are implemented for water security and unless it is prioritized as a key component of smart city development.

12.3 Component Details

Modern control valves can manage downstream pressure or flow and are controlled by sophisticated automation systems. This section gives an overview of different valves.

12.3.1 Automated Valve

Automated valve controls or regulates the flow of fluids by opening or closing or obstructing the passage of water without external power source. Valves are usually fittings. The fluid pressure is enough to automatically open the valve.

Types of valves: Valves are available in different categories and each type has its own benefits. Mostly they are classified based on how they are actuated.

Hydraulic valve: Hydraulic valves are mechanical or sometimes electromechanical devices that control the fluid flow in hydraulic systems. They must be designed to withstand more of fluid pressure. The required size of the valve is calculated by the maximum flow of fluid through hydraulic system and the maximum system pressure. Figure 12.7 depicts the image of the hydraulic valve.

Pneumatic valve: The valves in a pneumatic valve monitor the switching and routing of liquids or gases. The valves are responsible for regulating the flow of compressed gases or liquids, as well as the flow of exhaust to the atmosphere. Figure 12.8 illustrates the picture of a pneumatic valve.

Manual valve: Manual valves are those that involve the use of a manual operator to operate. Although some designs can be used for simple manual throttling, manual valves are mainly used to stop and start the flow (block or on-off valves). Figure 12.9 represents the image of the manual valve.

Fig. 12.7 Image of hydraulic valve

Fig. 12.8 Image of pneumatic valve

Fig. 12.9 Image of manual valve

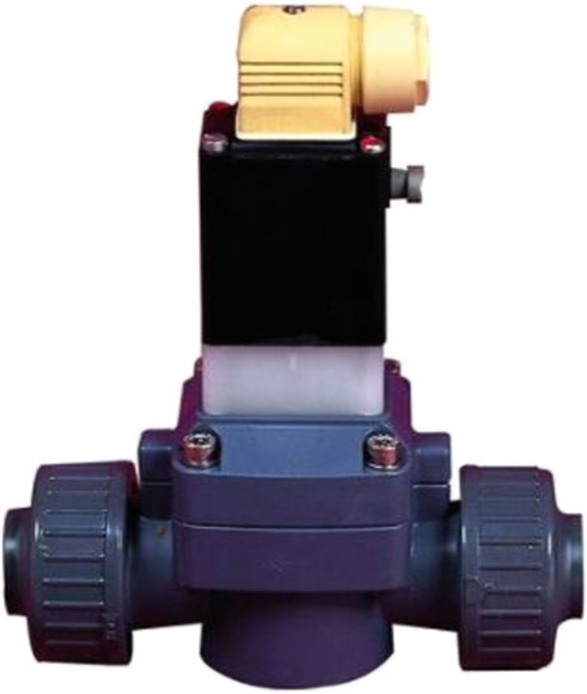


Fig. 12.10 Image of solenoid valve

Solenoid valve: Solenoid valve is controlled electromechanically. The valve has an electric coil with a movable ferromagnetic core at its center, which generates magnetic field when electricity flows. Figure 12.10 depicts the image of a solenoid valve.

Motor valve: Motor-operated valves are also known as on-off valves because they use motors to completely open or fully shut valves in pipelines. Figure 12.11 represents the picture of the motor valve.

12.3.2 Flow Sensor

A flow sensor or flow meter is an electronic instrument that regulates the rate of flow of air (gas) or liquid through a conduit. They are connected to gauges to reduce the measurements and able to detect pipe bursts and leakages. Figure 12.12 illustrates the image of flow sensor.

Fig. 12.11 Image of motor valve

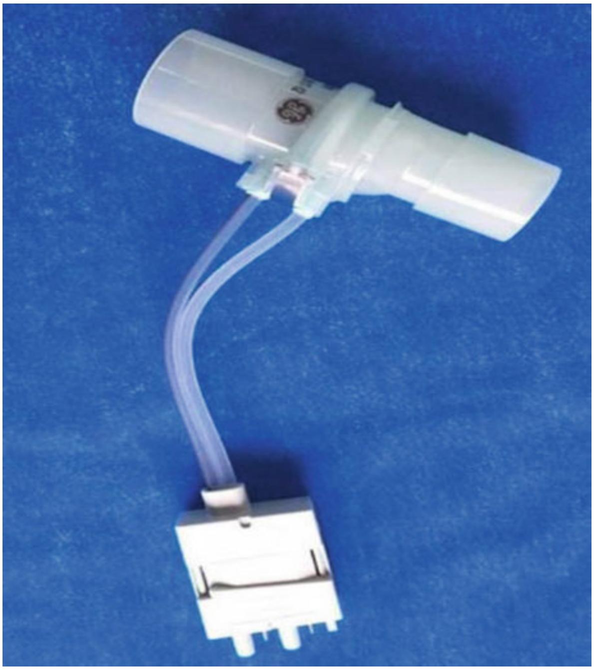


Fig. 12.12 Image of flow sensor

12.3.3 Types of Flow Sensor

Contact flow sensor: Contact flow sensors are used in systems where the oil or gas metered is not predicted to be choked in the pipe when it comes into contact with the sensor's parts. Vortex and mechanical flow sensor are the two most contact flow meters for measuring the flow rate of water. A sensor tab is comprised of a flow meter that slackens whenever vortices pass through.

Noncontact flow sensor: It does not have any moving parts and it can be used to monitor a good product. Noncontact flow sensors have no moving parts, and they are generally used when the liquid or gas, (generally a food product) being to be monitored. Ultrasonic flow sensor is a type of noncontact flow sensor which sends high-frequency pulses across liquid to determine the flow rate.

12.4 NodeMCU

The NodeMCU (Node MicroController Unit) is an open-source environment for designing IoT projects on ESP8266. Initially, it included firmware running on Espressif Systems' ESP8266 Wi-Fi SoC (System on Chip). Later ESP32 32-bit MCU was added and it comprises node and microcontroller. Figure 12.13 depicts the image of NodeMCU.

12.5 Proposed System

When water flows to the tank via the submersible pump, water is pumped into the tank until it reaches a certain level. Then the water is delivered to the house or reservoir through a pipeline that runs from the bottom of the tank to the house.

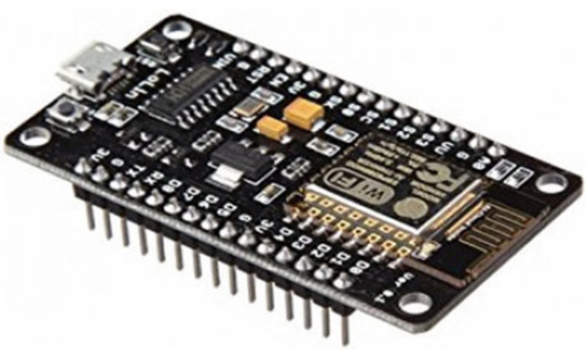


Fig. 12.13 Image of NodeMCU (ESP8266)

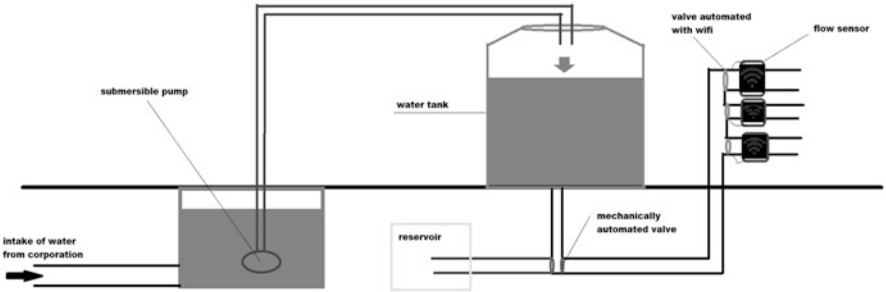


Fig. 12.14 Systematic diagram explaining the entire process/structure

Both sides of the pipe have two mechanically automated valves attached to them. Depending on the need, the valves should be manually opened. The water flows to the residences when the valve for the house is opened. The pipes are divided into three parts, each of which delivers water to the buildings. Three valves are connected to the pipes and are operated by Wi-Fi. When the water level in the tank reduces below a certain level, users will be notified via mobile applications on their phones, which are connected to the valves via Wi-Fi. The valves will be closed even after the users have been notified if they are using the water excessively. The water will be left in the tank if all users use it without wasting it. The pipelines will transfer the remaining water in the tank to the reservoir. There is a valve that directs the water that has been left out to the reservoir. This valve should be manually opened to allow the remaining water to flow into the reservoir. Furthermore, the housemates are given smart taps in their homes, which read the water level using a flow sensor and control the flow, reducing the water quantity and increasing the flow rate, thus facilitating water conservation.

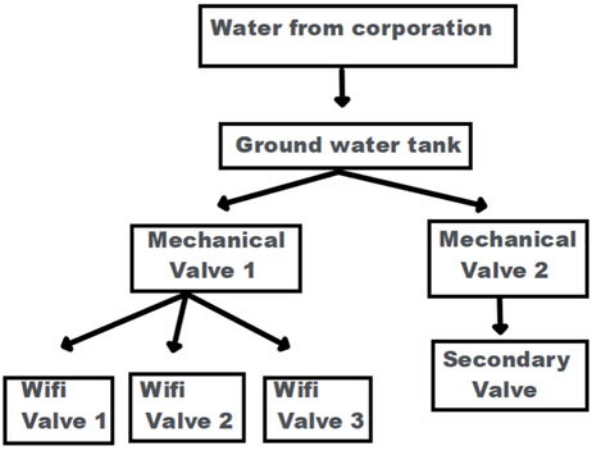
Finally, the unused water is stored in a secondary reservoir and used for future domestic purposes. Figure 12.14 shows the systematic explanation of the entire process/structure.

12.5.1 Working of Smart Tap

In case of a normal tap, when we turn on the tap and lift the knob the water gushes up from the pipe and flows through the hole and when we close the knob down again on to the pipe it cuts the flow of water from the pipe, so water stops coming from the hole of the tap; this is how a normal tap works but a smart tap has many advantages; this tap can save up a lot of water and the tap has regular and saver mode. Figure 12.15 shows the flow and working procedure.

Some advantages of smart tap are figured out: Smart tap is an advancement in household water tap to reduce the water consumption in our day-to-day life. This can save up to 50 percentage of water usage in our regular amount from

Fig. 12.15 Flow analysis



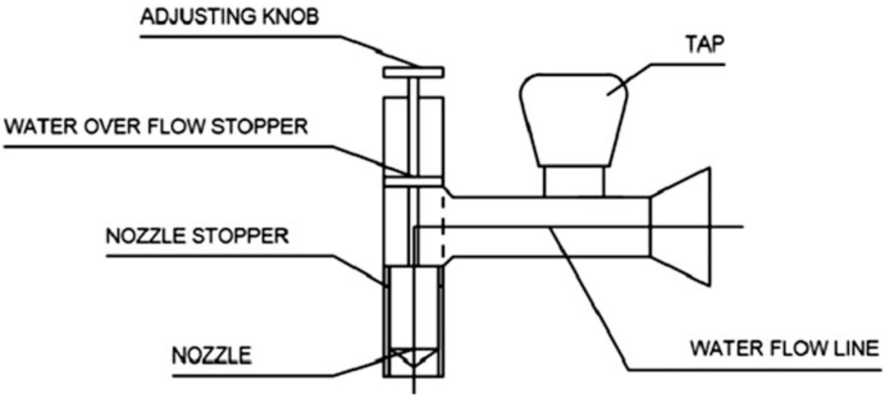


Fig. 12.16 Design of smart water tap

utility consumption. The tap has regular and saver mode. By current estimation the smart tap is expected to conserve our water consumption; in nearer future it can be developed to conserve more water. Figure 12.16 shows the design of smart water tap.

12.5.2 Working on Regular Mode

Regular mode is the normal flow of water from the tap. Water flow is normal without any intermediates. Splashing occurs when water strikes the sink. Consumption will be more than saver mode. It is easier for filling purpose. Figure 12.17 depicts the working of regular mode.

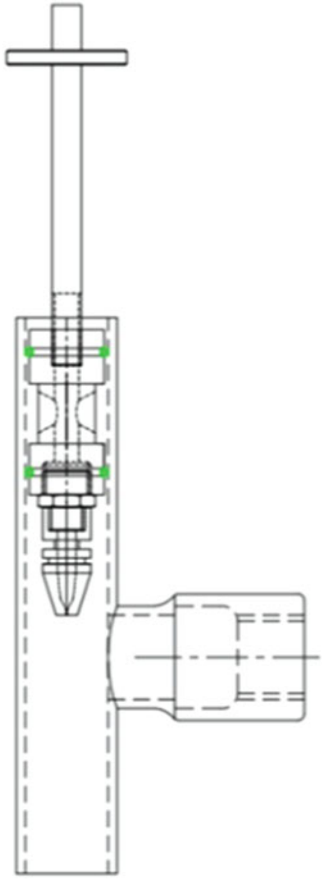


Fig. 12.17 Working of tap on regular mode

12.5.3 Saver Mode

On saver mode water consumption can be reduced when compared with normal level. Nozzle is fitted in the tap so it does not allow the water as it comes only with the type of mist. It requires fewer amounts of energy and estimation to heat and transport the water. No splashing of water occurs. It sprays widely and evenly and it is easier for cleaning purpose. Figure 12.18 depicts the working of saver mode.

