Chinmay Chakraborty *Editor*

Green Technological Innovation for Sustainable Smart Societies

Post Pandemic Era

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Foreword

This book will mainly cover the innovative and efficient technological solutions for sustainable smart societies in terms of alteration in industrial pollution levels, the effect of reduced carbon emissions, green power management, ecology, biodiversity, the impact of minimal noise levels, and air quality influences on human health.

Current advanced technology helps to promote green and clean modern societies. The Internet of Things (IoT) will play an important role in the upcoming years in environment protection, remote health monitoring, and sustainable development. Over time, technological innovation has altered the overall efficiency regarding sustainability. As per the Gartner hype cycle model, we have been observing how emerging technologies play a big role in human life as well as whole societies. This book will focus on the technology-enabled different societal applications like water, soil, atmosphere, oceans, seas, biodiversity, sanitation, transportation, health, and farming.

The scope of this book is the reflective study of past trends and the current state of artificial intelligence/machine learning oriented features for future smart societies. It provides future directions in this specific domain of special interests: green technological advancement for smart societies' management implementations that deal with adaptive decision making, robust clustering, power saving, and other crucial security and forensics requirements. This book aims to attract works on multidisciplinary research spanning across computer science and engineering, environmental studies, urban planning and development, social sciences and industrial engineering on technologies, case studies, novel approaches, and visionary ideas related to data-driven innovative solutions and big data-powered applications to cope with the real-world challenges for building smart societies. It emphasizes and facilitates a greater understanding of all existing available research, that is, theoretical, methodological, well-established, and validated empirical work, associated with the environment and climate change aspects. The authors have associated with experts in the field from industry and academia to contribute to the book chapters.

The book also highlights the significance of uplifting the sustainable environment for smart cities by providing smart solutions using energy-efficient communication technology, the Internet of Things, artificial intelligence, security, and machine learning as an integrated part of governance for development, both on social and economic fronts. The book also highlights the issues associated with transport, farming, and healthcare sectors, which can be overcome by the utilization of new innovative technologies.

I, the editor, am grateful to the authors for their contribution to the book by illustrating the technological innovations for smart societies.

I believe that this book is an important contribution to the community in assembling research work on developing a green sustainable society. It is my sincere hope that many more will join us in this time-critical endeavor. Happy reading!

Deoghar, Jharkhand, India Chinmay Chakraborty

Contents

About the Editor

Chinmay Chakraborty Dr. Chinmay Chakraborty is an assistant professor (Sr.) in the Department of Electronics and Communication Engineering, BIT Mesra, India. His primary areas of research include wireless body area network, Internet of Medical Things, point-of-care diagnosis, Smart City, green technology, m-Health/e-health, and medical imaging. Dr. Chakraborty is co-editing 12 books on smart IoMT, healthcare technology, and sensor data analytics with CRC Press, IET, Pan Stanford, Elsevier, and Springer. He is a recipient of the Young Research Excellence Award, Global Peer Review Award, Young Faculty Award, and Outstanding Researcher Award.

Smart Cities: Building Sustainable Cities

Andreia de Bem Machado, João Rodrigues dos Santos, Marc François Richter, and Maria José Sousa

Abstract Thinking about sustainable actions for big cities is one of the problems of the twenty-first century. This demand is faced by cities in the different dimensions that make it up: social, economic, and environmental. Just as companies should think about adopting and investing in Environmental, Social, and Governance (ESG), cities need to become smart cities, an important step to transform themselves into sustainable cities with a higher quality of life. ESG, in companies, refers to the three central factors for measuring the sustainability and social impact of an investment process. Cities need to focus, in addition to modernizing their infrastructure, on strengthening the circular economy, investing more in education, reducing school dropout, which is closely linked to the area of security in cities, and based on these measures, seek balance in all areas of society. The concepts of smart cities and sustainable cities will be presented, showing the interconnection of both concepts. The purpose of this chapter is to show how to build smart cities and how they are transformed into sustainable cities. Thus, a systematic and integrative review was carried out in the Scopus database, in order to answer the following questions: (1) What are smart cities? (2) How to transform cities into smart cities? (3) What is the interconnection between the two concepts: smart cities and sustainable cities? (4) How do smart cities contribute to building a sustainable city? The results converge

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in the relationship between intelligence and sustainability, being the basis for a new type of city that directs its growth in an intentional, collaborative, and inclusive way to transform urban centers into a place with a higher quality of life. This chapter brings two examples of smart cities: one in Portugal and another in Brazil, explaining how the national legislation of each country and its social reality interfere in the construction of smart cities. The main innovation presented is the indicators for transforming smart cities into sustainable cities. For this purpose, the chapter is divided into eight sections, which are entitled: Introduction, Smart Cities, Sustainable Cities, Methodology, Relationship Between Sustainable Cities and Intelligent Cities, From Smart Cities Toward Sustainable Cities: Inclusion and Life Quality, Case Studies: Smart Cities from Brazil and Portugal, and Conclusions.

Keywords Smart cities · Sustainable cities · Life quality · Inclusion · Systematic review

1 Introduction

Smart cities are planned through aim of improving all dimensions of society, creating accessible spaces, providing more security in the lifestyle, and well-being of citizens living in that city, in addition to having companies with responsibility focused on green in sustainable practices. Therefore, these cities promote investment actions in renewable energy sources, as well as sustainability in both technological and financial resources.

Thus, this chapter proposes a mapping of the different dimensions of smart cities. The study is not only focused not only on the governance of smart cities, technology and, but researchers have chosen to focus on sustainable practices with the aim of creating a more sustainable world, with high levels of life quality for citizens.

This chapter based on exploratory methodology to conduct a research on how to build smart cities and how they are transformed into sustainable cities.

The chapter is planned in eight sections: first section is Introduction, the second section Smart Cities, the third section Sustainable Cities, the fourth section Methodology, the fifth section Relationship Between Sustainable Cities and Intelligent Cities, the sixth section From Smart Cities Toward Sustainable Cities: Inclusion and Life Quality, the seventh section Case Studies: Smart Cities from Brazil and Portugal and the eighth section Conclusions.

2 Intelligent Cities: Smart Cities

Smart cities integrate with multiple information and communications technologies (ICT), which aims to provide solutions to urban challenges and simultaneously improve life quality of the population. However, it is a concept that is still under

Table 1 Definitions of smart cities

Definitions
Smart city, smart island, or digital city are cities that, through their own planning of information highways, use a national high-speed broadband network that offers interactive multimedia applications and services for all homes, schools, and offices, in addition to having complete and uninterrupted commercial and government services, cybershopping, online banking, internet commerce, virtual college, and digital library [23]
Ubiquitous cities are those that use ubiquitous computing practices in the formation of cities [21]
A city that offers quality of life through intelligent relationships between infrastructure systems such as: Transport and communication of energy in different places such as buildings, areas, neighborhoods, and cities [11]
Sensory cities that adopt information systems to renovate the metropolis with technology and software organizations that improve Well-being conditions in cities [16]
Information cities adopt e-governance as one of the foundations for innovation where they adopt measures for the development of ICT infrastructures and information services through policy programs to develop an impact on the information society [9]

Source: Authors of this Chapter (2020)

construction, not very clear, without a standardized nomenclature that could be described effectively and without standardized criteria and structures to visualize a clear concept. Smart city has several definitions: digital city [23], ubiquitous city [21], sensory city [15], and information city [8]. The literature review revealed that most of the authors define a smart city based on the technological aspect, according to different concepts of Table 1.

Smart cities consider ICT for creating healthy and sustainable cities (topic discussed below).

3 Sustainable Cities

Since the 1980s and 1990s, sustainability issues were prominent on the academic and political governance scene. The discussions on this topic related to urban studies have been gaining prominence and allowing the conceptualization of a new city concept. Therefore, a set of strategies for urban planning must be planned and designed in line with the concepts of sustainability.

At the beginning of the new century, the term urban sustainability is being related to a set of concepts that add intelligence to technological solutions on an ecological basis. This design relates to innovative technologies and policy tools that chart the path to sustainable urbanization by establishing indicators for sustainable practices in a city.

Sustainable city promotes the economic development of a municipality, region, state, or country through sustainable practices [7]. Sustainable cities can also be called healthy ecological cities, a concept that originated from the discourse on sustainable development in all dimensions of society.

The issue of sustainability has also permeated organizations, companies, and other institutions. Three letters (E, S, and G) have become important in economy, because the term ESG is used to refer to business and investment practices that are concerned with sustainability criteria and not anymore just with profit. ESG is used as a kind of measure to guide good business practices regarding its sustainability actions. The ESG criteria are the environmental and social impacts of the business chain, carbon emissions, waste and tailings management from a certain activity, labor and worker inclusion issues, and accounting methodology, among others. Investors have increased in recent years their demand for the adoption and dissemination of ESG-based business practices, as the lack of environmental commitment has been seen as an increasing risk to sustainability of the global financial system. More and more private and public corporations have invested in specific actions and improvements for social and environmental impacts, benefiting also urban centers [10].

Several countries around the world concerned about climate change have highlighted the responsibilities of cities to reduce its carbon footprint at international conferences, such as the Paris Conference in 2015, as well as another important international conference, in September 2015, brought together representatives of the 193 member states of the UN in New York.

The so-called Agenda 2030, main result of this meeting, which addresses the objectives of sustainable development, states that many goals need to be met for a more sustainable world, including the eradication of extreme poverty. Countries have committed themselves to taking transformative measures to promote sustainable development over a period of 15 years (2015–2030). The Declaration of the Agenda 2030 is a framework for results with 17 goals and 169 targets, a section on means of worldwide partnerships and a roadmap for follow-up and review.

The fact that cities are the protagonists for sustainable transformation and sustainable development in favor of a better world is clearly reflected in the Sustainable Development Goals (SDGs) of the Agenda 2030, which aims to make cities sustainable.

Moreover, half of humanity live in urban centers, and this number keeps rising, with, presumably, by 2050, almost 70% of the world's population [19]. Today, the situation is even more alarming in Latin America and the Caribbean, where already 80% are living in urban areas, prospecting 87% by 2050. This means that 650 out of a total of 750 million people are expected in urban areas in that region by 2050 [19]. In addition, 28 megacities have been formed with more than ten million inhabitants to date, with a projected number of 41 megacities in 2030. The metropolises of São Paulo, Mexico, and Mumbai, each with a population of about 21 million, rank fourth among the world's largest cities, surpassed only by Shanghai, Delhi, and Tokyo, with 23, 25, and 38 million, respectively (United Nations 2014).

Sustainability has become an increasingly applied and studied concept, being widely exposed on the basis of the Triple Bottom Line theory, where sustainable development is only possible if the social, economic, and environmental spheres are taken into account. Moreover, many authors point to sustainability as the great paradigm of this century [1]. In social terms, building and developing a greater role for the population in decision-making processes allows the incorporation of knowledge, cultures, and people's desires, which open perspectives for greater convergence in plans, programs, projects, and activities aimed at the development of cities on a sustainable basis [19].

Urban centers, with so many social and environmental problems nowadays, have a fundamental and determining role in the strategic development of a more sustainable world. The issue of "sustainable cities" is a concept that provides guidelines to improve public policies of an urban area and prepare it for future generations. To be sustainable, the city administration must consider three basic pillars: (1) environmental responsibility, (2) sustainable economy, and (3) cultural vitality. Cities are the scene of many global environmental problems, and it is in the urban context where the social, economic, and environmental dimensions converge most. Some authors are adding another pillar to define sustainability, which is described as "institutional," indicating that sustainable cities should be governed in transparent ways.

Different initiatives can create a sustainable place in the urban environment, which is essential if the stability of cities over the years is not to be threatened. The idea that should guide these actions is that sustainability is a development factor, not an obstacle to it. And just as important as being a development factor is that it can be a growth factor in the income of the neediest families and in the implementation of social policies. One example is waste separation and recycling, which, if carried out in municipalities, would greatly reduce the amount of waste going to landfills or open dumps. In addition, recycling would produce income for many people by being an important source of labor. Therefore, it is an example of sustainable urban policy, which, if implemented, would bring environmental and social benefits. The challenge of building cities, with new parameters, cannot be restricted to conceptions of a green urbanism that is satisfied with promoting compact cities, capable of saving space and energy, nor one that has in sustainability a mere additional symbolic attribute for the interurban competition developed through the marketing of cities. It is a question of thinking about a better urban development model, based on the democratization of territories, the fight against socio-spatial segregation, overcoming social inequality, and access to urban services, which is also evident in the conditions of exposure to urban risks. It is essential that the community is given the opportunity to act differently with attitudes toward better use of resources and constant concern for the protection of the urban environment. Therefore, environmental education should be a central guide to sustainability. Concrete attitudes of city governments are fundamental for cities to be sustainable, both as direct factors of sustainability and for a gradual environmental education of citizens. In this perspective, the law must be impregnated with predictions to make cities sustainable.

A city to be considered sustainable must: (1) properly dispose of and reuse solid waste; (2) offer quality water without running out of springs; (3) reuse rainwater; (4) create and use renewable energy sources; (5) offer alternative and quality transport for the population; and (6) guarantee culture and leisure options; (7) restructure and relocate industries based on energetic administrative policies; (8) cleanup its rivers; (9) prioritize municipal public transport; 10) construct bicycle paths; (11) expand its green areas; (12) reduce air pollution; and (13) offer selective garbage collection.

The World Bank and the OECD, an intergovernmental economic organization, indicate that USD 7 trillion investment a year is necessary until 2030 to meet the 17 SDG goals, but currently only around USD 3–4 trillion spending on infrastructure is invested. Therefore, governments, which are often fiscally constrained by society challenges such as education, health and increase of its population. This indicated the importance of designing and implementing, in addition to public funding, private mechanisms for financing the sustainable urban agenda. Still investments at scale in SDG-based projects, and more specifically in sustainable and smart cities projects, need more efforts and remain a key challenge [17].

Until today, according to researchers, economists, and managers, there is yet no city in the world that is totally sustainable. However, more and more cities are turning these ideas into reality, at least partially, which transform them increasingly into sustainable cities.

4 Methodology

The research method used is based on a systematic search in an online database, followed by an integrative analysis of the results. The database chosen was Scopus, as it is a peer-reviewed impact reference of scientific literature. Initially, the aim was to work using the five steps [25], elaborated during the integrative literature review described below. To address this research problem, an exploratory-descriptive perspective with the inductive method was used, with the objective of mapping the subject and expanding the familiarity of researchers with the fact from sufficient data allowing the researcher to infer a truth. These are divided into five steps, namely: problem research formulation, definition of search sources, selection of articles and conferences, analytical reading, and analytical summary of results.

The search terms or expressions for each of the search problems were delimited as listed in Table 2.

It was identified that these scientific articles were written by 23 authors, linked to 16 different institutions. 48 keywords were used to identify and index all the publications, which are distributed in 8 different knowledge areas.

The countries with two publications each are Finland and Spain, followed by Belgium, Croatia, Denmark, Greece, Italy, Poland, Portugal, Slovenia, United Kingdom, and United States with each having one scientific publication in the area.

The six scientific articles obtained in response to the database search belong to the following areas of knowledge: Computer Science, Business, Management and Accounting, Energy, Environmental Science, Earth and Planetary Sciences, Medicine, Social Sciences. This information makes it possible to verify the breadth of the subject in different dimensions of knowledge, thus allowing to weave the state of the art of the subject.

Table 2 Search problems

Search problem	Search terms	Recovered articles	Free access
1) What are smart cities?	"Smart cities" "Systematic review" "Concept or history"	60	17
2) How to transform cities into smart cities?	"Smart cities" "Sustainable cities"	4098	535
3) What is the interconnection between both concepts: smart cities and sustainable cities?	"Smart cities" "Sustainable cities" "Life quality"	484	68
4) How do smart cities contribute to the construction of a sustainable city?	"Smart cities" "Sustainable cities" "Life quality" "Inclusion"	23	6

Source: Authors of this Chapter (2020)

Table 3 General bibliometric data obtained from Scopus database

Database terms	Scopus database results
Search terms	Smart cities and sustainable cities and life quality and inclusion
Search fields	"Title," "abstract," "keyword"
Total number of scientific articles recovered	6
Authors	23
Institutions	16
Countries	12
Key words	48
Areas of expertise	8

Source: Authors of this Chapter (2020)

Table 3 presents the result of the data collection in a general analysis of the results obtained from Scopus database.

The first publication on the topic was published in 2012, entitled "Smart Apps for Smart Cities – New Approaches to Innovation." The aim was to focus on the issue of intelligence and its applications in cities to improve living and working conditions of its citizens.

The recovered six scientific articles were studied, with the aim of analyzing the criteria used by the authors, of how smart cities must be constructed to build sustainable cities. With the systematic reading of these works, it was found that the criteria defined in these articles studied for smart cities to become sustainable cities are based on: employment, development, inclusion, security, and quality of life. In addition to this issue, it was identified that the internet of things (IoT) is the central point for transforming smart cities into sustainable cities, to promote inclusion by guaranteeing an ecological, sustainable, and pleasant environment for the entire society that lives in these cities. It is pointed out that information and communication technologies can make urban infrastructure accessible to the entire population, based on accessibility and quality of life. Another criterion is that, in order to guarantee quality of life, it is necessary to check the noise pollution produced by road and rail traffic in cities. The reduction of air pollution can cause associated impacts with respect to ecology and biodiversity, the impact of reduced noise levels, and the influence of air quality on human health, treatment, and management of biomedical waste. This measure allows to reduce the amount of noise. Another criterion for making a smart city sustainable is to enable mobility and accessibility for the elderly through a personal referral service [5]. There is also an example of a tool to check the Performance Index for Inclusion in People with Disabilities (DIPI). This verification will provide the architectural planning of accessible areas for the inclusion of people with disabilities, based on the definition of political, legislative, and standardization structures. The work also indicated that there are investments by member states of the European Union with the objective of promoting energy reforms in their construction stocks, promoting the well-being of citizens living in public housing.

The analysis on the keywords used in these 6 articles from Scopus database revealed 48 different keywords. The highlight was the keyword Smart City with 3 hits and smart cities, Urban Design with 2 hits. The other occurrences have not been considered in this article, as they appear with a low frequency: only once.

Finally, according to the qualitative analysis, it was found that the criteria for transforming intelligent cities into sustainable cities (a theme that will be deepened in the next topic) are related to pollution reduction, accessibility, income distribution, and technological infrastructure that promote actions for sustainable development ensuring a better life quality for citizens.

5 Relationship Between Sustainable Cities and Intelligent Cities

Today, just over two centuries after the Industrial Revolution and only a few decades after the invention of the computer, we continue to adapt to the enormous changes resulting from the increasingly intense and accelerated communication on a global scale. This reality, derived from the Technological Revolution, brought us to a new paradigm: the more innovation accelerates, there is also a significant increase in the acceleration of the pace of economic, social, and political changes. In the context of health, augmented reality and virtual reality are being applied to patients, hospitals, and research organizations while adopting technology to ensure quality of life [27]. Therefore, the way of life and social coexistence of each person in the present are not immune to this situation. Therefore, society requires, at every moment, new processes of adaptation and change.

In this sense, smart and sustainable cities, more than a utopia or futuristic imagination, are a reality that is both possible and indispensable to focus on growing urbanization challenges. In this regard, ICT play a major role due to their intrinsic nature. ICT provide solutions/improvements aimed at the economic, environmental, and social spheres.

Urbanization has its benefits, but also many challenges. The rapid increase in urban population augments pressure on the resource base (energy, water, and sanitation), and the necessity for high quality public services [13]. Consequently, the various social, economic, and environmental issues, which affect competitiveness and the quality of life in urban spaces, are strongly intricate, requiring, therefore, integrated planning and management approaches.

Territorial competitiveness has been gaining prominence in a highly globalized and constantly evolving world. As cities realize the importance of affirmation at the international level, they seek competitive advantages and intervention models consistent with strategic territorial management and global influence. Nowadays, on a global scale, it is the concept of sustainability that occupies the epicenter of territorial planning and management processes. Thus, only respecting this assumption, urban spaces become more competitive.

Refer that among the definitions of smart and sustainable city, "the points of convergence are that smart cities are complex systems, where different actors and different factors converge to take advantage of features such as interconnection, adaptation, organization and, above all, feedback" [15].

And in the context of urban competitiveness, smart cities are central entities. At present, according to [26], researchers identify the following components of a competitive territory as the main ones: 1. smart management; 2. smart people; 3. smart environment; 4. smart mobility; 5. smart economy; 6. high standards of living (pp. 23, 24).

In world, it is more and more free of barriers to the movement of people and goods, the evolution of urban spaces is fundamental to mitigate the enormous pressure that cities are presently facing. Therefore, it is necessary to develop smart and sustainable city models based on ICT, which, in turn, evolve according to processes based on the interconnected performance of different actors in the social, environmental, economic, and governmental dimensions.

This framework presents significant challenges. And in this context, cities are the central element, as they are the paradigm of a highly complex system, with immense interactions and connections between different actors and the environment.

Therefore, it is urgent to generate planning and adaptation strategies for the environment, for economies, for cities, and for society in general. The necessary conditions (domains of intelligence and sustainability) are achievable with the use of ICT, whose development is highly advanced at present.

The indicators for having a smart city according to the Digital Cities and Knowledge Based Cities Committee of United Cities and Local Governments (2019) are based on three pillars of sustainability: economic, environmental, and social. Therefore, the public administration needs, first, to consolidate the digital transformation process, with a view to integrating new information with the traditional one and to achieve a properly calibrated urban planning that adequately weighs all the resources available these days. Thus, today, the challenge for urban spaces is to achieve high levels of "intelligence," through the extensive use and integration of ICT in strategic sectors such as education, health, energy (efficient consumption), water, waste management, security and safety, housing, road traffic, economies in general, among others. This scenario would result in economies of scale and efficiency gains that could be channeled to the most vulnerable sectors of territories and societies.

Reinforcing the idea of the previous paragraph, the UN Regional Information Center for Western Europe (2015) emphasizes that ICT have the potential to accelerate the fulfillment of the 17 United Nations SDGs defined in the so-called 2030 Agenda, including the SDG 11, which aims to build sustainable urban centers.

6 From Smart Cities Toward Sustainable Cities: Inclusion and Life Quality

The debate on the role of cities in the global economy has been intensifying, particularly as an increasingly noticeable concentration of people is being observed in large urban centers.

For several authors, it is extremely important to relate socioeconomic trends with the characteristics of cities [18]. For these authors, cities function as key spaces in the global economy, where the effects of globalization are observed: strong accumulation and influx of capital, deindustrialization, expansion, and spatial concentration of specific sectors of production and services, segmentation of the labor market, socio-spatial polarization, and ethnic and class conflicts.

One of the most important designs of smart and sustainable cities is "technological convergence, and therefore the guarantee of sustainability and a higher level of social cohesion, competitiveness and security at its different levels" [15].

These models necessarily imply an intensive and extensive use of ICT, mainly because "they imply technologies that promote a set of innovations, both technological and scientific, organizational, social and institutional, as well as generate new economic opportunities and social return in the most varied activities. In the educational context, they use computing using machine learning approaches" [4]. Thus, ICT are now considered not only a vehicle for technical progress, but also for reducing inequalities in societies, especially in developing countries.

This city model provides, according to the essentials of the inclusive innovation process, greater integration and social equality, that is, greater access to different public services. In addition to facilitating the implementation of environmental protection programs and increasing mobility and sustainable economic competitiveness, "[smart] cities play an important role in providing a set of requirements […] for quality-based innovation" [28].

The present days reveal that intense urbanization has associated losses of basic functionalities, which significantly affect the life quality of its citizens [28], point out, in this regard, the following problems: “deficiencies in waste management; scarcity, waste and poor management of natural resources; restrictions on health, education and public security systems; limitations in urban mobility and transport systems; and obsolescence and shortening the life cycle of public infrastructure”.

Theoretically, smart cities are fundamental to counter the problems resulting from the intense urbanization that has been occurring over the last decades. Several authors include the notion of “quality of life” in their definitions of “smart city“[14].

Therefore, smart cities ensure more efficiency in the management of (scarce) resources that society has at its disposal. Being managed “intelligently,” these urban spaces contribute to achieving more utility (in the sense of utilitarianism) from the available resources. This marginal utility available—due to the greater efficiency that smart cities allow to achieve in the management of resources—is channeled to guarantee a better life quality for its inhabitants. And, in the twenty-first century, the improvement/consolidation of people’s living standards and the increase in the total utility generated in the territories depend heavily on inclusive policies, which ensure universal access to valences and urban functions whose access is typically conditioned for some population segments.

In this context, [20], regarding utility and utilitarianism, states that:

> In the field of economic science, utilitarianism focuses on the moral concerns that result from inequalities in the redistribution of wealth. Utilitarianism assumes theoretical relevance for welfare states. It is using the conceptual essence of utilitarianism that welfare states proceed to economic redistribution, using the respective tax systems for this purpose. Redistribution occurs to guarantee, for example, social security, education, and health for all citizens regardless of their socio-economic status. (p. 64)

Access to public goods and services is a hallmark of developed countries. According to [20], a developed economy allocates “a greater portion of its higher income to public goods and services (road network, environmental protection or higher education)” (p. 35). This allocation must be effective. People must effectively benefit from this type of public investment. Otherwise, the scarce resources available will literally be wasted.

Thus, an intelligent, inclusive, and “human” city is first and foremost a territory where services, uses, and general goods of a common nature are built, aiming to satisfy the basic needs of its citizens and their well-being.

Being the “city” entity, in the twenty-first century, a space of life and encounters, the convergence of social uses, ubiquitous technologies, and new models of sharing will continue to bring new life experiences and will give rise to new uses and services in practically all domains of urban intervention. Sikora-Fernandez corroborates this idea, stating that a smart city fosters and promotes “communication and the exchange of information between citizens of the urban space” [22].

For these reasons, it is crucial to use rationality first in planning and then in managing urban spaces. This premise is fundamental because only then, on the one hand, the use of resources with gains in scale is guaranteed and, on the other, the potential and dangerous social cleavages that may occur in urban spaces are prevented. In this regard, it is important to underline that, due to their functional density, urban spaces today are highly heterogeneous in practically all levels of analysis (economic, social, geographical, environmental, cultural, functional, among others). In this way, strategic rationality should guide the decisions of decision-makers in large urban centers toward harmonization and inclusion in access to the functions of large urban centers. In this context, inclusive policies take center stage.

Nowadays, there are already many examples of services and activities that, using "urban intelligence," promote social inclusion: car sharing, urban public spaces with free connection to the world wide web, distance healthcare (telemedicine), better quality of life for the senior population (digital proximity to many services considered essential for this population fringe), mass online education, open spaces for culture, art and leisure, participatory democracy, collaborative governance systems based on online information, among others.

All these aspects of smart cities ensure more effective access to different urban functions and services. The conceptual nature of a smart city is a central model for promoting life quality and inclusion in the broadest sense.

7 Case Studies: Smart Cities from Brazil and Portugal

The transformation of cities into smart and sustainable cities across the globe is a relevant and challenging issue, as it involves raising the awareness of the whole of society and of government institutions of the role of transformation agents. The participation of different social actors in this process is fundamental because they are those who live in the cities and have the necessary local insight to propose innovations applicable to their context. Local governments are key players in influencing this transformation, as they are responsible for the planning, management, and governance of public services.

The determining factor for the construction and maintenance of quality spaces to transform intelligent cities into sustainable ones, providing the inclusion of all citizens through accessible constructions. This is possible through a set of urban legislation and through the actions of the public institutions responsible for its implementation and maintenance. The Brazilian Federal Constitution of 1988, in its Chapter on Urban Policy, defines that it is up to the municipalities to implement urban development policy, through municipal law guidelines, to seek full development of the city's social functions and well-being of its inhabitants. Paragraph 1 of Art. 182 establishes the so-called City Statute, which must be approved by the city council, mandatory for cities with more than twenty thousand inhabitants, is the basic instrument of urban development and expansion policy in Brazil. There are also the City Statute, the federal Law no. 10,257/2001, establishes general guidelines for urban policy, guaranteeing equal rights for the entire population in the city and especially to housing. This Law also guarantees the protection of the environment, seeking for an inclusive and sustainable city. Brazilian urban legislation is based on the following legal instruments: Law of the Master Plan; Law of Land Parceling for Urban Purposes; Law of Urban Perimeter and Urban Expansion; Law of Urban Land Use and Occupation—Zoning; Law of the Road System; Code of Works; and Code of Postures. However, to implement the instruments of the City Statute, additional legislation is important such as: the environmental laws and the Sanitary Law. In addition, Law 10.098 from 2000 establishes general standards and basic criteria for the promotion of accessibility, regulated by Federal Decree 5.296/2004, which makes it compulsory to obey the spatial accessibility standards, among them NBR 9050, which has been updated in 2015. This law is one more piece to make cities more accessible and sustainable. Finally, the Law of Inclusion, Law no. 13.146 from 2015, was promulgated, establishing the Brazilian Law of the Statute of the Person with Disability, which establishes the obligation to approve architectural, urban, communication, information, and transport projects, as well as their execution, meeting the accessibility requirements provided for by current technical standards and in accordance with the principles of Universal Design.

In Brazil, this subject is much discussed in the whole academic and political context. However, there are not many effective and legal actions being taken in Brazilian cities. Thus, the first city in the country to approve the Municipal Innovation and "Smart City" Law was Juazeiro do Norte (State of Ceará), which was sanctioned on June 14, 2018, establishing the first master plan of technologies and smart cities. This municipal law is based on the Law and Regulation of the Federal Framework of Science and Technology in Brazil and follows the guidelines of the National Ministry of Science, Technology, Innovation and Communications (MCTIC) and the National Bank for Economic and Social Development (BNDES) under the National Plan for the IoT, focused on smart cities.

In Brazil, we still have other examples of cities that through actions to provide life quality and inclusion are building infrastructure to become smart and sustainable cities, as shown in Table 4.

In Brazil, there are several challenges to transform smart cities into sustainable cities mainly in terms of the social and political realities of the country. But the issue

Table 4 Projects for building smart and sustainable cities in Brazil

Brazilian cities	Projects/actions for building smart and sustainable cities
Rio de Janeiro	Promoting digital inclusion Rio digital 15 minutes project Actions to implement green areas Knowledge centers
Porto Alegre	Implementation actions for green areas Intelligent traffic signals Extensive fiber optic network Digital inclusion actions
Curitiba	Fiber optic network interconnecting different public equipment Transparency and efficiency in public management Sustainability actions Promotion of the democratization of information

Source: Authors of this Chapter (2020)

of smart and sustainable cities is emerging to solve the intricate organizational, social, and material problems arising from rapid urbanization.

Regarding Portugal, the policy of spatial planning and urbanism, established by Law no. 31/2014, of 30 May, which approves the general basic law that ensures public policies and urbanism, aims at achieving several objectives, among which: “ensuring equal opportunities for citizens in accessing infrastructure, equipment, services and urban functions, in particular equipment and services that promote support for the family, the elderly and social inclusion“; “minimize the emission of greenhouse gases and increase energy and carbon efficiency”; “ensuring the safeguarding of ensuring the safeguarding of the health and well-being of citizens and the environment“; “rationalize, rehabilitate and modernize urban centers”; “ensuring the rational and efficient use of the soil, as a scarce natural resource”; “promote accessibility in buildings for people with reduced mobility, equipment and green spaces or other spaces for collective use” (article 2).

According to paragraph 2 of article 38 of the same diploma, “the territorial management system is organized within a framework of coordinated interaction that leads back to national, regional, intermunicipal and municipal levels.”

At the municipal level, territorial plans “establish […] the spatial planning regime and its implementation.” In the municipality, there is the municipal master plan, the urbanization plan, and the detailed plan” (paragraphs 1 and 2, article 43, Law no. 31/2014, of 30 May).

It is at this level of planning that the territorial organization/evolution model is defined in the areas of human occupation, organization of urban networks and systems, and in the definition of land use parameters and environmental quality assurance.

Municipal spatial planning plans are still decisive in the context of territorial management policies. Being territorial planning instruments, they have a regulatory nature. For this reason, they are automatically binding not only for public administration, but also for private individuals.

A Law no. 31/2014, of 30 May, which deals with soils, territory, and urban infrastructure, focuses on different dimensions of sustainability such as: environmental, social, and economic sustainability, regarding the establishment of models of territorial organization in Portugal.

As a result of this territorial planning logic in Portugal—well defined in 2014 with the publication of Law no. 31/2014, of 30 May—there are already many projects across the country that aim to guarantee the efficiency in the management of resources. The high levels of efficiency sought with these projects are indispensable to the guarantee of sustainability referred to repeatedly in the mentioned Law.

Considering that smart cities are characterized by investment in technology, with the aim of improving municipal management and providing its population with life quality and sustainability of spaces, “intelligent” cities are, therefore, the models of spatial organization preferred by many Portuguese decision-makers to comply with Law no. 31/2014, of 30 may.

Thus, in Portugal, more and more municipalities are following the technological innovations capable of building smart cities, promoting healthy lifestyles, contributing to the responsible use of public spaces, supporting sustainable development, and promoting an ever-better quality of life.

In the Portuguese panorama, Aveiro is one of the cities that has distinguished itself in this chapter. For example, the Aveiro Steam City project:

> Will contribute to the preparation of the near future, the first step to create an intelligent city, based on knowledge. To do so, Aveiro STEAM City will retrain human resources with the required competences to the digital world - STEAM competences (Science, Technology, Engineering, Arts & Mathematics) will stimulate the digital transformation within the city, attract and retain talent, promote the renovation of companies' network and the socioeconomic structure of the city [2].

The project is based on a network of 5G infrastructure, fiber, and sensors that will be implemented in the Urban Center of Aveiro, allowing to test new products by companies and business innovation centers in the areas of smart cities and Internet of Things. This factor is very important within cities as explained. Sensors and smartphones are used in industry and health technology for data collection [6].

This infrastructure will also allow the Aveiro City Council, as well as its partners, to develop some case studies in the areas of environment and energy with the purpose of sustainable behavior of the city. In Aveiro, the area of mobility is also very relevant in this context, with the use of geolocation sensors installed in public vehicles (buses, municipal cars, bicycles, and "moliceiro" boats, a typical river transport) to obtain information about the habits, routines, and preferences of the population, to identify problems and optimize mobility in the city.

Still in the domain of the environment, the use of environmental sensors (fixed and mobile) also deserves mention, with the objective of generating an environmental map of the city, with data available to citizens, management entities, and research centers.

Aveiro also stands out in the field of energy, namely, in the promotion of electric vehicles, investing in charging stations so that "moliceiro" boat operators can replace the current motors with electric motors.

In Leiria, another Portuguese city, the investment in technology, specifically aimed at the industrial area, has been constant in recent years. This bet was materialized, above all, in TECNEA, "a space of innovation that promotes the development of disruptive solutions, resulting from the close collaboration between companies that operate within the scope of technologies to support the industry" [24].

Still in Leiria, the U-Bike project, promoted by the Instituto Politécnico de Leiria, is an initiative worth mentioning, which makes 220 electric bicycles available to students and employees in the community. "The U-bike Portugal Project, nationwide and coordinated by the Instituto de Mobilidade e Transporte (Public Institution), aims to promote smooth mobility and provides for concrete actions to encourage the adoption of more sustainable mobility habits in higher education academic communities" [12].

Regarding Leiria, it is also important to highlight that the city leads the UrbSecurity, which corresponds to "a network of European cities and regions that aim to think about cities in relation to sustainable growth and mobility" [3]. In this way, UrbSecurity will contribute to the smart, inclusive, and sustainable growth of cities.

Finally, still in Leiria, it is important to speak about the international project GAMELabsNet, which is part of the institute Politécnico de Leiria and which aims to promote industry in Portugal through the "creation of a laboratory dedicated to supporting the digital transformation of companies in the molds, agro-industry, healthcare and tourism sectors" [3]. There are several Portuguese cities with projects that fit the "smart city" model. It has been a trend in urban planning for some years now. In the following table, some more of these cities and respective projects are identified.

Portuguese cities	Projects/actions for building smart and sustainable cities
Viseu	The municipality wants the city of Viseu to be an incubator for new projects, namely related to smart cities "AIGA concept," which is an innovative solution for water treatment "TOMI," an interactive communication, and urban information solution that provides information about the place and time with assertiveness
Águeda	It is known as the "city of bicycles." Invested in various technology solutions, from smart meters in public buildings, data platforms available to all citizens, and facial recognition systems at the municipal headquarters "i4C platform," which allows the automatic collection of data from sensors and other sources of information. Then, after being structured, they are made available. In this way, management becomes more transparent once the information reaches all citizens "Águeda Cityfy," which is an app aimed at advertising news and events, disseminating information, and promoting tourism, culture, and sports in the municipality of Águeda. The set of features provided allows the municipality to communicate and receive direct feedback from residents through the provision of some services The app "Águeda Smart City platform" promotes a proactive attitude of citizens, who can either report a hole in the street or an abandoned animal or garbage in the public space
Torres Vedras	App "SIGE," which is an integrated and centralized technological infrastructure for parking management, which includes the management of parking, availability of "Agostinhas" bicycles (public use bicycle), resident/business credentials, use of technology GPRS, and new forms of photovoltaic energy "EcoCampus platform," which promotes the incubation of business solutions about green economy, sustainability, and circular economy The "green key" program is an award that promotes sustainable tourism through the recognition of tourism enterprises, local accommodation, camping sites, restaurants, and conference centers that implement good environmental and social practices "Torres Vedras circular purchases," a project aligned with the Municipality's vision for the circular economy, as a strategic objective for the decarbonization of the territory and a determining factor for the dynamization of the local economy "OesteLED" project, which allowed the installation of 14.511 LED technology lamps, causing more than half of the municipality's public lighting to be done through these lamps

Source: Authors of this Chapter (2020)

8 Conclusion and Future Scope

The study contributes to the discussion of the concept of smart cities as this research raises awareness of the potential of smart cities in the lives of citizens. In addition, it warns of the need for cities to become more intelligent, establishing criteria through quality standards, thus formulating recommendations for decision-making.

Thus, to make smart and sustainable cities, cities should no longer treat their citizens as just beneficiaries of services or even as customers, but as cocreators of mechanisms to improve the quality of life in that community.

Sustainability is a dimension that needs to be further developed in line with the SDGs, in various sectors such as financial, social, environmental, among others. It is essential to use resources in a balanced way, thinking about new generations. The dimensions of society, environmental impact, green technologies, and finance are the core of a sustainable smart city.

Considering the theoretical and methodological framework of the chapter and articulating it with the characteristic elements of the so-called smart cities identified in each of the countries (Brazil and Portugal), it is concluded that there are economic, social, inclusive, environmental, and cultural benefits for the territories object of technological application as a way to increase efficiency in the management of the scarce resources available.

This greater efficiency in the management of the resources of a territory (achievable with the implementation of "intelligent" management solutions) allows the population to benefit from more utility from, rigorously, the same resources.

Within the scope of this chapter, and specifically regarding the approach to the different Brazilian and Portuguese urban spaces, with distinct idiosyncrasies, and to the various typical "smart cities" projects implemented in these territories, the assumption in the previous paragraph was reinforced and consolidated through the empiricism associated with the registered data and arguments reported in the various official sources of information consulted.

In conclusion, to make a city "smart" and sustainable, it is necessary to use information and communication technologies and continuous correct practices. Only this way will be possible to guarantee that the territory remains sustainable for many decades, ensuring continuous evolution, growth, development, and investment. For future research, it is proposed to analyze public policies for the implementation of smart cities in sustainable cities.

Moreover, the model that emerges from the study of different geographies and realities within the specific scope of a given subject, together with the approach to the conceptual premises for framing that same subject, allows, on the one hand, to verify the theoretical harmony between the factual elements collected and the previously registered theoretical dimension and, on the other hand, fine-tune, calibrate, and, therefore, develop the respective study area.

In the future, it may be interesting to compare the content of this study with other results achieved in studies of a similar nature but focused on urban spaces belonging to other continents.

There will certainly be a set of cross-cutting variables that are indispensable for the successful implementation of "smart" projects in any urban space. Hypothetically: the stage of technological development of geographical spaces; the macro and micro economic stability of countries; and, from an even more structural perspective, the democratic maturity of the territories will constitute essential variables for the pursuit of any project within the scope of "smart cities."

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Wearable Sensors for Smart Societies: A Survey

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Abstract Lately, numerous new well-being Global Positioning System beacons and smart watches have shown up in a few worldwide electronic item shopper displays. The idea of wearable gadgets keeps on being hot, and the market request keeps on developing. As of now, the item types of wearable gadgets fundamentally incorporate brilliant glasses, smart watches, keen wristbands, and so on. By interfacing with the web-service and consolidating with different programming, we can furnish customers with some significant essential signs data and keep clients in contact. In any case, in down-to-earth clinical applications, wearable gadgets ought to guarantee the exactness of securing and guarantee comfort during the time spent employing. By lessening the volume of implantable devices, it improves their biological compatibility and perseverance. The solace insight of customer's influences by the soundness of battery power gracefully, administration life, sensor position, power utilization, precision, and so forth. The proposal provides a summary of various contributions in the wearable devices domain. The contributions of various authors are analyzed and summarized.

Keywords Sensor network · Wearable sensors · Physiological data · Smart society · WoT · GPS · Bluetooth

1 Introduction

Wearable devices [1–3] are making their way in many areas. Some of the domains include hospital monitoring [4], sports personnel surveillance [5], elderly supervision [6], etc. This equipment aids in providing assistance to the embedded. The setup includes an enormous arrangement of detecting devices [7, 8] actuators, clothing supporting the technology, systems connecting using wireless technology,

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components equipped with processing power, instruments having multimedia capabilities, interfaces provisioning user input, programs supporting the technology, and procedures assisting in the capture of data, processing the received data and components evaluating the input. The instruments that make the system compute based on the received data. Some of the parameters measured include fundamental measure, heart pace, computation of body fluid force, oxygen saturation level, rate of breathing, etc. Web of Things (WoT) [9] is a framework that consolidates sensor/camera, network, and a cloud worker that compelling to encourage the trade of information naturally without continually using people. The Web of Things (WoT) innovation is being grown consistently. WoT comprises sensors and actuators associated with a remote organization that can screen through the UI at the same time. Some new innovative advances permit the rise of WoT, for example, nanotechnology, remote sensor organizations, portable correspondences, and pervasive registering.

Wearable detecting devices expected for outpatient use face more tough prerequisites in showing that the information gathered is of adequate quality to be utilized in clinical dynamic. When the technology is utilized for normal checking of a patient‘s imperative signs, the batteries are needed. The end product of the cited measurement is that current checking techniques are as of now recognizing most patients with anomalous fundamental signs, and the issue much of the time is not to do with an absence of information however because of the helpless dynamic in light of that information. It decreases in the quantity during in-emergency clinic heart failures or during patient [10] disintegration. for instance, impromptu admission to Intensive Care can be accomplished all the more viably and that’s only the tip of the iceberg economically through improved cycles and preferable preparing of staff over by checking all ward patients, or even a subset of ward patients, utilizing wearable sensors.

The chapter is a summary of various contributions in divergent domains to create smart city. The system complexity of suggestions is analyzed and jolted down. The chapter also discusses future work. The work is divided into four sections. The introduction section is followed by a literature survey in the second section. The work is concluded in section three.

2 Literature Survey

This section narrates the contributions made by various authors about the topic of interest. An AI calculation [4] arranges active work power into four unique levels: inactive, light, moderate, and energetic. These levels are Compendium of Physical Activities arranging active work dependent on movement power. The classifier prepares to utilize information from numerous situations because of meetings held with clinic laborers. The Brilliant Badge used in this examination contains a Printed circuit board that incorporates a micro-comptroller, a Bluetooth low-energy driver, and an Inertial Measurement Unit. The information assortment convention characterizes considering exercises laborers answered at the medical clinic. The information assortment convention comprised 14 exercises that recreated the errands of medical clinic laborers. Every action was performed for 2–6 min to gain an aggregate of 10 min in all movement force levels. They utilized sci-pack to learn v0.19.1, a Python Machine Learning library. The library separates significance from the gathered information in preproduction, highlight extraction, include choices, and order. The Smart Badge measuring instrument estimates speeding up brought about by gravity or inclining activity on the three actual tomahawks. The signs of each Smart Badge's measuring instrument divide into fixed-length windows without covering. The data collection isolates into train and test sets. The train set forms by 15 members and the test by 5 members. The test was never used for preparing the classifier.

The sensor [11] assembles utilizing adaptable electrical device and equipment for a decent variety to the state of the head, a decent warm interaction. This detector has dual invariants. The extended period consistency relates to the formation of the isothermic geographical area under the sensor. The brief time frame consistency compared to the little changes of the warm field. The exactness is about ±1/10 °C. The sensor was adjusted and tried utilizing a few actual frameworks and ghosts for the reproduction of the warm boundaries of the regions under the detector, tegument, connective tissue, and cerebrum. The skin body heat estimates on the contrary sanctuary. During the expansion of cerebrum body heat, the skin body heat diminishes perplexed. Simultaneously, the skin body heat of the distal regions diminishes. The warmth misfortunes diminish, and the body heat of the sensory body fluid which flushes the cerebrum increments. This estimation was performed in the middle for the examination and attention of time unit beat at the Douglas medical clinic in Montreal. The topic is put on furniture in an area in steady status. The outcomes, utilizing BCT detectors on two subjects, show an awesome concurrence with the focal body heat demonstrated by the rectal body heat. The mobile variant of BCT, the WBS, is easy to use. Its form and substantial permit estimations without torment and its magnitude approve a discrete use. The hardware electrical devices, recollections, information science, telephonic transmission, and electrical device are put in a little applied science suit set by an accessory. The independence and the region of communication rely upon the magnitude of the electrical device.

The examination [12] gives an actual slightness aggregate evaluation device utilizing a solitary wrist-sensor with no extra data from segment information. These endeavors are in course of encouraging the organization of the calculation in a cell phone stage or generally accessible wrist-worn stages. They fragility aggregates highlights from whirligig sensors, which permit estimating the precise speed of the wrist and upper arm. The calculation for ideal determination of boundaries depended on straight relapse demonstrating incorporating bootstrap with recursive component disposal procedure. The recursive element disposal method was additionally used to acquire the ideal number of highlights for recognizing among delicate and non-slight gatherings. The procedure depends on arbitrary inspecting with substitution. It permits us to resample accessible information to frame an irregular arrangement of preparing datasets and approval of datasets. By haphazardly relegating subjects to prepare and approve datasets, we could test any conceivable mix of subjects with various example magnitudes.

The hand connected instrument [13] has actualized an arrhythmia calculation dependent on the non-straight change for R-wave recognition with a versatile edge. The remote detector is tacky and joined to the deceased person's thorax. It will ceaselessly quantify and remotely send tested electrocardiogram chronicles by the utilization of an inherent RF-radio communicator. The RF-receiver collector changes over the electrocardiogram tests by the utilization of a micro-comptroller before sending the electrocardiogram tests to a standard individual computerized aide with an RS232 connector. It is utilized a little plastic nook for the beneficiary with a similar magnitude as the personal digital assistant which is a Fujitsu-Siemens Pocket LOOX 700 utilizing Microsoft Windows Movable programs 2003 for Pouch terminal. It is customized in C# dependent on a .net compiler for Astute Instrumentation Programs. The personal digital assistant is furnished with a CF-space GSM or GPRS framework. It is RTM-8000 from Audiovox and constrained by the product the Personal digital assistant that associates with the General Packet Radio Service portable organize and send vital information to a web-service-associated worker. The WPR worker comprises a Microsoft Server 2003 with an SQL information base and an electronic program created on a Microsoft .net stage. The worker sets in a protected zone in a neighborhood. The signs from the hybrid hard drive are communicated utilizing a document move convention, and the recorded information is put away in the dataset. To get to the web-application for the clinician, it is set up a scrambled realistic secluded web burrow between the worker and the security system at the edge of the medical clinic's local area network. A standard computer with a program can be utilized for the experimental analytic base.

Indispensable electrocardiogram [14] is a savvy wristband, a wearable gadget recently created and protected by the very research facility that records, stores, and breaks down electrocardiograms. It is another age of ease, wearable gadgets that cooperate with cell phones or tablets to gauge understanding imperative boundaries, for example, electrocardiogram, pulse, blood oxygen level, temperature and stickiness of the skin, and patient actual work. The gadget does not need a specific ability or situating to perform signal procurement. It is an ordinary wristband that everybody can utilize. Recognition, inevitable alert, understanding area, and information transmission to the checking focus just require the weight of a catch on a cell phone's application with no arrangement procedure. Battery charging of the gadget is completed with a similar charger as the telephone itself. The Remote Assistance Center has an independent computer application to see understanding information, channel the records relying upon the examination and the pathology that is under clinical examination, increment or lessening the goal of the generally procured records, subsequently guaranteeing a total investigation. The reconciliation of a Bluetooth handset on the board permits the circuit to impart the information straightforwardly to a cell phone, definitely lessening the memory needed to get a few investigations. It is battery-powered through a typical miniature USB connector. This is similar to energizing the client's cell phone. The anodes are made in hardened steel, and a few tests were done to contemplate the achievability of a few materials like copper, vigorously oxidized copper, silver, intensely oxidized silver, gold, and steel. The beat oximetry is obtained with a MAX30102 detector, which incorporates two LEDs and the getting photodiode, permitting procuring the considered signals straightforwardly chip, limiting space necessities and force utilization.

Detector hubs [15] catch and store detector information, figure highlights, and react to demands from the base station to download information and change examining and capacity modes. The center of the application-explicit rationale dwells in the driver running on the base station, which can be redone by an end-client to help a different scope of clinical applications. Mercury gives a straightforward API to the driver to control detector hub activity and recover information. The Mercury driver can utilize a wide scope of approaches for tuning information inspecting, stockpiling, and downloads to compromise energy utilization and information loyalty. They suggest a standard setup of approaches for accomplishing a given battery lifetime target, getting high-esteem information from detector hubs, and adjusting the detector activity dependent on the action profile. Moreover, Mercury gives an exact framework test system that allows an end-client to quickly survey the effect of changes to the driver code on information quality and battery lifetime.

The recorded dataset [16] were dissected utilizing a robotized calculation executed in Matlab. The calculation comprises two stages—the heart/beat degree inconstancy count and a seizure recognition calculation. The pulse evaluates the beat-to-beat variety in the HR, though the PRV measures the beat-to-beat variety in blood throb. In the initial step, the electrocardiogram signal is fragmented into ages of 60 s. From that point, the electrical cable obstruction at 50 Hz is eliminated by a step channel, and the mean of the sign is taken out. An adjusted Pan-Tomkins calculation is utilized to discover the R-top areas. The calculation comprises two stages: a direct separating change and a versatile threshold activity. The sifting step comprises a straight stage limited drive reaction low-pass differentiate channel, which is utilized to complement the sudden high slopes of the PPG beats. The unexpected high slopes compare to tops in the separated sign, which are distinguished by a versatile threshold activity. The calculation utilizes the heart or heartbeat rate as the info. In the wake of separating, the calculation looks online for a pulse increment. On the off chance that this pulse increment fulfills the mandatory principles, highlights are removed and characterization is performed. Four measurements were utilized to portray the seizure location execution. The ability and bogus positives every hour were determined. Seizures were recognized when a caution was given between 30 s previously and 90 s after the seizure beginning. Bogus alerts inside 1 min of one another were considered one caution.

The estimation framework [17] is created by the social decorations that depends on little dynamic Radio Frequency Identification gadgets. They are installed in subtle wearable identifications and trade super less-energy radio bundles. The force level is tuned so gadgets can trade parcels just when situated inside 1–1.5 m of each other, i.e., bundle trade is utilized as an intermediary for distance. People have approached clothing the gadgets on their chests utilizing cords, guaranteeing that the Radio Frequency Identification gadgets of dual can trade radio parcels when the people are confronting one another, as the manlike organic structure goes about as an RF protective covering at the recurrence utilized for correspondence. In outline, the framework is adjusted so it recognizes and evidence short proximity experiences while transferable illness contamination could be communicated, for instance, by a hack, sniffle, or hand contact. The data on up close and personal nearness occasions recognized by the wearable detectors is handed off to radio collectors introduced all through the clinic ward. The framework was tuned so that at whatever point two people employing the Radio Frequency Identification labels were in the eye-to-eye closeness, the likelihood to recognize such a nearness occasion throughout seconds was bigger than 99%. After the contract is set up, it is viewed as progressing as long as the gadgets keep on trading in any event one parcel for each resulting 20 s stretch. The contact designs were broken down utilizing both the numbers and the spans of contacts between people.

The detection device [18] estimates skin conductance undeviating stream to the layer corneum of the cuticle underneath estimating terminals. To accomplish a broad unique scope of connective tissue electrical phenomenon estimations, the simple molding hardware uses nondirect input-programmed predisposition control with less-energy functional enhancers. Moreover, the detector compartment likewise contains a trio hub measuring instrument for estimations of actual work. A micro-comptroller computerizes the simple signs employing a 12-cycle A-D at a testing recurrence of 20 Hz. The information is then kept in touch with a locally available micro SD card. They coordinated the detector compartment into a standard watch strap made out of terry fabric, bringing about an agreeable, appealing, and lightweight wearable detector. These cathodes are dispensable and can be snapped onto or taken out from the wristband easily. Two changed leads – 3 electrocardiogram was recorded at the same time with electroencephalography. Electrodermal activity detector wristbands were put on the wrists with the end goal so cathodes were in interaction with the dorso-ventral region of the lower arms. Electrodermal activity accounts were analyzed at 20 Hz and synchronous with the video/electroencephalography/electrocardiogram chronicles by creating specialized relics toward the start and last of every meeting for disconnected reorient. The transcription meeting endured roughly 24 work time and supply was supplanted consistently. Every electroencephalography seizure was explored for beginning and counterbalance times, electroencephalography area, and attack semiotics on visual communication accounts. Electrodermal activity chronicles were dissected utilizing exclusively composed programming in MATLAB.

Following individual performance with detectors venture [19] is an enormous scope study inspecting physiological, ecological, and social factors influencing worker well-being and employment execution. More than 200 volunteer clinic workers tried out 1 out of 3 rushes of interest, each with various beginning and end dates. Members in each wave were approached to clothing detectors and react to brief day-by-day reviews for ten calendar weeks, beginning the main epoch of cooperation for the movement. Members were approached to clothing numerous detectors for more than 10 weeks to gather physiological information including sound highlights, pulse, respiratory rate, and rest. Members additionally finished overview batteries toward the start and end of the examination and every day reviews all through the 10 weeks. The fruitful execution of the TILES venture expected us to defeat various difficulties, incorporating recognizing possible difficulties with wearable detectors and making changes varying, taking care of both the clinic's and potential members' interests concerning detector-based information assortment and protection. It also includes accumulating interest in a perplexing report with new detectors, guaranteeing that members were agreeable with requesting, detector-explicit examination strategies, and successfully actualizing the investigation inside spending plan and detector producer requirements.

A total cycle of observing is made out of three stages [20]: information assortment, information transmission, and information examination and input. The information assortment is accomplished by keen apparel and video recorder, whereby savvy attire gathers electrocardiogram signals and movement signs, and camcorder records video data. The information created by shrewd dress is communicated to the portable terminal utilizing Bluetooth, while the video recording is sent to the versatile terminal through Wireless Local Area Network. The general framework comprises two significant parts: information procurement and cloud stage. The brilliant attire as a wearable front end is made of cotton in a twofold layer way. Two silver material cathodes are sewn at the mid-parallel sides of the upper chest having two intenseness. MPU9250 deployed close to the sleeve between two layers. The simple potential contrast detected by material cathodes is preprocessed by an economically accessible simple front end ADS1292. The thing that matters is intensified by the locally available speaker and afterward changed over to a computerized signal by a 24-bit high exact Analog-Digital Converter. The relating computerized signal and the movement signal got from MPU9250 are moved to neighborhood micro-comptroller unit MSP430 through Serial Peripheral Interface. Signal molding is performed on the MCU including sifting and information pressing. All the preprocessed information is shipped off the upper terminal simultaneously through Bluetooth. All the frameworks are coordinated into a toy-like box for the accommodation of everyday nursing and substitution. The keen dress in general is modularized with the belt where the material terminals are installed and the toy-like framework all separable. The video recording framework gives continuous data about the checked patient. Video data empowers far off observing, which is not just appropriate for home consideration situations yet besides decreases the remaining burden of clinical staff. Movement signs and electrocardiogram signals are used for seizure identification. The gathered information is communicated to the neighborhood portable terminal. The client can see the gathered physiological signs and video through the product introduced in the versatile terminal with the programmed finding calculations.

A body detector network [21] includes numerous detector hubs and a facilitator worn on a man-like physical structure. The detector hubs valuate the biological science data of the client. The tactile information is conveyed to the organizer on the body which at that point, thus, shows the comparing data on an individual intersection or communicates the collected fundamental gestural to a distant worker through an organization convergence for additional preparation. The remote neighborhood passages are generally conveyed for public web-service benefits, a body detector network consistently associates with a pertinent wide local area network AP when different interfaces might be accessible. The sign weakens as it engenders over space in the body detector network. The constriction may either be because of engendering misfortunes brought about by the common development of the radio wave in the climate, alluded to as way misfortune, or multiple ways proliferation, alluded to as multiple ways incited smudge, or because of shadiness from deterrents influencing the wave spread, at times alluded to as shadiness smudge. The framework is the transmission of a manlike organic structure by presenting an on-organic structure correspondence passage model and a between-organic structure correspondence passage framework, where the passage qualities are set through test results.

The proposed framework [22] is the quantifiable Fugl-Meyer appraisal framework. The detector sends the information to the medical institution FMA proportion. Here we predominantly regard the superior appendage engine capacity of stroke diseased person, particularly center around the spheroid joint, cubitus, radiocarpal joint, and fingers. Considering the medicinal assessment with FMA scale is tedious work, in the past investigations, we have planned 7 top appendage preparing practices dependent on the short FMA. After the preprocessing step, they separate highlights that catch qualities, for example, power, direction, and sign unpredictability, from the crude detector information. After the significant highlights are extricated, the subsequent stage is to plan these highlights to the medicinal Fugl-Meyer evaluation scale. The measuring instruments were accustomed to observing the development capacity of the upper appendage while the flex detectors were accustomed to checking the development capacity of fingers and wrist. The measuring instrument detector chip is ADXL345, whose goal increments with g range, up to 13-piece goal at ±16 g. These qualities empower estimation of tendency changes under 1.0°, which is sufficiently delicate to catch the development highlights. The obstruction of the flex detector can modify from 10 K to 110 K while it is flexed from level to 180° states. The examining recurrence of all detectors was initialized to 20 Hz.

PVDF picture is a sort of electricity polymer, which is touchy to the difference in the stress utilized [23] to it. It is 16.5 mm by 37 mm by 0.003 mm and was underlying the accessory-kind detector to quantify the metastasis cycle. The detector head, which has a magnitude of 90 mm in breadth and 185.5 mm long, is made out of dual sheets of semi-conductive textures and a picture. Two sheets of conductive textures are utilized for estimating the electrocardiogram to extricate the heartbeat data. The picture detector is utilized for estimating the respiratory cycle because of the midregion uphill and dropping and the pulses. The detector gadget is made out of the belt-type detector head, information procurement circuits for both conductive textures and pictures, and a correspondence circuit to send the information to a terminal for information show and examination. One-chip micro-comptroller PIC16F873A is installed to control the information procurement circuits and to speak with a terminal worker by a product hinder and booking through USB. Two AD converter diverts installed in the micro-comptroller are utilized for changing over detectors' signs. The examining rate is initialized at 1 kHz. In the confirmation try, a business 3-lead electrocardiogram detector and pneumography are likewise used to approve the presentation of the created clothing cardio metastasis sign detector. In the test, a thermistor type detector is put in the external nose section to distinguish the body heat distinction between the enlivened chill airs and the lapsed warm air. Further, the 3-lead electrocardiogram patches are connected at three spots, two on the chest locale and unitary on the leftmost limb.

CodeBlue [24] is a remote interchanges framework for basic consideration conditions. It is deliberate to give guidance, denotive, disclosure, and safety for distant medicinal detectors, personal digital assistants, terminals, and assorted appliances that might be utilized to screen and treat sufferers in the scope of medicinal settings. It offers adaptable, strong coordination, and correspondence across remote medicinal gadgets. It gives conventions and administrations to hub naming, revelation, any-to-any impromptu steering, validation, and encryption. It depends on a distribute/buy-in model for information conveyance, permitting detecting hubs to distribute floods of crucial signs, areas, and personalities to which personal digital assistants or terminals got to by doctors and attendants can buy-in. To keep away from network clog and data over-burden will uphold filtration and accumulation of occasions as they course through the organization. For instance, doctors may indicate that they ought to get a full stream of information from a specific patient, yet just basic changes in status for different patients on their watch.

It is an adaptable Wearable Wireless Identification and Sensing Platform gadget [25, 35] created by our group, appropriate for clothing over articles of clothing at the sternum level. The W2ISP alluded to as just the detector consequently is a Radio Frequency Identification label that incorporates a trio pivotal measuring device and the chip with an adaptable reception apparatus for persistent solace and silver texture to confine the receiving wire from the patient. The detector does not need batteries as it collects its energy from the magnetism region created by the Radio Frequency Identification per user radio wires enlightening it during the cross-examination cycles performed by the Radio Frequency Identification per user. At the point when satisfactorily fueled, the detector essentially disperses the special ID and measuring instrument data utilizing the occurrence RF sign from a Radio Frequency Identification per user reception apparatus. The development observing detector framework gathers speeding up readings from the trio pivotal measuring instrument. The deliberate strength of the got disperse signal at the Radio Frequency Identification per user receiving wire is called the got signal strength marker. It comprises three primary stages-highlight extractions, movement characterization, and bed and seat leave acknowledgment measure. Highlight extraction alludes to acquiring fundamental data from the detector and Radio Frequency Identification information flow from which the movement arrangement stage, in light of the class-delicate characterization strategy for weighted help vector machine, can precisely order the performed action. They suggest a score work that first totals the assessed grouping chance for every action. The scoring capacity mitigates the subsequent impact of those not classified detector readings that could create unfortunate bogus alerts if they were considered in the choice to give a caution without the score work. The score work lessens conceivable bogus alerts by assessing the prevailing class name of numerous detector readings throughout a brief time frame as a more precise portrayal of the action being executed to produce a caution sign.

The detecting device [26] is a two-lead framework comprising of two fundamental parts: three indistinguishable estimated printed circuit boards as anodes for signal procurement and regular mode lessening and one mainboard for signal molding and transmission. Two of these anodes are appended to the chest for signal procurement from the body, and one of them is joined a long way from the chest on the correct hip. The sign obtained from the cathodes at that point goes to the mainboard to be intensified, sifted, digitized, and sent. The differential intensifier separates the signs coming from the two-lead cathodes and intensifies them to fit it to the simple information scope of a simple to-computerized converter. Undesirable recurrence segments are then eliminated utilizing a low-pass channel, a high-pass channel, and a 60-Hz step channel to improve the sign to-commotion proportion. The prepared sign is then digitized with a converter implanted in a small micro-comptroller and sent with a remote framework to the main station, which could be a computer in the home or a medical clinic organization. On the terminal side, this sign is then gotten by a business USB ANT stick and goes into the terminal for additional preparation and show on the screen utilizing a product interface, which likewise can store the sign for additional future assessment by medical services proficient. Every hub in a network comprises an insect motor and a host micro-comptroller unit. The motor is answerable for building up and keeping up association and channel operation. It is a versatile isochronous impromptu remote convention that works at 2.4 GHz and can convey over distances up to 30 m. The isochronous element identifies with how slaves and ace are made mindful of one another.

A computerized signal regulator [27] goes about as the control place is customized locally available through an in-circuit sequential programming intersection. DSCs consolidate the command ascribes of a micro-comptroller and calculation abilities of an advanced sign processor, in this way permitting application-explicit continuous complex investigation installed. The simple signs are examined at 32 Hz through A–D with a 12-digit goal on the DSC. Force is drawn from a solitary lithium-polymer power supply with an ostensible voltage of 3.7 V and a limit of 1100 mAh. The power supply can be energized straightforwardly from a widespread sequential transport port by an installed individual-cell Li-particle power supply device. A stage up/venture down charge siphon creates a fixed, managed yield of 3.3 V for the DSC and fringe segments.

The information assortment foundation [28] was created by the socio-designs venture and depends on dynamic RFID-installed identifications that members in the examination clothing on the chest. The gadgets trade super less-energy radio bundles in a shared style. The trading of radio parcels between identifications is just conceivable when two people are in short proximity and confronting one another, as the manlike organic structure goes about as a shield for the wireless recurrence used to convey. At the point when a connection closeness is identified, the identifications report this data to wireless recipients introduced in the clinic ward, and this data is then handled by a focal terminal framework. The Radio Frequency Identification labels were airtightly fixed in plastic sacks and appended to the members' apparel.

All labels have a special recognizable proof number which is utilized to interface people with the relating individual data. The investigation was affirmed by the Ethical Committee of the Bambino Gesu Hospital. The well-being workforce, patients, coaches, and guests who got to the checked pediatric ward were welcome to take an interest in the investigation and to sign educated assent. All members were given Radio Frequency Identification and requested to clothing it consistently.

The detector board [29] actualizes an exosomatic estimation of electrodermal activity, with the end goal that a little electromotive force is applied to the connective tissue and the subsequent potential drop is estimated. To expand battery life and keep a steady voltage rail for the operation amps and detectors, a less-energy low-commotion controller was added. This controller has a force empower pin to kill the ability to the whole detector framework in the middle of detector indication, hence diminishing the force utilization of the whole detector framework to less than 20 μW and empowering a few days of ceaseless use on a solitary charge. For estimating HR and HRV data, an extraordinary form of the detector board was developed, which incorporated a discretionary PPG path for estimating body fluid quantity beat. The PPG circuit is comprised of a Honeywell SEP8706-003 800 nm light-emitting diodes and a high-level Photonix PDB-169 photodiode arranged for reflectance estimation from the perfused skin. As of now, just the single 800 nm frequency was utilized, since it is an isosbestic point as for body fluid gas immersion; notwithstanding, an extra estimation at a subsequent frequency could promptly be added to gauge relative blood oxygen level to the detriment of more prominent force utilization. The wireless framework comprises an Atmel Atmega328 micro-comptroller and a Chipcon CC2420 wireless framework. The wireless framework was intended to uncover six 10-bit A/D portals on the micro-comptroller for interfacing with the detector framework. The reference voltage on these sources of info can be arranged using remote orders from the wireless store.

The work [30] is an agent started, realistic, individual locate, open-description, dual-arm, equal, irregular healthful preliminary directed from Sept 2015 to Jan 2016, for sufferer acknowledged to both of dual serious consideration units at a huge Academic Medical Center. The emergency component is under the watchful eye of post-cardiothoracic careful patients. The emergency unit has practical experience in the consideration of fundamentally medicinal, careful, and injury-accompanying sufferers. Study avoidance models were patients under 18 years old, infected with an issuing preventing viable detector attachment. Randomization was performed by the examiners and covering accomplished utilizing singular hazy envelopes. Permuted magnitudes of squares of two, four, and six were utilized to rough approach test magnitudes for every layer and treating administration group. A clothing infected detector was applied to the chest beneath the suprasternal score. Once enlisted, bunch assignment was uncovered and the sufferer observing framework was chosen to work in either a command or management manner. For infected assigned to the benchmark assemble, their detector was transcription; however, information did not input to bedside practitioners. Clinicians thinking about patients in the benchmark group depended on standard consideration works on depending on customary turning updates, unsupported by detector information [36]. Infected assigned to the management bunch had their detector information transferred back to a state of care splashboard, offering the clinician ongoing information on the nature of the turn played out, the infected present status, and the opportunity to-next bend.

The keen accessory [31] is utilized to identify when this tablet is gulped. It depends on a little electricity detector, otherwise called a motion detector, which produces a voltage because of mechanical pressure brought about by skin movement during a swallow occasion. The electricity part is attached to such an extent that it is in interaction with the connective tissue of the below-neck, however not very close as to limit movement. The test of putting the electricity detector accurately is to a great extent a component of the particular structure factor. The portable application utilizes a few calculations to order the approaching information into general classifications: spit swallow, prescription swallow, chewable nutrient swallows, and not one or the other. This savvy accessory innovation has recently been demonstrated to be compelling in recognizing eating conduct and effectively ordering between a little subset of nourishment. The detector utilized is the LDT0-028 K, which comprises a 28 m PDVDF polymer movie overlaid to a 0.125 mm substrate that develops potential inside regular CMOS input electromotive force ranges when redirected straightforwardly. The accessory can work under conditions going from 0 to 85 °C. The LDT0 is accessible with added masses at the tip, which lessens the full recurrence yet can enormously expand the affectability of the gadget. In the setup without an additional mass at the tip, the gauge affectability is around 50 mV/g at reverberation of 1.4 V/g. The accessory likewise incorporates a micro-comptroller for inspecting information from the detector, and an incorporated Bluetooth 4.0 LE handset to communicate gained information to an aggregator gadget for preparation. This Arduino-viable control panel is effortlessly modified, smaller, and highlights an RFD22301 SMT framework. The inserted mainframe is an ARM Cortex M0 with 256 kB of glimmer memory and 16 KB of RAM. The general framework incorporates a 225 mAh coin-cell electrical storage and can stay controlled by roughly 18 h. On the off chance that an electrical storage-powered coin-cell battery is utilized, the electrical storage can be revived by essentially interfacing the board to a USB supply generator.

A detector hub [32] for an WoT-based fall identification framework fundamentally contains a miniature regulator, a movement detector or detectors, and an RF block. The miniature regulator plays out the primary undertakings of social occasion information from detectors, organizing and sending the gathered information to the new square and controlling detectors and I/O interfaces. It burns through an enormous part of the absolute force utilization of the detector hub. Accordingly, it is critical to apply an ideal miniature regulator for playing out the referenced assignments effectively regarding dormancy and energy utilization. In light of investigations run by Atmel, an Atmel 8-digit AVR gadget is more proficient than an Atmel ARM Cortex®M0 + based 32-cycle MCU as far as equipment close capacities. For instance, an Atmel 8-bit AVR gadget requires 12 cycles to get one byte from SPI utilizing hinder while an Atmel ARM Cortex®M0+ based 32-bit MCU requires

33 cycles for playing out a similar errand. When executing an algorithmic 15-stage Fibonacci calculation, an 8-bit AVR micro-comptroller needs 70 bytes of the stack while a 32-bit ARM-based gadget needs 192 bytes. In basic applications, for example, getting information from SPI utilizing an intruder, accepting an SPI information data transfer capacity of 80 kbps, the 8-bit AVR miniature regulator burns through 36.1 uA while the 32-cycle ARM-based miniature regulator burns through 48.1 uA. During rest mode, an 8-digit AVR miniature regulator devours 100 nA while a 32-cycle ARM-based micro-comptroller burns through 200 nA.

The LOBIN framework [33] is characterized as the medical care IT stage to both screen a few physiological boundaries and observe the area of a gathering of infected inside clinic offices. The gadget used to quantify the physiological information should be clothing, nonintrusive, agreeable, and launderable, and the framework should store such information related to the infected for some time frame. It comprises a bunch of e-material-based savvy clothing to be worn by the infected. Each shrewd outfit is furnished with a bunch of physiologic detectors and a Clothing Collection Design. The physiologic detectors are responsible for estimating crude information that will be additionally handled to get the necessary biomedical boundaries. Each brilliant clothing is given three detectors: an e-material-based strip, a 3-pivot measuring instrument, and a measuring instrument. The e-material-based measuring tapes the biological electric capability of the manlike organic structure by utilizing two e-material cathodes coordinated into the keen clothing. The signs given by the 3-pivot measuring instrument are utilized to distinguish tolerant developments and to decide whether the infected is sitting down or moving about to help a suitable conclusion. The thermometer quantifies the internal heat level, and it must be in direct contact with the connective tissue of the infected. Both the 3-pivot measuring instrument and the measuring instrument are coordinated into the WDAD. The WDAD measures the information coming from the detectors and sends them remotely. It is additionally partitioned into two diverse printed circuit sheets—the Information Acquiring and Process Panel and the non-wired Transmitting Display panel. The DAPB gathers all the information from the detectors, measures them, consolidates them all in a message, and sends them using a sequential port to the WTB. The WTB fabricates another parcel by adding data identified with the sensor network to the message coming from the DAPB and communicates it remotely to the Administration System. The WTB depends on the MC13213 from Freescale Semiconducting material, which coordinates the 689S08A 8-cycle microchip and the MC1320x 802.15.4-consistent handset onto a similar chip. Both the DAPB and the WTB share similar electrical storage, and in a future business, the stage could be coordinated onto a typical printed circuit board. During the assessment stage and utilizing a 600 mAh battery, the battery life was tried to be around 8–9 h.

The meeting's members [34] referenced their systems for adjusting work, rest, and day-by-day life, and the significance of ensuring they were having enough rest, regardless of their flighty timetable. Observing actual work and rest periods assisted laborers with the comprehension if they were resting enough, and checking light introduction showed enough light during their works day. Also, the meetings recorded the utilization of advanced gadgets and gems in a clinic climate. Utilizing the cell phone as a detector for checking the laborer would likely be the richest arrangement; notwithstanding, this arrangement would require medical clinic laborers to complete their cell phones consistently during work shifts. Furthermore, the appraisal of the light introduction would not be conceivable, since the cell phone is once in a while conveyed inside the pocket. Another noticeable thought was to plan a gadget to clothing on the wrist, like most movement trackers; be that as it may, medicinal practices and clinic approaches debilitate medical services laborers from employing anything on their wrists and hands. Adornments pieces, for example, watches, wristbands, rings, neckbands, or even studs, are additionally prohibited or if nothing else unequivocally debilitate. The lone special case was the ID identification, which was utilized to offer admittance to saved regions of the emergency clinic and additionally show one's recognizable proof. Fitting detectors inside the recognizable proof identification has a few points of interest for the clinic setting. Laborers can clothing a checking gadget without breaking clean limitations, as the identification is now an exemption. There is no danger of the laborers standing apart with the identification since it appears to be a typical identification and effectively mixes into their uniform. Also, incorporating the detectors into the identification use existing propensities, hence it is less one item to neglect to convey. After settling with the identification as the packaging for the detectors, we need to comprehend where laborers utilized it, given the impact of the identification position on the estimating of actual work and light presentation. Laborers expected to have the distinguishing proof identification noticeable consistently during work. Nonetheless, laborers were allowed to put the identification anyplace they needed as long as it was obvious. As indicated by the photographic records and the bits of knowledge from interviews, laborers would either utilize the identification around the neck or cut to the uniform. A few interviewees announced liking to fix the identification to the uniform since when the identification was worn around the neck connected to lace, it could hit the infected when playing out certain exercises. Laborers utilized a spring clasp to append the identification to the uniform, and the identification was normally worn around the upper middle. Table 1 represents the system complexity of divergent proposals.

3 Conclusion

Many of the contributions are utilizing the cloud for storage and retrieval. The WoT devices communicate with each other assembling an enormous amount of data in the deployed domain. The web-service is enabling the transmission of data from one end to another with the help of cloud technology. The person responsible will be able to access the stored data. The collaborating technologies contribute to a health-aware society. Some suggestions include the following:

- The network we are addressing is quite large. Hence security issues are liable to occur. The systems with varying capabilities are serving various domains.

Table 1 System complexity of the various contributions

Contribution	System complexity
[4]	O(n log n)
[11]	$O(n^2)$
[12]	O(log n/2)
[13]	$\Omega(n)$
[14]	$\Theta(n)$
[15]	$O(n^2 \log n/2)$
[16]	n^2 O(log n)
[17]	Θ(n)
[18]	$O(n^3 \log n)$
[19]	O(n) + 2
[20]	$\Omega(logn)$
[21]	$\Theta(n)$ +1
[22]	$\Theta(n^2)$
[23]	$O(n^4)$
[24]	$O(\log n^2)$
[25]	$O(n^2 \log n)$
[26]	$O(\log n^3)$
[28]	$O(n^2 \log n)$
[29]	$\Theta(n^2)$
[30]	$O(n^4)$
[31]	$O(n^2)$
[32]	$O(\log n^2)$
[33]	$O(n^2 \log n)$
[34]	O(nlog n)

Depending on the domain they are deployed into, preliminary safety measures are to be incorporated. Along with security, some amount of reliability of using the system can be implemented.

- The contributions have come up with different software and hardware usage to cater to the needs of the suggested work. Each contribution has its advantage and pitfalls. Bringing all the contributions together will benefit society. The proposal should be able to serve different platforms to a certain extent. This method has to collaborate with divergent platforms into a single platform where a maximum number of users will be able to benefit from the technology.
- Self-surveillance aims in bringing behavior change and overcome health-related issues. The personnel can undergo different kinds of stress-related problems due to the shift basis of work. Some of the issues related include cardiovascular, diabetes, trouble during digestion, exhaustion, and dejection. The devices observe the personnel which enhances the functioning of the personnel diminishing their well-being-related issues.

Sensing elements are midget design positioned in the surroundings. These instruments communicate with each other forming an enormous network. They monitor the environment and provide readings to the predefined location. Advancement of the technology has enabled the devices to be used in healthcare applications. Monitoring elderly people, the health of sports players, and patient are some of the vital roles played by these devices. The survey analyzes the usage of the devices in the well-being of the individual. It also presents the analysis of divergent contributions. The work provides some suggestions which can be considered as future work.

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Postpandemic EdTech (Educational Technology) on Perspectives of Green Society

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Abstract The aim of this chapter is to describe how education system is being changed with the advancement of emerging technology in postpandemic situation. Smart society is incomplete without advancement of the education system driven by smart and sustainable technologies. Green society is being created with sustainable green technology. Education based on green technology is the latest trend for creating skilled person about "Go Green" and generating jobs with green technological education. Education and technology both are complementary with each other without any of them the smart society could not be built. This chapter illuminates the future of smart education system in the form of EdTech, operated by virtual technologies such as Education 4.0, Hologram technology (7D) in post-Covid-19 pandemic situation. When blended teaching-learning encourages faculties and students to be connected directly with each other for sharing range of information, at the same time, technology advancement is blooming globally. Education industry in India, or in other countries, will implement AI/IoT-based digital learning with Industry 4.0 or future version in next few years after this global pandemic. Industry is capable to digitalize business process in Industry 4.0, which includes automation, production, operation, and services by merging virtual and real world. In AI/IoT-based teaching-learning, faculties are capable to analyze mental state of students and act accordingly. As digital age learning is comprehensible through mobile phones, future 5G technology will enable mobile device to access digital platform "anytime anywhere." Visual interactive learning through holographic technology

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enables students to visualize and experience real-time physical classroom in virtual environment with virtual entities. It is projected that after 25–30 years, there will be no fence among countries in case of education, skill enhancement, and certification with Virtual Institution concept.

Keywords Smart society · Smart technology · Education 4.0 · Industry 4.0 · AI · IoT · Blended learning · Hologram technology · Virtual institution · EdTech · Green technology

1 Introduction

Education is the soul of society which is flourished by technology time-to-time. Any state or country cannot be a developed if its education system is affected badly. When it is about education system, then technology is much needed entity. Both "education" and "technology" are complementary with each other. In fifteenth century, "technology" stayed ahead than "education" when printing technology was invented first time. In near future, teaching-learning process cannot be limited only to physical classroom. In this Covid-19 pandemic situation, the teaching-learning process has bought a wave of worldwide changes. Changes can be witnessed in all spheres starting from general lifestyle to education. This recent time sees the development of virtual era. When the whole world standstill with the lockdown, the life still must move on and getting into the virtual era is the best option that humans had. With the intervention of technology, we have enabled a smooth movement toward integrating different technology to enable the virtual world take command. Trade and commerce have found a new face through different online platforms including the social media. Not only institutions but also organizations are running hassle-free and in fact more efficiently with the virtual mode on. However, the most drastic change can be witnessed with education where the entire traditional way or cultural or chalk and board education have found itself a new technologically enabled identity of success. Many new protocols also got attention during this time, which can serve a better prospect in laying the foundation of smart society. The organization of the chapter is as follows: Section 2 describes technological transformation of the education, the main technological innovation is representing in Sects. 3, and 4 shows how education and technology are complementary. Future technological aspect and education scenario in pre- and postpandemic situation are described in Sects. 5 and 6. Section 7 describes current teaching-learning process as blended learning, and Sect. 8 represents AI- and IOT-based Edtech. Holographic technology in education and 5G communication in blended learning are presented in Sects. 9 and 10.

2 Major Contribution

Internet of Things (IoT) plays major role in everywhere in daily lives. The proposed approach is to design smart education system with various advanced technologies like green technology and AI technology. This smart education system ensures to create skilled students with green technology to sustain in green society. In our approach, there are two perspectives: first, for green jobs, students need to learn about green computing with IoT. Second, students build positive attitude from green classroom. In this chapter, building positive attitude or concentration toward subject has been discussed. Concentration analysis is the only way to evaluate and analyze individual concentration. Brain generates various signals, but analyzing gamma signal, concentration is measured. Our proposed expert system considers the level of concentration and generates report based on which teacher can take necessary actions to motivate students toward the topic.

3 Technological Transformations in Education System

In fifteenth century, when press technology was invented, on that time, only few people were able to access printed books. During that decade, technology stayed ahead than education. That time schools and colleges used to design curriculum in which only important subjects were taught. By the mid of 1600s, pencil and modern library were introduced, and nineteenth century witnessed textbooks, blackboards, and chalk. Till middle of the twentieth century, learning has been focused to course rather than students. After that, technology advancement and application in education is huge. Mobile technology took market by introducing smart phone, smart tablets, and laptops with 3G, 4G, and 5G technologies. Schools were not the only place from where basic education can be found.

Unto 1980s (in Fig. 1), already computers were introduced and in widely used in various sectors including education. In 1989, above 90% academicians understood that computers can help in reading and writing, above 80% believed computers can have positive effects in education, and 85% said computers can increase student's interest in learning. Student and computer ratio goes from 12:1 to 9:1 with Internet in 1999. Teachers started to use software in classrooms for delivering lectures.

Educational technology is commonly known as EduTech or EdTech. It is the method where education is integrated with technology with the use of different hardware and software tools to facilitate learning. With time, the EdTech has managed to capture mainstream attention. With more and more people becoming technology friendly, different new EdTech platforms and methodologies evolved.

Different approaches have been tried in this regard. Some use common video sharing platforms like Youtube to share the online tutorials.

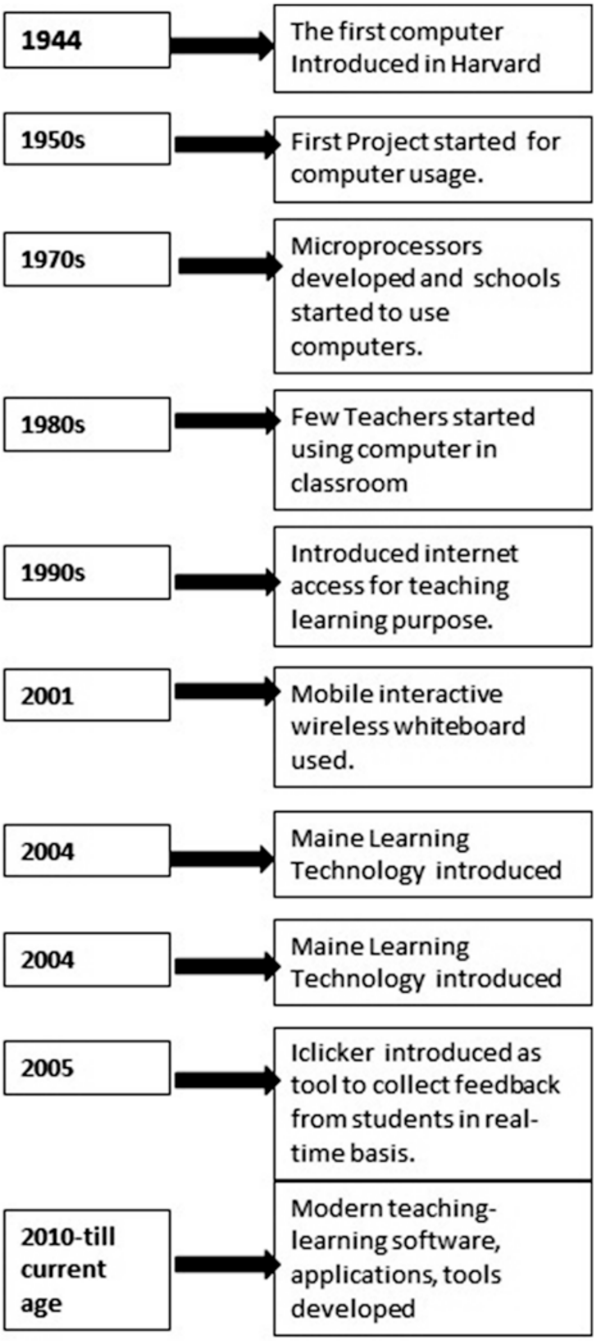

Fig. 1 History of education technology

3.1 Online Video Lecture Platform

Youtube is a popular video sharing platform. People can share videos independently or from institute by creating channels. People have turned these platforms to affordable mediums of sharing tutorials. Some channels like GATE Academy and NESO Academy provide free access to all their lectures, while some others take some registrations to access all the videos [2, 3].

Presently, Indian government initiatives like NPTEL and SWAAM (Fig. 2) stream through Youtube, making them not only affordable but also easily accessible.

3.2 EdTech with Learning Applications

Not only in India but also worldwide, different EdTech companies are taking over the market. Some of the teaching-learning applications are doing great business in this pandemic situation, such as Byjus, Unacademy, Coursera, and Vedantu (Fig. 3). They marked step ahead in lockdown by providing augmented reality-based teaching-learning environment to the students at doorstep. Mostly, there are different tutors for each subject. With the intervention of technology, these courses are becoming more attractive and interactive with tutors using 3D representation, live questionnaires, etc.

Unlike Youtube channels, people generally need to buy out the courses. The packages generally start from school level to undergraduate entrance levels. Coursera provides online course packages for free or paid basis.

Fig. 2 Different video sharing platforms

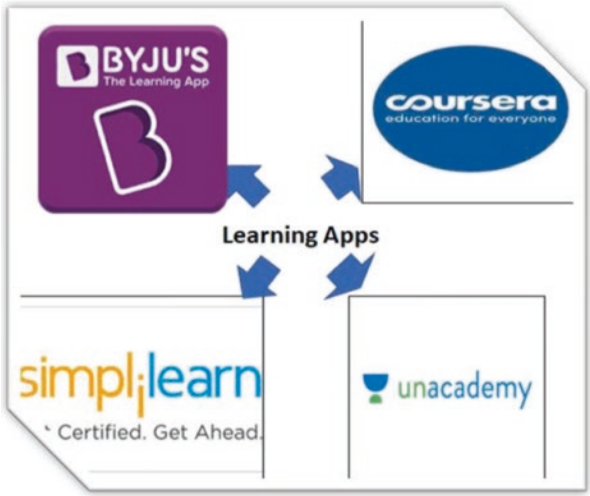

Fig. 3 Modern-age learning applications

3.3 Virtual Transformation of Institutes

During the harsh times of global pandemic, most of the institutions have decided to change their teaching-learning methods. Mostly, all of them have turned to the digital approach for the regular classes and even the practical classes. Using different video conferencing platforms like Google Meet, Zoom, and Webex, they have ensured that no student is deprived of knowledge irrespective of nationwide lockdown. This approach of the educational institutes can also be considered a beautiful amalgamation of technology and education. Not only the institutes but also the organizations have adopted this method to give training to their new hires. Internal training is often needed in organizations for skill development and project transfers, etc. Taking up the virtual method helped them to cope up with the requirements during pandemic.

4 Technological Innovation of This Chapter

Important motivation in every teaching-learning system is to build skilled students with knowledge of emerging technologies. Without positive attention of students, it is impossible to gather enough skill toward the topic. Our objective is to enable students with positive attention or concentration toward teaching-learning session. In one of our works, concentration signal has been analyzed by catching the brainwave signals. There are various brainwave signals such as alpha, beta, and gamma, visible in EEG signal of a human. Gamma wave is responsible for concentration. In Fig. 4, it is needed to create interface to generate brainwave signal and analyze

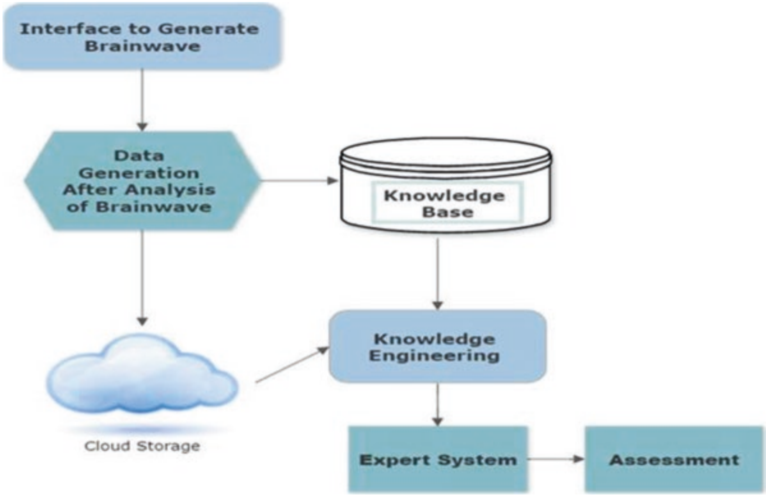

Fig. 4 Knowledge-base concentration analysis

concentration of individual with their knowledge strength by knowledge engineering process. Expert system will generate the assessment report. Main objective of green classroom is to enhance positive attitude, positive thinking, and problem-solving skills in students. It helps to develop skills for building up leadership quality within themselves. Our proposed approach is based on designing an expert system which will analyze concentration level and generate assessment report. Our aim is to provide information about future of EdTech after pandemic situation based on various emerging smart technologies, such as green technology, 5G, and 7D technology in education. Also, how AI-based teaching-learning will be the way to create skilled students with positive attitude in environment friendly with green classroom.

5 Education and Technology Complementary Approach

Although in present times we are witnessing a beautiful merger education and technology, this merger is always under question due to various reasons. EdTech encourages the use of technology to boost the practice of learning. Through EdTech, students use appropriate technology tools more effectively and do a traditional classroom activity more engagingly [1, 11].

Both education and technology are complementary with each other. In three perspectives, education and technology are related.

First, as technologies are updating day-by-day, education needs to be advanced and updated based on latest technologies. In this reason, courses are being designed in the way that students can learn about emerging technologies and can take part in innovation. Innovation is impossible without technology.

Second, in education sector, technology application is increasing to make teaching-learning process more innovative, interacting, interesting, and motivating for the students. Learning management system provides the platform where both teacher and students can interact, and students can get motivation and gain knowledge as shown in Fig. 5. AI-based teaching-learning (Fig. 6) provides all of these with knowledge base.

Third, many industries are growing by launching new products to provide platform for teaching-learning process. Countries are spending money in developing various types of learning software, applications by using emerging technologies (Fig. 7) and getting more profit. Fig. 8 shows how global expenditure has been

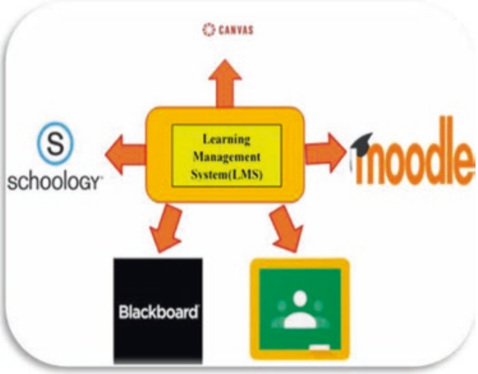

Fig. 5 Learning management systems

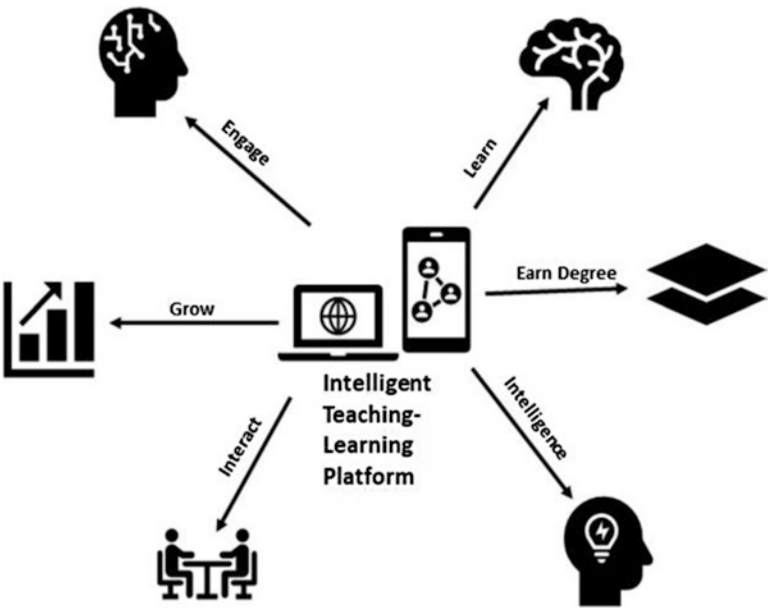

Fig. 6 Intelligent learning process

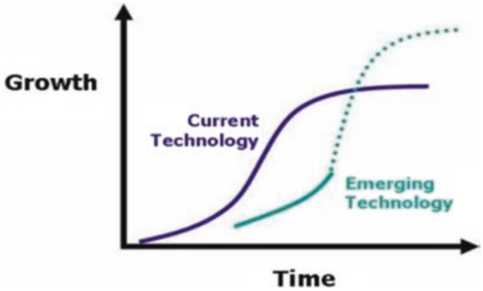

Fig. 7 Technology advancement

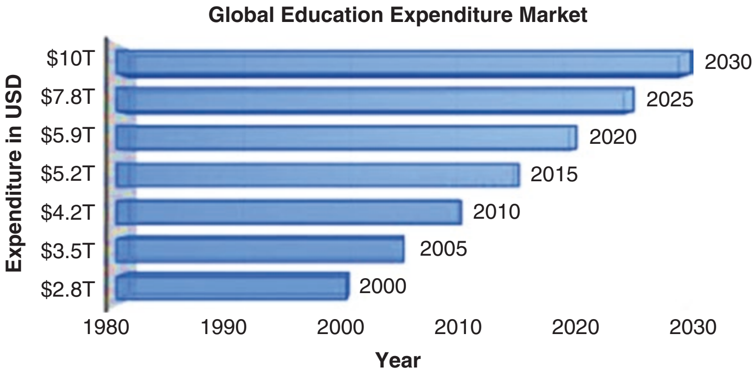

Fig. 8 Global expenditure market

increased to $10 T in education-technology sector. Green technologies are evolving rapidly for sustainability in incurrent smart societies. Green technology enables government to give more attention to develop sustainable innovation without effecting environment. Some of the green technological innovations are LED light, wind energy, solar panels, etc. Benefits of green technology innovation are recycle, reuse, reduce, and renew. Green technology can be applied to develop sustainable development education driver (ESD) [24] to solve environmental issues.

Benefits of educational technology in education are huge and are difficult to list. In general, mostly all institutions have embraced this EdTech era with all its advantages and some disadvantages as well.

1. Advantages.

- Fully Automatic.

EdTech promotes automation to prevent human errors. Each and every process right from record keeping to taking assessment can be automatic with the involvement of technology.

- Enhanced Creativity.

Some subjects like music, science, and mathematics are easier to follow when taught in interactive manner with pictures, videos, and animations than only with written text. EdTech tools allow students to use the Internet, search, study, create new content, and attend tests and assessments.

- Paperless.

Going paperless can be extremely beneficial for the institutions and organizations to save environment and to save money as well. Introducing technology and its resources like Internet, mobile applications, and software can save both time and paper. Future of paperless learning is based on green technology, which is one of the emerging and sustainable technologies. Paperless classroom [27, 28] is nothing but a green classroom, where with the growing use of tablet computers, students can learn and note the lectures in paperless mode.

- Improve Student-Teacher Collaboration.

Teachers can now assist every student without being present physically. They can have interactive sessions involving student's entire concentration. With EdTech comes upgraded classrooms with many benefits which promote better teaching-learning experiences. The use of artificial intelligence and machine-learning solutions has eased not only the learning process but also the assessment part. EdTech enables automation in evaluation too (Fig. 9a).

2. Disadvantages

The drawbacks of EdTech are very minimal. With mostly only benefits, it has a few countable disadvantages [4].

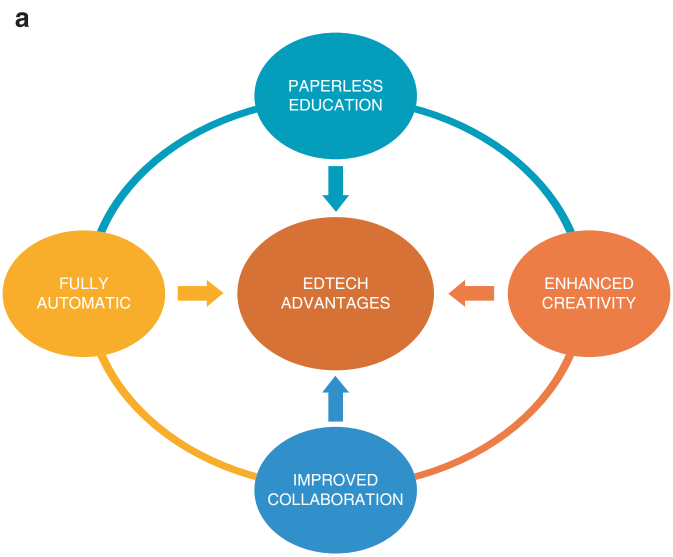

Fig. 9a Advantages of EdTech

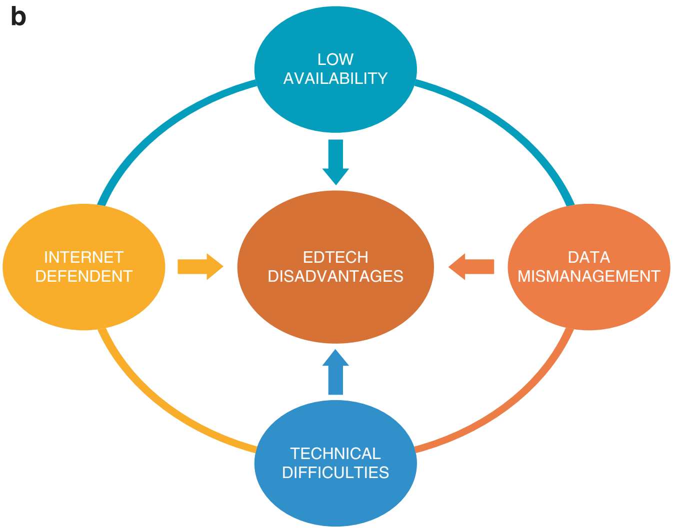

Fig. 9b Disadvantages of EdTech

- Technical difficulties.
- Availability.
- Dependency on Internet.
- Data mismanagement (Fig. 9b).

6 Future Technology Prospects

Big data, Internet of Things (IoT), and artificial intelligence (AI) all these new technologies effect major industries to transform jobs with Industry Revolution of the twenty-first Century. That means it not only affects industries but also transforms the way jobs because of the evolution of Education 4.0 [7]. Green technology [23, 25] enables to develop technological innovations which will be sustainable to environment.

6.1 Education 4.0

- Education 4.0 will enable workforce and machines to align to explore new possibilities depending on Industry 4.0.
- It will harness the potential of digital technologies.
- It will lay founding stones from school-based learning to workplace for the future of teaching-learning process.

- **Online or Remote Learning**

Taking the help of e-learning tools and applications, Education 4.0 provides us anytime anywhere learning method for remote and self-paced learning.

- **Customized Learning**

Customized or personalized learning depends on the capabilities of the student as and when required. This means that there will be individual learning processes for each student.

- **Education Tools**

A major pillar of Education 4.0 will be the technology-driven devices or tools used by students to acquire knowledge. Each student depending on its own capabilities can choose tools; also these tools provide option for easy access to knowledge and revision in blended learning (improved technique).

- **Project-Based Learning**

The competition in market for jobs is on the rise and will continue to do so creating the need for the students today to adapt to project-based learning and working styles. They will need to increase or broaden their skills and learn how to apply and shape them as per situations. This part will create more emphasis on imparting field-specific knowledge to the students within the existing courses. This means that schools will now provide more opportunities for students to obtain real-world skills that are relevant to the prospecting job opportunities.

- **Data Analysis**

The use of machine learning and AI enables us to collect data and analyze them for betterment of the purpose. This would also mean that the technology improves the theoretical knowledge of students and uses human reasoning to examine the patterns and predict trends.

- **Exam Pattern and Assessment**

With the changed mode of education, there will be a change in exam and assessment. The automation of Education 4.0 leads to self-assessment and online exams.

6.2 Industry 4.0

Industry 4.0 is the digital transformation of industry-related process and value creation processes like current trend of automation, Internet of Things, cyber security, and data exchange in manufacturing technologies. The main motive of this protocol is to enable the decision-making processes and ensure equally real-time connected value creation networks through early involvement of stakeholders, and vertical and horizontal integration [4, 10].

6.3 Green Technology

Green technology is also said as environmental technology, which helps us to conserve our natural energy and does not affect environment in anyway. It is used to develop environment friendly products to reuse, renew, and recycle natural resources. Different branches of green technology are green energy, green chemistry, green IT, green building, etc. Green education is about educating people for skill and knowledge development of green technology sustainability in environment. Green job will be created for which it is required to generate skilled green graduates and experts [26]. Going green [29] is not an easy task. Paperless learning [30] is the transformation from physical exchange of material to virtual exchange of materials. Students can learn, do research, and submit assignment with electronic resources.

In green technology age, for green innovation, it is required that researcher should be able to find innovativeness in technology with the complete understanding of this technology but still have limited understanding [31]. Green classroom is not only the transformation of physical classroom but also a platform to make students well prepared for green employment. In isolation period of Covid-19, it is realized that sustainable development is necessary for green environment [32]. Green technology with IoT together makes society as green society in every perspective like healthcare [33–35]. Cloud-based approaches are required to store big data, and machine-learning tools are applied to analyze big data.

7 Education Scenario of Pre- and Postpandemic Situation

The entire lifestyles of people have changed during this whole pandemic period. Starting with clothing to education, we can witness a whole lot of change. The teaching and learning process before and after pandemic has many major changes, which can be considered a necessary one for the upcoming future [8].

Before this pandemic era, the entire education system was traditional. Although there were small developments every now and then, but still mostly people were dependent on the traditional ways of classroom and board. However, this pandemic has bought some forced changes in the teaching-learning perception, and based on which, we can expect a dramatic change and a big step toward futuristic education. Below mention are some changes to be expected [12].

- Dramatic Increase of Blended Learning

Blended learning is a new technology of remote education learning where the conventional (blackboard, canvas, D2L) and nonconventional (Zoom, Google Meet, etc.) platforms will provide a combination of face-to-face interaction with virtual mode.

- Online Education as a Strategic Priority

Apart from a very few colleges and universities, all the institutions have discovered this online education very well. During this Covid-19 period, online education adapt a wide variation from central to an institution's strategic planning.

- Existing and Potential Office of Personal Management (OPM) Partnerships

Covid-19 has made us to rethink of outsourcing core educational capabilities. Schools have invested in resources to design online teaching learning resource to enable integrated technology.

- Current Aspects of Online Teaching

So far, we have discussed that how the teaching-learning aspect has changed in recent times and how it got boosted with the Covid-19 pandemic followed by the worldwide lockdown. The new era teaching or basically the virtual or online teaching has proved itself a boon as per the requirements of recent times [9]. However, it is still facing questions in developing countries where smart devices or Internet is not fully accessible.

According to studies, most of the population now-a-days have smartphones. Mostly, the populations of young generation have personal smart devices, or else they have a common smartphone in a household. The online video conferencing platform's splendid user interface supported in android devices has enabled people with smartphone to embrace the virtual education or online teaching-learning [5].

8 Current Teaching-Learning as Blended Learning

The remote teaching-learning improves the quality of online learning program to develop and needs significant investments to run. The biggest future scope of virtual instructions is that the students return to their physical classrooms.

There are different types of blended learning concepts that come in post-Covid-19 situation.

- **Station rotation blended learning:** In a fixed schedule, student can rotate through a station. Lab Rotation Blended Learning is like this type of learning.
- **Remote blended learning:** Students complete their online course intimating with their teachers as and when needed.
- **Flex blended learning:** Students learn from the recoded material by teacher except for any homework assignments.
- **Individual rotation blended learning:** Students to rotate through stations on individual schedules set by a teacher or software algorithm.
- **Project-based blended learning:** Student can learn from courses by project-based learning assignments or products. Assigning individual project to the students, it is easy to understand courses (Fig. 10).

The necessity of teaching and learning with asynchronous and synchronous platforms is to provide environment with face-to-face instruction. In pandemic era,

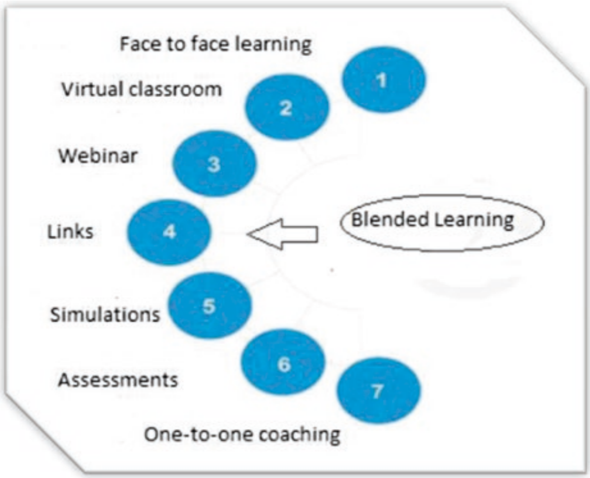

Fig. 10 Different types of blended learning

digital tools are the complements, not substitutes, for face-to-face teaching-learning. With this modern technological teaching-learning process, courses are designed in such a way that precious classroom time will be more productively utilized for discussion, debate, and practice.

In pre-Covid-19 situation, colleges and universities were following neither the online teaching-learning platform for interactive classes nor the online platform for examination or evaluation. Most of the institutes were controlled centrally in every aspect.

In pandemic situation, administrative body has realized that online education platforms can be proved as flexible environment to continue academic activities and accordingly can be planned.

Virtual laboratories are being established for students to practice regular experiments without physical presence. Previously decentralized and distributed online course development and student support functions will be centralized, and management of online learning will be integrated into existing academic leadership structures and processes.

9 Artificial Intelligence (AI)/Internet of Things (IoT)-Based EdTech

In emerging smart world, smartphones are certainly available and accessible object for students. Modern day's teaching-learning process is getting worse because teachers need to compete for student attention with smartphones and other technological gadgets that are more interesting than geometry, literature, and math. Incorporating AI in education, both students and teachers will be benefitted, including checking homework, providing grades, finding the gap in knowledge, 24/7 answering, and many other things.

9.1 AI in Modern Education over Traditional Process

- **Less Administrative Tasks for Teachers.**

In traditional classroom teaching, teachers need to do various administrative work, such as answer-script checking, homework assessment, marking, grade assessment, and preparing teaching materials.

Application of AI in education automates all processes by developing intelligent education system. Intelligent system will analyze performance of individual student and provide assessment reports and grades. Knowledge-based intelligent system examines student in terms of cognitive ability and knowledge adaption ability. Various AI techniques like machine learning (ML) and knowledge engineering are available to provide the above abilities. In one of the patents about Concentration Control Switch [10], brain waves are investigated to determine concentration power of the individual with proposed device to switch on the power. With this approach, analyzing brain waves, cognitive power of each student is easily detectable. After brainwave analysis, generated data are stored in cloud storage or local storage for further analysis. Knowledge engineer is responsible to analyze the concentration power and to ascertain how attentive the student is in particular topic.

- Basic Education Is Available in Anywhere Anytime.

In past decades, depending on financial support, children were able to get basic education from schools and colleges. In modern age, education is accessible to anyone, anywhere even with low financial support. Smart devices including smartphone and smart tablet are easily available with emerging mobile technology (4G, 5G). After this global pandemic, AI/IoT-empowered digital learning will be implemented fully by 2022.

- Common Platform for Every Teaching-Learning Process.

Each person has unique talent in arts, science, literature, and technology. Sometimes, it is difficult to determine each student who is interested in which subject. AI-based common platform is the solution where talent or unique ability can be clearly identifiable for the students. Most of the existing platforms are unable to identify mental ability. AI-based common platform will be benefitted for teachers and students as well, including determination of knowledge gap among students, assessment based on performance in examination, assignments, and grading (Fig. 11).

- More Interesting Classrooms.

In postpandemic situation, it is obvious that students are become more inclined toward games and entertainment than any subjective lesson. Thus, it is a challenging

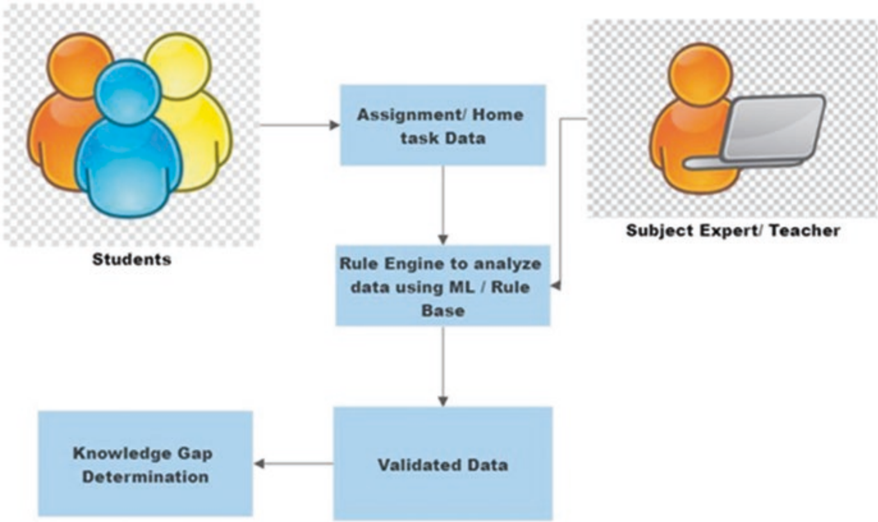

Fig. 11 Common platform for faculty and students

task for the teachers to make the digital learning process more interesting than games and other entertainment. Expert system-based teaching-learning is the best solution for this. Incorporating visual representation in lectures, any lesson can be formed as an interactive lesson. Also, during lecture, some interactive question answering session using Google form makes more interesting. Concentration of the students can be analyzed to determine knowledge gap.

- Provide Expert System for Mentoring Students, Automatic Grading, and Performance Assessment.

In traditional classroom, it was difficult to put same attention to every student for problem solving. But AI-based classroom provides real-time environment where every student gets same attention from teacher and can solve any query. Incorporating AI-based expert system in education enables teacher for continuous monitoring, assessment, and their performance evaluation. Domain expert or knowledge expert provides grades or marks to the students based on real-time analysis of the assignments, home-task, or quiz. With natural language processing, speech recognition, and machine learning, AI is powerful technology in education. Different AI-based industries are blooming with their marketing strategy.

- Provide High-Quality Education.
- It is not everyone's fortune to receive high-quality education from Oxford, Cambridge, or Stanford. Due to lack of resources, providing high-quality education is impossible in rural areas of developing countries. Irrespective of location, online teaching-learning will provide high-quality education.

9.2 Existing AI Applications in Education

– Century Tech [11].

One of the AI-powered platforms is Century Tech which provides automation platform for checking tests and grading students. It finds knowledge gap among students by applying data analytics and cognitive neuroscience approach. This platform is especially useful for teachers to suggest learning material and automation of question and answers. Teacher will be able to monitor each student and whole-class performance.

– Gradescope [12].

This online application is developed by different AI algorithms to identify numerical words, single-word, or one-line answers from handwritten homework by students. To train the data, various ML algorithms are applied.

– Kidaptive [13].

Cloud-based adaptive learning platform is used to predict academic performances using Bayesian network. Students are more intended to involve in learning environment, and they become engaged into different learning procedures with interest.

– Knewton [14].

Adaptive learning platform is used to find gaps in a student's knowledge and provide supporting assignments to improve knowledge gap. It is developed by AI and ML algorithms.

9.3 AI-Based Education Industry Perspectives

In smart age, smart platform for providing education is only way to sustain in smart society. Smart system is the system which is as intelligent as human being. Various AI techniques are available to design intelligent system [17]. As technologies are applied in online education platforms, many industries are operated depending on designing AI-based education platforms in smart application form, software form, or web application form. Development of smart education platform follows many steps as in Fig. 12.

Different learning management system has been used widely as software application for administration, documentation, automation, material management, tracking, reporting, etc. Some popular LMS software are MOODLE, Google Classroom, Canvas, Blackboard, etc.

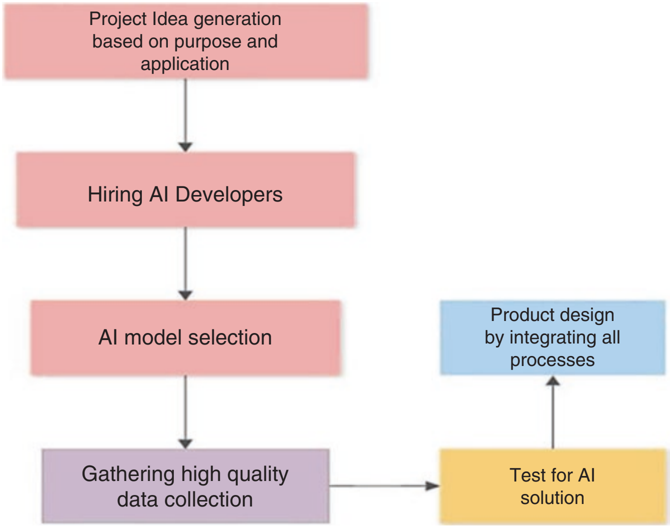

Fig. 12 AI-based start-up generation process

9.4 Scope of Industry to Develop Intelligent Education Platform

- Smart Content Management.

Existing limited LMS software provides platform to the teacher with features like creation of new course, course materials, add/update materials, assignment creation, and making of question. For the teachers, it is needed that they can manage course and course materials effectively. This is one scope to develop new software with advanced features.

- Customized Learning.

Teaching-learning can be possible from anywhere to anytime, environment should be real-time. Online platform should be designed and developed in the way that scheduling of lectures, evaluation process, and course management must be handled efficiently.

- Virtual Institution/Virtual Environment Improvement.

In postpandemic situation, virtual institutions are being established, but effective and good-quality online platform should be developed.

- Real-Time Education Assistance for Students.

Various education platforms are available as teacher assistance. Teacher can handle assignments, homework, examination control, and smart evaluation. Teacher can provide grades and assessment reports from anywhere.

- Facial Recognition.

Facial recognition is the new thing to be developed in online teaching-learning process. Using facial recognition, it can be determined that how much attentive any student is.

- Management of Examination and Evaluation Process.

In Modern age, every institution is adapting online examination and evaluation process. For this activity, many organizations are forming to take that responsibility. Those organizations/firms manage online examination and evaluation process for any institute.

- Adaptive Learning.

Learning ways are different for every student such as one may like video lectures, one may like spatial platform, and one may want to learn in logical way. Ability to absorption of knowledge varies for each student. Levels of intelligence, learning ability, and disability all must be characterized. Adaptive learning environment is needed to support all of these. Combination of adaptive learning and predictive analytics is the scope to develop AI-based adaptive learning platform.

- AI-Based Chatbot Service.

Chatbot-based learning means teacher can deliver lecture through chat conversation. Texts, images, audio, and videos can be sent to grow interest within students, and easy evaluation process is also done.

- Automated Assessment.

Online assessment procedures already exist in the form of AI-based remote proctoring technology. It provides the environment where students can appear for examination, and they can be monitored by the invigilation process. After completion of test, students can see result instantly. Eklavvya [22] has collaborated with various institutions for conducting and invigilating examinations efficient manner.

10 Holographic Technology and EdTech

Modern technologies are inclined toward virtual classroom and virtual environment. Hologram technology is based on "augmented reality" which transforms perceptions of real-world things to digital format. When two beams are interfered with each other then the laser light hologram is recorded [15] by several processes in Fig. 13. Holography projection technology is growing interest for entertainment, education, and many more applications. In recent advancement, 7D holographic projection technology [16] is basically optical wave front reconstruction phenomenon in that light beam is propagated through space with interference and diffraction. As it is also closer to augmented reality, we can enjoy virtual reality. Any real-world

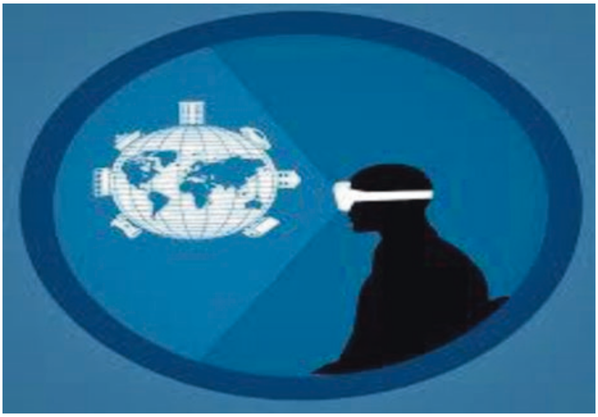

Fig. 13 Example of AR/VR environment

Table 1 Different types of dimension technologies

Features	1D	2D	3D	4D	7D
Video	√				
Audio	√	√			
2D projection	√	√	√		
3D motion	√	√	√	√	
Virtual reality	√	√	√	√	√

object is represented as virtual 7D projection remotely. Holography is the science, and holograms are the graphic copy of light field. Holographic technologies are used in school, colleges, and universities. In global pandemic situation, when teaching-learning process is fully virtual mode, for kindergarten, middle schools, high schools, or colleges, students will be more focused if teaching is fully 7D virtual mode. Students can experience the environment of physical classroom with teachers present as 7D virtual projection, and interactive teaching-learning will be generated. In 2015, Microsoft introduced HoloLens as a holographic projector which is awfully expensive. But many companies are launching and selling similar products in much less cost.

10.1 Recording of Holograms

Light falls into beam splitter divide into two identical beams in two different directions. One is object beam, and another is reference beam. Object beam is reflected by the surface of the object and falls into the plate where reference beam falls directly onto the plate. When two beams are interfered with each other then laser light hologram is recorded (Table 1).

10.2 Use of Holograms in Virtual Teaching-Learning

Using holographic technology, teaching-learning process will be more interactive because human brain is participated more in learning and due to AR, all ages people interact directly. It connects classrooms geographically. Teachers cannot be present many places at the same time. Holographic technology enables teachers or instructors to deliver lectures in many places at the same time.

In teaching perspective, holographic technology can be applied in following areas:

1. History: students can take a tour virtually in different historic places.
2. Science: different physical experiments can be done virtually.
3. Mathematics: equations solving.
4. Skill development: Holograms help people to develop job-related skills and how to interact with others.
5. Gaming: students can create environment and interact with that through educational games.
6. AR-VR laboratory: in pandemic situation, students are unable to practice regular lab activities such as chemistry and physics lab experiments and other lab experiments where physical presence of equipment and instructors is required. 7D technology is modern developing technology and is key technology behind the establishment of virtual lab. AR-VR and digital twin-based teaching class/laboratories are the best solution for post-Covid situation. Virtual reality headset enables students to get reality experience.

10.3 Scope of 7D Technology to Form Virtual Institution

Virtual technology will enable institute to offer the courses and teaching-learning process online. Students will be able to enroll, choose courses, and get course materials from anywhere. Students can attend live lectures from instructors/teachers or can access recorded lecture anytime in virtual environment. Considering the pandemic condition, courses will be designed in that way to support digital learning-based courses. As 7D projection technology is based on AR-VR techniques, it is applied to virtual institution to bring any physical classroom environment in virtual reality including teachers/instructors. In future, virtual institutions will not be limited in digital learning, it will provide students to enroll into degree courses based on evaluation, and they can earn degree certificate from anywhere in the world.

10.4 Benefits of Virtual Institution

1. Provides education in student's doorstep. Offers various courses and student can access courses from anywhere, anytime.
2. As physical presence is not needed, institutions are reducing cost for courses with extremely limited resources.
3. Allows online teaching-learning process with flexibility. 24/7 interaction is possible between student and teacher.
4. Through virtual learning, student saves money without compromising in quality of learning process. Also, students do not need to quit day-to-day activities and not need to pay for accommodation and transportation.
5. Simple and easy learning with annotated teleconference media.
6. Teachers and students can schedule their teaching-learning process in convenient way anywhere, anytime.

Many virtual universities are forming to enable virtual digital teaching-learning from anywhere. Distance learning conducts and offers courses within one country. But virtual institutions are not limited in one country.

3D technology is already applied in virtual teaching-learning process [6, 7]. Virtual institutions will implement 7D technology in future (Fig. 14).

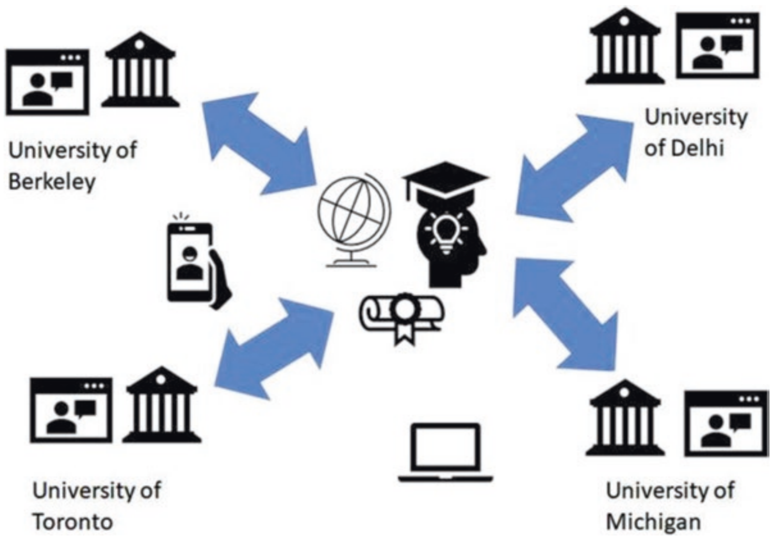

Fig. 14 Virtual institution concept

10.5 AR/VR-Based Education in India

Virtual reality is already implemented in digital learning in various countries. India is not far behind realizing benefits of it. AR/VR is transforming whole education process in schools and colleges. AR/VR market is expected to cross $100 billion in next few years. India is still in early stage in implementing 7D technology in education sector. Indian market is also far behind the global market. Indian market is expected to grow at compound annual growth rate (CAGR) of more than 70% in next few years despite the economic slowdown in global pandemic situation.

Many state governments are taking initiatives and actively participating in various start-up projects. Start-ups in area of content development and management are already done.

11 5G Technology in Blended Learning

In near future, 5G plays an important role in the field of wireless mobile communication. Improvements of 5G are significantly advantageous than current networking technologies in terms of a larger bandwidth, low latencies, reliable service, and higher density of devices. Organizing synchronous interactive educational sessions or sharing high-quality materials, the current network technology faces some difficulties. A comparative study of current network technology with 5G technology is shown in Table 2.

The availability of 5G technology can overcome the mentioned limitation. The characteristics of the service of 5G are high-quality video streaming, two-way real-time conferencing, and immersive experiences in virtual reality platform [18]. As per active-learning strategies, it shows that when students take part in classrooms, they learned more. VR is also an effective way to provide active-learning opportunities, while faculty members may already know two way with instructor's communication like engage students in collaboration, effectiveness of pedagogies that and problem-solving virtually. "**5G will add new types of content, from augmented**

Table 2 Technological comparison between 4G and 5G

Specification	4G	5G
Name abbreviation	Fourth generation	Fifth generation
Frequency band	2–8 GHz	3–300 GHz
Data bandwidth	2 mbps to 1 Gbp	1 Gbp to higher
Technologies	Unified IP, LAN/WAN/PAN and WLAN	Unified IP, LAN/WAN/PAN/WLAN and advanced technologies based on OFDM
Multiple access	CDMA	CDMA, BDMA

reality to virtual reality" — tools whose bandwidth requirements are beyond the Wi-Fi technology [19].

5G also helps for adopting virtual reality (VR) concept in higher education as many VRs are bandwidth-intensive and supporting network delivers immersive content and easier for faculty to take the advantages of this powerful learning tool.

5G technology supports traditional and novel applications, such as device-to-device communication and Internet of Things (IoT). The functionalities of this new technology facilitate the implementation of advanced e-learning services as well as audio and video data exchange service [20]. The main acceptance feature of this technology is to cooperate with different technologies such as 4G cellular telephony and in addition 4G LTE technologies.

- Need of 5G Network.

Radio Resource Control (RRC) signaling connection stay inactive and it becomes activated as and when required as shown in Fig. 15. So, minimum signaling is used at a time for communication so power consumption is less, whereas lots of signaling consume more power in 4G network. For this reason, 5G is more acceptable than other advance technology (like 4G LTE).

Integration of IOT with 5G technology helps in blended learning in many ways not only in new normal situation but also when everything works perfectly [21]. High-quality video broadcasting from the teacher end makes easier around of 100 students, simultaneously connected by 5G technology.

- Throughout the entire lectures and presentations, the signal remains strong as it takes larger bandwidth.
- The students can give feedback digitally.
- Video downloading can be done noticeably short period of time.
- Children need full-time assistance from teachers which can be served by 5G-enabled robots by responding immediately to help with learning exercises.
- It provides more flexible learning as every student's learning style and ability is different. 5G will help students to access the same information and exercises irrespective of distance.
- Finally, immersive lesson with AR and VR by 5G technologies: To maintain the traffic for AR and VR experience, 4G suffers lots of problem, whereas 5G gives

Fig. 15 Comparison of signal transmission 4G and 5G

seamless application regarding this. Students can visit other planets in VR, whereas touch and pinching can be done by AR.

12 Conclusion and Future Scope

In Covid-19 pandemic situation, all necessary parts have been damaged and mostly total education process has been changed drastically. A few decades back, technology was ahead of education. But decades over decades, education has been improved with technology by holding the hand of technology. In modern age, both education and technology are founding stones of society. EdTech is the concept which is already implemented in several countries. In India, in next few years, EdTech will successfully build the smart society. In this current situation, education technology and education industries are incorporating AI-based smart techniques to sustain in growing smart society. Institutes will enable virtual laboratories to provide real experiments in virtual reality environment. With recent advancement in virtual reality, in future there will not be any barrier in physical presence to earn graduation degree from any institute in this planet. Virtual institution is the key concept behind this. Education cannot be sustained without smart technology in smart society.

In future, applying our proposed idea, expert system will be developed which will enable students in positive thinking toward online class. Online green classroom will be developed based on green technology. By catching brainwave signal, concentration analysis will be done.

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Toward Sustainability 4.0: A Comprehensive Analysis of Sustainability in Corporate Environment

Varynia Wankhar, Leena Fukey, and Mudita Sinha

Abstract Sustainability is one of the key requirements for any business, and continuously changing business requirements and the environment are the main drivers of sustainable business practices. However, there exist gaps in recognizing and aligning these sustainable practices with everyday operational activities. This study's aim is to explore the current awareness level in business leaders and stakeholders about corporate responsibility toward sustainability and reflects on the obstacles encountered by them in diverse built environments, laying the groundwork for addressing these hurdles and contributing toward the overall sustainable development. The study has two major findings: the analysis revealed that there is a paradigm shift in the understanding of sustainability; in contrast to earlier publications, newer publications focus on technological advancements such as the use of "Green Building Information Management" and "Green Internet of Things" illustrating the real-time implications of sustainable practices. Further analysis found a knowledge gap that exists among business leaders in understanding the concept of sustainable development. This, in essence, poses a burden for corporate leaders to keep up with ongoing technological developments. The study concludes that to achieve sustainable growth, leadership in the corporate environment needs a 360-degree view of sustainability, allowing them to assign equal value to the envi-

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ronment, social, and economic pillars of sustainability to address the current issues leveraging from the state-of-the-art technological innovations.

Keywords Circular economy · Net-zero energy buildings · Greenhouse gas emissions · Corporate sustainable responsibility · Green Internet of Things · Green Building Information Management

1 Introduction

Earlier studies gathered evidence that humans' collective impact during the middle of the eighteenth century was small on planet earth before the dawn of the Industrial Revolution; however, developments in technology have allowed humans to implement extensive, systemic changes that affect many facets of the Earth's ecosystem. Urbanization and globalization have continuously introduced interconnected feedback loops to our world, contributing to an unparalleled negative human effect on our environment [60]. Over the past few years, there has been a paradigm shift concerning the sustainability of our planet. According to the Intergovernmental Panel on Climate Change [36] report, human-induced warming reached approximately 1 °C above preindustrial levels in 2017, on average increasing at 0.2 °C per decade (Global Warming of 1.5 °C, 2019). Goodland focused on this need for sustainability; according to him, the deterioration of global life-support systems imposes a time limit, and we are already crossing that limit [29]. To reinforce Goodland's claims made 25 years ago, Gee explored the current global scenario of the "Covid19 Pandemic" and the "wildfires that hit the California, USA." According to him, such phenomenon is created by human intervention in Mother Nature, activities such as deforestation for animal cultivation and in search of food and wild plant disrupt the ecological balance introducing various complications, such as unknown diseases and viruses, into the human realm [28]. These recent events are proof we need to rethink our activities to survive on this planet. Building living facilities for a rapidly increasing population has been another main cause of deforestation. In the context of the Built Environment, "sustainability" includes the development phase of planning, designing, constructing, renovating, operating, and demolishing a building, considering how the building can be adapted to fit with the purpose of its users, optimizing its resources during its life cycle [69]. Another point of concern is that the bulging population's negative impact is multiplied by the increased carbon emissions due to the plethora of human activities. By reducing carbon emissions, organizations not only generate value for the shareholders and stakeholders but also add value to the society and environment at large [20].

This is where the management team plays a vital role; a manager who is aware of these activities and their repercussions and who has the willingness to make a change can go a long way to help fix the Anthropocene's dent. Ahvenniemi et al. [2] discussed how incorporating Building Information Management into the already existing building rating system can help ease the decision-making process to achieve sustainability. Over the years, the smart building concept and sustainability have gained due recognition in international organizations. Through a systematic study of current sustainability research in the built environment, this review aims to explore the current understanding of business owners and stakeholders about corporate sustainable responsibility, highlights/analyzes the barriers faced by leaders in different industries, and lays the foundations for overcoming these challenges.

This chapter explores the awareness level of the leadership teams in terms of environmental sustainability in the corporate setting; the extensive review of literature provides the readers with data on the current trends, barriers, policies, and technological advancements that aid as well as hinder management teams to achieve their sustainable goals. This chapter divided into five themes critically analyzes the work of renowned researchers in the field providing groundwork for future discussions and further research on the topic.

2 An Overview and Background of Sustainability in the Corporate Environment

2.1 Concept of Sustainability

Sustainability in the Built Environment: Multinational corporations' operating activities in developed countries have raised questions about social and environmental problems, such as resource exploitation, biodiversity destruction, and human and labor rights, especially in regions where governments have either shown no desire to control and provide social well-being or lack capacity for implementation. Sustainable growth could not be accomplished without business involvement; the authors found that green economics and modern methods such as the co-evolution theory of management reflect a shift of emphasis from understanding what sustainability means to businesses to how to encourage sustainability of businesses [8].

As key actors of human society, businesses play a significant role in achieving these three central priorities, which include eradicating hunger, reforming unsustainable production and consumption patterns, and preserving the ecosystem; setting forward the World Summit on Sustainable Growth, the Johannesburg Plan of Implementation and reaffirming the Future We Desire [16]. The multilevel perspective approach highlights from CSR to green economics; the ideas undergo an expanding phase in which researchers widen the study spectrum from businesses to wider social structures [68].

Education's Position in Sustainability Creating: Building awareness of sustainability involves a radically new approach to how academic institutions coordinate curriculum and science and contribute to society. The concept of awareness of sustainability includes understanding the complexities of system dynamics, being socially robust, recognizing different epistemic cultures, and integrating normative requirements. The authors also advocated a system in which sustainability components and their challenges might conveniently blend into numerous analytical methods, such as chemistry, economics, ecology, geography, government, history, physics, and sociology [49]. In addition to teaching and learning, sustainable knowledge sharing needs to be taken into account across the university or educational institution, adapted to evolving social demands, and coproduced sustainability with society. At all stages of university teaching and activities, it needs to involve "walking the talk" [37].

The Role of Technology in Sustainability: While studying the effect of public science on the technical advancement of industry in the field of green energy, the authors found that the extent of establishment positively influences the degree to which the industrial sector draws on green public awareness for further technological advancement, the scale of implementation, and the technological reach [4]. It is becoming more crucial for managers to monitor performance data in today's knowledge-driven era, using methods such as Computer-Aided Facility Management (CAFM) or Building Information Modeling (BIM) through the implementation of software solutions [7].

Role of Artificial Intelligence (AI) in Building Sustainability: Intelligent, sustainable solutions will shape the future. A brief review of the various developments in AI is highlighted in this section. These technical advances include real-time data functioning as key instruments in the manager's toolkit, facilitating early decision-making and timely action to avoid harmful environmental impacts. Computer-Aided Facility Management (CAFM) is used as a tool to provide data on the operation and repair details of a building, helping administrators to take appropriate and prompt steps that are more cost-effective over the life cycle of the building [64]. The Building Information Management (BIM) consists of the whole building's information and a complete collection of construction documentation contained in an electronic database [75]. The entire data are parametric and hence interlinked made possible through innovations such as the Device-to-Device (D2D) model that satisfies even the emerging needs of 5G Networks (Fifth Generation Networks), this further enhances the efficiency of leaders in the service industry [17]. The associated assemblies and constructions are immediately influenced by changes in an entity within the model since the model includes the necessary relational information. The authors also noted that BIM has now modified the way designers communicate with consultants and architects, and also it has the potential to lead the industry toward construction efficiency that follows the objectives of sustainable development [75]. Maksimovic investigated green technologies and examined the Internet of Things (IoT) that transforms how people manage their lives and connect in different fields of society. The IoT is a global network of intercommunicating physical objects/things that reorganizes. It changes the lives of individuals, companies, and culture in general through the amalgamation of people and things with anything and anyone, anyway, and anywhere. Green technology encompasses renewable environmental construction, production, usage, and recycling, with substantially reduced or no environmental effects. G-IoT is, however, a new concept, is more energy efficient, lowers greenhouse emissions and waste, and has tremendous potential to improve the competitiveness of the economy and the environment [47]. Green IoT makes it possible to introduce safe and environmentally friendly smart cities, delivering data via wireless sensor network (WSN) to users with various applications through the cloud infrastructure and process sensor layer. The future will see an interaction between societies as communication mechanisms and control systems become more simplistic and intellectual [40].

A recent emerging trend in the Architecture, Engineering, and Construction (AEC) industry is the integration of BIM with sustainable strategies; this is acknowledged as the Green BIM technology, perceived as the use of BIM-based tools that help to achieve and assess enhanced building efficiency [35]. A review of the Green BIM literature indicates that the key obstacle for the adoption of Green BIM is inadequate and insufficient knowledge sources of established structures, which impacts management decision-making [61]. The emphasis on BIM ensures a paradigm change in the Architectural, Engineering, and Construction and Operations (AECO) sector [7].

Green Design: Zou et al. [77] proposed that realistic solutions are roughly classified into three groups: improved regulation solutions, project team strategies, and preparation recommendations to help reduce the energy efficiency deficit resulting from building design-related factors. A performance discrepancy exists when estimation methodologies and methods or input parameters are improperly used in the design process [39].

2.2 Corporate Sustainable Responsibility

Proactive Sustainability: Increasing internal and external sustainability challenges interrupt a company's approach to sustainability issues, including regulatory guidelines, the sense of top management's social and ethical responsibility, emerging business opportunities, and cost considerations, such as a carbon tax [58]. It is easier for businesses to combine corporate responsibility to maintain and handle environmental issues alongside economic development. The welfare impact of CSR on the social and natural climate, however, has given mixed results [46].

All activities that involve design, analyze, measure, and improve environmental, economic, and social activities to (i) create a sustainable development of the organization itself and (ii) enable the company to contribute to the sustainable development of the economy and society as a whole is known as corporate sustainable management [66].

Corporate firms have deeply embedded in their corporate governance structure a mission to contribute to sustainability [32]. The use of sustainability control systems (SCSs) goes beyond proactive sustainability strategy also enables corporations to manage sustainability threats and opportunities and to respond to stakeholders' sustainability demands by enhancing the transparency and accountability of operational activities [5].

For effective strategy implementation, proactive sustainability strategy and operations of other internal functional departments must be aligned; this alignment will help top management to systematically address external sustainability concerns [74]. Lower-level managers have more operational responsibilities to deal with long-term sustainability concerns; therefore, top-level management should be made explicitly responsible for dealing with long-term sustainability concerns creating more room for lower-level managers to be more forward looking [31]. The fact that there is no significant association between CSR and energy intensity suggests that incentivizing corporate sustainable responsibility will motivate firms to be more responsible as it will provide them with more competitive advantage [59]. Regarding the Kyoto Protocol, there is a blame game in which developing countries hold developed countries responsible for CO_2 emissions. In contrast, developing countries argue that developing countries have a huge emission reduction potential at a lower macroeconomic cost to their national wealth. Hence, instead of decreasing, CO_2 emission has, in fact, increased since the 1990s, especially in developing countries like India and China [15].

This stand against each other can have disastrous consequences. Unless and until economic prosperity is supported by a strong commitment toward enforcing the provisions of various international treaties and investment in subsiding activities in the renewable energy sector, it will not solve the global environmental problems [11]. The study further mentions that India lacks commitment and measures to reduce and control carbon emissions while prioritizing social and economic development seems to need the hour for the Indian economy. In their longitudinal study of social responsibility expenditure, Verma and Kumar [72] studied 30 companies of the BSE Sensex. The results showed that the environment is not a priority area for CSR in India.

2.3 Perception of Corporate Sustainable Responsibility

Organizations Perception of Sustainability: Aune et al. [6] believed that a facility manager can "see" both the users and energy being used; therefore, they are in a unique position to improve the interplay between technology and use and to contribute to more energy efficiency. Some of the crucial enablers for proactive O&M practices are competency, skill-base, and motivation levels of FM teams; the authors further recommended that the profile and competency level of facilities management personnel can be raised strategically at the national level through relevant initiatives [50]. Improving employee engagement with CSR can be achieved by choosing the right leadership style within an organization [30]. Choi et al. [19] noted that there is a positive relationship between ethical leadership and employees' attitude toward CSR. Ethical management plays an important role in exercising correct values and good individuality; they can help organizations to become more environmentally accountable and socially responsible [54]. Reinhardt [62] believed that there is no general answer as to whether it "pays to be green"; however, whether the social and environmental engagement can contribute to the success of the company's economy depends on the activities and measures undertaken in the name of sustainability.

Evidence from past literature suggests that tension arises because both negative and positive relationships can be found between voluntary environmental and social activities and corporate economic performance. Schaltegger and Burritt [66] discussed four broad motivations, which may underpin the behavior of managers concerning sustainability: reactionary business case is characterized by implementing CSR activities only if they are viewed as necessary to secure the existing conventional business case with its profit-driven, financial rationale; reputational business case of sustainability follows from narcissistic CSR management with a sole focus on media sensibility to reputational matters; responsible business case of sustainability results from technocratically driven sustainability management and performance; collaborative business case for sustainability results from dialogue-based management and engagement with a broad range of stakeholders, including vulnerable stakeholders. Out of these four, the authors believed that the "collaborative business case of sustainability" expresses care for the vulnerable, including the environment, a user orientation, dialogic participation, nonhierarchical transdisciplinary teams, and evidence gathered from the field. From this perspective, the strongest business case can be launched in business settings where monetary motivations have been found heavily deficient.

Stakeholders Perception of Sustainability: One of the major barriers for implementing sound and sustainable facility management is the lack of consensual understanding and focus of individuals and organizations about sustainability; this calls for a re-evaluation of skills and training provision, traditionally offered separately to designers, and facilities managers [1]. The facility managers should make use of their position and integrate all the three pillars of sustainability, also getting the top management on board by keeping them informed of the benefits and cost-efficiency of the green practices [48]. There is a large green knowledge and skills gap among managers; this proves to be cost inefficiency for the Green Buildings. They have initially invested a large sum of revenues on installing energy-saving technologies, affecting green building potential. The study further investigates a need for managers to equip themselves with the necessary know-how by undertaking training and online courses.

However, due to the expensive fees and time constraints, a majority of the managers hesitate to join such classes; the authors suggested that if the government or the company subsidizes such courses and training, the majority are willing to join the courses [45]. The firm's leaders should intentionally collaborate with external knowledge providers to benefit the firms' reputation where they can be leaders of change and innovation rather than just adapting to the change. Leaders should consciously adopt new green policies in line with the firm's efficiency demand; this will help to identify opportunities, solve existing problems, and give the firm a competitive advantage [45]. To ensure that the company's CSR initiatives are not in vain or remain superficial, the employee's involvement becomes very crucial [53]. Gazzola and Colombo [27] noted that employees' engagement is one of the toughest and the most critical elements to ensure CSR success in a company. Lean-green integration can reduce waste, is more cost-effective, and can improve safety with the support of close relationships with suppliers; the integration can also improve work processes and create value by transforming waste into valuable resources through innovation [43]. Both lean and green management focus on only waste management when it comes to sustainability; therefore, leaders should analyze the impact of the integration on all the three dimensions of sustainability to truly achieve sustainable production [12].

2.4 Current Tool and Concepts with Regard to Sustainability

Circular economy is a concept drawn from the ideas of industrial ecology and industrial metabolism formulated during the 1970s and 1980s through a rethinking of the industrial processes [26]. It is scientifically defined as an economy constructed from societal production-consumption systems that maximize the service produced from the linear nature-society-nature material and energy throughput flow. This is achieved by using cyclical materials flows, renewable energy sources, and cascading type energy flows. For a circular economy to be successful, it should contribute to all three sustainable development dimensions: economic, environmental, and social.

It limits the throughput flow to a level that nature tolerates and utilizes ecosystem cycles in economic cycles by respecting their natural reproduction rates [42]. Loiseau et al. [44] had identified circular economy, green economy, and bio-economy as key and interconnected concepts in sustainability research, and they had suggested a hierarchical relationship among them. Upon comparing and contrasting the three concepts of circular economy, green economy, and bio-economy, it was found that these concepts, although being global concepts, are being viewed differently in different parts of the world. Furthermore, when compared, they are missing the sustainability aspect. The three concepts show a wide variation in underlying assumptions, overall aims and objective, specific focus, level of detail in policy guidance, and operationalization of sustainability [23]. There has been a postcautionary trend when it comes to environmental concerns caused by mass production and manufacturing. Still, this approach is beginning to change; the EU has started recommending guidelines for the design of many new products and has started linking together various regulations covering resources and wastes [70]. Plastic has over the years become a cheap substitute for raw materials like wood in designing furniture to building car bodies; they are single use and do not decompose pioneered in the early years of the twentieth century, and further perfected through branding, mass-marketing, and computerized stock control evident in giants like K-Mart, Wal-Mart, and IKEA, today, the mentality of humans remains the same when it comes to consuming; problems are dealt with only after they have affected the environment [22]. The EU stipulates construction and demolition as among the largest contributors to waste. Smart and Industrialized Prefabrication (SAIP) provides an opportunity to further advance the transition into the circular economy in the construction sector [24]. Lack of information sharing among stakeholders within the reverse logistics process is another factor that hinders widespread adoption of the Loop of the Construction Supply Chain (CLSC) in the construction industry [34].

Nascimento et al. [52] discussed implementing circular business models combining it with technology from Industry 4.0, such as 3D printing, using CAD software (Computer Aided Designing) giving rise to models such as the circular smart production system (CSPS) having seven stages: product life cycle; selective waste collection; waste sorting; waste treatment; product printing; product assembly; and product selling. The Industry 4.0 concepts used in the CSPS model are web technologies, designing in Computer Aided Designing/Computer Aided Engineering CAD/CAE 3D parametric tools, Additive Manufacturing, and product assembly using robotic factories with little or no human intervention. This model uses an app to track down waste from households and companies, then collects and segregates them, and then chemically processes the waste to convert them into powder or liquid form to use as an input for 3D printers. This is how the waste discussed in the previous studies resulting from mass production can be decreased and reused to make better value-added products contributing to the circular economy concept of reducing wastes and reusing as much as possible. Taking the Covid 19 Pandemic into account sorting of waste becomes all the more important especially in metro cities where the sewage consists of waste coming in from Covid treating Hospital facilities, using technologies such as sludge hygienisation to eradicate the viral particles, as mentioned in the book by Chakraborty et al. 2021 [18].

Green Rating Systems: Different efforts have been made within the real estate profession to develop a method to certify environmental performance. In the United Kingdom, the BRE Environmental Assessment Method (BREEAM) uses a consensus-based weighting system to aggregate performance into one overall score for a building, rated on a scale ranging from the past, good, very good to excellent.

In the United States, the Leadership in Energy and Environmental Design (LEED) scheme by the US Green Building Council uses a point-based system, similar to BREEAM, but resulting in buildings being awarded bronze, silver, gold, or platinum status. Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) is the German building certification system that also uses bronze, silver, gold, or platinum certificate [64]. To enhance the successful implementation of LEED projects, Ofori-Boadu et al. [55] discussed that management should critically focus on (a) the role of leadership; (b) strategic planning; (c) customer; (d) analysis, measurement, and knowledge management; (e) workforce; and (f) operations.

Sustainability Indicators: Creating markets on which carbon may be traded is but one manifestation of the policy response to global climate change (GCC), but one that has a direct and immediate impact on corporations. With sustainability consisting of a complex set of issues, it is becoming important and valuable for the indicators to be simplified [51]. Five main objectives of sustainability indicators identified by Waas et al. [73] are as follows: communicate information simply, operationalize sustainable development, facilitate continuous learning, demonstrate accountability, and identify knowledge and data gaps. However, the existing indicators of environmental, social, and economic should be revised to highlight the distributive impacts of sustainability efforts [57].

2.5 Institutional Pressures and Barriers in the Path to Sustainability

When it comes to sustainability, the FM sector is lagging in the sense that it has mainly embraced its environmental responsibilities; still, the social, cultural, and economic potential of sustainability has not yet been fully optimized [65]. Støre-Valen & Buser [69] believed that FM practitioners need to develop more process-oriented competencies, social, and take into account the behavior of end users to achieve the potential of sustainable FM.

Organization: Within the context of the organization, higher cost and unseen financial benefits are still seen as barriers when it comes to sustainability measures [3]. A lack of (a) steering mechanisms, (b) financial skills, (c) clients' understanding, (d) process knowledge and underpinning knowledge, and (e) lack of the availability of methods and tools and competencies related to the innovation process have been identified by Häkkinen and Belloni [33] as the main barriers to sustainable facility management.

Technological Advancements: The rise in technological advancements, such as Building Information Model (BIM) and smart house technology, makes it difficult for the facility practitioner to make the viable decisions of choosing the right technology to help reduce energy consumption [63].

For making the right decision to implement these technologies, FM practitioners require knowledge, understanding, and appropriation, which need to be continually updated [71]. Leaders of organizations need to stay up-to-date with advancements such as Edge Intelligence, Data Mining and Deep Learning to be able to interpret real time data from sensors and IoT to make effective and informed decisions [14]

End User: Despite the end user's awareness of sustainability concept, limited experience from building owner and rewards are the two main barriers to the steady progress of professionals taking the green building certification in developing countries like Indonesia and the adoption of green building [10].

Policies – Green Certifications: Scofield [67] had raised concerns about the efficacy of LEED certifications; in his study, he used the data made available to the public due to New York City's local law 84 and investigated the nonresidential buildings studying their energy use and GHG emissions. He then compared the 21 LEED-certified buildings to other noncertified buildings; he found that gold-certified buildings outperformed the other buildings by 20%, while silver LEED-certified buildings underperformed due to the lack of accurate Energy Performance Ratings followed by LEED. This raises the questions of whether the existing models and tools to measure sustainability are equipped enough to cater and match the needs of a Green-Building certification?

Furthermore, in another study, Komurlu et al. [41] investigated how LEED certification and its standards are more relatable only to the US buildings. Whereas in countries such as India and Abu Dhabi, more localization is required to consider the local laws and procedures while constructing and operating the buildings. This confirms that LEED and other global bodies that monitor sustainable development need to adapt and evolve as per the need of the hour and location.

Barriers in Emerging Economies: Although the three pillars of sustainability: environment, social, and economic are presumed to work in harmony, in reality, there are often conflicts among the three; Jayanti & Gowda [38] cited a straightforward example: managers wonder whether it pays to be green. When it comes to environmental regulations, emerging economies present interesting dilemmas; this is due to urbanization aimed at raising the standard of living but poses threats to environmental health. By learning from the mistakes of developed economies, emerging economies can have the upper hand in sustainability innovation.

Companies like Godrej, Boyce, and Tata group, even small companies such as Kirloskar, treat sustainability as a strategic priority in India. India has unique factors: (i) maintenance of backup generators that increase carbon emissions; (ii) higher material costs that provide an incentive to avoid waste for a higher payoff; and (iii) supply chains that embrace economically vulnerable villages necessitating efforts to keep them viable by upgrading water supplies, education, and providing a better connection from farmer to market.

Pressure from the Indian government: (i) the largest 100 companies in India are now required to publicly disclose their sustainability initiatives; (ii) companies in the energy-intensive sectors are required to comply with an energy-efficiency cap and trade program launched by the Bureau of Energy Efficiency; and (iii) a recent overhaul of India's corporate law requires large businesses to devote 2% of their profits to CSR [76].

3 Methodology

The current study conducts a systematic review of research articles relating to five themes: (i) concept of sustainability; (ii) corporate sustainable responsibility; (iii) perception of corporate sustainable responsibility (stakeholders and shareholders); (iv) current tools and concepts used to measure sustainable performance; and (v) institutional pressures and barriers in the path to sustainability. The referred articles were considered qualified for the present study based on their resonance; date back to the last 12 years; and published in cited journals such as Emerald, Elsevier, Springer, and Taylor and Francis in Scopus Indexed. The scholarly search engines used to search for related articles are Google Scholar, Scopus, and CORE. Keywords such as "sustainability, circular economy, net-zero energy houses, green house gas emissions, and carbon foot print" were included in the filtration process. Sixty-two articles were considered eligible after referring to 100 articles, while 38 articles were disqualified on the basis that they were ahead of print, some were not

Table 1 Exhibits articles reviewed under each theme from the year 2008 to 2019 (source: author's own elaboration)

Themes -> Years	Sustainability	Corporate sustainable responsibility	Perception of corporate sustainable responsibility	Current tools and concepts with regard to sustainability	Institutional barriers and pressures in the path to sustainability	Total
2008–2009	0 (0.0)	1 (9.1) (33.3)	2 (15.4) (66.7)	0 (0.0)	0 (0.0)	**3 (4.8)**
2010–2011	4 (28.6) (50.0)	1 (9.1) (12.5)	1 (7.7) (12.5)	1 (7.7) (12.5)	1 (9.1) (12.5)	**8 (13.0)**
2012–2013	1 (7.1) (11.1)	2 (18.1) (22.2)	0 (0.0)	2 (15.4) (22.2)	4 (36.4) (44.4)	**9 (14.5)**
2014–2015	0 (0.0)	4 (36.4) (30.8)	4 (30.8) (30.8)	2 (15.4) (15.4)	3 (27.3) (23.1)	**13 (21.0)**
2016–2017	5 (35.7) (41.7)	1 (9.1) (8.3)	1 (7.7) (8.3)	4 (30.8) (33.3)	1 (9.1) (8.3)	**12 (19.4)**
2018–2019	4 (28.6) (23.5)	2 (18.1) (11.8)	5 (38.5) (29.4)	4 (30.8) (23.5)	2 (18.1) (11.8)	**17 (27.4)**
Total	**14 (22.6)**	**11 (17.7)**	**13 (21.0)**	**13 (21.0)**	**11 (17.7)**	**62 (100)**

compatible with the intent of the current study, and others were not published in *Scopus Indexed Journals*. The articles were chronologically organized under each theme with Excel's assistance, which allowed organizing the data and re-tracing the articles. The same is presented in Table 1, indicating the "year of publication" and the "themes" of the current study.

The articles have been arranged thematically in chronological order. According to the themes out of the 62 reviewed articles, 22% discussed the "concepts of sustainability" followed closely by an equal distribution of 21% each for "perception of corporate sustainable responsibility" and "current tools and concepts with regards to sustainability"; an equal percentage of 18% each discussed "corporate sustainable responsibility" and "institutional barriers and pressures in the path to sustainability."

The study followed a bibliometric method of review, which analyzes data focusing on the research trends using the bibliographic material [9, 13, 21, 25, 56]. This scientific method of reviewing the articles has helped organize and compartmentalize the data to track organizational trends concerning the perception, management concepts, and tools relating to environmental sustainability over 11 years.

4 Discussion and Findings

This review highlights critical areas for further discussion in sustainability literature, especially the management team's institutional barriers and pressures. There is a need for more investigation into the obstructions on a firm's path toward achieving

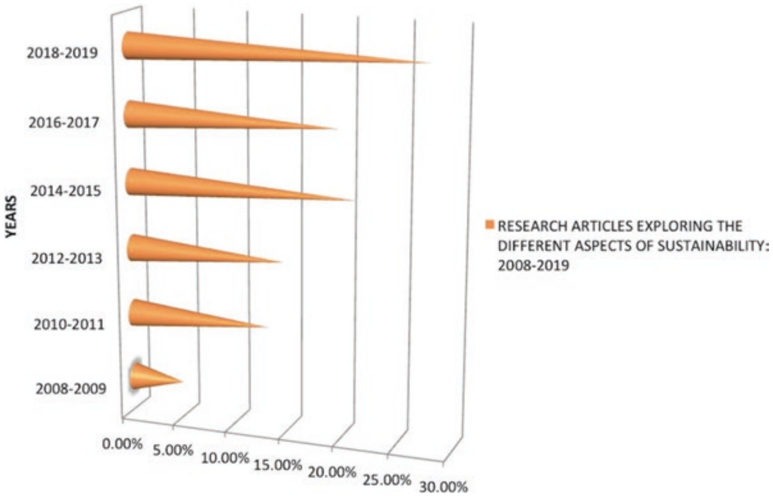

Fig. 1 Exhibits research articles discussing various aspects of sustainability throughout the years 2008–2019

sustainability. This is because, at the moment, the literature largely discusses technology for sustainability as a new phenomenon rather than a strong contributor to sustainability. Leaders look upon it as a challenge instead of a future opportunity. The following section systematically presents an analysis of the theoretical landscape.

Systematic Presentation: Figure 1 displays the articles that addressed environmental sustainability in the built environment over an 11-year period between 2008 and 2019. Out of 11 years, most of the articles from 2018 to 2019 referred were a total of 27.4% making the analysis applicable to the present scenario, followed by 21% in the 2014–2015 time period, by 19.4% in the 2016–2017 period, and by 14.5% in 2012–2013; in the 2010–2011 period, the referred articles comprised 13%. As the articles in the current study concentrate more on the current understanding, from 2008 to 2009, the minimum numbers of articles comprising 4.8% were referred.

Figure 2 demonstrates how the articles listed are classified under the five themes described in this study. The highest proportion of publications is 22% under "concept of sustainability"; the equivalent significance of 21% is given to articles under "perception of corporate sustainable responsibility" and "current tools and concepts with regards to sustainability." With a total of 18% each, the subjects "corporate sustainable responsibility" and "institutional barriers and pressures in the path to sustainability" were also given equivalent significance. This equal representation has helped appreciate each of the themes better and reduce prejudice toward a single theme.

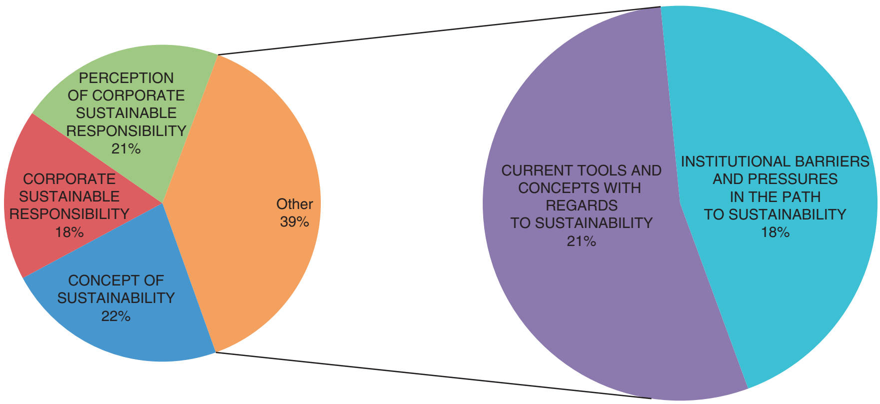

Fig. 2 Exhibits research articles discussing the themes explored in the present study

4.1 Thematic Overview of the Reviewed Articles

Concept of Sustainability: The articles addressed under this theme illustrate how important businesses are to society's sustainable development, which is impossible without their sustainable development support. Recent studies, including Green IOT and Green BIM, have highlighted the use of technology that is being applied to develop advanced and greener infrastructure.

Corporate Sustainable Responsibility: This theme emphasizes proactive sustainability, which implies that companies should aspire to take a step ahead by implementing sustainable policies. Analysts have also observed that top-level management rather than lower-level managers should be accountable for long-term sustainability decisions. In the Indian context, corporate social responsibility has not yet achieved its maximum potential; regulatory bodies and organizations' efforts have led to substantial changes, but India needs commitment and effort to reduce and track carbon emissions.

Perception of Corporate Sustainable Responsibility: Corporate leadership is an essential factor in turning the ship to a better future. Workers can follow the examples of the top-level and contribute to the cause. Researchers have also noticed that a more collaborative solution involving more vulnerable partners requires sustainability targets. From the stakeholders' viewpoint, there is a clear lack of environmental understanding, which calls for a reassessment of the organization's skills and training.

Current Tools and Concepts Concerning Sustainability: The study explores the Circular Economics and its development in recent years, describing the root cause of a large part of the environmental destruction, which has led to recent events. Recent publications note that circular and smart systems that integrate the circular business model with Industry 4.0 are being designed; one such innovation is 3D printing technology, which aims to reduce waste and reuse existing waste. This section also sheds light on the numerous green classification schemes, including

Leadership on Energy and Environment Design (LEED) and the Building Research Establishment Environmental Assessment Method (BREEMA), used worldwide.

Institutional Barriers and Pressures in the Path to Sustainability: Organizations find it hard to engage in environmental activities when the gains only occur in the future. A detailed analysis of previous publications found a lack of sustainability awareness and expertise at the lower and top levels, such as its founders. Technology innovation is both a blessing and a burden since it is difficult for most managers to keep up with change and make a reasonable decision to choose the right technology that fits sustainable and profitable business needs.

4.2 Results

This part of the study includes two sections introducing the findings condensed from the analysis of sustainability literature in the built environment for over 11 years. As stated in the beginning, the main purpose of this study is to explore the current awareness of business leaders and stakeholders concerning corporate sustainable responsibility and to reflect on the obstacles encountered by business leaders and top-level management in diverse sectors to lay the groundwork for addressing these hurdles and contributing to sustainable growth.

To accomplish this purpose, the first section of the study reviewed articles addressing the existing perception of business leaders and stakeholders concerning corporate sustainable responsibility. The findings from the analysis indicate that there is a paradigm shift in the understanding of the sustainability concept as compared to earlier research; recent research centers around technological advancements such as the use of "Green BIM" and "Green IOT" to help understand the real-time ramifications of sustainability.

The second section of the analysis discusses the obstacles encountered by business leaders and top-level management in different sectors. The results indicate that there is a difference between business leaders in recognizing the concept of sustainable development, resulting in a lack of passion and commitment toward the sustainable cause. In turn, this creates a challenge for the corporate leaders to keep up with the continuous advancements in technology, eventually leading to incorrect decision-making at the expense of the organization.

5 Conclusion and Future Scope

During the process of this study, four limitations were found: the first being the small number of publications covering green technologies and information; the second limitation found during the analysis period being that certain articles of the current year 2020 are ahead of publication, and even if the results were valid and useful, they were not eligible to be included in the current study; the third can be traced to the bias of the referred authors toward the environmental pillar of sustainability almost ignoring the social and economic pillars; the fourth limitation found during the study was a lack of previous years publication while concentrating on recent publications provides a glimpse on potential success, but the study would have gained more if more publications from the past were included to help appreciate the disparity in green expertise that occurs within leadership teams. Because of this significant disparity in leadership awareness of green technology innovation, it is strongly recommended that future studies resolve this void by offering better insight on green information and how it can be gained and applied successfully in organizations working toward a more ecologically responsible future. Another advice is for prospective scholars to focus further on the three sustainability elements to provide a 360-degree sustainability perspective. Further analysis should also be conducted on the evolution of sustainability in the built environment to help the leadership teams gain insight into historical and future sustainability priorities and obstacles.

This systematic literature review is done to collect the evidence and devise an analysis of current sustainability trends, procedures, and processes used in the built environment. The main purpose of this study is to explore the current awareness of business leaders and stakeholders concerning corporate sustainable responsibility, reflecting further on the nature of the built environment; the study discusses and explains the different issues influencing corporate executives, management teams, and the organization as a whole, shedding light on crucial strategic decisions that impact CO_2 emissions and the energy consumption of the firms. Of the 100 articles referred to, 62 were found to be eligible for the current study.

Using a bibliometric method, the analysis was conducted on research articles relating to five themes: (i) concept of sustainability, (ii) corporate sustainable responsibility, (iii) perception of corporate sustainable responsibility (stakeholders and shareholders), (iv) current tools and concepts used to measure sustainable performance, and (v) institutional pressures and barriers in the path to sustainability. Two major findings have been highlighted following the articles' analysis: (i) Recent research centers around technological advancements such as "Green BIM" and "Green IOT" to help understand sustainability's real-time ramifications. (ii) There is a disparity among corporate leaders in recognizing the concept of sustainable development. This leads to incorrect decision-making at the expense of the organization.

With these results in mind, more training and knowledge exchange within management teams should be facilitated; continued appraisal of the skills and knowledge regarding green management is needed for improvements and preservation of the information. More webinars and digital training can be encouraged to fit the busy schedule of the managers. Due to this significant disparity in green technology innovation leadership awareness, future research should offer better insight into green information and how it can be gained and applied. Scholars should further focus equally on the three sustainability elements to provide a 360-degree sustainability perspective of the built environment.

Therefore, it can be concluded that to achieve overall sustainable growth, leadership teams need a 360-degree view of sustainability that will allow them to assign equal value to all three sustainability pillars: society, economy, and environment while addressing the current issues' using state-of-the-art technological advancements such as Internet of Things (IOT), virtual reality (VR), additive manufacturing (3D printing), and so on.

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Smart Health Care for Societies: An Insight into the Implantable and Wearable Devices for Remote Health Monitoring

Jeet Ghosh, Gopinath Samanta, and Chinmay Chakraborty

Abstract Advancement in digital health-care system has enthused to develop wearable and smart sensor with high-performance index. Mobile health-care technologies induce great potential for reducing health-care cost and provide assurance in continuous health monitoring of a critical patient from a remote location. The major demand in this domain is to establish a secure, harmless, and reliable medical device for accurately monitoring important signs of the human organ or the environment inside/outside of the human body through flexible sensors. Nevertheless, it is expected that the wearable or implantable medical devices do not possess additional health risks and allow the patient for daily activities; thus, biocompatibility of the sensor is the other essential consideration. In this chapter, a comprehensive review of the latest progress concerning these smart wearable sensors is presented with a focus on biosensor and the telemetry link. In addition to these several issues related to the device reliability, safety of human health has also been addressed.

Keywords Biomedical · Health care · Sensors · Telemetry · Biocompatibility

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1 Introduction

With the advancement of the information and communication technology (ICT), the "smart hospital" or "smart health care" became one of the most important and inevitable parts in a smart society [1]. The smart health-care system is defined as a health-care system where the new generation of information technologies, such as the Internet of Thing (IoT), artificial intelligence, big data, and cloud computing, is incorporated. Due to the adaptation of ICT, the health-care industry becomes more versatile, more personalized, and more efficient and convenient. Thus, this advancement in the health-care system became a prime requirement in the time of COVID-19 pandemic [2]. The conventional and "old-school" hospitals are struggling to handle the massive number of patient and to provide quality and personalized care. Moreover, smart hospitals and health-care unit can maintain better social distancing. Due to the incorporation of reliable communication technique, a doctor can monitor the patient and get real-time physiological data without visiting them. In addition to this, the rapid increase in the population of the senior citizens, shortly, the smart health-care industry will become an unavoidable part in the society for monitoring the health from the home of the patients. A population survey shows that within the year 2045, the population of the senior citizen will be more than the young adult population. Thus, there will be a shortage of home health helpers and nursing assistants. This indicates that the old-age people need to run at the hospital by themselves which might be far away from their home. This will create discomfort to the elder people as well as health may be deteriorated without getting proper treatment. In this regard, smart health-care system and remote health monitoring play a pivotal role in the medical system [3].

The adaptation of technology in health care is expected to rise further in the coming 2–3 years because of intensive quality care and substantial productivity gains. A survey in the global health-care market indicates that in 2018, the smart hospital market was valued USD 22.2 billion worldwide, and it is assumed that this value will be increased to USD 83.1 billion in 2026 with the compound annual growth rate of 18% [4]. However, smart health care and a smart hospital are not only simple technological advancement and monitoring data but also changing the concept of medical management and the concept of medical treatment. With the advancement of smart technology, health-care systems focus more on "prediction and prevention" compare to "diagnosis and treatment" policy [5]. For this purpose, continuous remote monitoring of the several physiological data of the patient is the prime requirement.

The wireless-based sensor for the health monitoring can be classified in two types, such as wearable [6] and epidermal sensor [7] and implantable sensor [8] as shown in Fig. 1. The main goal of these sensors is to provide constant invigilance to the patients' vital physiological parameters while allowing them the freedom of movement. Besides this, the internal or implantable sensor also became very useful for advanced health care. The implantable sensors are used for long-standing

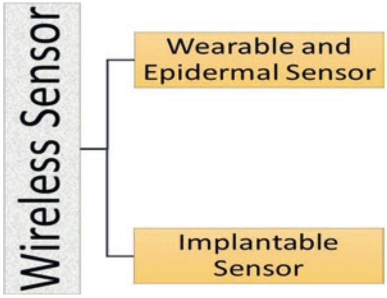

Fig. 1 Different types of RF-based sensor for health-care monitoring

monitoring and complex monitoring during the medical investigation and surgeries of a patient.

Besides this sensor, for effectively monitoring the data in the real-time scenario, a highly efficient telemetry link must be established [9]. For this telemetry link, it is necessary to incorporate the radiating unit, that is, antenna, for both the wearable and implantable sensor networks. In this regard, there are several technical challenges such as system reliability, safety, quality of service, as well as privacy and security that are needed to be addressed. In this chapter, we describe not only the operating principle of the wearable and implantable sensor but also the implantable and wearable antenna, link budget, and other safety and security issues. The reminder of the chapter is systematized as follows. In the subsequent section, that is, Sect. 2, the prime requirements of wireless sensors for medical applications are described. In Sect. 3, we present the state-of-the-art research based on the wearable sensor and the working principle of it. After the detail discussion about wearable and epidermal sensor, in the following section, a detailed review is presented based on implantable biosensor. In the next section, Sect. 5, we discuss the telemetry link and wireless network for implantable and wearable antenna. After that, in Sect. 6, we focus on different challenges and issues like power issues, safety and specific absorption rate-based issue, and antenna pattern distortion problem in the implantable and wearable environment. Finally, we explain the future scope of sensor and draw our conclusions in Sect. 7.

2 Requirement of Wireless Medical Sensor

The wireless medical sensor, such as implantable, epidermal, or wearable sensor, are mainly used to sense biological and physiological information from either inside or outside of the human body. For diagnostic purpose, after sensing and assembling the data, the sensor devices transmitted the information to the remote location via wireless body area network (WBAN) [10]. In this regard, the transmitting unit with high-efficiency needs to be integrated into the sensor devices. Specifically, a sensor for health-care application should satisfy the following requirements.

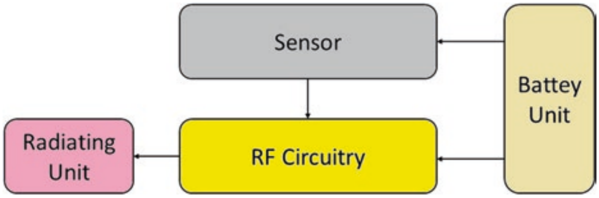

Fig. 2 Block diagram of the WPT system

2.1 Lightweight and Miniature Size

Size and weight are the most prime constraint for designing a biomedical sensor. For continuously monitoring physiological data of a patient, size and weight of the device should be very less that not affect the comfort level of the patient [11]. The basic block diagram of the sensor device is exposed in Fig. 2. It is observed from the block diagram that the size and weight of the sensor devices mostly depend on the battery unit. Moreover, the size of the battery is directly proportional to the capacity of it. In recent time, the advancement of system-on-chip, microelectronics, and low-power wireless communication paved the way to develop tiny size battery with sufficient capacity [12]. Both flexible battery [13] and printed battery [14] hold the promises of a new era for solving the power and size issue of the sensor devices.

In multiple application, such as transcutaneous drug delivery, temperature monitoring, or RFID tracking, printable and flexible battery provides major advantages over the other traditional techniques [15]. Besides these, radio frequency-based wireless power transfer (WPT) system for charging the battery of the implantable and wearable sensor devices gained a huge interest in recent time [16]. In Sect. 5, the detail of the WPT-based charging system is discussed.

2.2 Safety

The new generation of the health-care system is focused to improve the quality of the human life standard by providing proper and personalized medical facility with a high comfort level. Thus, the safety feature of the wearable and implantable RF-based sensor devices is one of the important concerns for the engineer. The electromagnetic field associated with the RF sensor and the radiating unit may raise significant concerns about possible health hazards [17]. The long-term exposure of human tissue in a high-frequency electromagnetic wave increased the risk of acoustic neuron, skin, and nerve cancer. Thus, we need to consider about the radiation and specific absorption rate in the time of designing a sensor. By controlling the specific absorption rate, one can enable the use of sensor without additional health hazard. The specific absorption rate (SAR) [18] is defined as the rate of absorbed energy per unity mass of human tissue. SAR can be expressed as follows:

$$SAR = \frac{\sigma |E|^2}{m_d} \quad (1)$$

where σ is the conductivity, m_d is the mass density of the human tissue, and E is the electric field produced in the device. The mass density and conductivity for a different type of head tissue are shown in Table 1. For patient safety, the sensor designer should monitor the SAR value, and it should be kept in the range. As per the guideline of Federal Communications Commission's (FCC) and IEEE C95.1-1999 standard, the average SAR value for 1 g of tissue model in cubic-shape tissue must be restricted to 1.6 W/kg. In case of IEEE C95.1-2005 standard, the limit of the SAR value is fixed to 2 W/kg for the 10 g of tissue [19]. Besides this, biosensors need to be placed very specific on-body placement or body postures for reliable measurements. To overcome this issue, a smart wearable system [20] or a flexible and robust system can be useful.

2.3 Security and Reliability

One of the fundamental requirements for the sensor-based health-care system is the reliability and security of the data. The data integrity in the WBAN network should be ensured, which indicate that the sensor devices satisfy the privacy requirement set by the law [21]. Besides this, the transmitted data should be encrypted to avoid eavesdropping attack.

Table 1 Mass density and dielectric parameters of the head tissue at 900 MHz

Tissue type	Mass density (m_d) kg/m^3	Permittivity ε	Conductivity (σ) s/m
Skin	1010	41.4	0.87
Muscle	1040	55.0	0.94
Bone	1810	21.0	0.32
Blood	1060	61.4	1.54
Fat	920	11.3	0.11
Cartilage	1100	40.8	0.81
Gray matter	1040	54.7	1.19
White matter	1040	35.7	0.61
Humor	1010	74.1	1.97
Lens	1100	51.3	0.89
Sclera	1170	52.1	1.22
Cerebellum	1040	49.6	1.03
Hypophysis	1040	49.6	1.03
CSF	1010	74.0	2.12
Parotid	1040	49.6	1.03
Tongue	1040	57.0	0.80

Similarly, another prime concern in medical application-based WBANs is reliability of the network [22]. As the designing of a high-bandwidth channel in the sensor network is complicated, one can use a sampling technique more efficiently to transmit the data. As an example, we can say that if one needs to transmit the electrocardiogram (ECG) data, instead of transmitting raw ECG data, it is better to transmit some extracted features from the sensor data. By this way, we can reduce the requirement of high bandwidth and also save total energy expenditures, and consequently increase battery life. Thus, the efficiently handling of the communication and computation in a sensor device is crucial for the system designer.

2.4 Biocompatibility

Biocompatibility of the devices is one of the key factors for designing an implantable sensor. The whole implantable sensor device should be covered by biocompatible materials. The encapsulation of the biocompatible material not only shields the devices from the direct contact to the human tissue but also reduces the electromagnetic coupling, specifically at near field with the human tissue environment.

2.5 Robust Communication and High-Throughput Network

In a wireless sensor network, the signal received by the wireless node is highly distorted by the environmental as well physical hindrances [23]. This problem impacts on the communication capability of the system. The fading in the signal strength arises due to the interference from other wireless networks that share the same radio spectrum. These phenomena deny the wireless node to maintain uninterrupted communication with other nodes and hence effects on the performance in terms of reliability and energy efficiency. The issue of the interface in the on-, in- and off-body communication can be solved by the channel diversity. The problem of interface became more severe and challenging for the sensor used for biomedical application. Due to the closeness of the human body in all the cases, the signal got attenuated and distorted depending on the body size, posture, and movement [24]. It is desired that the implantable device must consume very low amount of power. This low power communication provides the long-life time to the implantable sensor, which in turn ensures less surgeries required for the replacement of battery. In addition, for the camera-based medical diagnosis, such as intestinal tumors, a robust network to support real-time video monitoring is required.

In the next section, we describe the wearable and implantable sensor in detail.