12.5.4 Mobile Application

A mobile application will be used to send notifications and warnings to reduce water consumption levels. This application will track each user's water consumption and provide real-time monitoring and updates on each household's water consumption. This app will also display the current water level in the tanks and forecast the amount

Fig. 12.18 Working of tap on saver mode

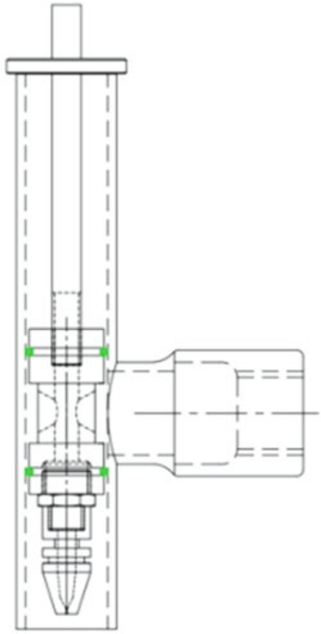


Table 12.1 Determining the type of nozzle

Type 1	Type 2	Type 3	Type 4
Cone-edged nozzle Spray angle: 95 Pressure required: 2.8 kg/sq.cm	Flat-edge nozzle Spray angle: 100 Pressure required: 2.8 kg/sq.cm	Hollow cone mist spray nozzle Spray angle: 100 Pressure required: 2.8 kg/sq.cm	Flood jet cone nozzle Spray angle: 110 Pressure required: 0.7 kg/sq.cm

of time until the tank runs dry if the water consumption rate remains constant. The admin will also be able to turn on the water supply if it has been turned off, as well as edit the water level assigned to each house. This feature will aid in the allocation of water levels per house based on the number of inhabitants.

12.5.5 Nozzle Selection

Nozzles break the water into droplets from the water tap. Water-saving nozzles come in various forms that divide the water flow into multiple streams. Table 12.1 shows the type of different nozzles for selection.

Table 12.2 describes the spray angle and pressure in household tanks to finalize the nozzle selection. Figure 12.19 depicts the smart water meter. Figures 12.20 and 12.21 show the real-time water usage and conservation statistics.

Table 12.2 Finalizing the type of nozzle required for the system

Types	Spray angle	Available pressure in household overhead tanks (psi)	Status
Type 1	95	40	Required motor to spray
Type 2	100	40	Required motor to spray
Type 3	100	40	Required motor to spray
Type 4	101	10	Overhead tank above first floor is sufficient

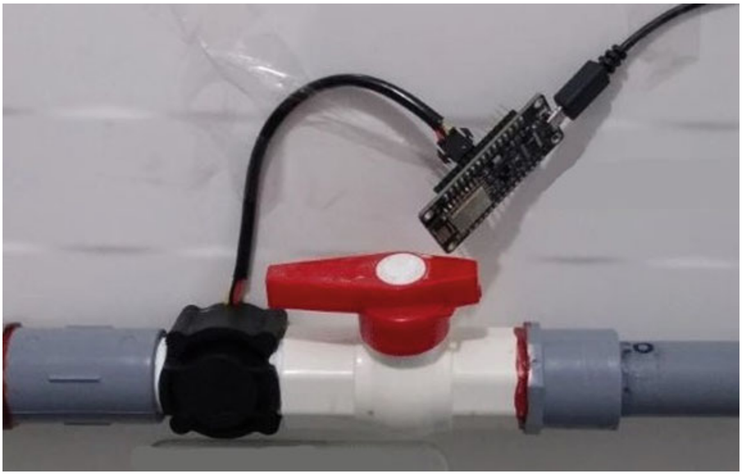


Fig. 12.19 Smart water meter

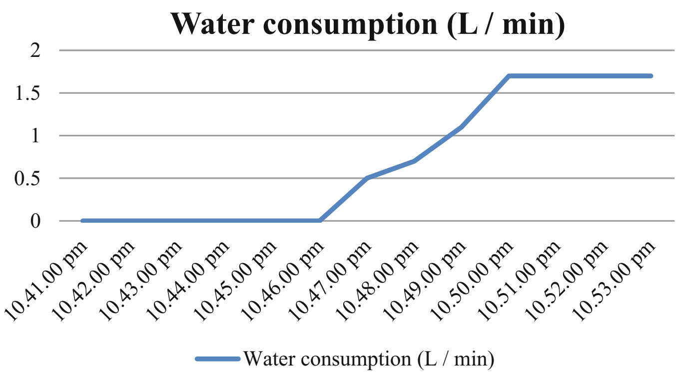


Fig. 12.20 Real-time water consumption data of a user

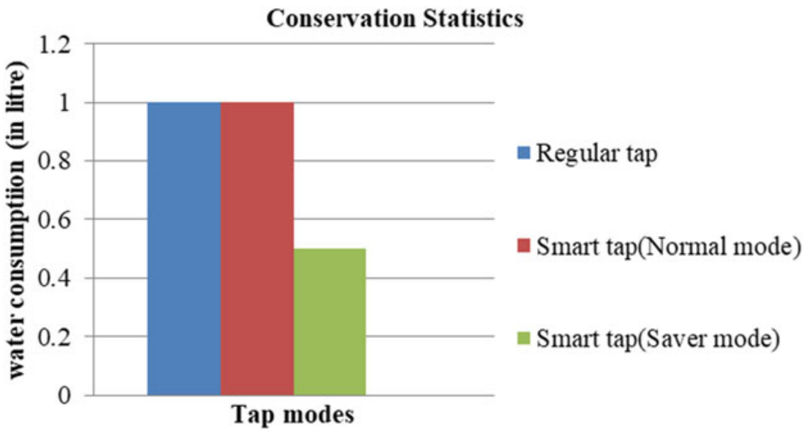


Fig. 12.21 Conservation statistics

12.5.6 Conservation Statistics

12.6 Conclusion

Thus, our system premises to provide a simple yet efficient way to monitor the water tank level and also the water consumption by individuals. In addition, smart water automation is created using an advanced logic that makes household routines more comfortable. In addition, the system provides additional hospitality through smart taps, making city life even more productive and mind-blowing. Smart taps decrease water use and save almost half of the water we use in our daily lives, with the potential to change even more in the future. Installation of smart tap in every house, industries, and public areas can improve conservation of water. It saves good water for our future needs and it also helps in reducing our water taxes. Furthermore, using mobile apps for real-time monitoring and control allows for easy access. Smart cities can conserve water in this way, ensuring that there is no scarcity during dry or scarce season.

The future scope of this project is to detect leakages and bursts in pipes to prevent wastage of water, thus making it robust and fail-safe in any case. Adding an automated system for turning on and turning off the motor when the water level in the tank falls down a particular point will save users time and also prevents water wastage when the tank is full. In addition to that it makes smart taps even more efficient to conserve water.

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Chapter 13
IoT Technology-Based Urban Water Management Strategies Using Indian Traditional Knowledge System

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13.1 Introduction

Water though covers more than 70% of the earth's surface, less than 1% is fit for human use. The pressure on this limited quantity increases tremendously because of different uses, pollution, and contamination [1]. The per capita availability of water is decreasing rapidly. Water scarcity can be observed more in urban areas due to the ever-increasing population and migration from rural to urban areas along with other factors such as industries, population density, mismanagement of watersheds, pollution of groundwater resources, and water-intensive traditional farming practices. Water is one of the basic needs of living organisms, and it is

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needed to sustain all the activities carried out by human beings; thus, it should be available for use at the desired quantity, quality, and time [2]. The United Nations has identified this as a fundamental challenge and has added water sustainability in the Millennium Development Goal and then later added it to goal number 6, "clean water and sanitation," of the Sustainable Development Goal 2030 [3].

Taleshi [4] observed that to have sustainable development and focus of managing water, equipping and conserving natural resources are among the most critical factors. Water management is also dependent on a country's or region's social, cultural, and traditional values and is also dictated by the country's or region's economic capital [4, 5]. Cities in developed countries are doing much better than those in developing countries because of the availability of better infrastructure and financial resources [5]. Nations worldwide are taking severe measures to manage water efficiently by implementing water taxes, using technology, or having a central management system [6, 7].

In India, after independence in 1947, the Ministry of Water Resources, Government of India, suggested implementing a central water management policy throughout the country and directed the state water resource departments to make necessary changes. The Ministry of Water Resources also suggested implementing the water management techniques adopted during India's British rule, such as the drought mitigation strategies and increasing the canal irrigation networks. The water management plan mostly ignored the local geographic characteristics and wholly ignored traditional water management knowledge [2]. Dwevedi et al. [8] observed that there is already stress on India's water sources, and the water resources available at the surface level are drying up faster than any country in the world. The water infrastructure developed after India's independence is in poor condition in most Indian cities, and now, either up-gradation to new methods of water management or moving towards the traditional knowledge systems seems like a difficult task [2, 7].

In today's context also, the relevance of traditional knowledge can be gauged by the fact that the Indian villages and rural areas can still meet water demands with their indigenous knowledge and with minimal support from the government. Traditionally, people used to take ownership of the water bodies; they considered them sacred, worshipped them, and had unique water harvesting knowledge systems [2, 9].

Thus, the need for the study arises because of the primary reason that fresh and human usable potable water has a finite source and is in limited quantity and there is a lack of sustainable management of the resource. This study also highlights the importance of traditional water management knowledge in the Indian subcontinent and understands the practical implications and modern application of the traditional water management knowledge systems. This study is not just an exercise to revisit and appreciate the past traditional sociocultural knowledge systems pertaining to water use and management. It further investigates the problems and challenges faced by the following 12 selected HRIDAY cities: Amaravati, Gaya, Dwarka, Badami, Puri, Amritsar, Ajmer, Kanchipuram, Velankanni, Warangal, Mathura, and Varanasi. Finally, the study recommends socially and culturally acceptable, feasible, community-focused strategies that are mostly long-term solutions. This study tries to identify some of the best successful water management practices in the Indian context and how to replicate such practices in regions with similar geographic characteristics. The feasibility, upscaling of such a project, and detailed water management documentation of such practices are not the scope of this research and may be taken up in future research or taken up by government agencies as a pilot/consultancy project. The research questions that this study tries to answer are as follows:

RQ1: Is the traditional water management knowledge still relevant culturally or technologically for Indian cities, and if technological interventions, specifically IoT, help use the traditional knowledge in the present scenario?

RQ2: Do cities with complex heritage characters face unique and distinctive water management challenges compared to other urban areas?

RQ3: Which traditional water management system has the potential to help solve the problem of water shortage in urban areas, and which of the two, long-term or short-term solutions, is better economically, culturally, or sustainably?

The structure of the research is as follows. Section 13.2 of the chapter discusses the methodology used in this research. The literature review is presented in Sect. 13.3 of this chapter. It discusses the traditional water knowledge system and its importance and the importance of IoT, the AMRUT scheme, and the community's role in managing water. The study area and its associated problems and challenges are discussed in Sect. 13.4. Long-term and short-term strategies are presented in Sect. 13.5 "discussion and strategies." Sect. 13.6 concludes the chapter, and throws light on the managerial implications and the study limitation.

13.2 Research Methodology

The research methodology used in this study is as follows:

Step 1: Review of Relevant Literature The literature search was carried out from December 5 till December 21, 2020. The broad area of the literature review was the "traditional Indian water management system." The study used Google Scholar (scholar.google.com) and Scopus (scopus.com) search engines to collect relevant literature. To obtain the desired articles, the keywords used for the literature search were water management, water conservation, water tax, planning strategies, traditional knowledge, community, government, water infrastructure, Internet of Things, smart cities, and India. The articles without digital object identifier (DOI) were screened out during the first-level screening. Only the articles which were published in the English language academic journals were considered. The search result gave 231 articles, and after careful screening, the authors finally used 41 articles related to the broad objective of the study. Further, some articles, book chapters, and theses cited in the selected articles were reviewed, and after careful reading, four more research works were added to the study.

Step 2: Review of Government Schemes, Policies, and Programs The varying geographical features in India have diverse location-specific issues which need location-specific approaches and solutions. The study identifies the different kinds of schemes, policies, and programs undertaken by the government at the center and state levels to address water management-related issues. The study further tries to identify the different water availability and management problems faced by the selected 12 HRIDAY cities and possible reasons for the problems.