3 Wearable and the Epidermal Sensor for Health Monitoring

Over the last decade, to cope with the huge demand of real-time health monitoring, fitness tracking, and disease forecasting, wearable sensor technology has found a rapid growth. A recent survey report [25] stated that in 2015, globally the value of wireless sensor market was around USD 189.4 million. As per the forecast, between 2016 and 2020, it can be expected that the growth of USD would be 1,654.0 million at a CAGR of 30.14%. The major application of wearable sensor is in the fitness band, and it holds the largest market share. Besides this fitness band, in recent time, smart watches and other health monitoring devices integrate the wearable sensor. With the advancement of the technology, the giant telecommunication and electronics industry, such as Apple, Samsung, and Fossil, are developing some game-changing products based on the wearable sensor. Thus, shortly, the wearable sensor became one of the driving forces in the smart health-care industry [26, 79]. More specifically, the very recent COVID-19 pandemic provides a strong and inevitable impact on the wearable sensors market. Due to this pandemic, the health-care industry is focused on telemedicine to avoid public gatherings and maintain social distancing [1]. By the help of a wearable sensor, doctors are taking the telemedicine route for the treatment of the patient without scope for any virus spread.

The wearable sensor collects several physiological data, physical signs, and habitual physical activity and analyzed the data to indicate the existence of fatal disease [27]. In Fig. 3, a schematic diagram on application of wireless sensor is depicted. Wearable sensors can be placed on the head, arm, body, and leg/foot, or

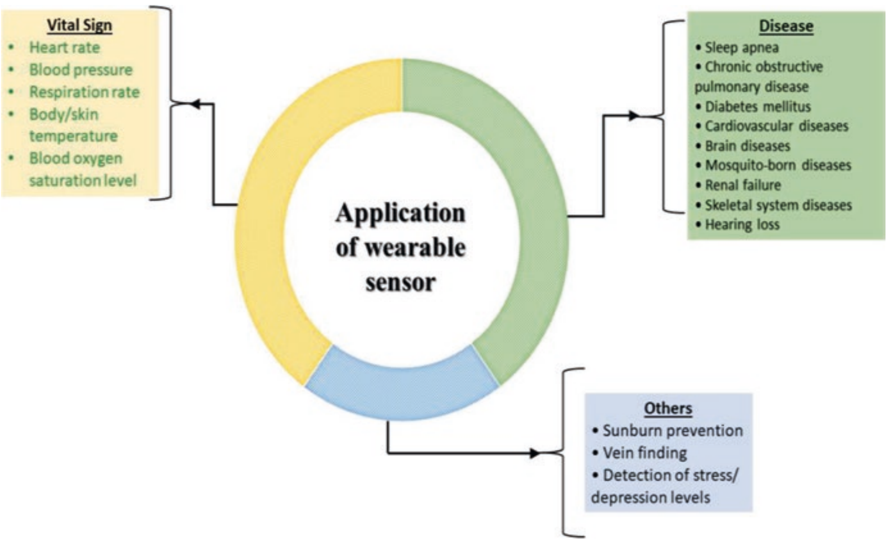

Fig. 3 Some biomedical applications of wearables sensor

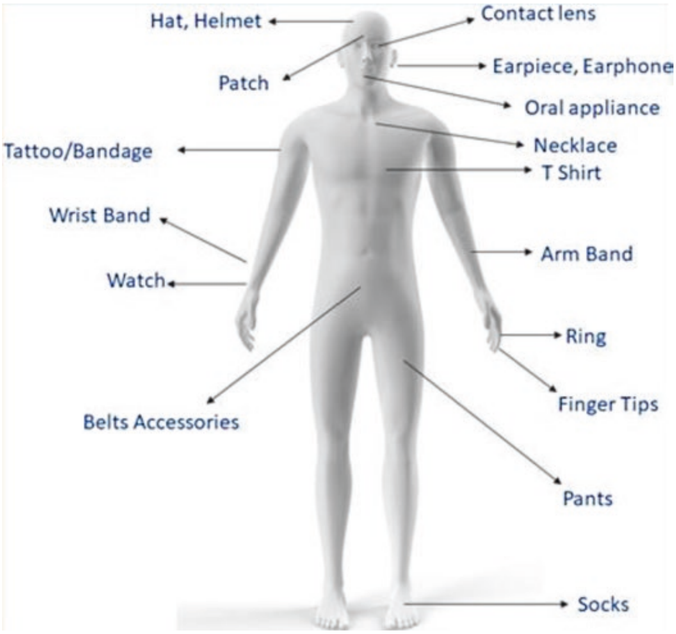

Fig. 4 Wearable devices worn on various body parts

over T-shirt (see Fig. 4). In this section, we elaborate present advancement in the materials and technologies for the development of sensors with optimal properties. The wearable and epidermal sensors can be classified into three segments, biocompatible sensor, biodegradable flexible sensor, and antenna sensor.

3.1 Biocompatible Sensor

As the goal of the smart health-care industry is to provide better treatment and medical facility to the society, it is expected that the wearable sensor and medical devices do not pose any health risk to the patient and do not create any obstacle on the day-to-day activities [28]. As the wearable sensors are exposed to the human body, the biocompatibility of the sensor is the essential requirement. Thus, to develop a wearable sensor for health monitoring, researchers and engineers are looking for developing biocompatible material-based sensor. A silicon-based sensor for brain mapping is reported in [29]. In this chapter, authors stated that the silicon-based sensor is a completely biocompatible. Moreover, it is also confirmed that 8 weeks after implantation, there will be no formation of the glial cell. From this study, it can be concluded that the traditional semiconductor-like silicon is a biocompatible material and can be used for developing the sensor. Besides this, another prime advantage of the silicon-based sensor is that this type of sensor can be fabricated by the traditional microelectronics technique.

Beside this semiconductor-based sensor, some researchers developed conductive polymer-based sensor. To sense the pressure and sense, Bao et al., developed a polymer-based sensor [30, 31]. This sensor is capable to test the pressure and strain by two vertically isolated devices without interfering to each other. Due to this exclusive feature, this polymer-based sensor is useful for real-time tissue healing and personalized rehabilitation. In this work, the sensor is attached to the tendon and monitors real-time healing. A schematic diagram to understand the concept of pressure and stress sensing is shown in Fig. 5. When the sensor is operating as a stress sensor, two thin-film comb electrodes are slide in the transverse direction, which will create the variation of the capacitance. On the other hand, in case of the pressure sensor, the capacitance between the electrodes is changed due to the varying distance between the electrodes. The biocompatibility of the sensor of the device is also monitored, and it is observed that this polymer-based sensor does not provide any health hazards. A carbonized silk fabric is reported in [30] for monitoring the stress and human body movement. Moreover, this type of carbon material is developed from natural and renewable sources. Thus, the carbonized silk has a great production capacity, and also it is environment friendly.

It must be noted that the contact between the human body and a single substance is very complicated and needs to be carefully handled while design a wearable or implantable sensor. It is very difficult to predict that the developed material is biocompatible or not. The most common way to improve the level of biocompatibility is to introduce natural materials like silk [58], cellulose [32], and wood [33]. These materials shave excellent behavior of nontoxicity. Chitosan is one of the most investigated and used materials. The conductive property of chitosan can be improved by several techniques. For example, in [34], a high conductive graphene is used to enhance the conductivity of chitosan.

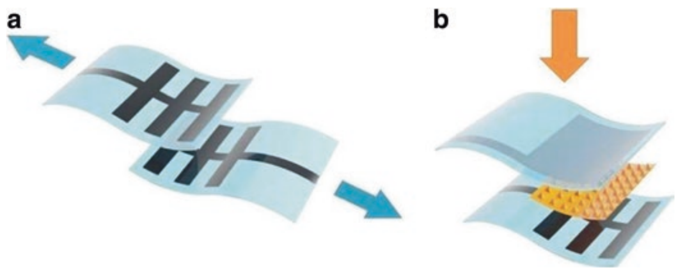

Fig. 5 Working principle of the sensor (**a**) stress sensing mode (**b**) pressure sensing mode

3.2 Biodegradable Sensor

In the recent year, the biodegradable material has attained huge interest in developing sensor and health monitoring devices. The biodegradable sensor not only reduces the environmental footprint but also used for advance health monitoring. The main requirement for the biodegradable electronic is biodegradable substrate to develop conductor, dielectric, and semiconductor. In [35], an efficient conductor is designed by blending polyaniline (PANi) with a natural protein, gelatin, and co-electro spun into nanofibers. It is observed that PANi-gelatin-based substrate is useful for conductive support in biomedical engineering. For the designing of implantable sensor, biodegradable material is more useful. The paper-based sensor [36] has also become popular because of its lightweight property, seminatural property, inexpensive structure, and environmental friendliness. In addition to these, there are other materials that are derived from natural materials which can also be used as biodegradable substrates, such as natural collagen, gelatin, shellac, chitin, protein, and seminatural/semisynthetic materials.

3.3 Antenna Sensor

Besides these biocompatible and biodegradable sensors, in the wearable sensor domain, another new comer is the antenna sensor. The main advantage of the antenna sensors is its dual functionality. Thus, simultaneously, this antenna sensor can be used for communicating and sensing. The resonance frequency of the antenna has a strong dependency over their geometrical or intrinsic material change. Thus, by changing the shape and property of the material, the resonance frequency of the antenna changes. By monitoring the changes in the behavior of reflection coefficient as well as resonance frequency, one can detect the changes in the material. The physical parameters like strain, temperature, pressure, and pH level, can manipulate the resonance frequency and reflection coefficient of the antenna. In Table 2, we explain different types of antenna-based sensor and their measured parameter [37].

Table 2 Comparison of some previously reported works on antenna sensors

Ref.	Measured	Antenna type	Size (mm^2)	Freq.	Material	Type of material	Sensing parameter
[38]	pH level	Hexagonal split ring resonator	19 × 23.3	3–20 GHz	PCB	FR4	Transmission coefficient
[39]	Strain	Dipole antenna	17 × 16	8–12 GHz	Polymer	Polymide Rogers	Frequency shift
[40]	Body temperature	Patch antenna	10 × 6	38 GHz	Textile	Cotton	Frequency shift
[41]	Blood glucose	Patch antenna	40 × 40	2.4 GHz	Textile	Denim	Specific absorption rate

However, for some applications, wearable or epidermal sensor is not useful for monitoring some critical physiological parameters. For this purpose, the implantable sensor is required.

4 Implantable Sensor

In addition to the wearable and epidermal sensor, implantable sensor is another key candidate for the smart health-care industry. The implantable sensor or device can be defined as a sensor or device which is implanted inside the human body. The use of implantable sensors has several advantages over other monitoring paradigms. The conventional chemical methods used to sense a sample under test are cumbersome (several reaction steps), time-consuming, and require large volume. In [42], a biopsy-implantable chemical sensor is proposed to collect the chemical information of the body. All these tools provide rapid sensitivity, real-time measurements, and nondestructive type sensing characteristics that judges to be an effective and promising sensing technique. In addition to the sensing physiological parameter, implantable sensor is revolutionizing the drug delivery. With the huge advancement in the microfabrication technology and materials science, the implantable drug delivery (IDD) system has become very attractive for delivering drug in a specific localized environment [43]. Due to this localized drug delivery, IDD devices help to maximizes dose efficiency and reduces toxicity and side effects. To monitor the drug delivery, some electronic components are integrated with the IDDs. A schematic of monitoring drug delivery using IDD is exhibited in Fig. 6. Besides the chemical-based sensor [41], RF and microwave frequency-based sensor also attained huge

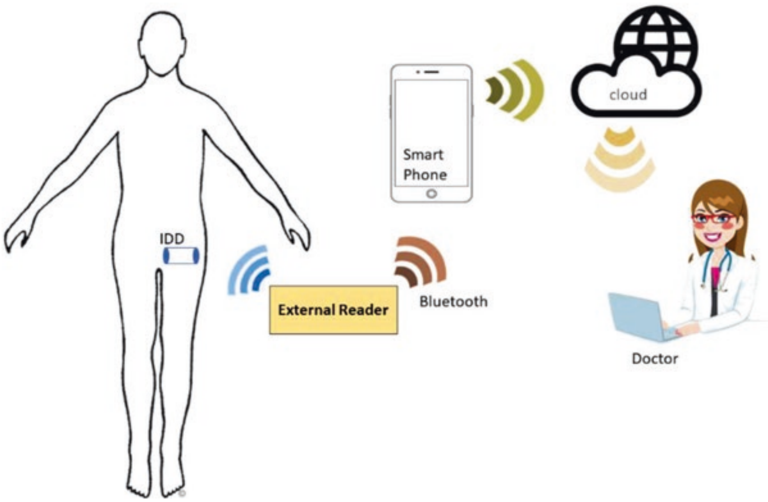

Fig. 6 IDD -based drug delivery system

interest in recent time. Some common applications of RF, millimeter wave sensor are useful for detecting fibroblast cell, cancer, and monitoring glucose, and other vital parameters.

Sensors are deployed inside the human body accordingly to monitor the vital data from inside the body. To track the vital signs such as heart rate and respiratory rate, sensors would be deployed inside the human body. As an example, we can state that the patients who suffer from congestive heart failure or other chronic obstructive pulmonary disease, implantable sensor with heart rate tracker becomes very useful. In some applications, such as home-based rehabilitation interventions in stroke survivors, one needs to record the data related to movement of human body parts. In this type of application, implantable sensor plays a pivotal role.

On application of an electromagnetic wave with range of kilohertz to a few terahertz, the EM spectrum of biomatter shows several dispersions such as α-dispersion (kHz), β-dispersion (MHz), and γ dispersion (GHz) in permittivity due to ionic diffusion, interfacial relaxation, and dipolar relaxation, respectively [44]. The choice of frequency is based on the information of interest. If we want to track the changes in cell membrane potential, the α-dispersion and β-dispersion are useful, whereas γ-dispersion is used for obtaining intercellular information.

RF sensing techniques are categorized as the nonresonant and resonant methods [45]. The former methods are generally used to characterize a sample that provides wideband behavior with moderate accuracy. On contrary, the resonant methods are preferred over nonresonant methods to achieve better accuracy over a narrow band of operation. In resonant methods, the sensing and characterization of a sample is accomplished either using rectangular waveguide cavity resonator [46], H-slot cavity resonator [47], or with the help of planar resonant sensors [48]. Among these techniques, the main drawback of three-cavity resonator method is its requirement of bulky and costly metallic cavity. With this respect, the planar resonant sensors provide several advantages such as low cost and easy fabrication. Additionally, the planer sensor can be integrated with other microwave circuit component easily [49].

Planar resonant sensor has been designed based on various resonant structures, such as split ring resonators (SRR) [50], complementary split ring resonators (CSRR) [51], substrate integrated waveguide (SIW) [52], slot-line-based RF sensor [53], stepped-impedance resonator (SIR) [54], series resonators [55], fractal capacitors [56], spiral inductors [57], and interdigitated capacitor (IDC) [58]. Some of these structures, such as fractal capacitors, spiral inductors, and IDC, are easy to be fabricated using microstrip technology and provide a decent amount of sensitivity. On the contrary, in case of the SRR and CSRR structures, the SRR and CSRR are coupled to the microstrip line either electrically or magnetically depending on the positioning of the resonator with the microstrip line [59], thus reducing their sensitivity.

To recognize different types of biological parameter, sensors are extensively used. In this sensing process, the bioreceptors should be immobilized over the sensor surface. These immobilized biomolecules are responsible to change in permittivity. The sensor is designed in such a way that the small changes in the permittivity can be measured. Apart from immobilization, microfluidic channels are used in sensor devices. This microfluidic channel is a small channel allowing passage of analyte over the detection area of the sensor, sensitive to permittivity change. In this discussion, analyte refers to a substance that is being measured or identified, bioreceptor is a biomolecule that recognizes the target analyte in sample solution, immobilization indicates the process of binding bioreceptors to the sensor's surface, and biomarkers are measurable chemicals in an organism whose presence indicates a disease, infection, or environmental exposure.

4.1 Sensing Techniques

Generally, capacitive sensors are mostly used for the sensing purposes. It is modeled as a parallel combination of capacitor and inductor, where capacitance changes due to change in permittivity and inductance changes due to change in permeability of the medium. A resonator is a circuit cum device that naturally oscillates at frequencies, known as resonance frequency. Therefore, whenever there is a change in sensing sample, the capacitance will be varied that in turn change the resonance frequency. The different interaction modes of biomatter with electromagnetic waves, namely radio-microwave, millimeter wave, and THz wave, are discussed in the following paragraphs.

4.1.1 Capacitive Sensing Using Affinity Binding

Capacitive sensing is a very common and fruitful method to quantity the changes in permittivity. This technique is useful for measuring the biomolecule concentration as well as biomarker identification in a sample. In order to find the resonance frequency for the affinity-binding process, it is assumed that the resonator has its intrinsic resonance frequency before the bond. As soon as the analyte starts to make some bonding to the sensor surface, the permittivity/permeability of the sensor's surface changes at the near-field region. As a consequence, the effective capacitance/inductance are modified that results the change in resonance frequency of the sensor. The resonance frequency $f_m$is given by Eq. (1), where L_{eff} and C_{eff} are the effective inductance and capacitance of the resonator.

$$f_m = \frac{1}{2\pi\sqrt{L_{eff}C_{eff}}} \tag{2}$$

So, it can be stated that in the affinity-binding techniques, the change in permittivity is transduced to a change in the sensor resonance frequency. This shift in sensor resonant frequency for different biomatter makes it a popular sensing device.

4.1.2 Capacitive Sensing Using Microfluidic Channel

The change in permittivity can also be detected by using a microfluidic channel. In this technique, immobilization and capturing of analytes for detection are avoided, while the analyte in suspension is passed over the detection area through microfluidic channel. The impact of variation in permittivity on the scattering parameters (reflection coefficient S_{11}) can be approximated using the following Eqs. (3) and (4) for an ex vivo sensor detecting glucose [60]. In the following equation, Z_{air} is the characteristic impedance of air, k_{air} is the wave vector in air, t_{tt} and t_{td} are the thickness, and $\varepsilon_{glucose}$ is the dielectric constant of silicon tube and glucose solution.

$$S_{11} = 20\log\left|\frac{|Z_{in}| - Z_0}{|Z_{in}| + Z_0}\right| \tag{3}$$

$$Z_{in} \cong jZ_{air}k_{air}\frac{(2t_{td} + t_{tt}) - k_{air}^2 t_{tt} t_{td}^2 \varepsilon_{glucose}}{1 - k_{air}^2 t_{td} \varepsilon_{tube}(t_{td} + t_{tt}) - k_{air}^2 t_{tt} t_{td}^2 \varepsilon_{glucose}} \tag{4}$$

It is revealed from the equation that the impedance of the sensor depends on the concentration, and any change in concentration is reflected as a shift in the reflection coefficient.

4.1.3 Microstrip Structure-Based Capacitive Sensing-Coplanar Waveguide Transmission Lines, Open Stub and Shunt Stub

An open-ended microstrip line (Fig. 7a, b), known as open stub, can be demonstrated as having an input capacitance and conductance, while a shunt-stub can be realized with input inductance and resistance. These microstrip lines are very much sensitive to changes in permittivity on their surface and have been placed in an oscillator [61] in such a fashion that the characteristic impedance and frequency of

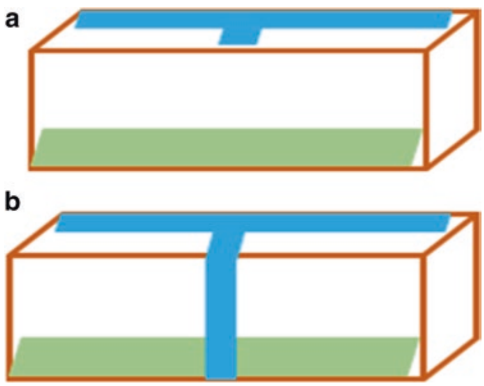

Fig. 7 Microstrip line structure used for sensing (**a**) open stub and (**b**) short-circuited stub

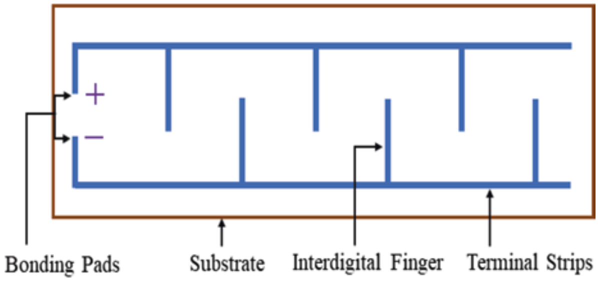

Fig. 8 Interdigitated capacitor structure for sensing

oscillation are a function of permittivity. Capacitive sensing can also be accomplished using coplanar waveguide (CPW) transmission lines [62].

4.1.4 Capacitive Sensing Based on Interdigitated Electrodes

An interdigitated capacitor (Fig. 8) is also a sensitive element to the permittivity change of the medium surrounding the detection area. An unknown material can be characterized by embedding the interdigitated capacitor on a LC tank of a voltage-controlled oscillator (VCO) [63] and placing that VCO in a PLL. A change in permittivity of the medium nearby the interdigital capacitor contributed sufficient information to characterize materials, for example, methanol-ethanol.

4.1.5 Radio-Frequency Identification (RFID)-Based Biosensor

A fascinating approach is proposed in Ref. [64] operating at 915 MHz, where the strength of the reflected RF signal varies continuously in accordance to the change in analyte concentration. On impinging RF waves, although the reflection occurs at the desired frequency, the signal strength is different depending on target concentration. Here, strength of the reflected signal is high for higher concentrated analytes. The strength of the reflected signal or alternatively the detection range is sensed using an RFID reader.

4.1.6 Tera Hertz Biosensor

Nowadays, THz biosensors are gaining huge popularity and seem to be advantageous over other EM wave sensors in various perspectives like improved detection range, sensitivity, volume of sample, and cost [65]. The tera hertz frequency range (0.1–10 THz) is of significance as it matches with the vibrational frequency of some vital biomolecules. Thus, any change in the concentration of biomolecules is reflected in form of shifting in resonant frequency in the dielectric spectrum. The information regarding the protein-protein interactions is essential to understand several natural occurring processes inside every living species. When the various molecules interact with each other, their molecular structure deforms, resonance peaks, as well as the intensity of the resonance is continuously varying, thus enabling it to be sensed [66] by a sensor. It is discussed in [67] that by sensing and measuring the shift in THz resonance frequency, the hybridized and denatured DNA can be successfully separated. A metamaterial-based THz sensor [68] is implemented for detection of biomolecules with high sensitivity.

5 Wearable and Implantable Telemetry Network

From the previous discussion, we get a clear understanding of different types of wireless sensor used for collecting physiological data. However, the collection of data is not sufficient for smart health monitoring system. In this regard, we need to transmit the data to external unit or remote unit for analyzing the acquired data from sensor. Thus, a telemetry unit is another important part for the both wearable and implantable sensor devices.

5.1 Telemetry Unit for Wearable Sensor

For tracking and monitoring vital data and activities of patients and providing a personalized health-care solution, an efficient sensor-based telemetry device is required [68]. These devices can be placed on the body (e.g., bracelets and watches) or in an electronic textile incorporated into fabric to collect the biological data. By installing this wearable device over the human body, the device turns out to be alert systems notifying the medical staff about any medical emergencies required in the patient's body [69]. For several application, a continuous monitoring is required which can also be done by the wearable sensor. In [69], a wearable sensor has been implemented to record the heartbeat and respiration rate. The sensor system consists of tri-axial accelerometer, temperature sensor, and air pressure sensor. The collected data by the sensor are sent to the PC or handheld devices via wireless communication link. Another example of the wearable smart sensor is the "Google smart contact lens." By this technology, the tears are analyzed by the lens to find out glucose that are present. This lens has the feature to restore the eye's natural autofocus. To measure the different parameters like body posture, electrocardiograms (ECG), and electromyograms (EMG), "Wealthy" and "My heart" are the two EU-funded project where several sensors are embedded over a cotton shirt [70].

The wearable network is a multistage network as shown in Fig. 9. In the first stage of the network, there are the nodes of WBAN. Each of the nodes senses the physiological signal and transmits to the second stage of the network architecture. The second stage of the network is based on personal server application that runs on

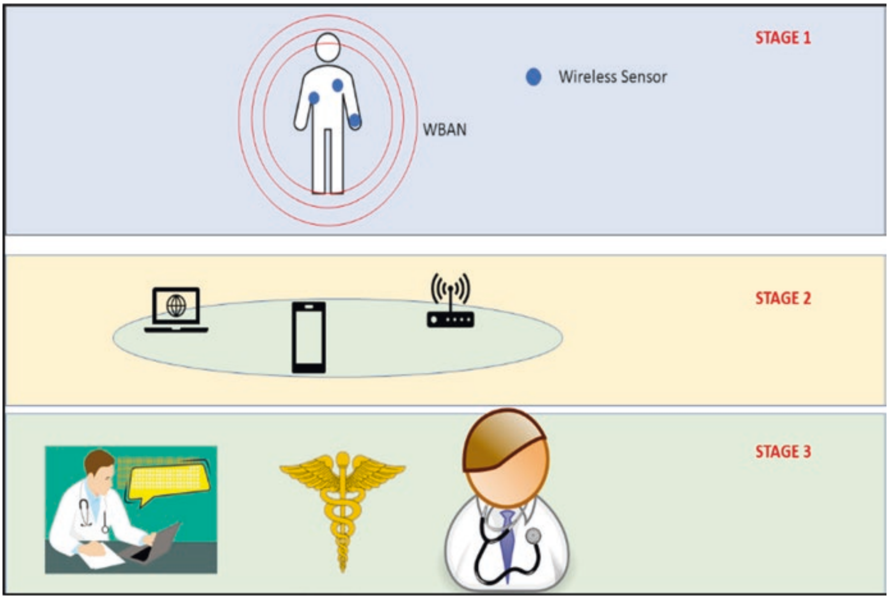

Fig 9 Wireless body area network architecture

a personal cell phone or personal computer. This personal server acts as a bridge or interface between the user and medical server. By the help of this second layer, several medical and management feature, such that registration of the sensor nodes, initialization of sensor, initialization of sampling frequency, and mode of operation, are enabled and communication network is established. Once the wearable network is setup, managing network is the next challenge. By the managing network, it means the channel sharing, time-synchronization, data retrieval, etc. The final stage of the network includes access of the medical server via the Internet.

5.2 Telemetry Unit for Implantable Sensor

Telemetry systems are capable to capture, process, and transmit specific information sensed by the sensor to an end device, wired or wirelessly. Implantable telemetry systems are gaining popularity in various sections of medicine, including diagnostics and monitoring, neurology, drug delivery systems, audiology, and cardiology. The use of catheter as an attachment to the external base station for processing telemetry does not allow the living beings to roam freely in the surrounding environment. To provide them that flexibility, implantable system is preferred that contains all sensor electronics as well as data and power transmission electronics within a same unit. Power consumption is one of the major concerns for an implantable system since lesser power consumption can lead to smaller battery sizes that in turn miniaturizes the systems volume. These two criteria let a sensor system to be implanted for a higher period of time. The overall telemetry system can be alienated into two units: external and internal, as exhibited in Fig. 10. In this block diagram, right half of the wireless system indicates the internal unit that consists with four main modules: power module, microcontroller module (processing module), RF module (transceiver module), and interface module. In the implantable wireless telemetry system, all these modules are interlinked with each other through a commutation bus. The inter connection of each module is depicted in Fig. 11. In the figure, the auxiliary module is used as the development module for testing and programming purpose [70].

The power module provides power to the whole system and contains all electrical and electronics components. The major elements in the power module are (a) battery, (b) supervisor device, (c) an analog switch for the interface module, and (d)

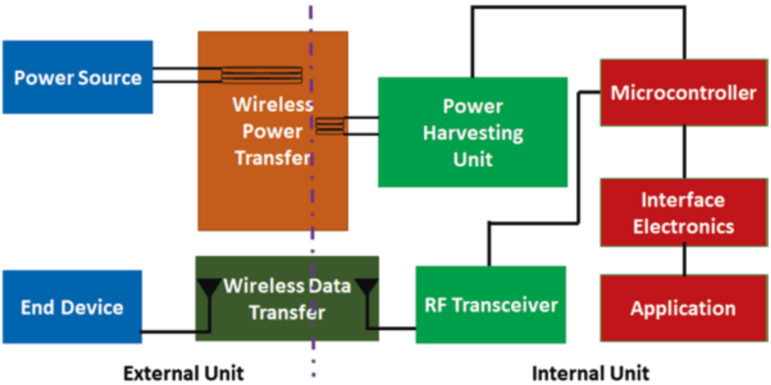

Fig. 10 Block diagram of the wireless telemetry system

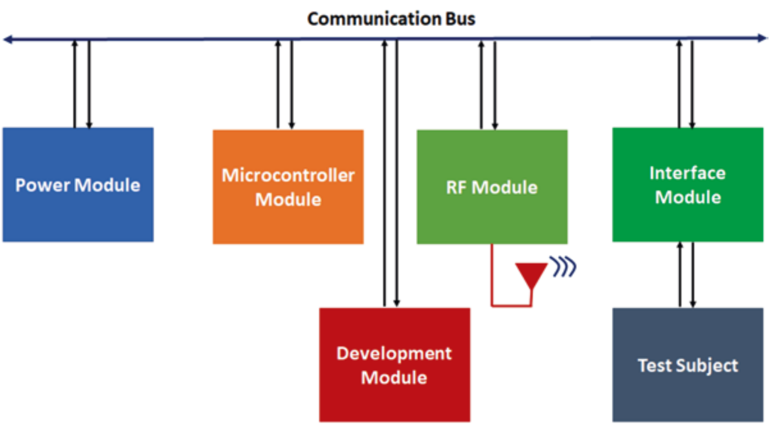

Fig. 11 Block diagram of the implantable wireless telemetry system

low-dropout regulator. The microcontroller module is considered the main communication hub among the RF electronics, power electronics, and interface electronics. The main function of the microcontroller module is to receive the analog data coming from the interface module, then digitize the data, and finally process the data for RF module. The radio module activates the wireless communication to an end device. The RF module has four essential components: matching network, antenna, RF transceiver, and a clock source. The radio module wirelessly transmits information via a RF antenna by following a specific RF protocol. Various wireless protocols are available to transmit data, such as Bluetooth, Wi-Fi, and nonstandard 2.4 GHz. Data can be transmitted to the base station by an external antenna that is interfaced to the RF transceiver. Usually, a matching network is used to match the output impedance of the transceiver to the 50 Ω impedance of the transmission line. A clock is used in the RF module for synchronizing the data communication between the RF transceiver and the microcontroller. The communication bus is used for digital as well as analog communication between each module and the outside network. To design the bus structure, multiple signals are considered, such as ground signals, power signals, input/output programming pins, and charging pins. Lastly, the interface modules help the electronics system to link the medical catheters with the telemetry system. Each catheter is linked to the interface module directly with the intended electronics that assist to convert the raw analog signal captured by the sensor to the exact physiological data.

6 Other Issues and Their Solution for Implantable and Wearable Sensor Devices

The wearable and implantable sensor devices experience significant problems, such as power issue, issue of specific absorption rate (SAR), and antenna placement issue. In the following section, we discuss about these facts and different solution method to overcome these problems.

6.1 Power Issue

One of the most important features for manufacturing an implantable and wearable device is to design a reliable power source. The problem became severe for the implantable sensor. Traditionally, the battery is the most popular solution. Due to the limited lifetime, we cannot state that the battery is the best candidate to power the implantable devices. After the end of the lifetime of a battery, one needs to operate again to change the battery. As an example, for the pacemaker, an average lifespan of the battery is 5–15 years [71]. Short battery life means more frequent replacement surgeries, which come with a 1–5% infection rate. Sometimes, patients experience hematomas (clotting of blood under the skin) in the wounded area due to the multiple operations. Besides these health hazards, the cost of the operation is also a big issue. For instance, in a country like India, pacemaker surgery cost is in the range between INR 2.25 and 3 lakhs (USD 3000–4000) [72].

To overcome the problems regarding battery replacement in implantable medical devices (IMDs), some charging mechanisms are reported in various literatures. For example, IMD such as pacemakers or ICDs can be powered by implantable fuel cell systems that are capable of converting endogenous substances and oxygen into electricity using a spatially separated electrochemical reaction [73]. Vibrational kinetic energy can also be used to charge IMD devices. But, inside the human body, the availability of vibration intensity is very low. Thus, this methodology cannot be considered an appropriate method to power the cardiac pacemaker system. For charging the IMDs, wireless power transfer (WPT) methodology can be useful. Some methodologies based on WPT systems are reported in the literature.

6.2 Issues Regarding SAR

In general, the radiation of electromagnetic wave creates lots of health hazard in human body. Additionally, in the case of wearable and implantable sensor, the device is placed very close to human body or inside the human body. For this purpose, the engineers should be more concern about the specific absorption rate. The definition of SAR is already discussed in Sect. 2. To overcome this issue, an artificial magnetic conductor (AMC) is developed as a back plane of the antenna which resists the penetration of EM wave inside the human body [74]. For the same purpose, a textile-based electromagnetic band gap (EBG) structure [75] and magneto dielectric composite [76] are also reported in the literature.

6.3 Antenna Placement Issue

In the implantable and wearable sensor, different electronic components such as sensor, battery, and antenna are placed very close to each other. Thus, the scattering from other metallic elements degrades the radiation performance of the antenna. In Ref. [77], a detailed analysis of antenna placement is performed to reduce the effect of scattering. A novel approach is reported in [78] for reducing the scattering in implantable environment using mantle cloaking method.

7 Conclusion and Future Scope

In this chapter, a thorough discussion is accomplished regarding the smart health care with emphasis on implantable and wearable sensor. The important requirements for the design of such wearable and implantable sensor devices were addressed, including security, safety, modestly as well as in reliability. Addition to this, a detail discussion of the telemetry unit of implantable and wearable antenna is highlighted. Here, we also explain different research challenges related to the medical sensors for various health-care applications. Fueled by recent advancement, wireless biosensor networks are going to offer significant advancements in health-care industry.

As the medical and health-care system moves from the conventional industry to the smart one, the implantable and wearable biosensor became the inevitable part of it. The main pillars of the smart health-care industry are continuous health monitoring, personalize treatment, and telemedicine. For all these purposes, we need to collect the several physiological data of the patient. For collecting the data, the sensor devices which are implanted or placed within or over the human body, respectively, require a very minimal human action. The biosensors are needed to be small and lightweight and should not provide any health hazards. Thus, the biomedical researchers are focused to design very compact and lightweight biosensors. Furthermore, the sensor systems should also consume a little power for the operation, such as data processing and data transmission, and thus, the frequent replacement of battery is not required. Thus, designing of advanced implantable systems requires an expertise in different fields, such as material science, electronics, chemistry, and biology. Mainly, for the implantable sensor, they may have a disruptive effect. Thus, it will be essential to rethink and do a rigorous research about the safety feature of the sensor. Besides the sensing, the implantable devices are also used for delivering personalized drugs. However, for the management and detection of chronic diseases, the implantable and wearable sensor devices should be more effective and cost effective.

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Power Management Technique for Energy-Efficient Communication Systems in Telemedicine

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Abstract An embedded system is a specialized computer that is resource constrained to sense and control its environment. Embedded systems usually consist of hardware and software. The mostly used hardware materials are processors, peripheral communication devices, actuators, sensors, power supplies, and memory storage. The application-specific algorithms, device drivers, and operating systems are the typically used in software section. Normally need a standard protocol to communicate the particular type of embedded system, for example, nodes in sensor networks are the specialized embedded systems. Sensor nodes with wireless communication capabilities can form wireless sensor networks (WSN). Normally two types of wireless networks are used, such as personal area networks (PAN) and wireless sensor networks (WSN). The WSN can contain hundreds or even thou-

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sands of sensor nodes. The WSN used in industrial applications and can be deployed in hazardous environments, such as in battlefields, volcanoes, and wildfires. Personal area networks usually require measurement, and minimization devices are implemented in small numbers. PAN devices are designed for Wi-Fi and Bluetooth common-use technologies and standard protocols, for use such as web browsing, file transfer application, audio and video streaming application. Today's research in WSN focuses on generating large-scale network system of electricity using very specialized algorithms. They usually feature exhibits for science, hospital, military, and professional use usage scenarios. Therefore, this research work introduces hybrid method to reduce the power consumption of WSN used in hospital based on patient healthcare monitoring system. To reduce the power consumption in wireless sensor networks (WSNs) for healthcare systems has generated tremendous efforts in recent years. In any case, in a large portion of these investigations, sensor information handling assignments, for example, health decision-making and emergency reaction, the message is sent by the remote server. The proposed system consists of sensor nodes, central processing control module, and transmitter with indicator and receiver module. This research work uses direct power management technique to control the base station – to disable the working of unused nodes, and self-executing path resource allocation (SERA) method is used to detect the active nodes through WSN in receiver side. The direct power management (DPM) technique is used to reduce the power consumption in sensor nodes for base station. The DPM is the effect of initializing the energy of each sensor node without significantly degrading performance when reducing system power consumption. The basic idea is to turn off or not need to sleep mode devices and wake them up when needed. If the energy and performance overhead of the sleep-state transition is negligible, the genetic algorithm is executed so that the idle speed will be perfect when the system enters deep sleep state. A large sensor networks that are environments also require the deployment of a large number of sensors such as for intelligent patient monitoring, object tracking, and low power consumption or high battery life using energy-efficient cluster formation algorithms. The proposed wireless sensor network system using self-executing path resource allocation (SERA) strategy is used to implement in the hardware implementation using ARM Cortex-A 72 controller. This implements an analysis of the energy consumption of the system. The experimental and simulation results of proposed system shows low-power energy-efficient data transmission with security, reduce the packet losses, and improve the throughput ratio.

Keywords Wireless sensor network (WSN) · Personal area networks (PAN) · Self-executing path resource allocation (SERA) · Direct power management (DPM) technique · ARM Cortex-A 72 controller · Energy-efficient cluster formation algorithms (EECFAs) · Genetic algorithm (GA) · Base station (BS) · Healthcare systems · Wi-Fi

1 Introduction

1.1 Introduction to Embedded System

An embedded device is a specialized processor restricted to sensing and manipulating its environment by means of energy. Normally, embedded devices consist of development tools. Systems, cameras, power devices with storage are the primarily used hardware products. In the program portion, computer devices and operating devices are usually used. In order to communicate the unique type of embedded system, a common protocol is typically necessary, such as nodes in network sensor are unique [1].

Two network types, personal area networks (PAN) and wireless sensor Networks (WSN), are usually used. So many sensor nodes may be found in the WSN. Personal area networks typically require estimation, and in small numbers, minimization systems are applied. PAN devices are designed for the use of common-use Wi-Fi and Bluetooth technology and popular protocols, such as web access, file sharing, audio and video streaming applications. Today's study at WSN focuses on the development of a large-scale electricity network infrastructure using very advanced algorithms. They usually feature exhibits for science, hospital, military, and professional usage scenarios [2].

Therefore, in this research work, WSN is used in hospitals focused on patient healthcare management framework to implement hybrid approach to minimize power usage. In any event, sensor data handling functions are submitted by the remote server in a significant proportion of these inquiries. Huge volumes of data launched and delivered. Sensors use several more networking tools, bringing difficulties with period of the decision time. The Hybrid is used in this work to reduce the use of embedded system-based power consumption [3].

Network embedded devices are divided into multiple functional systems that run multiple applications simultaneously and provide users with a number of optional operating systems per number. An energy measuring design system is used for hospitals. The energy consumption characteristics are caused by the low-duty cycle operation of the sensor nodes. At the software level, sensor network provides the trade-off of the energy quality accessible by the user. Power-aware computer design involves the hierarchy of the entire system. Understanding the nature of energy trading transactions, the use of this software will extend its own energy consumption hardware [4].

The self-executing path resource allocation (SERA) algorithm of cluster head responds to topology innovation research to reduce communication overhead. The spatial discovery algorithm logically organizes networks in the form of clusters. A tree is installed as a root cluster on the monitoring node. This can only be reduced to a certain extent due to the slowly increasing energy density of conventional energy sources [5].

This work concludes with two different approaches, one is to optimize the life cycle of the network, its deployment complexity using sub-sink selection, and the maximum network lifetime. To avoid this problem, the regenerative clustering mechanism consumes more power, and SERA has cluster processing when the network is released. In the phase with the network, the transmit power supplied by the sink node sends a signal to the network. Therefore, the percentage of SERA energy consumption is continuously transmitted based on the data obtained from the simulation. Path analysis (clustering) in self-functioning is clearly seen in wireless sensor networks as long as more energy is consumed in a good communication environment. However, there are still areas for analysis and performance improvement along the path of self-implementation. Several variables that contribute to the decay efficiency have been established by the method, showing the energy distribution of adjacent nodes and the lifespan of the nodes in the expanded network. This will reduce as much of the node system's energy consumption as possible [6].

In this wireless network, using routing-based energy-efficient QoS is efficient for multipath routing protocols. The SERA algorithm is intended to effectively transfer data over a short distance. Any packet transmission fails during the transmission; if the route is targeted, it will be transmitted through another path. For any contact, the routing table states the energy level of the next sending node. If the amount of energy is reduced, so the direction to the next transition will change. During transmission, this will decrease route loss. The hardware system comprises of ARM's Cortec-A72 controller. The performance measures of this wireless system can be evaluated using parameters like packet loss, energy consumption, delivery ration using NS-2 software for obtaining the simulation results. Embedded system is used to construct the hardware for the proposed system [7].

The wireless sensor nodes are activated to focus area of the hospitalization with monitoring of the ARM's Cortex-A72 controller to the entire network. In reconstruction algorithm iteration, the amount of subspace of the congestion windows is required to be scanned, sparse model collective architecture is decreased, and the amount of measurement of mobile sensor nodes is required to effectively recreate network data [8].

The current multimedia sensing network compressed for sensing algorithm that can effectively reduce the transmission for multiple kind of data such as text, image, video, or audio of scanning reports is generated in the reconstructing network, which depends on medical components like CT scan, MRI scan, X-ray, ECG, thermometer, and laser. Each node in the WSNs has a microprocessor, memory types, RF transceiver, and various sensors (Heart beat, pressure, Temperature,) and actuators. With limited capital, computing capacity, storage, and most importantly, electricity components are installed. This is because they are normally powered by batteries. Owing to the inaccessible location of the body area networks, batteries in the sensor network are often difficult to recharge (BAN) [14]. The level of service is appealing, while the efficiency of WSN depends on several criteria. Undoubtedly, with the central output scale in this domain, the power usage of sensor control plays an important role in the lifetime network. WSNs are often characterized by dense deployment and WSN at large in the environment. The designers are well experienced to in order to meet the various constraints imposed to reduce power consumption during packer transfer. The multimedia devices are developments in the sensor nodes and are very powerful and cost-effective devices [9].

The algorithms and protocols used by distributed WSN networks offer high-quality transactional energy storage options. A built-in commercial processor, a digitally customizable controller, and a power-aware operating system are used through dynamic voltage management to allow energy-efficient sensor nodes. In vast distributed wireless sensor networks, the system-wide methodology of power control is used. By using embedded ARM's Cortex-A72 operating system with two sleep states and active power control, the power-aware solution decreases node energy usage. In building networks of hundreds of thousands of distributed wireless sensor systems, the energy consumed by contact is a major concern. Using advanced RISC machine (ARM) can increase the performance of many devices, including wireless sensor networks (WSN) for processing [10].

In addition, ARM devices allow remote and hardware runtime reconfiguration, which means better deployment and maintenance of wireless sensor networks and ultimately reduced costs. So, large circuits can reach this level. In logical processing, the wireless sensor node is designed and implemented, which shows the functions of the master controller before the actual deployment of the transmitter, receiver, and node. As a result, nodes will only support the hardware components of the desired target application, which will reduce node power calculations. In this work, the main task-based prototype of ARM is to increase the power requirement and analyze the performance of real-time applications in wireless sensor networks [11].

Embedded systems and wireless sensor technology are introduced in small and sensible portable devices with computer and wireless communication capabilities. In many civil, military, and industrial applications, these device networks are useful for automatic knowledge collection and distributed sensitivity. For their service, wireless nodes need limited external assistance. The wireless, distributed multisensor system allows multiple applications to be tracked and managed. Power-aware computing and networking, low power signals, networks, nodes, and routing are used for sensor networks [12].

Following points motivate us to work on the proposed work:

- The proposed work motivate to improve the performance of execution time compared with existing and also reduce the power utilization and end-end delay response.
- An electronic medical document is a convenient way to exchange patient medical information between different medical providers. These records of the patient contain the confidential information required on a mandatory medical document to protect patient privacy and prevent unauthorized access.
- Because the proposed work is patient-centric and can be used by multiple patients, a huge amount of data will be shared between the various entities of the system. So, this prompted us to propose such a bandwidth efficient solution that would reduce bandwidth requirements and increase data rates [13, 15].

1.2 Objectives

- This research work mainly reduces the power consumption in wireless sensor network using embedded system. This system automatically disables the function of unused nodes. Here, the application is related to check the patient's health using the proposed health monitoring system with sensors like body temperature, heart beat, temperature and pressure.
- Develop an improved adaptable routing that suites for high-dimensional network by flooding sequence demands to the particular region in the network.
- The recognition system must create less start to finish delay, routing overhead, and crash rate, and furthermore it must improve identification proportion and throughput in various situations.
- Improve the way assumed by performing location-based sequence disclosure and adaptable routing in a working network.

2 Literature Survey and Problem Statement

In this research work, the traditional power management methods in wireless sensor network and the problem statement of existing methods are discussed.

2.1 Literature Survey

Miguel Lombardo et al. (2012), implement RAM-based FPGA for wireless sensor networks (WSN) in high-performance node with power management techniques. The power management methods consist of three periods to reduction of current consumption. Power management technology, based on the current, focuses on the three periods of consumption reduction. The sleep period perfectly reduced the power consumption of switching components that only require the determined wake-up conditions. But the current consumption bit is independent in type of flow in configuration period, and the current consumption is reduced by the reconstruction time period. Finally, the computation period is implemented to reduce the overall power consumption from software into hardware [1].

Yu Ge et al. (2013) present a unified wireless mesh infrastructure used for different smart services. The giant network controller is a service adaptation module, a network knowledge module, and wireless mesh network. The important feature is that it can be used to obtain a low-cost wireless hybrid area network. With the help of this technology it is possible to manage the resource in the delivery module. Wireless network design space is expected to improve the efficiency of access to intelligent services – knowledge models and proximity access spectrum structure [2].

Peter Karsmkers et al. [3] implement and discuss the feasibility of noncontact fall detection and vital sign monitoring. It represents an emerging asset in ambient assisted living (AAL) applications, which seek to promote new technologies to improve the quality of life in older peoples.

Zuhairy et al. [4] discuss a large number of applications for cluster functionality in wireless sensor networks. Multiple compilation approaches are difficult to do, but ultimately there are unbalanced asymmetric clusters and network overload. Two of these suggested energy-efficient balanced network load balancing method. In this account, the parameters in the cluster between the remaining clusters are taken as energy, low within the cluster, low between clusters, and communication distance.

Akshay Mahajan et al. [5] present the how to process efficient information using wireless sensor network and Localization Cyber-physical systems and things growing systems like the Internet of Things the context-security is prominent. Transmitting Data with Multiple latencies on a Network of Sensor Nodes in VSS.

Fatih Alagoz et al. [6] discuss the dynamic spectrum availability to utilize licensed spectrum when it is inactive. The cognitive radio (CR) technology will be applied to the appearance of wireless ad hoc sensor networks chirms, respectively. An efficient topology has been managed by controlling clustering and communication and allocating spectrum resources according to the C capabilities of the nodes. In this article, we investigate the advantages and functions of well-being in this network, such as spectrum, energy, and management.

Guangjie Han et al. [4] introduce underwater acoustic sensor networks should be deliberately enhanced with marine environmental monitoring, auxiliary guidance, and marine military protection. However, current underwater data collection projects typically have high latency problems such as high energy consumption. The application task assignment in addition to multiple autonomous underwater vehicles (AUVs) contributed to more problems with load balancing [7–12].

According to Guanglin Li et al. [13], discussions of advances in communication technology have allowed the transmission of medical information using wireless body sensor networks. The biggest challenge of a smart healthcare is that patient data are convincing and secure transmission is critical [16, 17]. This article aims to explore intelligent communication, health, and safety communications. For a web health application, it discusses the need for a secure, accurate, and efficient transmission of information. Moreover, in security, especially biometric keys, the main challenge in the field of modernization is to explore the signals of human life signals.

2.2 Problem Statement

- Due to multiple nodes and different data acquisition rates, the number of packets arriving on the queue network can vary, which leads to the maximum number of packets reaching the maximum value compared to other packets.
- The earlier methods produce more latency, which reduces the throughput of the network. Depending on the Routing Procedure the values will be determined by the source node and it takes long time to live.

- The conventional methods produce more packet drop ratio, the poor route management, as well as reduced security for intrusion detection because the node deletes the path available once there is no data transfer for some time.
- The prior strategies delivered more inactivity, which reduced the throughput of the network.

3 Proposed Model for Embedded System-Based Power Management in WSN for Health Care Applications

In recent years, enormous strides have been made to reduce power usage on wireless sensor networks (WSNs) for healthcare systems. In any event, sensor data handling functions, such as health decision-making and emergency response, are submitted by the remote server in a significant proportion of these inquiries. Huge volumes of data launched and delivered. Sensors use several more networking tools, bringing difficulties with a remote server and delaying the notification period of the decision time. Hybrid approach (Direct Power Management Method for Base Station and Self-Executing Route Resource Allocation Method for Server Section) is used in this work to reduce the use of embedded system-based power consumption. The home automation system can be constructed using ARM Cortex-A72.

A bridge between the wireless sensor network and the public communication network is created which is compatible with internal data. The choice of framework and the lightweight database, the proposed intelligent gateway system empowers tolerant health choices to get fast reaction times for low power and minimal effort implanted frameworks and for emergencies. This system designed a communication protocol between the WSN, the gateway, and the remote server with low energy consumption for the data communication process. The block diagram of transitioned system is shown in Fig. 1. This system consists of sensor nodes, central processing control module, and transmitter with indicator and receiver module. This research work uses Base Station-Directed Power Management Technique to disable the working of unused nodes, and self-executing path resource allocation (SERA) method is used to detect the active nodes through WSN in receiver side.

3.1 Base Station

In base station, the ARM Cortex-A72 reads the details from sensor nodes; if temperature needs to be monitored, only temperature sensor will be in active stage and other sensors will be in inactive stage; therefore, the power consumption will be significantly reduced. After reading the sensor details, the ARM Cortex-A72 transmits the details to hospital server module through WSN and if the patient there is in

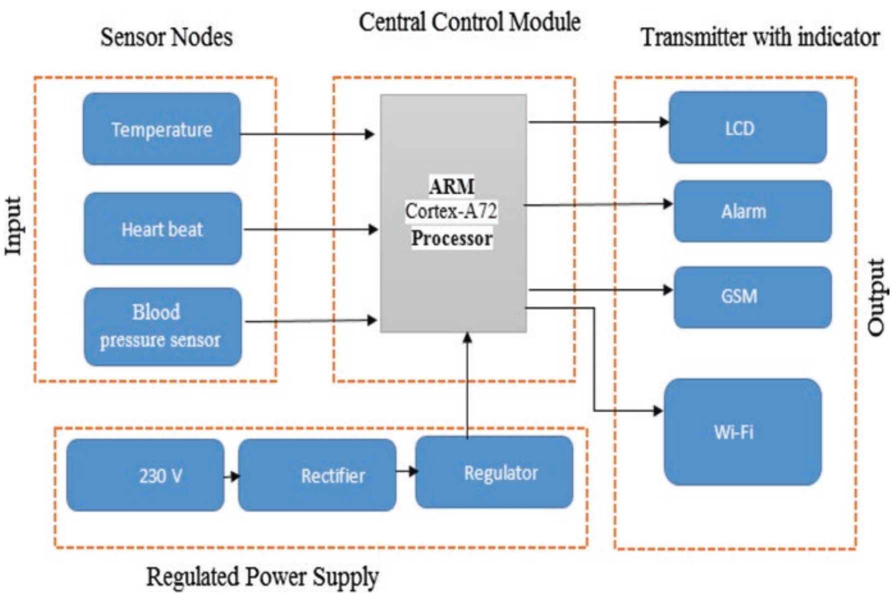


Fig. 1 Block diagram central control model with transmitter

critical situation, the ARM Cortex-A72 sends the message to the patient's family members and also to the duty doctor.

3.1.1 Sensor Nodes

The sensor nodes are used to obtain the health status of patient. In this work, total three sensors are used, which are temperature sensor, heart beat sensor, and blood pressure sensor.

Temperature Sensor

The LM35 series has a precise integrated circuit temperature sensor. The LM35 output voltage is Celsius. Another type of sensor that is calibrated at °Kelvin. The LM35 delivers high accuracy compared to other temperature sensors with no external calibration and ±3/4°C over a full temperature range of −55°C to +150°C. Therefore, the LM35 is sensitive to other sensors. The LM35 has a very low self-heating in still air of less than 0.1 °C because it consumes only 60 μA current from power supply. The advantage of LM35 has a linear output and easy control circuit to provide accurate built-in calibration. In case the temperature is abnormal, the ARM Cortex-A72 sends the message to patient's relatives and doctors with the help of GSM.

Heart beat Sensor

The heart rate sensor is the combination of infrared light-emitting diode (IR LED) and optical sensor to measure the heart rate, that is, pulses per minute (ppm). Along with an IR LED, light sensor generates a signal that can be increased and filtered after sensing changes in the blood volume. The filtered signal is processed by the ARM Cortex-A72 and finally receives the data to receiver end Wi-Fi transceiver. The received data also displayed by the LCD at the transmitter end. In case the BPM is abnormal, the ARM Cortex-A72 sends the message to patient's relatives and doctors with the help of GSM.

Blood Pressure Sensor

The pressure measurement of arteries using a blood pressure gauge is called a tension meter. In case the blood pressure level is abnormal, the ARM Cortex-A72 sends the message to patient's relatives and doctors with the help of GSM.

3.2 Central Control Module

In any wireless sensor network, central computer module is the main part. It is additionally responsible for transferring information received on the Internet and visiting a doctor consistently. It is a wireless network S2 receiver module, which means a coordinator wireless network connection is placed in a star topology that receives data from all data receivers in the health center; Wi-Fi Module Operates 802.11b/g/n Wi-Fi protocol used to upload data; With the ARM Cortex-A72 processor, it interfaces with the I/O system, Wi-Fi module and run code. The location identification of the transmitter on the network and the location of the patient in the health center using that information is performed. The central module block diagram is shown in Fig. 2.

3.3 Receiver Module

The receiver module block diagram is shown in Fig. 3. Here, Wi-Fi receiver receives the data from patient and upload to server. In the receiving section, self-executing path resource allocation (SERA) method is used to detect the active nodes through WSN.

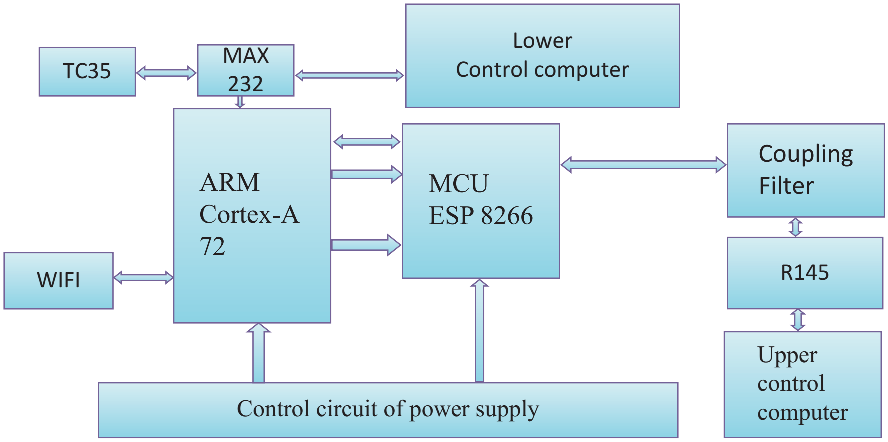


Fig. 2 Central control system module

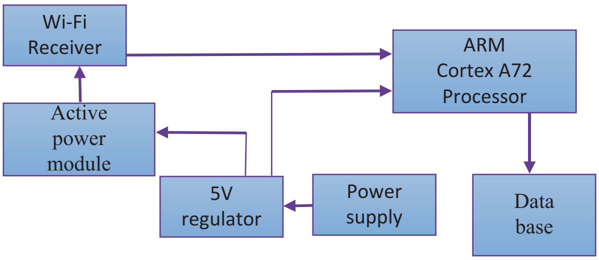


Fig. 3 Block diagram of receiver module

3.4 Base Station Control Using Directed Power Management Technique

The directed power management (DPM) technique is used to reduce the energy consumption in sensor nodes for base station. The DPM is the effect of initializing the energy of each sensor node without significantly degrading performance when reducing system power consumption. The basic idea is to turn off or not need to sleep mode devices and wake them up when needed. If the energy and performance overhead of the sleep-state transition is negligible, the genetic algorithm is executed so that the idle speed will be perfect when the system enters deep sleep state. Large sensor networks that are environments also require low power consumption or high battery life using energy-efficient cluster formation algorithms.

The working flowchart of power management for hospitalization environment using WSN is shown in Fig. 4. The base-station-directed power management technique is used to generate the status of power ON/OFF during active /sleep mode.

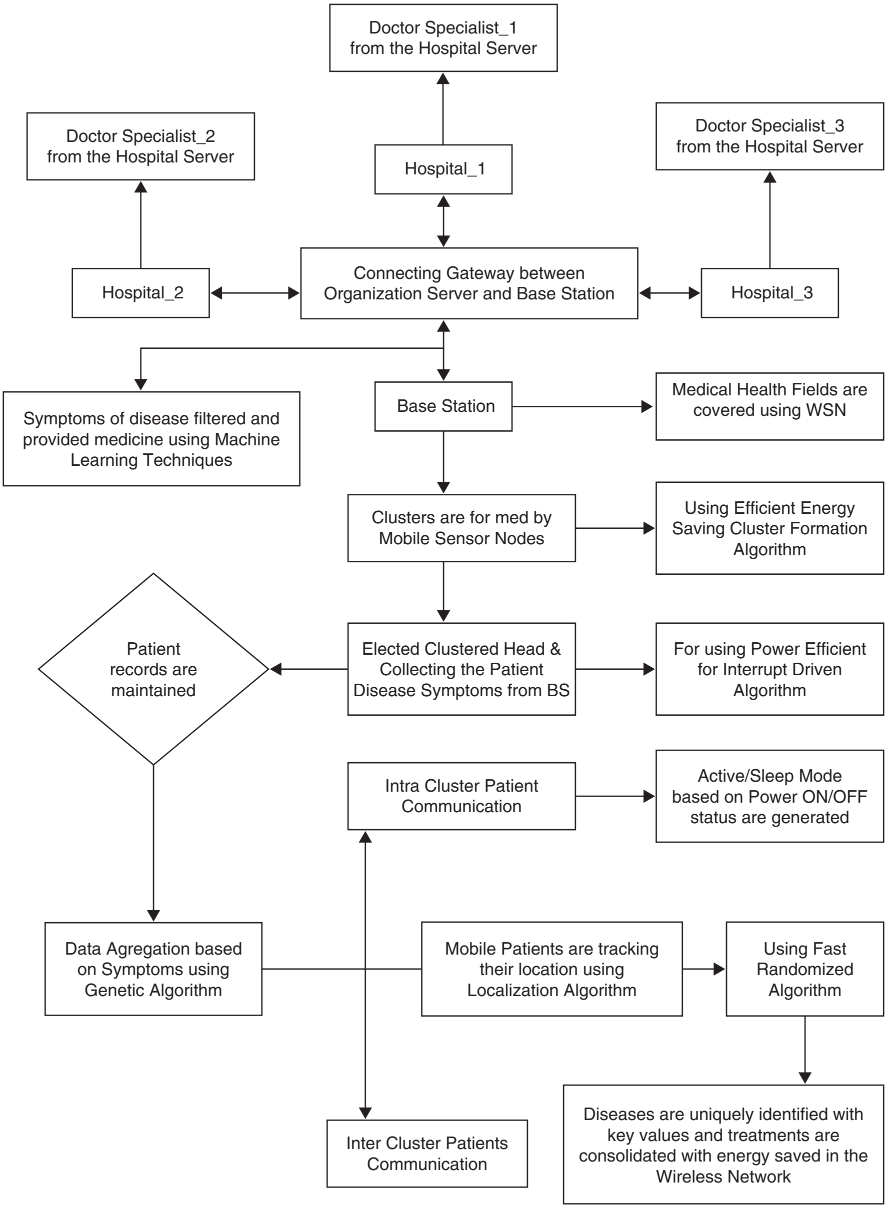


Fig. 4 Power management for hospitalization environment using WSN

3.5 Server Section Self-Executing Path Resource Allocation (SERA) with Network Communication Using Sensor Nodes

In a sensor node, each node is dependent on event sensitivity rate, node distance, and the location of each node's location factors, such as the power rate changes. This imbalance in WSN energy consumption causes an imbalance in the node power level. The protocol performs three levels, where one is synchronization node selection, another standard for authentication and cluster head range, and finally, optimize path selection is shown in Fig. 5. In this approach, the path is disconnected to optimize the power and discover the track which is done by transferring the data without loss. Multiple monitoring routing path and node information of the data and any lost routing are detected before the transfer data. The proposed wireless sensor network system using self-executing path resource allocation (SERA) is implemented in the hardware implementation using ARM Cortex-A72 controller. This implements an analysis of the energy consumption of the system.

The block diagram of proposed wireless sensor network with self-executing path resource allocation (SERA) method is shown in Fig. 5. It consists of four section.

- **Synchronization Nodes Selection:** The most common and simplest example of a sensor network can be that all sensor nodes of a very complex set of gestures

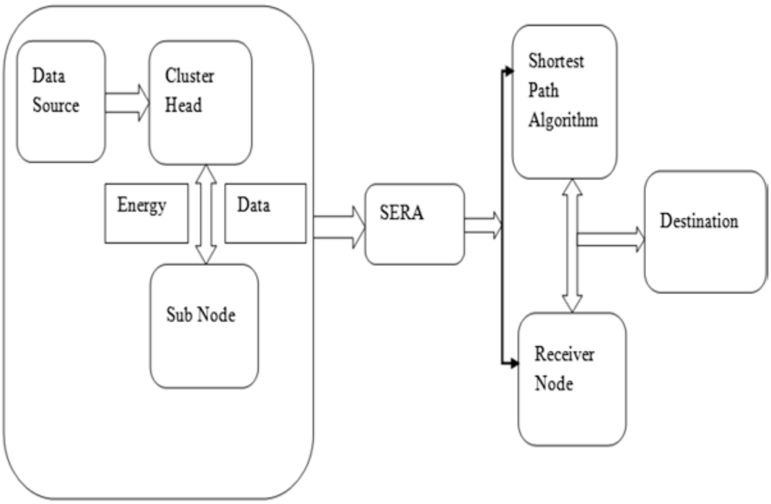


Fig. 5 Proposed wireless sensor network System

can communicate directly with each other. Therefore, the synchronization of nodes selection needs to be added. This can be avoided by using an overlay network to provide virtual, single-hop communication from each sensor node to a master node.

- **Cluster Head Formation and Authentication:** The Cluster Head (CH) election process occurs during the initial deployment of the sensor network and after some time. For cluster head elections, the submodule collects information such as neighbors, their number of distances, and the power level data receiving capacity of the network nodes.
- **Optimize Path Selection:** The role of optimize path selection involves the allocation of energy load between sensor nodes in a two-sided network of nodes at the cluster head. The identity of the cluster head check node is in its area, used for node service total data, and for the nodes of the CH and nodes.
- **Trust Module:** The trust is based on the level of the subjective possibility of the trustee who is the trustee and it is the relationship between the two companion nodes. it's also known as router

3.5.1 Self-Executing Path Resource Allocation (SERA) Algorithm

The given node edges are the shortest path problem for all pairs that give the shortest path of each pair, the self-executing path resource allocation (SERA) algorithm to solve.

Above Fig. 6 shows a particular transmitter node process based on a proposed SERA algorithm. In the transmitter, the node performs the attribution table process and finds the shortest path to efficiently transmit the packet.

Figure 7 describes finding the shortest path by using the SERA algorithm operating in all pairs.

From the above Fig. 3.7, describes finding the shortest path by using the SERA algorithmoperating in all pairs.

Algorithm

Input: Source Message form CH

Output: shortest delay communication time

Step 1: Source and destination node initialize

// Data packets split

Next, how many data packets will be sent from source to destination

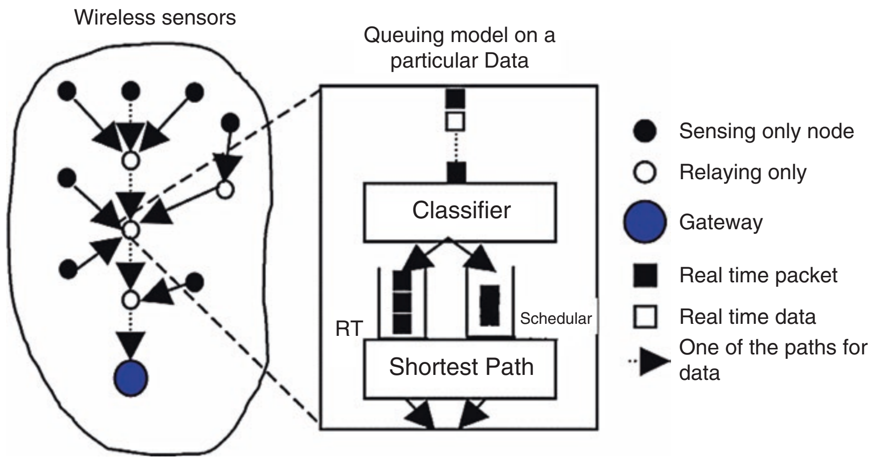


Fig. 6 Single transmitter node process

// Delay and longest network lifetime

If (path already cached in the node)

The received data;
Else
$B\ Delay\ is\ calculated\ as\ in\ (n_0)\ldots\ldots..\ n_n{-1}$
$If\ (it\ is\ the\ first\ node\ received\ this\ is\ index)$
Node time schedule.
$Else\ if(B\ Delay < timer\ value)$
Node timer is rescheduled to B delay // that means longest network lifetime
End
// network lifetime
Start
For each node (data path node P (n))
{
$For\ each\ packet\ (Previous\ trip\ P\ (d))$
{
To calculate the number of transmissions data n (Td);
To calculate the amount of throughput n (Tp);
To calculate the amount of data transmission speed n (Sg);
To calculate the Packet delivery ratio P (Dr) with n (Td), n (Tp);
}
}

End

Assume n (Td) and n (Tp) as the delay of the initial node.

Packet delivery ratio – P (Dr)

N (Tp)-Throughput

N (Tt)-Transmission

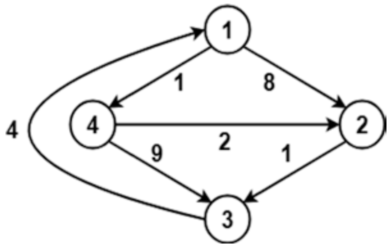


Fig. 7 Shortest path example

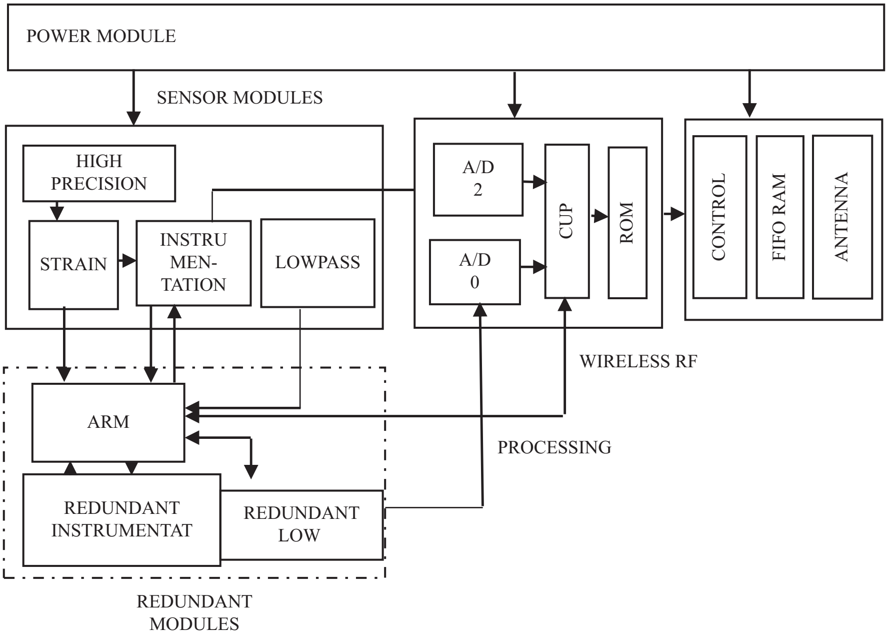


Fig. 8 Proposed hardware model For WSN system

The Edge node approach computes the distance from their first neighbor and identifies the node with more range. Based on the distance, the method removes concern neighbors from the list (Fig. 8).

3.6 Hardware Model

ARM is also in charge of network interface power management. The ARM is connected to the Node MCU with ESP 8266, which is shown in Fig. 9. The controller sends/receives data From WSN to/from the bus. Implementing the controller in the ARM provides an opportunity to exploit both Node MCU and Display simultaneously.

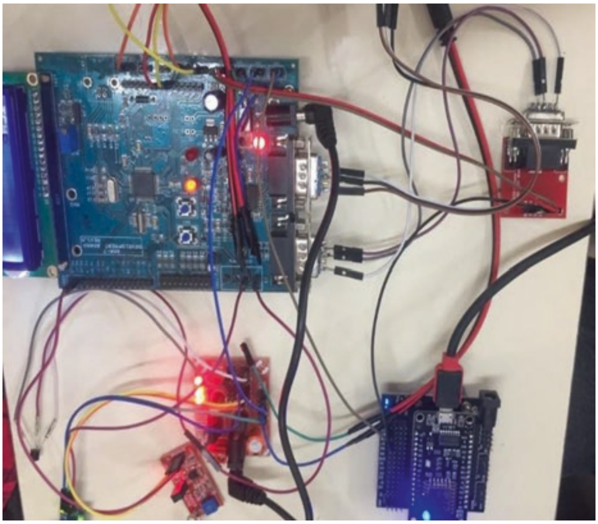


Fig. 9 Hardware implementation of WSN system

Figure 10 shows the DSO output waveform, the peak amplitude "ON" state condition while transmitting the data and "OFF" state; without transmission period this operation is done by using node MCU model. The System SERA Controller provides the interface to operate the configuration manager and power manager control, the runtime reconfiguration, and low power mode, so that adaptation can be achieved with energy capacity.

4 Results and Discussion

4.1 Results for Power Management Technique by Using NS-2

The performance of the proposed algorithms for the given input is evaluated based on the delivery ratio, time complexity, delay ratio, energy efficiency, and link stability. The proposed algorithm states that the process of inter- and intracluster communication. This section discusses simulation results and performance analysis of the proposed system.

Here, the number of mobile sensor nodes is available in the medical field organization to find out the symptoms of the patient's disease level. So, the connection establishment between base station and hospital server to be covered in this wireless sensor network is shown in Fig. 11.

There are some distance range covered from base station to the cluster group formed uniquely identified at different colors in the network, as shown in Fig. 12.

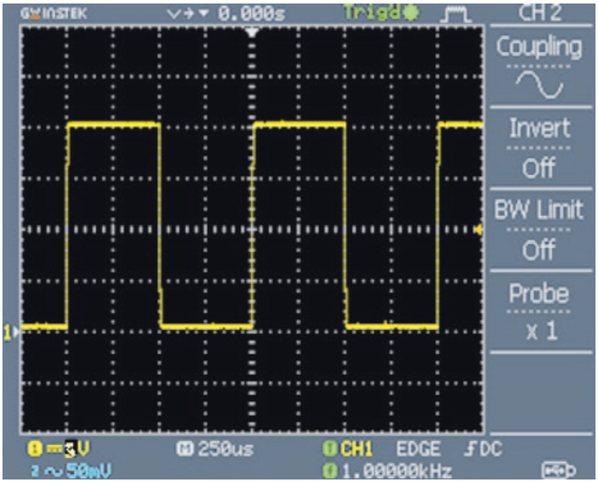


Fig. 10 DSO output waveform of the WSN performances

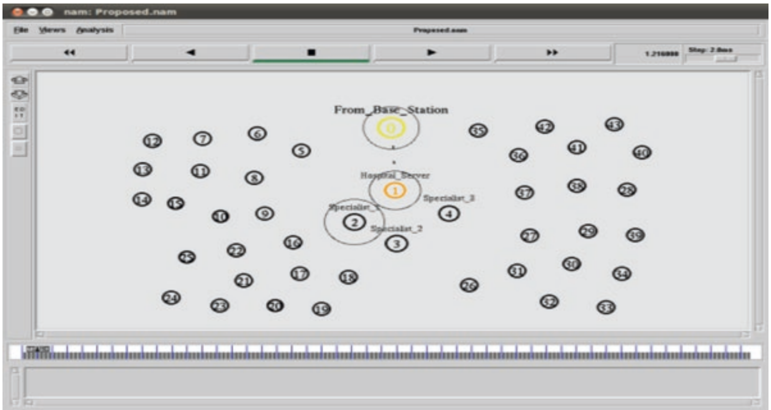


Fig. 11 Connection establishment between base station and hospital server

Each mobile sensor node forwards the disease symptoms to the elected cluster head and cluster head forwards to the base station to get the disease outcome from each cluster group level, as shown in Fig. 13.

Here, patients' disease are identified based on assigned energy level, and each disease status is received by the cluster head and then forwarded to the base station from the separate cluster group, as shown in Fig. 14.

Once received, the symptoms should then be forwarded to the base station to get the prescription of the medicine from the hospital server in this organization field, as shown in Fig. 15.

After receiving the symptoms status, then it is forwarded to the hospital server with collected disease of symptoms level, as shown in Fig. 16.

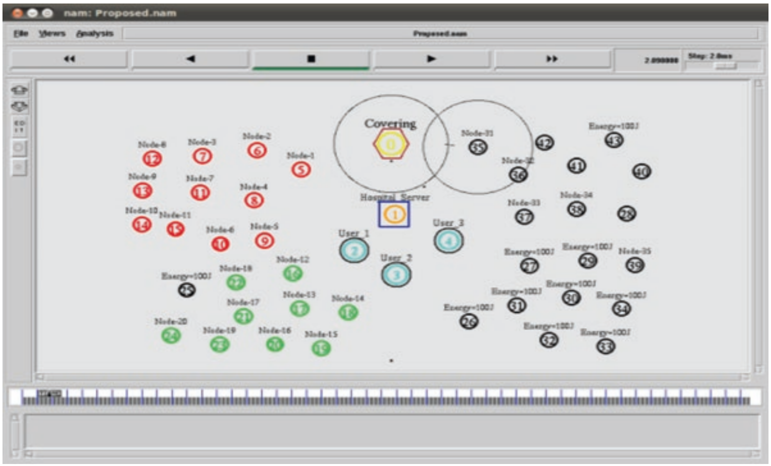


Fig. 12 Cluster group formation

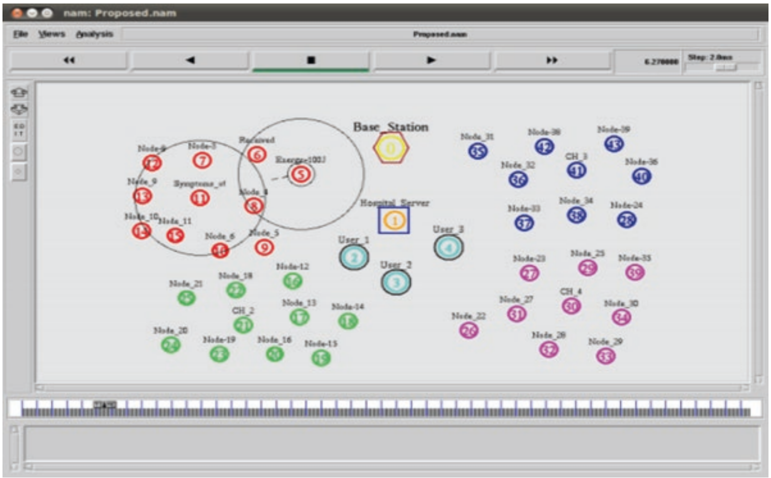


Fig. 13 Assignment of initial energy level

Here, the energy level status is received based on filtering the symptoms of disease status and gets the result of specific disease medicine from the hospital specialist, and it is then forwarded back to the base station in the medical organization, as shown in Fig. 17.

Here, the medicine for specific symptoms of disease is received from the specialist, and it is forwarded to the medical base station network. All the disease symptoms of the medicine received from the medical base station network with prescription of the medicine are forwarded to the related patients based on energy level, as shown in Fig. 18.

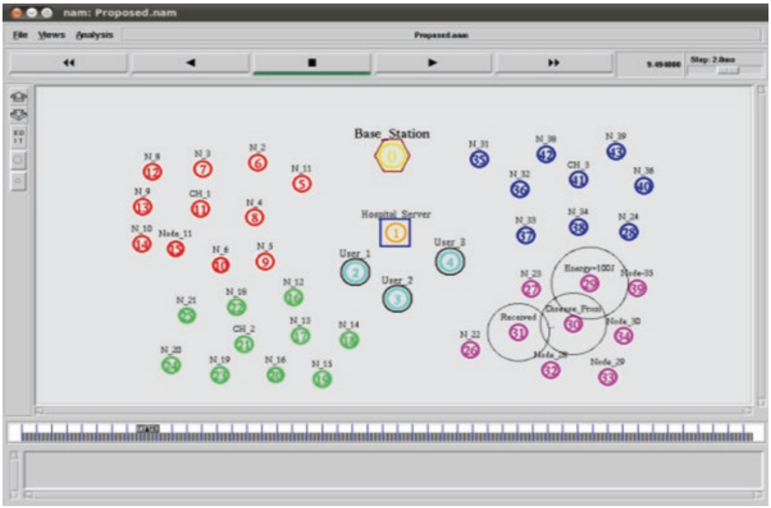


Fig. 14 Energy level identification in each group

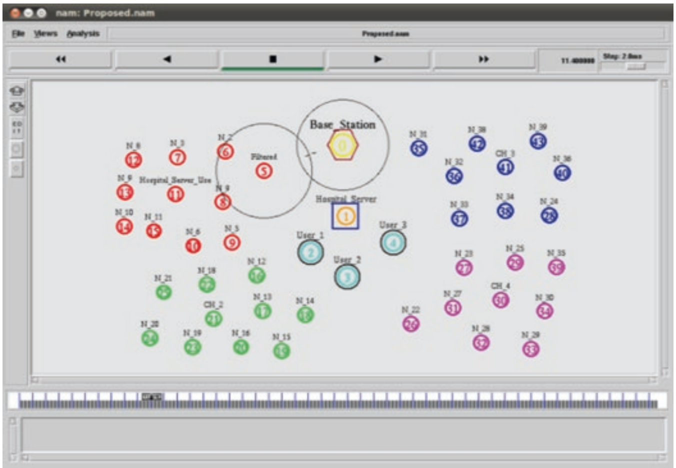


Fig. 15 Symptoms received from cluster head

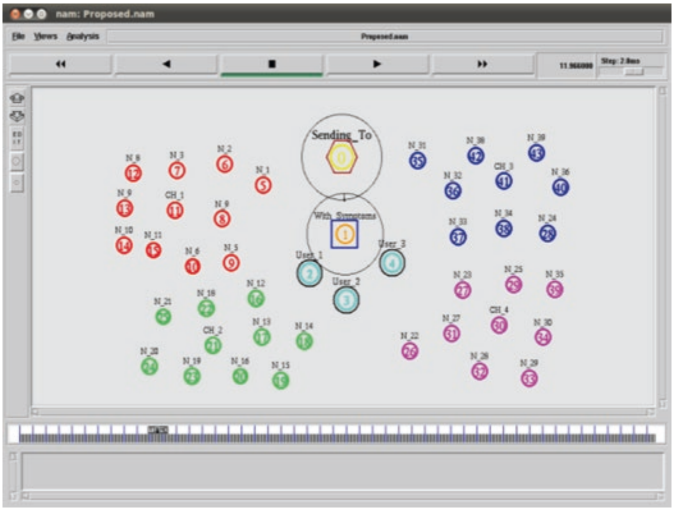


Fig. 16 Symptoms sent to hospital server

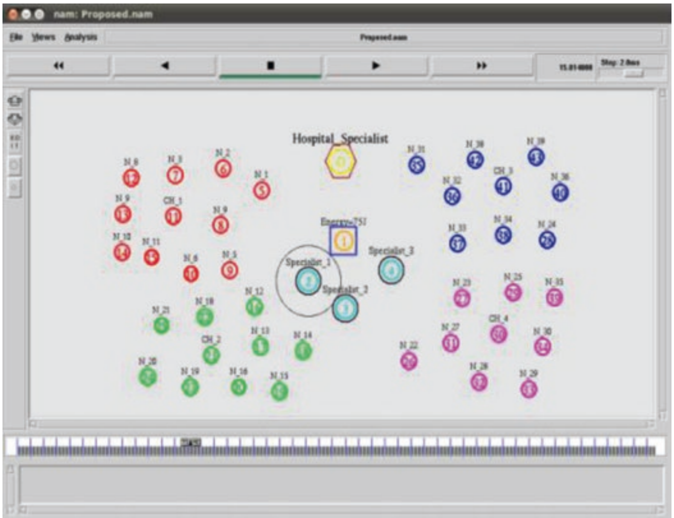


Fig. 17 Symptoms sent to hospital specialist

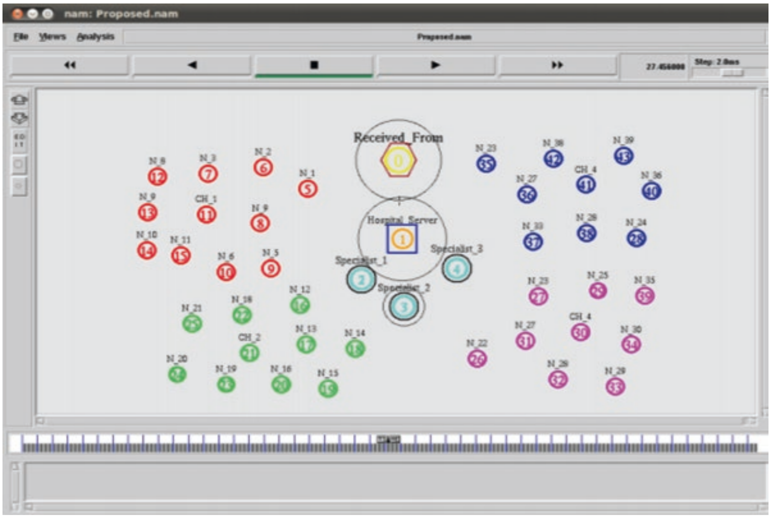


Fig. 18 Medicine received from the hospital server

Here, we received symptoms of medicine forwarding to the related patient with their specific cluster group level in the network organization, as shown in Fig. 19.

4.2 *Number of Patients vs Packet Delivery Ratio*

In the graph, the packet delivery ratio or data communication for lifetime of the patient status to be increased, as well as the hospital specialist of the doctor-status level also to be increased, as in Fig. 20.

4.3 *Number of Patients vs Network Performance*

The below graph is the cluster connection establishment for improving the network performance in the medical field. The increasing cluster formation facilitates easy identification based on the symptoms of patient for the particular disease level, thereby reducing the mental agony to the patients (Fig. 21).

4.4 *Result of Energy Consumption*

In Fig. 22, red color represents the number of packets archive the energy consumption. Every two packets are shown to save their relative energy; 97.5 MJ of energy is saved when sending 10 packets per second.

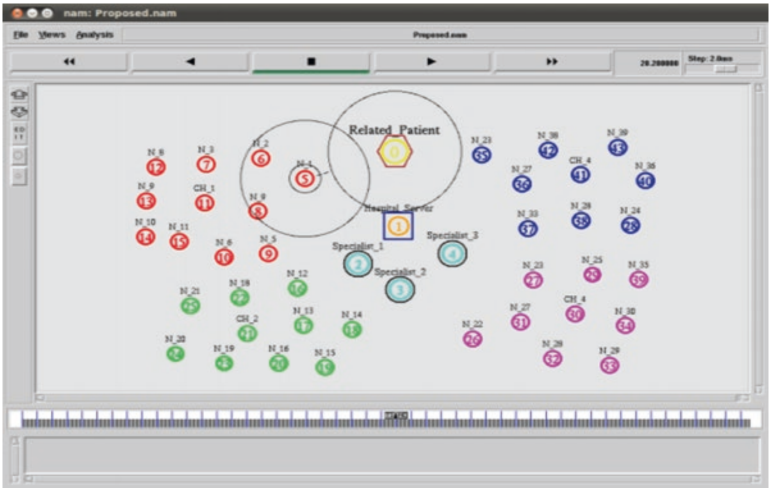


Fig. 19 Retrieving medicine from base station

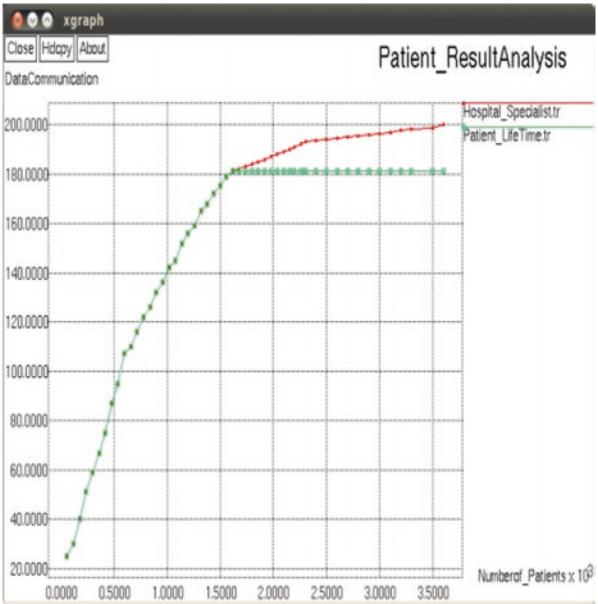


Fig. 20 Status – Lifetime for patients

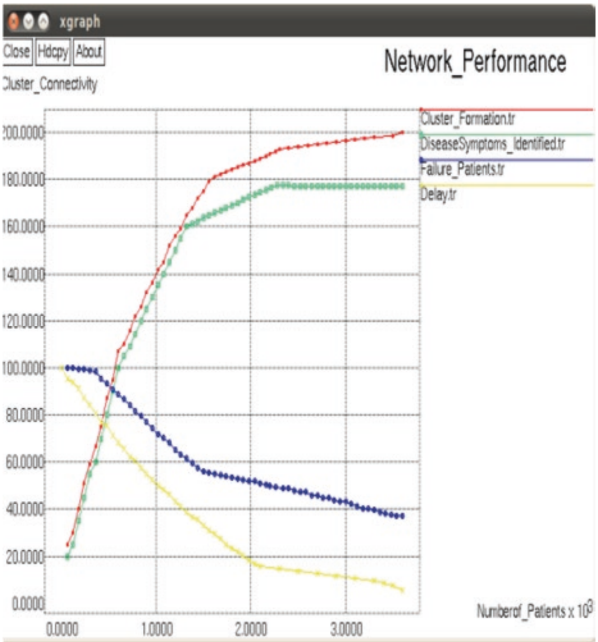


Fig. 21 Network performance

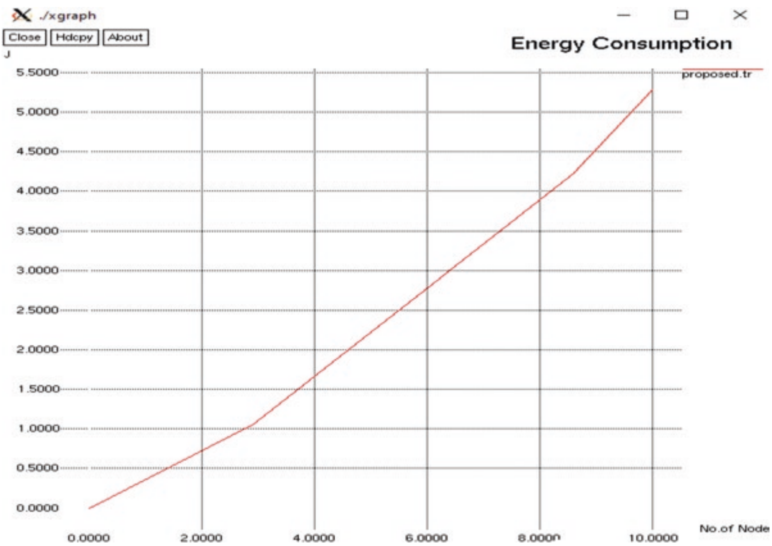


Fig. 22 Energy consumption

4.5 Performance Analysis

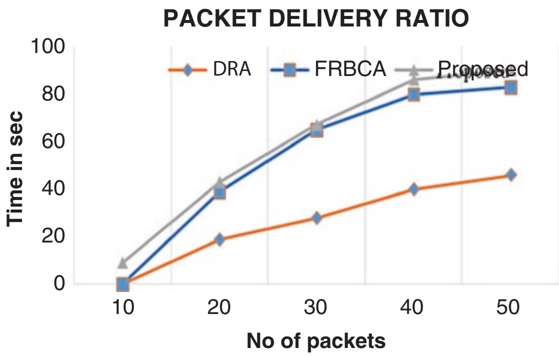
We consider a 150 m × 150 m to the destination in the experiments. The node communication range is 50 m and their sensing range is 10 m. We think all sensors 20j have the same hardware capabilities and initial power. The proposed algorithm gets a better network lifetime than other existing algorithms like FRBCA and DRA.