Step 3: Study Area Review The selected twelve cities under the HRIDAY program, namely, Amaravati, Gaya, Dwarka, Badami, Puri, Amritsar, Ajmer, Kanchipuram, Velankanni, Warangal, Mathura, and Varanasi, are facing water shortages due to the old water infrastructure and rapid unplanned growth postindependence [10]. Further, the study lists the vital common issues in the selected cities where the traditional Indian knowledge of water management can be used and implemented using the Internet of Things (IoT) technology.

13.3 Literature Review

The literature review section is divided into three sections. The first section discusses the traditional Indian water management knowledge from different cultures and geographies across India and the need and benefits of bringing in the knowledge in the present age of development driven by technological interventions. The study reviews the AMRUT scheme launched by the Indian Government in 2015 and its provisions for water management in urban areas. The study further discusses the IoT-based water management strategies and interventions suggested by contemporary researchers. Further, the study lists the benefits of integrating traditional knowledge with IoT technology and sheds light on the community's vital role in water management.

13.3.1 Importance of Indian Traditional Water Management Knowledge

Traditional knowledge in water conservation and management has proved time and again its importance. Emperor Akbar ignored the centuries-old knowledge while laying out a new city and had to abandon Fatehpur Sikri's city in Uttar Pradesh, India, only after fourteen years of building the city. Some of the best known flourishing ancient civilizations thrived because they respected and practised the traditional knowledge and knew the importance invested in watershed management technology. The civilizations such as the Roman, Mohenjo Daro, Indus Valley, and Mesopotamian and the Chinese drainage system used the traditional knowledge available at those points to flourish [1].

People in the rural areas have used the indigenous water management system for centuries and have been able to meet the growing needs without much help from the government at the local (gram panchayat), state, and center levels [7, 11–13]. Though there is no denying the fact that there is migration from rural to urban areas, the population trend has shown that the birth rate in rural areas is much more than the urban areas [14]. Without water conservation methods, increasing per capita water demand would have been catastrophic for the rural Indian population [12].

City planners need to look at their "less affluent" neighbors and introspect the mistakes they are committing in utilizing traditional water management knowledge. Urban and regional planners need to understand the importance of traditional water management. This very knowledge system is the sole reason for humankind to survive even in the regions where water is hardly available [1, 5]. Honwad [11] noted that the education system developed postindependence was a significant catalyst in ignoring our centuries-old knowledge base and giving more importance to the Western education system. Western technology was incorporated in Indian city planning during the colonial period through their water supply and sanitation policies through municipalities. This brought about a significant discontinuity in traditional watershed management practices in urban areas. India's robust system of transferring knowledge from one generation to another has become vulnerable. In 2018, Chennai became the first city in India to run out of human-use water [1, 15]. In India, indigenous knowledge's success was mainly because water, water bodies, and water sources are considered sacred and worshipped by many communities [11]. A gradual sociocultural shift is notable towards this reverence for water, especially in urbanized contexts. Fast-paced industrialization led to the exploitation of water policies by using loopholes in the system. This exploitation and poor planning are the primary reasons for water mismanagement in the Indian urban areas presently [16, 17].

The following points and observations by contemporary researchers highlight and identify the relevance, importance, and need of protecting the traditional water management knowledge system in India, and why we need to respect and revisit that knowledge and reinvent it:

1. The traditional knowledge system has evolved over centuries and respects the local values and traditions, and fits well in India's sociocultural system [2, 18].
2. The indigenous knowledge is used and developed by the community and has more acceptance as it respects the community's culture [7, 19, 20].
3. It is the outcome of experiments and experience and has faced the harshest of disasters and is still relevant [21, 22].

4. The knowledge is passed from generation to generation through practical demonstrations, and changes are made according to the changing context [2, 9, 11].

It is pertinent to mention that the focus on revisiting cultural practices and reinventing their practices for contemporary applications in the field of climate-responsive architecture, watershed management, and use of local materials has gained academic ground since the building industry shifted towards sustainable development agenda, pushed by international efforts on climate change and sustainable development.

13.3.2 Review of AMRUT Scheme

The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) Scheme is mainly focused on improving the quality of life of the disadvantaged communities and the urban poor by providing essential city services like transportation facilities, proper sanitation, and safe and optimum quantity of water regularly [23, 24]. The Indian Government launched this scheme in 2015. Under this scheme, transportation and sanitation programs are addressed because of already existing mechanisms, but the urban planners and policymakers faced problems in managing water because of the poor infrastructure condition and unavailability of large-scale best practices [22]. The reason for focusing on the poor and disadvantaged is because the affluent societies can afford water at premium prices, as has been the case in the national capital territory of Delhi [16]. The main objective of the scheme related to water is to ensure that each house in an urban area has a tap water supply. The scheme's target is to get the desired result in 20 years, i.e., by 2035, with an estimated cost of rupees 39.2 lakh crore (3.92 trillion) at 2009-2010 prices. The scheme will solely operate as the centrally funded scheme and will be fast-tracked as the scheme has only one funding source, thus reducing confusion [23].

13.3.3 IoT in Water Management

The growing need for water due to the rapid increase in population and depleting water resources makes it necessary to optimize, monitor, and distribute water efficiently [13, 25]. The use of the Internet of Things (IoT)-based technology in our daily use has increased tremendously in the last decade. Barbhuiya et al. [26] suggested that water management-based systems should also use IoT-based sensors to manage water efficiently. However, this use of IoT is not straightforward and simple. It is done through a series of IoT sensors placed at desired locations and generates massive data that needs to be stored for future up-grading of infrastructure [27]. The real-time analysis and solutions suggested to problems by the IoT sensors are much appreciated, but there is a considerable amount of minute detailing that goes in the process [10, 28]. This micromanagement, detailing, and proper networking need resources, in terms of human, technological, and financial, which is a significant amount of commitment in the Indian context.

The literature review in Sect. 13.3.1 gives a detailed impression of the need and importance of using traditional water management knowledge. Traditional management can be made “smart” by integrating indigenous knowledge with IoT technology [27]. Planners and architects have started using IoT-based solutions in managing water at the city level as the national capital territory of Delhi and micromanagement of water at the building level as in the case of most residential universities and college campuses in India. This use of IoT has increased effectiveness, brought in efficiency to the system and improvements to the water distribution process, and decreased the water loss during the distribution process [28, 29].

13.3.4 Benefits of Using IoT and Traditional Knowledge in Water Management

There is a considerable amount of literature on traditional water management and IoT technology, but very few talk about integrating sustainable use knowledge. This section lists the various benefits of using IoT and traditional knowledge in water management in the Indian context. The reason for city administration for not being able to upgrade the existing infrastructure is mainly that the city municipal corporations are not able to generate enough money; with the use of IoT technology, the city will be able to detect leaks and excessive use/waste of water due to illegal connections and will also have a set mechanism for revenue collection [16, 30]. This will lead to the improvement of services and better management of wastewater. Thus, IoT’s foremost benefit in water supply monitoring is surveillance and detection, consequently saving valuable resources, person-hours, and finance. This method is a reinvention of a traditional concept where water tanks and wells were part of state or temple complexes and monitored vigilantly. Researchers have also noted that the local ecosystem can be re-established with water savings to improve overall human quality of life [5, 31]. The depletion of water resources and drying up of the natural channels have entirely shut off the natural drainage system and, in turn, increased the risk of floods, stressing the importance of managing stormwater [17, 32]. Proper and efficient water management will gradually recharge the water bodies, rejuvenate the natural drainage paths, and decrease disaster risks. This requires technology-assisted real-time monitoring of watershed drainage patterns and protection from further disruption in natural water recharge. What was an embedded feature of reverence needs to be reinvented through IoT and incorporated into best practices.

The traditional Indian water management methods like use of wells, step-wells, distillation process, sedimentation process, rainwater harvesting, and using wastewater for kitchen garden are some of the methods which are still in use but are not able to meet the individual, family, or community demands for which they are designed and thus people are relying on the municipal connection which again is not compelling enough [21, 33]. IoT technology can efficiently address this gap, but presently it is only predominantly used in the municipal water supply system to measure household water usage and generate bills. The technology can help identify the areas where water is lost in the traditional systems and can be used to optimize the overall traditional water management process [8, 34, 35]. Further, IoT can detect the overuse or nonuse of resources and strategies can be developed accordingly.

13.3.5 Role of Community in Resource Management and Sustainability

Community plays an essential role in the management and sustainability of water resources. It is mainly through the community that the knowledge is transferred from one generation to another. The elderly play a critical role in the overall process of knowledge transfer and are considered the traditional knowledge hub [21]. Their contribution is immense as most of the knowledge is based on experience over the years. Since the local people are more aware of a particular geographic location's intricacies, the indigenous knowledge is based on the harshest of the crisis and reduces the disaster risks to a great extent. Kumar et al. [12] strongly support integrating the local community in water management development program discussions as they will bring in the angle of disaster reduction among many other important insights to the traditional water management system. Because of the strong community culture, the traditional knowledge system survived even though this knowledge system was not given due importance postindependence and is also not well documented [34].

The reason for dropping the traditional water management system was due to the water wastage during the process. To make the water management process sustainable, city planners and managers should look for ways to decrease water wastage and decrease the overall water demand [10, 29]. This becomes challenging for a country like India, with large population size, and the level of technology and management measures are not adequate due to insufficient financial resources [36].

Pingale et al. [37] suggested that in order to have a more sustainable water management system, the urban policymakers and the municipal corporations need to drop the present inefficient method of water supply, that is, to take water from the source, make it usable, use it, and then finally dispose of it. The study suggested that a circular economy approach should be used to make water management sustainable and suggested that instead of disposing of the water, there should be a strategy to reduce, recycle, recover, and reuse the used water [37].

13.4 Study Area

The AMRUT scheme has 500 Indian cities and has included all twelve identified cities under the National Heritage City Development and Augmentation Yojana (HRIDAY) scheme. The cities selected under the HRIDAY schemes have vibrant cultural heritage, namely, Amaravati, Gaya, Dwarka, Badami, Puri, Amritsar, Ajmer, Kanchipuram, Velankanni, Warangal, Mathura, and Varanasi. The scheme's objective is to improve the city's existing infrastructure, make it barrier free, restore and improve the city image, and conserve the city's rich heritage.

The reason for selecting the HRIDAY cities in this study is because a city cannot move forward in the long run without strengthening the water infrastructure and making policy-level changes for water-related challenges. The HRIDAY scheme is again centrally sponsored, and thus the policy-level suggestions and planning interventions can be implemented at an accelerated rate. The scheme's objective is to plan and design heritage-sensitive water management plan keeping in mind the delicate nature of the city's core area. These cities also experience a high number of domestic and foreign tourist visits, thus adding pressure to already limited water resources.

Eleven out of twelve selected cities have more than a million population, with eight cities having a population between two and four million. The city with the least population is Dwarka, Gujarat, with an estimated population of more than 750,000. The city with the highest number of people residing, with a population of nearly 4.4 million, is Gaya, Bihar (Fig. 13.1). Uttar Pradesh and Tamil Nadu are the two states which have two cities each in the HRIDAY scheme. Gaya is known as one of the important Buddhist pilgrimage places. All the cities have their mentions in the ancient Hindu mythologies and are known for their rich cultural and traditional heritage.

Table 13.1 shows that all the twelve selected cities are along major rivers in India or have access to essential lakes as in Ajmer city. The quantity of water available in these cities is not an issue, but the water quality and how the water is managed and distributed are areas of concern. It is worth noting that this problem needs to be handled carefully because of the city core's heritage importance and delicate nature.

13.4.1 Water Problems in the Selected Cities

In the selected cities, tourism activities, significant economic and cultural activities, rural to urban migration, constrained city core, and presence of unauthorized settlements and slums are the significant reasons for depleting water resources. Heena and Rai [15] noted that the ever-increasing population is further increasing the gap between the supply and demand of water. The problems are aggravated due to the poor management of administrative officers [33]. Urban water planning in most cities is not futuristic and has failed to forecast the demand that may arise due

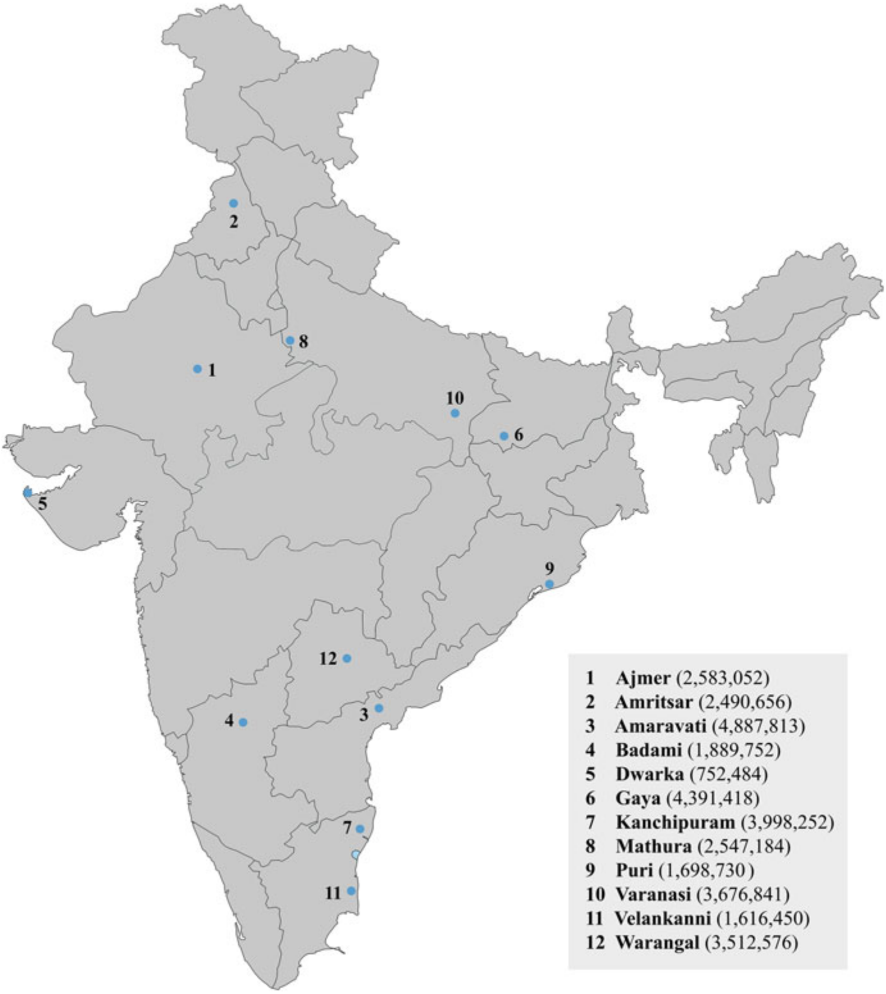

Fig. 13.1 Location of the selected cities along with the population it is catering to. Data: Census 2011

to population growth and floating population [10, 38, 39]. Another important reason for water scarcity is climate change [5].

Water disputes between communities have also halted many development-related projects in the selected cities [40]. Due to these disputes within the community and the gap between rich and poor societies within a city, there is an imbalance in water distribution [15, 40]. Heena and Rai [15] further observed that high-income groups consume considerably more water than the low-income group communities. Nandimandalam and Reddy [32] observed that due to the multiple uses of the limited

Table 13.1 Major sources of water for the selected HRIDAY cities

SN	HRIDAY city	Lake water source	River water source
1	Ajmer	Ana Sagar LakeFoy Sagar Lake	Luni River
2	Amritsar		Ravi RiverBeas RiverUpper Doab Canal
3	Amaravati		Krishna River
4	Badami		Krishna RiverMalaprabha
5	Dwarka		Gomti River
6	Gaya		Phalgu River
7	Kanchipuram		Palar RiverCheyyar River
8	Mathura		Yamuna River
9	Puri		Mahanadi Basin
10	Varanasi		Ganga River
11	Velankanni		Cauvery River
12	Warangal		Godavari RiverKrishna River

water source such as public, industrial and commercial use, and irrigation purposes, a water management plan is urgently needed for every Indian city.

Depletion of groundwater and unavailability of a mechanism to recharge groundwater at the desired scale are further opening up the cracks of water scarcity [41–43]. Though there is a ban on the use of bore wells beyond a certain depth, people are illegally using deep bore systems; this, along with improper rainwater harvesting, inadequate groundwater recharge, and problem of overdraft, will become a standard feature in every Indian city [32]. Below is the list of reasons for which almost every city is facing similar problems:

1. The water tax in India is set at a low rate and is highly subsidized. Thus, municipal corporations cannot generate an adequate amount of money to carry out the necessary development works because of low revenue generation. The municipal bodies are always revenue deficit and have to wait for funds from the center or state, even to carry out the regular maintenance works [44]. Because of the highly subsidized rates, people are not able to realize that water is a limited resource [15, 36, 40]. To make its importance and relevance felt, water tax must be levied at a higher rate.
2. Water loss is a significant challenge in every Indian city, regardless of its location. IoT sensors have been able to track the water pressure and flow at different nodes to check the water loss, but this technology up-gradation needs huge financial capital [31, 34, 36]. Without sensor-based technology, it is impossible to keep track of water loss at various city critical points. Though the process needs massive financial capital, corrective measures need to be taken. Cities worldwide have brought in more private investments to improve the water infrastructure; similar methods can be done in India [43]. The municipal corporations can also think of issuing municipal bonds, which will bring in the much-needed revenue [40].

3. Lack of autonomy and decision-making power is a significant setback for sustainable water management [4]. Many projects are delayed because of the existing lengthy procedures and unnecessary paper works. With more autonomy, municipal corporations can work independently and can get the projects cleared and completed within the sanctioned time frame [44].
4. Urban flooding is another problem faced by almost every city. The flooding is mainly due to the lack of proper drainage facilities and set mechanisms to mitigate such regular urban flooding.
5. The quality of water is at an unhealthy level for domestic use in many cities in India. This directly affects the health of the users and indicates the urgent need to bring in modern technology [6, 17, 29].
6. Surface water and groundwater contamination has been a significant challenge for every water resource department in the recent past [5, 16, 30]. Municipal corporations could not do much as these come under the jurisdiction of the state pollution control board. With increased autonomy, such problems can be managed better.
7. Though the water sources for the selected cities are lakes and rivers, there is a constant decline in the water level, which puts extra pressure on the existing machines and infrastructure, and it sometimes leads to system failure [32, 41].
8. The wastewater from domestic and industrial use further aggravates the problems by contaminating the surface water. A short-term solution to this problem is identified by Kakwani and Kalbar [31] and Starkl et al. [39] in improving the city's waste management.
9. Poor and not-well-thought-off urban planning is also a reason for poor water management in most Indian cities. Proper urban planning and water management plans can help cities meet the current and future water demands and manage the demands sustainably [1].

13.4.2 Integrating Existing Schemes, Programs, and Policies

Lack of proper coordination among the government ministries and departments results in inefficiency in water management. Though there is a strong need for water for both public use and irrigation purposes, water resources are not appropriately managed [19]. The major problem with this issue is the lack of clarity for the funding sources for various schemes, programs, and policies. The projects with only one funding source do much better than those sanctioned with state and central government partnerships. These issues are leading to delays in many important water development projects.

The existing levels of governance in India are shown in Fig. 13.2. As shown in Fig. 13.2, the organizational structure is excellent, but it needs more autonomy and decentralization at the lowest hierarchy level. Bassi and Kumar [44] suggested bringing in overall reforms in institutional, financial, managerial, and administrative departments of water management. They [44] further recommended decentralizing

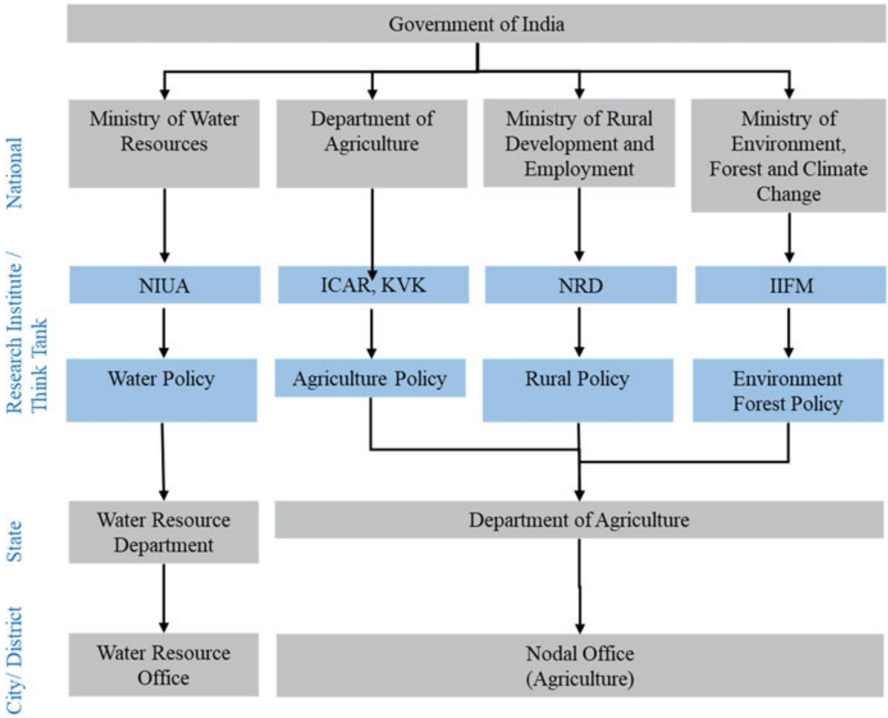

Fig. 13.2 Organizational structure of Indian water resource department

the organizations and giving more autonomy to the government institutions. Increasing the presence of the private sector and bringing in more community participation will be critical to sustainable development.

13.5 Discussion and Strategies

The importance of traditional knowledge and IoT technology and the benefits associated with their use were discussed in Sect. 13.3. Section 13.4 highlighted the problems associated with the study area and the government working framework. This section lists the problems identified and strategies to address the problems.

1. *Strategy 1:* Revisiting the process of rainwater harvesting using IoT. A city rainwater harvesting network can be created so that IoT sensors detect the areas with overdraft, and such areas can be given priority in water harvesting by directing more water.

2. *Strategy 2:* Timely cleaning of drains is crucial to reduce the risks of floods. During floods, water quality is at the most dangerous level, and such humongous water volume does not recharge the groundwater.
3. *Strategy 3:* Using IoT-based sensors to maintain the minimum water level so that the water bodies/sources do not dry up. This is needed as most of the natural running water paths are lost due to the water bodies' drying up.
4. *Strategy 4:* The 74th Constitutional Act of India gave extraordinary powers to the urban local bodies (municipal corporations), but the power transfer has not happened yet in the desired manner in many states, and there is an urgent need to strengthen the urban local bodies in India.
5. *Strategy 5:* At present, the citizens' water tax is not enough as they are not paying for environmental costs or giving any pollution fees. Unless there is a complete overhaul of the revenue generation model, water management and its related infrastructure development will not happen as desired.
6. *Strategy 6:* It is understood that water is an essential resource, and the government does not want to involve a private player, but the government can be more open to getting private investments. The private investments will help in the timely completion of development projects which are mostly delayed due to lack of clarity of funding.
7. *Strategy 7:* Government can further lease the cities to private companies to manage the city's water resources and manage water efficiently. Such practice will generate revenue, and overall water management will be the private companies' sole responsibility.
8. *Strategy 8:* Participation from the local community, especially the elderly, should be encouraged to bring in traditional water conservation knowledge. This traditional knowledge experience will help in dealing with water disasters.
9. *Strategy 9:* Human resource development is a vital aspect of any development. In the government setup, the departments that lack behind are the finance and the executive departments. With proper training and capacity building, these departments can work efficiently and coordinate in a better manner.

13.6 Conclusion

The importance of traditional knowledge cannot be underestimated. Many historic civilizations were located near a water body, and many times it gave them a strategic advantage over other civilizations. While there are many stand-alone exemplary examples of water management, there is a complete disconnect of such practices and literature. The study strongly suggests that such work's immediate documentation should be carried out and replicated in other locations with similar geographic characteristics with the government's help at local, state, and central levels. The traditional or indigenous knowledge system has been developed from the experiences and experiments of many centuries and should be implicated as they respond to the various contexts and have also survived many disasters. The present use of IoT is limited chiefly to the use of smart metering. The scope of IoT usage needs to be increased, and the necessary infrastructure development should be made.

The HRIDAY cities have cultural and historical importance and also have a very delicate city core. Proper care should be taken to upgrade the city water infrastructure. It is essential to involve all the stakeholders of the city during the development-related discussions. Also, the citizen should be made aware of the importance of water conservation. The study suggests that long-term solutions and strategies should be implemented rather than short-term strategies. Long-term strategies may require more time to show results but are sustainable and will show positive results to the local ecosystem in the long run. Administrative and managerial changes are needed, along with the need for capacity building and human resource development. Finally, a water tax needs to be introduced, and water should not be readily available at a very high subsidized rate. Else, the citizens fail to identify its importance, and we as a society might lose this precious resource that is vital for our survival.