- Flexible Route Based Congestion Avoidance (FRBCA)
- Distributed Route-Aggregation (DRA)

The proposed algorithm may be detrimental to finding the given weighted system in the graph weight. All high-energy neighbor chooses node's neighbor as nodes. In intermediate nodes receiving fast cause, data transfer in dynamic network makes their energy (Figs. 23 and 24)

Pattern utility methods are frequently based on a comparison of time complexity, which attempts to transform the original features into an appropriate time complexity. For pattern utility, the original meaning of the elements is generally lost (Fig. 25).

Fig. 23 Packet delivery ratio in percentage



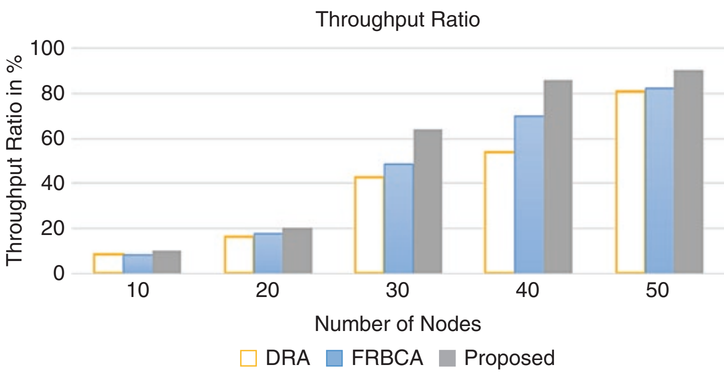


Fig. 24 Throughput ratio analysis

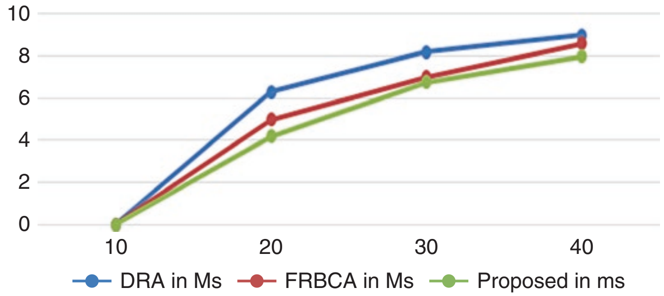


Fig. 25 End-to-end delay

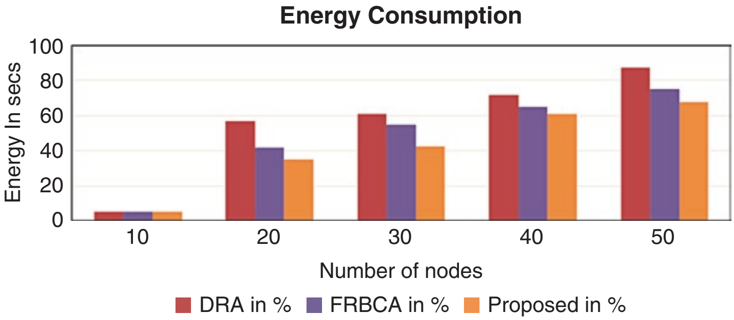


Fig. 26 Evaluation of energy consumption

End delay is based on the destination and the time it is measured from the time received by the transmission source. The difference between the two time values defines end-to-end delay or latency.

Figure 26 describes the construction of different methods of energy performance, which indicates that the project increased during the energy period.

The effect of the number of sensors on the life cycle of the largest network, and the efficiency of the algorithm are presented in order to determine them (Fig. 27).

5 Conclusion

This work uses various approaches, one for the base station direct power management system and the self-executing resource allocation path (SERA) algorithm used in the server portion. Dynamic Power Management Techniques are designed for sleep or active modes could be turned on or off situation in network. These nodes are communicated based on the cluster formation and election of cluster heads, which depends on the highest energy nodes in the wireless sensor node. Broad sensor networks that are ecosystems often involve the implementation of a large number of sensors such as the effective energy saving cluster forming algorithm for intelligent patient control, object detection, and power usage with low to high

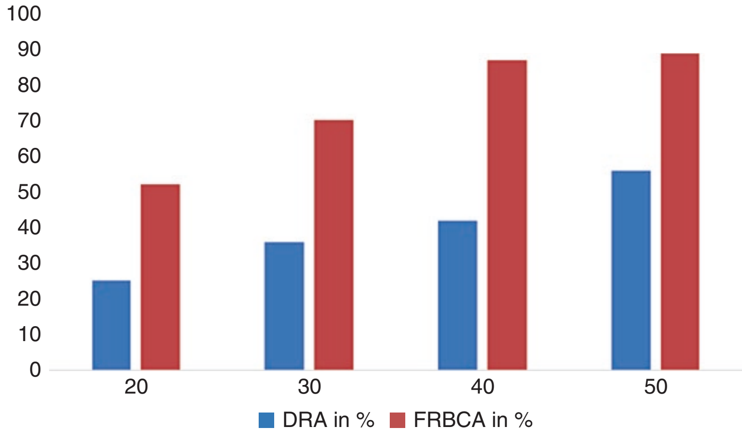


Fig. 27 Average network lifetime

battery lifetime consumed. The widely distributed nature of these networks provides an energy-efficient hospital environment that improves sensor nodes higher resolution and fault tolerance. To avoid the problem, the regenerative clustering mechanism uses a large amount of energy, and SERA has a clustering process at the time of network release. In the phase with the network, the transmit power supplied by the sink node transmits a signal to the network. The data thus obtained by the simulation were continuously transmitted based on the percentage of SERA energy consumption. Until more energy is consumed in a good mobile environment, that path analysis (clustering) in self-functioning is clearly seen in wireless sensor networks. However, there are still some areas for analysis and performance improvement along the path of self-activation. We have identified some factors that contribute to the decomposition efficiency, thus illustrating the energy distribution of the neighboring node and extending the lifetime of the nodes within the network. This can presumably reduce the power consumption of the node system as much as possible. In three density areas of low density, medium density, and high density network scenarios, and wireless sensor protocols used at node points, the three parameters of the packet transport ratio, end-to-end delay, and throughput are analyzed. Finding work in wireless sensor networks is focused on reducing the consumption of wireless sensor networks. The proposed SERA techniques improve the wireless sensor networks improved its throughput ratio to 90% and the energy performance is 4.07%.

5.1 Future Scope

Location-based optimized clustering: Rather than having a CH node selection based on probability of clustering, if each node specifies its location (using GPS) and energy level to the BS (Base Station), BS can run an optimization algorithm to determine the CHs for that round and hence uniform distribution of cluster heads throughout the network can be done, which improves performance of the network.

a) Low computing data encryption can be used as part of the future to secure a higher amount of data transfer process.
b) In the future, we intend to elaborate and analyze complex issues related to connection routing, such as responding to transient (restricted) properties of packet flow (i.e., state full Russia levers).
c) The time consumption and the data deliver in system are improved by increasing the number of multiplexes.
d) Multi-hop routing through border nodes: In cluster-based routing protocol like multi-hop-LEACH, after the clustering operation, if the optimal path between cluster heads is set through cluster border nodes energy can be still minimized.
e) Secured clustering a multi-hop routing with secured clustering can be provided to meet the fundamental requirement of security in certain applications where more security is required.

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Influence of Reduced Noise Levels on Human Health During Quarantine Lockdown

T. S. Shwetha and Husena Dhariwala

Abstract The coronavirus disease (COVID-19) pandemic is one of the greatest challenges humanity must overcome and a defining global health crisis of our time. With the initial outbreak in December 2019, the acute respiratory disease has had an exponential rate of infection and a staggering death toll. There is experimental evidence suggesting an interaction between environment and virus mechanism using the aggregation-disaggregation process. As a result of this, risks factors for humans being infected increases. For example, in the current scenario, the COVID 19 virus and air pollutants both result in acute respiratory infection among humans. Hence, it becomes impendent to understand the interactional patterns of relationship between the environment and human beings. With the advent of urbanization and technological advancement, there has been a high amount of depletion rate of the environment in terms of pollution, climate change, inadequate natural resources. This chapter brings in a distinct focus on environmental noise and its impact on humans. Noise is an unwanted sound characterized by intensity, frequency, periodicity and duration. Environmental noise pollution has become widespread in the form of industrial noise, traffic noise, to name a few. Chronic noise can be placed at parallels with chronic psychological stress and can affect general health and well-being. Further, noise pollution has also been seen to lead to medical, psychological and social issues. To minimize the spread of community transmission of the disease, several countries including India underwent periods of lockdowns and everyone was confined to their homes. The pandemic with its chaos and unpredictability also brought a drastic change in the environment as man-made activities were at its lowest during the quarantine/lockdown periods. This chapter aims to highlight these changes concerning decreased environmental noise. Further, using the lockdown activities as baseline, we propose a positive psychology perspective and principles

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of mindfulness that can bring about the pro-environmental behaviour during this crucial period.

Keywords Noise pollution · COVID-19 · Lockdown · Mindfulness

1 Introduction

The past year, that is 2020, has seen tremendous changes all over the world as it faced a new challenge in the form of a global health crisis. While the world has come across several major pandemics in the past two decades that includes H1N1, the Ebola virus and Zika fever, the coronavirus disease (COVID-19) has so far been the most widespread and has had large-scale impacts. The COVID-19 is a form of respiratory disease caused due to the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and spreads through close human contact (via respiratory droplets). The disease typically exhibits flu-like symptoms such as fever, dry cough, fatigue and an upper respiratory tract infection, but with increasing severity it also can invade into the gastrointestinal, cardiovascular, nervous systems and ultimately the immune system of the body. As a result, individuals with comorbidities such as asthma, diabetes and high blood pressure are considered vulnerable due to their compromised natural immunity. This makes the virus highly unpredictable and dangerous.

The number of death toll as of December 2020 has crossed the 1.6 million mark with more than 70 million people affected worldwide [10]. While the first isolated cases of the novel virus can be traced down to the city of Wuhan, China, the spread of the disease was unmanageable due to the lack of proper resources and precautionary measures for almost 30% of the nations. This led the World Health Organization only a small span of around 70 days to declare the epidemic into a pandemic with a global-level crisis that spread in over 200 countries. Over time, major hotspots of the disease included countries like United States of America, Europe, Russia and India, to name a few. The worldwide precautionary measures remained the same and included simple tasks like wearing a mask, washing hands regularly, maintaining a safe distance between two individuals, and in case any symptoms persisted to isolate from others. The measures however did not reach all the masses and the transmission continued to grow. Despite the issue being a global issue, the effort to contain and prevent the spread to the community, efforts were taken at a local level. Nations imposed periods of social lockdown that forced individuals to stay at home with the only venture outside in case of emergencies or for necessities like groceries and medicines. The aim of such an imposition among many countries was three-fold: (1) prevention of high infection rate at a certain time point, (2) containing community-wide infection and (3) providing better healthcare to those infected with limited resources.

Even though the lockdown aimed to contain the virus spread, it impacted several other domains of the world negatively. *Economy Depletion* – the global economy has entered a recession worse than the 2009 downturn based on reports from the International Monetary Fund (IMF); 81 nations across the world are seeking support from emergency funding program as financial aid from the IMF [7]. Depending on the duration of lockdown, a loss of about 10–31% of the estimated GDP for the year 2020–2021 is analysed for the Indian economy.

Isolation and restricted socialization were other factors that had a negative impact. Not only was the COVID-19 pandemic a novel scenario but the resultant imposition of lockdown created a situation which no one was prepped for. It required individuals and families to be separated and most usual activities prohibited. Any form of change causes individuals to feel anxious and unsafe and social support acts as pillars during these uncertain times. Further, individuals who were at risk or infected were quarantined and kept in isolation. *Social isolation* acted as a catalyst to an increased amount of stress and emotional disorders because of boredom, frustration, loneliness, lack of supplies and poor communication. Post the quarantine, isolation and poor mental health outcomes continued due to the societal misinformation. Individuals were victims of discrimination and marginalization. A range of maladaptive behaviours were adopted due to the health crisis such as excessive hand washing, avoiding enclosed and public spaces and reduced direct contact. For people with an already existing mental health condition, isolation presented with exacerbation of the problems. Many people in the vulnerable group also rely on support groups, which were interrupted due to the restrictions [45]. The global health crisis by default led to increase in a biomedical waste generation. For sample collection of suspected COVID-19 patients, diagnosis and treatment along with disinfecting the area, huge amounts of biomedical waste were generated. For instance, 206 m tonnes of medical waste was generated as per day in Dhaka, the capital city of Bangladesh, because of COVID-19. Similarly, in Ahmedabad, India, medical waste increased from 550–600 kg/day to 1000 kg/day (as cited in [35]).

Some positive impacts that were seen were in the form of an increase in personal and family time. Human beings have been so busy to conquer the world and have fast-paced lives, which care for self and family gets side-lined. While lockdown left several individuals isolated from family and stranded at various part of the world, individuals who remained at home were given an opportunity of an unplanned vacation. The lockdown was a period for individuals to reflect on what is important for them. Individuals spent more time with family members, engaging in family mealtimes, enjoying homemade cooking, sharing the household chores equally, or playing board games and engaging in bonding time. In the aspect of self, individuals actively engaged in times for hobbies, actively experiments via cooking cared for pets and house plants, rekindled old friendships. Use of technology had a major boost during the past year. The global pandemic led to advancement in technology with the usage of digital technology for pandemic preparedness and response. Digital technology was used for contact tracing of infections, maintaining records and tracking period for quarantine and self-isolation during infection. Applications were used for screening for infection amongst the masses. Further, providing medical supplies, clinical management, on a digital platform reduced the amount of surface contact. Other medical management also adapted the digital media in the form of telemedicine and tele-psychotherapy for people in need of medical emergencies [46]. Digital media was also on demand in terms of virtual platforms for socialization. Individuals embraced conference calls and video calls with friends and families as a means of communication to their loved ones. OTT platforms took a major boost in usage to counter the effects of boredom amongst individuals and providing a source of entertainment. Companies also adapted to the digital platforms and the option of work from home to keep the companies functional, as well as maintain the performance and productivity levels.

An unexpected but precedented effect of the pandemic was on the improvement of the environment. As global economic activities like industries, transportation, entertainment companies shut down, many countries including the USA, Canada, India, Italy and Germany had notable changes in their environment. The containment strategies had a dramatic impact on aviation sector as well with a 96% drop in air travel. Consumption of fossil fuels, use of coal-based power generators and emission of nitric oxide (N_2O) and carbon monoxide (CO) were the effects of the lockdown resulting in a drastic drop in the emission of greenhouse gases and an overall improvement in air quality; similarly, on the ground level, reduction in domestic, chemical and industrial wastes that are usually dumped into water bodies. For instance, the river Ganga and Yamuna reached a significant level of purity with the absence of waste disposal during days when India was on lockdown. The Grand Canal of Italy also turned clear and many aquatic species reappeared. Water pollution also reduced in the beach areas of Bangladesh, Malaysia, Thailand, Maldives and Indonesia [35]. Along with the aviation sector, a drastic impact was seen in tourism as well. Not only did local administrations banned public gatherings, but tourists spots like beaches, mountains, islands were also shut for visitors leading to a drop in carbon footprint. The ecological imbalance due to carbon footprint, dumping of waste and impaired natural beauty was on its way to revive back to their former glory.

Horton and Horton [15, 16] rightly hypothesized that a large-scale catastrophe is needed to unite the globe toward a change. The pandemic has become that catastrophe that can have staggering effects but also has the scope for positive and impactful changes toward the betterment of the entire ecosystem.

This chapter firstly discusses foundational theories regarding the mechanism of viral interaction with humans and the environment and psychology of behaviour. It further introduces environmental conditions with a distinct focus on noise pollution. The lockdown and the pandemic have made a major lifestyle transition, which is discussed based on the discipline of positive psychology. Lastly, the chapter highlights small insights and changes in everyday routines that can help restore and sustain a better environment along with blockades that might prevent sustainable actions.

2 Interactional Pattern Between Humans and the Environment

To have a deeper understanding of this web of linkages, three major themes help us in organizing the pattern. They are firstly environmental determinism, that is the determining effect of nature over the society. Over the historic events from the Roman emperors to geographer like Ellsworth Huntington believed that common determinants such as moderate seasonal changes, availability of adequate water, natural vegetation and topography are ideal for human flourishing. This view was criticized due to its generalized nature and unclear methodology. This gave way to a more bidirectional view of the relationship. The second theme corresponds to cultural determinism that understands humans place in nature based on cultural contexts. Needs concerning one's social life, personal space, choice of lifestyle, neighbourhood context and various other experiences are different from one culture to another. Another factor that is dependent on culture is the norms, rules, strategies and policies. For example, while in an urban living the individuals prefer to live in anonymity, indifference to others and exposure to various types of stress, while others feel solidarity in the neighbourhood, and community is a sign of security and togetherness. Culture also plays a role in values and attitudes. While collective cultures belief in sharing of resources to those in need, individualistic societies have the idea to prioritize own self-interests over others even the environment. This aspect of interaction points towards a need for solutions that are in line with the culture of the target population.

The final theme and the one which we shall focus on in detail is the human-environment interaction, which is concerned with the emphasis of human actions on the ecosystem. Over the years, environmentalists have understood that human-environment relationships influence each other, as well as depend on each other for their survival and maintenance. The effects human behaviours have had on the environment have been detrimental in terms of over-use and exploitation of the silent giver, that is the nature. They have tried to exhibit control and power over the natural environment. Humans have influenced the environment via urbanization, unplanned constructions and the industrialization that aimed at boosting economy and employment but had far facing long-term consequences to the ecosystem. Environment pollution can be in the form of air, water, soil or noise pollution that is created based on improper disposal of garbage, industrial and chemical waste, use of pesticides and insecticides, use of equipment that emit a large number of greenhouse gases in the form of carbon monoxide, nitrogen dioxide etc. Due to the bi-directional nature of these interactions, the increase in pollution levels is hazardous to physiological health and indirectly affects psychological health as well. Breathing in toxic substances from the air, using contaminated water for drinking and cooking can have detrimental effects. The advent of urbanization has led to a major stressor to humans and the environment in the form of overcrowding as well. The presence of crowding makes individuals feel uncomfortable, challenges a sense of privacy and is perceived as a loss of control over social situations. Further, with the growing population, there is a requirement for space. This requirement is limited causing individuals to stay in compact spaces in form of housing resulting in overcrowding. A major intrusion in the form of crowding is with the concept of personal space and privacy. Absence of these has a negative toll on mental health increasing the quotient of global distress.

While pollution, overcrowding industrialization are caused by human activities predominantly, natural disasters are the consequence of these disturbances. Nature's fury, floods, drought, earthquake, cyclones, tsunamis etc. are large-scale environmental consequences that cannot be predicted. The timing, nature, the amount of destruction are all unpredictable and once suffered have been known to cause traumatic experiences to their survivors. They are beyond control, but humans can be active to take necessary precautions and preventive measures to curb the after-effects of these disasters. The consequences of these problems have not only been on individual and community levels but have had a much larger impact globally. These maladaptive behaviours have led to factors like global warming and climate change. That entire planet's temperature is rising with the heat melting glaciers, shifting precipitation rates and patterns and endangering the wildlife as well. It calls for urgent attention and needs to adapt to environmentally friendly behaviour for a less-polluted and healthier environment for all of us.

The environment also influences humans. It brings about changes in lifestyles and attitudes. Such as whether people rely on agriculture or hunting, or corporate-based jobs highly depends on the natural environment of a particular region. Further, human emotions and perceptions also vary based on the environment. The initial abundance of resources and ever-giving mother nature have influenced us with a false perception leading to exploitation. Similarly, facing an earthquake or floods can be traumatic causing emotions of fear, worry, lack of control etc.

3 Interaction Between Virus-Human-Environment

Man-made environmental practices have made pandemics more likely. The assumption that we humans are victims of nature can be false, it is likely the other way around. The author of the 2017 book *Pandemic* Sonia Shah argues that about how a microbe that existed for ages suddenly can turn into a pandemic-causing pathogen. Shah (2017) studied several virus outbreaks ranging from cholera to Ebola and reports human activities to have a huge but under-recognized role to play in the transmission. Our understanding of how microbes, especially viruses, interact with each other comes from studies regarding natural environments, especially the marine and atmosphere.

Microbiology experiments indicate that viruses in suspension tend to aggregate or accumulate based on different mediums such as changes in pH, salt concentration, natural organic matter etc. This association with a particular matter makes the microbe more resistant to disinfectants and increases the chance of their survival. For example, when the SARS virus encounters aerosol droplets in the air, the survival rate of the virus is for 72 h [8]. Gerba and Betancourt [11] through experimentation conclude that virus aggregation-disaggregation is a complex process and generalization of viral behaviour with the environment is difficult, while the interaction in laboratories after manipulation remains different. Studies have also indicated that viruses not only can transfer genetic material from one organism to another but also between ecosystems. They infer that viruses can infect and replicate in an unrelated environment and show support to the COVID-19 virus reach worldwide through this means of transmission. Further, if we consider the air quality around the world, the industrial and vehicular pollution has made it difficult to breathe during normal circumstances. The viral aggregation with these air pollutants directs us to the interactional patterns.

The United Nations Environment Programme (UNEP) team have been working on scientific facts about the coronavirus. While the origin and the transmission pathway of the virus are unknown, they stated some important factors that show us the interaction of COVID-19 with the environment and how human activity is also linked with the emergence of these global disasters. They are as follows:

1. The risk of potential pathogens arises from the interaction of humans or livestock with wildlife. For many zoonoses (an infectious disease caused by pathogens that have jumped from animals to a human), livestock acts as the mediating agent between wildlife and human infections.
2. The hosts of these zoonoses usually emerge with changes in the environment because of activities like land use or climate change. For example, bat-associated viruses emerged due to loss of bat habitat from deforestation and agricultural expansion. Bats are night pollinators and eat insects and play an important part in the ecosystem.
3. Man-made environmental changes reduce biodiversity, resulting in new environmental conditions that favour pathogens and hosts. Hence, human health and development are dependent on ecosystem integrity.
4. Ecosystem integrity helps in supporting the diversity of species, thereby regulating spillover, amplification, or domination of a particular pathogen on humans.

It is important to understand that the evidence point that epidemics and disease outbreaks will become more frequent with the depletion of the environment and climate change. Nature is in crisis due to habitat loss, toxic pollutants, global warming, and this pandemic act as an alarm to address these issues and save the earth, save humanity.

3.1 Psychology of Behaviour

A behaviour in simpler terms is an interaction between individual characteristics and the characteristics of the environment in which the act occurs. While the major criticism of behavioural psychology is the mechanistic nature of behaviours, two major theories form the base of any learned behaviours. The pioneering work of

Pavlov and Skinner describes behaviours to be based on conditioning principles and rewards/reinforcements are the driving forces. The second pioneering work is regarding modelling behaviours as proposed by Bandura. Individuals model others and hence learn appropriate/problem behaviours. For example, a child observes his/her mother have a system of garbage disposal by dividing it into biodegradable and nonbiodegradable and models the same behaviour. Further, when the mother praises him/her for it, the behaviour gets reinforced and is maintained.

The environmental factors play a major influencing role to these behaviours as well. All aspects of the outer world that can be observed and perceived affect individual behaviour. Further, the social environment, that is friends, family, the cultural factors, that is norms, rules and laws of the immediate environment also influence these behaviours. While we have discussed that human activities have influenced the emergence of diseases over the years, these factors can be seen to have developed using behavioural psychology Moser [26]. For example, our schools do not emphasize enough about environmental integrity during the developing years for children to model these behaviours. Further, governmental policies to protect the wildlife or the environment are not strictly implemented and have loopholes, which humans can escape from. Based on operant conditioning principles, humans also focus on rewards, which are short term instead of thinking about long-term poor consequences. For examples, plastic bags are convenient to carry and dispose of after use, which acts as a short-term reward, but the inability to think of nonbiodegradable nature of plastic is a long-term consequence. Aarts and Dijksterhuis [1] proposed a script-based approach where the consistent pairing of environmental cues and behaviour followed with short-term rewards leading to the formation of behavioural scripts, which initially are goal-directed and later become automatized. These are known as habitual behaviours. Studies have indicated that habits lead to a bias in information processing about alternative behaviours. Hence, it is resistant to change. For example, consider a man driving his car to work for every day for 2 years. He is given the opportunity of carpooling, but that information is not perceived properly due to the habit and results in biased decision-making [1]. Invariably, the environment and human beings are interconnected, and the more humans act towards exploiting it, the worse is the reaction the ecosystem provides.

4 Noise Pollution: Its Effect and Aftermath of Lockdown

With the advent of modern living environments, some environmental noise is present 24/7 in the form of cars, trains, planes, ventilators and thermostats, the sound of music playing on speakers or neighbours fighting. This is perceived as annoying, irritating or unpleasant. World Health Organization (WHO) considers noise pollution as the third most hazardous form after air and water pollution. Globally, around 360 million people are prone to hearing loss due to noise pollution [40]. It is characterized by intensity (e.g. decibel), frequency (e.g. pitch), periodicity (continuous or intermittent) and duration (acute or chronic). Rapid and unplanned urbanization has led to a high level of road traffic noise with residential and school building at proximity to the urban roadways [2]. Other forms of noise pollution are construction and industrial activities like building of flyovers and bridges, generators and compressors to accommodate more traffic can be proven noisy. Amplified music at parties and other social gatherings and household activities like mixer grinder, washing machine also contribute to the ever-present noise that leads to annoyance. The multitude of adverse effects that noise pollution crates are as follows:

- **Disturbance in physical health:** Hearing is a skill, which has survival value. The sensory systems are wired to detect a threat and act on it. Presence of unwanted loud noise not only results in annoyance but can result in damage to our eardrums. Further, it also reduces the sensitivity of sound that our ears are tuned to pick unconsciously to regulate our body. Further, excessive noise pollution due to working in construction sites or heavy machinery industries is also known to have caused increased levels of blood pressure, cardiovascular diseases. The mechanism is that the intensity of loud noise increases the heart rate, vasoconstriction causing cardiovascular problems. Exposure to high-intensity noise is also known to have raised levels of adrenaline and noradrenaline. The endocrine responds to high intensity in the form of recognizing a threat or a stressor and acting in response to them in a 'fight' or 'flight' mechanism [42].
- **Disturbance in communication:** High decibel noise can act as a barrier for individuals to communicate freely, leading to comprehension difficulties, important information being missed out and misunderstandings in relationships. For example, when two colleagues are speaking to each other in a construction site with an active power driller in the background, the conversation will get lost with loud noise.
- **Effect on wildlife:** Since wildlife is more dependent on sound than humans as a means of communication and survival, noise pollution is a greater harm for wildlife. Disturbances at the home level where pets get disturbed by honking or bursting crackers result in behavioural disturbances, and aggression is one of the common examples. At a nature level, animals tend to have hearing impairments, in turn, become easy prey and decrease in the species population. Some animals who are dependent on mating calls to reproduce and sound waves to migrate also get affected to the unwanted noise. This results in dwindling of populations and risks of endangerment and extinction.
- **Disturbance in mental health:** There is empirical evidence for a mind-body relationship. Studies indicate that noise can lead to irritation and strain in one's mental health as a by-product or independent reactions as well. A model suggested by Passchier-Vermeer (1993) explains that dealing with noise is not a passive process. The person continuously adjusts their behaviour in noisy conditions. Factors that further influence this adjustment are the appraisal of the noise and coping abilities. Community-based studies indicate that individuals exposed to high levels of noise reported of chronic headaches, 'feeling tense and edgy' in high noise areas. Subjective responses to noise also indicate perceptions such as

noise is intrusive into personal privacy, fear and anger that it is harmful, interference with concentration levels and task performances. Sleep disturbances in the form of regular traffic noise or aircraft noises or loud music from a house party is another concern. Chronic sleep disturbances cause mood changes, decrements in productivity and long-term effects on health and well-being that includes physical distress. Night-time noise is also reported to have its rippling effect for the following 24 h [12]. Noise is not reported to be independent of psychiatric illness. But it does act as a diathesis to an individual already under mental strain in the form of work pressure or other vulnerabilities in family and personal life leading to depressive and anxiety disorders. Noise annoyance is aversive in nature and the associated reactions also affect the social behaviours in forms of aggression and withdrawal reactions. Subtle behavioural changes like closing the house windows, non-participation in loud crowds in a party or avoiding the use of balconies or huge decisions like shifting house or jobs are also seen [42, 43].

- Children are a particular group that is vulnerable to the effects of excessive noise as they are still developing physically and cognitively. Research evidence-based on children in preschools and primary levels indicate changes in central processing and language comprehension and attention & concentration levels. Behavioural changes were reported in children exposed to high intensity and high-frequency sounds. They were hyperactive in nature with high levels of catecholamines compared to the controls. Physical impairments are seen with raised blood pressure levels in children as well [42]. A biological model that explains the relationship between noise and stress suggests that noise acts as a trigger to stress response activating amygdala and cortisol for a signal of impending nature. With the advent of noise pollution, the hyperactive amygdala and high levels of subsequent cortisol release are a sign of increased stress. This is further implicated to disorders of the cardiovascular system, stroke, sleep, cognitive dysfunction like learning, memory, problem-solving, behavioural disturbances like aggression and annoyance and motivation Stansfeld [42, 43].

Studies indicate that the majority level of noise exposure is through road vehicular traffic (Khan et al. 2018) [2]. However, the imposed lockdown in various parts of the world due to the COVID-19 pandemic showed drastic effects on the reduction of environmental noise levels. The lockdown involved a halt in all forms of transportation. The large number of noise levels that accounted for airport traffic, roadway traffic, working industries along with other public places like shopping malls, movie halls were shut down. Further, as preventive measures, schools were asked to shut as well, reducing the footfall that came out of the houses. National Geographic termed a coin 'Global quieting' to describe the phenomenon of a hushed planet as an unintended consequence of lockdowns all over the world. In Germany, with the restriction on travel, noise pollution due to air travel has been reduced by over 90%, car traffic has slashed more than 50% [as cited in BBC Future article [40]]. A study based on Dublin, Ireland, indicated that noise levels reduced for every monitoring station posted across the city due to the lockdown. [2]. 50% reduction in the form of air quality and average noise levels were also seen in India during the lockdown phases. Just as natural events like earthquake causes movement of the Earth's crust, accumulated noise from moving vehicles, industries and other background noise also get detected in form of seismic movements. Belgium-based researcher Thomas Lecocq reported that human-based seismic noise fell by about one-third based on banning of all non-essential travel. He further reports that this drop may account to an increase in the sensitivity of detection of small earthquakes and blasts, ocean waves and volcanic activity. Similar reports were seen across other several cities in the United States and Mexico [21]. Lecocq et al [21] suggests that the reduction on earth's vibration levels can help identify a minor earthquake happened in Japan with the help of instruments in offices of the UK. COVID-19 lockdown and the low number of economic activities has led to a reduction in noise pollution around the globe.

Scientific data currently also suggests that the reduction in human-related noise could mean that birds are getting quieter. It can be hypothesized that the birds do not have to compete with the background sonic noise levels and hence they are softer in their calls. The evidence to back his hypothesis suggests that birds sing more quietly during the early weekends when there is less road traffic [9]. It is also suggested that birds are more willing to sing under these relatively quiet conditions. These songs are perceived also better by us humans, which can be attributed to the quiet. These benefits in wildlife extend beyond communication. Reduced noise levels are associated with higher reproductive success, less migration, and ultimately lower mortality rates. Coincidently, the mating season coincided with the lockdown, increasing the mating rate as the lower intensity of mating calls may travel for long-distance due to the *global quieting*. Residents from Kolkata, India, reported that birds seemed to have reclaimed their lost territory as they spotted birds descending to main roads and they could hear bird calls more prominently and started to appreciate nature at its glory [3]. Noise pollution affects not only birds many creatures ranging from frogs to fish, mammals and snakes. Another major habitat that has benefitted from the reduction in noise pollution is the ocean. Early research after the 9/11 attack found that less shipping traffic seemed to make whales calmer. The source of noise pollution ranges from shipping to wind farms and powerful blasts from seismic air guns to test oil and gas deposits under the ocean bed. Marine biologists speculate a healthier marine life and wildlife; however, data to back up these hypotheses would only be available once underwater noise recorders are available on land post the pandemic-related restrictions.

5 Positive Psychology: Basic Concepts

Martin Seligman is his Presidential Address in the year 1999 proposed that psychology while flourished in curing mental illness as a field largely neglected two of its three mission, that is helping all people to be more productive and increase well-being, and identify and nurture high talent. Based on this, he inaugurated a new discipline of psychology, which favoured a shift towards positive psychology. Positive psychology aims at positive human functioning and flourishing on multiple levels that include biological, personal, relational, institutional, cultural and global dimensions of life [38].

One of the basic models in positive psychology is the PERMA model, which had five core elements of psychological well-being and happiness. The elements are as follows:

- **P- Positive Emotion**

- The most obvious concept is the emotion of happiness that can relate to positive emotions. It involves more than just smiling and laughing. It involves changes in attitudes, a change which is more optimistic and constructive. It also involves some amount of intellectual stimulation and creativity. For example, a child completes a jigsaw puzzle that requires a lot of concentration. On completion, the child might feel ecstatic but also satisfaction with a work well done. This combination is what foster psychological well-being.
- **E – Engagement**
- People find enjoyment in different things like dancing, playing a sport, travelling, but there are only a few things in which people can be truly engaged. These activities flood the body with positive neurotransmitters and help find calm, focus and joy. It always feels like time flew away. This measures the concept of 'flow', that is the blissful engagement in a task. This helps in fostering intelligence, skills and emotional capabilities.
- **R – Relationships**
- We are social beings and need to engage in healthy relationships. Isolation can be difficult. The love, intimacy and emotional interaction that a relationship garners help in building self-esteem and resilience. It is crucial to have positive relationships with co-workers, friends and family to experience overall joy.
- **M – Meaning**
- 'What is the purpose of my life on this planet?' The one question that shakes the roots of our existence. Material possessions like wealth, popularity is short-lived to the pathway of happiness. Concepts like religion and spirituality provide individuals with meaningful practices such as mindfulness. Along with that, volunteering for the greater cause, creative expressions, work and family satisfaction act as the true gateway to happiness.
- **A – Accomplishments**

- Having realistic goals and aspirations provide us with a sense of accomplishment. Not just that, only by putting effort towards the goals gives a sense of satisfaction that cultivates well-being. Having accomplishments pushes oneself to thrive and flourish.

To summarize, certain strategies that promote the PERMA model and foster subjective well-being are as follows:

- **Positive Emotions** – Pleasure, optimistic, happiness and satisfaction
- **Engagement** – Flow, Hobbies, Fulfilling tasks

- **Relationship**s – Love, intimacy, friendships and social network, emotional interactions
- **Meaning** – Purpose of life
- **Accomplishments** – Realistic goals, ambitions and aspirations

5.1 Effects of Lockdown: A Positive Psychology Perspective

The COVID-19 pandemic and the resulting social lockdown was one of the major life transitions throughout the globe. While several factors like the rise in infection rates, the uncertainty of the transmission and treatment modalities, the high mortality rate did increase the amount of mental strain and worry among individuals worldwide. The surveys conducted in various countries reported a dip in the mood at the beginning of the pandemic. However, UK-based researchers concluded that it was the disease and not the lockdown that created the mood disturbances. Almost 50% of individuals were found to be happy based on Google searches and mood tracker apps. Dr Foa from Cambridge University cited that with the government's support in employment and finance, lockdown may be one of the effective ways to maintain psychological welfare. The assumption that social interactions are an important part of well-being was also questioned during the lockdown period. Separation from friends and families, workplaces and public life led to a shift in perspective of well-being. The individualistic version of happiness fostered during these times. Individuals adopted the principles of positive psychology that happiness is a conscious effort and directed inwards towards personal care. The attitude 'Self as an independent work-in-progress' fostered the level of productivity. Research participants also explored strategies like adjusting their attitudes and values, practising mindfulness and being responsible citizens. The same participants also reported a collective sense of well-being. To maintain the economy, remote work became a huge part of the lockdown. The millions of employees that would travel daily, the hundreds of companies using thermostats, paper, electricity reduced tremendously causing a decrease in the amount of air and noise pollution. This likely would have the same potential impact on nature as planting an entire forest of almost 100 million trees. Further, the customized home-based office and a healthy work routine with no worries about traffic or late hours increased the performance and productivity of these employees [6]. Data from a study based in New Zealand indicates that individuals staying in quiet locations, that is those away from busy roads and industries when compared to those in a noisy location like near airports or mills had a higher score in the rating of the quality of life, with a special reference to health-related quality of life [39]. The reduction in noise pollution would have had similar effects on an individual's quality of life and well-being during the current lockdown period. A pan-India online survey across 23 states revealed that individuals were also happy about the decrease in the background noise levels at the workplace, during the commute to places. Some respondents were astonished by sounds of chirping birds and nature being bright and green that they would ignore on a normal hectic routine. Some also reported to feel joy about the Earth healing and reclaim itself, and those spiritually inclined reported this unlikely event as nature's way to heal itself and bring justice [5].

Individuals also gained accomplishments during this lockdown period. They invested their time in exploring nature, engaging in hobbies, indulging in an unpaid vacation filled with relaxation. While the recommended guidelines for the lockdown included that individuals should engage in exercising once a day, few of them took to taking walks as a step outside the house [6]. They reported nature to be reviving to its glory. Bright green leaves, blooming flowers, fresh air and almost complete silence. This itself acted as a source of relaxation for them. Social media posts also showed accomplishments like gardening. The time to care for the house plants, water them regularly, as well as to try growing home-grown produce gave individuals a chance to prevent the risk of contact and inculcate a hobby.

While the lockdown was a sudden imposition on everyone and filled with uncertainties, individuals adapted to the crisis. With the adaption, some also flourished in terms of engaging in pro-environment behaviours and turn improved their subjective well-being as well.

5.2 Actions to Be Implemented: Using Lockdown as a Baseline

Pro-environmental behaviour includes both actions that are meant to protect the environment from problems, as well as promote a healthy flourishing environment, A major concept of behavioural change is motivation. The level of motivation determines the driving force of actions to reach a particular goal. Our goal for a pro-environment largely depends on the motivation of one and all. A subtheory of motivation proposed by Ryan and Deci [36] referred as Organismic Integration Theory also suggests that extrinsic motivation and intrinsic motivation lie on a continuum with a motivation at one end and intrinsic motivation on the other. This theory suggests that even if new behaviours learnt are with an extrinsic motivation for reward or praise, it can be internalized and automatized based on practice, interest and satisfaction. The process of behavioural change can also be postulated based on the transtheoretical model of change, which is divided into five cyclic stages, which are as follows:

- **Precontemplation:** In this stage, individuals are not concerned about any behavioural change or action. They are unaware of the problem behaviours and the negative costs of maladaptive behaviour.
- **Contemplation:** Individuals become aware that behaviours are causing more harm than gain and consider the costs and benefits of the new behaviour. It is a period of ambivalence and some never move forward from this point.
- **Preparedness**: In this stage, rigorous planning takes place regarding the course of action for appropriate behaviours to be conducted in the immediate future.

- **Action:** The actual behavioural change is practised in this stage. The action is further evaluated for modification or to attempt other alternatives.
- **Maintenance:** Individuals actively work on preventing relapse. The practice and support increase confidence in continuing with adaptive actions.

Along with personal motivation, a similar concept that influences pro-environment behaviour is human values involved. Steg et al. [44] proposed four types of values, which seem important about pro-environment actions. They are as follows:

- **Biospheric:** As the name suggests, the values focus on larger perspective, that is nature and ecosystem. For example, using carpool for commute.
- **Altruistic:** The betterment of others and the society are associated with these values. For example, volunteering at old-age homes and retirement centres.
- **Egoistic:** These values are associated with one's selfish needs such as materialistic possessions, fame, wealth etc. For example, using old engines to save a large investment in the company.
- **Hedonic:** These values aim to increase one's level of pleasure and comfort. For example, switching on air-conditioners during the summer season.

Based on the definitions it seems that the Biospheric and Altruistic values target pro-environment actions and profit the nature. The other two values are self-directed causing more harm to the environment. It can be postulated that ignorance and lack of promoting proper values have led to environmental damage [5]. Based on these theoretical understandings let us focus on some of the strategies that can promote sustainable behaviours and benefit individuals, as well as the community.

- **Based on information and awareness:** Two forms of information are provided to promote behaviour change. First, individuals have the provision of information based on environmental problems like brochures regarding the causes of noise pollution and its drastic effects on mental and physical health. The second form of information is action based, which involves strategies one can implement to alleviate the problem. For example: Using protective gear in construction sites or installing silencers in machinery are suggested. Studies indicate that if this information is conveyed via 'models', that is those on a higher stature they are more effective, providing prompts and feedback about appropriate actions are also strategies that provide awareness about one's actions and direct behavioural change.
- **Based on rewards and punishers:** As suggested by the motivation continuum, small incentives can garner one's interest to continue doing a particular action. Therefore, programs that provide a monetary incentive on returning products for recycling or companies and schools having bonuses and extra credit as a 'Green initiative' can foster positive environmental behaviours. Some natural incentives also come into play in the form of pride and satisfaction. For example, a man cycles on his commute to work has a two-fold reward, that is has engaged in physical activity, as well as engaging in eco-friendly behaviour.

- Natural as well as extrinsic punishers can also be used for behaviour change. While the biggest example of natural punisher would currently be the impact of COVID-19 pandemic, certain small-scale punishers would be chronic headaches due to loud machinery. Penalty for improper waste disposal or for loud music can act as negative consequences to reduce these problematic behaviours.
- **Based on persuasive technology:** Bloom in technology is one of the causes of a large amount of radio waves. However, we can take advantage of digital media to propagate pro-environmental actions. Adopting various modalities like audio, video, virtual realities, games, we can promote change. They act as anonymous tools that can persuade sustainable actions. Using smart systems like 'Alexa' or 'Siri' to remind certain daily behaviours such as watering plants, or to switch off unused appliances can be helpful [4].
- **Based on policymaking:** Policymaking can promote sustainable actions based on three key variables: a) individual policy outcomes that are associated with negative consequences for problem behaviour, b) collective policy outcomes implementation of strategies reduces collective problems and c) outcomes distribution, which is fair and equally distributed to the masses [13].

5.3 Pro-environment Strategies Based on the PERMA Model

A positive psychology perspective for pro-environmental behaviours using Seligman's PERMA model Pascha [32] is a proposal that needs empirical evidence and validation. The model is proposed keeping both the positive and negative effects the pandemic and lockdown have had on humans and the environment and this interaction of virus-humans-environment acts as a baseline. The model focuses on simple strategies that can be adopted by individuals to turn the negativistic outlook of the global crisis into a particular meaning based on the discipline of positive psychology.

Based on Fig. 1, positive emotions as simple put includes being happy, having pleasure and fun, as well as being optimistic. An outlook that fosters positive thinking about behaviours that are environment friendly, having the vigour to make these habits enjoyable, engaging in these activities to have the sense of satisfaction, and pride of doing good for nature. It acts as a eudemonic motive for change. Active engagement would be effortful. It requires behavioural changes in daily activities. Using eco-friendly products, avoid the use of plastic and promote the use of sustainable resources such as jute or cloth-based goods, decrease carbon footprint by using green transport like cycling or carpool, promote local home-grown produce, proper disposal of waste into biodegradable and non-biodegradable are few of the behaviours that would tremendously affect the environment. Further, using the time to engage with the environment itself fosters a sense of joy within the self. Mindfulness is one strategy that can help achieve it.

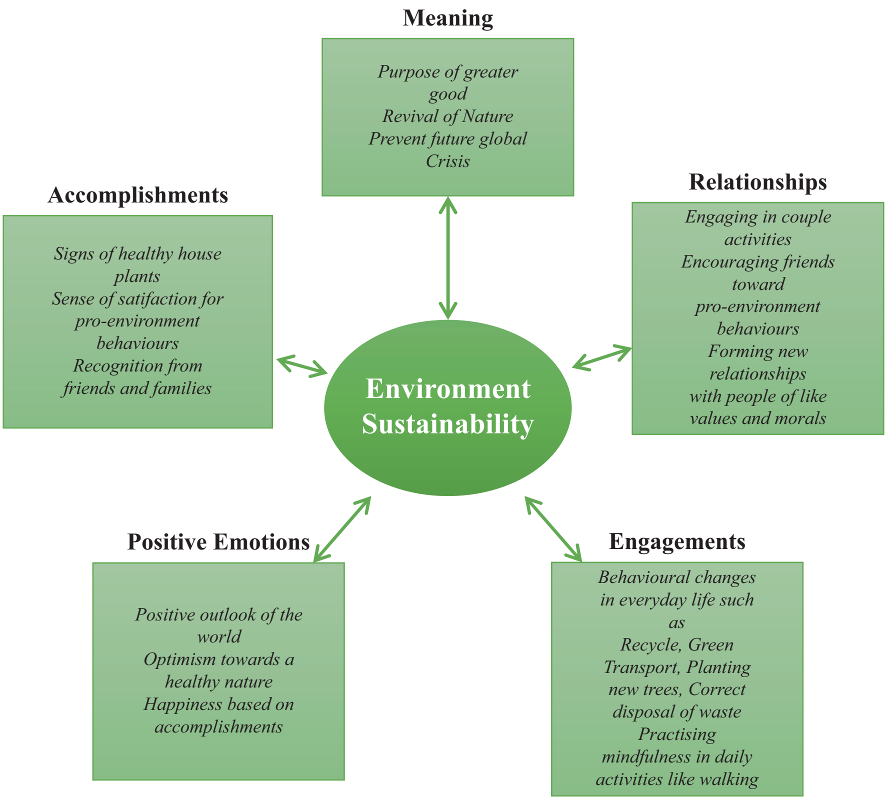

Fig. 1 Figure depicting pro-environmental strategies based on PERMA model

Mindfulness has its roots in Buddhist philosophies, which are characterized by non-judgemental acceptance with a focus on the present moment. One of the most adopted applications of mindfulness is in stress reduction as proposed by the pioneering work of Kabat-Zinn [18] on Mindfulness-Based Stress Reduction therapies. Everyone works on an 'autopilot' mode with a fixed routine from the moment they wake up till they sleep with limited time to acknowledge their activities, their feelings and their behavioural responses. Practising mindfulness of daily activities will aim to increase awareness of the otherwise unconscious routines that guides behaviour. Strategies such as doing 'mindful activities' like eating, gardening, walking, which gives you a heightened sense of awareness and opportunities to appreciate the minor details of everyday behaviour.

Hede [14] conceptualized a model that theorizes the dynamics of mindfulness aimed at reducing the reactivity to aircraft noise. He distinguishes mindfulness into two types: an active form (meta-mindfulness) and a passive form (supra-mindfulness). While meta-mindfulness can target dysfunctional thoughts and facilitate cognitive defusion, supra-mindfulness helps individual to disengage from their own identity with negative thoughts. In the case of aircraft noise, meta-mindfulness targets the negative reactivity of noise exacerbating health effects of an individual and supra-mindfulness helps disengage these thoughts from a sense of identity, which is over consumed by aircraft noise activity. Some mindfulness practices also suggest using the background noise as the medium for the mindfulness. The practice involves deliberate awareness of the environmental sounds and focuses on their characteristics with a non-judgemental acceptance. The practice involves one to notice the source, the intensity, the various sounds some sharp some subtle and experience them in the present moment. The wise poet Rumi spoke to the human tendency toward irritation and distraction in his poem 'Only Breath: There is a way between voice and presence where information flows. In disciplined silence it opens. With wandering talk it closes'. The practice of 'sound meditation' is the idea to target these annoying everyday noises and could detach from it and not react to them. While some believe that these activities are tedious and based on behavioural theories, we would prefer short-term rewards, but engaging them with a calm and focus can result in experiences of *flow*.

We as social beings respond to the relationship's aspect of the model deeply. The isolation, social withdrawal, the precautionary distance the past year has had a deep impact on mental health. Fostering new relationships with individuals who have similar values and morale about the ecosystem at large will not only promote sustainable actions but also increase social support amongst us. Further, the model also proposes that behavioural change can occur in others based on social learning theory as proposed by Bandura. Modelling pro-environmental behaviours for other family members, children, friends not only garners praise but also acts as a motivation and learning experience for them to adopt the same. Activities like planting new trees or recycling objects as DIY (Do-It-Yourself) projects can be activities that individuals can indulge in with their partners and children as a family activity. This would be a pro-environmental behaviour, as well as increase emotional bonding between the family members. Further, if an individual is acting pro-environmentally, a possibility of *spillover-effect* is present. Small task spills over and leads to a bigger commitment step by step. For example, a small step like not using boomboxes during parties can spill over to bigger commitments like carpooling to commute or other pro-environmental behaviours. The component of meaning in PERMA model can be regarding a purpose for the greater good, the purpose of bringing change to the world or as simple as a preventive measure from a future global crisis like COVID-19 to happen again. These meanings highlight an individual's sense of a cause, which is beyond wealth and social esteem. The final element of the model accomplishments highlights the sense of joy and satisfaction that comes when engaging in positive behaviour. The signs of bright green house plants, the smell of fresh air, the inner peace following mindfulness practices are some examples of the achievements. All these factors and discussion points are targeted to have bi-directional influence, that is foster a sustainable environment, as well as increase the psychological well-being of individuals practising them.

The model also works towards a technology-driven pro-environmental behaviours. The engagements and accomplishments for enhancing well-being also extend to the environment. For example, the use of noise cancelling headphones as a protective gear from the large industrial base or use of the same headphones as a hearing device for self while keeping the noise out of the hearing from others in the environment. Further, plants are natural buffers to noise Lusk [22]. Home grown plants and produce can not only be effective economically and decorative but also screen the urban noise from the roadside traffic or heavy machinery. The mere use of the environmental noise as a daily mindfulness activity empowers one to screen out the desirable and undesirable noises and deal effectively to combat the undesirable noise.

The proposed model is a conceptual design based on the available literature. Validation by the researches is needed before predicting the effectiveness of the model and implementation to the larger masses. However, it is important to understand that every single individual's actions are important but for the expanse of damage, global level action plans are needed for the healthy maintenance of the ecosystem.

6 Blockages to a Sustainable Environment

While we have discussed that one's level of motivation and values system is crucial for any form of behavioural change, certain factors act as barriers despite a favourable ecological norm and attitude. If an individual with attitudes favouring the environment engages in an activity that causes harm or disagrees with the attitude, a tension arises, which is known as cognitive dissonance. This tension is relieved if either I change my behaviour or change my belief following the wrong behaviour. Humans have been evolutionarily trained to value instant gratification over delayed. Hence, it is more likely that they change the belief system following the behaviour that provides instant gratification [33]. This results in habit formation of anti-environmental activities, as well as provides relief from cognitive dissonance.

A great faction of the world is assumed to have a lack of knowledge about the environment and it's deterioation. Some also consider this as not affecting them but others. Any behaviour that is opposite of the attitude results in cognitive dissonance and feelings of guilt. Individuals who have an emotion-focused coping hide these unwanted feelings of guilt and shame by the faulty coping mechanism in the form of denial of the problem or feign lack of awareness about it. Individuals also quickly adapt to an external locus of control. They may resort to putting blame on their neighbours, other cities or even foreign countries for the problem. On a community level, the hindrance arises due to urbanizations. The high standards of living has resulted in unplanned construction of buildings, roadways, bridges for ease dwelling and commute the space provided by deforestation of trees. Further, there is not available space in between high risers for planting new foliage. Another blockage to sustainable action comes with the limited availability of resources in low-middle income countries. While the idea of sustainable environment points towards installing solar plates or such alternative methods to renewable resources, these countries fail to have adequate resources for their basic needs like food, water, sanitation, proper education, health facilities. In highly compact areas like slums and rural areas, lack of basic resources target them to increase exposure to pathogens and are at high risk for contamination. This was seen in the slums of Dharavi in Mumbai, India, where more than half of Mumbai slum dwellers had COVID-19 as reported by BBC reports in July 2020. Protecting the environment and engaging in pro-environmental behaviours is a far-fetched thought for these individuals who fight for their lives every day [44]. It sometimes is rightly quoted 'To him that hath, more shall be given; and from him that had not, the little that he hath shall be taken away'. (Percy B Shelly, 1840)

7 Conclusion and Future Scope

The COVID-19 pandemic and subsequent unique situation of lockdown and social distancing have given rise to several issues including fall in the economy, a possible recession around the globe, a threat to survival and uncertainty about infection, isolation and discrimination from loved ones and strangers as well. It has challenged the global mental and physical health. However, an unexpected effect of the same was the betterment of the ecosystem. Nature started to revive itself. While the WHO reports noise pollution can affect over 360 million individuals every year, the restriction of activities and confinement to indoors has led to a tremendous decrease in the noise levels around the globe. With more than 50% decrease in the levels of noise pollution, individuals faced a sense of calm in nature despite the worry about the global crisis. Individuals recognized the sound of bird calls, they reported a calm from the annoyance due to traffic noise or the background noise of chatter, machinery etc. The reduction in noise pollution seemed befitting to the wildlife as well with significant results seen in birds, whales, fishes and snakes. On a larger impact, it reduced the level of vibrations at the Earth's crust that can help seismologist with sensitive data. Undoubtedly, these changes have resulted in an improvement in the quality of life of individuals who adopted positive outlooks during the lockdown in search of happiness and personal growth. The crisis has been a wake-up call regarding the chaos human activities had on the environment and an urgent need to maintain the environment's improvement by engaging in sustainable actions. The scope of sustainable development is needed at an individual level, a community level, a cultural level and most importantly at the national level. Small acts like reduced waste generation or carpooling to implementing large-scale policies such as compulsory protective gear for industry workers or construction of sound noise protected buildings is the demand of current time. There is an unprecedented need to focus on this growth and form policies that are pro-environment and target the bi-directional nature of human-environment interactions. The pandemic has acted as a catalyst to bring about environmental awareness. Let us as part of this Mother Nature promote sustainable actions that not only befit us but the global health, wealth and peace.

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Green Technologies for Handling and Management of Biomedical Waste

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Abstract Biomedical waste management is of great significance because biomedical waste can adversely affect health, causing serious implications for people who come into contact with it. Segregation, storage, and safe disposal of biomedical waste is the key to effective management of it in a workplace. The health of a community or a society is estimated according to the health status of each individual residing in it. Various factors affect community health. One of the major factors associated with it is waste generated by health care institutions. Waste generated by health care activities includes a broad range of materials, from used needles and syringes to soiled dressings, body parts, diagnostic samples, blood, chemicals, pharmaceuticals, and radioactive materials. The biomedical waste that is generated may carry risks of various infections and diseases (typhoid, cholera, human immunodeficiency virus, hepatitis, etc.) in the long run. Therefore, use of proper storage, disposal, and treatment techniques are needed in order to minimize waste generation by hospitals. Effective management procedures should be employed for proper prevention and control of these types of waste. Various methods are used for treatment of biomedical waste, such as chemical methods, mechanical processes, biological processes, and irradiation processes. Green technologies—such as water treatment, solid waste treatment, and air purification—also play major roles in management of biomedical waste. Governments need to make arrangements for dedicated trash bins

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to be provided for disposal of hazardous waste. Appropriate management strategies are crucial for preservation of an equilibrium between the environment and mankind.

Keywords Health · Biomedical waste · Infectious ailments · Green technologies · Hospitals

1 Introduction

As a consequence of developments in automation, infrastructure, health care services, computer technology, and the cultivation sector in the past 20 years, people have become more fulfilled, comfortable, and secure, but the environment has been badly affected by enormous growth in environmental contamination due to our high waste generation rate. Waste material that consists of infectious, hazardous, or radioactive agents released during production processes, diagnostic processes, and treatment of medical conditions is defined as biomedical waste (BMW) [17]

Health care is essential for achievement of a good quality of life. Generation of waste from medical-related activities causes major concern regarding contamination of the environment [50]. Inappropriate control of waste generation from medical facilities has led to adverse impacts on the health of communities, workers, and the environment [41]. On average, each day, an abundance of contagious and hazardous waste is produced in medical care facilities and hospitals all over the world [35]. Untreated biomedical waste and its release into water are polluting the environment and threatening the health of human beings. Earlier studies estimated that approximately half of the entire world's residents are affected by improper biomedical waste management (BMWM), which causes increased prevalence rates of various diseases [42, 57].

Advancements in science and technology are expanding further to improve the future of mankind. As a result of automation, treatment of various illnesses and ailments that were previously hard to detect and diagnose is now possible, but this evolution in the health care field has also had major adverse effects and drawbacks [53]. It has been shown that in many countries across the world, the problem of biomedical waste is managed very poorly. According to information from the World Health Organization (WHO), of the total amount of waste generated by health-care activities, about 85% is general, non-hazardous waste. The remaining 15% is considered hazardous material that may be infectious, toxic or radioactive.

Numerous communicable diseases can be spread by waste generated by hospitals. Examples are hepatitis B, hepatitis C, human immunodeficiency virus (HIV), and tetanus. As a result of unprofessional mismanagement, the rate of the spread of these diseases has increased rapidly over the past few decades. Improper sterilization of needles, intravenous (IV) sets, glass bottles, and syringes is also one of the main reasons for the extensive spread of contamination [39]. In addition to these causes, insects, flies, and rodents play roles in transmission of these diseases. The places where this waste is most likely to be found are domestic areas, and hospital and industrial waste is often found on the outskirts of cities. While searching for useful waste among the junk, rag pickers and slum residents are more vulnerable to infections. Serious harm may be caused to their health by direct exposure to toxic chemicals and other substances [13].

Basically, developing countries are at high risk of health hazards due to improper handling procedures and mismanagement of remunerative and technological processes ([6]). Developed countries are at lower risk than developing countries because they have better infrastructure and techniques for disposal of waste. Thus, appropriate systems for management of biomedical waste must be introduced urgently throughout all countries to lessen the associated environmental hazards [23]. In many countries, waste management is not addressed in legislation; however, it is the responsibly of every human to help preserve the environment. The majority of health-related problems are due to inappropriate disposal of waste, which can be decreased by providing proper education to the population [27].

2 Biomedical Waste Sources

The origination of biomedical waste is variable in many aspects, both qualitative and as quantitative, depending upon various health care factors. Analysis has shown that the quantity of biomedical waste produced by the health sector is expanding yearly [32]. Types of waste that contribute to biomedical waste are pathological waste, pharmacological waste, sharp material waste, and cytotoxic waste. They differ in their composition, their sources, and the percentages they contribute to the total waste that is produced. Health care waste contributes about 80% of all biomedical waste, pathological waste and pharmacological waste contribute 15% and 3%, respectively, and sharp material waste and cytotoxic waste each contribute less than 1%. As shown in Table 1 [1, 27], biomedical sources of waste can be classified into major and minor sources.

3 Biomedical Waste Classification

3.1 Hazardous Biomedical Waste

This class can be subdivided into two types.

Contagious Hazardous Biomedical Waste: This waste has the ability to spread or cause infections in humans and animals. According to the WHO, "It is suspected that pathogens (bacteria, fungi, viruses or parasites) are present in contagious waste in enough amounts and concentrations to cause infectious disease in hosts" [20]. Only 10% of the total biomedical waste that is produced is contagious hazardous waste. The types of infectious biomedical waste that are generated are laboratory waste; pathological waste; dressings and swabs contaminated with blood, pus, or other fluids; sharp materials; and plastics [22].

Table 1 Major and minor sources of biomedical waste

Sources
Major sources
Hospitals, nursing homes, and dispensaries
Primary health centers
Medical colleges
Animal research facilities
Blood banks and mortuaries
Production units
Biotechnological institutions
Minor sources
Physician's and dentists' clinics
Animal housing facilities
Blood donation clinics
Vaccination centers
Funeral services
Institutions for disabled persons

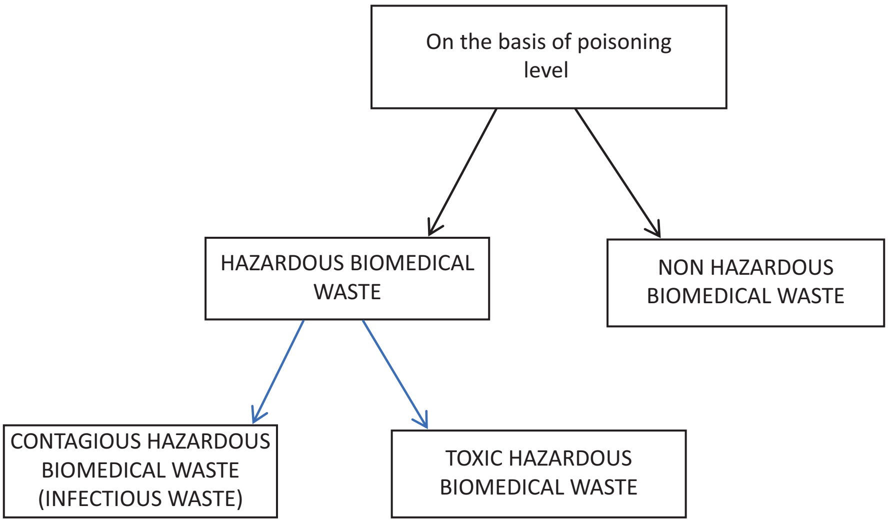


Fig. 1 Classification of biomedical waste

Toxic Hazardous Biomedical Waste: This waste can increase toxicity levels in various ways, such as contamination by radionuclides from radioactive waste, cancer therapies, or medical equipment. Other types of toxic biomedical waste are pharmaceutical waste, chemical waste, genotoxic waste, and cytotoxic waste.

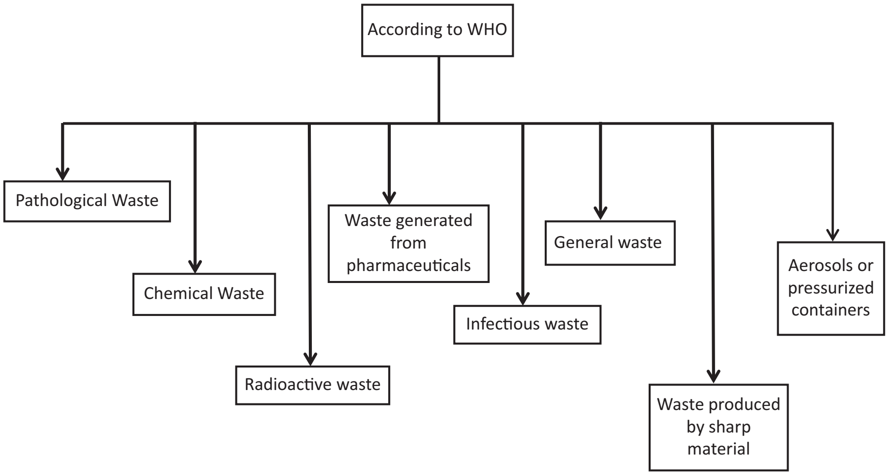


Fig. 2 World Health Organization classification of nonhazardous biomedical waste

3.2 Nonhazardous Biomedical Waste

This waste causes no direct harm to animals or humans. It is neither infectious nor toxic. It includes leftover food, fruit and vegetable peel, and paper cartons. About 85% of the total biomedical waste that is generated is nonhazardous biomedical waste [60]. According to the WHO, nonhazardous biomedical waste is classified into various categories on the basis of its sources, as shown in Fig. 2.

4 Elucidation of Nonhazardous Biomedical Waste Types

4.1 Pathological Waste

This is waste that originates mainly from the health care sector (e.g., from hospitals and dispensaries) in various ways and includes contaminated equipment, human excreta, body organs, and other tissue. It can be pathogenic, thus leading to various diseases [9].

4.2 Chemical Waste

This is waste that is generated from poisonous chemicals during forensic research, disinfection processes, cleaning, and detection of disease. The chemicals that release this type of waste can be in different forms. Some examples are listed in Table 2.

Table 2 Examples of chemical waste

Form of waste	Examples
Heavy metals waste	Mercury and cadmium waste
Liquid waste	Organic and inorganic solvents, formaldehyde, and photographic chemicals
Gaseous waste	Anesthetic, ethylene oxide, oxygen, and compressed air

Table 3 World Health Organization classification of different types of radioactive waste

Type of waste
Waste that has leaked from sealed sources
Generated radionuclides
Low-level liquid waste
Radioactive chemical residues
Radioimmunoassay materials
Gas released through fuming cabinets
Solid waste (including swabs, syringes, and glass equipment)
Materials used in decontamination of radioactive spills
Excreta from patients treated with radionuclides

4.3 Radioactive Waste

This is the most dangerous type of waste, as it is produced by an atomic reactor or an atomic power plant (nuclear energy). It includes substances such as unused radiotherapy liquids, contaminated glass equipment from laboratories, blotting paper, and radionuclides (e.g., α emitters, β emitters, and γ emitters) used during radiotherapy for cancer etc. [30]. The WHO classifies radioactive waste into different classes, as shown in Table 3.

4.4 General Waste

This is waste that is generated from household products, such as polythene, damaged packaging, leftover food, vegetable and fruit peel, carrier bags, food containers, and broken crockery or glasses. It generally causes no direct harm to human beings.

4.5 Waste Originating from Pharmaceuticals

This type of waste consists of expired medicinal stocks; leftover medicines; adulterated pharmaceutical products; unused vaccines; waste discharged by the pharmaceutical industry; and discarded cartons, gloves, masks, bottles, syringes, etc. It causes major harm to the environment.

4.6 Infectious Waste

This waste is produced during any medical procedure, such as treatment or testing processes (for diagnostic purposes). As its name indicates, this type of waste has adverse impacts on humans because it causes infections. Examples are contaminated needles, blood products, bandages, and dressings.

4.7 Sharp Material Waste

This refers to sharp-edged materials from any equipment employed for medical purposes, such as needles, syringes, blades, glass Pasteur pipettes, glass slides, and cover slips. [61]. This category is further divided into four subcategories:

1. Sharp materials that are either contaminated or uncontaminated with other materials
2. Radioactive sharp materials
3. Sharp materials that are infected with chemotherapy drugs
4. Laboratory glass sharp materials

4.8 Aerosols and Pressurized Containers

This type of waste includes aerosols and compressed gas cylinders or cartridges. Sometimes, it can cause fatalities if it explodes.

5 Case Study of Biomedical Waste Management at KVG Hospital

A case study performed in India showed that the awareness and implementation of biomedical waste management by health care professionals is suboptimal [18].

In India, people involved in the health sector have inadequate knowledge and practices related to waste management. Hence, this case study was performed to appraise the awareness, knowledge, and execution of various methods for disposal of biomedical waste by health care workers at KVG Medical College and Hospital in Sullia (Karnataka, India) [49].

5.1 Subjects and Methods

Transverse data collection was performed among health care workers employed at KVG Medical College. The survey was started in May 2012 and ended in August 2012. There were 391 workers who were who are working in three slots in alternating sequences at KVG Medical College. By use of a suitable sampling method, 120 health care workers were chosen by a selection panel. They consisted of four clusters of 30 respondents: physicians, nurses, laboratory technicians, and class IV waste handlers.

This cross-sectional study, conducted among 30 health care workers and was done using an opinion poll. The data for the study were gathered in different departments, the emergency department, and laboratories by the main analyst, in the presence of the superintendent of high-ranking members of the medical staff [58]. In addition to being selected by the sampling method, these individuals had to have had more than 6 months of work experience in the organization. The individuals were free to leave the study if they were not interested in participating. Consent and behavioral clearance of each participant was received from the organization. SPSS software version 17 was used for data compilation and analysis. Percentages and proportions were used to elucidate the results [55].

5.2 Outcomes

The study disclosed poor knowledge about management of biomedical waste among all four groups (physicians, nurses, laboratory technicians, and class IV waste handlers) [38] (Table 4).

Only 47% of doctors had sufficient knowledge about color coding of biomedical waste. Only a few respondents had knowledge about the total generation of hospital waste and knew that the percentage of infectious waste was less than 25%. The fact that isolation of biomedical waste had to be done at the first step of waste generation was known by 98% of doctors and 70% of nurses [26]. With the exception of class IV waste managers, all groups had adequate information about the hazards of transmission of disease through biomedical waste management, as shown in Table 5.

Ninety percent of the study volunteers considered it their responsibility to properly dispose of biomedical waste generated by various medical procedures. Participation of the private sector, along with the government sector, in conventional

Table 4 Knowledge about biomedical waste (BMW) among health care workers

Accurate knowledge	Physicians; *N* = 30 n (%)	Nurses; *N* = 30 n (%)	Laboratory technicians; *N* = 30 n (%)	Class IV waste handlers; *N* = 30 n (%)
Regulation of BMW management in India	3 (10.00)	1 (3.33)	0 (0.00)	0 (0.00)
Waste sorting using a color-coding method	14 (46.67)	13 (43.33)	9 (30.00)	5 (16.67)
Proportion of infectious waste out of all waste produced by the hospital	8 (26.67)	6 (20.00)	4 (13.33)	4 (13.33)
Initial separation of BMW	28 (98.33)	21 (70.00)	14 (46.67)	11 (36.33)
Decontamination of BMW prior to disposal	30 (100.00)	25 (83.33)	27 (90.00)	8 (26.67)
Diseases communicated by BMW	29 (96.67)	22 (73.33)	21 (70.00)	3 (10.00)
Techniques for individual safety from BMW-associated risks	25 (83.33)	20 (66.67)	22 (73.33)	13 (43.33)
Storage of BMW	11 (36.67)	21 (70.00)	6 (20.00)	9 (30.00)
Management and final disposal of BMW	14 (46.67)	7 (23.33)	5 (16.67)	0 (0.00)
Recognition of danger signs	23 (76.67)	9 (30.00)	19 (63.33)	7 (23.33)

Table 5 Viewpoints about biomedical waste (BMW) among health care workers

Viewpoint	Doctors; *N* = 30 n (%)	Nurses; *N* = 30 n (%)	Laboratory technicians; *N* = 30 n (%)	Class IV waste handlers; *N* = 30 n (%)
Appropriate separation and disposal of BMW considered part of respondent's duty	28 (98.33)	30 (100.00)	27 (90.00)	23 (76.67)
Agreement with contribution of private sector to BMW disposal	27 (90.00)	21 (70.00)	19 (63.33)	21 (70.00)
Agreement with requirement for strict application of BMW management rules	28 (98.33)	29 (96.67)	23 (76.67)	20 (66.67)
Agreement with necessity for training in BMW management	23 (76.67)	18 (60.00)	19 (63.33)	27 (90.00)

waste disposal was referred to by two-thirds of participants. Laboratory technicians and class IV waste handlers were not trained for management of biomedical waste, although it is essential to train all workers properly [3, 53]. Separation of biomedical waste according to color coding was done by 36% of doctors, 43% of nurses, 30% of laboratory technicians, and 13% of class IV waste handlers. Fewer than two-thirds of all groups took care to dispose of sharp objects in puncture-proof bags or containers. Only 30% of class IV waste handlers used personal protective devices [59].

5.3 Discussion

Inadequate knowledge was reported in all groups, mainly in class IV biomedical waste handlers. There was lack of awareness of the government's biomedical waste management rules for appropriate disposal of waste. The main reasons were insufficient training and leniency in execution of biomedical waste management policies. Across all groups, knowledge about color coding of biomedical waste was very limited [46]. Mathur et al. undertook a similar study in Lucknow (Uttar Pradesh, India), in which 91%, 92%, 85%, and 27% of clinicians, nurses, laboratory technicians, and hygiene staff, respectively, had sufficient knowledge of biomedical waste management. Knowledge about proper decontamination of waste prior to its final disposal was limited among all groups. Only 10% of class IV waste handlers were aware of the risks involved in disposal of biomedical waste. Comparable findings were documented in other studies performed by Mathur et al., Bansal et al., and Pandit et al., who reported awareness rates of 27%, 43%, and 43%, respectively.

It was noted that knowledge about color coding and the hazards involved in management of biomedical waste was very deficient, specifically among class IV waste handlers; therefore, there is a necessity to provide teaching programs and reskilling workshops and seminars on biomedical waste management [12]. It is essential to supply suitable protective gear—such as masks, gloves, and protective footwear—to class IV waste handlers and to instruct them on how to use it. They also need to be instructed to immediately contact their managers in the event of any damage or injury. Record keeping and management of needle stick injuries are inadequate; every department must record the names and emloyee code/ numbers of the affected individuals in all instances of needle stick injuries [29]. Every medical care provider must be immunized against tetanus and hepatitis B. The cost of immunization should be subsidized by the employer.

6 Requirements for Biomedical Waste Management

The main reasons for the great necessity of biomedical waste management in hospitals are:

1. The risk of infection transmission to waste handlers, waste scavengers outside the hospital, and citizens living near the hospital site
2. Injuries associated with sharp needles and syringes, which can lead to infections in hospital workers and waste handlers
3. Illicit repackaging and resale of disposable equipment without proper cleaning and disinfection
4. Air, water, and soil pollution due to the presence of discarded or incompletely combusted ashes, etc.
5. Illicit repackaging and resale of unused materials

6. In-hospital transmission of infection to patients because of inadequate anti-infection practices and substandard waste management [8]

6.1 Benefits of Appropriate Biomedical Waste Management

Appropriate biomedical waste management has the following benefits:

1. Reductions in in-hospital infections and contamination
2. Maintenance of high living standards
3. Robustness of supporting infrastructure [16]
4. Reduced mortality and disease rates
5. Reduced costs associated with infections
6. Reduced total costs with a suitable waste disposal system [39]
7. Reduced occupational health risks [3]

Management of biomedical waste involves the steps detailed below.

1. **Biomedical Waste Production:** As earlier discussed in this chapter, generation of biomedical waste by health care organizations is classified into diverse types, depending upon the degree of toxicity. Sources of waste are classified as either major or minor on the basis of their waste output. The first step in productive waste management starts with doctors (or other experts) and cleaning staff. In addition to these workers, nurses, engineers, chemists, inspectors, etc. are involved [24]. Waste is generated by individual departments and put in specific places where it goes through rectification processes. In the case of liquid waste, it should be sorted on the basis of its contents (chemicals, testing agents, etc.) and then—if appropriate—channeled into drains [37].
2. **Biomedical Waste Separation:** Separation of waste is important for efficient functioning of waste management [31]. Conventional separation of waste depends upon which techniques will be used for treatment of the waste. Appropriate, transportation, and disposal systems are necessary. As a result, waste volumes are decreased [59].
3. **Biomedical Waste Collection:** A crucial step in management of biomedical waste is its storage and agglomeration. The place selected for collection of waste must be situated near the location of waste production and its processing for disposal. Thus, a suitable exterior site needs to be selected, where different large containers (appropriately labeled) can be used for storage purposes. These containers must have a suitable holding capacity and must be made of an appropriate material that does not react with the waste material content. For sharp substances, the containers must be puncture-proof to reduce the risk of needle stick injuries. At big hospitals, the waste should not be stored for more than 8–10 h, and at nursing homes, the storage period should not exceed 24 h. The containers should be properly labeled with this cautionary instruction [60]. Furthermore, proper procedures should be followed for cleaning of the storage site to prevent the

spread of infection. Surfactants and disinfectants can be used for sterilization [11].

4. **Biomedical Waste Transportation:** The main objective of biomedical waste management is uncomplicated and protected transportation of waste to reduce threats related to contamination and disease [28]. This duty should be assigned to highly trained personnel who have good experience in transportation of biomedical waste [36]. The vehicles used for transportation must be leakproof, with safe door opening and a combustion-proof interior [37]. Signage regarding hazards and precautions must be displayed on vehicles [20].
5. **Biomedical Waste Treatment and Disposal:** The procedures for treatment of biomedical waste are as follows:

    1. *Thermal processing:* The process of management of biomedical waste includes use of heat for disinfection purpose. This is subclassified into the following types:

        (a) Low-heat systems, using temperatures between 90° C and 180° C
        (b) High-heat systems

    2. *Mechanical processing:* Mechanical shear and stress forces are utilized to change waste material from one form into another to alter its characteristics. The two steps involved in this are as follows:

        (a) Shredding (e.g., of paper or plastic), which is preferred so the material can be utilized again
        (b) Compaction, which applies force to reduce the volume of the waste

    3. *Chemical processing:* Chemicals are used for disinfection purposes in processing of biomedical waste. Examples of the substances used in these processes are ozone, chlorine dioxide, and hydrogen peroxide.
    4. *Biological processing:* Enzymes are utilized for processing of biomedical waste. It is known that suitable biological degradation of components reduces the risk of infection from residue left on glass or plastic.
    5. *Irradiation processing:* Removal of radiation involves utilization of ionizing radiation or ultraviolet (UV) rays in specialized vacuum equipment for destruction of this type of waste [8, 44].

7 Technologies Used to Degrade Biomedical Waste

The following technologies are used to degrade biomedical waste:

1. **Moist Heat Sterilization:** This is a type of low-heat technology. An autoclave is equipment used to kill microbes or disinfect material, using the principle of moist heat sterilization [54]. In this process, steam comes into direct contact with the material to remove all types of contaminants. This technique is employed in treatment of biotechnological waste, microbiological waste, sharp objects used

in laboratory equipment, and infectious waste (including soft waste such as gauze bandages and surgical gowns) ([43]).

There are different types of autoclave:

(a) The vacuum type
(b) The gravity type
(c) Retort autoclave or Canning autoclace for sterlization

In the vacuum type of autoclave, a vacuum pump is used to remove air from the system, then steam is used to sterilize the contents for 30–60 min at 132° C. In the gravity type of autoclave, the air is displaced by steam, with the help of gravity, and the contents are sterilized at a pressure of 15 psi and a temperature of 121 °C for 60–90 min. These types of autoclave can hold large volumes of air at high pressure and high temperature.

2. **Microwave Treatment:** In this process, humid warmth and vapor are created by microwave action to treat contamination. It is mainly used to treat infectious waste. The main advantage is that it involves minimal emissions; however, one disadvantage is the risk of leakage of microwave energy [51].
3. **Incineration:** This is a process by which pathogens and other microbes are killed by use of high temperatures. However, various different types of toxins can be released in this process, such as dioxins and products of incomplete combustion [19]. Metals are not destroyed by this process, and this limitation causes serious medical concerns. Dioxins can be inadvertently generated by incineration of waste. Medical devices made of polyvinyl chloride (PVC) are the main sources of dioxin production. Other very toxic carcinogens can also be generated, which can be very harmful to the human immune and endocrine systems [48].

Method: This thermal process uses high temperatures to convert materials into inert forms, with release of gases. Three different types of incinerator are used in this form of biomedical waste management:

(a) Rotatory incinerators
(b) Multiple-hearth-type incinerators
(c) Controlled-type incinerators

Optimal levels of combustion are achieved by systems that include primary and secondary chambers.

Objective: Reduction of organic waste to inorganic waste and reduction of waste volume and weight.

Disadvantage: Incinerators involve large capital costs.

2. **Hydroclave Treatment:** A hydroclave is basically an autoclave. In it, the pressure is maintained at 35–36 psi and the temperature is kept at 132 °C for 20 min. The treatment involves a multistep process:

(a) Start up
(b) Heat up
(c) Sterilization
(d) Venting

(e) Dehydration
(f) Shredding

Advantages: This is a safe, closed-loop system, with minimal air emissions and chemical emissions [15].

3. **Landfilling:** This process is used in order to minimize the volume of waste that requires storage. This machinery used for it is designed in such way that the waste is treated inside the landfill environment. The substances resulting from this process that can be hazardous to humans [45] are:

   (a) Solids
   (b) Liquids
   (c) Gases

8 Applications

Proper management of waste disposal leads to creation of a workplace that is safe for workers, patients, and the environment [4]:

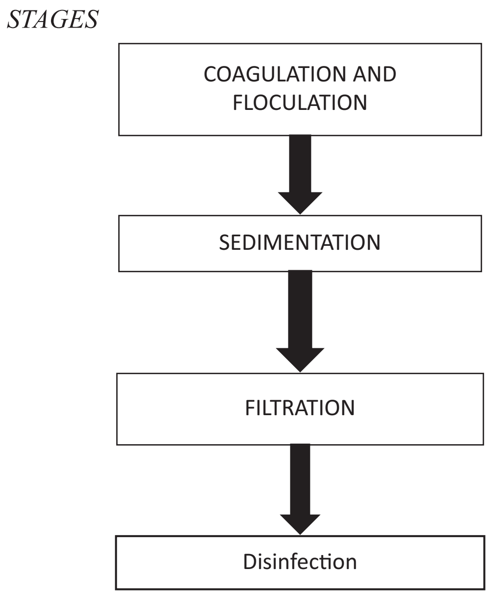
1. Proper waste management facilitates appropriately dispose of every form of waste.
2. Proper waste management creates economic benefits by growing the gross domestic product (GDP).
3. Jobs are created for workers in waste services and in the recycling and recovery sector.
4. Waste incineration (after segregation of recyclable materials) enables energy recovery.
5. Biomedical waste is segregated, contained, transported, and disposed of.
6. Polythene bags, gloves, and blood bags are incinerated in appropriately designed facilities to reduce the emissions of dioxins and furans that would occur if they were incinerated in the open air.
7. As per new rules, a barcoding system enables tracking and identification of rubbish bags and investigations for quality control and assurance.
8. Red- and blue-coded waste is sent to authorized recyclers for processing in order to decrease pollution and conserve resources.

9 Sustainable Green Technologies: An Innovative Strategy for Future Implementation

Water Treatment

One of the most necessary elements in life is water. Water pollution is one of the greatest problems confronting the biosphere. Liquid biomedical waste includes

Fig. 3 Steps involved in wastewater treatment



contaminants that lead to water pollution. These contaminants may be blood, body fluids, liquid residue after forensic research, excreta from patients, etc. [10]. Other undesirable substances include biological, chemical, and physical pollutants [2]. For safety and reduction of water shortage, it is important to treat water before it is used. Water treatment is a common method used to disinfect contaminated water [25], as shown in Fig. 3.

Sewage Treatment
This treatment is one of the advanced technologies that makes management of water resources sustainable. Extraction of solids, organic materials, and nutrients from wastewater generated by households and businesses is known as wastewater treatment. This technology has evolved over the centuries [21]. The main objective is to make effluent eco-friendly by removing contaminants from it.

Some factors that influence the design of wastewater treatment plants [62] are described in Fig. 4. Wastewater treatment includes the following objectives:

1. Removal of solids
2. Removal of pathogens
3. Extraction of organic materials
4. Biodegradation

Solid Waste Management
Developed countries and developing countries use different methods of waste management, which differ in terms of technologies and types of waste production. Schemes launched by governments manage waste materials on a large scale and use the best technology available [47]. The following six solutions are considered

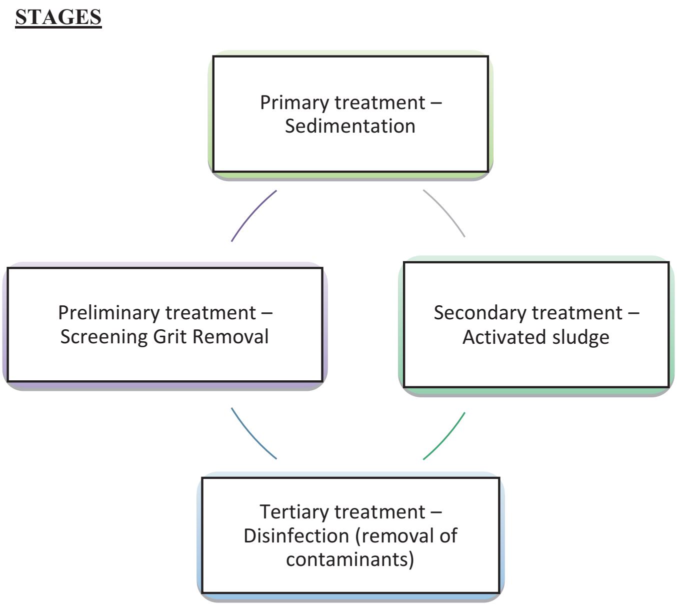


Fig. 4 Steps involved in sewage treatment

important and are specially recommended: reduction, reuse, recycling, recovery, repurposing, and landfilling. The landfilling approach is less favored because it takes more time to replace landfilled resources if one must start from scratch [14]; moreover, it requires large amounts of resources and also results in emissions of carbon dioxide and methane. There are a lot of differences between the old and new technologies that are applied in waste management; for example, old technology generates fertilizer, whereas new technology has led to development of aerobic digesters such as bioreactors ([7]).

Agricultural Technologies

Use of standard agricultural technologies is one of the reasons for disruption of the environment, causing atmospheric release of greenhouse gases (GHGs), and contamination of water. Green development technologies include drip irrigation, which decreases use of water, and use of natural pesticides instead of machinery-based cultivation in the farming sector. The following parameters are influential:

1. Cost effectiveness
2. Consumer preferences
3. Regulatory obligations
4. Public perception

To overcome water and soil pollution, green technologies are being applied to optimize practices used in crop planting and harvesting. Replace the chemicals used for fertilizing soil and for controlling pests, weeds [3]. Research institutes are conducting various investigations into eco-friendly practices aimed at decreasing atmospheric release of methane, replenishing soil, and replacing fossil fuels with fuels generated from plant biomass [34].

Air Purification

Air pollution is one of the major technical issues that need to be resolved. It is defined as emission of injurious chemicals and GHGs into the air. As result of air pollution, various diseases have spread rapidly among humans and animals. Air pollution is a result of human competition with nature to achieve development [33]. Harmful gases (SO_2, NO, CO, and other toxic gases) are released in huge volumes from industry and transport vehicles.

Green technologies that are now being actively applied in industry include air purification. In this process, released air is filtered to reduce its content of GHGs and other pollutants [5]. Along with this, lead-free fuel is now being used in vehicles such as buses, which is also contributing to reduction of air pollution. Fuel-efficient vehicles and hybrid electric cars are also being introduced for reduction of air pollution. These cars are expected to reduce the consumption of gasoline by 50% by the year 2030. These technologies are now being widely implemented in the urban sector [40].

10 Waste Management Initiative and Regulations in India

The following regulatory initiatives have been introduced in India for appropriate waste management:

1. Operation of laboratories, management of microbiological waste, and disposal of blood bags must adhere to WHO and National AIDS Control Organization (NACO) regulations.
2. Use of plastic bags, gloves, and blood bags is now prohibited.
3. Use of a barcoding system has been introduced for use on containers of biomedical waste that leave the premises for disposal.
4. Common biomedical waste treatment and disposal facilities (CBMWTFs) now provide services to health care operators for proper disposal of biomedical waste.
5. If any accident occurs during handling of biomedical waste, it is documented in a report by the appropriate authorities.
6. Biomedical waste disposal has to be regulated on a daily basis and its registration also simplified.
7. Implementation of rules is monitored/maintained by the Ministry of Environment, Forest and Climate Change.
8. District magistrates have the power to ensure maintenance of guidelines at the district level.
9. Every 6 months, reports on waste management must be submitted to the State Pollution Central Board (SPCB).

11 Conclusion

Biomedical waste is classified according to its source, its composition, and the issues involved in its management. Separation of different types of waste is an important step in the process, and the "3Rs" (***r***eduction, ***r***euse, and ***r***ecycling) must be done in a proper manner. Inventive, decisive, and progressive measures need to be taken to improve problems associated with waste disposal in the health care sector. New steps are necessary for compliance with new government regulations for waste management. To save our environment and ensure the health of society, we must take energetic action against this problem not only as health managers but also as part of society. For appropriate biomedical waste management, especially in hospitals, there is a great need to reduce risks associated with hazardous chemicals, drugs, and personal handling of waste at all levels. This type of management system includes proper separation, safe storage, and appropriate disposal to make it more effective. Proper biomedical waste management is also employed in handling of COVID-19-related biomedical waste; thus, it also helps to control the spread of that disease.

In the current scenario, we need to improve management of hospital waste by following proper processes for disposal of biomedical waste, including use of various green technology methods, which are eco-friendly, easy to apply, and less time consuming. The foremost challenge is to control and manage increasing volumes of biomedical waste and to implement regulations for disposal of biomedical waste by health care organizations. The security and safeguarding of all health care professionals and other waste-handling staff should be a major priority. It is the responsibility of both the public and the government to participate equally in proper disposal and management of biomedical waste in an appropriate and environmentally friendly manner.

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Patients' Health Surveillance Model Using IoT and 6G Technology

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Abstract To upgrade the healthcare infrastructure, it is now possible to collaborate Information and Communication Technology (ICT) and the medical field together. After the pandemic of Covid-19 worldwide, it has been more crucial to renovate a new dimension to make the healthcare system more predictable, controllable, and handy. This chapter focuses on a patients' health monitoring system model based on the advantages on IoT and 6G technology. It identifies a cluster of patients for whom a continuous surveillance over health is priority. About 30–35% of deaths occur each year because of the time delay in getting the right treatment or having obstacles and less facilities in the rural area. Lack of an even distribution of a sound treatment everywhere in the country is a big challenge. To overcome the geographical barriers and human intervention, we propose a wireless health monitoring model where treatment is possible from any location without thinking about physical distance or networking barriers. On one hand, Internet of Things (IoT) is making life easier in every sector including healthcare and disease management system. On the other hand, 6G technology is a newly known terminology in the field of wireless cellular communication. It can provide a sustainable healthcare system for the citizens and make wireless devices more viable to the community, even in the remote area. This chapter aims to combine the idea of these two utmost new technologies to provide a better health monitoring system for a sustainable future and also discusses healthcare system establishing challenges and possible solutions for a better health service and support. The major contribution we provide here is the deployment of two biggest technologies in the health sector to provide higher degree of automation, reduced operating costs, and fastest decision-making process.

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1 Introduction

An improved version of healthcare system is a crucial demand in order to reduce health risks worldwide. Healthcare defines a set of parameters followed by a society to maintain the fundamental needs of human being. The effectiveness of any healthcare system depends on the services it provides, the feasibilities and availability it may have, and the usability, acceptance, and reliability rate of the citizen. In spite of standing in the era of twenty-first century with all the modernized technological supports, the world has still faced the ferocity of Covid-19 pandemic in 2020. The spreading of the virus was fast evolving and elusive even before understating the biological properties of it. Less than 20% cases could lead to serious clinical conditions in young individuals and adults >60 years, who are identified as the most vulnerable group [32]. It is incurred that a situation similar to Covid-19 pandemic can arise again and question the existence of the mankind at stake. Since the beginning of the century, the world has faced many natural disasters, calamities, and, in this decade, the biggest pandemic. These fatal damages not only caused the death of thousands of people and health at stake but also collapsed financial and economic mobility. With all of the unprecedented behaviors, it can result in more damage even in countries with the best facilities in health system. To avoid these circumstances, a new thought, a reconstruction, is necessary in this field. During the period of quarantine in Covid-19 pandemic, there is a focus on paradigm shift in sustainable development for the green environment [1]. Utilization of the newest emerging technologies, stronger communication network, AI-driven data analytics, and smart devices can carry out improvements over the limiting factors and provide a developed healthcare system.

Also, most countries with lowest-middle-income economy and densest population can hardly deal with impulsive crisis cases. Countries like Bangladesh suffer from both shortage of hospital facilities in rural areas and geographic maldistribution of human resources in healthcare (HRH). In Bangladesh, there are 3.05 doctors and 1.07 nurses per ten thousand patients estimated by the Ministry of Health and Family Welfare (MoHFW) HRD in 2011. Maximum health workers, medical service providers, and doctors are concentrated in urban secondary and tertiary hospitals, whereas 70% of the population is remaining in the rural area [30]. As a result, basic healthcare support, elderly lifestyle disease patients, children's malnutrition, hygiene awareness, pregnant women's healthcare support get disrupted in the rural and remote areas. The preemptive issues include the unorganized healthcare infrastructure, weak administrative activities, fragile public service community and delivery, and overly capital-centric health services with outnumbered patients and less equipment. These scenarios regarding the public healthcare system can be mitigated by using modern science and technology. Thus, healthcare needs to be more preemptive, focused, collaborative, and supportive throughout the barriers. With the help of emerging technology, we already have been introduced to the smart healthcare system, which is based on the communication network and AI-driven machines. It has been initialized in many developed countries but not been yet applied or used widely in the developing and lower developing countries. Most of the death cases can be reduced by a robust response time and faster medical support, but most of the time we lack this because of mismanagement and insincerity toward working on the system. Most of the health workers are city or capital centered, whereas maximum patients cannot afford to come and have treatments in the city because of geographical hindrance or living in a remote area. It also complies more cost and hassle to the family of the patients and patients themselves to come over a long distance for a treatment and stay within a limited budget parallel to maintaining the health cost.

This chapter provides a conceptual model of establishing a healthcare framework which can enable a strong communication network between the hospital and the patients, home treatments services (HTS), Emergency Support (ES) for example, ambulance services, first aid providers, online consultations from the doctors or pathologists, etc. Our prioritized patients are adults >60 years with elderly and lifestyle diseases such as blood pressure, diabetics, asthma, pregnant women, patients with critical diseases such as cancer or kidney failure. This system model focuses on this group of patients so that they can have better health support without moving physically. However, this system model must be addressed to a strong wireless communication network which can be provided by 6G wireless communication network, and the surveillance of the patients' health logs can be obtained by using Internet of Things (IoT) devices. Our most primitive technological innovation is to surplus the basic advantages of both IoT and 6G technology in the healthcare monitoring system for sustainability in near future.

This chapter provides a perceptual model of patients' healthcare surveillance system by combining these newest technologies to ease the concepts of the manual healthcare system and break the geographical barriers. Despite having challenges to blend these technologies, a sustainable wireless healthcare surveillance model can be made for future use. It can ease and aggregated the process of collecting potential data from the users by the sensors, transferring data to cloud for archive storage hereafter retrieved by the medical teams. The data are analyzed and valuable information can be collected by the back-end users. The most crucial challenge in this stage is the confidentiality and security of the data provided by the patients. If the security is not ensured properly, confidential data can be interrupted and have security threats from intrusive third party. Therefore, security, secrecy, and privacy management are important features that need to be ensured by this model. Also, this chapter provides a feasibility study over how the communication network can reduce the cost and mobile devices can be a self-sufficient user end for the benefit of the patients even if they are staying in the rural area. By studying the general nature of the healthcare system, it has been incurred that heterogeneous amount of data are generated by sensors in IoT networks that need to be managed efficiently for further analysis and decision-making [3]. IoT has been keeping contributions in healthcare since several years and 6G is newly being introduced in this sector. 6G can bring a huge change over the scenario of healthcare system. Connecting objectives and components with promising determinants can bring together the biggest revolution in this field. The quality of life (QoL) can be improved by using 6G network features [4]. We primarily focus on the application scenario where IoT and 6G can be blended together to develop a novel approach for coherent health monitoring system. It provides a holistic manner over how sensitive patients can be treated with utmost facilities in remote areas using modern technologies.

This entire chapter is segmented into eight sections. Section 2 describes some of the related works in healthcare implementations. Section 3 presents a brief discussion over 6G technology in healthcare. Section 4 elaborates the illustration of hypothetical IoT healthcare services. Section 5 presents the methodology of the proposed model. Section 6 discusses the results expected from this model. Section 7 highlights some vulnerabilities and challenges regarding the model. Finally, Section 8 concludes the chapter and also discusses future scopes for improvements.

2 Related Works

To obtain a robust and successful healthcare system as well as avoid disastrous situations, the first priority for any medical professional is fast and rapid access to the healthcare database and information [26]. In the last 50 years, life prospects have led to a percentage increase of over 64, and by 2020, there will be more 60-year-olds than children under 5 [23]. This shows that aged population is increasing by each year. People aged from 55 to 59 years generally suffer from chronic lifestyle diseases. Several research studies have been done regarding the improvement of the healthcare sectors. Some of them are discussed in this section. In [24], a K-healthcare model is proposed which coordinates four corresponding layers, which are "sensing layer," "networking layer," "internet layer," and "application service layer." They have also discussed cloud IoT platform implementation over remote patient monitoring with critical issues. In recent years, many research and studies have been done for a healthcare support and innovation involving elderly patients in remote area. In [25], the authors have studied different healthcare systems based on various perspective and properties, such as disease management, various kinds of chronic and critical diseases, patients from different ages, etc. Then they have discussed and presented different IoT-based healthcare systems, some implemented with existing technologies such as networking, sensing, and data analysis. In [4], the authors have shown a different perspective on 6G technology-based smart healthcare system. They have proposed some future works and possibilities using 6G technology in health market sector. For example, in future using 6G technology, telesurgery can be enabled based on holographic communication. They presented some remarks on how 6G technology can provide a better lifestyle by enhancing quality of service (QoS), quality of experience (QoE) and quality of life (QoL) of patients. They addressed how pandemic and epidemiology crisis can be managed using 6G and how holographic communication can take part in the intelligent healthcare system. They also draw a business model where hospital can become health insurance mediator for patients and how to reduce cost over the business model. The authors in [33] present a survey on IoT-based healthcare system and their various applications such as monitoring kids, surgery handling, chronic disease management, and motion sensors. They have also studied the healthcare management of the IoT devices based on their battery life, network connectivity, and other parameters.

The researchers in [27] have surveyed on Cloud of Things (CoT) and the service provided by them in smart healthcare applications. They have also reviewed CoT issues, their platform, compatibilities, and energy efficiency-related issues in the healthcare applications. In [28], the authors present a health monitoring model which can be used in emergency services. They have used Intel GALILEO 2nd Generation development board which connects to a server for displaying collected data and integration among the data. They also discussed compatibility rate of IoT data in healthcare management system. They claim that this model helps to reduce risks in emergency scenarios and manages to collect, sense, and store and transfer data in real time. Another research work in [23] presents the study of future healthcare module using 6G technology. They have presented a study of wireless healthcare network and Internet-of-Big-Nano-Things for a sustainable healthcare solution in future. They have reviewed future parameters on how aged population can undergo a wireless healthcare support without being deprived of physical treatments.

3 Wireless Healthcare Service Using 6G Technology

6G technology will dominate the health sector in near future by providing an integrated smart heath service. It is an AI-driven communication technology [6] with some basic features that are discussed in this chapter. The fundamental requirements of 6G technology for healthcare system is high data rate, low latency, high capacity, high mobility rate, and wavelength of ≤300 μm [5]. It is expected that 6G technology will be backed up fully by satellite and will consume 3D architecture including space-time-frequency [4]. Thus, 6G will overcome the geographical barriers which are the major problems for most of the remote patients. Also, with the strong communication facilities between sensors and other devices, it can stream real-time data. 6G technology is an integrated schema that includes AI algorithms and edge technology. By blending these technologies, edge intelligence (EI) can be designed. Edge intelligence (EI) is edge computing with machine learning (ML), data mining (DM), and advanced networking capabilities that are associated with the domain of computational intelligence [2]. It is a distributed smart computer paradigm that can be implemented through 6G as a self-sufficient data processing, analyzing, and decision-making module.

6G communication technology requires 1THz frequency operation, 1Tbps data rate and 1000 km h mobility range, and wavelength of ≤300 μm [6]. These prominent and promising features of 6G enable a fast real-time operation, and user can have the full support from the medical system immediately. In the application of recent years' smart healthcare, it is shown that some aspects are needed to be considered to fulfill the reliability rate of the users. However, 6G technology illustrates an AI-based intelligent system which can be self-sufficient, self-compute, and self-aware based on any stochastic situation. As aforementioned, 6G will be an AI-integrated network so it will provide real-time communication which is an important aspect for modern healthcare. AI can provide high accuracy and performance in real-time communication which is a prerequisite for an intelligent healthcare system. Mostly 6G is considered to have deep learning algorithm (DL), which does not require data preprocessing. It can process data in real time. Deep reinforcement learning (DRL) is an AI algorithm which has been recently implied in health technology [4]. DRL includes advantages of both deep neural network (DNN) and reinforcement learning which can bring about the huge revolution if implemented in the 6G technology as well. 6G can also provide vital role in integrating communication medium, promising better reliability, Big data analytics, and pandemic and epidemic crisis management. Most importantly, the purpose of this chapter which is the distributing healthcare support by monitoring patients in real time can be fulfilled by using this technology. Remote or rural areas' geographical barriers, human resource in healthcare (HRH) crisis, can also be overcome by implementing this technology over the field of public health management.

With high modulating frequency and high mobility rate, it is also important to take account the security threats that can be raised using 6G technology. Physical layers include the raw data collected by the sensor devices from the user, data link layer, transport layer which directs to the cloud storage, and the application layer which switch backs to the user end. The entire process needs a step-by-step security enhancement scheme.

4 Role of IoT in Healthcare

Internet of Things (IoT) is a technological paradigm that includes physical objects, sensors, and other devices into a common integrated network. It has been enabled by the implementation of enhanced technological advances, spectrum sharing, identification of radio frequency, and big data analytics. The network things, objects, and devices can communicate between each other to retrieve required and vital information, analyze data, and complete each other's tasks [7]. Most of the objects in IoT is deployed with sensors, actuators, integrated micro-controller chips, communication networks with a set of standard protocol stacks that can communicate throughout the network [8]. To enhance the implementation and applications of cyber-physical IoT, a massive amount of devices are expected to be involved for sensing, processing, and controlling those models [2]. Usually IoT-based healthcare module sensors are supposed to monitor and collect data from the user or patients and transfer them to the cloud for archival storage over the internet. In most of the cases, these are the real-time data [9]. Thus, IoT provides a smart healthcare platform which can measure attributes of patients in a ubiquitous and pervasive manner [10]. Device-to-device (D2D) communication paradigm is a central part of the third-generation partnership project standards to facilitate peer-to-peer connectivity that will be an important part of IoT [21]. It gives a solution to the health management challenges with optimum costs.

IoT works with multiple devices with divergent protocols. They connect together to produce information. IoT includes very low powered devices such as "Bluetooth sensors," "RFIDs," "Zigbee," etc. These devices do not cover a wide range of communication network. Generally, these devices are only used in personal area network (PAN). By using IoT over these devices, the services can be amplified. IoT also introduces intelligent wearable devices (IWD) that can measure several body parameters of a patient, such as blood sugar level, nutrition level, water level, etc., and produce a diet chart for the patient [4]. Mostly, IoT gives a flexible and convenient framework by which human can communicate with devices even with a huge amount of heterogeneous environmental data [11].

As an embedded service, IoT is segmented into four layers in a sequence: 1. physical layer, 2. network layer, 3. middleware layer, 4. application or service layer [12]. Every layer performs defined tasks and serves the layer upward. "Physical layer" is considered to be the first layer of the system which includes physical objects as sensors. Sensors can sense information from the environment and collect them to transfer in the upper layer for further prosecution. The next layer is the network layer assigned with IP addresses to transfer information to the destination node. Middleware network combines the idea of smart management which can be established using Cloud platform and data storage. Finally, the application layer provides the final service such as smart healthcare.

Cloud platform and big data are two major aspects considered in IoT-based healthcare model. The adaption of Cloud platform in IoT is economic, cost-effective, scalable, and reliable. Cloud provides an on-demand platform to store, transfer, deploy, and retrieve data in a cognitive and efficient way. It has been widely used in many applications such as smart city, smart agriculture, smart industry as well as smart healthcare system. Cloud platform plays a vital role over remote health monitoring because of its less complex features, optimal costs, and flexibilities [13]. It also enhances the quality services over patients' life. Hybrid cloud is an integrated platform where it can be segmented into three parts: "private cloud," "public cloud," and "community cloud" [12]. In this way, security and privacy of the data are preserved in an efficient way. Additionally, cloud plays an important role to break the geographical barriers as the information are available and accessed from any location worldwide within the shortest range of time [14].

Big data is used in IoT healthcare as a value-based system [31]. Enormous amount of data with diverse properties can be collected by the sensors. They are handled using the Big data technology. "Big data in healthcare" refers to the abundant health data amassed from numerous sources including electronic health records

(EHRs), medical imaging, genomic sequencing, payor records, pharmaceutical research, wearables, and medical devices, to name a few [31]. It changed the typical method of manually managing medical health records with the manipulation of human interference. It helps in risk management of losing or distorting sensitive medical logs and data because of its three distinguishable features. These three characteristics of Big data is known as 3Vs of Big data. They are: velocity, variety, and volume. It comprises a massive amount of data, consumes a high speed of data at a time, and comes from different resources with different types. Analyzing these data are crucial for feature extraction, prediction and decision making. Recently Big data has a widespread implementation in most of the fields including medical technology. Undoubtedly, keeping patients' health in a sound state is the first priority for healthcare data analysis. It delivers the lower cost on investing health monitoring and basic health treatments with better outcomes, flexible treatments, and enhanced diagnosis procedures. With the wealth of data gathered each day worldwide, healthcare data analytics provide medical and technological administrators or caregivers a high accuracy-enabled medical and financial decisions that accelerate the care giving process of the patients with critical or minor health issues. It reduces time and increases reliability, scalability, and acceptance among people, thus contributing to improve quality of life.

5 Methodology

The proposed model of patients' health surveillance includes IoT and 6G communication technology. A conceptual framework has been proposed in Fig. 1, the entire process of the model is discussed in this section.

This model is designed for a specific patients' group. They include patients from rural and remote area, patients carrying lifestyle diseases such as blood pressure, diabetic, and asthma, adults >60 years with critical conditions, and pregnant women. This group of people has sensitive cases, and they need a continuous monitoring by a system. It is not always possible to ask for human resource support for this type of maintenance. Elderly people suffer from loneliness and lack of treatments sometimes. Pregnant women specifically in the remote area lack sufficient knowledge about their own healthcare and amount of nutrition they need for both themselves and the infant. Critical patients, such as patients with cancer or dialysis, need chronic support from the healthcare system. Considering these scenarios, this model is designed to give a healthcare support using technological objectives. Thus, dependency on human resource-based infrastructure won't be necessary, and it will minimize the cost of the user as well. IoT devices are user friendly and low powered device so with little amount of skill and knowledge they can be operated by the patients themselves, and they can get full support from hospital to home only by using their smart phone or mobile healthcare service. To make this schema more practical and realistic, we merged the concept of 6G technology so that the communication network can get more scalable and highly reliable for the user. It reduces

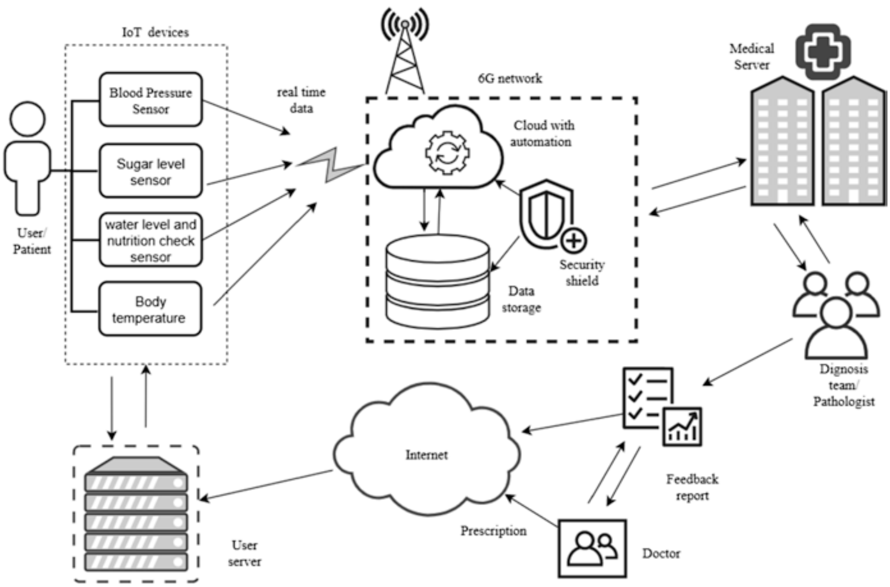

Fig. 1 The proposed model

the problems of communication between the doctor and the patients from remote area. It also gives an idea of wireless health service come true.

In the proposed model, user node consists of several IoT devices including blood pressure sensor (BPS), blood sugar sensor (BSS), nutrition measuring sensor (NMS), and intelligent wearable device (IWD) [4]. IWD is considered to be one type of Intelligent Internet of Medical Things (IIoMT) which can measure the nutrition level as water level of the patients and make valuable decisions accordingly [4]. The sensors are implied to the user as per the requirement of the disease they have. They can have subscription to the local as well as remote hospitals with flexible choices. Medical servers must consist of several diagnosis teams or pathologists and consultation doctors for the verification of the data sent by the IoT devices from the user nodes.

Though 6G technology is considered a fully AI-driven communication paradigm, still it is in the very premature stage of implementation. Also, AI-based system is not completely accurate or reliable yet in the health sector. As the health of a person is a very sensitive issue, to take care of, it is wise to start with human influence at the start of the study. Therefore, the data we can store at the cloud platform need to be check-listed by a team of pathologists or corresponding responsible doctors. The additional help which 6G AI-based algorithm can provide is a prepared data, which can be necessary in decision-making and saves valuable response time. To avoid redundant data and information silos, cloud platform needs to auto updated. Also, a data warehouse is saved in the network for saving vital information of the patients. As security is one of the key features of this model a secured framework must be developed to protect information of the user. As a solution, a hybrid cloud model can be implemented where private and public cloud storage will precisely be distinguished to keep confidential information safe and encrypted and cannot be accessed without the permission of the user. Sensors can pass real-time data to the cloud for archival storage and database communication from the user body and environment values. The medical server can keep a surveillance log over the data time to time. They can retrieve processed data and check the patients' condition by a team of diagnosis or pathologist. If the feedback report needs doctors' consultation, the report is directly forwarded to the consultation doctor. The doctor will verify the feedback report and give bookmarks if necessary. They can send e-prescription, online video consultation alongside the final feedback report to the user over the internet as well. If any emergency situation arises, IoT devices can send alarm notification over the internet to the medical server, for example, they need an urgent consultation or ambulance service for the patient. To save response time and valuable bandwidth, the system will be auto sensible if there is no continuous data transmission needed. The system will go in hibernation in such cases so that data won't be wasted over high data rate speed unnecessarily. The system will be auto alarming and send immediate notifications if any emergency situation arises. We expect this model to give a satisfactory and remarkable result close to the desired output with higher accuracy and smoother performance. Cryptographic algorithms will give efficient service in case of data privacy and confidentiality.

Hence, this model introduces a new dimension to the healthcare system. It enhances the facilities user can get from the health services. It reduces the possibilities of patients' deaths because of not being capable of reaching hospitals in time. Also, it helps to take care of the pregnant women so that they can have a safe delivery with a healthy infant. With the help of AI-based communication network, high reliability, high data rate, and scalability, a smooth system can be designed and maintained. So forth, the need and dependency to the fragile human resource support in the healthcare system can be reduced with a minimum amount of cost.

6 Discussion

In this chapter, the proposed model prioritizes a specific cluster of patients which includes rural and remote area-based patients, pregnant women, patients with critical issues such as cancer and dialysis, and lifestyle diseases such as blood pressure, diabetic, and asthma. A hypothetical study over the expected result is done in this section.

In the results of patients group, the utilities that are statistics of male, female, and children will be clarified. Some important statistical representation is necessary while clustering the patients' data. Some inputs parameters needed to be taken in consideration are as follows:

- Data sharing
- Non-data sharing

- Diagnosis
- Treatments
- Task scopes
- Prescription and drug dose

Evaluation matrices can be classified by various data analysis and verification platforms. After collecting sufficient amount of data from the targeted patients, data analytics can be performed to extract hidden information such as how critical the condition of the patient is or what requirements and necessary steps they desire for that particular moment. These data will be sensed and collected by the sensor devices that might be integrated in the smart phones or remain independently. Afterward, these data will be sent over cloud platform for archival storage following the standard network protocol of 6G technology. The cloud platform will be hierarchical to maintain data privacy and have auto update feature for processing data in an efficient way. Data can travel within the range of terahertz frequency bandwidth which will have minimum distortion and reach the destination faster. This will be a compatible application than Bluetooth or Wi-Fi in local area network (LAN). The data will be received in medical server, and they can analysis the data for further requirements by a group of expertise. If any doctors' consultation is necessary, there will be a viable communication to the corresponding doctor before sending the feedback report to the user node back.

In [29], the authors discuss a systematic review on the implementation of augmented reality (AR) and virtual reality (VR) in spinal navigation where clinical results have shown considerable accuracy. This paper also proposes an effective scheme of how AR-VR-based healthcare technology for spinal surgical operations helps to get an economic feasibility for the stakeholders and the users. The estimated reduction of reoperation procedure by accepting AR-VR imaging technology is $2.74 billion in total on an annual basis of US market. This can reduce the hospital stay cost of patients up to $8.945 in 2025.

In [15], they have considered several attributes as provider profession, task scope, data sharing, experts support, and measured the sub-levels between patient and non-patient group by conjoint analysis procedure to detect lifestyle disease management. Some of the statistics are insignificant, whereas some are statistically significant. For example, relative importance of task scope (9.02) and data sharing (10.39) for patient group and task scope (5.08) and data sharing (12.00) for the non-patient group. Nevertheless, both groups have shown least utilities in medical data sharing to the public healthcare. They have shown the results systematically with different parameters and coefficients precisely.

We have estimated that by 2020–2030, the market demand of IoT-based healthcare system will accelerate up to 20%. Already the healthcare system is getting popular in North America and Europe. Other countries such as Malaysia are focusing more on developing smart hospitals that would be much more cost-effective and optimal in the near future. We anticipate if 6G technology can be merged successfully in the deployment of this model, then it can superimpose the highest reachability in the remote area with 89–92% accuracy and drop of extravagant costs in healthcare maintenance up to 34%. 6G is a great medium for telemedicine technology though this technology adoption has been slower for the past years, but after the Covid-19 pandemic, it has thrown a rejuvenated reason to think again about utilizing it. If this model gets market acceptance by both the stakeholders and service providers, it can offer more sub-technologies by 2027.

Moreover, managed service segments will have higher demand on IoT and 6G technology in the healthcare sector within the forecast timeline. The improvised operational efficiency will definitely influence the market growth by service, platform, and region.

7 Research Challenges

7.1 Providing Service

As medical IoT healthcare model is a convergence of ICT and medical field, it will involve stakeholders from both sides. So a critical question arises that who will lead as a key player in the field of technological healthcare service. It is necessary to maintain a professional discipline as a service provider to gain trustworthiness and acceptance capability of the user in this field [15]. The aim of developing a model using IoT and 6G technology is to reduce human intervention. To develop a business strategy over this type of system also needs a sincere and responsible patronization and investment. As the two fields relates to the model, they need to be explored for further collaboration. An efficient administration, public demand, a strict government regulation is also some major prerequisites to develop such projects in reality.

7.2 Device Management

Devices used in IoT are sensors that sense, collect, and transmit data over the internet. Usually, these devices consume low power and are less costly. They can be independent devices with microcontroller chips, monitoring screen, standard protocol stack, and wearable in body parts or they can be integrated into the smartphone of the user. In both cases, the features of these devices have to be user friendly and scalable. In real scenario, people living in the rural area, especially elderly person, aren't very familiar with the technological products and supports. They hardly can use any types of devices let alone IoT medical devices. Therefore, it throws a major challenge in this issue to increase the acceptability response rate from the user for developing this model in reality. Encouraging the community to rely on the system, usefulness of the technological support in the healthcare, and provision of the process are also some necessary steps regarding this context. Expert support to enhance the usability of the devices is a major task. Expert support can be supplied from valuable resources including IT expert and rural area volunteers as well. Range of medical data sharing is a fundamental requirement of knowledge that should be acquired. They need to know the limit of information they can share to the medical server; concurrently the service providing team shall keep complete integrity in the context of receiving information from the user. Medical data carry enormous amount of personal data of the user. The big data analytics require vast range of openness and accessibility from different sources. Management of this huge amount of data and keeping consistency and security intact is a crucial task. Otherwise, the unawareness may lead to fatal damage to the whole system infrastructure.

7.3 Security and Threats

IoT-based systems are designed by combining various types of objects, components protocols, and network services. Objects in IoT can communicate with each other, make decisions in some cases, and compute data if necessary. By this procedure, a smart city, smart industrial automation and management, smart home, and healthcare system can be developed. This improvement needs lots of things to come together to collaborate and share common platform [16]. Cloud platform for IoT model is a necessary stage where all the computation, data storing, data accessibility, availability, robust applications, and data mining are performed [17]. Confidential data of the patients are collected by smart phones or sensor devices than cycles back with feedback to the user node through the same devices. During passing these feedbacks sensitive data can get leaked to unauthorized third parties. This scenario can get more vulnerable when the information carries the location of that particular patient, behavior, habits, personal details, and so on. Sometimes cloud suffers from vulnerability management dilemma because some of the smart phones suffer from code injection attacks while sharing and accessing information. In code injection attacks, the unauthorized user can control the device and memory from remote location and create malicious activities [19]. However, cryptographic deployment is very crucial for this system also keeping some security checking goals in mind, such as:

- Compact confidentiality
- Privacy and Availability
- Integrity from each node
- Ensuring efficiency during transmission
- Fault tolerance ratio
- Keeping resources robust in a distributed system
- Avoiding deadlocks
- Continuous monitoring of malicious activities
- Identifying security loopholes

- Security shield for the encrypted data
- Authentication of the user

Though cloud has given so many overwhelming benefits to the humankind and eased our daily life activities, still it can cause some vulnerability while performing huge data management and analytical tasks. Health cloud is a sensitive platform. The services it makes need to be specified and sincere. The transmission delay, data packet loss, malicious activities should be monitored continuously. Data packets which are lost should be identified by the service management teams. The network demands more security while flaws like packet loss should be lessened [18].

7.4 IoT Limitations

In healthcare hierarchy, IoT system suffers from severe types of attacks. Some attacks can directly hamper the whole system. For example, at the "physical layer" state, all of the data are collected by sensor nodes [12]. Malicious attacks can be made by "node prediction" attacks. Third party can identify nodes in a remote location and crush that particular node to affect the whole hierarchy. Onward, they can create a clone of that node to retrieve sensitive information such as encryption keys, cryptographic algorithm, etc. and use them later in a harmful way. As IoT devices are low powered devices and not much AI driven, they won't be self-sufficient to damage this type of attacks. As mentioned earlier, code injection attacks do similar activities as such. If the attacker succeeds to deploy malicious virus to the node, they can control the devices as well as the process of the system. They can drain battery, create storage leakage and information distortion, and send them to the unauthorized destination for further fatal damage and malicious use. In "network layer" while the transmission of the information is occurring, they can get interfered by several attacks. For example, "Denial-of-Service" attacks where lots of network traffics are sent to the victim nodes which results in transmission delay and lengthy response time. These attacks can cause the system quality degradation, user dissatisfaction, unreliable acceptance, loss of important data packets, storage consumption, power loss, and other massive damages. In the "application layer" on the IoT system, other vulnerabilities may occur such as password stealing, login failure, etc. Thus, a standardize IoT system model for any of the application fields are yet to be developed. For an improved provision to avoid deadlocks of the resources, the system needs to be independent so that while any of the nodes faces any attacks, failure, or damages, other part of the system may run with any affects or influences from that particular damaged node.

7.5 Challenges of 6G Technology

From the professionals' point of view from both medical and ICT fields, 6G can change the future vision of healthcare technology. It enables new windows of communication strategies, multidisciplinary visions, research aspects, and challenges. 6G technology is an AI-driven communication network which integrated many other technological features [4]. But some obstacles may have to be faced while having services from 6G technology:

(i) Providing quality of services (QoS): 6G-enabled network ensures terahertz communication operation, high data rate of 1 Tbps, high reliability, availability, high mobility, and accessibility. Thus it gives provisions of all possible QoS parameters such as: extremely reliable and low latency communication (ERLLC), enhanced mobile broadband (EMBB), long distance and high mobility communication (LDHMC) [20]. In terahertz communication, spectrum reuse techniques need to be addressed to cut of the extra expenses and cost saving. Cognitive radio (CR) spectrum reuse techniques have already been introduced to some field where wireless devices can share same spectrum at a time with some interfacing protocols without getting disrupted by others [4]. However, designing an antenna with such spectrum and terahertz frequency communication is very challenging and difficult. Situation may arise like signal gets attenuated at zero and molecular absorption may occur time to time [34]. This can bring extra hassle to the system and can get cost expensive for designing, deployment, and maintenance. QoS may enhance the quality of life (QoL) of the patients, but QoS is not a direct key functionality of 6G technology. Trade-off between the low-cost feature with high quality service might get difficult while deployment.

(ii) Artificial intelligence in 6G: 6G technology provides AI-driven features to boost up the healthcare industry. Algorithms like deep learning (DL), convolutional neural network (CNN), deep reinforcement learning (DRL) can be used as AI-driven 6G technology so that devices can be self-sufficient, self-driven, and can make decision by their own valuable values and analytical capabilities. AI also provides high accuracy and performance to the health data so that it can get precise results from the computation. Intrusive properties of AI also reduce human intervention. Nonetheless, AI algorithms take account of high computational tasks which can be time consuming and difficult at some point. High computation takes longer times and consumes massive amount of power. 6G is not capable to bring relaxation or solutions to such cases yet. Additionally, depending on AI completely for a sensitive field like healthcare would be an unwise and unrealistic step to take without the help of any human expertise at all.

(iii) Contrast with IoT devices: IoT devices are less expensive and do not consume a huge amount of power. They can be independent devices or integrated as a software system in a smart phone. Challenges arise when they are blended with the implementation of the 6G technology. IoT devices are less power consuming and capable of small area network transmission whereas 6G is a powerful communication network with large frequency bandwidth. Thus, it throws a huge challenge regarding the compatibility and interoperability of these two technologies working together to have a successful desired output. Moreover, transferring data through a huge range of terahertz frequency bandwidth may cause human body difficulties is also a matter of discussion.

8 Conclusion and Future Scopes

This chapter proposes a model of healthcare monitoring system based on IoT and 6G technology. Most of its features ameliorate the hassle patients go through from the medical health support in physical architecture. Our system with modern technological support IoT-based devices, and stronger communication strategy feature of 6G can give a better expected result in the deployment. In this model, both the advantages of IoT and 6G have been utilized. Also, auto-updated Cloud platform is integrated in this model to have a robust application and user acceptance. To handle a huge amount of big data passing through the user node, the medical server needs maintenance. It can be handled by automated cloud platform. Also to secure the system with highest privacy, several security parameters have also been addressed. Majority of the research study regarding healthcare has implied IoT or 6G separately. This chapter incorporates basic features of both IoT and 6G technology to build an integrated model of improved healthcare.

The most significant strength of this model is that it aims to develop a collaborative healthcare support system to the people in remote area and deprived to get a proper healthcare support. There is room for improvements in this system model and lots of scopes to work on future as this has not been deployed yet. Sensitive and important parameters need to be taken in consideration while developing such systems. In near future, 6G will dominate the health market and promises to enable a suitable framework with utmost facilities. It is hoped that 6G will provide a deeper and stronger navigation and satellite network. Internet of Things (IoT) will be changed to Internet of Everything (IoE). IoE is the intelligent connection of people, process, data, and things. The Internet of Everything (IoE) describes a world where billions of objects have sensors to detect measure and assess their status; all connected over public or private networks using standard and proprietary protocols [22]. Smart devices will be transformed to intelligent devices with self-computation and navigation facilities. Edge intelligence will give birth to a new revolution to the health market which can enable virtual heath service, mobile hospital, emergency doctor consultation, enhanced telemedicine facilities, improved quality of life, and an integrated system where patients will not be deprived of getting necessary treatments. In near future, blockchain can provide better support to the security system management of healthcare. Blockchain is the newest technology that has been started to imply in most sectors and is hoped that it will also contribute to healthcare for more scalable and secured data management. Efficient and effective implementation of 6G technology can also add more features to the patient monitoring system. As it is very suitable to process big data analytics, it can provide a suitable framework handling pandemic and epidemic crisis in near future. With real-time simulation and navigation, patients from remote area can be monitored easily with the help of smooth 6G communication technology. As a result, the spreading of any virus and their motion can be easily monitored and controlled within the systems regulations.

IoT has many applications in several fields, and it is also contributing successfully to healthcare market mostly in the developed countries. But the features of 6G technology need more familiarization in this field, and it has yet to be implemented. This chapter reviewed some related articles about IoT-based healthcare architecture as well as the studies have done based on 6 g technology. It also describes briefly how 6G technology can enhance the health market within the next few years. The basic requirements of 6G technology, its functionalities, and properties are also discussed. 6G will play a key role in healthcare with its promising features and higher accuracy level. From the perspective of society, the foreseeable implementations of 6G and IoT are multiple. Indeed, they will introduce personalized healthcare support system in next decade. This will make the whole medical infrastructure more flexible and resources will not go at waste. The dynamic adaption of healthcare policy will bring evolution worldwide. The rationalized health costs will be introduced so that improper distribution of hospital services can cut off. This chapter also presents the key role of IoT in healthcare sector, fundamental architecture of it, and the functions it plays. This proposed model can ease the obstacle of patients they get while having treatments for critical diseases and enable a home hospital service. It will reduce the human intervention and facilitate to have communication faster virtually. Patients can communicate to the medical server for any kind of help with fastest replies. With the help of this model, dependency over human resources would be reduced and remote patients can get an improved support from the medical team. It will reduce the barriers of geographical distance. With the help of 6G technology, a wireless healthcare communication system can be introduced to the mankind. This chapter discusses about major challenges while establish such model. However, these challenges will be overcome with further improvements to the system. This intensive research leaves room for further study in this field to make this system developed and usable to the humankind. Despite having facilities, this system incurs some weaknesses too such as high deployment cost, acceptability among stakeholders and service providers, and lack of awareness. It has room for improvements, and further research can be done in this field as well. Although it needs to overcome few challenges, collaborating two technologies together, it requires assistance from each node: administration both from the medical-ICT field and the users to emerge a new dimension of innovation in the healthcare industry.

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Application of Innovative Eco-Friendly Energy Technology for Sustainable Agricultural Farming

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Abstract Agriculture is very important to human beings because it is the sole provider of basic human food. However, agricultural process requires constant energy resources in machinery's operation, pumping water for irrigation, greenhouse heating, and so on, conventionally operated with fossil fuel energy sources that release greenhouse gases. It is, therefore, essential for farmers to adopt innovative eco-friendly techniques in various operations of food production, including agricultural farming, to meet the growing consumption of the growing population and also to save energy and water usage so as to reduce the emission of greenhouse gases from using fossil fuel energy. This made scientists to find alternative environmentally sustainable and cost-efficient agricultural farming, using innovative eco-friendly energy technology, that is, green renewable energy technology to mitigate the environmental problem and also to solve the alarming fear of exhaustion of fossil fuel energy. The authors present this chapter by reviewing literature from various available sources and is organized on the following objectives: (1) the importance of innovative eco-friendly energy technologies for sustainable agricultural farming; (2) application of different eco-friendly energy technology in agricultural farming; (3) how innovative eco-friendly energy technology is used for sustainable agricultural farming; (4) the advantages and disadvantages of using eco-friendly technology and recommendation as an innovative solution. The chapter is finally concluded with the need to promote and optimize the combination of eco-friendly energy technology application and agricultural cultivation among the agricultural farmers due to its environmental as well as economic feasibility.

Keywords Innovative eco-friendly energy technology · Environmental · Green renewable energy · Sustainable agricultural farming

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1 Introduction

There is an increasing trend of the world population, which is estimated to reach 9 billion by the year 2050 [17, 21] and the food production process for feeding human beings consumes about 30% of the global energy. As agriculture is the sole provider of basic human food for survival, it is therefore important to increase the food production globally by adopting innovative techniques in various operations of food production, including agricultural farming [25]. However, the agricultural process requires constant energy for irrigating farm land with water supply to have higher yield. Due to this close interdependence of food, energy, and water, there have been many research activities, innovative projects, and policies to provide solution by reducing energy and water consumption in agricultural activities [15, 29].

Energy is increasingly needed in machinery's operation, irrigation water pumps, greenhouse heating, and so on, conventionally operated with fossil fuel energy sources. Using this fossil fuel energy in agricultural farming has many disadvantages, such as it is costly to poor rural farmers; there is fear of energy exhaustion; and it accelerates climate change as it emits lots of greenhouse gases for the various agricultural operations [36]. This has directed scientists, researchers, and academicians to increase the food production by finding alternative environmentally friendly, sustainable, and cost-efficient agricultural farming, using eco-friendly energy technology [9, 35, 79, 80]. Agriculture also needs water for irrigating the farm land specifically in arid and semiarid regions. Like energy, there is also an increasing challenge of fresh water resources exhaustion since the global consumption of water for irrigation is estimated to increase by 41% in 2050 [108]. So, it is essential to adopt innovative application of irrigation technology, including green innovation, drip fertigation, and sprinkler in agricultural farm so as to improve efficiency in water usage, reducing wastage of water for sustainable agricultural farming [40, 64, 91].

These challenges led to the growing importance to study various applications of innovative eco-friendly energy technology in agriculture farming with the objective of reducing CO_2 emissions that have impacted the global environment. The application of eco-friendly innovative energy in agriculture farming has lots of advantages, as it can mitigate environmental depletion while maximizing agricultural farm productivity with minimal economic investment or cost. So, eco-friendly energy can be termed as the energy that has minimal impacts on living beings and ecology, that is, the environment. Herein lies the importance of the present article, which aims to promote the application of eco-friendly energy technology for sustainable farming. The authors present this chapter by reviewing literature from various available sources. This chapter attempts to review with the objectives as follows:

1. The importance of innovative eco-friendly energy technologies for sustainable agricultural farming.
2. Application of various innovative eco-friendly energy technology in agricultural farming.

3. How innovative eco-friendly energy technology is used in agricultural farms for sustainable agricultural farming.
4. The advantages, challenges, and recommendations for using eco-friendly energy technology as an innovative solution for agricultural farming.

2 Importance of Innovative Eco-Friendly Energy Technologies for Sustainable Agricultural Farming

On reviewing literature from various sources, it is found that there is a growing global challenge from using fossil fuels energy in economic activities, due to global changes in the Earth's natural environment, such as changes in the climatic condition, resulting in damage in agricultural production and ecosystem, thereby threatening the future sustainability of the agricultural farming system. So, it is important to conduct more research studies in order to reduce the usage of fossil fuels energy and switch to eco-friendly energy usage in a country's productive activities, as fossil fuel energy usage causes a severe negative impact on the environment [97]. Also human activities including inappropriate land use, waste management, pesticide, and chemical fertilizers cause excessive CO_2 emission, resulting to warming on the Earth's surface and other forms of changes on the environment. Therefore, it is very important to minimize this emission by switching to sustainable eco-friendly energy sources, obtained naturally and renewable, such as green innovation, solar energy, wind energy, etc., along with green innovation [1, 4, 10, 46, 52, 61, 62].

Asafu-Adjaye [3] has conducted a study for four developing countries in Asia, viz, India, Indonesia, the Philippines, and Thailand, to estimate the association between income and energy consumption. According to him, these developing countries are having the pressure to search for energy sources for sustainable economic development as their population growth is high. So, while considering energy sources for economic development, green or eco-friendly energy concept is very important to sustain the demand of increasing world population as the worldly ecosystem is polluted due to the emission of gases after prolonged usage of conventional fossil fuel energy [79]. In addition, fossil fuels are nonrenewable energy and will be exhausted in the near future due to increasing consumption. Renewable eco-friendly energy, being inexhaustible, and less adverse impacts on the environment could be used as eco-friendly energy to solve many existing environmental problems [43]. The analysis of the above literature shows the importance of switching to eco-friendly energy sources, like solar, wind, hydropower, etc., to save the world's environment from the adverse impact of climate change and at the same time adopting innovative method to increase the productivity of the farmed land [37]. In other words, the application of innovative green technology is important to improve energy efficiency and performance. Here, innovation means the development of new ideas into green energy products applicable for agricultural farming [70]. Carrillo-Hermosilla et al. [8] have reviewed the concept of sustainable innovation, eco-innovation, or environmental and provided the meaning of eco-innovation as the ability to improve environmental performance. The European Commission [18] defined eco-innovation in relation to environmental sustainability as any form of innovation, with aims toward the sustainable development goals significantly, through lessening environmental impacts or using natural resources, including energy, more efficiently and responsibly. Similarly, Sarkar [75] states that the concept of eco-innovation has a close relationship with eco-efficiency and development process through the application of innovative environmental technologies. Another operational definition of the current chapter is given by Rennings [73] who distinguishes eco-innovation as innovation for sustainable development, from environmental innovation, in terms of measures or activities of firms or private households for idea development, behavior, production process, and application for ecological sustainability. It is, therefore, important to switch to cost-effective, abundant, and long-lasting natural sources of energy which is also called renewable energy. Renewable energy can be used to meet the increasing demand in energy consumption due to increasing population and at the same time helps to reduce greenhouse gases emission. Solar energy is one renewable eco-friendly energy, which is clean and freely available for long-term use to solve the negative impact of energy as well as to meet the shortage of energy for consumption in economic activities in the future. So, many applications of solar energy technology are being used in many production processes, including agricultural farming, due to its excellent performance, availability, cost-effectiveness, and sustainability [2]. Kannan and Vakeesan [41] also discuss the necessity of solar energy application in the world's energy demand, by highlighting previous research on the application of solar energy technology in economic activities, its benefits and excellence in performance, and available barriers in order to overcome future energy crises. Similarly, Hassanien et al. [33] have reviewed the application of solar energy technology in agricultural farming and highlighted its significance in the present world as it is eco-friendly. So, this energy has been used to increase the productiveness of developing countries. It also helps to develop their economic status, and increase the sustainability of many underprivileged rural people. This is done through applications of different innovative eco-friendly technology in agricultural food production, which enhance the productivity at a lesser cost. Some of the innovative eco-friendly energy technologies included in this article are discussed under the headline "Applications" in Sect. 3.

3 Applications

3.1 Green Innovative Irrigation

Water is a natural resource which is very important in agricultural cultivation, and agricultural cultivation consumes the largest amount of water resources. Conventionally, 60% of world food production is dependent on rainwater. But in recent decades, there is an unevenness of rainfall, due to the impact of climate change and other weather conditions, caused by global warming, thus affecting crop yields or food production [21]. Scarcity of rainwater, thus, makes the cultivated plants dried and so there is more demand for water supply for agricultural crop cultivation, especially in hot humid weather conditions of today's environment [20, 74]. So, appropriate irrigation is very essential to increase the productivity in agricultural farming, to have efficient water supply all over the years to the plants to increase the yield for long-term sustainability of agricultural production, especially in countries that receive scarce water due to inadequate rainfall. This can be done through the optimization of the design of irrigation application, incorporating energy-saving green innovation technology of irrigation in agricultural farming [26]. Green innovative irrigation technology uses new and innovative energy generation techniques to create environmentally friendly products by using renewable energy, which is efficient, recyclable, and safe. Even though global irrigated agriculture is only about 300 million hectares, that is, less than 20% of the global cultivated lands, it produces more than 40% of the world's food and agricultural production [21, 57]. Irrigation water technology enhances the productivity of crops as it supplements the water in the off-season, when there is no rainfall, moisturizes the soil, and raises capillary of groundwater. There is no adequate rainfall in many areas of the world, but the productivity of crop cultivation depends on an adequate amount of water supply, and thus, the application of innovative irrigation technology is very important for food sustainability [102]. It has enabled farmers to reduce their dependence on rainwater for the successful harvesting of cultivated crops and so the currently irrigated land has expanded gradually to more than 270 Mha worldwide, comprising about 18% of total cultivated land [24]. Conventionally, fossil fuel energy is used in pumping water for irrigation, and this consumes lots of energy and water which is not cost-effective to the poor farmers. Therefore, there should be innovation in agricultural technology in the form of green innovation irrigation, to achieve objectives as efficient and economical utilization of water to increase higher yield from cultivated crops and at the same time reducing the negative impact on the environment. A gradual expansion of irrigated farm needs more energy consumption in various processes of irrigation as to lift and distribute the water through different irrigation systems including surface floods, drips, or sprinklers. There are two popular types of green innovation irrigation technology, using green energy as (1) sprinkler irrigation and (2) drip Irrigation, as shown in Fig. 1 [102].

3.1.1 Sprinkler Irrigation (SI)

There is a growing importance of sprinkler irrigation systems due to two main factors, namely, unpredictable and uneven rainfall under the impact of climate change and shortage of labor due to the increase in wages [83]. Sprinkler irrigation is a product of green innovation technology, which is an energy and water-efficient method of distributing or spraying water (80–85% water use efficiency) to agricultural crops, similar to natural rainfall and can be used to irrigate many kinds of crops. A system of pipes under medium to high pressure is used to sprinkle through a nozzle of small diameter by pumping and spraying the water into small drops of

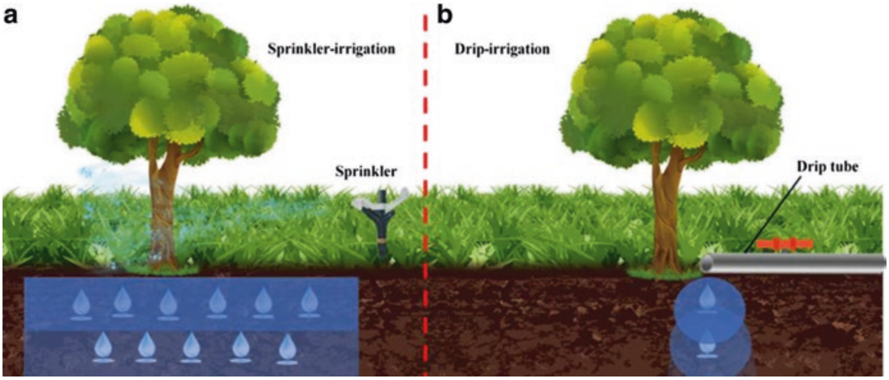

Fig. 1 (**a**) Sprinkler irrigation and (**b**) drip irrigation

water on an entire agricultural farm quickly like rain. An efficient and uniform application of sprinkler irrigation systems depends on the pump, sprinklers, and other operating conditions [23]. Sprinkler irrigation method is widely used in the area where there is inadequate rainfall for crop cultivation and growth. It is an artificial creation of natural rainfall for spraying water on the cultivated agricultural farm. However, sprinkler irrigation is not suitable in arid regions, which has a high temperature, high wind velocity, and low humidity.

3.1.2 Drip Irrigation with Fertilizer (Fertigation System) Technology

Drip irrigation is one of the modern and powerful water-saving micro-irrigation systems with excellent distributing efficiency, contributing to more profits to farmers due to increasing quantity and quality of yielded crop [31]. Drip irrigations are cost-effective irrigation, designed to spray small drips of water directly to the plant root zone [80], and commonly used in areas with inadequate water supplies, with many benefits such as in terms of water savings, ability to spray fertilizers efficiently, increase in productivity, with fewer weed problems, soil erosion, and energy consumption. Some of the common problems which many farmers face are low quantity and quality of crop yield due to the degradation of agricultural land soil fertility along with the presence of inorganic fertilizers. To remove these problems, agricultural scientists designed a new innovative technology of fertilizer application, in which soluble organic fertilizers are blended along with the irrigation water and then distributed evenly through drip irrigation called "Fertigation system." The blend is usually kept in a tank and the drift of fertigated water is controllable, and the fertilized water is then delivered through drip nozzles on the root zone of the agricultural crop. So, the application of fertigation method technology, as shown in Fig. 2, helps to increase the level of nutrients received by the plants and reduce water wastage and soil fertility depletion and therefore has high efficiency (80–90%).

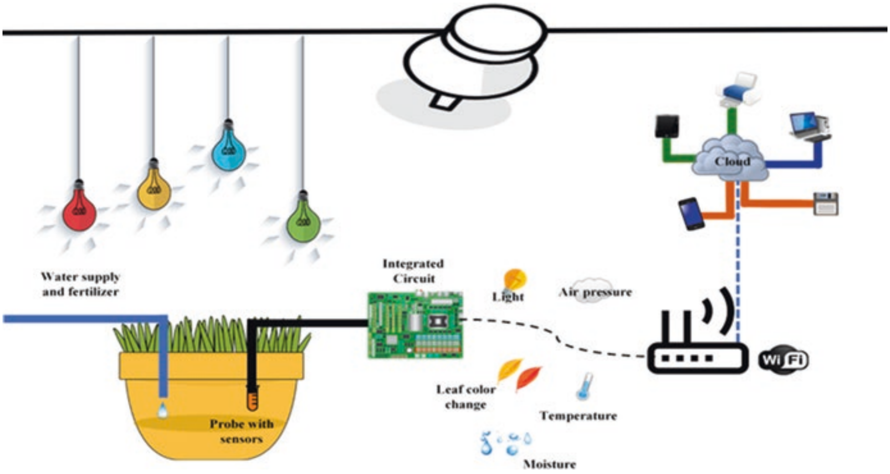

Fig. 2 Drip irrigation with fertilizer (fertigation system) by using online technology schematic

In this way, fertigation saves a substantial amount of water, fertilizer, labor, time and energy [40, 88].

Bennis et al. [6] consider drip irrigation as the most essential application of precision agriculture technology due to its efficiency in water saving (95–100% water use efficiency) and soil nutrients distributing system for cultivating crops, helping millions of farmers across the world as it enables them to have higher yields from any land in any regions while saving water, fertilizer, and energy. Under the drip irrigation system, water and fertilizers of the right amount are directly delivered to the agricultural plant's root zone in smaller pipes called "drippers" at the right time, so each plant gets the appropriate needful fertilizer to grow optimally. So, it enables farmers to get maximum yields from the harvested crop, while saving water, fertilizers, and energy [63]. This irrigation technology is commonly used to deliver appropriate water quantity in orchards, greenhouse, and crops planted in rows with minimal water loss [84]. Installation of wireless sensor networks (WSNs) technology helps to monitor soil moisture, soil temperature, light, air pressure, and changes in leaf color accurately and these data are then transmitted to the microcontroller, to help in estimating the accurate water quantity requirement of the cultivated plants/crops. The data that have been received are updated regularly to the server and these data can be accessed easily at anytime and anywhere, in PC or even in mobile phone applications [69]. Drip irrigation is different from other irrigation systems as this application provides farmers an efficient, simple, and cost-effective way of operating their farms, called fertigation [89]. Most farmers prefer this combined method of providing appropriate irrigation water along with fertilizer in the root zone due to the following reasons:

- Ensure maximum absorption of water and nutrients from the applied fertilizer
- Higher quantity and quality of crop yields
- Improvement and consistency in the quality of crop yields

– Efficiency in water saving in the absence of evaporation, runoff, or wastage
– Utilized 100% of the cultivated land in any topography or soil type
– Energy saving since it works on low pressure
– No leaching with efficient use of fertilizer and crop protection
– Lower risks and dependency on fluctuating weather conditions

3.1.3 Advantages and Disadvantages of Drip and Sprinkler Irrigation

Both sprinkler and drip irrigation are efficient in distributing water directly to the root zone of the cultivated crop, thus leading to an increase in efficiency of water usage and higher yield from the harvested crop. It is also cost-effective as it consumes less energy, less labor power, easy to apply, and low water wastage due to evaporation [48]. Another advantage is that both can also be used in all kinds of topography and soils [39].

Even though both sprinkler and drip are micro-irrigation methods, there are remarkable differences in certain characteristics of their work processes and performances, distinguished by their advantages and disadvantages [60]. Table 1 provides the details of their advantages or disadvantages.

3.2 Wind Turbine Energy

Wind energy is another promising renewable eco-friendly agricultural technology in terms of its potential and prospects. Wind turbine energy has lots of potential as it is cost-effective, clean, environmentally friendly, reliable but site-dependent and can be used as alternative energy for different agricultural purposes such as transporting agricultural yields, milling grain, and pumping water. Traditionally, before the invention of electricity, all grinding works of grains and legumes were done by wind turbines. The wind power supply can provide 12% of global electricity demand (Chel and Kasushik 2011) [11, 68] (Fig. 3).

Wind energy can be generated provided the agricultural land area has the following conditions: (1) powerful winds, (2) location is near existing transmission networks, 3) economically competitive depending on initial cost investment as well as other available energy options ([37]. P. 25–28). A wind turbine system operation has certain components consisting of a turbine, a tower, a controller, a grid-connected inverter, and a meter. Controller functions to ensure safety in operation and adaptation if there are any changes in the frequency power of alternating current (AC) to direct current (DC). The operating system of wind turbine pumping water is passing the DC power to the inverter, then converting into electricity of the same power AC voltage and frequency from the grid. Lastly, the resultant AC voltage is then used to pump the water from the well or tank [7, 25]. Table 2 shows the advantages and disadvantages of wind turbine energy.

Table 1 Advantages and disadvantages of sprinkler and drip irrigation

Sprinkler irrigation		Drip irrigation	
Advantages	Disadvantages	Advantages	Disadvantages
Achieve higher levels of spatial uniformity and efficiency [86]	Wind interference reduces the effectiveness of uniform sprinkling. Also, not suitable in soil with poor infiltration [83]	The maximum efficiency level in water usage as water is directly distributed at the crop's root zone [42, 62]	High initial installation cost, unaffordable to small-scale farmers, and unavailability of small system sizes for small plots of small-scale farmers [31, 59]
Control leaching of salts, avoid soil erosion and land loss [83]	May affect pollination and fruit set if sprayed during the flowering period [83]	Increase in profit due to increase in quantity and quality of yielded crops [31, 42]	Inefficient water filtering may cause clogging in the tubes [89]
Presence of continual optimum soil moisture maintenance in the crop root zone [83]	Cost of the initial investment is high [83]	Water is directly supplied to the root zone of the crop through a network of pipes with the help of emitters resulting to efficient usage of water and fertilizers [42, 60]	Moisture distribution, germination, and salinity problems [89]
Water efficiency is about 80–85% [63]	Energy requirements are usually high [83]	Reduction in leaching, water and fertilizer wastage due to root zone application [42]	Need high skills for the application [89]
Ensures adequate seed germination with only one light application of water after seeding [83]	Ripening soft fruit or delicate flower may be damaged due to spray [83]	Operational cost is low [42]	Difficulties in evaluation and monitoring uniform operation in water irrigation for it may be difficult to observe [45]
		Water efficiency is about 95–100% [63]	

3.3 *Solar Panel Energy Technology*

Solar energy is considered as one of the most abundant and the best future renewable eco-friendly because the Earth receives approximately 1.8×10^{14} kW out the total sunlight emission at a rate of 3.8×10^{23} kW [96]. As it is abundantly available with no cost, Kumar [44] reported that solar energy can be utilized to meet global energy demand. Hassanien et al. [33] stated that it can be innovatively applied in agricultural food production processes, to enhance the productivity at a lesser cost of energy for economic growth. So, ecological scientists are trying to invent eco-friendly and cost-effective applications of energy, while enhancing productivity for a sustainable world in terms of energy utilization [41].

Climate change is heightened by using machinery operated by fossil fuel energy in the agricultural farm as it emits lots of greenhouse gases. Using solar energy does

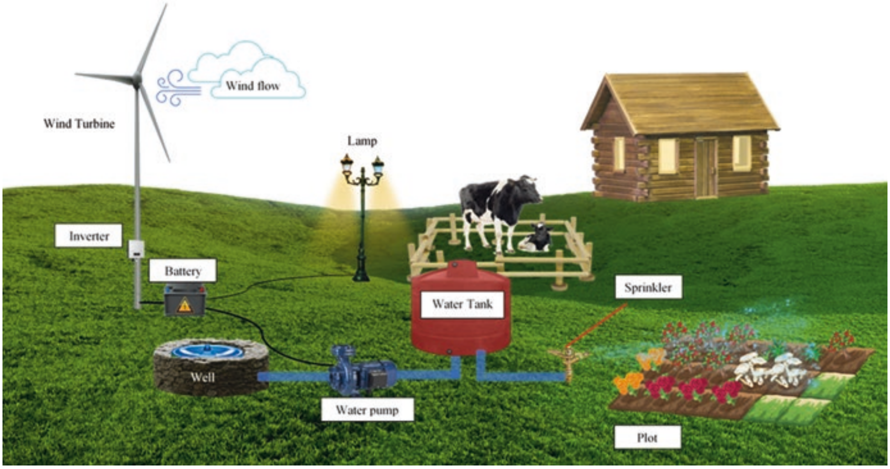

Fig. 3 Wind turbine energy for irrigation and lighting

Table 2 Advantages and disadvantages of wind turbine energy

Wind turbine energy	
Advantages	Disadvantages
Unlimited, free, renewable resource [47]	The first investment cost for setting and construction is very costly [47]
Wind energy creates no harmful emissions [19]	Noise pollution and are not visually pleasing and also affect fauna, especially birds on the on-shore system [19]
It is too costly and challenging to connect small rural villages to the national power grid by the use of off-grid low-speed wind turbines in rural areas [19]	For off-shore, wind turbines require a vast network of underwater cables, this could destroy coral reefs and the habitats of marine animals and plants [19]
Ability to place turbines wherever necessary [47]	Wind farm requires a lot of space [19]
Farmers can yield higher valued crops after installation throughout the year [11]	Some of the associated problems are lack of skill farmers, unavailability of spare parts and technician to repair the turbine in case of faults, and less public awareness [11]
Cost-effective as it is one of the most efficient and lowest priced energies of all renewable energy technologies available today. 2.5% of global energy is currently supplied by wind energy [27]	

not emit greenhouse gases, unlike fossil fuel energy. Due to these reasons, many developing countries are switching to eco-friendly energy technology, which can be used for various purposes, such as solar panel water pump for irrigation, greenhouse cultivation, drying products, space heating, ventilation, and so on. Using this innovative green technology helps to minimize the environmental problems as global warming [2, 3]. There are two methods of converting electrical energy from solar energy as solar panel (Photovoltaic, PV) system and solar capture heating systems [38]. In the PV system, the Sun rays are converted directly to electricity by semiconductors but need more investments. Recently, due to technological advancement, thermal methods are also used for solar power supply, but this chapter focuses on the application of solar panel (Photovoltaic, PV) technology since this energy system technology has the main objective to satisfy the demand for electricity power effectively, efficiently, and reliably within technical, environmental, and economic considerations, and also the best renewable energy option for rural areas that have an unstable electric power supply [90]. Adopting this energy system is efficient, affordable, and reliable since 50% of the global population lacked access to conventional energy supplies, and thus dependent on fossil fuel energy, which is hazardous for health as well as environmentally. Due to this, in recent decades, the number of users of Solar Panel Energy Technology in the distant rural farm is gradually increasing [28]. It is the most effective option for watering or water storage for the rural distant farmers where there is no power line connection [9]. Dupraz et al. [13] also discussed solutions for converting sunlight into energy for agriculture productivities, by designing the light transmission system at the cultivated crop, using an array of solar panels on a crop model that can predict its productivity. It is also called photovoltaic agriculture and is a natural response to supply green and sustainable electricity for agriculture [98]. This system was developed by raising the solar panels to 2 m above the ground to increase the moderate shading of the crop [94].

PV energy offers the best solution for remote agricultural and there are numerous applications of solar panel technologies in agriculture farm due to innovations in agricultural technology [14, 78] as given below:

- Water pump for irrigation of cultivated crops
- Mechanical power for farm products supplies, transportation, storage, wastewater purification, and disposal
- Greenhouse heating

3.3.1 Solar Panel Water Pump

Solar water pumping is the most effective option for watering or water storage for the rural distant farmers where there is no power line connection [9]. The operation process of the PV solar pump system needs the following: adequate sunlight, solar panel, pump controller, motor pump, water resource, and water tank. The solar panel contains several silicon cells or solar cells. A solar cell is the smallest unit of the panel. When sunlight falls at a solar panel, the energy from the Sun is absorbed by solar cells. The solar energy will be converted into direct current electricity (DC) by semiconductors, then the inverter in pump controller will convert DC to AC (alternating current) and the energy will flow to a motor pump, after that the water from water resource will be pumped by a motor pump and collected in the water tank [11]. In this way, during daylight, the batteries are charged, and then the stored energy from sunlight is then used for pumping irrigation water whenever needed.

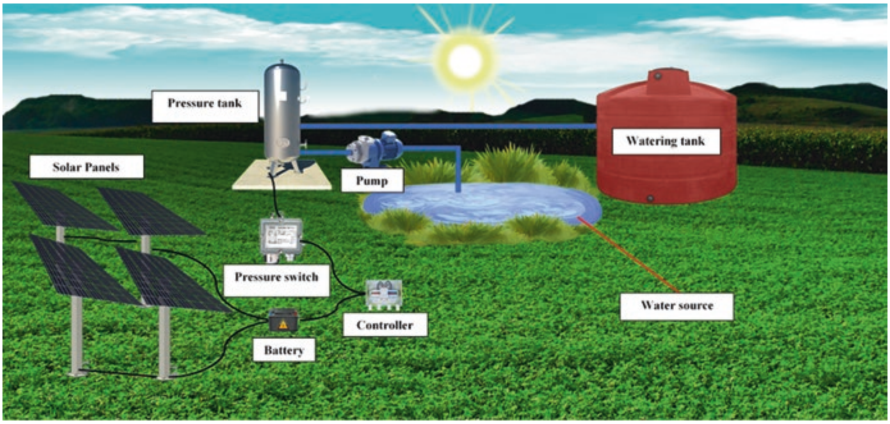

Fig. 4 Solar panel energy for agricultural farming

Using a battery provides a balanced operation to the pump's DC motor voltage and thus can deliver water even at night time. Water can be stored in different ways such as in large watering tanks or smaller watering tanks and the water storage capacity influences the pumping system. It is advisable to store water in a close tank, even though it is expensive, as some water may be lost due to evaporation [14]. Figure 4 shows the operating process of a solar panel water pump. Periodic checking, maintenance as well as the availability of spare parts are some requisites essential to increase the lifespan of a solar panel water pump and to improve its performance. A reliability assessment of the solar panel water pump was conducted in a study in Thailand and it was found that 45% have failed to pump water blockage after a periodic use because of blockage by sediments within the system [42]. Therefore, regular checking, as well as easy availability of spare parts and technical knowledge, are important for the successful operation and maintenance of solar panel pumps [55].

3.3.2 Solar Panel Energy in Agricultural Greenhouse

A greenhouse is an innovative eco-friendly agricultural technological system created for optimal plant growth to produce higher yield from the cultivated crop in any season, topography, or weather conditions, by controlling the ideal indoor temperature, relative humidity, light, and CO_2 at every stage in the process of crop cultivation. In some very cold temperature areas of the world with less than 0°C, appropriate heating systems are required to control the internal temperature for greenhouses [82]. Greenhouse along with appropriate heating or cooling system shows remarkable efficiency, by shortening the duration of cultivation while improving the quality and quantity of the yielded crops [33, 81]. Besides, the solar greenhouse farming system helps in controlling indoor optimum temperature and humidity conditions

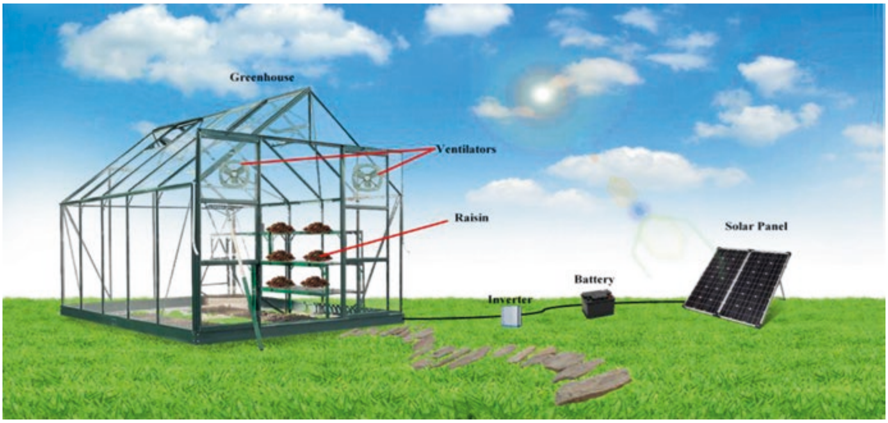

Fig. 5 Solar panel energy for indoor greenhouse temperature control and ventilation

for higher yield as well as for drying the harvested crop, as shown in Fig. 5, consisting of solar panel, battery, inverter, and ventilation system. Solar energy drying systems can be done in three ways as convection, radiation, and conduction [5]. In greenhouse drying, the harvested crops will be dried by the heat of the Sun and the product's moisture will be removed by airflow of ventilators [66]. For operating solar panel greenhouse systems, the energy (DC power) from the solar panel is supplied to the battery, then given to the inverter to convert it into AC power.

The function of AC power is to operate the ventilators to ventilate heat or control temperature in the greenhouse [85]. Maher et al. [50] also presented a model of a greenhouse with a fuzzy-based induction control system, which helps to monitor the indoor temperature, ventilation, heat, and humidity of the greenhouse for sustainable farming at optimal temperature for maximum crop yield. Their study also has shown the effectiveness of the fuzzy controller as well as the PV generator into greenhouses as it is energy saving and cost-effective. Analysis of research investigations on solar panel greenhouse technologies shows efficiency in terms of energy saving (80%), cost-effective, and environmentally friendly [12]. Table 3 discusses the advantages and disadvantages of solar panel energy in agricultural farming.

4 Conclusion

A review on application of eco-friendly energy technologies in agricultural farming highlights the works of previous researches done on green energy or eco-friendly energy technologies, including green innovation, water irrigation, wind turbine, solar panel, solar water pump, etc., with objectives for cost-efficient usage of water and energy for sustainable agricultural farming. The review of literature proves that there is an alarming fear of climate change and its impact on the global environment, global population, and the need of using innovative technology in human

Table 3 Advantages and disadvantages of solar panel energy

Solar panel energy	
Advantages	Disadvantages
Reduces usage of fossil fuels energy, economical, clean, no noise, pollution-free, easy to operate and repair [2, 3, 16, 65]	Initial investment cost in purchasing a solar PV system and energy storage is moderately high [30]
Offers green energy at a low cost, which is the best solution for remote agricultural farm operation as water pumping for crop irrigation [14]	Heat may be lost depending on the pipeline length between the solar collectors and heat storage tanks [33]
Become a solution for crop drying, greenhouse heating, water pump systems for crop production, livestock, and small-scale irrigation [3]	Factors that affect the performance output include load resistance, sunlight intensity, cell temperature, shading, etc., beside environmental factors such as the deposition of dust due to the soil, salt, bird droppings, rainfall, snow, etc. [13, 30, 49, 53, 93]
Abundant and available everywhere and low cost in maintenance and spare part is cheaper than using generator operated by a diesel engine [2]	Humidity and the presence of chemicals in greenhouse roofs could affect the PV panels. [33]
Even though the initial cost of solar panel technology is high, there is low carbon emission, provides unending resources, and needs little maintenance [44, 96]	
Saves the farming area [95]	Some problems associated with greenhouse cultivation are (1). Internal climate control (2). Changing the decision on the management of production (3). The necessity to make the system adaptable to alternating weather conditions [34, 35, 58].
Able to retain heat for night use and even for cloudy weather conditions [16, 65]	
Prevent CO_2 of 1.5 tonnes per year [86].	Toxic and hazardous materials, if used during the manufacturing process can indirectly affect the environment [30]
Applicable for different purposes in agriculture farming [56].	Requires a lot of space, depending on electricity requirements [30]
Helps to cultivate all kinds of crops or fruits all through the year without regard to season [16, 65]	

productive activities for sustainability, including agricultural farming, which is the main source of providing food to mankind. This chapter presents the importance, performance, applications, advantages, disadvantages as well as the future scope of eco-friendly energy technology. The application of eco-friendly energy technology can be improved further with green innovation. This is due to the significant contribution by academicians, scientist, manufacturers, and policy-makers to make the future world sustainable. The result of their significant contribution is expected to widen the future scope, by making the future world sustainable. Using eco-friendly energy in agricultural farming will help to mitigate the impact of climate change on agricultural productivity and food insufficiency. Finally, it can be concluded that this review has made a modest attempt to promote green energy usage by adopting innovative eco-friendly energy technology. Reducing the usage of fossil fuel energy in agricultural activities will help to combat the impact of climate change. However, adopting this green energy technology in agricultural farmers has some challenges, which made it to be adopted by only a few farmers and places, due to its high initial investment cost, lack of awareness or training. These difficulties can be overcome or solved through more research studies to optimize the combination of eco-friendly energy technology application and agricultural cultivation among the agricultural farmers due to environmental as well as well as economic feasibility.

The following provides the recommendations to widen the future scope of eco-friendly energy technology.

– Distant rural areas that are not connected with a conventional energy network that has a problem in the construction of a sprinkler irrigation system should be properly addressed by the concerned government to provide timely assistance. And there should be development priorities for sprinkler irrigation system development in areas with a lot of sunshine. Similarly, priority should be given to the development of small and mini wind-powered sprinklers in areas with sufficient wind energy irrigation systems [99].
– Need to innovate drip irrigation system, to make it affordable to all farmers so that the number of farmer using the system increases for any kind of cultivated crops and at the same time increasing the irrigation ability even with poorer water quality [48].
– Need periodic monitoring of the drip system, to fix the problem that affects performance such as leakage or other issues in the pipe, drip lines, clogging, etc., to provide adequate irrigation water to the crops. Besides, care is needed for delicate crops during germination phases that require uniform water application as baby greens or carrots [77].
– Need to improve in drip irrigation system design technology, efficiency, and easy to use so as to attract all farmers to install drip system in their farms [50, 91 Soponronnarit48, 87]. Currently, poor farmers cannot afford to start installing micro-irrigation system as the first-time investment cost is high. Also, farmers of low-income countries are slow to adopt new technology [54]. Also, a lack of cash and expertise and the crop specificity associated with available micro-irrigation technologies further reduce its desirability. It is also important to motivate more farmers to use water and energy savings' new technologies in agricultural farming.
– Since the first-time cost and installation of solar PV water pumping systems is very expensive, the Government or NGO should provide finance or low-interest loan assistance to local rural farmers, especially of developing countries [55, 71].
– Periodic maintenance and availability of spare parts are recommended to solve some of the problems of parts as the pump, controller, pipe, etc., as it may affect the performance of the solar panel water pump [42].

– Since greenhouse operation and performance are affected by many factors, such as size, site, position, roof material and other quantity and quality of material used, cultivated crops, day and night temperature [72], these factors require further research and attention for the maximum utilization of solar energy technology in agricultural farming [41].
– Since there is low awareness of using solar panels or wind turbine energy among the distant rural farmers, it is recommended to provide training and education to improve their awareness of the benefits as well as the operating process of these technologies for rural agricultural farming [9].
– Need to conduct more research studies to investigate innovative application of solar energy technology, along with the support of local governments to create energy policies for the development of this technology [33].
– Even though solar energy technologies in agricultural greenhouses have significant advantages, there should also be steps to overcome some challenges such as firstly, PV water pumping operation and maintenance, as well as the distances to the grid, the water elevation, and water storage. All these are critical factors when determining the economic feasibility of PV pumping technologies [55].
– To integrate PV arrays with greenhouses, a specific and new PV greenhouse design or adaptation of existing structures is required. It has been reported that the position and orientation of PV modules on greenhouses roofs must be considered carefully to provide sufficient electrical energy with minimum shading of plants [100].
– To reduce the production costs of solar cells and modules, the amount of material used to manufacture the cells should be reduced [67].
– Semitransparent PVPs should be used as it could increase the light transmission to the crop [13].
– To improve long-term system conversion efficiency needs to use concentrator cells in sunny regions [92].
– To create shades on the cultivated land, the position of solar panel should be elevated to a height of 5 m, along with different solar panel design configurations so that the cultivated crops on the underground surface can yield equally [32].
– A unified standard must be set up to standardize the design and scale of projects of solar panels or photovoltaic agriculture. Solar panel producers need to produce a variety of applicable PV products for agricultural production to meet farmers' requirements [98].
– Government designers need to design innovatively with due consideration of cost and efficiency to motivate farmers as the alternating eco-friendly energy-generating device rather than using conventional fossil fuel energy for a pollution-free environment [56].
– Need training of the farmers on how to use and maintain the PV system along with the availability of good support service [51].

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Review on Smart Farming and Smart Agriculture for Society: Post-pandemic Era

Nagarjuna Telagam, Nehru Kandasamy, and M. Arun Kumar

Abstract Smart farming is one kind of application of modern communication technologies in agriculture, leading to the third green revolution. The third green revolution will transform agriculture into a new dimension with Internet of Things (IoT), Big Data, and sensor technologies. These technologies, like robotics, unmanned aerial vehicles, machine learning, and artificial intelligence, increase crop quality. Today's agriculture industry is precise, smarter, and data-centered. The Internet of Things is evolving rapidly, and IoT technologies have redesigned many sectors in the real world, including smart agriculture. These redesigned methods have changed the conventional agricultural practices and developed new opportunities for many researchers with different challenges. This chapter mainly highlights the IoT architecture's capabilities post-pandemic in the real world and smart agriculture sensors' potential and challenges while integrating the technology with conventional farming practices. Sensors were mostly available for agriculture applications such as soil identification, crop status, pesticide detection, etc. The IoT technology that helps sow crops, packing, and transportation is broadly explained in this chapter. Furthermore, the unmanned aerial vehicle (UAV) or drone usage is described broadly for applications such as surveillance of crop and crop yield. The types of sensors that are suitable for farming will be explained extensively in this subsection. The requirements of the UAV's and future applications of using drones in smart farming are broadly discussed. Finally, based on this chapter, the researchers can identify smart agriculture and farming's future trends.

Keywords Internet of Things · Unmanned aerial vehicle (UAV) · Pandemic era · Sensors · Crop

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1 Introduction

The visions of society are changed after the post-COVID-19; the urban areas' opportunities need to be increased. The failure of effectiveness of the political party and its response to the virus's outbreak have given a warning to all the places, such as big cities, small cities, urban areas, etc. The recovery from pandemic situation plays a key role for many government officials to become more active to reshape public good's smooth functioning and provide a better security. The political party/ government alone cannot define the strategy to overcome the pandemic situation, and a proper response is needed from the people also [1]. The COVID-19 virus pandemic has questioned scholars, scientists, and growth utilization strategies of the populated cities. The new insights are discussed to develop urban cities and towns, reshaping growth [2]. The severity of this virus across the globe has affected millions of people and significantly impacted stock markets, labor markets, and ordinary people's social lives. This virus impact has created a global recession [3]. The change in people's social activities is being witnessed, which leads to economic reduction and delay in schools' reopening, work from home, and remote work access [4]. The challenges faced by the people in the pandemic era are related to financial, social life, and this era has made people rethink about growth and economic structure in individual life [5]. The pandemic diseases from different times have made a significant impact on the average lives of humans. Illnesses such as the Spanish Flu, HIV, SARS, and Ebola had already destroyed the economy, which had led to disturbances in agriculture, tourism, and transport facilities [6]. Every country around the world has taken extraordinary measures to fight against COVID-19. The travel restrictions and halting the trading happened in most countries to limit the disease from spreading. The economic sectors are majorly affected in developing countries. One of the economic sectors is agriculture, which plays a key role in health and food for every individual affected drastically [7].

Agriculture is the backbone of the world economy and one of the biggest industries in any country in the world. The majority of agriculture in any country depends on cultivation land in urban and rural areas. Many countries have announced a financial package for farmers to help them financially for the production of crops. The study shows farmers' marketing affects and losses in crop production and pasture [8]. The production of fruits and vegetables is in a vulnerable position because of the time validity. Small landholders of agriculture generate only lower incomes and negatively impact household food security [9]. The agriculture field visits, pest controlling and monitoring, surveillance, and training services have also been disturbed in this pandemic. The support for the farmers is very crucial in most countries. Consider, for instance, the state budget allocation is reduced, limitations in travel are increased, and the increase in pesticides' cost have a significant impact on farmers' daily lives [10]. The people of Sudan live in rural areas, and 95% of them are entirely dependent on agricultural production and consider it as the primary source of income generation for their livelihood. Sixty percent of the people in the world rely on agriculture in the world.

Sudan government has taken many creative measures to reduce the COVID-19 effects and help people make income for their livelihood. The actions include lifting the travel ban, removing the restriction in mobility, opening the market for a long time, and increasing the business value [11]. In the last decade, the world has suffered from the global food crisis and rice production issues in African countries. The countries such as Benin, Burkina Faso, and Nigeria remain challenging for crop production. Due to the COVID-19 outbreak, challenges have come up for the farmers in food supply chains, production, and marketing. The major rice exporters in Asian countries have increased the international price. This crisis has made backward countries to suffer from financial problems [12]. Table 1 shows the various pandemic situations faced by the world in the last century. The Spanish Flu has taken more human lives when compared to COVID-19. The death toll has crossed 50 million in the year 1919. The other Asian Flu, which originated in 1958, took 11 million people's lives. The most dangerous HIV/AIDS was identified in 1981, with a death toll of 6.9 billion lives worldwide. Some of the people are living without even knowing that they have been affected by HIV. In the last decade, the world also suffered from other viral diseases such as EBOLA, MERS), and Swine Flu, and their death toll is also close to a million, as shown in Table 1.

With the deaths of millions worldwide, the impacts on the world economy are very high, and many countries have prepared future contingency plans [13]. After the implementation of the lockdown, and the shutdown of businesses, factories, industries, the world has recovered in green. The researchers and scientists have noticed a considerable drop in the carbon dioxide (CO_2) and nitrogen dioxide (NO_2) levels. The people in Italy are colossally shocked to see the fishes playing hide and seek in the clear water, and the atmosphere is apparent [14].

Table 1 Pandemic comparisons for the last century

S. no.	Virus	Deaths
1	H1NI-Spanish Flu (1919)	50000000
2	H2N2-Asian Flu (1958)	1100000
3	H3N2-Hongkong Flu (1970)	1000000
4	HIV (1982-PRESENT)	6900000
5	SARS (2002)	774
6	H1NI-Swine Flu (2009)	575400
7	MERS (2012)	866
8	EBOLA (2014)	11300
9	COVID-19 (2019-PRESENT)	2.1400000

2 Pandemic Era Impacted Agriculture Quality

Twenty-five percent of the world's population is involved in the agriculture business, in that 25% of the people, 92% of the people are from Burundi, India, and 65% of the people are from Nepal. The highly populated countries in the world are China and India, in which only 25% and 42% of the people are dependent on agricultural lands [15]. Besides all these matters, the farm sector has faced many hurdles because of the COVID-19 pandemic. The lockdowns in countries have forced the people to self-solation, self-social distancing, and a ban on travel, leading to food security issues because the agriculture-related industries and factories are closed. The migrant workers, daily laborers, and the transportation halt have created a deficiency in the market [16]. Some of the crop production is weather dependent. Suppose there is a delay in harvesting the crops or planting the crops, which leads to less production, massive loss to farmers, and technical defect leads to the food crisis in rural areas. Fresh vegetables won't be waiting for the lockdown before they perish [17]. The world is going against regular food items. Many people are coping with zero hunger efforts on one side; on the other side, the COVID-19 pandemic is provoking the poverty of 22 million people [18]. Millions of tons of crops are destroyed by locusts and insects [19].

Once the national lockdown was announced in India on March 24, 2020, the Finance Minister in India announced and declared 1.7 trillion Indian rupee stimulus packages to protect the farmers and various sections of the society from the pandemic. The Rs 2000 Indian rupees were also credited to the Indian farmer's bank account under the Prime Minister Scheme. The Indian ministry also announced other grains and food allotments for laborers and farmers and even the creation of relief funds under emergencies. The Indian Council of Agricultural Research (ICAR) committee members issued the statewide measures during the lockdown time. The farmers' loan and crop money has been granted a moratorium for three months by the Indian banks. COVID-19 pandemic has significantly impacted India's farm economy because of the rabi season and crops like gram, wheat, and mustard, which are at the harvesting stage. Due to this lockdown, the rural and urban customers and middle-class people never visited any mandi or market to buy vegetables and crops. The migrant workers also travelled to their native places; without them, the harvesting operations and handling of crops, storage, and marketing center management came to a standstill. The transportation supply of vegetables, fruits, and food grains to the costumers in rural and urban areas is difficult for the government [20].