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Chapter 14
X-IoT: Architecture and Use Cases for an IoT Platform in the Area of Smart Cities

Eldar Sultanow, Alina Chircu, Sergey Patsko, Pierre-Adrien Hanania, Sean Cox, Markus Stellwag, and Marie Jansen

14.1 Introduction

Throughout history, cities have defined the way societies and citizens live, interact, work, create, and consume resources. Large, dense, highly organized, and self-governing communities, cities have emerged thousands of years ago and have been gaining in importance ever since. As depicted by Jeremy Rifkin in "The Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World," cities now stand on the brink of a new historical transformation, driven by digital tools and channels [1]. Today, cities are an integral part of our connected

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world, housing more than half of the world's population and increasingly adopting innovative technologies to improve the quality, efficiency, and competitiveness of urban environments. Remodeling the elements of city life and advancing qualities of cities for learning, innovation, doing business, and creating jobs are crucial qualities for location competitiveness, growth, and investments. This makes the European Union, for example, pay particular attention to making urban areas smarter and more sustainable [2, 3]. This is the dawn of the new era of smart cities, as defined by the United Nations Economic Commission for Europe: *"A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness while ensuring that it meets the needs of present and future generations with respect to economic, social, cultural and environmental aspects"* [4].

Smart city definitions from the existing academic literature emphasize different facets of the concept: improving people's quality of life, enhancing interactions among businesses and citizens, improving government and participation, and optimizing transportation networks and resource utilization [5]. Common among the variety of definitions of a smart city are the concepts of data-driven improvements in living standards, integrated information and systems, better awareness, and maximization of sustainability and environmental conservation [6]. The practitioner perspectives on smart cities contain similar definitions—with particular emphasis on improving the social, environmental, and infrastructure aspects of a city, including citizen services, public security, healthcare, transportation and mobility, electric, water and waste management, and sustainable development [2, 3, 7], as Fig. 14.1 indicates. The development of smart city solutions is supported by the emergence of new ICTs including, among others, the Internet of Things (IoT) for data collection through sensors, cloud computing for storing and processing big amounts of data, and artificial intelligence (AI) for deriving insights from data [5, 8, 9].

In this chapter, we discuss smart city problems and solutions as well as technical implementation challenges and best practices using insights from the practical work several of the chapter co-authors are involved in every day as well as from relevant academic literature. We then propose that a general-purpose practitioner-developed IoT ecosystem solution, X-IoT [11], can be used to support smart city development.

This chapter is organized as follows. Section 14.2 explains how smart city IoT data can be captured and processed using a data and AI platform. Section 14.3 describes typical technological challenges and best practices for implementing smart city solutions, and describes a reference architecture for a smart city platform. Finally, Section 14.4 provides conclusions and future research directions.

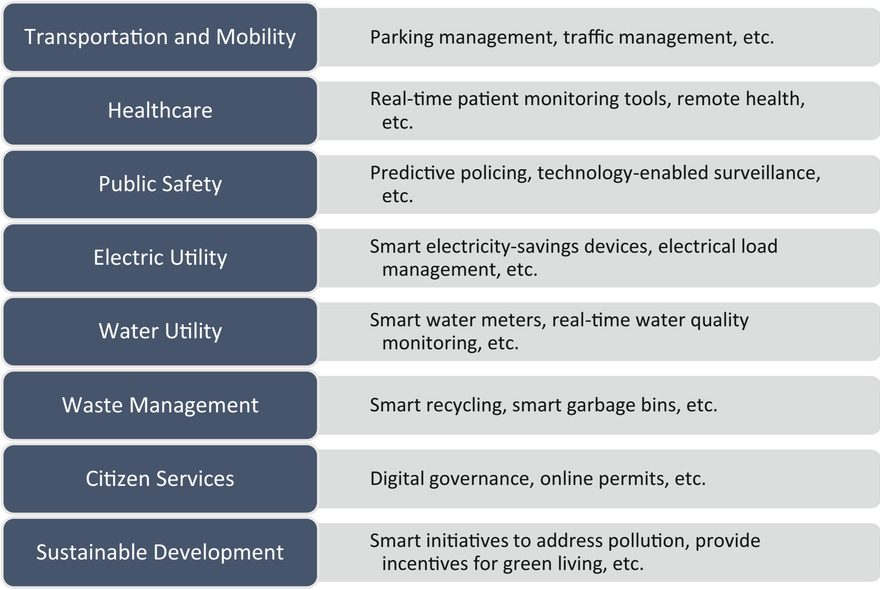

Fig. 14.1 Smart city initiatives (source: [7, 10])

14.2 Role of Data and AI Platform in Collecting IoT Information in Smart Cities

14.2.1 Literature Overview

Smart city solutions are built using a variety of technologies [8, 9]. A keyword analysis of over 3500 articles on smart cities published between 1996 and 2018 reveals that IoT is the most central concept in the literature, followed by big data, analytics, security, privacy, as well as cloud computing, among others [12]. Sensors and sensor networks, as well as other smart objects connected through IoT, help collect a variety of data from their environment. Motion, position, and parameters such as temperature, pressure, light, sound, speed, and many others can monitor buildings, vehicles and transportation networks, resource consumption and its environmental impacts, and human behavior and health [13, 14]. Edge computing enables processing of contextually rich local data in near real time. Cloud computing (together with related technologies such as fog computing or cloudlets) provides the on-demand infrastructure to analyze data and process transactions. And AI and related analytics technologies—especially those designed to handle big data volumes—extract patterns and make recommendations for improving the operational efficiency of smart cities as well as the effectiveness of offering their services to citizens [8, 9, 15]. Open data portals allow smart cities to share data with businesses and citizens to support problem resolution [13, 16]. Marketplaces where data and services can be traded can further ensure that the smart city services are useful, of high quality and competitively priced [8]. Geospatial technology (GPS, geographical information systems, remote sensing, and Internet mapping) can support collaboration and coordination among different smart city elements [9]. The data can be secured and authenticated with customized security mechanisms or even with blockchain technology [9].

Data enables cities to become smart—or, in other words, to be ubiquitous, digital, information and knowledge driven, and intelligent [17]. Smart cities create big data—data that is large in volume, high in variety, and fast moving and growing. Despite its complexity, proper harnessing of this big data, however, can improve city governance—by increasing efficiency and transparency, reducing hassles for citizens, increasing timeliness, and decreasing errors and costs, and even leading to sustainable economic development [5, 17].

One of the most promising technologies for smart city solutions is AI. In a recent literature review of 79 AI in smart city articles, the authors found that the numbers of academic publications in this area are increasing exponentially, with healthcare, transportation, and resource and utility management applications being the most popular [18]. A similar systematic review of 39 data mining and machine learning (ML) papers identified predictive analytics as the most common technique and the smart mobility and smart environment areas as the most popular [19]. Emerging AI techniques such as deep learning can be used for extracting insights from data in a variety of areas such as urban modeling, infrastructure management, and governance, among others [20].

According to these studies, AI can support and improve decision-making based on accurate and detailed data, provide insights into complex and often time-sensitive problems, improve monitoring levels as well as improve economic outcomes and relationships with citizens, and reduce the city's environmental impact [18–20]. In smart city contexts, data also comes from multiple sources in heterogeneous formats [21], and AI can help make sense of this complexity and derive new insights. For example, key performance indicators from multiple governmental agencies can be used to predict variables of interest, such as crime, which in turn can lead to inter-agency collaboration for a coordinated response that leads to better efficiency and optimal services in multiple areas [22].

However, AI technology also presents a number of challenges, including barriers to data collection, poor design, complexity, inflexibility, lack of explanations, and most importantly ethics (both in terms of design and use) [18]. There is a need to develop new approaches that enable both big and fast data analytics and to design smart devices capable of running complex AI algorithms at the edge [23]. Security and privacy also remain ongoing concerns, especially for mobile devices used to interact with a smart city infrastructure, the infrastructure itself (the collection of specialized hardware and software that collect and process data), and its power grid, as well as for specific applications such as healthcare which are subject to additional security and privacy rules [6, 23, 24].

To capture the complexity of deploying technology in cities, researchers have proposed using systems theory to build smart city models. Some models depict a smart city environment consisting of various systems focused on transportation, energy, etc., which are in turn composed of networked sub-systems (such as vehicles and infrastructure for transportation, or power plants and electric grids for energy, etc.). This allows for simulating the behavior of the systems and sub-systems in light of varying smart city strategies and selecting the best configurations and technologies for actual implementation [25]. Other models view smart city development from the lens of (a) inputs (resources) such as human resources and entrepreneurship, data, ICT infrastructure, and financial resources; (b) transformational processes such as management of data, infrastructure, knowledge, innovation, and financial assets and governance and leadership through relationships among governmental entities, coordination among actors, and leadership capabilities; and c) outputs, such as applications developed (mobility, energy, healthcare, etc.) and externalities (environmental sustainability, economic sustainability, and quality of life, among others) [12].

14.2.2 Practitioner Context

A smart city with a population of one million inhabitants may generate 200 million gigabytes of data every day [26] originating from different smart city initiatives: healthcare, public security, energy, water and waste services, as well as transport and weather forecasting and monitoring. The data is generated in structured and unstructured formats, from sources ranging from IoT sensors to surveillance cameras to patients' data in natural text or voice.

Analytics applications that create value for smart city citizens require data ingestion, data cleaning, data modeling, and often combining data from different domains (i.e., electricity demand, generation capacity, and weather conditions in order to perform electric power grid balancing). Data should be securely transmitted and stored. The solution should allow for possible interruption in network connectivity (queuing of messages), data retrieval by analytics applications, and data audits or backtracking. Given the size and the speed of the data, as well as the need to apply complex AI and ML models, smart cities need to make use of cloud computing and storage for data processing [5, 8, 9]. Based on Capgemini internal research, the path from data source to analytics insights for the citizens, as reflected in practice, is depicted in Fig. 14.2.

In each step of this journey, the data should be secure, accessible, and trustworthy, allowing for transformation, data quality checks, data pipeline, and analytics orchestration. The best practices of implementing the data journey in real-world projects [27, 28] suggest that this is possible by deploying a next-gen data and an AI platform based on a reference architecture with five main layers, all underpinned by secure data:

1. "Platform foundation: hybrid cloud platform implementation, cloud strategy and end-to-end provisioning, and platform infrastructure management

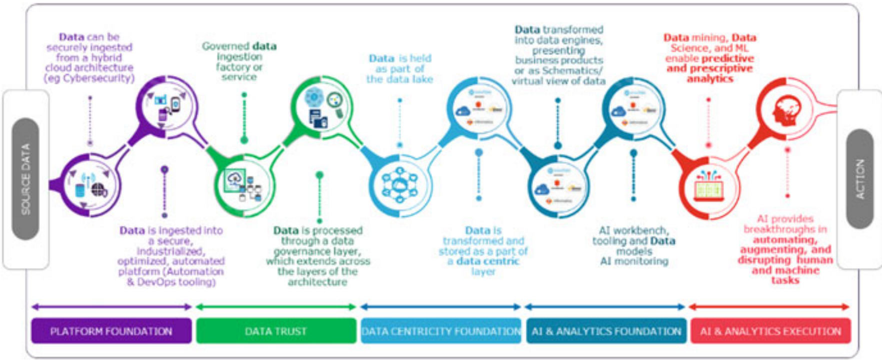

Fig. 14.2 The journey from data acquisition to action (source: [27])

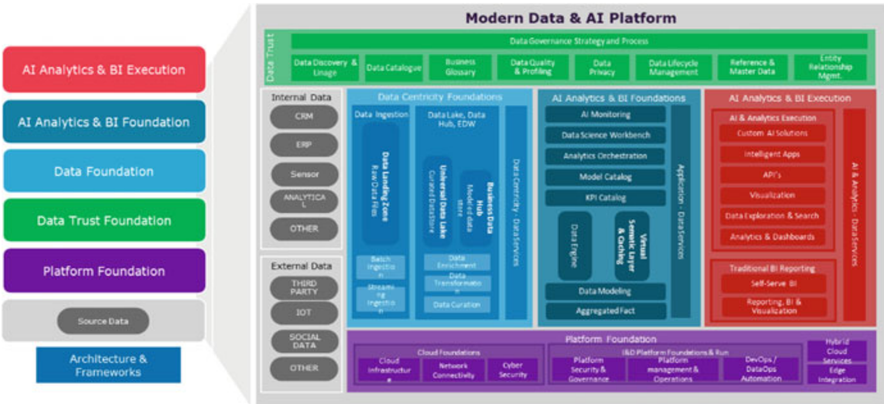

Fig. 14.3 Five-color structured architecture for modern enterprise data and AI platform (source: Capgemini)

2. Data trust: accelerators, frameworks, and services to define and implement data life cycle management.
3. Data-centricity foundation: capabilities for data preparation, transformation, and storage.
4. AI and analytics foundation: capabilities to design and deploy AI/ML services supported by the data-centricity foundation.
5. AI and analytics execution: capabilities to deploy and execute custom AI and BI applications in production at scale [28].

This modern data and AI platform emerging from Capgemini research, depicted in Fig. 14.3, allows for data centricity, bringing together technology, people, and processes to govern, utilize, and extract value from the omni-structured smart city data. In future sections, we will take a deep dive into the business, analytics, and technological aspects of the platform implementation, giving priority to the most important data generated in the smart city environment: IoT data from sensors. However, before considering the technological aspects of the platform architecture, we must first understand the business applications of a smart city and the corresponding data processing requirements, as described in the following sections.