3 IoT Solutions to Agricultural Problems

In the tradional methods, the farmers work day and night on farming land for cultivation and has no knowledge about latest technologies such as usage of drone, scanning the crop to identify whether it is effected to any diesease or not. In the present day, at least millions of users are using the Internet. Still, the economy or industry has no idea whether the farmers are using smartphones supported by the Internet for its primary purpose. The agricultural companies in any country are not mostly dependent on rural farmers, and the major challenge is awareness. The research reports in top-tiered publications or journals mention that only 68% of farmers depend on IoT. Technologies such as Big Data, deep learning, and machine learning will be more challenging for crop diversity. The farmers need a proper training to handle the works in the agricultural area, which increases the agriculture economy and growth year-on-year. The estimated population of the world in the year 2020 will be around 850 crores, which means 850 crores of mouths need to be fed. This will significantly increase the market's money investment and demand farmers in the future.

Smart agriculture, also called precision agriculture, is the best solution for monitoring the crops in a pandemic situation. Technologies such as Big Data and IoT provide high efficiency to the society during the COVID-19 time. The effective method is precision agriculture, which helps monitor the crops, seeding the crops, water usage, and fertilizing them. The advantages of this method are the decrease in environmental impact and improvement in economic profit. In the early 2000, many farmers had used the precision agriculture method, but they faced high cost, possessed no knowledge about the equipment, and had less technological experience [21]. The precision agriculture method's prototype depends on the Internet of Things technology, Big Data technology, and sensors' cost. Smart control depends on monitoring, analyzing, and planning, as shown [22] in Fig. 1.

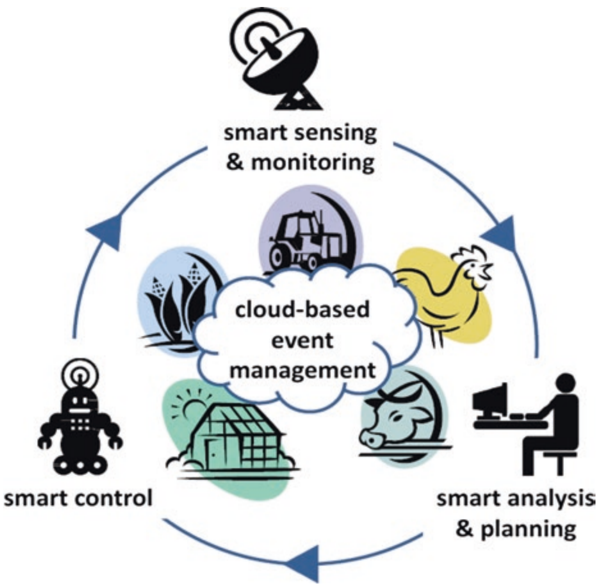

Fig. 1 Generic sense-model-act cycle

The IoT has many challenges to the farmers, that is, replacing the conventional methods with mechanical work types of equipment and systems. With these implementations, the food economy in the country has increased. The European Commission (EC) has initiated a project called the Internet of Food and Farm 2020 [23], which studies farming culture and food distribution activities in the European industry. The sensors will be able to monitor the climatic conditions and help in the smart greenhouse automation process. The crop requirement data are stored in cloud technology. The decision in farming for a single crop can be made using precision farming, which helps the farmers fertilize the entire field or single crop [24].

In this project, the main benefits of smart farming are explained. The architecture shown in Fig. 2 is classified into three types, that is, IoT, Future Internet platform (FI-ware)-enabled cloud platforms, and services offered. FMS is referred to as a Fleet management system, a real-world IoT cloud system. FMS is responsible for the management of the Fleet of electric vehicles in and around the world. Mainly, the cars are deployed in golf counties. The vehicles or animals, or houses are equipped with sensors, actuators, and data sources. The cars will communicate the data using Wireless fidelity (Wi-Fi) modules or fourth-generation long-term evolution (4G LTE) data through the cloud to the server. The monitoring of vehicles,

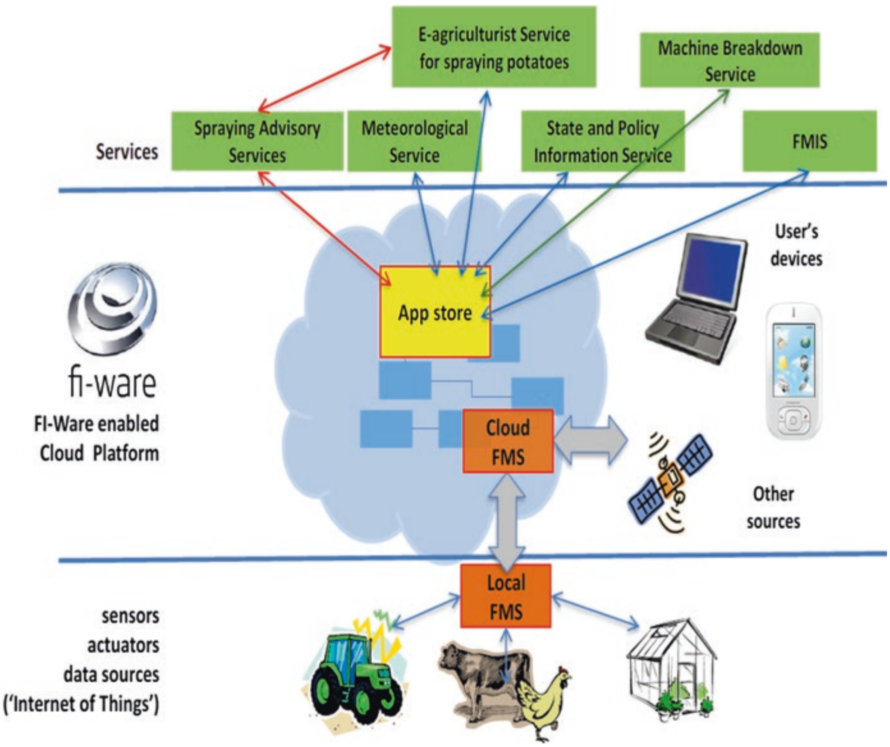

Fig 2 The architecture of the cloud-based platform that was envisioned in SmartAgriFood

remotely controlling the vehicles, and even diagnostics can be done using the FMS service. The cloud plays a crucial role in this architecture [25].

The FI-ware-enabled cloud platform‘s basic functionalities are classified into three types, that is, identity, compute, and storage services. The identity services are related to creating accounts, accessing the cloud portal, and mapping to the world's organizations. The second type of service is computed services where the security group is created to access the key pair to the virtual machine. The public Internet protocol is associated with the instance in the FI-ware lab cloud hosting. The third and final service is service-related—the services such as E-service related to agriculture, metrology, and advisory guidance to the farmers [26]. The new agricultural practices need to be implemented by the farmers, and they have to follow the rule of ADOPT, that is, Adoption and Diffusion Outcome Prediction Tool. This helps the farmers to predict the agricultural practices for new crop types, grazing options, etc. The ADOPT tool can provide information to researchers worldwide for undertaking projects for the development of the country's economy [27].

4 Unmanned Aerial Vehicle in Agricultures

In the upcoming generation, smart farming will reach the end of the world for every country. The UAV (unmanned aerial vehicle) plays a significant role in agriculture during the post-pandemic situation. The farmers need to be motivated to use UAVs in their farm fields. Most of the UAVs are monitored by remote control using radio waves. The technologies such as Wireless fidelity, ZigBee, and Bluetooth are also used for handling drones. Farmers can use the smartphone even to control the agriculture drone. The sensors play a significant role in drone architecture [28].

The drone is one type of aircraft that flies autonomously in the air without the pilot. But the motion of the drone is being controlled remotely by the operator. The drone architecture consists of sensors [29], and cameras that help in recording are shown in Fig. 3. They are commonly used in military applications, surveillance, agriculture, and disease detection. The advanced features include low maintenance costs, response time, acquiring cost, setup time, and live data capture. The UAV has a better option to farmers for monitoring crops, weed detection, sowing seeds, crop spraying, etc. [30].

In this chapter, the sensors which are suitable for smart farming are explored.

5 Location-Based Sensors

These sensors play a role in identifying different areas and spots in crop fields [31]. The farmers used these sensors during the life cycle of plants. These sensors play a vital role in monitoring the crops, fertilization, sowing seeds, and weeds' treatment.

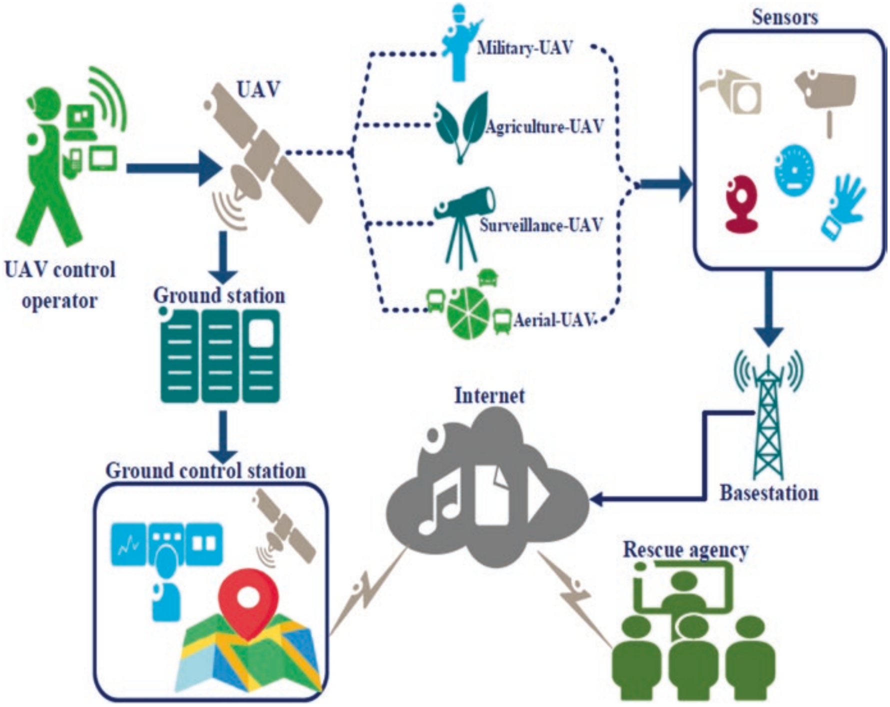

Fig. 3 UAV monitoring system

6 Electrochemical Sensors

The electrochemical sensors are used to extract composition from plants or soils. The electrodes in the sensor will detect the specific ions in the ground. Every soil has pH values between 3.5 and 10. In the high rainfall countries, the soil pH values will range from 5 to 7. These sensors can detect the pH levels of different soils [32].

7 Temperature and Humidity Sensors

The temperature and humidity play a critical role in weather conditions. Sensors help the farmers to monitor the levels of temperature and humidity in their field crops. These sensors are dependent on the battery and many types of temperature sensors are available in the market. These parameters will affect the health and growth of the crops [33].

8 Optical Sensors

Optical sensors work on the principle of converting the light rays into electrical signals. The sensors such as red green blue (RGB) camera, spectrometer, infrared camera sensor, etc., that is, all these sensors are being used in UAVs. The optical sensors can be classified into three types [34].

8.1 Visible Light Sensors

These RGB sensors are mostly used in precision agriculture. The human eye can easily recognize red color, green color, and blue color of light. The imaging sensor inside the UAV camera can capture the images, and it reproduces the same effects as in the human eye. The cost of these sensors is low, which helps the farmer capture the entire crop field's images in a single instance. These cameras help in the detailed analysis of agriculture [35].

8.2 Multispectral Sensors

In the multispectral image, the pixel contains more than three spectral points. These sensors are also called high spectral cameras, which capture more spectral points in a snap. These sensors play an essential role in the farmer's crop field. Even the researchers use them for high spatial resolution images for crop analysis. For precision analysis of the area, these sensors use multiple light bands to identify the diseased plants and to help in weeds' detection [36].

9 Thermal Infrared Sensors

The temperature of the object can be sensed with the help of thermal infrared sensors. The infrared sensors are mostly used in thermal cameras to capture any human beings' thermal energy. Based on the absolute temperature concept, the infrared radiation at a particular wavelength is identified and converted to a grayscale image. Farmers in the agricultural field can use this sensor to find the condition of the crop and soil. The maturity of crop harvesting and the detection of crop disease can be easily analyzed using this type of sensor [37].

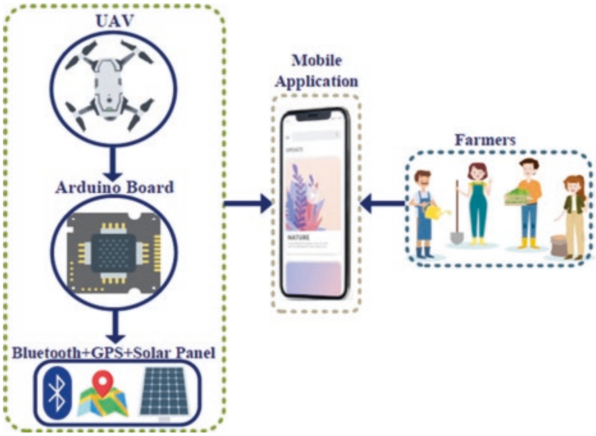

Fig. 4 Bluetooth, renewable energy-based UAV for agriculture

10 Bluetooth-Enabled UAV for Agriculture

The drones will operate remotely with visual contact of the operator. The importance of fertilizers in the cultivation fields is analyzed using this type of drone. The drone architecture is shown in Fig. 4.

The READ pesticide will spray on the field and reduce the human resources for the farmers. The farmers can control this micro drone with the android application by using the Bluetooth module. The aircraft operator will have preprogrammed paths using the global positioning system (GPS). The Arduino board will interface with Bluetooth and GPS with inbuilt programming. The stability and orientation of wings in the drone are managed by magnetometer and gyrometer. The high-energy efficiency can be achieved using solar energy. The solar panels will provide high additional power, and the flight time can also be improved. Moreover, the coverage area in the land is increased dramatically. The framework can be available at a low cost to the farmers. This drone's potential applications depend on monitoring, planting, spraying, and irrigation management [38].

11 UAV Agriculture Control System

The drone can be used in many applications such as irrigation of crops, spraying of pesticides, livestock management, and aerial mapping, as shown in Fig. 5. The future needs to integrate all the applications that help in the sustained ecosystem in reducing human labor. This architecture is shown in the above figure. The control system has to be integrated with the drone, consisting of sensors, simulators, and radio waves. The drone's hardware uses many sensors and software to monitor the

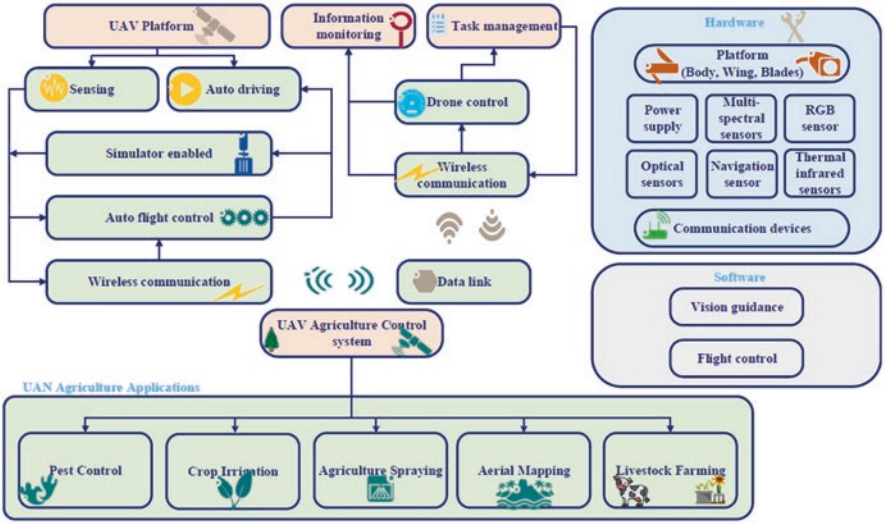

Fig. 5 Agriculture UAV system

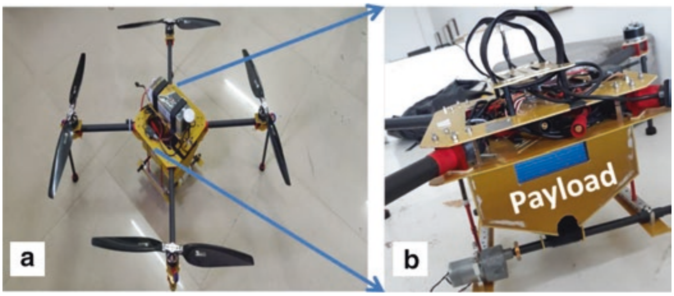

Fig. 6 Photograph image of the drone. (**a**) Complete design. (**b**) Cross-sectional view of payload

vehicle and track the drone movements. The above architecture will increase the agricultural economic condition of any country.

12 Design of UAV for Sowing Seeds

The drone's general structure was designed by using CATIA V5 software (Fig. 6a and b). CATIA is the product design software developed for creating the 3D design structure, computer-aided engineering, and manufacturing solutions. The complete installation was designed through CATIA V5 software, and the fabrication steps followed it.

Computer numerical control router (CNC router) is a computer-controlled cutting machine related to the handheld router used to cut various hard materials, such as wood, composites, aluminum, and steel plastics, and foams. Based on the design structure, the plate must be designed to fix the motors and external battery. The battery plate design and motor mount plate design were made using the CNC router, as shown in Fig. 7a and b.

After the plate design, the Arduino breakout board was made to control the application using PROTEUS software. Herein, the system used PROTEUS software to design the Arduino breakout board that can be used to program and control drone applications. Subsequently, the system was focused on the application part. Herein, the seed balls acted as a payload, and it plays the application role in the system. The conveyer belt performed the payload method. The conveyer belt system worked as a carrying medium of the objects shown in Fig. 8a and b. The conveyor has many types, such as gravity conveyor, belt conveyor, wire mesh conveyor, etc. In this mechanism, the motors are used to control the conveyer belt.

The soil material was used to prepare the seed balls, and the crop‘s seeds were covered completely by the soil. The soil material was prepared by a mixture of clay, compost, and coco peat. The clay helps to keep the seed balls healthy. The compost is a kind of fertilizer that is used to supply the essential nutrients to the plants. The coco peat helps to moisturize the seeds, and it creates the growing medium. The seed ball preparation is shown in Fig. 9. The seed balls' main advantage is to protect the seeds from the birds, insects, weather, miniature animals, etc., and impart a healthy growth to the plants without spoiling.

13 Requirements for Farmers to Implement Drone in Agriculture

13.1 Regulation of UAVs

The drone should follow the regulations set up by the Committee for the Application of Smart Agriculture. Many countries in the world are not operating drones because of various reasons. The committee, such as CTA (Technical Center for Agricultural and Rural Cooperation), has instituted drone laws to be used for agricultural purposes in the field. According to Article [39], 73% of countries, such as African and Pacific countries, do not use drones and have not satisfied the regulations. The committee in Europe called Electronic Communication Committee had laid down new laws, which are under review now.

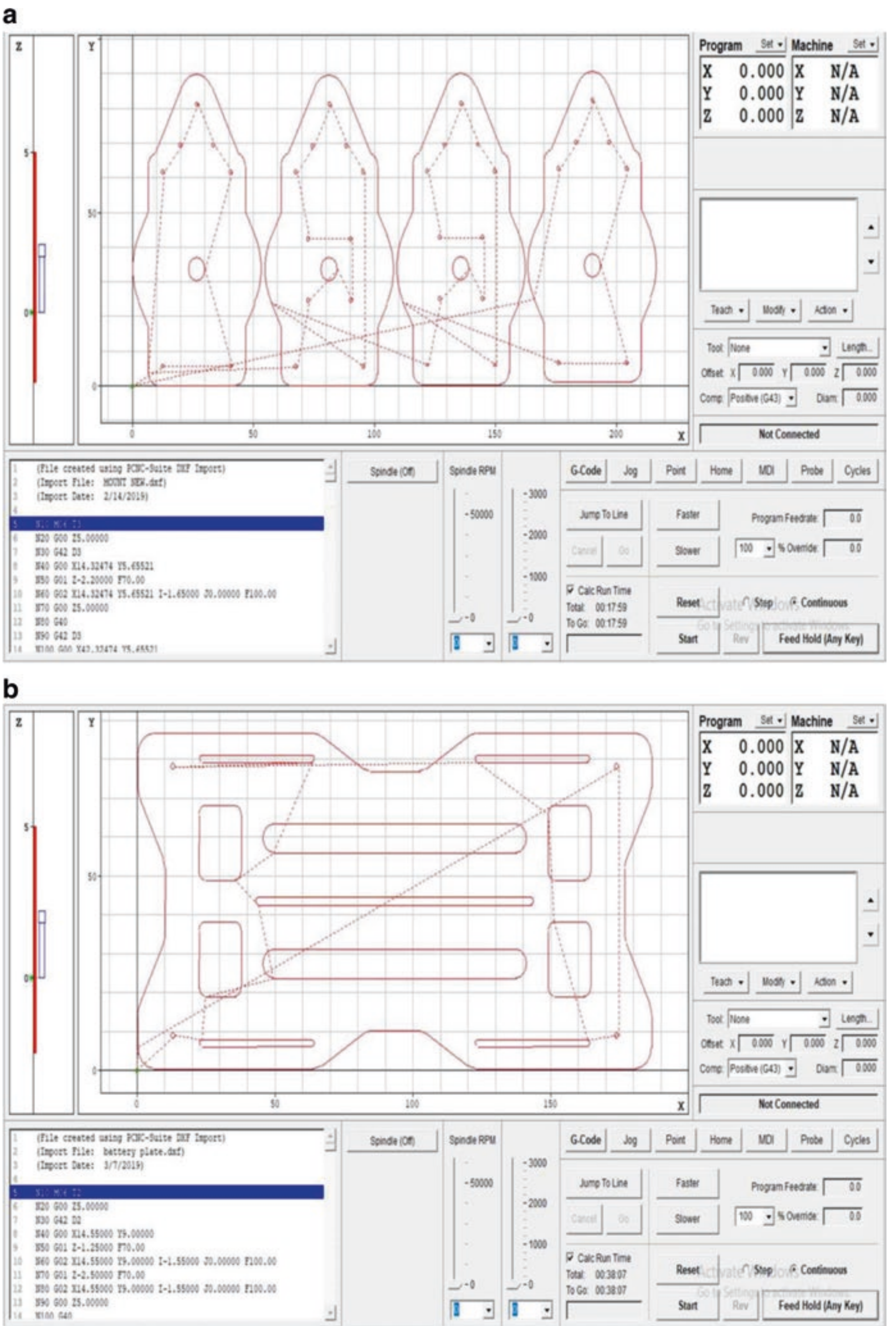

Fig. 7 Plate design using the CNC router. (**a**) Motor mount plate design. (**b**) Battery plate design

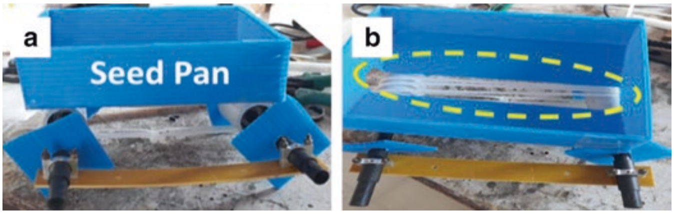

Fig. 8 Belt conveyor model for payload. (**a**) Seed pan. (**b**) Conveyer belt

Fig. 9 Seed ball preparation process. (**a**) Mixing of clay, compost, and coco peat. (**b**) Making seed ball. (**c**) Seed balls

13.2 Network Availability

The network availability is mandatory in any country. Although some of the drones are Bluetooth-dependent, a storage platform is needed for a strong Internet connection and a high bandwidth. Suppose there is a glitch in any mobile network during an application like smart agriculture, it has consequences for farmers. The upcoming fifth-generation cellular network can solve routing problems and has a strong Internet connection, and sending the data to the cloud to analyze plays an important role in deep learning algorithms [40].

13.3 Data Storage

The drone applications in precision agriculture need capturing high-definition images, log files extraction, and data acquisition, while the storage of data is inbuilt in the drone itself. The UAV is equipped with a capacity of 2GB to 4GB. One of the latest quadcopters, named DJI Mavic Air, has been released with an 8GB storage in the market. The data storage for UAV is cost-effective based on the cloud storage. A low-cost solution is required for farmers [41].

13.4 Security and Privacy

Security is needed for the drone to protect it from eavesdropping and denial of service attacks. The injection of information can affect the drone severely. The privacy concerns, such as images security, the spy documents-related concerns, need to be adequately addressed. Hardware attacks are common on any platform. The drone also suffers from seizures. Blockchain technology offers a potential solution for managing the drone's security and privacy concerns [42].

13.5 Low Efficiency and High Accuracy

Usually, the drone can fly up to 30 min with a single battery source. There are many precision agriculture applications, such as livestock monitoring, analyzing soil moisture, detecting weeds, and monitoring the humidity of crop cultivation. The drone's complex operations are aircraft duration time, high-resolution images, power requirement, and finally, the battery life. The farmers use robotic tractors in the field, which are connected to the drone. They even use them for irrigation and fertilization in less time frame. The inconsistency in the drone altitude depends on the angles of the sun [43].

13.6 Operational Ethics

Ethical issues are present even in drone usage. The evaluation of drone action depends on user regulations. The agriculture-based drone has no limitations in using them in the farm field. The use of drones and their data collection have more advantages for researchers and farmers worldwide [44].

14 Applications of Sensor Networks in Agriculture for Farmers

14.1 Smart Irrigation System

A keen water system is a fake water system application that controls the amount of water by settling on where water is required. It is the main constituent in agribusiness, which significantly affects harvests' well-being, cost, and profitability. One significant part of the intelligent water system is in evading water wastage since most nations face water shortage issues. A smart water system framework was introduced in [45], in which a Raspberry Pi was utilized alongside two sensors: a dirt dampness sensor that was used to survey the water level in the dirt. In contrast, a temperature and stickiness sensor was used to screen the natural condition. The Raspberry Pi was associated with these sensors and the water supply organization. A portable application was created for far-off checking; furthermore, a far-off water stream control empowered both manual and programmed water stream control. The water stream was naturally turned ON/OFF dependent on the dirt's water level without human intercession in programmed mode. In manual mode, the client had the option to screen the dirt dampness level. An alarm was created when the water level of soil was getting under a particular limit, and the client turned it ON/OFF utilizing a portable application. Force is a significant worry in IoT-based stages. Countless such scientists have created power-efficient frameworks. A force proficient water system framework was introduced utilizing sun-based force [46], in which the regulator was associated with the dirt sensor and water supply valve. The water valve was turned ON/OFF dependent on the water level checked by the dampness sensor. The sunlight-based board provided the force, so that the framework was free of any external force module [47]. The regulator controlled the opening and shutting of a solenoid valve dependent on the dirt's water level. What's more, a progression of climate alarms was shipped off the client through a versatile application to refresh the climate's temperature and dampness, which impacted the dirt's water level. In [48], an energy-productive water system framework for developed harvests was introduced, utilizing a remote sensor network. This framework assessed the amount of water required for a typical water system dependent on the stickiness, temperature, and wind speed gathered by sensors alongside accurate information (Fig. 10).

Fig. 10 Crop reflectance sensors are mounted on a high-throughput vehicle for a smart irrigation system

14.2 Smart Fertilization System

Compost is a counterfeit or regular substance with some compound components used to improve plants' development and profitability. Manual showering is a typical procedure utilized for preparation. Nonetheless, the ideal treatment method requires detecting capacities to locate the specific spot where compost is required, which compound segments are missing, and the necessary measure of manure. It is critical to give composts in an exact sum to improve profitability [49]. Scientists have introduced numerous preparation methods since the most recent decade utilizing wireless sensor network (WSN) and IoT. A computerized treatment framework was introduced in [50] using ongoing sensors to gauge the dirt fruitfulness—the framework comprises three modules: info, yield, and choice help. The choice help module estimated that the ideal measure of manures required for the plants' development depends on the sensors' continuous tactile information. A mechanical sensor named the "Pendulum Meter" was presented in [51], which was utilized for ideal preparation. The IEEE 802.11 Wi-Fi module was being used for correspondence alongside GPS. Constant information on soil was gathered by a few sensors, that is, soil dampness, temperature, conductivity, NO_2, and CO_2.

14.3 Smart Pest Control and Disease Detection System for Farmers

Irritation assaults are the primary driver of low efficiency in the farming area. These irritations bring about a few genuine illnesses in plants that influence the plant's development. Be that as it may, infection expectation gives early admonition to the ranchers, which empowers them to settle on fitting choices to control the illness on schedule. Bug control frameworks are included in electronic gadgets that enable people to recognize traps in a particular scope of these electronic gadgets [52]. These electronic gadgets are sensors fit for figuring the ecological boundaries for additional investigation.

Much exploration has been done in the agribusiness area for early sickness location and vermin control frameworks utilizing further developed and complex innovations [53, 54]. Various analysts have used numerous symbolism sensors to gather symbolism information, for example, RGB sensors, fluorescence symbolism sensors, ghastly sensors, and warm sensors [55]. The friendly sensors are utilized to gauge the plant's water status by estimating the temperature since this boundary impacts the plants' water level. RGB pictures have three shading channels, that is, red, green, and blue, which can be utilized to see the plants' biometric impact. Multi- and hyperphantom sensors catch pictures containing the spatial data of items in different wavebands. The spatial goal is reliant on the distance between the article and the sensor. That is why satellite pictures contain fewer spatial plans when contrasted with low elevation stages, such as drones. The fluorescence sensors are utilized to recognize the photosynthetic exercises in the plants. Different picture preparation methods are applied to this symbolism information to distinguish the infections in plants. In [56], the sensors, are planted in the cultivation land which observes climatic conditions such as temparature, dew, mugginess and windspeed. The sensors have been conveyed in plantations, and the information gathered from these sensors is shipped off the cloud. The rancher is educated about the disturbing state of the irritation assault on the harvests. From an alternate perspective, hyper-ghastly pictures are utilized to dissect yields' well-being and bug assault using monitored or automated vehicles on which phantom cameras are mounted. The caught images are examined top to bottom using artificial intelligence (AI) strategies to recognize the sickness in the plants. Advanced neural networks (ANNs) are more typical for preparing symbolism information because of their capacity to learn complex structures and examples.

For measurement decrease, Sammon's planning was utilized for multimeasurement scaling, that is, to lessen the measurement additionally for solo learning. For high dimensional information, measurement decrease is needed preceding performing further information investigation for better information perception and exactness, since excess measures lessen any information investigation calculations' viability. In [57], the soundness of wheat crop was checked, utilizing close to surface symbolism caught by an advanced cell. The yield was delegated reliably or undesirably depending on the green level by registering at the Global Health Council (GCC). A large portion of physician assistant (PA) applications has been either IoT-situated. Different sensors are utilized to survey the well-being of the yield or distant detecting strategy situated in which the crop well-being is evaluated by playing out some calculation on ghastly pictures. To exactly screen the harvest well-being, as proof of idea, we present a contextual investigation, in which the harvest well-being checking framework dependent on IoT and distant detecting strategies is proposed. We give a total start to finish arrangement in the agribusiness area by encouraging the rural client with web and portable administrations, so that he/she could be educated about the most recent state of the yield in an ideal way. This way, cure activities could be acted as expected, which will bring about upgraded creation.

15 Future Research Directions

In this chapter, a few difficulties faced by the Bluetooth-enabled UAVs (BLEs) for agribusiness are introduced.

15.1 Short Remote Range

One of the fascinating challenges lies in the short scope of a Bluetooth-based drone. As determined before, the most recent BLE adaptation's most recent extent is 100 meters, which is very low for many ranch lands. Nonetheless, accomplishing synchronization among expert and slave UAVs, limiting inactivity, accomplishing stable information move rate, and so forth are not many challenges that require dreary exploration endeavors [58].

15.2 Achieving Higher-Data Rates

There are various variants of BLE that are accessible, with Variant 5 having a hypothetical information pace of 24 Mbps, superior to its archetypes. There are a few applications in brilliant cultivation, for example, livestock checking, which requires a lot of higher information rates for information move. As additional progressions are coming in BLE adaptations, it is expected in future BLE renditions with a lot of higher information rates will be accessible. With a data center of only 24 Mbps, dynamic stockpiling of information into the cloud- or edge-based stages appears unrealistic [60]. A solitary picture from a superior quality camera utilizing area-based sensors is more than 24 MB in size. In this manner, to store various images in an ongoing situation on a cloud/edge-based stage isn't conceivable, except if and until higher information rates are accomplished [61, 72].

15.3 Interference

BLE utilizes the recurrence scope of 2.4 GHz. This reach is additionally used by Wi-Fi, Zigbee, and ordinary Bluetooth advances. Consequently, there is a tremendous danger of impedance and decreased idleness when the quantity of gadgets working on this recurrence rises. Because of the obstruction, the devices may get detached suddenly or perform ineffectively [62]. Even though ranch lands are distantly secluded in country territories where the chance of block is low [63], one of the standard methods of relieving impedance incorporates eliminating obstructions such as metal, concrete, glass, and so forth [64].

15.4 UAV Technology Acceptance

The accomplishment of any innovation relies on its client's acknowledgment. Variation and precise utilization of cutting edge and modern design like UAVs require aptitudes and information. The utilization of UAVs by ranchers with

Fig. 11 A quadcopter flies above crops to image them in Corpus Christi, Texas

restricted or no facilities is a difficult task [59]. Besides, sufficient acknowledgment of any innovation relies on the eagerness to utilize it by its buyers. High expertise necessities for flying UAVs by the ranchers with no or restricted flying aptitudes will likewise influence utilization enthusiasm [65]. Another factor that may influence UAVs' acknowledgment is to guarantee others' security while utilizing these UAVs. Ensuring others' safety and evading any lawful suggestion looked at because of security infringement may likewise upset these UAVs' acknowledgment in horticulture. Accordingly, it is challenging to support and persuade the ranchers to acknowledge the UAVs [66]. So, there is a need to plan and create powerful client acknowledgment models that recognize and give answers for convenience, eagerness to utilize, and guaranteeing others' security for fruitful transformation and utilization of UAVs in horticulture and to get full advantages from these cutting-edge, complex innovations. Figure 11 shows the UAV taking high-resolution images for crop monitoring. The drone data can also be stored in the virtual instrumentation server [67, 68]. The smart sensor networks play a crucial role in future trend applications, mainly in robotic automation, where the robots will provide a major contribution to the farm fields [69, 70, 71].

16 Conclusion

The purpose of smart agriculture is to increase the crop productivity for the upcoming generation. Many technologies play an important role in increasing the productivity, some of them being cloud computing, Big Data, and sensor networks. Machine learning and deep learning algorithms play a key role in analyzing the cloud data. This chapter mainly highlights the IoT architecture's capabilities post-pandemic in the real world and smart agriculture sensors' potential and challenges while integrating the technology with conventional farming practices. Sensors are mostly available for agriculture applications such as soil identification, crop status, pesticide detection, etc. The IoT technology that helps sow crops, packing, and transportation is broadly explained in this chapter. Furthermore, the unmanned aerial vehicle or drone usage is described broadly for applications such as surveillance of crop and crop yield. The types of sensors that are suitable for farming will be explained extensively in this subsection. The requirements of the UAVs and future applications of using drones in smart farming are broadly discussed. Finally, based on this chapter, the researchers can identify smart agriculture and farming's future trends. The case study based Bluetooth-enabled agricultural drone is explained broadly, which shows effectiveness in smart agriculture. Precision agriculture-based modern technologies enable farmers to use spraying resources and water supply in the farm field at any crop growth stage.

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Applications of Machine Learning and Internet of Things in Agriculture

Arij Naser Abougreen and Chinmay Chakraborty

Abstract With the rapid advancement of technology, people are passionate to get more intelligent living. Since agriculture is one of the significant industries that need to be developed in order to feed rapidly growing population. Thus, there is a need to support agriculture with technology in order to get the best yield. In recent years, automated field irrigation systems have been introduced to replace the traditional agricultural system. Lots of research have been carried out in smart agriculture. The intelligent agriculture is becoming one of the biggest applications of the Internet of things (IoT). IoT and machine learning have helped researchers to develop smart and reliable systems. There are many different systems such as crops irrigation system and crop health predication systems. These systems assist farmers to increase the productivity. The irrigation system can be categorized either manually or automatically. Manual irrigation needs a lot of time and effort. In comparison with automated irrigation, the automated irrigation system can conserve water and increase productivity because water is supplied only when it is needed with limited or no human assistance. Moreover, the plant may suffer from diseases, which negatively affects the yield. Therefore, it is necessary to identify the disease in the early stages and find an appropriate cure. Machine learning allows systems to learn and improve automatically from experiences. Hence, intelligence can be applied in interpreting agricultural data obtained and accordingly analyze data for predicting the output. This chapter highlights the work done in agriculture field using machine learning and IoT.

Keywords Machine learning · Internet of things · IoT · Agriculture · Manual · Automated · Irrigation

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1 Introduction

The World Bank has said that there is a need to produce 50% more food by 2050 owing to the continuous increase in the world's population [10]. It is expected that by the year 2050 the income will increase and thus the demand for food will increase especially in developing countries [11]. Therefore, attention must be paid to agriculture in order to double the production [10, 11]. Agriculture is not the primary profession of most farmers, but rather a secondary profession for most of them, and therefore they do not have enough time to care for crops. Thus, a system capable of saving time, resources, and effort on farmers should be provided [1]. The agriculture sector is very significant in India, as 60% of the land is devoted to agriculture and 50% of the population depends on agriculture and is a source of income for them [5]. Therefore, it is believed that the use of smart agriculture in developing countries will contribute to raising the yield while reducing human supervision [5, 6]. Crop irrigation is an important process in agricultural production and that irrigation can be manual or automatic. A disadvantage of traditional irrigation is that it requires time and effort, while automatic irrigation has the advantage of providing water only when needed and contributes to increasing productivity [2]. The need for fresh water increases with the increase in the population and as farmers consume a large amount of fresh water, therefore there is a need for a sophisticated system capable of optimal use of water [3]. Increased irrigation or decreased irrigation negatively affects the crop; therefore, an automatic irrigation system is necessary [8]. Crops may also suffer from diseases, and it is important to discover these diseases early [2]. In traditional farming, farmers often need to visit the field to have a good knowledge of crop conditions [11]. Many crops are constantly damaged due to the lack of appropriate conditions, which results in revenue losses, so farmers need to use technology and develop smart and effective systems that are able to monitor crops [4]. Smart farming can fight crop diseases and reduce chemical costly approaches [32]. The management of farms is difficult, especially when the geographical area is large [6]. Many people have lost interest in agriculture because it requires a lot of effort to take care of the crops [7]. IoT permits devices to communicate and share data with each other. This technology has a positive impact on our live [9]. IoT is now employed in different sectors and the agriculture sector needs to use this technology. To remotely monitor soil features, farmers need an IoT system which comprises all the web-enabled devices that gather, transmit, and act on data they obtain from their surrounding environment with embedded sensors, processors, and communication equipment. To know the soil information, several sensors are placed on the farm. Machine learning (ML) is a branch of artificial intelligence through which systems can be designed to learn and make decisions and predications based on the data [5]. The development of agriculture will contribute to the prosperity of the sustainable development of mankind and will also assist prohibit conditions such as famine and malnutrition. Smart agriculture must be available at an affordable cost for its effect to reach billions of individuals around the world [8].

This chapter is aimed to provide researchers a review of the applications of ML and IoT in agriculture. The major contributions of this chapter are as follows:

- It reviews applications of ML in smart farming.
- It reviews different types of IoT sensors for agriculture.
- It reviews IoT protocols for agriculture.
- It discusses the challenges of using IoT in agriculture.
- It reviews applications of IoT in smart farming.
- It reviews applications of merged ML and IoT in agriculture.

This chapter will empower the researchers to further work on ML and IoT in agriculture.

This chapter is arranged as follows: Section 2 discusses issues that faced farmers in the irrigation process. Section 3 presents applications of ML in smart farming. Section 4 reviews IoT sensors for agriculture. IoT protocols for agriculture are listed in Sect. 5. The challenges of using IoT in agriculture are discussed in Sect. 6. Sections 7 and 8 present applications of IoT in smart farming and applications of combining IoT and ML in smart farming, respectively. Figure 1 depicts the structure of the chapter.

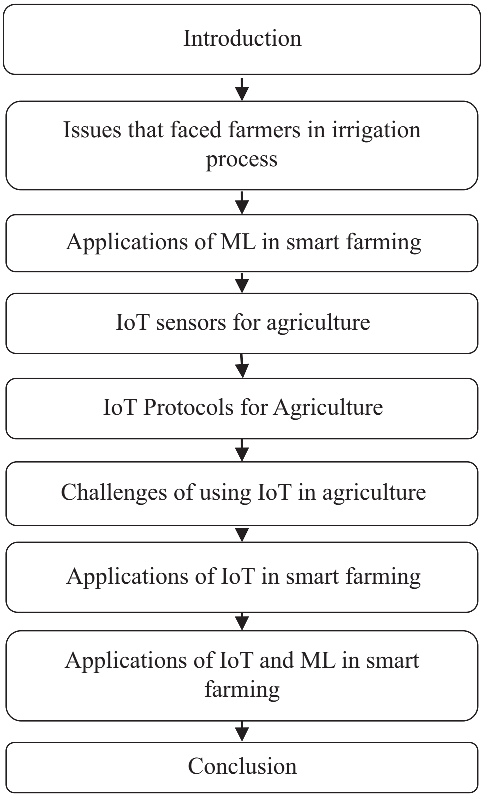


Fig 1 Methodologies for smart farming

2 Issues That Faced Farmers in Irrigation Process

Farmers have faced many problems such as insufficient supply and uneven distribution of water in rural areas. Large amount of water is used for watering crops and thus it becomes difficult to provide water to the villagers for other purposes. In addition, the forecast of precipitation is an important factor and the economy of several countries like India relies on it. However, farmers cannot predict the amount of rain owing to the lack of knowledge [12].

3 Applications of ML in Smart Farming

In this section, an overview of ML applications in smart farming was presented. Rajeswari et al. [13] proposed a smart farming forecasting system. To feed the system, 3000 datasets were used. Two types of data are needed, which are training data and test data. Training data are the survey data gathered in the period of 12 months, whereas test data are the current survey data. Feature extraction process was done to extract features like soil type, temperature, humidity, etc. Random forest algorithm was employed to predict the crop percentage that will grow in the type of soil in a period of some months. Fang et al. [16] proposed a system for determining the degree of disease of crop leaves using convolutional neural network (CNN). CNN is commonly utilized in image recognition. In this system, ResNet50 was used. The obtained accuracy was 95.61%. Ferentinos [18] presented a CNN model to detect and diagnose plant disease. The training was performed using a database of 87,848 images which contains different kinds of plants. The models were trained on both of plants with disease and healthy plants. The best achieved performance was 99.53%, which demonstrates that ML has the capability to detect and diagnose plant diseases effectively. Türkoğlu and Hanbay [19] have tested the performance outcomes via distinct methods of nine effective architectures of deep neural networks to detect plant disease. These architectures are AlexNet, VGG16, VGG19, GoogleNet, ResNet50, ResNet101, InceptionV3, InceptionResNetV2, and SqueezeNet. Transfer learning and deep feature extraction approaches were employed. The extracted features were classified using support vector machine (SVM), extreme learning machine (ELM), and KNN approaches. This study has been performed using disease and pest images from Turkey. The findings exhibit that deep feature extraction and SVM/ELM classification have achieved better outcomes than transfer learning. Furthermore, the fc6 layers of the AlexNet, VGG16, and VGG19 models have achieved higher accuracy scores than the other layers. Farmers do not have much knowledge about cultivation process which may lead to cultivating undesirable crops. Hence, smart prediction analysis on farming is needed to assist farmers take suitable decisions to achieve profitable and effective farming.

Shakoor et al. [25] used supervised machine learning techniques to analyze a static set of data of several crops in previous years and perform crop predictions.

This proposed system presents a list of cost-effective crops in a specific area via decision-making algorithms which are k-nearest neighbor and decision tree learning, ID3 (iterative dichotomiser 3) algorithms. Chung et al. [28] proposed an approach for detecting Bakanae disease in rice seedlings using ML and image processing techniques. The SVM classifiers were utilized to distinguish healthy and infected seedlings at the age of 3 weeks. The obtained accuracy was 87.9%. Barbedo [31] investigated the effect of dataset size and variety on the efficiency of deep learning (DL) and transfer learning for plant disease classification. Owing to the need of CNN to huge dataset with various conditions, appropriate image database should be constructed. Thus, database consisting of 12 plant species with various features and conditions have been used. It was found that using small image datasets leads to unwanted findings. The work of Durmus et al. [32] was aimed to detect diseases of leaves of tomato plant using DL. Two various DL network architectures have been employed which are AlexNet and SqueezeNet. Ten various classes involving healthy images have been employed. Trained networks have also been tested on the images from the Internet. Mohanty et al. [36] used DL to detect crop diseases. A dataset of 54,306 images of diseased and healthy plant leaves was employed to train the system to identify 14 crop species and 26 diseases. The obtained accuracy on test set was 99.35%. Rice is one of the most significant crops in China and all over the world. Rice diseases have a negative impact on productivity. Lu [37] proposed a new system for identifying rice diseases using CNN. The system was trained on dataset of 500 images of diseased and healthy rice leaves. The achieved accuracy was 95.48%, which is larger than other traditional ML methods (Table 1).

4 IoT Sensors for Agriculture

Different environmental parameters can be captured or monitored by sensors. There are various types of sensors which can be used in agriculture [23].

4.1 pH Sensor

It is employed for monitoring the precise amount of nutrients in the soil which is vital for watering. Based on the pH value, nutrients are provided to the crops for healthy growth [26, 27].

Table 1 Summary of ML applications in agriculture

Authors	Proposed technique	Advantages/accuracy
Rajeswari et al. [13]	ML	Intelligent farming forecasting
Fang et al. [16]	CNN	Identification of the degree of plant leaves disease
		The achieved accuracy was 95.61%
Ferentinos [18]	CNN	Detect and diagnose plant disease
		The best achieved performance was 99.53%
Türkoğlu and Hanbay [19]	Deep neural networks	Plant disease detection
Shakoor et al. [25]	Supervised machine learning techniques	Perform crop predictions
Chung et al. [28]	SVM classifiers	Detecting Bakanae disease
		The obtained accuracy was of 87.9%
Barbedo [31]	CNN	Investigating the effect of dataset size on DL for plant disease classification
Durmus et al. [32]	DL (AlexNet and SqueezeNet)	AlexNet has performed better job in classification of diseases of tomato leaves
		The obtained accuracy was 0.9565 and 0.943 for AlexNet and SqueezeNet, respectively
Mohanty et al. [36]	CNN	Detecting crop diseases
		The obtained accuracy was of 99.35%
Lu [37]	CNN	Identifying rice diseases
		The obtained accuracy was of 95.48%

4.2 Gas Sensor

These sensors are utilized for measuring the amount of toxic gases in greenhouses by monitoring consumed radiations [26, 27].

4.3 Soil Moisture Sensor

It is utilized for measuring the level of moisture in the soil [26, 27]. This sensor collects data of soil moisture and then transmits these data to the server in order to take the proper action according to soil moisture status [24].

4.4 Temperature Sensor

It plays a significant role in the productivity of yield. The changes in soil temperature influence soil moisture and the absorption of soil nutrients [26, 27].

4.5 Humidity Sensor

It is employed to measure the level of comparative humidity in air. Moisture negatively affects plant leaf growth, photosynthesis, and pollination [26, 27].

4.6 Motion Detector Sensor

It plays a very significant role at night. It can detect undesired movements such as theft or animals' movements and the farmer will be notified to take the proper action [26].

4.7 Barometric Pressure Sensor

It is utilized for measuring atmospheric pressure. Low pressure indicates the possibility of rain, while the chance of rain decreases when the pressure is high [26].

5 IoT Protocols for Agriculture

There are several IoT telecommunication protocols that can be utilized in smart agriculture. These protocols can assist farmers make an effective decision for smart agriculture to improve and observe the growth of crops [26]. The most commonly used protocols are:

5.1 IEEE 802.11 WIFI

IEEE 802.11 is a set of communication standards wireless local area network that is 802.11a, 802.11b, 802.11g, 802.11n, and 802.11ac [26, 41].

5.2 LoraWan

It is a low-range wide-area network protocol [27]. It was developed by a nonprofit association called Lora TM Alliance. The aim of this protocol is to ensure the interoperability between different operators [26].

5.3 WiMax

WiMax is a wireless telecommunication protocol that provides broadband multi-access connectivity which involves fixed, portable, and mobile communication [26]. It supports high data rates. It is appropriate to control and monitor various agriculture applications like crop monitoring and remote diagnosis of agriculture systems [27].

5.4 2G/3G/4G Mobile Communication Standards

There are several generations of mobile communication standards which are of 2G, 3G, and 4G. The communication between IoT devices is performed via these standards over mobile networks [26].

5.5 ZigBee

It is one of IEEE 802 standards which is established by ZigBee Alliance. It is a group of specifications for device-to-device network [26, 42]. It provides high-speed data transfer [27]. It is employed in applications which need a low data rate and long battery life. ZigBee supports various kinds of topologies such as mesh, star, and tree network topology [38].

5.6 MQTT

It is a messaging protocol in IoT which is a highly secure protocol [9, 26]. This protocol enables remote connections. It is a bandwidth effective protocol and utilizes small battery power. A cost-effective web-based IoT solution can be provided via MQTT for monitoring, tracking, and analyzing the agricultural data. Also, this protocol presents cost-effective irrigation system [26]. It is utilized for transmitting and receiving sensor information. Thus, it has solved the irrigation issue that it can control the water pump actions. It also sends the status of the water pump and the soil moisture condition to the mobile app of the user [27].

5.7 RFID

RFID assigns a different number to each object. RFID is composed of readers, host, and tags. Each tag receives and transmits radio waves. Tag is also named as responder. RFID tags are composed of active tags and passive tags which differ in shapes. Compared to active tags, passive tags are cheaper. Tags can be embedded or attached in many objects for identification purpose [26, 39].

5.8 Bluetooth

It is a low-power and short-range personal area network. This wireless technology is utilized for short-range mobile communication. Its working frequency range is 2.4–2.485 GHz. It is appropriate for applying in IoT agriculture systems owing to its advantages of low power consumption and low latency [26, 30].

5.9 SigFox

It is a low-power wireless technology. It utilizes ultra narrowband technology. It is employed for handling low data transfer speeds of 10–1000 bits per second, and can run on small batteries. Its transmission range is from 30 to 50 km. SigFox supports star network topology [38].

6 Challenges of Using IoT in Agriculture

There are several challenges which are related to implementing IoT applications [27].

6.1 Security

Low level of security may lead to loss of data. In agriculture field, there is a high risk that IoT devices can be attacked by animals [27].

6.2 Cost

There are several cost-associated problems like setup and running costs. Setup costs involve IoT devices/sensors, base station infrastructure, and gateways. In addition, running costs composed of continuous subscription for the administration of IoT devices and the trading of data among other services [27].

6.3 Insufficient Knowledge of Technology

It is the main obstruction for farmers who live in rural regions. Developing countries suffer greatly from this problem as the majority of farmers are uneducated. Thus, IoT implementation in agriculture is a huge challenge owing to the urgent need to train farmers before deploying IoT infrastructure [27].

6.4 Reliability

Deploying IoT devices is done in an open environment. Hence, severe environmental conditions may lead to communication issues. Thus, it is necessary to assure the physical protection of the deployed IoT devices/sensors to secure them from extreme climate conditions [27].

6.5 Localization

It is significant to choose the best deployment position which permits devices to communicate with each other and share data between them without any interference [27].

6.6 Inefficient Storage for Huge Farming Data

In smart farming, massive amount of data are generated from various IoT devices (sensors, camera, weather stations, etc.). In order to store this huge amount of data, a great repository is required. Generally, database is utilized for storing these data, but it is not adequate to deal with such a huge data [35].

6.7 Inefficient IoT Platforms

Existing IoT platforms are unable to ingest and visualize huge amount of real-time data. Also, these platforms cannot analyze this huge sensor data quickly [35].

6.8 Networking Challenge

Energy is consumed by sensors owing to huge performed computation and the battery power of sensor is limited. Thus, effective management of energy is required to maintain communication between various sensors in the network [35].

6.9 Resource Optimization

There is a need to optimize resources for measuring the number of IoT devices and gateways, cloud storage capacity, and volume of transmitted data. Owing to various farm sizes and factors, optimizing resources becomes difficult because various sensors and devices are needed to accomplish each task. Thus, complex mathematical model is needed to decide the allocation of resources for increasing productivity [26].

6.10 Quality of Service (QoS)

The capability to ensure that devices that require to send sensitive data are able to accomplish this task using IoT without any hindrance is one of the hot research issues that need to be solved [26].

7 Applications of IoT in Smart Farming

Ali and Padmapriya [14] designed a system to preserve the required soil moisture; it send data to the Arduino, which in turn supplies the plants with water based on the measured values so that no excessive irrigation or decrease occurs as it works as a control unit as well as the amount of water in the tank is sensed using water sensor. Information from the soil moisture sensors is continuously updated to the web page via the WIFI unit and when the soil is dry, an alert message is transmitted to the user. When the soil moisture values are less than the predetermined threshold value, the water is automatically pumped to the plants without human intervention (Fig. 2).

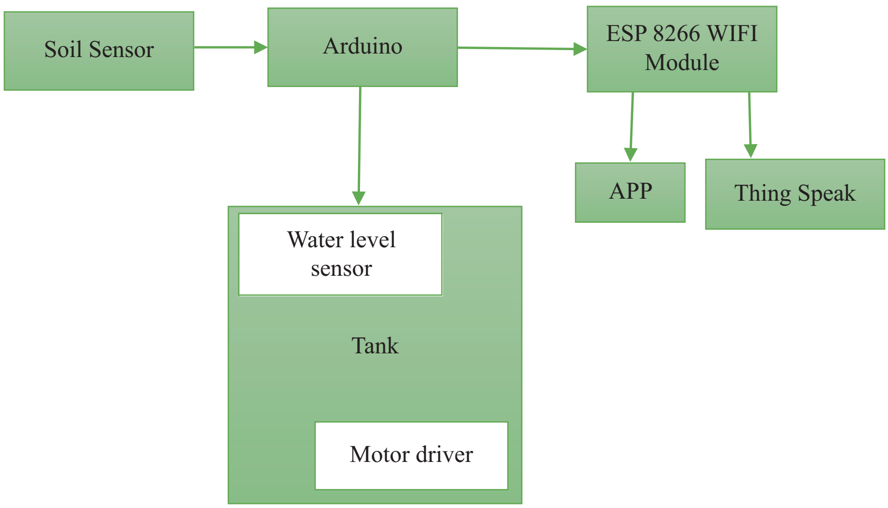


Fig. 2 Architecture of the system

Nóbrega et al. [21] presented an IoT-based stack for smart agriculture solutions, this system controls grazing sheep within vineyards. This system involves a wireless sensor network (WSN), a gateway, and a computational platform. WSN consists of mobile nodes to monitor the sheep and fixed nodes to monitor the plants and soil parameters. The findings exhibit that the gateway does not cause traffic congestion and it is appropriate and able to support the processing and timing requirements of the application.

There are two essential parameters that should be considered when designing an IoT system for soil moisture monitoring, which are cost and power. Heble et al. [22] proposed a cost-effective IoT system with low power for monitoring the moisture of the soil. Various sensors were used such as temperature, humidity, and light intensity sensors. Also, IITH Mote was employed for providing low-power wireless communication. This system has been tested and the outcomes have demonstrated that the presented system has on average 83% prolonged lifetime at a low cost.

Smart farming aims to increase the productivity and meet the increased population requirements [23]. It is also named as precision farming [24]. Ashifuddinmondal and Rehena [23] proposed a smart farming IoT system for monitoring soil's temperature and humidity. The measured values of temperature and moisture of the soil were stored in ThingSpeak cloud for future analysis purpose. Arduino board can control the agriculture devices based on prespecified threshold values of soil's temperature and moisture.

IoT provides accurate and effective farming [24]. Dagar et al. [24] presented a simple IoT architecture for crop management. In this model, sensors aggregate information and transmit it via Wi-Fi network to the server. Then, the sever can make any required actions based on this information such as watering process.

Arun et al. [33] proposed smart water management system using IoT. In this system, sensors are utilized to gather data from the soil. Also, watering action is decided based on threshold value. This system uses the filter to gather the water drained from the surface of the soil. The drained water is detected and gathered using suck motor for future recycling purpose. This recycled water is stored to use it later in irrigation process. Arduino was utilized as microcontroller for the system and Wi-Fi module was utilized for transferring the data from Arduino to the user. The information can be received via SMS or online broadcasting.

Low-power wide-area network (LPWAN) technologies support IoT applications in a superior conceivable manner [42]. Thus, these applications can conquer bandwidth, power, and coverage limitations which are major disadvantages in other wireless communication technologies. LoRa in LPWAN space offers additional benefits such as scalability, security, and robustness in implementing IoT applications. Kodali et al. [34] proposed a secure IoT system for monitoring the farm. This system has employed LoRa communication mechanism for sending sensor information from the transmitter node to receiver node. The receiver node was Wi-Fi enabled and it utilized MQTT services for monitoring the data in IoT platform and for storing the same data in the cloud. Figure 3 demonstrates the methodology of this system.

Singh et al. [38] proposed a system for smart irrigation appropriate for multicrop cultivation. In this system, sensors were used to aggregate data from each field. The aggregated data were transmitted to the cloud through master router. In the cloud system, integration of data was done to create field dataset. This dataset was compared to other datasets in the cloud. A data analysis process was conducted to find out the ideal values for the appropriate water requirements for each field. The best values were sent to digital pump and the automated valve was turned on and off according to the required amount of water. This system is effective and economic.

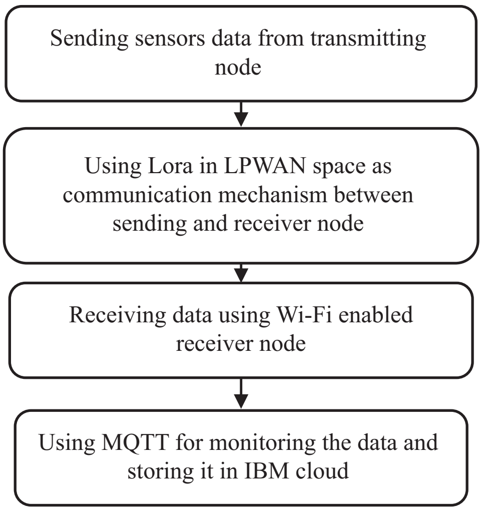


Fig. 3 Methodology of system

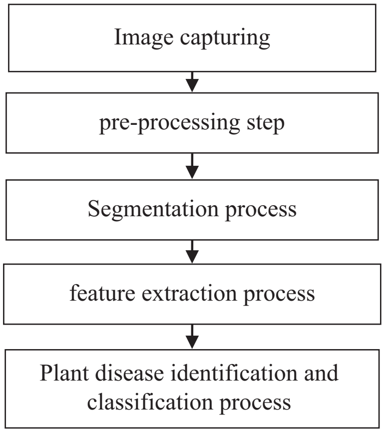
In addition, a mobile application was provided to assist farmers keep track of their fields.

8 Applications of IoT and ML in Smart Farming

IoT combined with ML was also used in smart farming. This section presents the recent solutions that were introduced for smart farming using ML and IoT. Abhishek and Rishi Barath [1] used an automatic system for smart agriculture, whereby through this system, agricultural crops suitable for cultivation are predicted based on weather and soil information, and this is done with the assistance of supervised machine learning. This system also performs automatic irrigation based on continuous monitoring of soil conditions during the growth of crops. These conditions include temperature, moisture level, and water level in the soil. Various sensors were used to determine the soil and weather conditions and then send these data through the multihop communication, which enables monitoring of crop health and irrigation control. Arduino UNO was employed to collect and transmit these sensor values to Raspberry Pi, which contains Apache web server and SQL storage database. The ZigBee module was employed to create a communication link between the sensor arrays and the server. Farmers can access the server to know the state of the field at any time and from anywhere, which saves effort and time. The server has performed various work after analyzing data on soil conditions, the most important of which is the irrigation process, as the server determines the amount of water required for irrigation after analyzing the daily water needs of the crop and the amount of water already in the soil. The server also controls the opening and closing of the valve of the automatic irrigation system and based on the daily water requirements of the water obtained from data analysis, the irrigation time is determined. The server also warns farmers if any of the interpreted data goes out of the required conditions. This project has achieved efficiency and precision in agriculture using IoT and ML.

In Nataraj et al.'s [2] study, plants were supplied with water automatically using a microcontroller (Arduino UNO). This method has the advantage that plants can be watered automatically even when we are on vacation without having to ask anyone to do the watering process. This device is characterized by the ease of learning using supervised learning. Arduino receives inputs from many sensors, then controls motors and solenoid valves. Image processing techniques have been used to detect plant diseases. As well as the necessary steps in the detection of plant diseases are as follows: the first step is the process of capturing the image followed by the image preprocessing that includes removing noise from the image and softening the image and enhancing it and other processes. Then the segmentation process is performed, followed by the feature extraction process and the plant disease identification and classification process. Figure 4 shows the steps to detect plant diseases. K-nearest neighbor algorithm (KNN) was used. KNN is a very powerful learning model. Configuration of KNN is a difficult process and it takes time to train, but once set

Fig. 4 Steps of plant disease detection



up, the app becomes very rapid. We also need first to preprocess training data and then train the system using the KNN algorithm so that it can predict whether the plant has any diseases or not. The data obtained by the sensors from the surrounding environment are sent to the cloud using Wi-Fi. During system design, the soil moisture threshold was set so that when the data sent by the soil moisture sensor reaches a minimum, ubidots send the farmer an e-mail and the water pump is started by a microcontroller. Ubidots is the IoT deployment platform where data obtained from the sensors is analyzed and displayed. The user uses ubidots via a standalone system for displaying and analysis and can also control the sensors. The system has provided a solution for agriculture using ML and IoT.

Most irrigation systems do not take into account forecasts of rain in making their decision to irrigate, which negatively affects the crop when it rains after irrigation, and therefore this is a waste of water [3]. Goap et al. [3] developed an intelligent and efficient system that is able to predict soil moisture based on the data obtained from the sensors in the field and weather information on the Internet. This project has proposed an IoT-based intelligent irrigation system along with a hybrid supervised and unsupervised ML-based method to predict the soil moisture. Support vector regression (SVR) and k-means clustering have been used to estimate changes in soil moisture owing to weather conditions. Figure 5 shows the predication and irrigation algorithms.

Farmers lose many crops annually owing to the absence of adequate conditions, so there is an urgent need for a smart system at a reasonable price that is capable to monitor crops and forecast the future status of the crop based on its previous state. A highly effective approach to ensure intelligent and economical agriculture was developed. The system is capable to measure the amount of water available in the soil in real time, revealing the level of humidity and environment temperature. When the amount of water or temperature/humidity in the soil or the environment is less than the predetermined threshold value, then warning message is transmitted to the user. The process of monitoring the crop is done through android app or web application. ML and IoT assist the system to water the crops and predict the health

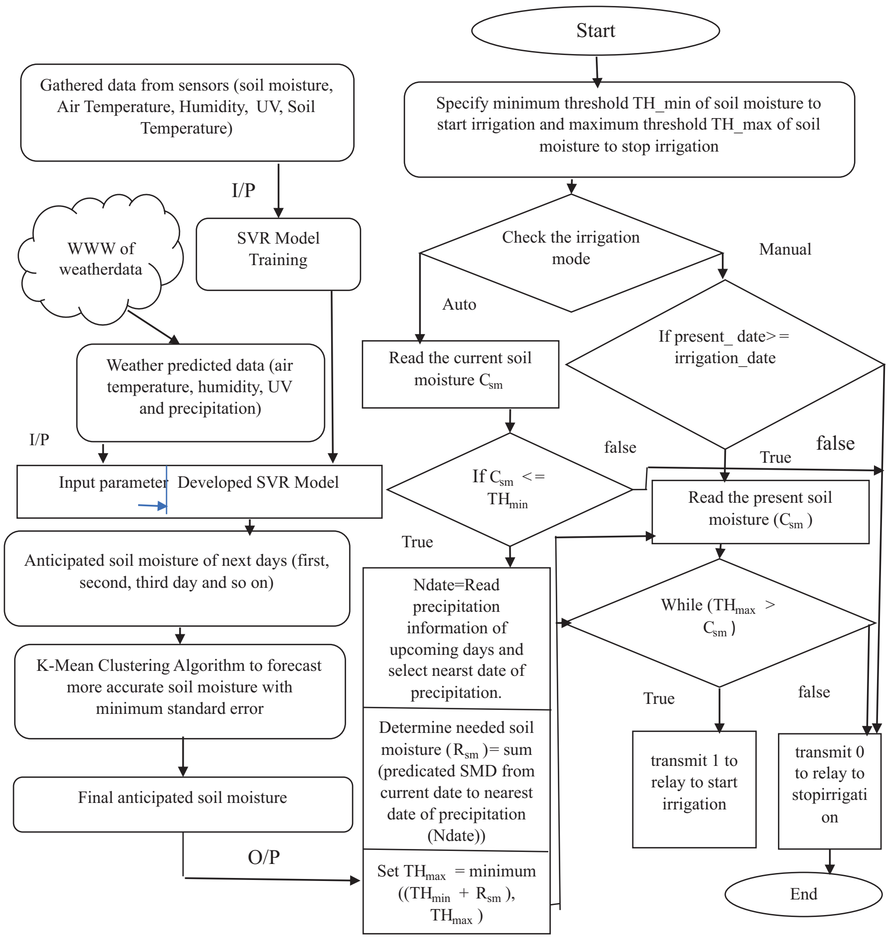


Fig. 5 Prediction algorithm with irrigation planning

of the crop. By using ML, the system will also be able to predict the type of the crop suitable for a specific type of soil and environment. A logistic regression model using TensorFlow has been trained whose inputs are soil condition, temperature, humidity, and crop that will be grown as inputs and predicts whether the conditions are ideal for this crop. In addition, SVM has been used which requires current soil conditions as inputs and proposes ideal plants for this soil conditions [4].

Syed et al. [9] used ML to analyze each of the crops that has been grown in the previous season, the nutrients that were used in the soil, the soil type, and the weather condition for the current season. Based on this information, the most appropriate crop for the soil, minerals and nutrients needed to be added to the soil is predicated. Smart irrigation has attracted the attention of many researchers. In this project, an IoT-based smart irrigation system was developed. The soil moisture sensor was combined with the Raspberry Pi to detect the soil moisture. A set of data was prepared, which was classified according to the level of moisture in the soil as low, medium, and high. ML was used to train the model to classify images in real time and determine if the plant was healthy and whether it needed watering or not. Classification process of the crops current condition is done using TensorFlow software and then a suggestion is made based on the information in recent years and the current season. With the necessity of checking initially the chance of precipitation within the next 24 h via an intelligent weather detection system. This method aims to protect crops from over irrigation. Thus, this leads to an increase in production. IFTTT (if this is after this) weather applet service was employed to gather weather information in real time from the nearest weather station. And in case of the possibility of rainfall for the next 24 h, a short message will be sent to the user and then the irrigation will occur [9]. Message queue telemetry transport (MQTT) protocol has been employed to connect devices at remote locations.

The work of [8] has proposed an economical method for automatic irrigation based on IoT. IoT and ML algorithms such as SVM and support vector regression (SVR) with radial basis function kernel assist in classification and predictions of soil type, crop kind, and amount of irrigation needed by the crops. This method depends on two kinds of microcontrollers which are Raspberry pi 3 and Arduino Mega. Using different sensors, the variable parameters will be continuously observed and irrigation appropriate to and particular to the kind of crop will be carried out [8].

Nawandar and Satpute [15] developed an affordable smart system for an intelligent irrigation. IoT was used to make devices used in the system speak and communicate on their own, with abilities such as supervisor mode for user interaction, one-time setup for estimating the irrigation schedule, neural-based decision making for smart assistance, and monitoring data remotely. The neural network offers the necessary smartness for a device that takes into account the input of the current sensor. The system uses MQTT and HTTP to inform the user about the current crop status even from far away. This work has proposed a farm observation and automatic irrigation system able to track the crop water needs, notifying the irrigation unit and user concerning it, giving real-time and history of farm data. It has also achieved an efficient usage of water with the assist of an automatic irrigation system for plants by taking into account the soil requirements.

Machine-to-machine (M2M) technology permits devices to communicate with each other and send data to server or cloud. Shekhar et al. [17] proposed an intelligent IoT system for automatic irrigation. The data are collected through moisture and temperature sensors. In this system, KNN ML algorithm was used to predict the soil condition based on training dataset. When irrigation is needed, the Arduino will operate the pump to irrigate the field. The predicted data are stored in the cloud server and farmers can access through their smart phones and know the status of the soil.

Aruul Mozhi Varman et al. [20] presented an intelligent agriculture system based on DL and IoT. This system can perform two functions, which are anticipating the appropriate crops and irrigating the field. Data of soil parameters have been gathered using WSN. The gathered data are transmitted to the cloud via gateway to

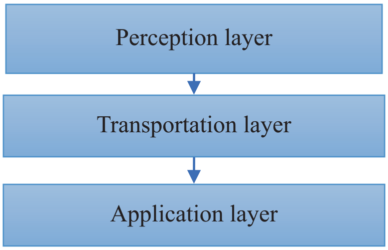


Fig. 6 IoT system layers in agriculture

analyze the data. The advantage of this system is that anticipating was done based on soil conditions of a fixed period of time and not for only one day as other systems. It was found that long short-term memory (LSTM) network was the best appropriate algorithm to predict the soil parameters for the year after the year in which this study was conducted. Based on the prediction, it was found that tomato is the best appropriate crop. The outcome is sent to the user via Twilio API. Also, if the soil moisture level is less than the required level, the engine will start until the soil moisture level reaches the appropriate level.

Gupta et al. [29] proposed a crop disease prediction system. This system is based on DL and IoT. The drone has been used to capture the images of the crops. Also, sensors were employed to capture soil moisture, salinity, and other data. The captured images were tested with trained CNN to produce the suitable prediction. The main challenge of this system is sensor damaging due to long time of using sensors which will lead to stopping the transmission of data from sensors. Thus, sensors must be checked regularly.

IoT supports precision farming. IoT system is composed of three layers involving perception, transportation, and application. Sensors act as the perception layer. The function of transportation layer is to deliver agricultural data via TCP/IP. Agricultural IoT is not quite the same as industrial IoT, since crop growth environment is complex and wireless transmission is seriously influenced by climate changes. Hence, special requirements are needed for the communication network. The application layer can provide smart management tool for crop production and processing [30]. Figure 6 shows IoT system layers in agriculture (Table 2).

9 Conclusion

IoT has proved its importance in all fields as it helps to make human life easier and more relaxed. As the world is moving toward new technologies, it is an essential goal for advancement in agriculture as well. With the increasing population and the need for food there is an urgent need to increase production. It is also necessary to increase the production of cotton, rubber, and other crops on which the economy of many countries depends. India is heavily dependent on agriculture. The traditional agriculture suffers from poor water management, resulting in a lack of production.

Table 2 Summary of combined ML and IoT applications in agriculture

Authors	Proposed technique	Advantages/accuracy
Abhishek and Rishi Barath [1]	Supervised machine learning (ID3 decision tree classifier)	The obtained accuracy was about 94%
	ZigBee for data transmission	
Nataraj et al. [2]	Supervised learning (KNN)	Automatic watering
	Wi-Fi	Saving time and water
	Ubidots	Effective water management
		Good result even with existence with noise
Goap et al. [3]	A hybrid supervised and unsupervised ML (SVR) and (k-means clustering)	Intelligent irrigation management
	ZigBee to transmit data from sensor node to gateway node	It provides a prediction for the required irrigation
	A Wi-Fi module or mobile data communication to send data from the gateway node to the server	The prediction of soil moisture differences using hybrid method has achieved better accuracy and lower MSE than SVR method
		The accuracy of prediction of soil moisture was 96%
Varghese et al. [4]	SVM	Cost-effective approach
		Smart farming
		(Prediction of the future status of the crops, monitoring the crops, watering the crops)
Syed et al. [9]	ML for analyzing purpose	Cost effective
	TensorFlow software was used to classify the crops present condition	Smart irrigation system
	MQTT	Prediction of the best appropriate crops for the soil
		Providing the amount of minerals required to be added to the soil
Vij et al. [8]	SVM and SVR with radial basis function kernel	Smart irrigation system
	WSN	Accurate solution to the farm requirements
		Effective method to classify and predict the soil kind, crop kind, and amount of irrigation needed by the crops
Nawandar and Satpute [15]	MQTT and HTTP neural network	Intelligent and effective irrigation system
		Cost effective
		Appropriate for green house, farms
Shekhar et al. [17]	KNN	It needs minimum maintenance
		Cost effective
		Smart irrigation system

(continued)

Table 2 (continued)

Authors	Proposed technique	Advantages/accuracy
Aruul Mozhi Varman et al. [20]	LSTM algorithm	Forecasting the appropriate crop for the next crop rotation
	WSN	Intelligent irrigation system
	Zigbee	
Gupta et al. [29]	CNN	Crop disease forecasting
		It offers good findings on large datasets
Bing [30]	Neural network	Crop monitoring
	4G	Notification of disease at early stage
	Bluetooth	Increase productivity

Hence, it is necessary to manage the water well. Farmers need to monitor crops without going to the field, so wireless sensors help farmers to collect data from the field quickly, and also assist discover any unwanted conditions. In addition, plant diseases have a negative impact on productivity. Thus, it is significant to detect diseases in an early stage. In this chapter, applications of ML have been discussed. It was found that ML has the capability to detect and diagnose plant diseases effectively. For plant disease detection, the findings have exhibited that deep feature extraction and SVM/ELM classification have achieved better outcomes than transfer learning. Furthermore, the fc6 layers of the AlexNet, VGG16, and VGG19 models have achieved higher accuracy scores than the other layers. Regarding plant disease classification, it was found that CNN can only learn the features exist in the training dataset. When test images differ largely from training images, the accuracy will be very low. To overcome this issue, a comprehensive training dataset should be constructed which is a challenging task. In addition, SqueezeNet is good candidate for the mobile DL classification owing to its lightweight and low computational requirements. In addition, this chapter highlights the applications of IoT in smart farming. It was found that, IoT can provide accurate and effective farming. Also, the application of ML and IoT together in agriculture has been presented. IoT and ML can provide solutions to current traditional agriculture issues in order to increase the productivity. With the help of these technologies, crop monitoring and effective watering management can be achieved. Also, irrigation needs can be predicted.

10 Future Scope

Advanced system can be designed to discover the type of soil and the kinds of seed from images. Also, some improvement is needed for detecting disturbances in the field because some birds or animals may damage the crops. In addition, smart farming system which can deal with unstructured data can be designed. Also, smart IoT-based irrigation systems can be improved to perform additional function which is deciding on spraying suitable chemicals for crops. Furthermore, more work is needed to build a comprehensive image training dataset with various capture conditions to be used in CNN for plant disease classification purpose. Moreover, water management system which has recycling feature can be designed in real-time land. Furthermore, implementing systems which has the ability to overcome challenges of using IoT in agriculture are needed. In addition, if pesticides and fertilizers are used in large quantities, it will have a negative impact on the soil and crops. Thus, there is a need for a system capable of controlling these quantities. Also, more research work is needed in the field of soil nutrient management.

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Automation, Modern Tools and Technique for Sustainable Agriculture – An Important Parameter Toward Advance Plant Biotechnology

Ritambhara, Shiv Kant Shukla, and Susmita Shukla

Abstract Recent study reveals that the world's population will land at 9.6 billion by 2050. Among challenges such as extreme atmosphere conditions and climatic changes, new innovation is addressing these troubles and assisting us to address the worry of improving food production. Throughout the world, mechanical developments have been brought into agribusiness functions in the late twentieth century, incorporating inventive technology with cultivation. Brilliant farming fundamentally depends upon advanced innovation that will decrease the actual work of ranchers and cultivators and consequently extend the productivity in every possible way. With the progressing cultivating designs dependent on agriculture, new innovation has brought monster points of interest like capable use of water, headway of wellsprings of data and some more. What made qualification were the giant favorable circumstances and which has gotten a disturbed cultivating in the continuous days. Web of Technology will improvise the agriculture by noticing the field ceaselessly. With the help of sensors and interconnectivity, the Internet of Things in Agriculture has saved the hour of the ranchers just as decreased the extraordinary usage of resources. Having unseemly data about climate estimate will overwhelmingly separate the sum and nature of the yield of the harvests. Notwithstanding, present day tech plans enable ranchers to understand the progressing atmosphere conditions. Sensors are set inside and outside of the yield fields. They assemble data from the atmosphere which is used to pick the right gathers which can create and uphold in the particular climatic conditions. Creative movements have almost changed the cultivating exercises, the Ground and Aerial robots are used for evaluation of reap prosperity, crop checking, planting, crop sprinkling, and field examination. We are

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living in a modern world with full of gadgets, the primary work of these is to help us and make our life more comfortable. Well farming is extremely important for humankind to grow, if we combine these two fields of technology and farming; one will get a tool to design and reshape the future of agriculture and farmers.

Keywords Smart Farming · Agriculture · Tools · Technique · Population

1 Introduction

With the growing population of the world, food production and cultivation need to be enhanced in term of production [1]. As per the UN Food and Agriculture Organization, "the world should deliver 70% more food in 2050" to satisfy the need; farmers and agrarian organizations should push their current practices as far as possible. Just as the Industrial Revolution increased levels of cultivation in 1800s, it is urgently required for bringing in advancements, innovations, and application of modern technology to have a similar impact on agrarian business in future [2]. This progress from farming to agritech has now became imperative if we guarantee to have food on the tables of everyone around the globe. Intense cultivation and precision farming include the mix of trend-setting innovations into existing farming practices so as to expand production efficiency and the nature of produce [3]. As an additional benefit, they also improve the personal satisfaction for farm laborers by decreasing heavy work and tedious tasks. Keen cultivation has been a much-studied topic among agrarian associations during the past decade. As the world ends up being more populated, the interest in food grows rapidly [4]. Ranchers are searching for ways to deal with increasing the capability of their endeavors, decreasing the biological impact, and mechanizing work in the field. In this setting, new developments offer answers for some challenges experienced by the business [5]. Today, executing advancement in cultivating goes far past purchasing new hardware with redesigned capacities. Such developments as systems administration, Artificial Intelligence, and GPS enable ranchers and agronomists to make food in a significantly more astute manner [6]. Appropriately, the reaction of agritech game plans is rising, and this example changes the business standards wherever they are employed. New advances open limitless doors for ranchers and associations working in the agrarian market. Here are the most notable front-line plans that are changing customary development [7]. If a developing business is to stay significant and genuine, it needs to turn be more insightful. The additional benefit of the modern tools and techniques need to implement to ease farm laborers' work by minimizing heavy and tedious tasks [8]. Innovation-based plans may improve the ranch's advantage, diminish costs, increment the proportion of convey and by and large lessening the regular impact. It is moreover an ideal opportunity for new organizations planning to enter the farming business to change their focus into this present reality. Farmers

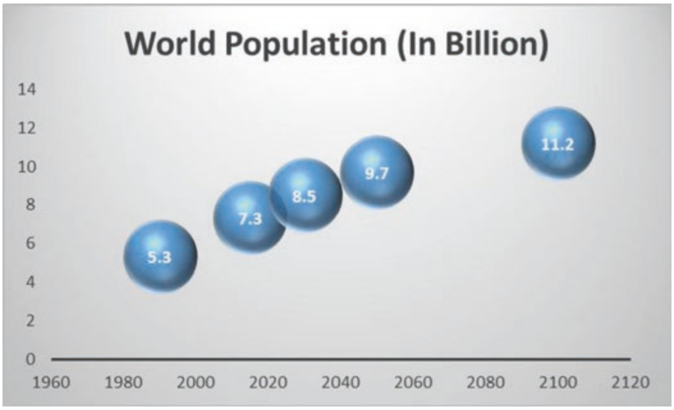
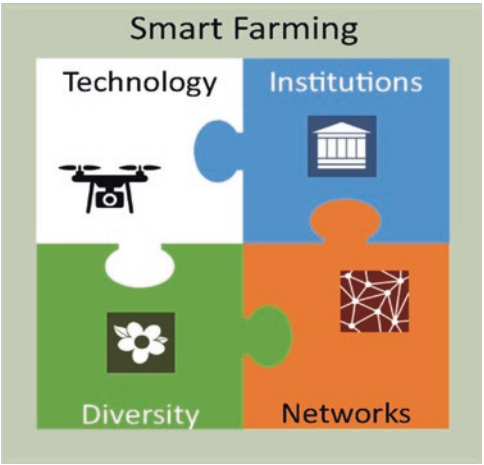


Fig. 1 Trend of Increase in world population from 1990 to 2100

Fig. 2 Smart farming is a result of combination of technology, Institutions, Diversity and network



need innovation-associated agriculture for now and the future. Such applications incorporate farm vehicles, animal monitoring, and storage checking. The coming years will see the expanding utilization of these brilliant advancements in cultivation and other agricultural applications. [9] (Fig. 1 and 2).

2 Hydroponics

Current agribusiness is in an opposition. Ranchers need to grow more things in soil that is breaking down, on land that is decreasingly available, and amid continuing atmospheric change. New developments empowered ranchers to screen their

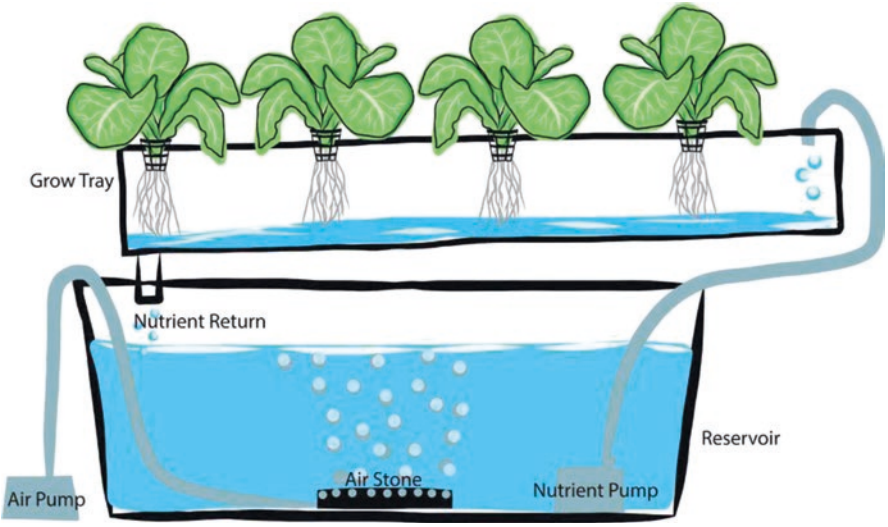


Fig. 3 Diagrammatic representation of hydroponics system

process of plantation and conditions continuously. They quickly acquire knowledge and can anticipate issues before they happen and make informed decisions on the most ideal approach to avoiding these issues. At the point when we have nine billion people on the planet, 70% of them will live in metropolitan areas [10]. Hydroponics empowers food production gracefully and faster and should be able to take care of these individuals. Savvy shut cycle rural frameworks permit developing food basically everywhere in markets, on high rises' dividers and housetops, in steel trailers and, of course, in the solace of everybody's home [11] (Fig. 3).

3 Plant Sensors

The sum and nature of harvest yields have consistently relied upon various variables ranchers could barely quantify or control [12]. Be that as it may, innovation is making a huge difference. "Smart" sensors set in the fields can screen the temperature, mugginess, barometric pressure, and other significant markers that sway the soundness of a plant [13]. Simultaneously, a worker side stage can dissect this data [14], assisting ranchers with figuring the measure of compost they need and take some preventive measures if needed [15]. In addition, crop-observing frameworks controlled by manmade consciousness take into account prescient investigation that offers ranchers a chance to settle on information-driven choices [16] (Fig. 4).

Fig. 4 Smart Plant sensors useful in giving various plant updates like requirement of light, water etc.

4 Atmospheric Conditions

One of the benefits of utilizing technology in agribusiness is the expanded flexibility of the processes [17]. Thanks to constant observation and forecast frameworks, farmers can rapidly react to any critical change in atmosphere, clamminess, air quality similarly as the prosperity of each collect or soil in the field. In the conditions of exceptional atmosphere changes, new limits help cultivation experts save the harvests [18]. Atmosphere stations furnished with shrewd sensors can accumulate atmospheric data and send valuable information to a rancher. Also, the information is explored by special programming and the rancher gets assessments that provide information to prevent crop misfortunes. For instance, this will help farmers in climate conditions which alert the early cautioning of outrageous temperatures, ice, and storms on their homestead fields. Notwithstanding sourcing natural information, climate stations can consequently change the conditions to coordinate the given boundaries and to give the most fitting condition to each greenhouse [19]. Some greenhouses are likewise an intriguing item that utilizes smart agriculture sensors such as sprinkler regulators that permit farmers to deal with their water system and lighting frameworks distantly [2].

5 Yield Checking

Information-driven agriculture enables the development of more and better things. Utilizing soil and yield sensors, robot noticing and ranch arranging, ranchers better comprehend circumstances and conditions affecting harvests [20]. Using associated frameworks, they can imitate the best conditions and addition the dietary advantage of the things. These factors can thus facilitate higher yield. Owing to checking of atmospheric condition, sensors for crop condition moreover assemble all data like gather prosperity, sogginess, precipitation, temperature, and various limits such as extreme atmospheric limits which a crop can withstand. If there are any deviations, ranchers may recognize them ahead of time and make reasonable moves. These new sensors will assist farmers and will notify exactly when to start sowing and harvest crops [21]. This will help farmers to anticipate for observing harvests, provides farmers with controller of atmosphere and infection checking.

6 Domesticated Animals

Technological applications help farmers to gather information with respect to the location (a farm or any animal husbandry), prosperity, and reliability of their cattle. This data enables them to recognize the state of their domesticated animals [22]. For example, they can disconnect weakened creatures from the group and thwart the spread of an illness to the entire herd. The ability of ranchers to manage livestock with the help of innovation-based sensors helps in reducing expenses. Ranchers can also utilize technology such as insight neck collars for bovines, for managing dairy ranch tasks in their homestead [23]. Nonintrusive systems solidify dairy science, by monitoring significant information such as temperature, development (healthy growth parameters of cattle), rumination, and lead for any wellbeing alerts, sickness results, estrus ID, and feed headway [24]. Devices for observing steers come in various configurations, similar to central processor inserts, collars, ear labels, etc. [25]. These devices can gauge the animal's internal heat level, impart signs to a veterinarian if something isn't right, and tell ranchers when the bovine or sheep is ovulating [26]. Thus, ranch laborers can without much of a stretch discover lost steers, eliminate a wiped-out animal from the group as expected and estimate the animals' birth rate [27]. Every one of these elements can alleviate significant dangers related with raising steers and fundamentally increment the homestead's benefits [28].

7 Drones

In smart farming, drones can be utilized to examine fields and sprinkle pesticides. Robots can be used with different imaging progressions like hyper-ghostly, multi-spectral, warm, etc. that can outfit the ranchers with time and site-explicit data about wellbeing, contagious diseases, development of crops, and so on. Drones can likewise recognize drier locales in a field and measures can then be able to be taken to manage such regions with better strategies [29]. Exactness in agriculture gives farmers concrete information that empowers them to make educated choices and use their assets more efficiently. Many agribusiness drones can cover multiple sections of land in a single fight for incredibly efficient crop observation and examination. The improvement of the agriculture area will consistently be needed, particularly given the elements of the present reality. In this way, utilizing technology in agriculture has a promising future as a major impetus of efficiency, sustainability, and adaptability in this industry [30]. Overriding human work with automation occurs in many ventures, and agribusiness is no exception. Most pieces of developing are remarkably work raised, with a considerable amount of that work included monotonous and standardized endeavors an ideal claim to fame for mechanical innovation and advanced mechanics. There are some green robots which show estates and performing tasks going from planting and watering, to social event and organizing. Eventually, this new convergence of sharp equipment will make it conceivable convey more to and more great food with less work. Robots furnished with cameras would now have the option to make similar pictures at a limited quantity of the cost, which was created by enormous machines. In like manner, advances in imaging developments suggest confinement to recognizable light and still photography [31]. Cameras can provide everything from standard photographic imaging, to infrared, bright, and considerably hyper-phantom imaging [32]. These cameras can record video which are available in drones. Picture objective across all these imaging methods has extended as well, and the assessment of “high” resolution with “significant standard” has been introduced in order to enhance the quality of image. These diverse imaging types enable ranchers to accumulate more clear data than ever before, improving their capacities for observing harvest prosperity, assessing soil quality, and planning planting territories to propel assets and land use [33]. These all can be done with the help of high-quality drones. These will have the choice to utilize these field reads, improve courses of action for seed planting, water system management, and zone arranging in both 2D and 3D, which a drone can assist from every angle. With this data, ranchers can upgrade each piece of their property and harvest the board. In any case, it isn’t just cameras, and imaging capabilities having a robot helped impact in the cultivating circle drones are similarly noticing use in planting and sprinkling as well [34]. Because of these drones, the tedious job of a farmer can be made easier which is very tough to be done manually. There are also meanders at present open and being developed for crop sprinkling applications, offering the occasion to robotize one more serious undertaking. Using a mix of GPS, laser estimation, and ultrasonic arranging, crop-showering robots can adjust to height and territory adequately, changing for factors such as wind speed and geology [35]. This engages the robots to perform crop-showering endeavors even more effectively, and with more prominent exactness and less waste [36]. For example, a robot which is arranged explicitly for rural yield showering, with a tank breaking point of 2.6 gallons (10 l) of liquid pesticide, herbicide, or fertilizer, and a battle scope of seven to ten areas of land for consistently [37]. Microwave radar enables this robot to keep up right great ways from the yields and guarantee even consideration. As ranchers profited by it and can see it working normally, self-loader or manual.

8 Driverless Tractors

The work vehicle is the core of a farm, utilized for different assignments relying upon the sort of homestead and the configuration of its subordinate hardware [38]. As independent driving innovations advance, farm trucks will probably be the machines to be changed over earliest [39]. In the beginning phases, human effort will in any case be needed to define up field and limit maps, program the best field paths using a way arranging program, and choose other working conditions. People will still be needed for regular repair and upkeep [40]. As indicated by some industrial partners in 2016, "later on, these idea farm vehicles will have the option to utilize 'huge information, for example, genuine time weather satellite data to naturally utilize ideal conditions, free of human input, and paying little mind to the hour of day." This is a modern time where we are living with so many gadgets for fun and easy living. These machines will help us to build a sustainable and eco-friendly world for future generations. The driverless tractor is best for farmers and will help them to solve many problems, assist in time management for different crops, and help to manage farm functions. There are some prototype samples still available in the marketplace and many are in production and will someday make life and work easy, sustainable [41], and free of waste.

9 Customized Watering and Irrigation

Subsurface Drip Irrigation (SDI) is as of now an inescapable water framework methodology that licenses ranchers to control when and how much water their yields get. By coordinating the ranch structures with dynamically refined innovation engaged sensors to consistently screen clamminess levels and plant prosperity, ranchers will have the choice to act at vital moments, in any case allowing the system to work in a self-governing modality [42]. While SDI structures aren't really mechanical, they could work absolutely independently in a smart estate setting, depending on data from sensors around the fields to perform water framework shifting [43].

10 Effect of Modern Agriculture Techniques

Agribusiness-heightened developing, natural cultivating, and efficient cultivating are various pieces of present-day farming which are described below. The upgrade of hardware had denoted their essence in current agribusiness as different sensors and analyzers utilized in field and nurseries. The rundown of instruments and hardware that help this area is colossal, but can be characterized into different classes for ease of understanding.

Hardware: There are different sensor intensifies like pyranometer (measures daylight) or soil analyzer which assist the farmer with understanding the inadequate or overabundance component and mechanical technology to help some assistance. Modern day apparatus with various abilities can supplant work assignments and make it more simple, modest, and safe. With decreased reliance on synthetic specialists, the provisions will in general be fresher and more beneficial, which certainly is sought after because of medical advantages and simple accessibility. Likewise, the requirement for concentrated work and water system is radically diminished simultaneously while yield from farmland is shockingly expanded.

Fortunately, there is artificial intelligence and enough figuring capacity to make up for this deficiency. For instance: With GPS work vehicles, furrowing a field is simple and requires little manual intercession. Sunlight based fields that produce power synchronous assistance in the development of plants that need conceal. Programmed water sprinklers supply water when moistness diminishes and the soil goes dry. So, dealing with a small farm without any assistance with present-day horticultural advancement is simpler than at any other time.

It is clear that advanced agribusiness helps boost the yield to increase the benefit. Aside from that, however, the significant advantage for everybody is manageability. In this cultivating practice none of the methodologies are damaging or comprehensive, hence securing the prolific dirt, preserving water, regular assets are productively used lastly keeps the produce solid and new. In current cultivating, it is tied in with tuning in to plants on what they need, to such an extent that you don't squander assets. Step by step, new advancements are being brought to the market. All it requires is for somebody to pick the correct innovation and acquaint it with the cultivating. With long periods of study and exact designing, a field can be transformed into a research center that delivers the most characteristic and solid items. It is about the utilization of most recent tech into farming practice like sensors for perusing plant vitals, GPS for mechanization of hardware, water system enhancement utilizing programming examination, and so forth. Likewise, banks, investors, and funders are edified about this developing field of cultivating and are prepared to invest in it. It is an ideal opportunity to take a different approach from regular practice as more guidelines are being executed with respect to the utilization of composts and pesticides in cultivating after different investigations referring to their unsafe impacts.

The fundamental realities are clear: All over the world, more individuals eat more and better as a result of present-day agriculture. Expanded creation keeps on empowering and consistently improving weight-control plans, reflecting expanded accessibility, dietary variety, and admittance to high-protein food things. The current agriculture problems and nonavailability of food in different regions reflects powerless methodologies, low productivity, and lack of sources. Failure to continue applying new advances to drive benefits on the ranch and across the food structure just breaks down each piece of these issues, especially those that have an impact on individuals and families who live in poverty. To an outstandingly gigantic degree, current food vulnerability issues reflect horrendous courses of action, defenceless system, and low monetary effectiveness in the nations where these conditions occur. It is needed to improve the agriculture conditions by modern tools and technique and make it automatic so that required food can be arranged with the increasing population. The huge appetite and ailing health that persevere in numerous parts of the world would have been far more regrettable had rural frameworks not developed as they did. The actual weights on the climate that have become progressively conspicuous public concerns have been incredibly enhanced by present-day agribusiness, which has decreased. The need to extend land territory, and along these lines decreased strain to develop delicate terrains and forested zones.

Modern farming incorporates fruitful new innovations, including biotechnology to empower both more significant returns and diminished natural effects. These decrease the land, manure, and pesticide use per unit of yield. They reduce tension on meadow, forestland, and cropland, consequently expanding living space for untamed life. Preparing innovation and dealing with headways contribute greatly to improved sanitation through decreases in microbes and post-reap misfortunes that further damage food supplies. Sanitization of milk, canning, freezing, and other preparations advances fundamentally diminished wellbeing chances related with food. Dangers from microbes and different foreign substances are significant, but the dangers of disease and demise are far lower than previously, a reality that is broadly overlooked.

11 Agribusiness

It is the matter of rural creation which includes the assurance, deals and advertising of the item to fulfill the client's need. It incorporates agrichemicals, duplicating, crop creation (developing or agreement developing), movement, ranch equipment, taking care of crops, and seed supply, similarly as promoting and retail bargains. All experts of the food and fiber regard chain and those foundations that sway it are basic for the agribusiness structure. Inside the cultivating industry, "agribusiness" implies the extent of activities which are joined by current food creation. There are academic degrees specializinig in commonsense involvement with agribusiness, divisions of agribusiness, agribusiness trade affiliations, and agribusiness dissemination. Agribusiness is helpful for farmers in the modern era. The old traditional farming methods are good, but if incorporated with new tools and techniques, farming becomes easy and more profitable. Subsequently, it is routinely wandered from more unobtrusive family-had ranches. As stress over an Earth-wide temperature increase elevates, biofuels derived from crops are getting extended public and coherent thought. This is driven by components such as oil cost spikes, the necessity for extended energy security, stress over ozone hurting substance surges from oil-based commodities, and support from government sponsorships. In Europe and in the US, extended assessment and production of biofuels have been directed by law.

Investigations of agribusiness regularly come from the scholastic fields of horticultural financial matters and the thorough inspection to determine the quality, in some cases called agribusiness management. To advance greater improvement of food economies, numerous administration offices uphold the examination and distribution of monetary examinations and reports investigating agribusiness and agribusiness research. A portion of these investigations are on nourishments created for send out and are gotten from organizations zeroed in on food trades.

Agriculture tends to be established on a perception of climate organizations. There are various procedures to grow the practicality of agribusiness. While making agribusiness inside a sensible food systems, it is basic to make a versatile business cycle and to develop business practices.

There is a discussion on the meaning of maintainability with respect to agribusiness. The definition could be portrayed by two unique methodologies: an eccentric approach and a technocentric approach. The eccentric approach stresses no- or low-development levels of a human turn of events, and spotlights on natural and biodynamic cultivating strategies with the objective of changing utilization examples, and asset designation and use. Two different approaches to maintain and update agriculture is shown here: one is eccentric and the other is technocentric. In eccentric, the proper use of natural resources in agriculture is suggested, and in technocentric, the modern techniques and tools are used to help agriculture.

The main elements for a cultivating site are atmosphere, soil, supplements, and water assets. Of the four, water and soil protection are the most agreeable to human intercession. At the point when farmers develop and gather crops, they eliminate a few supplements from the soil. Without recharging, the land experiences supplement exhaustion and turns out to be either unusable or experiences decreased yield. Agribusiness and cultivating are the absolute most established and most significant callings on the planet. Since the start of humankind, our predecessors found that agribusiness, in its previous structure back in that time, was their primary wellspring of food. From that point forward, agribusiness has made some amazing progress by the way we cultivate and develop crops because of various advances.

However, it appears to be that mankind is moving toward food issues that will severely test us. Most important, we are as of now managing heaps of ecological worries that cause specialists to accept that the fruitfulness of soil is quickly diminishing. What's more, clearly, this will have a major effect on food production. Also, it is accepted that by 2050, the worldwide population will contact just about 10 billion individuals. Furthermore, as our present rural framework stands, specialists accept that we won't have the option to deliver enough food to take care of everyone. Indeed, specialists accept that worldwide food creation should increase by 70% by 2050 to fulfill the population's development needs. As the population increases all around the world, we will face an undefined war in future for food. It is an urgent need to update our agriculture so that it will take care of this growing population. All things considered, we would state that today, farming innovation is our smartest choice. What's more, over the previous century, it appears that the use of innovation in this area increases quickly around the world.

The $5 trillion overall agriculture industry is currently going to innovation to improve its delivery of food. From advances that assist us to utilize less land and deliver more harvests, to innovations that altogether influence the profitability and yield of those cultivated zones, innovation will make agribusiness appear to be unique from today forward.

12 Indoor Vertical Cultivation

However unusual the idea of vertical cultivation may appear to be at the present time, it is a quick strategy to create food in zones where soil is scant or insufficiently arable to deliver enough food. Besides, this cultivation strategy is likewise tending to the water shortage issue as it brings down the prerequisite of water up to 70%. In addition, by utilizing developing racks mounted vertically, indoor vertical cultivation altogether lessens the amount of land space expected to develop plants. This strategy is particularly convenient for difficult conditions, for example, deserts, mountainsides, metropolitan zones, and urban communities. What's more, most vertical farms are either aqua-farming or aeroponics. Fortunately, the two sorts require no soil, implying that the plants can be developed regardless of the fruitfulness of soil in the area. Additionally, this cultivation strategy can be the answer for the work lack in the agriculture business happening nowadays. Robots can be utilized to deal with all cycles from gathering to planting and coordination.

13 Contemporary Nurseries

Over the previous decade, the greenhouse business has encountered significant development from being narrow in scope and utilized principally by scientists, to a much broader business intended to be a contender in challenging customary land-based farming. Today, the whole worldwide nursery market consistently produces over $350 billion in vegetables. True to form, the present current nurseries are turning out to be progressively tech-substantial and utilizing technological advances such aas LED lights and robotized control frameworks to make the ideal conditions for food creation.

Presently, aside from being more practical by a wide margin than land-based cultivation, nurseries likewise limit the danger of the negative effects of climate. For instance, the plants are shielded from freezing or being pulverized by hefty precipitation. In this way, nurseries are likewise an extraordinary answer to limit these dangers and protect food creation.

14 House-Top Gardens

Housetop gardens are picking up energy nowadays, particularly in metropolitan territories where there is restricted land that can be utilized for cultivation. Besides, housetop gardens aren't only an incredible answer for satisfying the developing need for food creation. They are likewise an extraordinary answer for upgrading metropolitan scenes and decreasing metropolitan air contamination and improving air quality. It is legitimate: cultivation has changed much over the long haul. What's more, on account of every one of these developments in farming, ideally, mankind will defeat the test of delivering nourishment for a developing population in less positive atmosphere conditions.

Present-day advancement is used to improve the many types of creation practices used by ranchers. It uses cross-variety seeds of picked grouping of a singular yield, creatively advanced equipment, and lots of energy enrichments as water framework water, fertilizers, and pesticides. Cultivating remaining parts to be an unbelievable part in the period of pay and a wellspring of sustenance for certain people wherever on the world. Over the years, the field of agriculture has seen a huge number of changes and movement in the particular developing methodologies and techniques. For example, there is now the use of inorganic manure, the use of reduced proportions of pesticides, and the use of different work vehicles and contraptions. The availability of such data sources has seen the necessity for the usage of ordinary resources and cycle with the purpose of improving cultivating yield and decreasing expenses. The usage of present-day advancement in agribusiness goes with a huge load of points of interest. The current development in agribusiness can be achieved by updating the current agriculture practices.

15 Development Allotment in Agriculture

Innovation in horticulture can be used in different aspects of cultivation including, for instance, the use of herbicide, pesticide, fertilizer, and improved seed. All through the long haul, advancement has been extremely useful in rural regions. Eventually, ranchers can create crops in zones where they were previously unable to grow, and this is only possible through agrarian biotechnology. For example, innate planning has made it possible to bring certain strains into various characteristics of yields or animals. Planning for the field and using smart tools and sensors will help to increase the yield of crops and animals. Through development, farmers are in a situation to intervene in each food cycle for qualitative and quantitative improvement of food production.

There has been a restriction on the best way to speed the cycle of current innovative selection in farming. This can be ascribed to the way that accelerating this idea includes a great deal of information and the comprehension of a portion of the components that influence the choice of farmers to embrace current innovation in cultivating. Institutional, social, and monetary aspects are a portion of the elements that impact how quickly or moderately rural advances are embraced. The land size, cost, and advantages of innovation are a portion of the financial variables that decide the pace of rural innovation selection. Farmers whose operations are small face both internal and external challenges to the degree the allocation of current country progresses is concerned. This point of view accounts for the moderate rate at which such developments are grasped. Notwithstanding the troubles, what has any kind of effect is whether present day development has any a motivation in the plant territory. The going with fragment includes the enormity of present-day advancement in cultivating.

16 Use of Technology in Agriculture

There are various businesses of development in agribusiness including the going with. Homestead machines: One of the challenges that ranchers face these days is the need to satisfy work. There expense of work is growing, which calls for better approaches to ensure less cost on work. The introduction of solidified collectors and producer unravels the cycle. Creation and time are critical segments in agribusiness. It is critical, consequently, to plant early, procure true to form, and assure that the yield is taken care of within the ideal time and assure that the yield is taken care of within the ideal time. The use of current advancement in horticulture ensures that ranchers create a large food supply inside the briefest time possible. GPS development has been used in the progression of autopilot.

Advancement is larger in current farming than in any other time in recent memory. The business, generally speaking, is going up against huge challenges, from expanding costs of arrangements, an insufficiency of work, and changes in buyer tendencies for straightforwardness and legitimacy. There is extending affirmation from agribusiness organizations that courses of action are needed for these challenges. Huge development advancements in the space have been based on zones; for instance, indoor vertical developing, automation and mechanical innovation, tamed animals' advancement, current nursery practices, precision cultivating and modernized thinking, and blockchain. Indoor vertical cultivating can expand crop yields, defeat restricted land zones, and even diminish cultivating's effect on the climate by chopping down distance went in the production network. Indoor vertical cultivating can be characterized as the act of developing produce stacked one over another in a shut and controlled climate. Utilizing developing racks mounted vertically fundamentally decreases the measure of land space required to develop plants when compared to conventional cultivation strategies. This kind of development is frequently connected with city and metropolitan cultivation due to its capacity to flourish in restricted space. Vertical farms are remarkable in that a few arrangements don't need soil for plants to develop. Most are either aqua-farming, where vegetables are filled in a supplemental thick bowl of water, or aeroponic, where the plant roots are deliberately showered with water and supplements. In lieu of characteristic daylight, artificial lights are utilized. From practical metropolitan development to amplifying crop yield with decreased work costs, the benefits of indoor vertical cultivation are clear. Vertical cultivating can control factors such as, for example, light, stickiness, and water, expanding food creation with consistent harvests. The decreased water and energy utilization upgrades energy protection—vertical homesteads utilize something like 70% less water than conventional farms. Work is likewise incredibly diminished by utilizing robots to deal with reaping, planting, and coordination, tackling the test farms face from the current lack of work in the farming business.

17 Farm Automation

Ranch automation, routinely associated with "splendid developing," is advancement that makes development more viable and robotizes the gathering or tamed animals' creation cycle. An increasing number of associations are managing progressed mechanics headway to make drones, self-operating ranch haulers, mechanical harvesters, modified watering, and robots. Regardless of the way that these advances are truly new, the business has seen a growing number of regular agribusiness associations grasp ranch automation into their cycles. New headways in advances going from mechanical technology and robots to PC vision programming have totally changed current agribusiness. The essential objective of homestead robotization innovation is to cover simpler, ordinary errands. Some significant advancements that are most ordinarily being used by farms include: gather robotization, self-operating farm haulers, cultivating and weeding, and drones. Farm computerization innovation applies to significant issues like a rising worldwide population, farm work deficiencies, and changing purchaser inclinations. The advantages of mechanizing customary cultivating measures are stupendous by handling issues from customer inclinations, work deficiencies, and the natural impression of cultivating.

18 Animals Farming Technology

The customary domesticated animal industry is an area that is generally disregarded and under-adjusted, despite the fact that it is ostensibly the most indispensable. Animals give genuinely necessary sustainable, regular assets that we depend on consistently. Animals the board has generally been known as maintaining the matter of poultry farms, dairy farms, steers farms, or other domesticated animals related agribusinesses. Domesticated animals' supervisors should keep precise monetary records, oversee laborers, and guarantee appropriate consideration and care of creatures. Nonetheless, late patterns have demonstrated that innovation is upsetting the universe of domesticated animals the executives. New advancements in the last 8–10 years have tremendously enhanced the business that make following and overseeing animals a lot simpler and information-driven. This innovation can come as nourishing advances, hereditary qualities, computerized innovation, and the sky is the limit from there. Innovation in the management of domesticated animal can improve profitability, government assistance, or the board of creatures and domesticated animals.

Domesticated animals' innovation can upgrade or improve the efficiency limit, government assistance, or the board of creatures and animals. The idea of the 'associated bovine' is an aftereffect of increasingly more dairy groups being fitted with sensors to screen wellbeing and increase profitability. Putting singular wearable sensors on steers can monitor day by day movement and wellbeing while giving information-driven experiences to the whole group. This information is likewise being transformed into significant, noteworthy bits of knowledge where makers can look rapidly and effectively to settle on administration choices.

Creature genomics can be characterized as the investigation of the quality of a living creature and how they associate with one another to impact the creature's development and advancement. Genomics help domesticated animals' makers comprehend the hereditary danger of their groups and decide the future productivity of their animals. By being vital with creature choice and reproduction choices, genomics permits makers to upgrade benefit and yields of domesticated animals' groups.

19 Modern Greenhouses

In recent years, the greenhouse business has been changing from a small scope utilized basically for examination and tasteful purposes (e.g., botanic nurseries) to an altogether larger scope that contends straightforwardly with land-based ordinary food creation. These days, in huge part because of significant recent upgrades in innovation, the business is seeing advances like no time previously. Nurseries today are progressively arising that are enormous in scope, capital-mixed, and metropolitan-focused. As the market has developed, it has likewise experienced clear patterns. Current nurseries are turning out to be progressively tech-substantial, utilizing LED lights and robotized control frameworks to tailor the developing climate. Fruitful nursery organizations are scaling essentially and have placed their developing offices close to metropolitan centers to profit by the always expanding interest in neighborhood food, regardless of the period. To achieve these accomplishments, the nursery business is additionally getting progressively capital-injected, utilizing adventure subsidizing and different sources to work out the foundation important to contend in the current market.

20 Precision Agriculture

Agribusiness is going through an advancement—innovation is turning into a basic piece of each business farm. New accuracy agriculture organizations are creating advancements that permit farmers to boost yields by controlling each factor of harvest cultivation including, for example, dampness levels, barometric pressure, soil conditions, and miniature atmospheres. By giving more exact strategies to planting and developing yields, accuracy agribusiness empowers farmers to build productivity and oversee costs. Accuracy farming organizations have discovered an immense occasion to develop. The arising new age of farmers are pulled into quicker, more adaptable new companies that efficiently expand crop yields. Agribusiness is encountering progress as improvements become a major piece of each business farm. New precision agriculture affiliations are making degrees of progress that permit farmers to help yields by controlling each factor of cultivation: moisture levels, inconvenience pressure, soil conditions, and more modest than typical conditions. By giving more distinct frameworks to planting and making yields, precision agribusiness draws in farmers to build proficiency and direct expenses. Exactness developing affiliations have discovered a huge occasion to make.

21 Conclusion

The central idea of joining automatic mechanical technology into agriculture has the objective of lessening dependence on manual work while expanding efficiency, item yield, and quality. In contrast to their progenitors, whose time was generally taken up by substantial work, farmers will spend their time performing assignments such as, for example, fixing apparatus, investigating robot coding, examining information, and arranging farm operations [44]. As noted with these agro-bots, having a strong spine of sensors and technology incorporated with the farm's foundation is essential. The way to a genuinely "savvy" farm depends on the capacity of the apparent multitude of machines and sensors being capable of communicating with one another and with the farmer, even as they work in a self-governing manner [45]. The subject of practical agribusiness has two distinct focal points: multifunctional agriculture and environmental services. Both approaches are comparative but view the capacity of farming in an unexpected way. Those that utilize the multifunctional agricultural theory center around farm focused methodologies and characterize work just like the yields of agrarian activity. The focal contention of multifunctionality is that agribusiness is a multifunctional venture with different capacities beside the creation of food and fiber. These capacities incorporate inexhaustible asset the executives, scene protection and biodiversity. The biological system administration focused methodology sets that people and society all in all get profits by environments, which are designated "biological system services". In manageable farming, the administrations that biological systems give incorporate fertilization, soil development, and supplement cycling, which are all fundamental capacities for the creation of food. It is additionally asserted that supportable farming is best considered as a biological system way to deal with agriculture, called agroecology. Regardless, present-day tech recognizes there is a need to empower farmers to comprehend the advancing environment conditions. Sensors are set inside and outside of the yield fields. They gather data from the air which is used to pick the right collects which can make and keep up in the particular climatic conditions. Innovative developments have nearly changed the developing activities, as ground and aerial robots are utilized for assessment of procure success, crop checking, planting, crop sprinkling, and field assessment. In an advanced world brimming with contraptions, there is need to help humankind and make life more comfortable. Adapting the new technology and development of innovative resources with the use of plant biotechnology and advance farming will give new directions toward advanced agriculture ultimately helping in creating a smart farming world and fulfilling the aim of achieving sustainable development.

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Advance Security Schemes for Smart Societies

Mahesh Joshi, Bodhisatwa Mazumdar, and Somnath Dey

Abstract Internet technology has become a boon to humans as it transformed our way of thinking and changed our way of living. What looked like a scene from a sci-fi movie has become a reality within a span of a few decades. A handheld device, such as a smartphone, can connect an individual to the world. A smart transportation system provides the solution to several public conveyance-related problems within a city. However, we have limited natural resources and must preserve them while marching into a new digital world. The concern for the future of next-generation and the planet provided the way to divert toward green technology. The new-age investors are looking for startups with innovative ideas involving green technology to encourage budding talents. Smart cities are now transforming into smart societies as the public-centric solutions are gradually transforming to individual-centric solutions. The tech-giants believe that the new scenario would create increasing volumes of data, and provide multiple services to an individual consumer. The service providers and smart device manufacturers may look more earnestly to consumer demands and behavior realizing an exciting future. But there exists another side of the same coin that remains a big area of concern in the present day. The new world opens the doors for digital crimes, frauds, data breaches, security issues, and privacy and authentication concerns. We also require robust mechanisms to manage, control, and process the enormous volume of data generated by multiple smart devices possessed by each individual in the society. This chapter discusses various technologies that can reshape the new digital world into a safer and increasingly secure place for every user.

Keywords Smart societies · Digital crimes · Data breaches · Security · Data privacy · Data authentication

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1 Introduction

The Internet is empowering technological innovations in connecting individuals to individuals, smart consumer devices, and services. The evolution of Internet-of-Things (IoT) accelerated entering into fully connected smart cities and ultimately, a smart society for everyone on this planet. The increasing demand for these appliances and services has triggered the concern for the security and privacy issues related to them. We need to embrace advancements in the technological trends to offer a completely secure environment for everyone.

The major contributions of this chapter are as follows:

1. This chapter highlights security vulnerabilities and threats to the future smart society and proposes the countermeasures and mitigation techniques to address them.
2. The chapter further discusses the technological advancements to strengthen the IoT infrastructure providing smart services.

The structure of the chapter is as follows. Section 1 introduces the theme of the chapter. Section 2 presents the journey from smart city to a global smart society. We address security concerns in Sect. 3, followed by security schemes and countermeasures to smart society vulnerabilities and threats in Sect. 4. Further Sects. 5, 6, 7, 8, 9 and 10, provide a glimpse of advance technologies, which will improve the security in the future smart society. The green technological innovations fall under Sect. 11, followed by the chapter's conclusion and future scope.

2 Smart Cities to Smart Societies: An Overview

Information and communication technology (ICT) powered by the Internet has opened enormous opportunities for enhancing our standard of living in a safe and secure world. Every individual now is equipped with a handheld smartphone capable of providing hundreds of cloud-based services. An individual from a non-technical background is becoming smart enough to utilize digital payments for paying bills, online shopping, loan repayment, etc. Furthermore, his city administration has employed smart healthcare initiatives, smart city transport, smart street lights, and traffic signals to provide him convenient and comfortable services. Thus, we have a smart city with smart citizens. Now looking the picture in a broader sense, we need to march toward a smart society across nations, continents. A smart citizen when enjoys uninterrupted comfortable, secure, safe, and smart services everywhere, he is an integral part of the smart society. These services must be environment- and human-friendly. Experts predict that the number of smart devices would surpass the human population soon [1]. The diverse service providers would follow a single protocol stack and provide enhanced security and privacy. Common user authentication mechanisms and cryptographic implementations will be a reality.

Figure 1 shows the roadmap to smart society beginning with every person empowered with smart devices. A considerable proportion of individuals should use and promote the services and benefits of smart handheld devices and smart consumer appliances. These smart individuals would opt for a smart home and prefer smart personal and public transport systems. For such citizens, the service providers will provide environment-friendly facilities to achieve the smart city milestone. The businesses and financial transactions will follow the digital and smarter way to match the individual's needs. The government has to offer similar mechanisms and reach another breakthrough by transforming into a smart nation. When a large number of countries follow similar footsteps, it will usher a new digitally influenced, Internet-powered, and fully adaptive smart society across the globe. Smart individuals and smart consumer devices form the base for a smart society. When a smartphone user receives a voice call through the device, he becomes slightly unfit for the smart society as he is unable to explore the enormous services he can benefit from it.

Smartphones have reached maximum populations across major cities in the developed and developing countries. People have started using robotic vacuum cleaners, smart home appliances, CCTV monitoring, biometric controlled locking systems, smart home lighting, etc., and enjoying the digital services for a comfortable lifestyle. We now have a few smart cities powered by solar energy and encouraging the use of e-vehicles, smart transportations, and similar services governed by local municipal authorities to give a glimpse of future global transformation soon. Major tech giants are now trying their level best to change the way businesses operate across a specific geographic area. Hence, within a decade, we would witness a few smart nations with a new approach to governance. We thus need to understand the pros and cons of this exciting world before we enter into it.

In a nutshell, we can visualize the future with a more human-machine interaction than human-to-human. The devices will possess intelligent hardware and software to decide and act on their own without human interference. They will use raw data collected from their environment to learn on their own and improve their performance. During the entire process, we require several technologies to achieve the desired goal of a smart consumer appliance or a smart service. Figure 2 specifies the most impactful technologies employed for smart societies. These technologies play an essential role in data acquisition, data transmission within a LAN and over the Internet, data storage, and processing. Hence, it is crucial to learn the requirements and functioning of these technologies to understand the smart society concept clearly.

Cyber-physical system (CPS) possesses complex architecture comprising data acquisition (sensing) and controlling subsystems within a scalable network and

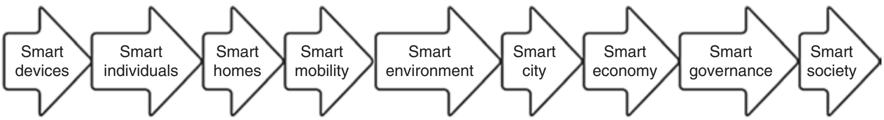

Fig. 1 Roadmap: smart devices to smart society

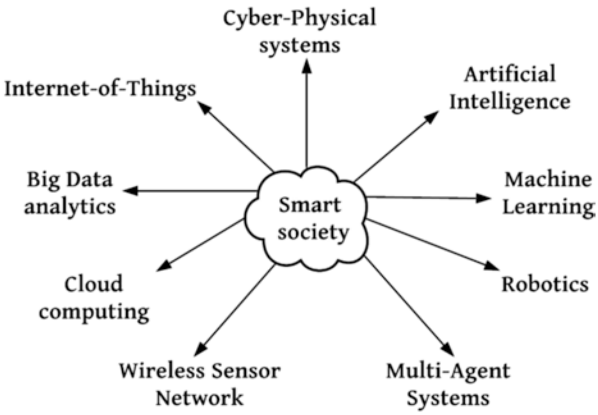

Fig. 2 Technological requirement for smart society

integrating the computational and communication capabilities [2]. Sensors play a pivotal role in CPS as they collect raw data from the surrounding. Information systems then transform the data into valuable information suitable for a specific system model. CPS is a combination of several heterogeneous systems in a distributed environment providing intense interaction and integration between physical and information systems. These systems provide real-time services. Some of the examples of CPS include autopilot avionics, smart grid, distributed robotics, and remote human-robot collaboration [3].

Artificial intelligence (AI) employs human intelligence in solving cognitive problems through adaptive learning [4]. Given a task that requires thinking and decision-making, AI uses algorithms to train the system such that it becomes capable of reaching a high-precision output and resulting action. Practical applications of AI started with the traditional approach the human brain applies while solving puzzles or applying logical reasoning to a problem. In recent times, practices have evolved by employing natural language processing (NLP), social intelligence, perception, and learning approaches [5]. A few examples of successful AI applications include military simulations, understanding and interpreting human language, applying winning strategies in games like chess, etc.

We usually categorize machine learning (ML) under the umbrella of AI [6]. In simplistic terms, ML algorithms are modeled on training data and evolve through experience when run on real-time data. The learning process may follow a supervised, unsupervised, or reinforcement approach. The models generally employed in modeling an ML algorithm comprise artificial neural network (ANN), support vector machine (SVM), genetic algorithms (GA), regression analysis, etc. ML is a widely accepted approach to solve problems in the areas of banking, computer networks, marketing, financial markets, bioinformatics, and many more. Currently, we have plenty of open-source software such as ML.NET, Octave, and pandas, which are suitable for specific needs and applications of a smart device or smart service.

Robotics involves adaptable, computer programmable, electro-mechanical machines assisted by sensors proficient in performing the complex sequence of actions automatically [7]. A robot may execute the desired task once installed at a fixed location, or it can be a mobile robot. Subsequently, the moving robots can fall under aquatic, terrestrial, or aerial type [8]. Robots act as a human replacement for specific tasks like inspection, lifting, and in the manufacturing industry. We broadly classify them as industrial (manufacturing and logistics) or service robots. Service robots are widely employed for home, defense, medical, and educational purposes.

Multi-agent systems (MAS) are a group of intelligent, programmable agents interacting with one another to fulfill a set of desired goals [9]. MAS attempt to solve those problems, which seem nearly impossible with a single agent. MAS mostly employ software agents, but may also involve robots or humans [10]. The simple obstacle-free goals require passive agents, whereas implementing a complex problem needs active and cognitive agents. The agents are autonomous, self-aware, but not wholly independent in functionality as they have a limited view of the entire system. They work in collaboration with each other, and no single leader or controller exists amongst them. Applications of MAS include movies, computer games, networking, transportations, smart grids, etc.

Wireless sensor network (WSN) comprises a large number of geographically scattered and dedicated sensors when collecting raw data from the environment and communicating with the centralized server [11]. An extension of WSN comprising heterogeneous networks capable enough to respond to its environment is termed as wireless sensor and actuator network (WSAN) [12, 96]. In the current era of Internet-powered systems and devices, we have an advanced version of WSN as a mobile wireless sensor network (MWSN) [13]. Due to their highly dynamic nature and quick response to node failure, such networks are useful to monitor natural habitats, detect and locate forest fires, battlefield, and traffic applications.

Cloud computing is an on-demand, online service of computing resources, for example, servers, data storage, software, and networking. Accordingly, we classify them as software-as-a-service (SAAS), infrastructure-as-a-service (IAAS), and platform-as-a-service (PAAS) [14]. Small startups prefer cloud-based services than investing in procuring costly hardware and software to run their business. The Internet has proved as a boon for cloud-based IT-related services. Tech giants, such as Google, Microsoft, and Amazon, are among the top cloud-service providers across the world [15]. Cloud computing is one of the widely accepted and used technologies for storing and processing massive real-time data with high-speed uninterrupted Internet connectivity 24×7.

Currently, all consumer services are available online, and every owner of a smart device is generating raw data through location tracking, usage statistics, search strings, etc. We have enormous data at our disposal to extract useful information and provide user-specific contents. Big data analytics applies to unorganized and complex data using a scalable infrastructure to facilitate storage, organize, and analysis of massive real-time data [15]. The resource requirement for dynamic high-volume data generated from various sources such as sensors and social media platforms is unpredictable. Cloud computing provides the scalable software and hardware infrastructure to realize the desired goals of big data analytics.

Internet-of-Things (IoT) comprises sensors, actuators directly interacting with the environment to deliver responsive services through smart devices [16]. IoT embeds a heterogeneous network of highly dense and distributed devices through high-speed communication channels, such as the Internet [17]. The Internet-powered IoT infrastructure senses raw data, communicates it to the local and remote server, receives the response, and acts according to a set of predefined rules. Smart metering, smart home, smart parking, smart traffic signals are a few IoT examples currently available through smart city initiative. As more and more consumer appliances are using IoT as a backbone, we can say that IoT will rule the smart society.

3 Major Security Challenges for Sustainable Smart Society

At one moment, it seems everything is smooth, secure for every individual to enjoy the benefits of smart consumer appliances and smart services available through various vendors. But then once we flip the coin and peep into the other side of the coin, the scene is not that pleasant. As technology has evolved, the tools to mount various attacks have become readily available and easy to use. Open-source software seems to be a great way to learn complicated software for a newbie, but they are adversely employed to build malicious code to break the security system. There is a high probability that an update for a smartphone app would download viruses or worms and damage the device or share confidential user information to a remote server. A smartphone user may not be aware of such incidences until he faces any financial loss or finds his device in an unusual condition.

The digital businesses have identified that data are going to decide the financial growth of an organization. For a smart consumer appliance user, the raw data he generates through his multiple smart devices seems useless, and thus he completely ignores what the vendors do with it. The use of social media has grown tremendously in recent times. Furthermore, people are becoming proactive in commenting at various video-streaming platforms. The web interfaces and websites are tracking user activities through cookies on browsers. The data analytics techniques use such data to provide user-specific contents but in an illicit manner. Hence, every individual should become technology literate about all such activities and decide what to share and with whom.

Figure 3 shows various threats and vulnerabilities associated with the smart society ecosystem. We have security and privacy concerns for smart devices and services. The privacy concerns include personal health records, location tracking, contact details, social life, political views, behavior and habits, digital media like images, audio, video, etc. [18]. The private data owned and generated through the consumer is expected to be entirely under his control. But in the new digital era, this hardly happens. Every service provider and business owner, including government and private sector, are looking for such data to build their businesses or track their

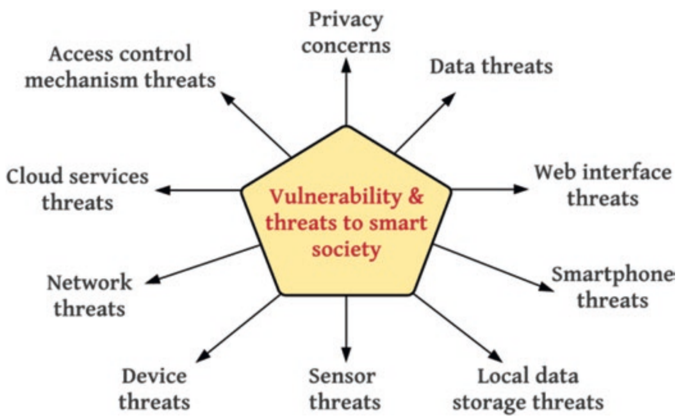

Fig. 3 Vulnerabilities and threats to smart society

citizens. The video streaming through public CCTV surveillance at traffic signals, government offices, public places such as railway and bus stations, airports have significantly high probability of being misused as we still do not have policies to control the usage of such data.

Data threats include unauthorized access and usage of consumer data for financial benefits [20]. When a consumer starts using a smart device, such as a health wrist band, the vendor wants him to install a smartphone application, and then synchronize with the device to monitor health records. As he has already paid for the device, he expects the application would assure that his records are private to him only. But at the time of installation, the application seeks permission for access to various resources, such as sensors, location, and contact, for the proper functioning of the application. The consumer provides access to everything required and starts using the device. As the consumer is least bothered about his data, the service providers does not lose any opportunity to exploit free data smartly that may be used for malicious purpose, in such case the service provider turns untrustworthy over a period of time.

Web interface for visualizing and monitoring smart home provides another mechanism to steal user data. The browser cookies, location permission, IP tracking are a few examples wherein the sensitive user information is accessible through web browsers [20]. When several smart devices collaborate to provide smart services, such as smart home, smart building, colony monitoring, and surveillance, a single application becomes inefficient to visualize and analyze the data collected through different sensors. In such situations, the service provider supplies web-based interfaces to the consumer. As security becomes the primary concern, people show least concern about how the interface is implemented, and what kind of data is being gathered and analyzed.

Smart devices such as smartphones are vulnerable to phishing attacks, botnets, personal spyware, and grayware [21]. Android devices share the maximum sales in the smartphone market, and unfortunately, they make up the most vulnerable devices out there [22]. The OS play store recommends games, kids, and categorized editor's choice apps to a consumer. Games, entertainment, and kids' apps constitute a significant source of malware and viruses through updates [21]. The user sometimes unknowingly clicks on the advertisement links on such apps and unknowingly falls prey to invite malicious code on their device. The apps auto-read one-time passwords (OTP) and follow the password reset link from text messaging apps and perform financial frauds.

The local gateways for services like smart home, smart grid temporarily stores the data communicated through various types of sensors within LAN. Usually, these devices are battery-powered and hence cannot afford additional hardware or software module for data encryption. Such data may include device-to-device authentication credentials, IP addresses of the cloud server for payment gateways, and data analytics. A Trojan Horse when inserted can steal such confidential information. Sometimes the cache and primary memory may become a victim of a side-channel attack.

IoT-based smart services require various types of sensing nodes like light sensor, magnetic sensor, proximity sensor, motion sensors, etc. [23]. Most sensors employed for collecting environmental parameters can malfunction and send incorrect data to the IoT gateway [24]. Additionally, sensors are vulnerable to denial-of-service (DoS) attack and information leakage like eavesdropping [23]. Such a DoS attempt can directly disconnect the services from the consumer, or it may halt an application expected to execute on the subsequent node or device in the network. A hacked sensor becomes the source of most common attacks on the devices. A spoofing attack attempt on a GPS sensor shares a false location of the targeted device.

The devices within a smart service infrastructure, such as forest fire detection system, wildlife monitoring system are also vulnerable to attacks. Some examples of such attempts include frequent reset operation; erase local storage through remotely executed command, and privilege alteration, etc., which fall under denial-of-service (DoS) attacks [25]. The adversary can even steal the encryption keys or third-party credentials from the secondary storage on these devices. During the firmware update, a malicious code can follow automatic execution steps and force the device to malfunction. Such a code can try to read sensitive URLs and disclose it to the adversary. A single device, such as an IoT gateway, once disconnected using malware or shutdown using a remote command-line interface can damage the entire system.

The sensors, actuators, and devices use low-range communication protocols for data transfer. Most vendors rely on proprietary (closed-source) protocols for smart services within a small region. As these protocols are not completely secure against all existing attacks, the adversary can intercept over such insecure channel. 6LoWPAN lacks integrity protection, as well as authentication [27]. The similar vulnerabilities, along with no secrecy, exist in CoAP too. Additionally, LoRaWAN stores 128-bit key on the devices within the LAN, and the adversary can discover them with minimal efforts [27]. In case of ZigBee and BLE, it is highly essential to change the network key and device MAC frequently to provide security and user anonymity, respectively [27].

Smart services highly require cloud-services for storing a continuous stream of data and performing analysis of such a massive amount of data. Preserving user anonymity and issues related to user identity such as authentication, and authorization are some of the significant challenges in the cloud [26]. The data over the communication channel are encrypted, but the security through a similar mechanism when the data are available in the cloud is not guaranteed. There exist only 10% of cloud-service providers having encrypted data storage [26]. The cloud services are vulnerable to DoS attacks that can interrupt the entire system and cause substantial financial loss to the organization. Additionally, a malicious thing in an IoT infrastructure can send executable malware code to the cloud and corrupt the entire stored data.

We have traditional ways such as password, patterns, and pass code to access resources and data within an IoT-based smart service or a smart consumer device. A well-equipped adversary can mount a brute-force attack or a dictionary attack to reveal such confidential credentials and misuse them to enjoy the benefits [28]. Hence, such access control mechanism may not be secure enough to protect data and provide user authentication. In a nutshell, we still have significant challenges to deal with when it comes to securing the future smart society. In an IoT environment providing smart services, starting from the remote nodes and devices to the smartphone app or web interface provided to the consumer, everything seems to be vulnerable to some form of threats. We thus present various security mechanisms employable in securing different components in smart services and devices. The subsequent sections of the chapter provides an insight into some of the significant recent technological advancements applicable for the same purpose.

4 Security Schemes and Countermeasures

Consumers must be concerned about their privacy and be careful while using and operating smart devices through smartphone apps or web interfaces. It is highly required to provide minimal permissions to apps and at the same time, avoid installing them through insecure sources such as third-party links. The users must ensure the use of secure and encryption-based protocols, such as resorting to HTTPS sessions while browsing on a smartphone to minimize threats using suspicious hyperlinks on the web page. Anonymous communication mechanisms like Tor assure protection against metadata [18]. A scheme such as smart card usually authenticates an individual without identifying them. The smart card can help in preserving privacy while providing secure user authentication.

Data Security One-way hashing technique, digital signature, and message authentication codes (MAC) are the standard methods, which ensure integrity protection and provide authentication [27]. The devices should employ a mechanism to verify software integrity during every restart operation to protect the device against executing malicious code and also modifying the system software code [26]. Key management schemes provide facilities such as key generation, storage, updates, and distribution within a limited area network. It also acts as a preventive measure to mitigate a masquerade attack and attempts to compromise the device. Self-encrypting drives (or devices) (SED) prohibit any unauthorized attempt to access or disclose the device data [26]. It is also possible to reconfigure the security parameters dynamically to provide adaptive security schemes within the network. Public and private key infrastructure can secure data over the communication channel between mobile and cloud-server [37].

Smartphone Security Majority of smartphone users never changes their default security settings and provides only physical protection (such as PIN, pattern locking, etc.) [31]. The smartphone OS developers can utilize various system software hardening approaches, such as address space layout randomization (ASLR) and stack protection [21]. User can opt for multifactor authentication schemes available with their devices to provide a higher level of device security [32]. The smartphone vendors providing near field communication (NFC)-enabled payment option can employ Cloud Secure Element (CoSE) [32]. Usually, smartphone manufacturers store the contact details on their cloud without any additional encryption, and thus, such confidential information becomes readily available if the adversary breaks into the cloud systems [19]. One possibility is to use a hashing approach while using the cloud server to store such personal user details [38]. Alternatively, Bloom filters may also help if we wish to thwart a brute-force attempt on hashed contact information stored on cloud servers [38]. Data execution protection (DEP) and address-space layout randomization (ASLR) can mitigate attempts of memory corruption attacks on Android smartphones [39].

Sensor Security The devices within the local network should have separate group identities, for instance, devices receiving data and forwarding commands to the sensors [18]. The device power consumption rate has become a key component in identifying sensor-related issues in the IoT environment. The power profiling of a heterogeneous wireless sensor device can predict and detect an attempt of a man-in-the-middle (MiTM) attack and a distributed DoS attack [40]. The WSN is vulnerable to the stolen verifier and user traceability threats. The symmetric key-based authentication protocols have shown resilience against such vulnerabilities and also thwart DoS attempts on WSN in IoT infrastructure [41]. Usually, nodes in clustered-WSNs (CWSNs) are vulnerable to ON-OFF attack, wherein the attacker can infect the cluster member frequently. The non-zero-sum game scheme-based trust model mitigates DoS and ON-OFF attempts on CWSNs [42].

Device Security Physically unclonable functions (PUFs) are highly beneficial in providing hardware-level protection to the nodes and devices [27]. Lightweight secure PUFs are resistant to reverse engineering attacks [29, 30]. Relocation, isolation, and blacklisting a malicious node are some of the responsive measures against compromised devices within the network [26]. Alternatively, tamper-resistant hardware can also be a preventive mechanism to deal with device-based attacks that may disclose confidential information, such as keys from the device memory. The system must maintain device registration schemes to make sure that only authorized and inspected devices join the network infrastructure. A device-to-device authentication between the local and remote node, devices, and gateways prevent malicious parties from masquerading the services [26]. An isolation and protection mechanism (IPM) that primarily employs reconfigurable hardware can provide dynamic isolation among the network and nodes within the network [45]. It uses communication analysis to prevent any damage to the devices from malicious actions.

Network Security Symmetric and asymmetric encryption schemes ensure confidentiality of the data during transmission. As the devices and nodes usually involved in smart service infrastructure are battery powered and have limited computing capabilities, a lightweight encryption scheme offers the required security. In such scenarios, the secret key size is small compared to standard encryption schemes, and the computations are simple but still guarantee high security [27]. Some ciphers under the umbrella of lightweight category include PRESENT, SPONGENT, PRINCE, PHOTON, etc. Sometimes it becomes infeasible for the vendors (especially startups) to afford the finances of development and installation of security protocols for securing the network. In such cases, software-defined networking (SDN) can provide device-level security at the network layer.

Cloud Computing/Services Security The access control schemes in the cloud should employ the attribute-based encryption technique and carry out data processing functionalities privately at third-party resources [18]. Cloud access security broker (CASB) enforces security policies on the cloud servers [26]. We have two-factor authentication secure watermarking sharing protocol to secure several issues related to mobile cloud computing platform [33]. An efficient and non-shareable public key exponent secure scheme (ENPKESS) designed for the cloud environment in IoT infrastructure can resist timing attack, which is one form of side-channel attack [43]. The Chinese remainder theorem (CRT) can act as a security scheme for storing encrypted data on the cloud [44].

Figure 4 shows technologies that can secure the infrastructure (nodes, devices, and communication channel), cloud-based data storage, and user authentication schemes in the smart society. We will introduce these technologies and their applications in smart devices and services.

5 Blockchain Technology

Blockchain technology's design extends the well-established and accepted concept of public and private key-based encryption scheme, hashing technique to create message digest, and digital signatures for source authentication [47]. Blockchain technology is a decentralized ledger capable of maintaining digital records, which

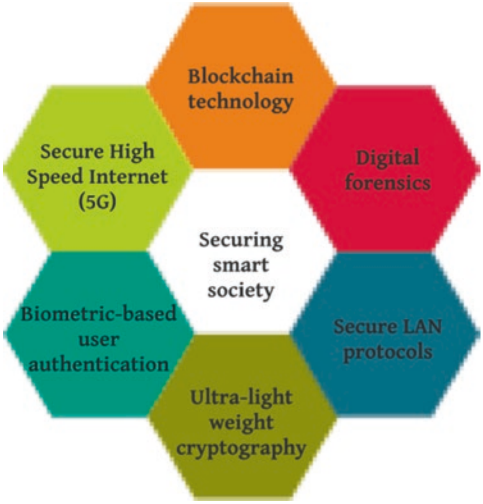

Fig. 4 Advance technologies to secure smart society

is projected to dominate future business and banking transactions and asset management over the Internet [46]. It is a slightly complicated blend of distributed agreement protocol, cryptography, and peer-to-peer networking. Blockchain technology can maintain verifiable and immutable transactions securely. Hence, it is expected to replace the trusted third-party agents [49]. Several data integrity issues and malware threats to data, such as CryptoLocker and wiper, can be mitigated using Blockchain technology [26].

In a recently proposed approach, every real-world sensor within an IoT system transmits its sensed data through Blockchain-backed data management. The verification platform employing its cooperator devices assure data integrity, and detect tampering with the data and spoofing possibility [48]. Blockchain technology has found its application in swarm unmanned aircraft system (UAS) networking [50]. As Blockchain systems create tamper-evident logs, it can also help maintain and control evidence flow, including collecting digital evidence, and police investigation records, to act as lawful evidence management in digital forensics [51]. We can also use it to keep a record of a smart home. This model stores secure data over several cloud service providers and saves the storage space and communication bandwidth significantly [52].

The technology also resolved the problem of maintaining electronic health records (EHRs). In this type of eHealth system, it is possible to audit the EHR and support tamper-resistant against data manipulation [53]. The technology also influences the complex business network of supply chain management. IoT and Blockchain have resolved the supply chain issues by enhancing the transparency in the value chain and bringing out the trust between businesses through effective transactions [54]. Smart grid cyber security schemes also employ Blockchain technology [55]. The Edge devices in the IoT environment usually suffer a threat of being tampered and even tackling unauthorized access from malicious users. The decentralized security of Blockchain technology secures such nodes [56]. Blockchain technology can also be used in securing smart healthcare system [57].

6 Digital Forensics

Digital forensic (DF) primarily involves data gathering, documentation, and investigation of a cybercrime [58]. As we have already entered a digital age, it is more likely that criminal activities will be more digital than physical like document leakage, forgery, financial frauds through Internet banking and credit cards, etc. Digital forensic techniques apply to digital documents, images, audio, and video. Advancements in technology opened new opportunities for criminals. *DeepFake* is one such example, wherein the adversary uses deep learning approach to tamper real authentic media files or synthetically generate a realistic media [59]. The evidence must withstand a forgery attempt and also possess the property of being verifiable. *LEChain* is a scheme based on Blockchain technology to preserve privacy issues in digital forensic [51].

We have Digital FOrensics framework for Reviewing and Investigating cyber-attacks (D4I) a DF platform, mainly targeting the examination and analysis phases, to examine and investigate cyber-attacks [60]. The framework is proved to be effective against a spear-phishing attack. Digital images are readily available through search engines on the Internet. They make most contents of evidence in digital forensic. Hence, deep learning and watermarking techniques have significantly impacted digital image forensic [61]. Digital forensics as a service (DFaaS) has emerged as an emerging cloud computing application [62]. It will solve the issues in DF such as automation, storage, and coordination among forensic experts. The correlation between a user and the digital data from a crime scene can trigger the investigation process and convict the criminal [63].

The public and private sector DF investigators face several hurdles while working on a criminal case. STITCHER is a tool to overcome most technical issues while investigating and controlling a lawsuit in IoT [64]. Cloud computing, software-defined networking (SDN), and Blockchain technology can provide a centralized framework to gather and protect evidence [65]. The system prohibits access to unauthorized individuals using a secure ring verification-based authentication (SRVA) approach. Existing technologies have led to emergence of low-cost video surveillance systems to monitor resource access at smart homes, smart grid, traffic signals, etc. The visuals captured through these systems form strong evidence in DF trial. But the quality of such streaming data is deficient in most scenarios, and the visuals may also face threats of being tampered or replaced with a fake video. Thus, we require a tool to improve video quality and deep learning techniques to assist video-based forensic investigations for detecting and identifying a suspect directly from the footage [66].

7 Secure LAN Protocols

Smart city and similar projects mostly employ locally gathered data to provide services to the consumers and industries. Hence it is highly required to secure LAN within such systems from intercepting and detecting or prohibiting any attempt to inject fake data into the communication channel. Lightweight intrusion detection schemes primarily track unusual behavior and patterns in consumption of computational power, memory, and network resources to alarm a probable ongoing attack on the system [27]. A lightweight intrusion detection system can resolve the concern up to a certain extent, but it is not the complete solution. So, a standard secure communication protocol has become a need of the time.

Tire pressure monitoring systems (TPMSs) have been incorporated into several new generation smart cars as an in-car wireless network throughout western countries [69]. But, the security of TPMS is still a vital concern. An additional random number generator and a block cipher hardware implementation can mitigate replay, spoofing, battery-draining attacks, and alleviate car tracking attempts [69]. Mobile robotics has become a solution to many problems of modern society, such as rescue and battlefield operations. In a multirobot scenario, a lightweight communication protocol helps synchronize useful information, such as alerts and obstacles, and thus, coordination among the robots [70]. M2M cross-layer routing protocol using dynamic network parameters has shown significant improvement in packet loss and delivery ratio, and deadline miss ratio in a smart city environment [72].

Lightweight DoS-resilient (LIDOR) is a multi-hop communication protocol, which secures safety-critical IoT infrastructure from DoS, replay, and wormhole attacks [73]. As the devices are mostly battery-powered in the IoT environment, a communication protocol utilizing optimal energy can drastically extend the device lifespan. An ultralow-power, adaptive, wireless communication protocol has shown a significant improvement in power consumption over Bluetooth Low Energy (BLE) in IoT system [74]. An energy-efficient, channel-aware, link-layer communication protocol, coined as cDIP, is applicable for low-range wireless communication in IoT systems [75]. The application of IoT to medical devices and equipment has opened new doors of threats to IoMT. A session key and nonce-based secure communication protocol employing hash function showed resistant against well-known attacks like data extraction within such IoT infrastructure [76].

8 Ultra-Lightweight Cryptography

The evolution of pocket-friendly gadgets, in terms of size and cost, and ultra-constrained devices like RFID and mobile SIM cards, has introduced the requirement of ultra-lightweight solutions to these battery-operated devices. These are the smart consumer appliances utilizing the Internet to connect with other similar devices and services owned by the consumer. Also, smart city, smart grid, and similar projects have started incorporating these devices due to low-cost and occupying less space in their infrastructures. Hence, security and privacy form the primary concerns to address at the earliest. Fruit-80 is an ultra-lightweight stream cipher [77]. It is an extension of Fruit stream cipher whose main structure resisted several forms of cryptanalysis. Its actual implementation requires significantly less physical space.

We can employ a one-way hash function to provide secure authentication through broadcast. This scheme diminishes the computing and storage expenses and thwarts existing threats to the smart grids [67]. Internet-of-Medical-Things (IoMT) have impacted significantly in the healthcare service sector in recent times [97]. Usually, these systems require radio-frequency identification (RFID) tags for medical equipment and patient authentication. But typically, these tags are capable of single authentication per session. Hence it requires a highly secure batch authentication protocol [68]. Privacy preserving in a highly heterogeneous IoT infrastructure is difficult to achieve. An ultra-lightweight device-to-device communication protocol based on a symmetric key encryption scheme has resisted the most harmful threats to a smart home system [71].

Ultra-lightweight encryption-based authentication protocol (UEAP) is an RFID authentication protocol, which has proven defended against existing active and passive attacks [78]. A Feistel network-based cipher, GRANULE, consumed relatively low power and expected to provide the required security to nodes within an IoT environment and RFID tags [79]. On a similar note, a compact and ultra-lightweight substitution and permutation network (SPN)-based block cipher, BORON, showed remarkable performance on its software and hardware implementation [80]. Mobile payment transactions have increased drastically in the past few years due to mobile apps and RFID technology. As financial transactions multiply, the threats and attacks on them grow in similar proportions; hence, securing online transactions through smart devices also needs to be prioritized. Ultra-lightweight RFID authentication scheme (ULRAS) employing only XOR operations on the bits thwarts DDoS attacks [81].

9 Biometric-Based User Authentication

Traditional mechanisms to provide user identification, authorization, and authentication may not be secure enough to provide device-to-device authentication, and identity management within IoT backed systems. Hence various tech giants have funded the FIDO alliance to standardize user recognition process [82]. The alliance came up with biometric-based protocols that are now a part of billions of devices worldwide within a short span. The use of fingerprint in multi-factor authentication to secure mobile cloud computing is already available [34]. A smartcard-based match-on-card (MoC) scheme employing fingerprint and palm vein can also provide multi-level security against storage-related issues associated with traditional authentication schemes [35]. We can also use an artificial neural network to authenticate a user through his handwritten password using a cloud-based server [36].

Biometric system research has also provided solutions during COVID-19 outbreak. One such application includes a decentralized, deep learning framework based on IoT guidelines for citizens' face detection during lockdown within a city [83]. Blockchain technology applied to the multi-modal biometric-based solution provides strong network security within an IoT system [84]. The scheme accepts finger vein and fingerprint as the source of biometric data. The noise-aware biometric quantization framework (NA-IOMBA) employed iris, fingerprint, electrocardiogram (ECG), and photoplethysmograph (PPG) during the experiments. The results concluded that ECG is the best biometric modality candidate for practical implementations [85]. ECG appeared to provide high accuracy results in a similar effort when employed as a biometric signature for individual identification and authentication [89].

A cancelable biometric system employing cloud-based services serves its purpose of privacy and security preservation, thus being a probable solution to IoT authentication problem [86]. A fusion of face and voice in a biometric scheme improved the IoT environment's authentication accuracy compared to accepting face as input biometric [87]. Smart homes can also use a biometric system to secure access to various resources, including entry and exit from the home premises. It is also possible to secure smart home with several interconnected smart devices with a biometric-enabled anonymous authentication protocol [88]. As we have highly secure and resistant authentication mechanisms for smart devices and systems, consumers worldwide will hugely accept such appliances and services.

10 Secure High-Speed Internet (5G)

The technology has already evolved to the extent that every business has entered into online mode. This change in the paradigm requires high-tech solutions to the currently available technologies, for example, the Internet. The Internet speed has evolved from a few kilobits per second (Kbps) to gigabits per second (Gbps) over two decades. However, even today, we feel the need to improve it further as the size of applications online has also grown simultaneously, and with the existing 4G solutions, it takes a few minutes to experience them. There is a rigorous research going on in the field of 5G technology. This revolution must be secure from all sort of existing threats and vulnerabilities as every business will adopt it in a short span of time after it is launched commercially.

In the future 5G infrastructures, distributed and generalized servers run the software-based mobile networks and services. Virtualized software running on standard hardware platform provides dedicated networking functionalities to IoT network and similar technologies. Hence, software-defined networking (SDN) and network functions virtualization (NFV) would facilitate instant provisioning to adapt to any new networking environment just by reconfiguring the existing infrastructure [90]. Cyber-physical system (CPS) operating on 5G infrastructures may be vulnerable to DDoS attack. It is possible to detect such an attempt using deep convolutional neural networks (CNNs) [91]. Network coding techniques in 5G technology may give rise to a possibility of probable pollution attack. In this case, the network bandwidth efficiency deteriorates substantially and obstructs the message decoding scheme [92]. Hence, it is a high priority task to defend such a threat to be suitable for futuristic practical implementations. The proposed method of employing a centralized controller on cooperating small cells would probably solve the issue and prove a mitigation approach against pollution attack [92].

5G New Radio (5G NR) cellular networking can use Blockchain technology to improve its security routing algorithm. A lightweight routing protocol based on these guidelines has proven to thwart attacks in the swarm unmanned aircraft system (UAS) networking [50]. It also averts the unauthorized connection requests, detects probable malicious UASs, and resists any attack attempt from such UASs. Feasibility of a unique integration of AI-enabled Blockchain technology can form the base for building a secure, smarter, and efficient cellular 5G network for the future generation [93].

11 Green Technological Innovations for an Environment-Friendly Smart Society

The technology is advancing at its own pace to realize higher goals targeted toward smart consumer devices and services. IoT-enabled solutions have found remarkable applications in the infectious disease tracing, such as COVID-19 [94] and smart transportation system [95]. But, high-tech solutions may sometime overlook the adverse impact it could create in the coming decades. We may harm the environment by polluting air, water, soil, etc. Hence, it is expected that more green technological innovations should get more exposure and acceptance from a large community to curb the unfavorable effect on the limited natural resources. Biofuel can replace traditional crude oil petroleum products. It would limit the emission of harmful gases and control pollution-related diseases like asthma. The government should subsidize and encourage the production of biofuel and the products consuming them. Similarly, green concrete can act as an environmental-friendly building material. Recycling of all possible sorts of waste would reduce not only pollution but also provide more business opportunities. We can also use garbage to generate electricity. The solar energy may also solve most of the problems related to electricity.

12 Conclusion and Future Scope

Smart home appliances are now a reality everywhere. Also, we are experiencing smart cities in a few countries. So, it will not be an exaggeration to be a part of a smart society soon. But we may feel short of the future requirements with the current trends in technology. And hence we will have to explore new possibilities. Such solutions' primary focus is to provide privacy and security preserving gadgets and services to the consumers to accept them quickly and speed up the progress toward smart society. The chapter introduces such technologies and the key areas of ongoing research in their respective fields. We highlight Blockchain technology, digital forensics, secure LAN protocols, ultra-lightweight cryptography, biometric-based user authentication, and secure high-speed Internet (5G) in this chapter.

We have to accept that the desire to deliver smarter solutions for humanity leads to an imbalance in the environmental ecosystem. The future is offering diverse applications for a comfortable stay on the earth. But we must address the adverse effects at the earliest to assure nature-friendly technological innovations. In this regard, the future work would pinpoint mechanisms that consume natural resources to build eco-friendly products, proper disposal methods and recycling of trash, applications of solar and wind energy, alternatives to pollutants, etc.

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Internet of Things for Environment Protection and Sustainable Living

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Abstract With the growing years, rapid changes are seen in both technology and the environment. But the issue is that these both diverse factors were never in hand with each other, that is, whenever growth is seen in technology, harm happened to the environment and considering the present pandemic situation where nature is reclaiming, all sectors are halted. So, the question arises as to how technology and the environment go hand in hand with each other. An intelligent answer to this would be the Internet of Things (IoT). IoT is a combination of different things such as devices, smart wearable objects, and interiors, which are embedded with sensors, actuators, software, and other technologies where interaction happens between them. Due to the connectivity between them, data are transferred. This book chapter presents algorithms that would help in the prevention of environmental issues and how the Internet of Things would help in the reduction of the harm that happened to the environments as well as how we protect the environment using technology. One of the important features of IoT is its ability to monitor real-time systems which would help us in keeping track of the environment's actions. Vast disasters can be avoided, immediate rescues can be performed, and proper maintenance can be taken using the IoT. The main focus of this book chapter is on three factors – prevention, reduction, and protection. Each factor would display different algorithms and systems which would help in protecting the environment. Environmental impact assessment (EIA) and fault tree analysis can be used in evaluating and preventing any damages beforehand. After preventing the damage, reducing the harm is crucial. The waste reduction algorithm (WAR) helps in evaluating environmental impacts. Later on, the protection is done using IoT models.

Keywords Environment · Internet of Things · IoT · Algorithms · Real-time systems · Environmental impact assessment (EIA) · Waste reduction algorithm (WAR) · IoT models

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1 Introduction

Industrial revolutions gave the initial push to innovations and technologies, and those were the times when everyone around started to understand the importance of manufacturing or producing a product. But little did they know the impact it would be showing on the environment in the long run [1]. The environment or the nature, in general, is accustomed to bottle up the impacts caused to it and answer it later on. Usually, the answer is dreadful to human communities and the other living beings. This tells us more about how important sustainable development is and how our today's actions would impact the future ones. Going back to the industrial revolutions, this has opened the door for many inventions from spinning wheels to the steam engines and also under which many factories have been set up, from textile factories to automobiles industries [2]. The trait of industrial revolutions is its production or simply the outcome; much focus is not given to the process. To be more precise, the focus of manufacturing mainly depended on 4 M's are – Man, Money, Machine, and Material. Good control and proper maintenance of these four M's brought great benefits from economic growth to ease of living. The resources which were used were in their purest forms. The most prominent industrial growth was seen around 1957 to 1970 where the economic growth was seen with low inflation and great stability on balance of payments (BOP) [3].

Now, the environment. Surely, there was not one particular event which caused the damages; there was a combination of different events which contributed to the damage to the environment and which are still damaging the environment. The impacts caused to the environment are always slow but vulnerable. Extensive use of nonrenewable resources, let go of pollutants from various sources, combustion of fossil fuels, overpopulation, and desertification are some of the main reasons for environmental damage [4]. Early on, we discussed 4 M's., but unconsciously another M can be included, which especially contributed to environmental disasters, which is Mistakes. History has a plenty of examples depicting what will happen if a small mistake is made intentionally or unintentionally. Man-made environment disasters are summarized in Table 1.

The number of natural disasters recorded in 2020 alone was 207, which is 27% more than the previous year, where the number of disasters recorded was 163 in 2019 [12]. These numbers raise the urgency for environmental protection and sustainable development. The year 2020 spoke many things from climatic changes (which resulted in bushfires in Amazon, volcano eruptions, swarms of locus, Philippines earthquakes, and cyclone Amphan) to human negligence (causing Vizag gas leak, Eluru outbreak, Assam oil and gas leak, Ahmadabad chemical factory blast).

Technology and environment: we have seen two sides of the coin but in a contradicting perceptive; it is time we see in a complementing manner. How crucial and devastating the relation between these two is that they are equally interdependent and affinitive. It is in our hands on how we develop technology that it becomes a boon and not a bane and how we mold the environment that it retains its best. Now

Table 1 Man-made environment disasters

Year and name	Incident and caused	Impact
1935 – Dust Bowl [5]	Severe dust storms - shift of weather patterns & over cultivation	Havoc on US agriculture and livestock
1954 – Castle Bravo [6]	Hydrogen bomb test, released 15 megatons of TNT in Marshall Islands	1000 times more powerful than Hiroshima & Nagasaki
1932–1968 – Minamata disease [7]	Hazardous waste such as mercury sulfate release from chemical factory by Chisso corporation	Neurological disorder affecting more than 17,000 people
1984 – Bhopal gas tragedy [8]	Release of 40 tons of methyl isocyanate by union carbide India limited company (UCIL) in Bhopal	The gas killed 3800 people immediately and affecting 600,000 more
1986 – Disaster at Chernobyl [9]	An accident at the reactor unit due to ineffective work force causing world's worst nuclear disaster	Released 5% of radioactive reactor core into the environment
1989 – Exxon Valdez Catastrophe [10]	Oil spill of around 10.8 million US gallons into the oceans by Exxon shipping company	Recorded as the worst oil spill in the world in terms of environment damage
2010 – Deepwater horizon oil spill [11]	Released 210 million US gallons of oil into the Gulf of Mexico	Largest marine oil spill in terms of volume

more than ever, many technologies contribute to this goal and are looking forward to grow more in their field of expertise. Different technologies put together bring out great benefits and advancements in living. More of environmental technologies and more of awareness will bring forth accelerating results in every section of life.

The entire book chapter enlightens about the utilization of technologies, especially Internet of Things for environmental protection and sustainable living. Brief introduction part in Sect. 1 is followed by the outline of technology and environment protection provided in Sect. 2. In Sect. 3, features of IoT from an environment's point of view are described. Under Sect. 4, algorithms and its assessment are given for preventing environmental damage. Section 5 talks about reduction algorithms and clean-ups to reduce hazardous wastes. Section 6 handles safeguarding the environment using IoT, mentioning various monitoring systems and smart disaster systems, including the comparison of various algorithms. Finally, the chapter concludes after mentioning a few challenges around along with future scope and conclusion in Sects. 7 and 8, respectively.

2 Technology and Environment

Nature or the elements of the nature are rare and diminishable; any technology cannot meet that of the nature [13]. At least with the present knowledge and resources, we cannot develop something which can replace or substitute environment and that is a very well-known fact to all of us [14]. Humans have taken for granted the benefits supplied by the environment and returned it with nothing but damage. How much the environment has benefited us, it has equal or even more power to destroy everything. So, it is extremely important to go hand in hand with the environment. To protect and sustain environment, in this book chapter, we focus on three important factors – prevention, reduction, and protection [15] – preventing the damages caused to the environment, reducing the impacts on already exciting issues, and finally, protecting the nature. To handle these factors, we would take the help of technology.

Technologies have the power to grow or to shrink. It has the power to build and also to destroy. Some of the important technologies which have popularly grown in the last few decades include artificial intelligence, machine learning, IoT, drone technology, blockchain, and few other technologies. Technologies that contribute to the wellness of the environment would be artificial intelligence to keep a track of different species [16], a feature of latest technologies called remote monitoring and management, which helps in real-time monitoring and planning, Big Data to handle the recorded data, machine learning for predicting outcomes based on previously happened actions, drones to personally monitor the field of concern and a few others, namely, Data science, block chain etcetera, all contributing in different forms [17]. Another technology that prominently helps in upholding the environmental well-being is the Internet of Things – IoT. We would be looking more into it in the upcoming chapters of this book. From the above mentioned, it is certain that to build what we have destroyed – the environment – there is a high possibility and along with the same, we can recover our environment.

Internet of Things is one of the promising technologies which has been an amplifying word in the last decade. Internet of Things is all about connecting and communicating [18]. Internet of Things (IoT) can be defined as converting real-world objects into an advanced virtual object, over a network to satisfy human-centric application [19]. IoT has surely gained huge recognition due to a number of features which are applicable for a wide variety of fields and sectors. Under IoT, precision and accuracy are precise, providing real-time visibility to the user. With the help of IoT, access to control and handle any device is possible [20, 21]. IoT is being adopted in various areas for better performance and to bring advancements to the market [22]. Not only for commercial or industrial purposes, but IoT can also be implemented in our households, which would enable ease of living. Considering the adaptation in various applications, IoT can be implemented to protect and sustain the environment [23].

3 IoT Features for Environment Protection

IoT ecosystem empowers almost everything, including the environment. A number of features in IoT help in safeguarding the nature and sustaining it [24]. Let us look into some features from the view of environmental protection.

Intelligence: IoT consists of different components including sensors, actuators, devices, protocols, algorithms, and many other diverse things that are made to think intelligently. Considering this feature for the environment protection, a well-equipped intelligent IoT system would help in taking a keen path in view of environment protection and sustainability [24]. With this, we can build many smart systems, giving an environment-centric goal which would reduce the harm done [24].

Dynamic nature: Almost all the IoT systems sense the surroundings and change their state based on the gathered information. The nature of the environment is never of one kind and in one order, which tells more about the importance of IoT in environmental protection. IoT systems are built in order to sense, record, and adapt to the surrounding; algorithms or programs are also made with the same point [24]. Not only to the surrounding, but IoT systems are even capable of changing the quality of the devices used based on the workforce, location, timelines, and some other factors.

Connectivity: In IoT, connection can be made between machine and machine, machine and human, and human and human. This can also be said as the connection can be made between machine and machine, machines and environment, and environment and environment. Connectivity provides links between diverse objects which contribute to one goal. Making use of this, there can be many systems that are connected together. For example, with this, we can have connectivity between the trees in the forests which would further be connected to the main server using which we can monitor actions happening in the forest and reduce deforestations and smuggling of trees [24].

Heterogeneity: A key feature in IoT is its heterogeneous nature, which means diverse objects can be connected over diverse network. Based on the requirements of the customer or any firm, a wide variety of devices can be used. These devices are adjustable and scalable. Different devices that would help in environment protection are sensors to detect hazardous gases, drones to monitor a large area of forests, and systems developed for smart agriculture, and many others [24].

Vast scale: IoT systems are capable of receiving huge data from sources and can transfer those data to specific destinations. IoT systems utilize various infrastructure protocols such as Zigbee, WIFI, LoRa, and also messaging protocols like MQTT, CoAP, and XMPP for communication. All these are capable of handling huge data, and apart from this, IoT also implements cloud technology to handle storage [25].

These are a few IoT features which put together can build systems capable of handling environment-related issues and help in sustaining the environmental norms. Further going into the book chapter, dividing the ecosystem of the environment in the view of protection, let us consider three important factors. First being the prevention, it is very important that we prevent the harm caused to the environment before taking any actions [26]. As the good old saying suggests, “prevention is better than cure,” taking a step closer to environment protection and sustainable development with a point of prevention is useful and compulsory. Some of the actions which should be halted or prevented are letting out of hazardous chemicals which may be in the form of gases, liquids, or in any other form.

Another action that should be prevented in order to help the environment is cutting of trees, wasting of non-renewable resources, and human negligence [27]. It was seen in 2020 the effects of human negligence on every living being from the

Covid-19 pandemic to many industrial disasters. Human negligence should be prevented by any means, as the history speaks of many deadly disasters and damages that were caused to the environment were due to human carelessness. To overcome this, technology can be implemented, especially the Internet of Things [28].

The next factor is reduction. Either in building technology or in using technology, a great harm or, in short, great wastage has been done [29]. This ranges from polluting the environment to dumping electronic waste to eroding the soil. It is impossible to completely prevent pollution, [30] as daily use of vehicles itself lets out so much of pollutants; in a similar way, not using electronic products is impossible, which would, in turn, generate waste by any means. So, it is necessary that without affecting daily needs, we control the harm which can be done by reducing the harm. In order to do this, we can build IoT systems based on algorithms which are implemented for helping in reducing wastes.

The last factor is protection. After a proper prevention and reduction, the concern should be on protecting the environment. For this, there are a lot of technologies for monitoring, supporting, and preserving the environment and its norms [31]. Under IoT, we can build many real-time monitoring systems. In industries, smart emergency systems can be developed so that no damages would result [32]. In dense forests, brushfire detectors can be implemented using IoT [33]. All these systems and devices benefit from damages including human losses, economic losses, and environmental losses. Implementation of these systems brings out the true need for technology in our living [34]. A more detailed view of these factors is seen below.

4 Algorithms for the Prevention of Environment Damages

Algorithms are the blueprints or the blocks of useful information for a specific and well-defined goals or functions [35]. Any system with merely devices and network connection limits the possibilities of technologies. In the field of IoT, algorithms play a vital role under certain conditions providing total utilization of devices used [36]. Good algorithms provide great power to technology in order to benefit every aspect of life. There are many algorithms derived for different sorts of problems. Similarly, for environment protection, there are algorithms [37, 38]. Mostly, the algorithms are to discover different areas and to monitor them. Using algorithms, scientists found new marine groups and are looking for more [39]. Algorithms can also be around detecting issues caused.

4.1 Environmental Impact Assessment (EIA)

EIA is environmental impact assessment that originated under the US National Environment Policy Act (NEPA) [40] in the year 1969 [41]. Under this act, the main purpose of EIA is to support the efforts made in preventing the actions which would cause environmental damages. The goals of protecting the environment from damages are managed by committees generally assigned by the government, who are in a view of development and environmental protection [42]. EIA can be considered as an educational tool by developers and innovators in planning and processing their ideas. This assessment creates awareness among the creators of environmental factors and sustainability. The agencies and the corporations integrate the environmental norms into the planning process to ensure the stability of the environment in their field of works.

The implementation of EIA is different in different countries. Some countries following EIA are the USA, Australia, France, Japan, and other nations [43]. Generally, the approaches to EIA by these nations differ from each other which is why it is different to make one rightful statement about this assessment. Environment impact assessment derives environment impact statement (EIS), which gives the statement about the assessment to the committees [44]. However, it should be noted that without a proper understanding of the assessment, proceeding can equally lead to environmental concerns, which would depict EIA in a negative format. So, a careful study should be made with the goal of environmental protection. EIA does not limit itself to environmental protection; it also handles social factors including social impact assessment and other cultural factors [45]. Under EIA, we have various other assessments such as SIA, SEA, and HIA dealing with social, health, and strategic environmental impact assessments [46]. A strong development has been seen around the 1970s–1980s, especially in countries like the USA. A major factor in EIA is its decision-making aspect considering the factors listed in the Act [47]. Environment impact assessment has a high scope in fulfilling its goals but due to external factors, the true meaning of EIA is not being successfully implemented and chaos is being generated between the two parties in implementing it [48].

The process of EIA systems would vary according to the proposals and also the approach followed by those particular nations [49]. In the initial process, the EIA systems have a detailed study of various things that are likely to affect the environment norms. If any such activity is detected under EIA, the agency should make an alternate decision or approach which would not negatively impact the environment. A study team is appointed to evaluate and review the given statements. There would also be the involvement of the public in some conditions. After a proper inquiry, a final report is submitted. After given an approved action, constant monitoring and mitigation should be carried out. And also, a periodic reassessment should be made based on the Act. Some factors such as openness of the process and ease of access affect the results of the EIA [50]. It should be noted that the process varies according to the countries' implementation policies of the Act.

Obtaining an overview of EIA has given an idea about the benefits of implementing this assessment in an orderly manner and has created awareness among the developers and creators about environmental protection. Under this assessment, destructive developments which could harm the environment are prevented at an initial stage among all nations to protect the environment.

4.2 Fault Tree Analysis

Early on, we have seen human errors and negligence causing disasters [51] – disasters leading to loss of human life, economy, material wastes, and apart from this, a huge impact on the environment. Especially, disasters in industrial sectors cause a great damage to living species from humans to wildlife and from resources to damaging the fertility of the soil. If a proper focus is not given in either the production or in the maintenance, there would be such damages for which a huge price should be paid in return. To avoid such disasters, it is a good practice to predict the damages beforehand. Using technology to do this job is more precise, well defined, and there is a high chance of an accurate result. Considering these benefits, using technology for such activities would save ourselves along with the nature. There are a few algorithms and analysis which help in predicting the probability of errors occurring. One such analysis is the fault tree analysis (FTA) [52]. It is seen that the environment impact assessment can be performed using this fault tree analysis.

Fault tree analysis is an analysis tool which helps in identifying events that are faulty and would result in damages and disasters if not corrected on time [53]. FTA is defined in a top-down approach detecting faulty pieces at every field of operation. It can be said that the fault tree analysis is a hierarchical model defining the top most columns – the ones that are the most important operations which include various fields of production, distribution, and maintenance based on the implementation area [54]. This is followed by a detailed view of elements associated with the defined upper columns. The process continues until a well-defined system of operations is defined. The link joining all the layers are usually Boolean logics such as AND, OR, NOT, and the other few based on the requirement. Thus, making the FTA defined events as a set of true or false assertions, cutting down all the undesirable conditions using the logic gates [55], and helping us to avoid faulty events. It would be a good practice to implement FTA before initiating any projects or activities to overcome hurdles later on and to avoid great tragedies. Some of the applications of fault tree analysis (FTA) are reliable power systems [56] and fuel cell diagnosis [57].

An example of using fault tree analysis to avoid oil spilling is given in Fig. 1 [58]:

Using fault tree analysis, we save not only the human life but also the environment in specified ways:

Oil spilling can be limited [59].
Gas leaks from the industrial sites can be halted [60].
Usage of hazardous methods in the production can be seized in its initial stage [61].
Identification of events that trigger environmental damages is recognized easily.

In short, human negligence and system defaults are shortened, in turn preventing damages resulting in great disasters. We can notice that using simple logic gates with an output of true or false combined together can help in the prevention of serious losses and damages caused to the environment. Implementation of both EIA and FTA together brings awareness in the public about the environment and helps in

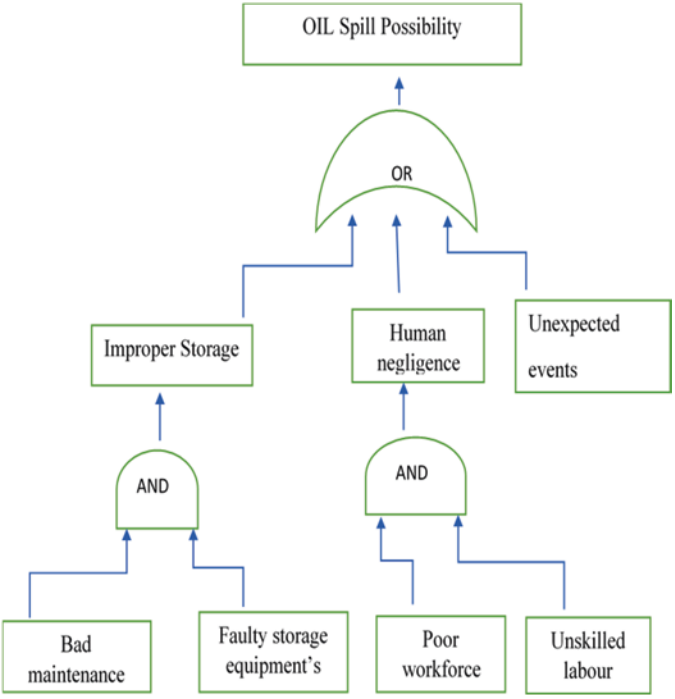

Fig. 1 Fault tree analysis to avoid oil spilling

detecting the areas of errors and prevents it from happening, ensuring a secure environment [62].

These sorts of analysis and assessment contribute to developing technology and also help in a sustainable environment. Smart devices dealt in the fields of IoT technology are usually a combination of various algorithms and applications which are advanced and work on various functionalities, unlike the past devices which usually work on simple information [63]. Any developer with the help of IoT, having a view of implementing the algorithms mentioned, will contribute way more in sustaining the environment than merely developing without any insight into how it is impacting the environment.

5 Reduction of the Damage Using IoT

Reduction mainly deals with waste clean-ups. Waste clean, if not properly disposed, can lead to dangerous cases. Especially, waste generated from industries, chemical plants, manufacturing units causes high damage compared to the waste accumulated naturally [64]. Artificial waste pollutes all forms of nature, be it air or water or soil or any living species. So, it is extremely important to decompose the waste in a well-defined manner.

Generally, waste is decomposed either by a method called incineration where the e-waste also called electron-waste is decomposed by burning the waste. Another way of decomposing waste is open dumping or landfills. There, the waste is dumped in open locations causing the entire area to be contaminated. By burning the electronic waste, toxic gases are released into the atmosphere, damaging the layers of the earth. Waste is also being thrown into water bodies, which not only pollutes the water but also kills the flora and fauna, damaging the ecosystem of the nature [65].

5.1 Ocean Clean-up

Oceans are the largest water bodies on Earth. They provide habitat to a number of marine animals and plants. It is one of the Earth's most valuable natural resources and a major "shareholder" of our economy. It plays a major role in storing carbon in the atmosphere and provides us with oxygen without which one would not survive, regulation of climate, recreation, transportation, and so on. Despite the multiple services, man being the needy mortal is over exploiting it for food, minerals, crude oil, and what not! Oceans are being used as a dumpster ever since the 1960s for the disposal of chemical, industrial, and radioactive wastes, not to forget sewage [66]. Regulation of ocean waste has been prioritized in the following years, as it causes harm to the marine fauna in succession affecting the human health. Reconciliation of waste starts with a conventional check at households and sewage units, which in turn paves the way for the reduction of marine pollution [67].

Thailand developed a new automation to supervise and gather the waste using sensor technology and IOT, as well as social media application LINE [68]. Urban Rivers, a company located in Chicago, used a robot controlled by man for the collection of waste, thus improving the water quality in metropolitan areas. Many disclosed smart trashes through IoT monitoring systems [69]. According to India Block, large amounts of plastic wastes in rivers are cleaned up through an automation system by informing the user when the trash exceeds the optimum level. IoT in the maritime industry deals with maintenance and monitoring of the equipment to reduce drastic failures and even save the onboard crew [70]. Internet of Underwater Things (IoUT) farther than IoT is a worldwide network that serves to connect smart underwater objects digitally with the water bodies to supervise the wrecked ships, to detect the onset of the tsunami, and to study the behavior and health of marine animals [71].

5.2 Waste Reduction Algorithm (WAR)

Prevalent chemical processes are always looked at broadway for their benefits rather than the detrimental effects. One of its resulting products has a potential impact on the environment. The waste generated through the processes is often neglected which can later on prove to be hazardous, when they are released into the environment.

Waste reduction algorithm (WAR) deals with these potential environmental impacts (PEI). It is based on the principle of reduction of PEI rather than cutting out the waste generated throughout the process [72]. The estimation of impact algorithm is indeed advanced, but it enables the user to highlight a particular hazard for a particular application. Waste reduction algorithm is used along with monitoring systems in a flowchart manner. Some interfaces used to implement this are CAPE-OPEN. These flowcharts are flexible in nature and can be evaluated as a whole or as a subset of the flowchart. The information obtained from the flowcharts has a potential to support environmental protection and also help in the sustainable development of nature [73].

Using the waste reduction algorithm, we can reduce the issues connected with pollution. Deriving a mathematical equation related to pollution balance can be obtained by waste reduction algorithm [74]. This algorithm can be implemented commercially by integrating WAR with simulators.

Internet of Things is seen in waste management under IoT-smart city application. IoT along with the features mentioned above and machine learning consisting of functions such as clustering, regression, and classification, combined together have a great scope in advanced technology. Using this combination, many systems can be developed along with the algorithms in reducing the waste, collecting the waste in an effective manner, and disposing of the waste accordingly. According to the cited study herein [75], household waste management can be done by collecting and extracting useful information, providing this information to smart IoT application which is capable of making decisions, learning from the obtained information and predicting the rightful approach using machine learning to manage the waste. Machine learning, similar to IoT, is seen in various application platforms such as health centers [76].