14.2.3 Safe, Healthy, and Livable: Smart City Solutions and Problems They Solve

Smart city designs vary depending on the needs of a city's inhabitants and the city's priorities. These needs and priorities result in solutions for emergency services (medical, police, and firefighting), healthcare, public transportation, public asset management (such as roads, parks, museums, etc.), waste management, public administration (inclusive of permits and licenses), and utility networks (such as water, gas, and electricity supply networks), as well as smart city initiatives for sustainable development [7]. Some solutions could be built from the perspective of a green smart city in order to minimize negative environmental impacts such as pollution or wasted resources. Other solutions could emphasize seamless mobility and minimize traffic or transportation availability issues [10]. And other solutions could focus on ensuring citizen's safety and minimizing their exposure to and fear of crimes. Surveys conducted by the Capgemini Research Institute indicate that city dwellers have several main concerns: cultural and personal, financial, health and sustainability, as well as infrastructural issues, as depicted in Fig. 14.4 [7, 10]. Not surprisingly, healthcare, public security, utilities (electric, water), waste management, transportation, citizen services, and sustainable development are the areas where smart solutions are being developed to address citizen needs [5, 7, 10, 18, 19].

At the center of this journey to build a smart urban environment lies one very important lever to activate: data. Just as in other fields of digitized services, the ability of cities to make effective use of their data and to build themselves as a data-powered structure (cf. Figs. 14.2 and 14.3) is the key to the promises of smart cities—whether at an airport, a hospital, or the city center. Once the smart city has determined its data governance and organized its data space, AI and analytics can be fostered in various ways. Depending on the needs of a particular city, the following four fields for operationalized AI can be established:

1. Intelligently automating the city's processes: With intelligent process automation and an end-to-end view on case management, the city's most trivial processes can be automated, giving citizens and city officials more time with more complex tasks.
2. Augmenting the interaction with the city's actors: AI can enhance citizens' interactions with security authorities (for reporting and resolution of incidents),

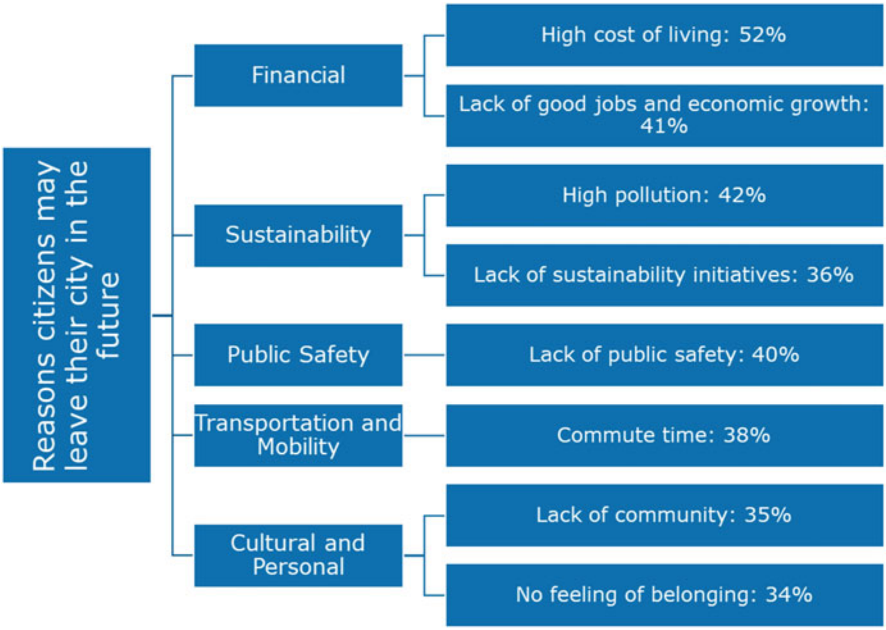

Fig. 14.4 Reasons for citizen to leave their city (source: [7, 10])

public servants for administrative queries, or others during daily life activities in the city.

3. Detecting anomalies: A city can leverage AI and analytics to more quickly detect situations of danger with its infrastructure, public safety, and real-time events.
4. Helping in the decision-making process: With its ability to identify patterns, predict occurrences, and prescript changes, AI technology can be an enabler for better informed decisions at the city level (Table 14.1).

14.2.4 Real-Life Implementation Examples

When Dijon announced its strategy "OnDijon" in 2018, the famous newspaper Le Monde described the city as the first smart city in France [29]. Since then, the city has lived up to this label and deployed an ambitious plan built on the goal to go from six separate data centers to only one, the central command center. The Dijon smart city initiative relied on the federation (or integration) of actors (industry, citizens, and regional authorities) and data (such as water, electricity, and mobility data among others) to reflect the real-world environment. The overall approach was based on a data platform and use cases à la carte: streetlights, traffic lights, parking spots, CCTV cameras, buildings, and air quality monitoring systems were

Table 14.1 Four fields for operationalized AI for different city needs

AI fields for a more ...	Greener city	Safer city	Inclusive city	Seamless city
Intelligently automating administration processes	Automated energy utilization alerts	Automated public safety alerts	Customized processes for different citizens' needs	Public transport schedules and real-time updates
Augmented interaction	Chatbot for queries on air quality monitoring	Mobile app for safety issues	Multi-language communica-tion/translation	Tourist app about tailor-made flow journey
Detecting anomalies	Garbage detection	Acoustic gunshot detection	Detecting inequalities in access to/utilization of city services	Detection of fallen trees on trackways
Helping decision-making process	Optimized traffic flow	Predictive policing	Optimized urban planning for disabled people	"Best way to work"—Driving app based on personal preferences and real-time traffic

all digitized. Additionally, a mobile app was developed for citizen communication (incidents, commuting to work). As a result, OnDijon created energy savings of 65% and infrastructure maintenance cost savings of 50% [30, 31].

From the perspective of a safe smart city, Traffic Agent [32] showcases the ability to empower the most vulnerable part of the population, such as children, and to turn them into connected and protected smart citizens. Traffic Agent is an app in Norway which enables primary school children to map their route to school in order to register positive and negative spots along the way. Thanks to the kids' digital feedback, the city receives the necessary intelligence to plan for further measures regarding mobility and safety.

From the perspective of green smart cities, Singapore has leveraged IoT and sensing to transform the Tengah forest territory [33], enabling smart lighting and helping generate energy savings of more than 40%. Working with an integrated environmental modeler and creating an insight-driven platform for urban planning, the Singapore Government's Housing and Development Board implemented its green city purpose around four pillars [34]: smart planning and design of buildings for optimal wind flow and minimum heat generation, smart energy management for optimal energy use and increased energy conservation, smart lighting adjusted based on real-time traffic analyses, and automated waste collection using high-speed air technology.

From the perspective of more connected smart cities, the city of Chennai has tackled the issue of long searches for a parking spot, which slows down the traffic and also harms the environment due to increased pollution. By developing a smart parking app connecting over 4300 parking spaces in 80 areas throughout the city, the city created a solution that minimizes wait times and offers a seamless citizen experience, including cashless payments and ability to find the appropriate parking slot before even leaving home [35].

Table 14.2 summarizes a selection of smart city applications around the world. In these real-life examples, federating the relevant stakeholders and data was key to success. In regard to the latter dimension, to build a smart ecosystem means to assess all aspects of data, along all stages, from the solution design through development, operations, and end customer use.

14.3 Typical Technological Challenges and Best Practices of Smart City Implementations

14.3.1 Data Availability, Open Data, and Data Sharing

Open data is data that is available online, in its entirety, in a machine-readable form, and for universal use and distribution [16]. Without open data, there is no smart city. Making collected data public and sharing it within and across the boundaries of smart cities are an integral part of developing and improving smart cities [13, 16]. It allows for building trust, making cities' undertakings more transparent, and interacting with citizens more efficiently. Real-time data collection can provide value for both the city and its citizens, help tackle societal and environmental issues, and support sustainable economic growth [36–38]. In addition, the data being used needs to be easily accessible (preferably already via open APIs), in high quality, and have informative metadata and permanent availability (permalinks, and up to date). Examples of such open access are the European Data Portal, which provides easy access to all data published within the union, and the European Urban Data Platform [38]. Cities like Dublin in Ireland, Amsterdam in the Netherlands, or Louisville, KY, in the United States have all implemented open data portals [36–38].

Despite its clear value, many obstacles to open data remain, including concerns regarding ownership and privacy, lack of high-quality data, or political and regulatory burdens [39]. As a result, "data openness" in smart city applications is a multidimensional concept that is just now starting to be investigated. For example, in the context of air quality, data openness has been defined as a combination of availability of real-time data and historical and forecast data, centralization of data, and connections with other related data sources (such as meteorological data) [39]. Adopting this approach indicates that different smart cities exhibit different levels of openness, and highlights best practices with respect to data centralization, data delivery, and useful developments (such as mobile applications, forecasting, or sensor deployment) [39].

Even when open data exists, it is usually siloed to one governmental agency. Better smart city solutions will need data orchestration—the coordination of initiatives

Table 14.2 Examples of smart city applications (based on [36–38])

Name of application	Location	Description of application	Smart city area
CitySDK	Amsterdam, the Netherlands, and other European cities	Toolkit for developing smart city digital services	All smart city areas
Dublinked	Dublin, Ireland	Open data portal	All smart city areas
City enabler for digital urban services (CEDUS)	Trento, Italy Malaga, Spain Rennes, France	Open data portal	All smart city areas
Open data portal	Louisville, KY, USA	Open data portal	All smart city areas
SacPark	Sacramento, CA, USA	Parking mobile app	Transport and mobility
Bike use data and maps	San Francisco, CA, USA	Bike traffic monitoring	Transport and mobility
GXBus	Montevideo, Uruguay	Route mapping application for public transport	Transport and mobility
Open transport net	Multiple cities around the world	Road conditions and traffic monitoring	Transport and mobility
Unmanned traffic management initiative	Kansas, KS, USA	Drone-based traffic monitoring	Transport and mobility
BlindSquare	Locations worldwide	GPS navigation for visually impaired individuals	Transport and mobility
Check my barangay	Philippines	Participatory governance initiative	Citizen services Sustainable development
InfoAmazonia Colombia	Colombia	Deforestation monitoring	Citizen services Sustainable development
Poverty in NYC	New York, NY, USA	Map/open data	Citizen services
Savvy citizen alerts	Richland, PA, USA	Location and smart device data integration	Citizen services
Energy block	Copenhagen, Denmark	Renewable energy sources	Sustainable development
Baltimore open air	Baltimore, MA, USA	Climate monitoring and analysis	Sustainable development

across many government entities in order to achieve a collective goal through data openness and supporting elements [40]. Data orchestration includes (a) openness—from a technology perspective (open interfaces, standards, and technologies) and an organizational perspective (open data portals, community sharing of plans and outcomes, exchanges with businesses); (b) diffusion—learning and knowledge mobility (small teams, ad hoc structures, and on-demand access to skills and expertise) and legitimacy and trust building (agile development, problem-based procurement, and pilot projects); and (c) shared vision—through governance tools (wider ecosystem values, wide representation on boards, incentives, and defined deliverables) and central coordinating structures (support for core capabilities and co-design) [40].

14.3.2 Data Governance and Life Cycle Management for Smart Cities

Smart cities generate huge amounts of data that needs to be managed using appropriate data governance processes and guidelines (the "who" of how data is managed, rather than the actual implementation of data-processing systems and processes) [41]. Data governance for smart cities needs to cover relevant data collection and generation, data management, data sharing, and data use, as well as legacy data and stakeholder collaboration issues. Overall, the smart city data governance approach needs to be responsive and collaborative in order to reflect the views and needs of all stakeholders—but also integrated in order to allow for broad data sharing. In addition, local data governance, even if part of multilevel governance structures, is best for ensuring relevant, understandable, and timely data [41].

Smart cities also need to use a life cycle management for data, services, and underlying components. Smart cities are ecosystems of stakeholders, information flows, systems, and processes, with both digital and physical components. At its core, such an ecosystem has the heterogeneous, uniquely identified, and connected objects. The principles of life cycle management can be applied to both the tangible and intangible components of this ecosystem [42]. From a product (tangible or intangible) perspective, life cycle management needs to focus on beginning-of-life activities (imagine, define, and realize), middle-of-life activities (use and support), and end-of-life activities (retire and dispose). From a service perspective, life cycle management needs to focus on beginning-of-life activities (ideation and requirements), middle-of-life activities (design, implementation, and testing), and operations and end-of-life activities (delivery and evolution). Finally, from a product-service system perspective (i.e., from the perspective of an extended product consisting of a complex combination of tangible and intangible elements), life cycle management needs to focus on the same activities as in service life cycle management [42], supported by product life cycle management activities as well.

Several characteristics of smart city life cycle management stand out. First, all components of the smart city ecosystem can be covered by life cycle management, but since they are developed and implemented independently and at different times, they will be in their own life cycle; as a result, "the life cycle of smart city is a life cycle of life cycles" [42]. Second, the design of the smart city components should allow for "loose coupling, modularity, composability, scalability, interdependency, and dynamic complexity" in order to support repurposing and reusing of the smart city components [42]. Third, data can be generated and used across different life cycle phases (in-work, in-process, in-review, released, as-designed, as-planned, as-built, as-installed, as-maintained, and as-operated) of the interdependent systems of a smart city [42]. Fourth, data can belong to multiple smart city ecosystem components (as a result of repurposing and reusing), and rights to access, create, modify, approve, and promote data may change during each component's life cycle as well [42]. Fifth, data is subject to a variety of policies and regulation related to security and privacy throughout the life cycle [42]. Sixth, smart city ecosystem components can have several versions, variants, or options due to modifications or upgrades performed during the life cycle [42]. Seventh and last, but not least, processes to report problems, make changes, and notify relevant stakeholders are needed throughout the life cycle [42].

14.3.3 Operationalization of Analytics and AI for Smart Cities

The implementation of the ambitious Dijon smart city plan in France uncovered core obstacles in obtaining the value from analytics use cases which are described in the following section.

A wide variety of stakeholders create an essential difficulty of establishing connectivity with each party involved, and even organizational alignment slows down almost any analytics application development that requires multiple data sources to be leveraged. Data from citizens to police to parking lot operators and beyond leads to hundreds and thousands of data sources that need to be connected in order to orchestrate the analytics. For instance, forecasting a parking lot availability will require to ingest the data of different types: the parking spot IoT sensor (time series data) and/or CCTV cameras (images and video streams), current weather conditions (time series) as well as weather forecast (geospatial and structured data), and any public events scheduled close to the parking location. HTTP, TCP, Modbus, or IoT protocols like MQTT can be used to connect the smart city devices. Generating RESTful API endpoints for accessing the data looks almost as the only viable path to establish data pipelines.

Data models and data management practices across such a big variety of stakeholders differ tremendously. Establishing the data connections with multiple organizations does not necessarily mean that the data can be immediately made available for analysis. It is unrealistic to establish any type of unified data model and data governance operations for the siloed and heterogeneous data sources that exist in smart city domains. Several prominent international organizations have been developing standards for smart city applications and data, but such work has just started, and we cannot expect a fast adoption of the proposed standards. Lai et al. [6] provide an overview of several important standards for smart cities. They note that, according to the IEC (International Electrotechnical Commission), there are over 1800 standards impacting smart cities, and that new standards specific to smart cities are also being created. For example, the International Organization for Standardization (ISO) introduced the ISO 37122:2019 (Sustainable Cities and Communities—Indicators for Smart Cities) standard comprising indicators for a variety of smart city domains. The World Council on City Data is another initiative which uses standardized city data to support smart city developments through the ISO 37120 (Sustainable Development of Communities—Indicators for City Services and Quality of Life) city data standard. And the International Telecommunications Union (ITU) overseeing standards for global communication and connectivity established Study Group 20 to develop international standards for IoT, smart cities, and communities covering the data layer, communication layer, and sensing/IoT layer. Finally, the Institute of Electrical and Electronics Engineers (IEEE) has launched the Smart City Planning Guide IEEE P2784 as a framework for smart city processes and technologies to allow for agile, interoperable, and scalable analytics solutions [6]. IEEE has further detailed it for specific smart city domains of smart grid, smart energy, smart health, smart mobility, smart education, and smart governance [6].

Given a slow speed of data standard adoption, real-life use cases utilize extract-load-transform (ELT) framework in order to ingest the data in its raw format into the data landing zone and store it in the unchanged form for further processing. Transformations most often will be designed based on a specific analytics requirement allowing for agile use case development and implementation. In case of another analytic target, the same raw data store can be reused, but transformations may change, adding more data pipelines and complexity on the one hand, while providing flexibility to data scientists and software developers on the other hand. Data quality and data trust can be ensured by additional checks and rules both during the data ingestion into the raw data store and during the transformation of data into the target data model.

API availability exposes data to security risks. To control API access and exchange authorization tokens, JWT (JSON Web Token) is widely adopted by the developers of modern applications with microservice architecture. JWT has its own vulnerabilities (such as the ability to copy a JWT string of characters and use it in an auth header). At the same time, authors capture another important security topic of smart cities related to the governance/access control that should be established for such a federated model of data exchange [43]. This can be addressed by setting up proper identity management components of the data and AI platform used for data ingestion, analytics orchestration, and execution.

Smart city use cases can often be solved with AI algorithms across multiple domains: anomaly detection with deep learning in time series IoT data or in video streams, augmenting the interaction with the city's actors through natural language processing (NLP) or voice recognition, routing algorithms, or geospatial analytics. Modular microservice-based architecture of smart city applications with data APIs is considered a mainstream approach for solution development. The feasibility of developing atomic services that are packaged as stand-alone services and can be reused by other cities has been demonstrated as part of a project covering 27 different cities and 35 different city services in Europe and South Korea [44]. The ability to reuse application in different locations/cities is one of the benefits of such

Fig. 14.5 Scaling AI (source: [45])

an approach. This leads to an essential requirement of cloud-based orchestration of analytics or data-processing modules into a bespoke use case solution, allowing to access open-source libraries or commercial analytics APIs. According to Capgemini Research Institute analyses, analytics and AI models for a variety of domains, including smart cities, can only be deployed in production at scale when the right IT infrastructure, tools, and processes are in place [45], as depicted in Fig. 14.5.

Even though a custom machine learning model for a point solution (i.e., a parking lot occupancy forecasting as mentioned above) could be developed by a data science team provided with historical data, retraining of such a model for many other locations could be of challenge. There might be thousands of parking lots in a city, and each of them may require organization of a separate data pipeline for data ingestion and transformations, as well as a new ML model deployment. Exploring historical datasets for each location and evaluating models to verify the applicability of it for a specific parking lot can be a resource-consuming and cumbersome exercise. Moreover, even if this step is successful and the ML model can be moved to production environment, monitoring the incoming real-time data drifts is necessary to ensure the required model accuracy. As such, automation in data operations (DataOps) and machine learning operations (MLOps) is a prerequisite for smart city analytics at scale. With DataOps, all data ingestion and transformation operations are considered as separate jobs that can be scheduled, monitored, and resolved. MLOps, in turn, do the same with machine learning development cycle: from training dataset version control to model evaluation and retraining, allowing users to trace back from model scoring results to initial historical subset of data used in training AI. Bias detection, fairness in the data, and model explainability at scale are all possible only with MLOps in place. Operationalization of DataOps and MLOps is achieved with different open-source or COTS tools available, with big cloud vendors offering their own cloud-native solutions for the same purpose. Given that administration of such tools is itself not an easy task for IT organizations, our experience demonstrates that leveraging a data and AI platform that has a consistent way of managing DataOps and MLOps instruments significantly reduces the effort required to develop and maintain smart city analytics applications.

Finally, flexibility in computing and storage resources is important for running smart city application in real time. This can be achieved with cloud resources that enable high data-processing throughput as well as analytics execution, at scale, and at a reasonable cost. The use of cloud is inevitable, also given the upcoming 5G networks. Some of the smart cities use cases, such as autonomous driving or safety applications, which will require data preprocessing and analytics execution at the edge, but even in this case, cloud resources remain the core infrastructure enabler as all edge devices will require remote management and firmware upgrades.

14.3.4 Reference Architecture for Data and AI Platform: X-IoT by Capgemini

Given the preceding considerations, the implementation of smart city solutions requires a technical platform capable of supporting the entire smart city ecosystem and the data it generates in a reliable and secure manner and of enabling execution of AI and analytics processes. An example of such a platform is X-IoT, a general-purpose, configurable, and secured end-to-end IoT ecosystem solution developed by Capgemini in collaboration with Intel and available for deployment in a variety of industries [11].

The platform is characterized by scalability, business agility, and continuous innovation potential (due to its design using proven standards, supporting millions of global connections of devices, delivering edge-to-cloud data, and reduced complexity) [46]. X-IoT also offers modularity and flexibility (such as choosing the cloud provider—private, public, or hybrid, integrating third-party providers, or running analytics from multiple sources) [46]. It also offers value-added digital services such as end-to-end cloud-connected digital services (including IoT strategy, innovation portfolio management, solution design and delivery, rapid concept and design prototyping, and global deployment) [46].

X-IoT is 100% dedicated to device management, ready to configure and securely connect the physical to the digital realms to improve product and asset performance and usage. Main characteristics are the focus on device management; the agnostication to devices, protocols, and cloud; the high security level including ANSSI accreditation; the edge and cloud mirroring architecture; the multi-tenant capability; the edge analytics management; the plug-and-play deployment; and the stringent use of open source with no third-party licensing.

For the sake of consistency, we assign the X-IoT elements, which we will describe in the following, to the five-color architecture that we introduced in the beginning of this chapter. Figure 14.6 maps these elements to each area of the five-color model. The interplay of the components itself is described by the functional architecture and shown in Fig. 14.7.

Fundamentally, the platform foundation enables the enterprise to integrate X-IoT into the cloud—either AWS, Azure, Google, or Bluemix or even private

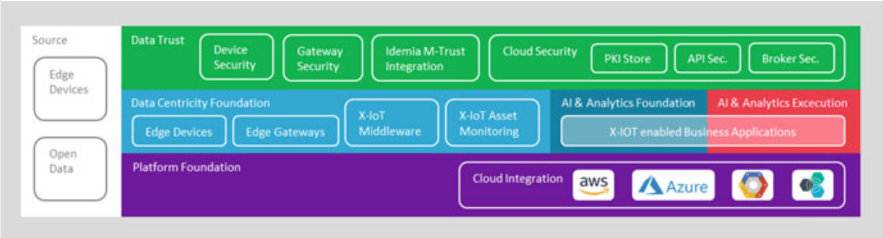

Fig. 14.6 Mapping the X-IoT components to the five colors (source: Capgemini)

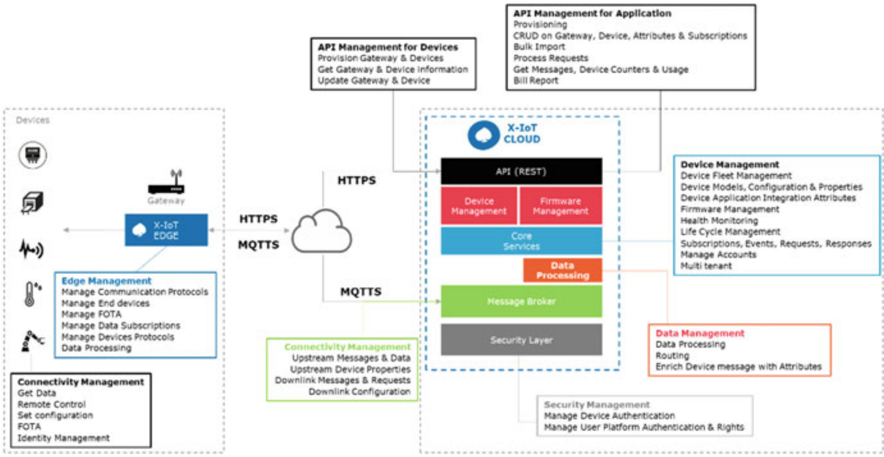

Fig. 14.7 Functional architecture of X-IoT (source: Capgemini)

cloud scenarios. An application based on the open X-IoT platform we associate with the AI and analytics foundation and execution layer—here is the starting point for generating business value. These X-IOT-enabled business applications capture a variety of types of data from different types of sensors, IoT devices, and business applications. These are part of the data-centricity foundation. Data trust encompasses security functionality which is implemented on devices, within the cloud, and essential security and trust features are provided by the IDEMIA M-TRUST solution.

Edge devices are IoT sensors that monitor and track the health and performance of relevant assets. Edge gateways (such as the Intel IoT gateways used in the solution) are located at the edge of the network and contain hardware and software capable of connecting a variety of end customer devices to the cloud, seamlessly transferring data back and forth, and providing security and intelligence at the edge [46]. Data aggregation and transmission to the cloud are supported by an X-IoT edge for device connectivity agent. X-IoT edge supports a comprehensive set of communication protocols with over 100 plug-ins between heterogeneous devices [46]. To name some examples of the variety of supported protocols, they include

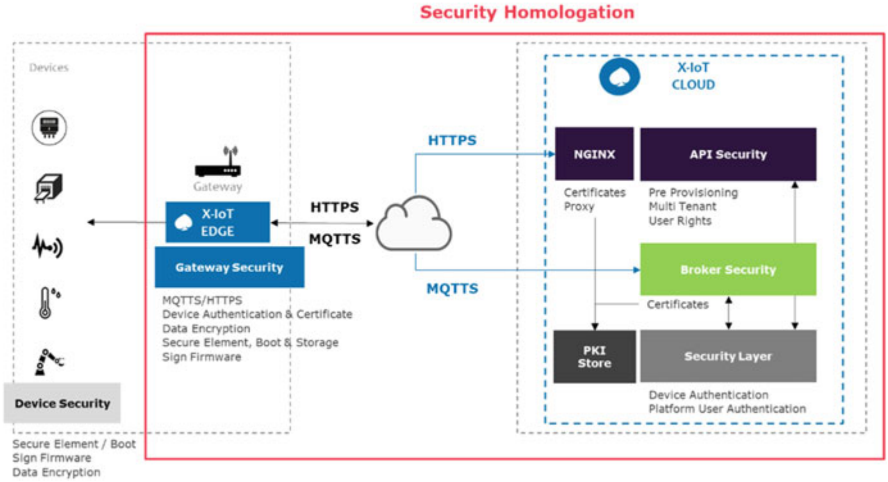

Fig. 14.8 X-IOT security architecture (source: Capgemini)

industrial protocols OPC, OPC UA, Profile bus, Modbus, and Operators LPWAN such as Sigfox and LoRa; wireless protocols like ZigBee, Enocean, Libelium, Bluetooth, iBeacon, AllJoyn, DLNA, and UPnP; and protocols for communication and smart energy including DLMS and 3GPP: 3G, 4G, and NB-IoT. Data flow from multiple gateways is managed by X-IoT middleware for device management, which enables device management and provisioning, firmware upgrades, fleet management, message management, health monitoring, and event processing, and enables data synchronization between systems with a connector library [46]. Finally, X-IoT intelligent asset monitoring is an analytics component that enables real-time asset monitoring and decision-making based on dashboards and real-time 2D and 3D data [46]. Thus, X-IoT enables the collection and analysis of data from all devices, sensors, machines, and people connected to the platform and related decision-making.

Security is an extremely important consideration for smart city solutions, and the X-IoT platform puts security at its core, offering end-to-end data security from edge devices to the cloud, and at each level in the architecture in order to provide the highest levels of protection. For example, each gateway and middleware component have hardware-implemented security (device attestation, configuration and management, asset information, policies, and metadata) [46]. Figure 14.8 shows the security architecture and Fig. 14.9 the IDEMIA M-TRUST Integration. M-TRUST is a solution to ensure end-to-end security from the connected device to the cloud. It is a cloud-based platform that enables the secure management of connected objects ensuring that data exchanged will not be tampered or read by unauthorized parties.

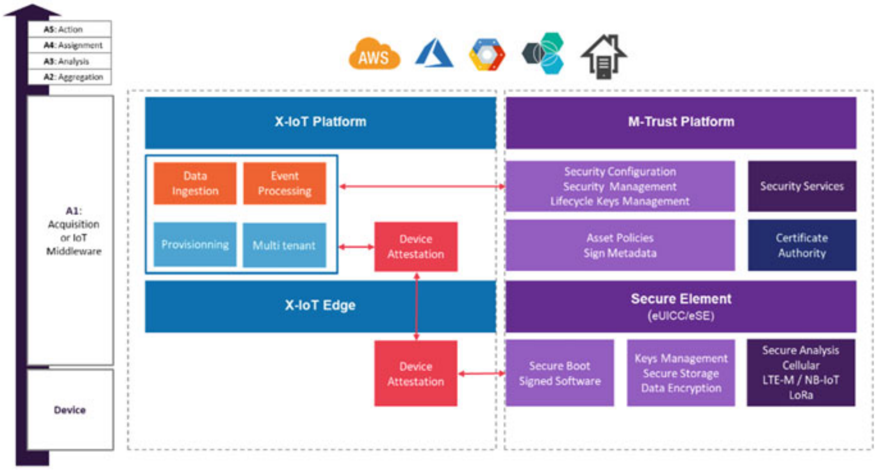

Fig. 14.9 IDEMIA M-TRUST integration (source: Capgemini)

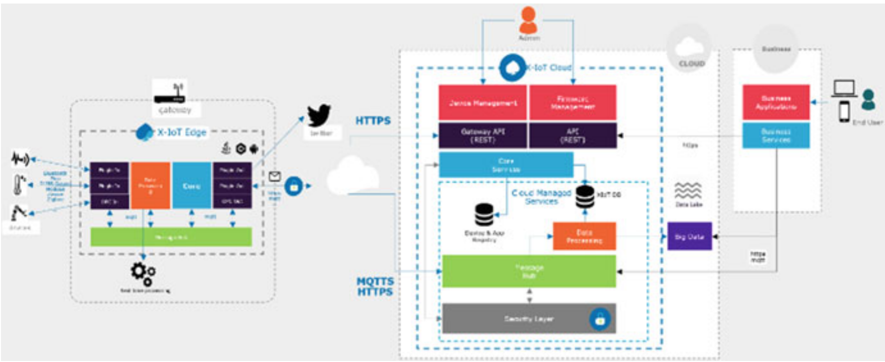

Fig. 14.10 Cloud and edge mirroring architecture (source: Capgemini)

The platform is cloud agnostic and can be independently integrated into Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform, or any private cloud. The cloud and edge mirroring architecture is shown in Fig. 14.10.

With the Internet of Things, new use cases are developing for companies from various industries. Predictive maintenance, connected logistics, and smart health monitoring, as well as smart cities, are some examples. An IoT platform such as X-IoT enables the IoT strategy to be implemented quickly and efficiently by connecting devices to people and processes and implementing concrete use cases with little development effort. X-IoT serves as a communication platform between the IoT hardware objects and the IoT apps. It combines connectivity, security, and analytics in a central software package that forms the core of any IoT solution. The use of cloud for the utilization of infrastructural resources, such as storage

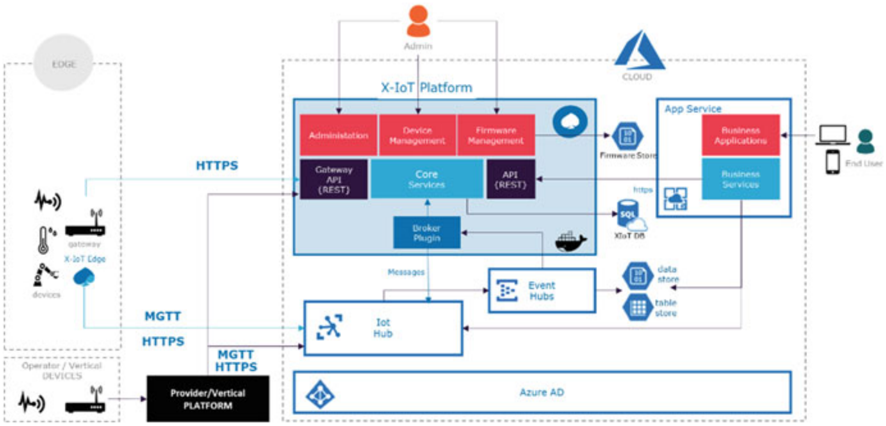

Fig. 14.11 Microsoft Azure architecture (source: Capgemini)

capacities and computing power, is what makes the management and processing of these huge volumes of data possible. The cloud provides immense computation capacity for analysis and evaluation of datasets. The results from these analyses are used to forecast events, make decisions, initiate actions, and optimize processes. Data, sourced from disparate devices, can be examined in real time for dependencies and patterns and transformed into usable insights. The results can then be output to the end user in any visualization options, enabling real-time monitoring of relevant information remotely.

Now, ultimately, every cloud, such as AWS, Azure, Google, and Bluemix, has cloud-native components and services that X-IoT must attach to or in other words integrate with. How this integration is accomplished and using which components is shown in Fig. 14.11 (the architecture for integrating X-IoT into Azure cloud), Fig. 14.12 (depicting the AWS architecture of X-IoT), and finally Fig. 14.13 (that shows the Google cloud architecture).

Openness wins—this is the guiding principle that has prevailed in practice. In the past, manufacturers have tried to establish themselves in the IoT market with their own proprietary standards. That was a shot in the dark. Today we have cross-company working groups such as Eclipse IoT Working Group including DB, Ubuntu, Bosch.IO, IBM, and Red Hat, or the Industrial Internet Consortium (IIC) including DELL, Microsoft, and General Electric along many more. Standards for the communication of devices, respectively, for the communication of interconnected smart city items have to be jointly developed, maintained, and openly provided. Otherwise, particular interests aimed at attempting to secure individual markets will oppose any overall progress.

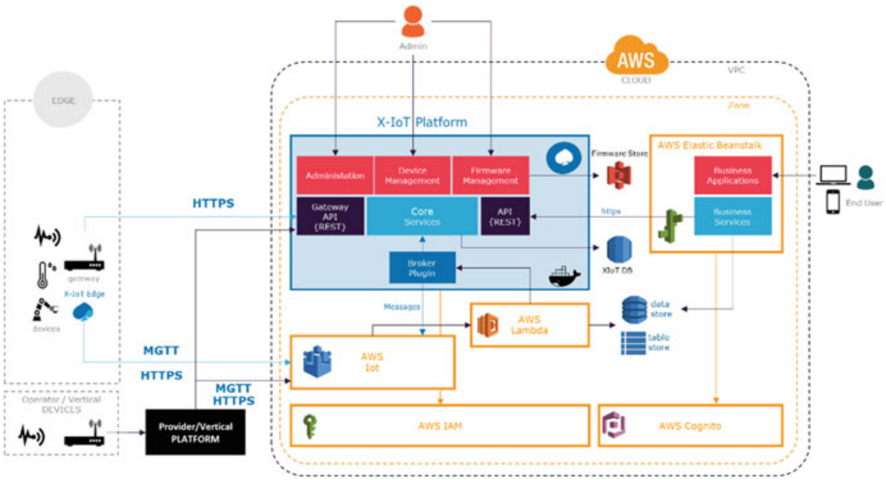

Fig. 14.12 AWS architecture (source: Capgemini)

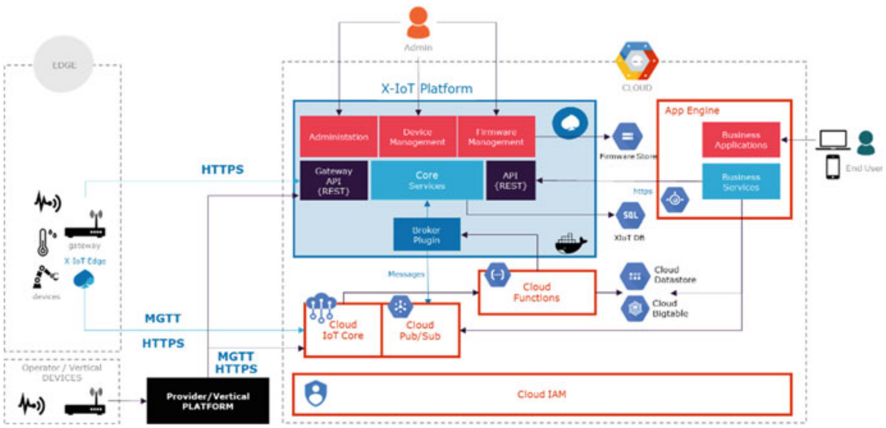

Fig. 14.13 Google cloud architecture (source: Capgemini)

14.4 Conclusion and Outlook

In this chapter, we have described how IoT, together with the related data and AI and analytics technologies to interpret it, plays a crucial role in smart cities. We have also argued that an integrated platform that brings the sheer variety of protocols under one roof is essential for the implementation of smart city solutions. Such an open platform makes it possible to connect diverse devices, or to be more specific, smart city components, with each other. Furthermore, the platform needs to ensure that the data generated by all these disparate devices can be collected and analyzed in real time and transformed into usable insights. For the entire solution to remain elastic and scalable, the use of the cloud is indispensable.

The next steps in terms of technical development might consist of the design of more detailed architectures geared towards specific smart city areas, since there is a lack of flexible and robust reference models in this space [21]. Testing the emerging system thinking models in more smart city contexts and refining the list of design variables that can be used to generate desirable smart city outcomes [12] are likely to attract both academic and practitioner interest. Structuring and synergistically combining as well as collecting and categorizing open data and reusable service components for smart cities, within and across city and governmental entity boundaries, are also areas for fruitful future exploration. There is still much to do here including finding answers to the questions of which open data covers which business capabilities, in which combination, and how, and how to design repositories and marketplaces for reusable service components [13, 16, 44]. Understanding how cities can build scalable and consistent data openness and data orchestration capabilities is also an important area for future research [40]. Last, but not least, future research should investigate ways to transcend the limitations of existing AI tools in complex, dynamic, and nondeterministic smart city environments, such as self-structuring, self-configuring, and self-learning AI technology [47].

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