6 Protecting the Environment Norms Using IoT

It is well known by now that technology can either build or break the environment. There are places where introducing technology has brought many benefits to the environment and is promoting sustainable development. A major role of IoT can be seen here. IoT is the technology behind various smart applications including smart cities, smart agriculture, and many other smart applications. Features of IoT which are discussed above are utilized by developing systems through a combination of hardware and software components connected over a network of those data stored in the cloud.

The hardware components used in IoT systems are mostly sensors, actuators, devices, RFIDs, barcodes, and other components which work to fulfil one specific function. All these things are effective, cost-friendly, and eco-friendly giving huge benefits. Sensors and actuators are transducers which convert one form of energy or command into a more useful form. Sensors are used to sense the outer environment and these are further connected over a network in transfer and receive the data [77]. RFIDs and barcodes are two different types of identification tags or codes. Under RFIDs, identification of objects is done using radio waves. These RFIDs are reliable and have applications in various sources. Single RFIDs have tags, readers, antennas, and other useful components [78]. RFIDs are also used to track moving objects [79]. Barcodes are codes encoded in a pattern of bars and spaces. Optical machines are used to detect these codes.

Protocols play an important part in every IoT system, especially in the area of communication. There are various types of protocols for various applications. As of now, the major addressing protocols over the internet are IPv4 and IPv6 [80]. IoT protocols can be divided into infrastructure protocols and messaging protocols [81]. Under infrastructure protocols, there are Wi-Fi, Bluetooth, Zigbee, and LoRa, which are used based on the requirements [82]. HTTP, XMPP, CoAP, and other protocols are present in the messaging protocols [83]. These protocols differ in their architecture and area of usage. But the motive behind using these protocols is for communication and messaging. With these protocols, the IoT systems communicate with the user through dashboards and also communicate with external components such as cloud, drones, or even other IoT systems.

Clouds or cloud computing is one such technology which is implemented in different areas of applications. There is no dictionary definition of cloud technology, and the definition varies from the place of application to the type of cloud. Cloud services can be public or private. Under cloud, we can integrate both hardware and software applications. The architecture of cloud computing is divided into three layer – IaaS, PaaS, and SaaS. Each standing for Infrastructure as a Service, Platform as a Service, and Software as a Service, respectively [84].

Internet of Things is no doubt an advanced technology, which is a pack of various components applicable on diverse areas. With the help of IoT, we can build various real-time monitoring systems for having a regular watch on the action done to or by the environment. With IoT technology, we can prevent damage, reduce wastes and protect the environment, and also combining other technologies such as machine learning, Big Data, and cloud computing increases the scope of protecting the environment and helps in promoting the concept of sustainable development.

6.1 Smart Disaster Response Using IoT

Disaster management is the process of addressing scenarios which have a high probability of showing serious damages [85]. Disaster may occur either naturally such as earthquakes and volcano eruptions or artificially, including industrial exploders, war activities, etc. These disasters not only damage the living ones but also erode and divest the environment. Surely, technology cannot stop these unexpected disasters from happening, but they can surely help in warning about the disasters, which can save the impact from being horrific. Another way of utilizing technology to its fullest is in the communication. Due to disasters, regular conventional or cellular mobile communications would be damaged, leaving us to rely on these advanced technologies [86].

Using IoT, smart disaster management systems can be implemented at various locations, especially in the disaster-prone areas. Some of the sensors which would help in identifying such activities are microwave sensors, remote sensors, infrared sensors, and these sensors detect the damage in its initial stage and send signals to the connected server or turn on the alarms if the readings are above the threshold values. Other devices such as Wi-Fi modules and Arduinos can be used for communication over the Internet [87].

Some prominent sensors used at the time of disaster are as follows:

MQ-2 sensors: It is a gas detection sensor. Identifying gases such as hydrogen, methane, LPG, and alcohol. Can be implemented at industrial areas and chemical plants.

DTH sensors: Generally, DTH sensors are for detecting the temperature and humidity of the location. Under DTH sensors, we have DTH-11 or DTH-22 varying in its accuracy and range.

Ultrasonic Sensors: Sense ultrasonic waves. There are four different types of ultrasonic sensors, which classify either by frequency or structure. They are widely used in IoT systems [88].

6.2 Real-Time Monitoring Systems Helpful for the Environment

The environment is uncertain, which requires a constant invigilation by either human force or with the help of technology. Invigilation by humans is not a good option, as it would require high accuracy, and negligence cannot be tolerated. So, the best possible thing to do is to monitor the environment using technology, especially real-time monitoring systems by IoT. Considering environment monitoring models [89], it can be classified in the following ways:

1. Air monitoring.
2. Waterbody monitoring.

3. Waste monitoring.
4. Remote monitoring.
5. Biodiversity monitoring.

Air monitoring: The effects of air pollution on humans, plants, and animals are known to all of us. The most harmful pollutants which should be avoided are ozone (O3), nitrogen oxides (NOx), carbon monoxide (CO), and few other gases [90]. The sources releasing these harmful gases are many. And the gas released from vehicles is mostly carbon dioxide (CO2), a greenhouse gas that contributes to the global warming [91]. Air quality monitoring system should be placed at areas like check points, industrial outlets where there is a constant release of harmful gases. The benefits of using IoT-based air quality monitoring system would be identifying the sources where hazardous gases are released. After identifying the sources, the required measure should be made in order to control air pollutions [92].

Waterbody monitoring systems: As the monitoring areas of the water bodies are huge, IoT-based monitoring systems are a must. Monitoring should be done at the seashores as well as underwater. These monitoring systems also come to great rescue at the time of floods, alerting the people to be aware of the danger. These monitoring systems are usually cost-friendly. Also, we have various sensors such as water-level monitoring sensors and ultrasonic sensors, which help in keeping a track of such systems [93].

Waste monitoring: From storing the waste to decomposing the waste, a proper waste management should be performed. Some wastes are impossible to decompose, such as plastic which is highly corrupting the earth. So, a replacement should be seen. Seaweeds are considered a replacement for the plastic packaging. An Indonesian inventor found this solution to cut down plastic waste [94].

Remote monitoring: Remote monitoring systems are systems functioning with the help of drones and cameras which are viewed by the operator. Large forest areas can be monitored with the help of these remote monitoring systems preventing any illegal actions from occurring in the forest areas. The surface of the oceans can also be monitored. Many monitoring systems have been implemented using drones to monitor areas like solar power plants [95].

Biodiversity monitoring: Environment can withstand any impact if its ecosystem is balanced. In order to protect the ecosystem and sustain them for the future ones, an implementation of biodiversity monitoring system can be employed. A tracking system on wildlife and plants would help us in monitoring the species. Avoiding smuggling of trees and animals' body parts [96].

These various monitoring systems contribute to environment protection. Just as environment protection is needed, in a similar manner, sustainable development is needed. Sustaining means protecting the nonrenewable or perishable elements for the future ones. The concept of a sustainable environment should be made aware to everyone. Through monitoring different elements of the nature, we not only protect the environment but also support and contribute to sustainable environment. Three factors dealing environment-related issues and ensuring the environment protection have been seen. Comparisons and applications of the algorithms and assessments used are shown in Table 2.

Table 2 Comparisons and applications of the algorithms and assessments

Algorithms and assessments	Comparison	Applications
FTA	FTA can be comparison with ETA. Event tree analysis is a complimentary technique to FTA. FTA focuses on preventing measures. ETA focuses on mitigation measures [97]	1. Fault tree for electrical injury. 2. Applicability in marine engineering. 3. Fault tree analyses train rear-end collision accident. 4. Risk assessment of a thermal power plant.
War	Waste reduction (WAR) algorithm is evaluated based on PEI which stands for potential Environment impact. The main goal is to minimize the PEI for any process, rather than reducing the amount of waste created by those processes [98]	1. Conversion of biomass into bioplastic [99]. 2. For estimation of ecological impacts. 3. Support to waste-to-energy technologies.
EIA	Other assessments such as SIA, SEA, HIA SIA - social impact assessment SEA - strategic Environmental assessment HIA - *Health Impact Assessment* [100]	1. Applied in the fields of energy conversion technologies. 2. Decision making support systems for water treatment plant optimization. 3. Environmental impact Assessment of Kol-dam hydropower project [101]. 4. Environmental impact assessment (EIA): Case study of a hydropower project.
Prediction algorithm	Uses multiple linear regression techniques Mostly stepwise regression is widely used for prediction algorithm for air pollution	For outdoor air pollution spatial surfaces
Environmental assessment Tool for organic synthesis (EATOS)	A key factor called as Q-factor is used to evaluate different hazardous effects on nature	Organic synthesis [102]

7 Challenges Dealing with Environment Protection with Technology

Technology has not yet reached a point where it can be completely modified to balance out development and sustainment. For developing such technologies, there are a few challenges to overcome. Initially, environmental technology should be promoted in the field of research and development. Due to lack of scientists and researchers, and also due to insufficient or unsophisticated infrastructure, research is usually not up to the mark. This in turn demands skilled workforce and trained assistants who are aware of various functionalities. Another major challenge on the way is that the environment and its issues mainly depend on a regional base, that is, environment varies based on geographical areas, so technologies adopted should be applicable to all types of climatic conditions [103] and also some challenges around communication paradigm [104]. Some more challenges can be considered as issues related to governments, which are not seeing the alarming signs of environmental damages. And also, the public, who are unaware of sustainable living of what, are the major hurdles from protecting the environment and having sustainable living [105].

8 Conclusion and Future Scope

Surely, technology cannot replace the environment and it would be foolish if anyone is making an attempt to do so. Instead, attempts should be made as to how we utilize technology to protect the environment and contribute to sustainable development. Over the last decade, there have been many technologies contributing to this goal and made it clear that technology and environment can go hand in hand with each other, ensuring a sustainable ecosystem with advanced technology. There are yet a few impacts and damages done to the environment which do not have a technological solution. But as new technologies are developed and more advancement are seen on a faster pace, there are more chances than ever before on seeing a clean environment.

From the initial stage of industrial revolution to today's pandemic situation, life has changed extraordinarily in both good and bad terms. So did environment and its ecosystem. Many events caused great damages to the environment and initiations have also been taken accordingly in order to halt them. Everyone is aware of the harm done to the environment and the rate at which environment is deteriorating; they should also be aware of how technology can be used to help the environment. Awareness among the public about environment protection and sustainable development would be the first and main step toward environment protection, along with creating awareness about how one can use technology to protect the environment. Making use of these technologies will protect our earth and sustain it for the future.

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Energy-Efficient Smart Cities with Green Internet of Things

Mudita Sinha, Elizabeth Chacko, Priya Makhija, and Sabyasachi Pramanik

Abstract With governments of different countries having a vision of smart cities, the technology adoption and implementation are at its peak and the current increase in the usage of advanced technology for a smart city has led to an increase in the carbon imprint across the globe, which needs immediate attention for the environment sustainability. Although the Internet of things (IoT)-enabled devices have changed our world by bringing an ease to our lifestyle, it has to be kept under consideration that they also have adverse effects on the environment. Over the past few years, enabling energy conservation via Internet of Things in the growth of smart cities has received a great deal of attention from researchers and industry experts and has paved the way for an emerging field called the green IoT. There are different dimensions of IoT, in which an effective energy consumption is needed to encourage a sustainable environment. This conceptual paper focuses on the key concept of green IoT and sustainability, knowledge of Smart cities' readiness to Green IoT (G-IoT)-enabled sustainable practices, and identifying the Green IoT sustainability practices for smart cities.

Keywords Smart city · Green IoT · Sustainability · Technology · Energy efficiency

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1 Introduction

1.1 Green Internet of Things

Almost all the sectors have been modified and updated due to the massive transformation and advancement in information technology (IT), with an increasing trend toward Internet of Things (IoT). Through IoT integration and connection of various gadgets to the Internet, no human intervention is possible [1]. The smarter the world is becoming with all the smart technologies to modify the life quality, the more burden there is on environment due to the increased carbon footprint. The answer to this problem is only Green IoT (G-IoT). Green IoT will aid in the reduction of emissions and pollution which exploits environmental maintenance and surveillance and will also minimize the cost of operation and consumption of power [2]. In other terms, it can be described as the form of power optimization, which can help in reduction of the Greenhouse effect [3].

There are various domains which are focused on G-IoT, starting from manufacturing to consumption as well as planning and in subsequent stages recycling and disposal which impact the environment [4]. Green society can be enabled with G-IoT with respect to energy utilization with different domains like Smart ecosystems, Smart cities, Mobile e-health, and Smart network [5].

Discussing further on Green IoT, it combines innovative resources to minimize the negative influence of IoT on the ecosystem. The main aim of G-IoT is in the direction of minimizing carbon dioxide, pollution emission to preserve the environment, and optimizing the cost of operation and power consumption [6–8]. For a safer environment, reduction of energy consumption by IoT is mandatory [4]. In the upcoming rapid development of green information communication technologies, G-IoT is showing a promising potential to boost the growth of economy and sustainability of the environment [6]. This upcoming and promising technology will make the world smart and environment-friendly.

2 Smart City

Smart city concept was coined in 1994 [9] and since then, the concept has been the topic of discussion [10]. Although the concept is quite a discussed one, there is yet no clear understanding about the concept of smart cities [11, 12]. As per common insight, smart cities are the innovative urbanization and smart concept to tackle urban problems associated especially with environment, houses, people, and their well-being [11]. Smart cities are also defined as a place where services are provided with efficiency by utilizing technology for benefitting the people or the environment [13]. The expansion of smart cities improves the life of citizens [14], productivity of the environment, sustainability, and safety [15, 16], along with technology that can be monitored and operated centrally.

The six key smart city components can be classified as: smart transportation, smart life style, smart economy, smart ecosystem, smart citizens, and smart governance [17]. Most sectors of urban expansion, such as government functions, city procedures, delivery of services, and intelligent analytics, improve the services, production, and usability by embedding Information and Communication Technologies (ICTs) [18]] and IoT [19]. The aim of smart cities is focused on the reduction of carbon footprint, improvement in energy efficiency, superior quality of living ecosystem, more green areas, advanced infrastructure, and evolution of the city [20]. Transition of smart cities is complicated and in an omni-dimensional phase. Collective integration of technical, policy, structural, and transitional components relies on the process of city transformation. Smart cities with business prospects [21] will provide technology and information-based services for economic growth.

3 Smart Cities with Green IoT for Sustainable Environment

Urban growth and population of cities are rising exponentially, creating numerous environmental, fiscal, and societal sustainability problems for cities [14, 22]. Congestion of traffic, weak infrastructure, health problems, resource scarcity, instructive difficulties [23], poor infrastructure, rising rates of crime, fewer jobs, old structure, power larceny, supply link problems, inadequate capacity for power generation, extraordinary loss of power in transmission, regular power interruptions, and absence of real-time information division are such problems. Critical infrastructure constraints [24] and reserve supply restrictions generate problems for growing populations to provide nutritious food, electricity, and clean water. Besides the steps of cost cutting, standard changes to online facilities, temperature change issues, economic rearrangement, and employment reduction, cities are under burden from public finances to reduce finance. Smarter ways are thus important for the people to handle urban problems and to face-lift city life, productive infrastructures, and value-added services [25, 26].

There is currently a need to build a sustainable place for living that should take care of all stakeholders, enterprises, and government because of the living style and quality of people's daily life activities. In addition, individuals will also have to play a role in the creation of a sustainable living space and attempt to handle issues like weather change, natural resource exhaustion, and biodiversity decline. The main goal of the G-IoT revolution is to advance the life quality and safeguard the world from these kinds of problems using technical advances [27]. G-IoT makes cities smarter by linking smart sensors, computers, cars, and infrastructure at all locations in the city. G-IoT helps stakeholders to reduce chemical omissions, water usage, and improve the protection of life and the health of human beings. G-IoT has two features for this smart city making design [27–29]: (1) Planning and development of G-IoT devices for improved networking setups, communication procedures and maximizing the bandwidth through minimal usage of energy. (2) The installation of these G-IoTs and advanced technologies minimize emissions of dangerous gases and enhance living space.

4 Methodology

This conceptual paper focuses on the current knowledge of Smart cities' readiness to Green IoT (G-IoT)-enabled sustainable practices. The researcher will focus on identifying and exploring how different empowering technologies like the internet, smart objects, sensors, etc. may be effectively utilized to attain G-IoT in smart cities. This research article will also evaluate numerous IoT frameworks, initiatives, and standardization efforts currently under way and the potential issues to be tackled in the future to implement green IoT for smart cities.

The following objectives should be fulfilled by literature reviews: Firstly, a review must consolidate all the findings of the research by studying and fusing various pieces of literature of a particular research area to find the research gap and act as a catalyst for upcoming research. Secondly, large amounts of data can be gathered by reviewing appropriate literature which will be reliable, precise, and can be retroflexed as per the requirement. Whenever G-IoT and smart cities come into the picture, people and ease of use are embossed as emerging research thrust areas for the future. The current research looks to answer the following:

1. The key concepts of Green IoT in smart cities.
2. What are the Green IoT sustainability practices for smart cities?
3. Readiness for G-IoT driven sustainability in smart cities.
4. The key concept of Green IoT and sustainability.

5 Literature Review

The World Wide Web (www) was used for surfing, networking, and learning long back. Slowly, there came an era of Information and Communication Technology (ICT) where individuals and organizations adopted technology, at a deeper sense. As the year goes on, dependency and more development in ICT have impacted the daily lives [4]. The growth in ICT solutions through the Internet of Things (IoT) is one of the emerging topics where visioning the future is based on the internet. IoT did make the connectivity of physical devices controlled by the internet. Transfer or collection of data became easier through the implication of IoTs. Organizations use smart systems these days to integrate data from any part of the world. Like in many organizations, employees can give a print to any branch office around the globe without the constraint of boundary. In IoT, a "thing" can be anything that can be connected to internet or broadband devices through wireless fidelity (Wi-Fi) or low-power wide area networks (LPWAs), or wireless sensor networks (WSNs) [30, 82].

It requires remote sensing of the objects/things to be controlled over the internet. IoT improves efficiency and works faster than human work. The current popular term IoT was coined by Kevin Ashton who founded an auto-ID center in 1999 for Massachusetts Institute of Technology (MIT), which then was a globally accepted system as RFID (radio-frequency identification), also connected to the physical environment with "ubiquitous sensors" [31, 32]. Before that, there was connectivity between machine to machine (M2M) but human intervention was existing like for Telegraph in the 1830s [33]. It was also envisioned by Nikola Tesla in 1926 that there will be a transformation from the time of inception of wireless systems and applied electricity, which will surely bring greater benefits to the human race [32, 34, 35]. It can be seen how the change and application of wireless systems were introduced in various sectors like the health sector using technologies and instruments enhancing getting equipped with updates like the heart monitor plant, etc. It can be the transport sector where integrating the wireless system with GPSs (global positioning satellites) can track the current location and estimate time of arrival. There are various other industries where IoT is included for production or logistic/supply chain. It was also predicted that IoT will bring a change where people can carry phones in their pockets [32]. Coca Cola company had used the concept where programmers connected the refrigerator with the internet to check the availability of drink and to know the cold condition. It was in the later years, more and more things got connected with the internet, not just heavy machines but anything a person can think. From "*2013 onwards the multiple technologies ranging from Internet to wireless communication and from micro-electromechanical systems (MEMS) to embedded systems*" [33]. If a device can take smart decisions like alert calls, messages, fire alarm, or can detect low in paper for print command with the support of micro-electromechanical systems (MEMSs) which can smart work as per temperature, light, weight, pressure, and motion [1]. According to the Cisco Annual Report [36], two-thirds of the population (66% globally) will have access to the internet by the year 2023. As per the Asia-Pacific region, the internet users will be 72%. This reveals that there are more internet users and an increase in M2M (machine-to-machine) applications used by various devices. In the coming years, there will be more disruptions in electronic applications and which will obsolete the present applications. Currently, the M2M connections are 8.9 billion through IoT, which will reach 14.7 in the year 2023. Also, the study of global mobile and connection preference is toward 5G and low-power wide range (LPWR) as per Cisco reports which will increase the global Internet Protocol (IP) traffic [36, 37]. The demand and increase in the consumption of electronic devices by individuals and businesses have reframed and reshaped the worldwide network and transformed the society as a whole [38]. The smart technologies did make the work faster, but year-by-year, updates and upgradation in the system make technologies go obsolete which, in turn, increase the concern for diverse e-waste disposal, greenhouse gas (GHG) emission, and nonrenewable resources' consumption [36, 38]. Green IoT is a way toward a greener environment by reducing the negative impact of technology on the global society by developing technologies that do not harm the environment, protect mental health, and conserve the natural resources to have sustenance. Green IoTs will develop technologies which can reduce fuel waste and energy consumption, promote recycling of paper, batteries, cans, plastic, and renew the ways to enhance the wind power, solar energy, and wastewater [38]. The innovation in the field of green IoT (G-IoT) requires components such as sensors, embedded processing, and connectivity, which can be applied with the suitable software for various services like smart homes, smart parking, smart health, smart energy, etc. This shows that the total consumption of smart energy is increasing, which causes GHG and CO_2 emission globally [38]. For a greener IoT, renewable energy needs to be bidirectional, where the central demand needs to be examined [39]. G-IoT gives way to volume and variety of data generation through the internet, from which required information is to be extracted for predictive modeling and impactful decision. The general principles for G-IoT are to have products, which consume less energy (nanopower) and are eco-friendly, to encourage the use of renewable sources like wind, solar, biogas, etc., by making products that can reduce the consumption of energy while not in use with proper use of sensors and algorithms. G-IoTs can work efficiently when provided with proper internet speed/bandwidth for which the recent connections need to be enabled. The old version of connections that are slow and not in use needs to be recycled to reduce e-waste. The greener environment must also focus on upgrading the existing technologies, so that optimum resources flowed in the market. Companies and developers must try to integrate new technologies for smarter work and not only for profits. The various factors to be considered while implementing green IoT must be based on (1) less energy consumptions, (2) sensors sense and exchange information to deploy successfully [37], (3) communication of network, (4) application that supports maximum devices, (5) security of data, and (6) alignment of IP providers, hardware developers, network design, and telecommunication. The G-IoT focuses on sustainability that can be achieved only when IoTs are applied ethically and efficiently in all aspects for individual, business, and society [1, 38, 40]. Authors examine the following IoT applications for sustainable smart cities under five main categories: [i] traffic control, [ii] waste management, [iii] G-IoT and smart buildings, [iv] G-IoT and smart city surveillance, and [v] air quality management. While discussing smart cities, we will also examine the sustainable smart world throughout these sections.

6 Green IoT for Sustainable Smart Cities

IoT is at its best when forming a smart world. It can happen when cities get smarter. The global world under the internet umbrella has to think beyond social networking and industries to communities where IoTs can make a better place for human beings by providing a green environment. According to the United Nations on World Cities Report 2020 [41, 42], there is an increase in urban sprawl, due to which two-thirds of the population have income inequality. Approximately, 1.6 billion people have inadequate housing living in slums and informal settlements. As the move toward urban living has grown up, smart living also called smart city or green city or intelligent city is looked like the global shift which must focus on sustainable development and reduce poverty, provide access to education, and reduce carbon emission. Today's scenario where every individual has a smartphone, itself is an indication that the use of technology has risen among the population. Technology applied to reduce climate change and an imbalanced ecosystem will be an initiative for greener tomorrow. Intelligent cities are new initiatives from a global view to have future sustainability [41, 43]. Smart cities can be defined where people have smart homes and where traditional appliances are switched by energy-saving technological solutions to reduce the use of electricity by increasing the consumption of solar panels and eco-friendly materials [44, 45]. Smart cities can be the place where everything is systematically applied through internet, it can be smart airport, smart water supply, smart offices, smart health care, smart garbage collection, smart travel, smart predictability of climate, and various other ways through which energy can be saved [46]. The cities can get smarter only when looking into the major concerns like citizen's livability and security. For smart cities, the biggest challenge with the government is the finances [43, 47]. For proper application of a defined smart city, there must be, technology enhancement at every step, as there are many [48]. states that, synchronization among people, things, and data is necessary to process the IoT systematically. As per IoT analytics, [49] states that *"active global IoT connections grow from 7B in 2018 to 22B in 2025, Low Power Wide Area Networks (LPWAN) are expected to be a key growth driver."* Various other connections that have market are 5G and WLANs (wireless local area networks), which too have features like low latency and high bandwidth to support the smart city applications. As these connections work on low energy and data rate, communication also operates without human interventions. It also has to connect with heterogeneous devices starting from personal computers (PCs), mobile, other battery-powered IoTs, and so on at any point of time and anywhere to have sustainable smart cities. To have connection with heterogeneous devices, the power supply must be continuous to transfer data for roper functionality and tracking.

Smart city in the context to India is a bold initiative from the Government of India which was taken in the year 2015 as "smart cities mission," while preparing the IoT policy [50–52] to plan for 100 smart cities [49, 53, 54]. The IoT applicability might improve the country financially too, as when cities will be using IoTs, it will generate data which will be accurate and help in smart decisions [52–55]. The core areas to look into are water supply, electricity supply, public transport, digitization, education, and health care [53]. It is also studied by the KPMG report on fifth Smart Cities India 2019 Expo that there are few levers for applying IoT for smart cities, and that they are artificial intelligence, mobile internet, cyber security, predictive analysis, digital literacy, and IoT platforms [52]. To successfully implement IoT for smart cities, we need to use innovation or creation of technology to solve urban problems and certifying safety, security, and privacy for the citizens. Also, it should cater to questions related to smart energy management [SEM] for smart cities in India [56]. Smart cities can reduce cost and resource consumption, which is the goal of each government [57]. To instil and procure "*Smart Cities can happen through a combination of government projects and Public Private Partnership (PPP)* *initiatives*" [54]. To have deeper insights into smart cities, let us discuss the various components related to it.

7 Green IoT for Sustainable Traffic Control

The increased flow of population toward urban areas, itself has made urban cities crowded and commuting has become a hurdle for citizens [58]. Traffic management is one of the core areas of problem in developing countries. As per the data by Forbes India, in the 1950s only 30% of the world's population resided in urban areas, but as per the study it is expected that it will rise to 60% by 2050 as cities are expanding [51]. Due to this factor, the urban mobility is facing issues like traffic congestion, inadequate parking spaces, poor roads, and other concerns like safety and pollution [51, 54, 58]. As per the report by the World Health Organization, 11 out of 12 polluted cities worldwide are reported in India [51, 59]. Furthermore, as per the 2019 report, 20 two out of 30 world cities again fall in India [60]. To have control over rising issues with mobility need to cater by improving the infrastructure, using the best quality materials to construct roads, to produce high-speed vehicles, and to encourage even more use of electric vehicles, and more importantly to enhance the smart traffic management. Smart transport can be applied through factors like smart parking sensors, smart streetlights, smart highways, and smart accident assistance [58]. Smart traffic lights' control can provide the real-time traffic congestion that can show diverted routes to the commuters, so as to avoid traffic jams. To implement, the technology needs to be very fast and sensors mounted at traffic places must study the weather conditions, to analyze the congestion and show suitable routes. Parking has also become "*Achilles heel*" in urban places [58]. Earlier, people used to travel through public transport, but now they prefer personal vehicles that also move toward four-wheelers. Urban cities are constructing more buildings to accommodate the flow of population, but space for parking thought is less. Many European cities have installed parking sensors to update the commuter with real-time data on empty spots for parking. In addition, policies have to be formulated for the *"do's and don'ts"* on parking and the citizens informed about the policies and trained to use applications for reduction in parking-related problems. Intelligent transport systems (ITSs) to support smart cities required investments and synchronization among vehicle, traffic signaling, assistance, and refueling stations. Cities need to improve the infrastructure and connect components with ITS through vehicle grid or V2V (vehicle-to-vehicle) operation modes [44, 61]. Vehicular ad hoc networks (VANETs) include factors like wireless propagation, congestion management, routing, infrastructure, and security to vehicle application for trust and authentication factors [44]. Transport system to support smart cities can be developed by encouraging electric vehicles, but before that the charging stations have to be built and future vehicles should be smart enough to examine the battery percentage and detect the nearby stations for charging, which can collaborate the technologies through the internet. The challenge in this scenario will be high-end vehicles, which cannot be afforded by citizens, and to set up charging ports in sufficient numbers to reduce queues [61]. suggested the installation of a vehicle automation and communication system (VACS) in vehicles for safety and global traffic control. The automobile industry should focus on the recycling of obsolete vehicles to reduce the automobile waste and bring in new vehicles installed with technologies like ITS or VACS to improve commuting, cleaner, and safer roads.

8 Green IoT for Sustainable Waste Management

The cities are densely populated, so managing of waste from its initiation to discarding it is the biggest challenge for the municipalities around the globe [1, 58]. Still, there are few smart cities that are doing well in the waste management category like Singapore which has bins that are solar powered, and hotspot connected which make them the first ones to implement the rubbish bin concept [55]. Seoul is yet another city having a waste management system (WMS) called Clean Cubes that are solar powered and that did reduce the waste collection cost by 85% [55]. The waste can be e-waste, biomedical, industrial, and solid waste-municipal waste. If the waste is not disposed of properly, it will add to critical issues like air pollution, spread of diseases, and climate imbalances. IoTs have brought about revolutionary changes in sectors like health, transport, automation, etc., as in waste management which can also use IoTs for garbage bins. The bins are connected to the central hub through the internet with ultrasonic sensors that can check the bin load and send messages when to collect the garbage [62]. Continuous monitoring and tracking will help in the segregation of waste by the machine itself by applying M2M (machine-to-machine) communication which will be able to detect cleanliness issues on a real-time basis [62, 63]. This will also detect the fire in waste materials and how to avoid uncertainties [64, 65]. The garbage trucks will get the signals from the bins and the nearest garbage pickup truck will collect the garbage. For future smart cities, municipalities around the globe have to install applications to bins and train the collectors for an efficient and cleaner future.

9 Green IoT for Sustainable Smart Buildings

IoT-enabled Building Management System (BMS) will be a game changer, as it will be automated building equipment and communication infrastructure [66]. Buildings can be industrial or residential, if connected with IoT, one can assess the temperature and control the temperature accordingly. Smart buildings can be defined as smart when homes have applications connected to Wi-Fi/other internet devices. These days, many homes have smart lights that get switched on with motion or controlled remotely through phones. Other home appliances like geysers, air conditioners, washing machines, music players, televisions, and fans can be connected to the internet, then controlled from anywhere, which is again energy saving [57, 67]. The BMS includes HVAC (heating, ventilation, and air-conditioning) systems, which can control the temperature within homes to have proper air flowing. BMS controls the lighting, elevators, windows, and various other electrical appliances through internet-connected gateways [34, 57, 66]. A proper implementation of infrastructure will be benefiting the building manager to take appropriate actions as per the data received and record information for the future.

10 Green IoT for Sustainable Smart City Surveillance

Green IoT does not just make waste management for smart homes it can also be applied for security purposes too. Surveillance is a broader term for all the applications of IoT for smart cities but the controversy related to the information about the citizens is always of concern due to the middlemen involved [68]. From smart buildings to waste management, everything is operated by information technology. Therefore, there will be centralized power for smart cities, as it can track and monitor the actions in different areas that are handled [69]. The city surveillance through IoT can be more secure for citizens and there will be regular control over thieves, drug dealers, those involved in human trafficking, and chain snatchers, as the whole city will be under surveillance and recorded. There are many examples of smart surveillance which have resulted in safety and creating no-crime zones. Like an incident in Hayward, California, there were one zone issues like drug dealing, prostitution, violent crimes, etc., which were being reported. To stop these, video surveillances, which were solar powered and deployable, were installed which brought the crime rate down by 60% [70]. The other surveillance case was regarding an illegal dumping of unwanted furniture and junk items, which cost one million US dollars to clean up. The IoT enabled that there was a "license plate reader," that resolved dumping issues and improved living [70]. Smart surveillance will be under control on a large scale and improve the city from unethical activities. Also, threat detection will be done at an early stage that can call for a quick remedy and promote safe environment and reduction in cost by eliminating the illegal dealings and crimes [28].

11 Green IoT for Sustainable Air Quality Management

Air, a mandatory component to live if polluted, will reduce the mortality rate and give birth to airborne diseases. Under the Smart cities project, air quality also has to be treated both indoor and outdoor. The indoor air can be controlled by building managers by adapting to smart building concepts. As the population is increasing and so does the construction of buildings, the rate of CO_2 (carbon dioxide) is increasing in place of oxygen. For air quality management, people must be able to monitor the air quality through smartphones or other fitness gadgets. Installing sensors across cities, industries, buildings, residential, and traffic areas helps to monitor the air quality to check the level of pollution caused by various types of pollutants like dust particles, CO_2, sulfur dioxide, nitrogen dioxide, carbon monoxide, etc. [71, 72]. The data collected from these sensors are shared with the people through phone applications to provide them awareness about contaminated air, so that the citizens can be cautious [58, 59, 71]. So, a smart city concept is a good thought, but implementation will be a challenge for the cities and technology developers.

12 Discussion

In every case, ranging from professional life to social relationships, the internet has radically altered the mode we live and communicate with everyone. Smart network access and knowledge simulation using machine capabilities are a big portion of IoT. The IoT is also about all that should be shared "always, whenever, most networks and everything" around us [73]. A wide variety of legitimate surveillance areas such as e-healthcare, smart homes, pollution management, transit sovereignty, industry automation, and wireless transmission advancement will be changed by IoT, where several optimization algorithms are engaged in the efficient exchange of knowledge, making group decisions and completing assignments [74, 75]. IoT is undeniably one of the largest enablers of sustainable transformation. IoT would be a facilitator of environmental and sustainability programs and ventures to combat climate change. IoT projects will contribute to achieving the 2030 Vision for Sustainable Growth, which comprises the 17 Sustainable Development Goals (SDGs) set by the United Nations. Industrial IoT alone would be expected to add 14 trillion dollars of economic value to the global economy by 2030 [55]. It is estimated that by 2023, 30 megacities will exist, around 55% in developing economies, while 60% of the global population might live in urban cities by 2025 [13, 76]. Smart cities would illustrate that the aim of sustainable mobility is to expand the use of electric vehicles within their city limits, thus reducing carbon emissions [77, 78]. Sensor networks have helped track the environmental effects of cities, gathering information on sewers, air quality, and garbage. Air pollution has recently become a major concern in cities like London, Paris, and Rome, where it is often cited as the most severe environmental problem and which could impact health worldwide; for this, many countries are moving to air quality eggs (AQEs), which are connected devices' air pollution networks that are freely available [79]. The IoT is in operation in the City of London, in which the town council, to increase the overall use and help combat artificial light in the Square Mile, has adopted a smart city lighting plan. At various times of the night, the lighting strategy aims to use technology to add a range of cost-effective light-emitting diode (LED) lighting and light colors to integrate illumination with surface and market lighting [79]. Smart energy, or the energy used during the transportation and handling of IoT information networks and sensors, will allow higher performance, lower kilowatt (kW) cost and improve the use of renewable energy in the energy mix. From here until 2030, all of this could contribute to over 1.3 trillion megawatts (MWh) of energy savings [55, 80]. A variety of government policies have already proven to be particularly cost-effective and productive for going green in our construction industry, like progressive standards of building, stimulated economies, capability-building activities, etc. By 2030, smart infrastructure technologies have the potential to deliver various advantages: a 16% reduction in greenhouse gases, 300 billion liters of water has been saved, 5 billion megawatts (MW) of energy has been saved, 360 billion US dollars (USD) in efficiency gains, and significantly improved working and living conditions [81]. G-IoT will alter the world and, indeed, the existence of lives for the better. Investment and cooperation in the growth, creativity, and use of G-IoT but also regulatory approaches to encouraging sustainable semantics and mass acceptance of G-IoT are justified by a wiser, healthier, and more prosperous planet and other projected benefits.

13 Conclusion

Typically, cities are dynamic structures that require numerous different systems which consist of stakeholders, residents, physical infrastructure, economic activities, housing, facilities, and amenities. The main issue of urban planning is related primarily to policy formulation, productive management, strategic execution, monitoring of resources, and monitoring of events of town place to enhance sustainable environment, performance, and living condition. To build an ambitious smart urban ecosystem, identifying ideas and effective approaches for operation over crowd contribution and corporation is important. The results indicate that proper infrastructure planning and integration (infrastructure of city, IoT strategies, sensors, network stages, and information analytics) improves facility quality performance. Smart cities need the progress of technological resolutions and use of adaptive technology that can respond rapidly to the shifting requirements of people. The planning of a Smart city advocates for the allocation of resources along with the usage of technologies by ordinary people to maximize resources. New projects can be planned based on the city data analysis. Governance of a smart city must closely work along with residents, in addition to the multiple shareholders, for determining the collection of facilities, prioritizing requirements, delivering efficiently, and less cost amenities for a longer city transition that can fast-track the growth of smart cities in order to achieve customer value. Smart service creation includes the integration of cutting-edge technology to urban actions through various spheres. The study proposes the different smart technologies, city renovation system, and simulation of mind maps for smart cities, but it does not elucidate the appropriate layout for physical layer, ICT and IoT infrastructure integration and interconnection. A period is required for program designing, application, and delivery of new amenities. The research does not discuss the implementation and impacts on people in real time. Usually, the necessary time required for an efficient application varies on several variables such as layout of the country, structure of government, requirement urgency, etc. It can also differ for various cities as well as nations. Upcoming research can do a comparative analysis of different countries taking this article as a steppingstone.

Smart city is pervasive and offers modification that has transformed the whole environment by the help of ICT and IoT devices that are sensor enabled. The improved and larger image of all situations, monitored by elevated visibility through different mediums, that is, audiovisual, acoustic, text, and imageries' information sharing is the core-idea of a smart city. However, owing to limited resources like excessive consumption of power along with restricted battery life characteristics of these small devices that are the building blocks of smart city, which handles huge volume of information, going green with IoT will be the best that can be done today for environmental sustainability. G-IoT is anticipated to bring major advances in our everyday lives, and it will help to realize the "green ambient intelligence" vision. We will be surrounded by many sensors, computers, and devices in the coming years, which will be able to communicate via 5G, behave "intelligently," "extend green help in task management. All these modern digital devices will be context-aware and equipped to independently execute certain tasks, paving the way for new ways of green communication between people and places as well as between devices itself, optimizing power usage and maximizing capacity usage. The initiatives for Smart Cities have already been introduced in places around the globe. The speed of adoption is expected to accelerate, as the baby boomer's generation is retiring and digital native generation has started migrating into cities, which is creating higher demands for connected technology-enabled services. IoT is a budding technology for the development of smart cities, which connects several digital devices over the internet, therefore offering numerous innovative amenities from academic world to industry and health care to professional for providing better services to consumers with a sustainable future.

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Materials Development for Energy Storage Applications

Souheyr Meziane

Abstract This chapter proposal deals with the electrochemical energy storage using batteries. Indeed, industry professionals throughout the world and state authorities are continuously looking for the most performing batteries because these are found in almost all industrial and service sectors, whether for nomadic energy storage, such as automotive industry and smartphones, or stationary energy storage such as renewable energy.

This chapter proposal aims to develop batteries capable of storing electrochemical energy. The system must be optimized and adapted to electrode materials (anode and cathode) and to the electrolyte used.

The quality and performance of the designed batteries depend directly on the choice of the material for the positive and negative electrodes.

Furthermore, the crystallographic structure, mechanical, electronic, and transport properties as a function of temperature are fundamental characteristics to optimize the capacity of the electrodes using the energy storage in batteries devices, for example.

Moreover, the electrochemical reactivity of the electrode materials with the electrolyte is substantial with regard to the aging phenomena that occur at the electrode/electrolyte interfaces.

In addition to these considerations, one may add the economic and environmental needs, which are necessary for the development of future applications of the battery technology, such as transport (electric vehicles), solar cells, photoelectric, electric energy, pyroelectric, triboelectric nanogenerator, thermoelectric [1] devices, and renewable energy storage.

This chapter presents the theoretical and experimental study of current and future electrode materials and is more particularly oriented toward understanding the physical/chemical mechanisms for the purpose of designing electrodes and electrolytes intended for more efficient Li-ion and Na-ion batteries.

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1 Introduction

Today, environmental concerns occupy a prominent place in national and international political debates. Environmental problems are thus a source of public concern. They are now part of political and economic choices. As much aware of their responsibility in pollution problems, the various industrial and political actors have been trying for years to reconcile mass production and ecology. That said, taking the environment into account is more of a necessity than a moral duty, because the survival of mankind depends on it (Fig. 1). This consideration must, however, take place within a framework of sustainable development that satisfies present needs without fearing future generations to satisfy their own.

Protecting the climate is a top priority. In this perspective, the commitment made by several countries to limit greenhouse gas emissions is confirmed. Global measures focus primarily on reducing the energy consumption of buildings and CO_2 emissions in the transportation sector. These measures are designed according to a joint approach to protecting air quality and mitigating climate change. Controlling energy demand is the sustainable solution to the problem of rising energy costs, particularly fossil fuels. Indeed, the pollution emission results from industry and

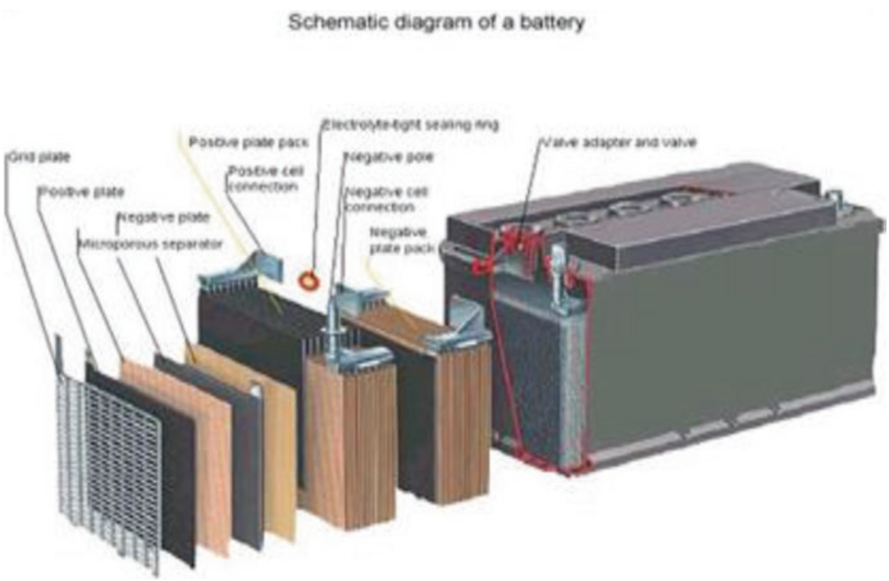

Fig. 1 The components of a battery

transport modify the composition of the atmosphere and degrade the quality of the air. Thus, the control of pollutant emissions is essential for the protection of health and environment. The regulations have defined discharge limits for certain polluting substances and impose periodic controls, the frequency of which depends on the type of activity in order to avoid these risks.

In automotive applications, the hybridization of internal combustion engines offers a temporary solution before the all-electric motorization event. The electrification of safety and comfort systems also contributes to reducing fuel consumption and therefore CO_2 emissions. In those configurations, the proper functioning of the systems is linked to the availability of the on-board network and consequently of the battery. The battery pack of hybrid vehicles represents one of the main additional costs of their engines. Both the industrialist and the consumer are unwilling to bear the financial cost of replacing these batteries during the life of the vehicle. The battery is therefore the limiting factor in the development of this type of vehicle.

The Geographic Information System (GIS) is already a massive imaginative step in the field in these days of urban planning [2].

The challenge for any automotive manufacturer who wants a clean environment is therefore based not only on an optimization of its powertrain, in terms of both cost and range, but also on matching the battery to the vehicle's lifespan. Consequently, any change in this area could only be motivated by significant gains in productivity or by the need for a technological breakthrough aimed at doing without hydrocarbons in the long term.

Several generations of accumulators have been appearing for many years, for example, lead-acid, nickel-cadmium (Ni-Cd), sodium sulfide (NaS), and lithium-ion (Li-ion) batteries [3]. The last-mentioned lithium battery is the focus of our investigation. We will attempt to optimize its thermoelectrical properties by choosing materials meeting the technological needs. Essentially used in the field of electronics for the consumer public, the resolution of some technical problems with the lithium-ion battery could enable this technology to become increasingly widespread, especially in the transport sector, but also in other different types as well: satellites, military applications, medicine, nanotechnology, etc.

2 Objective and Orientation of the Study

The life span of batteries is an essential element for the diffusion of electronic miniaturized components and clean vehicles with acceptable power, safety, and cost-effectiveness conditions. The choice of new materials suitable for the design of new batteries proves to represent the main key to satisfying these technologies.

Three main generations of accumulators currently share the rechargeable batteries product category. The technologies of NiCd, NiM-H, and Li-ion batteries are now a niche player in the automotive market but still account for less than 2% of total sales in terms of quantity.

While research over the past decade has tended to point to transition metal oxides as the best candidates for positive electrode design, many questions remain about negative electrode materials. Graphite is now the leading industrial material for negative electrodes [4]. Indeed, its assets linked to its electrochemical properties and its open structure offer a wide range of doping. Although still unequaled by other materials, it poses several problems that affect the optimum safety of Li-ion batteries and their lifetime [4]. To overcome these constraints, we will try in this chapter to substitute graphite with another type of material. Because of their open structures similar to that of graphite, it has been possible to insert a large number of atomic or molecular species, in our study we chose to introduce alkali metals such as lithium and sodium between the layers of oxide compounds.

Therefore, we will try to provide theoretical data in order to understand the various phenomena involved, interpret them, and finally predict new materials based on transition metal chalcogenides, which have large potentials for the thermoelectrical applications. In this study, we are particularly interested to optimize the physical properties of Li-ion batteries.

3 Context of the Study

The richness of the electronic properties is not only due to the variety of crystallographic structures but also due to the complexity of the interactions between electrons. The optimization of the geometry after intercalation by the alkali metal ions Li + and Na + is an inevitable step to understand their effects of the host compound. Indeed, the obtained intercalation materials would have deviations from the original crystalline order, such as inhomogeneity caused by impurities of atoms added in insertion.

Our entire study will be focused on the optimization of the geometries of the compounds and alloys as well as the intercalation of alkali metals. Qualitative treatments of the polarization effects induced by the small metal cations Li + and Na + on the electronic and topological structures of the host materials will be considered. Transport coefficients will also be determined for specific thermoelectric applications, including Li-ion and Na-ion batteries.

4 Approach Adopted

Although a large number of methodological and technical challenges persist, the development of new experimental methods for working in thermodynamic equilibrium has recently opened up more than ambitious perspectives for theoretical researchers, in particular to guide experimenters in their search for new and more efficient electrode materials. Over the last fifty years, electrochemistry, chemistry, and quantum physics have reached a maturity that gives us the opportunity to confront them today. It is the purpose of this chapter to bring these approaches into dialogue in order to understand the structural, electronic, topological, and transport processes involved in the insertion of lithium and sodium into electrode compounds. To achieve this, the following common simulation methods have been made available: ab-initio methods using the two codes Wien2k, VASP, and Boltzmann's semiclassical theory by means of the BoltzTrap code for the calculation of transport properties [4]. The description of these studies will be organized in this chapter.

5 Lithium Batteries: From Use to Understanding the Phenomena Involved

Energy needs and research for efficient ways to stock energy have become topical concerns. Lithium batteries are in this respect excellent candidates for the storage of electrical energy. In this chapter, we have been interested in the study of these lithium batteries, in particular the active material contained within the negative electrode. Before approaching the theoretical study of this material, it was essential to define some fundamental notions of electrochemistry, intercalation chemistry, as well as the industrial aspects specific to this field of activity.

6 Principle of Operation of the Battery

The functioning principle of an electrochemical generator is based on the restitution, in electrical form, of the energy stored in chemical form, through electrochemical reactions occurring at the electrodes, with ionic exchanges via the electrolyte and electronic exchanges via the external circuit. If the electrochemical reactions are irreversible, the system cannot be recharged, and we will refer to it as a battery. Otherwise, we will have an accumulator, commonly known as a battery. An electrochemical generator consists of two electrodes separated by an electrolyte that is both an ion conductor and an electronic insulator (see Fig. 1).

In generator mode, this potential difference spontaneously leads to the charge balance [5, 6], ensured by the migration of cationic species from the anode to the cathode via the electrolyte. The transfer of ionic species assuring by the chemical reaction takes place via electrolyte.

7 The Successive Technologies of Lithium Batteries

The first lithium batteries take their origin in the 1960s. The idea of using lithium is essentially based on the fact that it is the most reducing of metals, and therefore it can generate a large amount of energy (E_{0H}+/H_2 = −3.04 V at 25 °C). It is very lightweight, with a low density (equal to 530 Kg/m3) and has a very high mass capacity (Q = 3870 A.h.Kg^{-1}). All these remarkable combined properties give it the advantage of being a candidate of choice to increase the density mass of storage in a battery. But lithium has also major disadvantages for its use at the industrial level. It is highly reactive to air and water and leads to the formation of dendrites with a liquid electrolyte causing short circuits. Thus, other materials are commonly used in spite of a lower capacity than lithium: lithium alloys, carbon compounds, intermetallics, mixed oxides of amorphous vanadium, etc.

7.1 The Lithium-Metal Batteries

The first generation of rechargeable lithium batteries used a solid lithium anode in its metallic form. However, this technology was abandoned because of the difficulty of reconstituting the anode during successive recharges. The anode, once damaged, could accidentally reach its melting point (180 °C) and come into contact with the cathode, producing a violent reaction and the emission of hot gases. Abandoned for more than 10 years, the lithium metal battery could make a comeback in a few years, if current research aimed at finding a solution to the safety problem proves successful. Several research laboratories have tried to develop a protective layer that, once deposited on the anode surface, limits the formation of lithium dendrites.

Indeed, these dendrites bristle the surface of the lithium electrode, and their growth tends to cause short circuits between the electrodes (Fig. 2). Following a local short circuit caused by a dendrite generally acts as a fuse and self-destructs, which has no significant consequence on the integrity and performance of the cell [7]. In extreme cases, local heating due to a short circuit can lead to thermal runaway of the cell if unfavorable conditions are met (reduced thermal stability of the cell due to aging, cell brought to a high temperature related to the application).

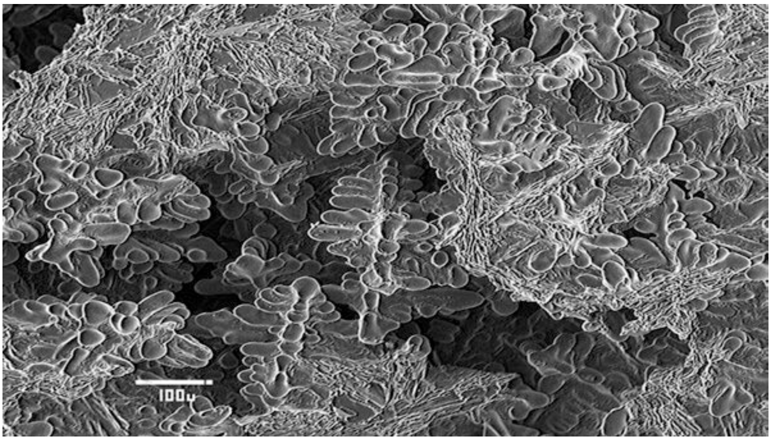

Fig. 2 Dendrites of aluminum in a shrinkage area; SEM (scanning electron microscope) image -alloy family Al-Si

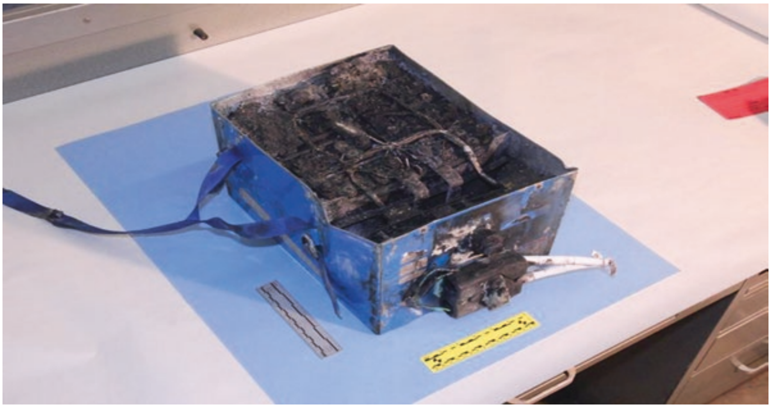

Fig. 3 Emission of a flammable gas, resulting from the formation of a structural defect (dendrite) in an airplane battery

Another solution would be to replace the electrolyte with a 100% ionic liquid that has almost zero vapor pressure, stable at high temperatures and is non-flammable, thus eliminating the possibility of hot gases being emitted if the battery overheated. A problem could also arise, that of the formation of a passivation film because lithium can react with the electrolyte to form a deposit of lithium salt on the surface of the metal. This insulating layer inhibits the possibilities of subsequent charge exchange (Fig. 3). One of the solutions considered is the application of an electrolyte that is much less reactive with lithium, in particular a solid polymeric electrolyte.

Finally, investigations are underway to develop a separator whose pores would close in the presence of superheating, thus preventing the chemical reaction from being performed.

7.2 The Lithium-ion Battery

Since the Li-metal battery is dangerous, manufacturers decided to use lithium in its ionic form. Thus, the radical solution of abandoning lithium in metallic form at the anode was adopted in favor of an insertion compound. Current technology uses a carbon anode into which lithium Li + ions are inserted by electrochemical reactions.

During the discharge, these ions migrate through the electrolyte, to be inserted into the cathode crystal structure, according to the following redox reaction:

$$\mathbf{C + x.Li^{+}\ x.e^{-} + Li_{x}C}$$

$$Li + ions\ Insertion\ and\ De - Insertion\ in\ Carbon$$

From this, we can deduce that the carbon microstructure of the anode plays a major role. It must be able to contain as many Li^+ ions as possible. However, the first tests were not convincing due to poor reversibility and a very short lifetime caused by the exfoliation of the carbon planes by the solvents used in the electrolyte.

For this reason, graphite, capable of absorbing one lithium ion per six carbon atoms (LiC_6), has been replaced by disordered carbon, a partially amorphous polycrystalline graphite capable of containing up to one lithium ion per four carbon atoms, and whose absence of planes prevents any intrusion of the solvents responsible for the degradation of the graphite.

This passivation layer prevents further degradation of the electrolyte and allows the intercalation material to remain a good ionic conductor. Then, this layer ensures the viability of lithium-ion technology.

The cathodes of Li-ion batteries are made of cobalt oxide (CoO_2) or manganese oxide (MnO_2 or MnO_4). In the event of overcharging, the cobalt electrode provides a surplus of lithium ions which can then be transformed into metallic lithium. An expensive protective circuit must be installed to prevent possible overheating. Manganese electrodes are cheaper and require only a simplified protection circuit. On the other hand, they can withstand lower temperatures and have a slightly shorter service life than their cobalt equivalent. New possibilities are constantly being studied by major industrialists and research laboratories: vanadium or titanium oxide, iron phosphate, metal oxide alloys, etc. Japanese university research is currently turning to Tin. In theory, it would still be possible to multiply by a factor of 10 the quantity of lithium-ions absorbed by the cathode.

Since the launch of the first rechargeable lithium-ion batteries by Sony in 1991, about 30 pairs of lithium-ion electrodes have been marketed, an average of one new combination every 6 months. The materials used are increasingly complex and there are many innovations. For example, Sony announced in February 2005 that its camcorders would now be sold with the new "Nexelion" lithium-ion battery, whose anode is based on tin, cobalt, and carbon (to stabilize the tin powder), and the cathode based on cobalt, nickel, and manganese (Fig. 4). This one would have a 30% higher capacity than traditional Li-ion batteries.

In addition, Toshiba has developed the "Super Charge Battery," a Li-ion battery that recharges to 80% of its maximum capacity in less than a minute and loses only 1% of its capacity after 1000 successive discharge-recharge cycles at 25 °C. This result was obtained by coating a cobalt-based anode with nanoparticles that have the property of capturing and storing large quantities of Li^+ ions. This battery operates at 80% of its capacity at −40 °C, allowing it to be used in objects as diverse as cars or cell phones. From 1992 to 2004, successive improvements have doubled the mass energy density of Li-ion batteries from 90 to 180 Wh/kg.

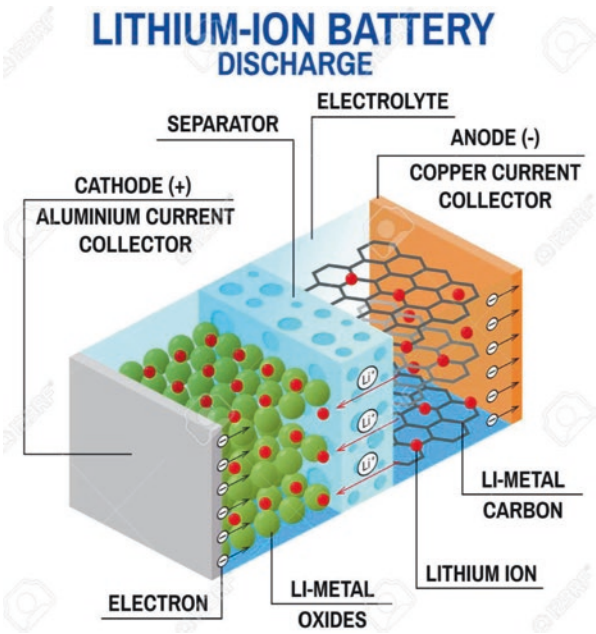

Fig. 4 The lithium-ion battery charge

7.3 *Lithium ion-Polymer Battery*

Li-ion polymer batteries perform on the same principle as traditional lithium-ion batteries. It is in fact replaced by a solid polymer matrix in which the conductive liquid is trapped (50–75% by mass). Since the battery now consists of three thin layers (one for each electrode and one for the electrolyte), it is possible to make batteries of all geometric shapes, some of which are flat enough to fit in a payment card. However, this system has a limitation: at the same temperature, the conductivity of the polymer electrolyte is lower than that of a liquid electrolyte. The minimum operating temperature of a polymer lithium-ion battery is more efficient than that of Li-ion battery (Fig. 5).

7.4 *The Lithium Micro-Battery*

A micro-battery is a miniaturized energy source. It can be defined as an assembly of electrodes and a solid electrolyte, deposited in thin layers of the order of a micrometer thick. The total thickness of the system is 5–20 μm, without the final encapsulation.

Fig. 5 Li-ion polymer battery

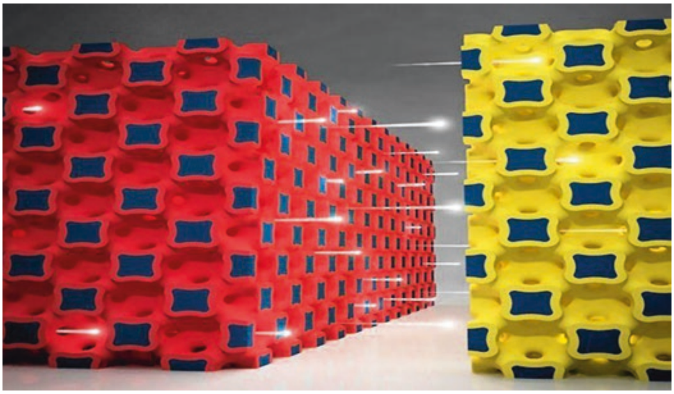

Fig. 6 Nex microbatteries combine the advantages of Li-ion batteries and supercapacitors

Lithium microbatteries are prepared by successive deposition of a current collector (e.g., stainless steel), a positive electrode, a solid electrolyte (ion-conducting glass) and a negative electrode on a rigid or flexible substrate. They are then encapsulated (polymer film or other) to protect them from moisture. Their operating principle is identical to that of a lithium battery (Fig. 6).

The materials used in microgenerators are generally the same as those used in lithium batteries. However, their thin film construction gives them certain specificities: their composition may differ from that of their massive counterparts and their structure is often less orderly. Their electrochemical properties can thus be appreciably different from those of massive compounds.

The choice of materials for use in a lithium micro battery is based on their ability to deposit easily in thin layers and their mechanical properties in this form. In addition, for the electrodes, the values of the surface and volume capacities are the selection criteria. Indeed, the mass of the layers being low, the mass capacity is not a suitable parameter to characterize a microbattery. Moreover, the cost of the material is less important than for massive batteries because it is present in smaller quantities. Finally, the difference in potential sought between the two electrode materials depends on the envisaged applications.

8 Fields of Application of Battery

8.1 Electronics

The Li-ion batteries are already used in all consumer devices, for example, in the computers, cell phones, or music players. The Japanese and world leader in this field is Sanyo, which manufactures 90% of the Li-ion batteries for cell phones in Japan. There are potentially as many applications for Li-ion as there are devices in a portable version that would have an advantage over a conventional version.

The envisaged applications concern in particular the fields of security (detection, reconnaissance, and surveillance systems), military (means of communication, thermal imaging and night vision, sighting systems), aerospace (batteries for satellites, robots and space probes – in this case the electrodes are made of noble materials, allowing the battery to operate at very low temperatures) or medicine (defibrillators and portable monitors) (Fig. 7).

8.2 Clean Vehicle

The greatest growth potential for the Li-ion battery lies in means of transportation, electric-assisted bicycles are already spreading, especially in China, but this is not yet the case for cars.

While battery capacity is currently insufficient to power a fully electric car over long distances, it is perfectly suited to hybrid vehicles that use it for short accelerations and recharging during braking. This system reduces fuel consumption by about 20%. Increasingly stringent standards for CO_2 emissions and the recent surge in oil prices are conducive to the marketing of such vehicles.

The Japanese manufacturers are the most advanced in the field of gasoline/electric hybrid vehicles:

Fig. 7 Defibrillator used in medicine

- A pioneer of the hybrid car, Toyota has been marketing the Prius since 1997. Approximately 300,000 Prius hybrid vehicles (combustion engine/NiM-H battery) have been sold, half of them in Japan.
- In April 2005, Honda reached the 100,000 hybrid vehicle sales milestone (Civic and Accord, both gasoline/NiM-H battery hybrids).
- Daihatsu and Nissan purchased its hybrid technology from Toyota to develop their own models, which were marketed in 2006.

The models equipped with lithium-ion batteries are for the moment relatively discreet. Even if in theory there is no battery more powerful than NiM-H, the use of Li-ion in the automobile is still insufficiently justified. Indeed, lithium being a highly reactive element, manufacturers are reluctant to introduce in their vehicles batteries that contain large quantities of it. Since automotive batteries have a much larger volume than those for electronic devices, overheating could have serious consequences. However, the gradual improvement in the safety and energy density of Li-ion batteries could make it possible to envisage their use in the near future.

- Since 2000, Nissan has been marketing the Hypermini in Japan only. This small city car equipped with Li-ion batteries has a range of 115 km in an urban environment – compared to 80 km of an all-electric “Saxo.”
- The two companies, Fuji-Heavy and Mitsubishi, are developing fully electric Li-ion cars that will be marketed in 2010. Various technical problems remain, and the charging time for current prototypes is long: nearly half a day with a household plug. In addition, their range is limited to 150 km per charge, which forces manufacturers to design small, light vehicles. Fuji-Heavy wants to cap the sale price at 1.5 million yen (11,000 euros).

The emergence of all-electric vehicles also implies the construction of charging stations. Japan’s fleet of electric cars is currently around 8000 units (Fig. 8).

8.3 An Alternative to Lithium-ion: The Fuel Cell

Direct methanol fuel cell (DMFC) is now on the verge of being the first model for computers and cell phones which have been on sale in Japan since 2007. These batteries, which draw their energy from the combustion of a consumable (a methanol cartridge), have a higher energy density than lithium-ion batteries.

On the other hand, while a Li-ion battery can withstand sudden changes in the power to be supplied, for example, when switching between the standby and operating modes of a laptop, this is not the case with DMCFs, whose combustion should preferably be without flow variation.

In the automotive field, the hydrogen fuel cell still faces many technical and economic obstacles. It is widely accepted that its commercialization will not take place before 2030 (Fig. 9).

Fig. 8 Electric vehicle in charge

Fig. 9 Hydrogen vehicles

9 Ab Initio Calculation Methods

Since the beginning of the 1950s, the historical works of physicists Metropolis et al. have shown a growing interest in numerical simulation in both theoretical and applied physics. Today, intensive numerical computation is a strategic issue in terms of scientific research. As a whole, numerical simulation and modeling of physical phenomena now constitute an essential complement to experimental research techniques.

Determining the physical and quantum quantities of a system containing a large number of electrons is not possible without certain approximations. Indeed, in a system with several bodies (or particles) with strong interactions between electrons, the resolution of the Schrödinger equation is only possible by considering certain approximations.

At the level of first-principle methods, two main schools meet:

- The Hartree-Fock (HF) methods is post-Hartree-Fock, common to chemists.
- The Density Functional Theory (DFT) methods used by physicists.

Their common goal is to solve Schrödinger's equation without introducing parameters adjusted to the experiment, that is, to determine the E energy and the wave function Ψ:

$$H\Psi = E\Psi \tag{1}$$

In the first-principle calculations, the primordial quantity is the energy of the fundamental electronic state for a given geometric arrangement [8]. If we can obtain the total energy accurately, then other properties can be deduced from it. Thus, reliable and quantitative material modeling will be enabled using the DFT methods. In this chapter, different approximations are required to find the solution of the Schrödinger equation of a complex system.

Then, the general characteristics of the FP-LAPW (Full Potential Linearized Augmented Plane Waves) [9] method and the pseudo-potential method will be described [10]. Finally, the semi-classical Boltzmann theory established for the determination of electrical transport coefficients will be presented.

9.1 Schrödinger's Equation of Stationary States

Schrödinger's equation is used to account for systems consisting of elementary particles (electrons and nuclei). Therefore, it seems essential to summarize the different steps usually followed when solving this equation. Thus, the total energy calculation of such a system is a very difficult task.

The interacting system is obtained in the general case by solving the Schrodinger equation of steady states:

$$\hat{H}\Psi\left(\{r_j\},\{R_I\}\right) = E\Psi\left(\{r_j\},\{R_I\}\right) \tag{2}$$

where $\hat{H}$ is the Hamiltonian operator, $\Psi(\{r_j\}, \{R_I\})$ is a multi-particle wave functions describing the state of the system (r_j the electron position vector j, R_I that of nucleus I) and E his total energy. Usually, the Hamiltonian operator writes:

$$\hat{H} = \hat{T}_{el} + \hat{T}_{nuc} + \hat{V}_{nuc-el} + \hat{V}_{el-el} + \hat{V}_{nuc-nuc} \tag{3}$$

where $\hat{T}_{el}$ and $\hat{T}_{nuc}$ are the operators of the kinetic energies, $\hat{V}_{nuc-el}$, $\hat{V}_{el-el}$, $\hat{V}_{nuc-nuc}$ the potential energy operators.

These quantities can be written:

$$\hat{H} = -\frac{\hbar^2}{2m_e}\sum_j \nabla^2_{r_j} - \frac{\hbar^2}{2M_I}\sum_I \nabla^2_{R_I} - \sum_{j,I}\frac{Z_I e^2}{\left|r_j - R_I\right|} + \frac{1}{2}\sum_{j\neq k}\frac{e^2}{\left|r_j - r_k\right|} + \frac{1}{2}\sum_{I\neq J}\frac{Z_I Z_J e^2}{\left|R_I - R_J\right|} \quad (4)$$

where $\hbar = h/2\pi$ and h the Planck constant, m_e the electron mass, M_I the nucleus mass I and Z_I its charge. In this form, the calculation of the fundamental system of state energy. In fact, except for isolated atoms, hydrogen for example, numerical calculations are often incommensurable because of the number of particles to be taken into account and complexity of resulting interactions. This is the case in particular of the electronic exchange and correlation effects, implicitly contained in $\hat{V}_{nuc-el}$, which act at a short distance within the set of electrons.

For this reason, there is inappropriate analytical solution to Schrodinger's equation [11]. The use of different approximations is necessary to overcome this difficulty. The first approximation introduced is Born-Oppenheimer approximation.

9.2 Born-Oppenheimer Approximation

All methods to determine the Schrödinger equation are focused on this approximation with a significant distinction in the mass of nuclei and electrons. As a result, the motion of the nuclei relative to the electrons can be neglected and the nuclei will be considered to be fixed. Consequently, the kinetic energy of the nuclei becomes null (T_{nuc} = 0) and the Coulombic energy due to repulsion between nuclei becomes a constant ($V_{nuc-nuc}$). Thus, we move from a system with N electrons and M nuclei to a system with N electrons feeling the potential of the nuclei. Thus, this simplification decoupling motion of the nuclei, electrons, and Hamiltonian will then only contain contributions of monoelectronic (T_{el} and V_{nuc-el}) and bielectronic (V_{el-el}) types:

$$\widehat{H_{el}} = \widehat{T_{el}} + \hat{V}_{nuc-el} + \hat{V}_{el-el} \quad (5)$$

It should be noted that the two representations N interacting electrons +M nuclei and n interacting electrons in the external potential (due to the nucleus) are equivalent from a formal point of view.

The Born-Oppenheimer approximation thus allows the search for the fundamental state of the system in two steps:

- Calculation of the energy of the fundamental state of electrons [12] for a fixed set of nucleus positions.
- Modification of the positions of the nuclei toward a decrease of the resulting forces.

This calculation method is repeated until the set of forces on the nuclei is sufficiently low (the criterion chosen depends of course on the problem under consideration).

We introduce now the theory of the density functional and its application to the case of crystalline solids for the relaxation of electronic degree-of-freedom.

9.3 Density Functional Theory (DFT)

The density functional theory is an effective method that has allowed to go from multi-electronic systems to systems depending on the electronic density of the fundamental state of the system.

It is based on two articles: the first by Hohenberg and Kohn, published in 1964, lays the foundations of the theory of density functionals. The second one, one year later by Kohn-Sham, proposes practical scheme to resolve the problem in the form of a density-dependent mono-electronic Schrödinger equation. These authors have shown the electronic structure of the system can be determined by its electronic density $\rho(\vec{r})$.

9.4 Theorems of Hohenberg and Kohn

The founding article by Hohenberg and Kohn is based on two theorems (relatively simple to dismantle) that state:

1. For an interacting electron system, the external potential $V_{ext}(r)$ is determined in a unique way, to within a constant, by the electron density of of the fundamental state $\rho_0(\vec{r})$ [13]. The function of total energy of the fundamental state is written as follows:

$$E\left[\rho(\vec{r})\right] = F\left[\rho(\vec{r})\right] + \int \rho(\vec{r}) V_{ext}(\vec{r})\, dr \tag{6}$$

where $\int \rho(\vec{r}) V_{ext}(\vec{r})$ represents the interaction between nuclei and electrons, $F\left[\rho(\vec{r})\right]$ is functional of $\rho(\vec{r})$, $V_{ext}(\vec{r})$ is the external potential contains kinetic and coulombic interactions:

$$F\left[\rho(\vec{r})\right] = T\left[\rho(\vec{r})\right] + V_{el}(\vec{r}) = T\left[\rho(\vec{r})\right] + E_{Hartree}\left[\rho(\vec{r})\right] + E_{xc}\left[\rho(\vec{r})\right] \tag{7}$$

where $T\left[\rho(\vec{r})\right]$ [14] is the kinetic energy of the electronic system and $V_{el}(\vec{r})$ is the term for electron-electron interaction that includes Hartree energy $E_{Hartree}\left[\rho(\vec{r})\right]$ (the coulombic electron-electron repulsion) and the exchange and correlation energy $E_{xc}\left[\rho(\vec{r})\right]$. This functional is unknown exactly because the expressions of kinetic energy $T\left[\rho(\vec{r})\right]$ and exchange and correlation energy $E_{xc}\left[\rho(\vec{r})\right]$ is also unknown perfectly.

2. For a defined external potential and fixed number of electrons, the fundamental state is the global minimum of the functional $F\left[\rho\left(\vec{r}\right)\right]$ and the density minimizes functional is the fundamental density of state $\rho_0\left(\vec{r}\right)$.

$$\left.\frac{\delta F\left[\rho\left(\vec{\mathrm{r}}\right)\right]}{\delta\rho\left(\vec{\mathrm{r}}\right)}\right|_{\rho\left(\vec{\mathrm{r}}\right)=\rho_0\left(\vec{\mathrm{r}}\right)}=0 \tag{8}$$

The functional $F\left[\rho\left(\vec{r}\right)\right]$ is universal for any multi-electron system. If the functional $F\left[\rho\left(\vec{r}\right)\right]$ is known, it will be possible to determine total energy and electron density of ground state for a given external potential.

However, Hohenberg-Kohn theorems do not give any indication as to the form of the density functional $F\left[\rho\left(\vec{r}\right)\right]$. Other approximations are then necessary to achieve this, the unknown functional $F\left[\rho\left(\vec{r}\right)\right]$ is rewritten in another form introduced by Kohn-Sham.

9.5 *Kohn and Sham's Method*

The proposed approach by Kohn-Sham in 1965 can be summarized by the following idea:

1. The electronic gas can be described by fictitious particles without interactions, represented by mono-electronic wave functions $\Phi_j(r)$, such that the gas of fictitious particles has the same electron density, and therefore the same energy $E[\rho]$ as the real electronic gas.

Kohn-Sham's theory is based on the hypothesis that it is possible to reproduce the state density of N interacting particles by the system of independent particles.

In this context, considering a gas with N electrons, represented by N fictitious particles, the wave functions $\phi_j(r)$ are consequently the solutions of Kohn Sham's equations:

$$\forall j \in || 1; N || \left[T_e\left(r\right)+V_{eff}\left(r\right)\right]\Phi_j\left(r\right)=\varepsilon_j\Phi_j\left(r\right) \tag{9}$$

where $T_e(r)$ the kinetic energy operator of the fictitious particles without interaction, and the state energy $\Phi_j(r)$. The fictitious particles undergo an effective potential $V_{eff}(r)$, sum of three potentials:

$$V_{eff}\left(r\right)=V_{ext}\left(r\right)+V_{Hartree}\left(r\right)+V_{XC}\left(r\right) \tag{10}$$

where $V_{Hartree}(r)$ is the Hartree potential, or coulombic potential of classical interaction between electron gas particles and $V_{XC}(r)$ the correlation exchange potential.

These two terms are expressed simply:

$$V_{Hartree}\left(r\right) = e^2 \int \frac{\rho\left(r'\right)}{\left|r - r'\right|} d^3 r' \tag{11}$$

$$V_{XC}\left(r\right) = \frac{\delta E_{XC}\left[\rho\right]}{\delta \rho\left(r\right)} \tag{12}$$

At this step, the resolution of the Kohn and Sham equations is impossible since the potential $V_{XC}(r)$ has no explicit formulation.

9.6 The Exchange-Correlation Function $V_{XC}(r)$

This potential is the key to the density functional theory as it enables to compensate for the loss of information on the exchange-correlation properties of the electronic gas, induced by the passage from a real multi-electronic wave function to fictitious single-electronic wave functions without interactions by Kohn-Sham's method.

In a real electron gas, the electrons with parallel spins undergo a repulsion linked to Pauli's exclusion principle. The energy reduction of the real electron gas compared to an electron gas which would present only Coulomb interactions is called exchange energy.

The energy of the system can be further modified by increasing the separation distance of electrons with antiparallel spins. However, the decrease in coulombic interactions increases the kinetic energy of the electron gas.

The energy difference between this set of real particles and the particle gas reduced by only the exchange energy (Hartree-Fock gas) is called correlation energy.

From these equations, it is possible to express easily the $V_{XC}(r)$:

$$V_{XC}\left(r\right) = \left[T_e\left(r\right) - T_e'\left(r\right)\right] + \left[V_{int}\left(r\right) - V_H\left(r\right)\right] \tag{13}$$

$V_{XC}(r)$ is then the difference of kinetic energy and internal energy between the real electron gas and the fictitious gas for which interactions between electrons are limited to the classical Hartree term. Then, the coulombic interactions being at long range while the $V_{XC}(r)$ is a local physical quantity.

The effectiveness of Kohn and Sham's approach depends entirely on the physicist's ability to calculate the most accurate possible $V_{XC}(r)$, which in the general case has an unknown analytical expression. If this function were exactly known, the N-body problem could be solved using Kohn and Sham's procedure of diagonalizing an effective Hamiltonian.

Moreover, we can confirm, according to Kohn and Sham by separating explicitly the kinetic energy of independent particles, and Hartree's terms at exchange and correlation energy is an "almost" local function of the long-range electron density [15]. Based on this result, we will discuss two categories of functionalities: the LDA

(Local Density Approximation) functionals and GGA (Generalized Gradient Approximation) functionals [16].

9.7 Local Density Approximation LDA

Now, it is necessary to give an algebraic form to $V_{XC}(r)$ that allows us to take the correct correlations between the movements of the electrons into account.

The easiest approximation of the $V_{XC}(r)$ potential is obtained in LDA (Local Density Approximation, initially proposed by Kohn-Sham.

Assuming that the electron exchange-correlation energy in the inhomogeneous real gas $\varepsilon_{XC}([\rho], r)$ is equivalent to the electron exchange-correlation energy in the homogeneous gas of the same density $\rho(r) = \varepsilon_{XC}^{\text{hom}}([\rho], r)$, then the total energy of the exchange-correlation of the real gas is:

$$E_{XC}^{LDA}[\rho] = \int \varepsilon_{XC}([\rho], r)\rho(r)dr \tag{14}$$

Combining the last equations, the expression of the potential $V_{XC}(r)$ under the LDA is:

$$V_{XC}(r) = \varepsilon_{XC}([\rho], r) + \rho(r)\frac{\delta\varepsilon_{XC}([\rho], r)\rho(r)}{\delta\rho(r)} \tag{15}$$

The LDA approximation suggests that the spatial fluctuations of the electron density in the real gas are generally not so great. To account for variations in the $\rho(r)$ beyond the first order proposed by the LDA, several other methods can provide improvements. The easiest contribution is the introduction of spin polarizations (LSDA) by modifying the density function to take the two possible spin states into account. Further developments include the generalized gradient approximation (GGA) and the weighted density approximation (WDA) [17].

Once again, LDA through its local density description gives the results of a precision unexpected at first time. However, some quantities such as the cohesion energy have strongly overestimated the lattice parameters. In order to remove the error due to this local vision of density, other functionalities such as GGA have been developed. Therefore, gap energies of the semiconductor and insulator materials are underestimated in this approximation.

For some systems with strong correlation effects (narrow f- or d-bands), the approximation LDA does not allow to describe properties of materials correctly, for example, the transition metal compounds of the type Mott-Hubbard insulators or insulators with the charge transfer type.

9.8 Generalized Gradient Approximation (GGA)

The term generalized gradient is derived from correcting the LDA expression of the exchange-correlation energy by an expression dependent on the electron density gradient, playing on the range of this gradient to obtain the desired electronic properties.

Thus, the GGA approximation consists in replacing the function $\varepsilon_{XC}([\rho], r)$ by a local function doubly parameterized, according to the density and amplitude of its gradient $\varepsilon_{XC} = f\left[\rho\left(\vec{r}\right), \nabla\rho\left(\vec{r}\right)\right]$. Thereby, this additional information will provide a better description of the system.

$$E_{XC}^{GGA}\left[\rho\left(\vec{r}\right)\right] = \int \rho\left(r\right) f\left[\rho\left(r\right), \nabla\rho\left(\vec{r}\right)\right] d\rho\left(r\right) \tag{16}$$

Many parameterizations of the GGA function have been proposed and tested for a wide range of materials.

In many cases, GGA approximation provides better results than LDA for total energies, cohesive energies, equilibrium volumes, and compression moduli.

9.9 Local Density (LSDA) and the Generalized Gradient (GGA) Approximations with Spin Polarization

One could think that the GGA approximation is better than the LDA approximation because of the gradient. In practice, this is not obvious, and it is essential to test the functionals. Generally, the LDA tends to overestimate the strength of the bond and causes the low values of the lattice parameters values in comparison with the experiment.

This tendency of the LDA is particularly marked in the 3d metals, but in the 5d materials it is considerably less clear. For magnetic 3d materials, this effect has drastic consequences on the magnetism properties: the magnetization being strongly dependent on the interatomic distances (the magnetization drops with a contraction of the lattice parameter) and affects the phase diagram of the different materials. It is well known that the most stable phase of LDA-treated iron is the non-magnetic face-centered cubic phase determined using the LDA approximation, which is in complete contradiction with the experiment.

Thus for magnetic systems, the electronic densities depend on the spin polarization. $E_{XC}^{LDA}\left[\rho^{\sigma}, \rho^{-\sigma}\right]$ and $E_{XC}^{GGA}\left[\rho^{\sigma}, \rho^{-\sigma}\right]$ are given according to the following expressions, depending on whether gradient corrections:

$$E_{XC}^{LDA}\left[\rho^{\sigma}, \rho^{-\sigma}\right] = \int \rho\left(\vec{r}\right) \varepsilon_{XC}\left(\vec{r}\right)\left[\rho\left(\vec{r}\right)\right] d\vec{r} \tag{17}$$

$$E_{XC}^{GGA}\left[\rho^{\sigma}, \rho^{-\sigma}\right] = \int \rho\left(\vec{r}\right) f\left[\rho^{\sigma}\left(r\right), \rho^{-\sigma}\left(r\right) \nabla\rho^{\sigma}\left(r\right), \nabla\rho^{-\sigma}\left(r\right)\right] d\vec{r} \tag{18}$$

where ρ^{σ} and $\rho^{-\sigma}$ represent the electronic densities of the majority spin and the minority spin, respectively.

9.10 Local Density and Generalized Gradient Approximations with Hubbard Correction (LDA + U and GGA + U)

It has been seen that the « LDA » and « GGA » approximations have some limitations. Unfortunately, there is no solution for the moment to systematically improve the processing of exchange-correlation energy. The problem is exacerbated in some materials with highly localized electrons, such as transition metal oxides and rare earth oxides. For instance, in the transition metal oxides such as FeO or CoO, the « LDA » calculation leads to metallic materials, when in reality they are large gap insulators. Several methods have been developed to provide solutions to these problems such as the « LDA + U » method [18]. The « LDA + U » or « GGA + U » method is exacerbated in some materials with highly localized electrons as transition metal oxides or rare earth oxides. For instance, a calculation of « LDA » of transition metal oxides such as FeO or CoO leads to metallic materials, when in reality they are large gap insulators.

The « LDA + U » or « GGA + U » methods involve adding to the « LDA » or « GGA » computation a Hubbard type of a Hamiltonian processed in a medium field (i.e., a Hartree-Fock type of Hamiltonian). The term “U” refers to the intra-atomic coulomb interaction applied to localized orbitals (generally d or f) to correct « LDA » errors. This allows to open gaps in correlated materials such as transition metal oxides.

It has also been shown that « DFT + U » approaches taking full account of the orbital anisotropy of the coulomb interaction which allows the description of orbital polarization effects and which plays a very important role on magnetic anisotropy.

9.11 Application of Density Functional Theory (DFT) to Calculation Physical Properties of Crystalline Solids (Solving Kohn-Sham Equations)

The Kohn and Sham approach, as discussed above, has brought us back to the resolution of three interdependent equations giving access to effective potential, single-electron wave functions, and electron density. Generally, the resolution of these three equations requires the utilization of a base of the density of electron, potential, and the Kohn-Sham orbitals.

In order to understand this step, we will consider a practical case of a crystalline solid. Throughout our study we calculated the energy of the fundamental state of condensed crystalline phases, that is, periodic in space as illustrated in Fig. 10.

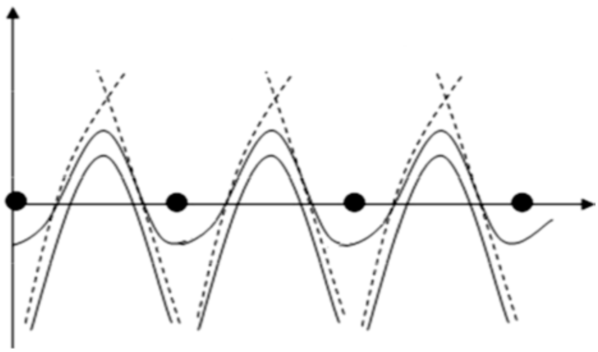

Fig. 10 Typical crystalline potential (U(r)) plotted along a line of atoms and on a median line with two planes of atoms. The black dots represent the equilibrium positions of the ions, the continuous curves represent the potentials along the rows of atoms, the dotted curves represent the potentials along a line between the atom planes, and the hatched curves represent the potentials of isolated atoms

In this paragraph, we introduce a particular formulation of Kohn-Sham equations by representing fictitious wave functions $\{\Phi_j(r)\}$ on plane wave bases.

In a perfect crystal model, a primitive mesh is reproduced indefinitely in the three directions of space to generate the crystal structure. This grid contains a lattice node (bravais lattice) to which a molecular pattern has been associated.

Qualitatively we can see that the shape of the $\Phi_j(r)$ wave functions depends on the periodic nature of the ionic positions in the lattice. The external potential is necessarily periodic because it is related to the position of the ions. So for a displacement of a translation vector of the lattice R, we obtain [19, 20]:

$$V_{ext}\left(r,R\right)=V_{ext}\left(r\right) \tag{19}$$

$$\mathrm{V_{eff}}\left(\mathrm{r,R}\right)=\mathrm{V_{eff}}\left(\mathrm{r}\right) \tag{20}$$

The Kohn and Sham equations being verified in all space, a wave function $\Phi_j(r)$ must depend on this periodicity.

The appropriate formulation of this idea is Bloch's theorem [21, 22]. When the potential has the translation periodicity of the crystal lattice, then:

$$\Phi_{j,k}\left(r\right)=e^{iK,r}U_{j,K}\left(r\right) \tag{21}$$

$$\mathrm{U_{j,K}}\left(\mathrm{r+R}\right)=\mathrm{U_{j,K}}\left(\mathrm{r}\right) \tag{22}$$

This formulation expresses each wave function as the multiplication of a plane wave $e^{iK,r}$ and a function $U_{j,K}(r)$, having the periodicity of the structure of the crystal with each wave vector k and corresponding to the reciprocal space. Each function $U_{j,K}(r)$ can be written as a Fourier series [23]:

$$U_{j,K}\left(r\right)=\sum_{G\in]-\infty,+\infty[}C_{j,k,G^{e^{iG,r}}} \tag{23}$$

where G is a translation vector of the reciprocal network such that [24] $G.\ R = 2\pi p$ with p is an integer; we can then verify that $U_{j,\,K}(r + R) = U_{j,\,k}(r)$.

Combining the equations (III. 20) and (III. 21), we express each wave function $\Phi_{j,\,k}(r)$ as a Fourier series:

$$\Phi_{j,k}\left(r\right) = \sum_{G \in \left]-\infty,+\infty\right[} C_{j,k,G^{e^{i(K+G).r}}} \tag{24}$$

Each wave function $\Phi_{j,\,k}(r)$ expressed infinite sum of plane waves on an infinite set of vectors k, in reciprocal space. The practical application of this method requires the choice of a discrete set of relevant k vectors to correctly reproduce the fictitious states in reciprocal space. In this section, we have chosen the approach proposed by Monkhorst Pack, which produces a discrete and regular set of special k-vectors in the first Brillouin zone [25]: $\{k\}_{MP}$. The set of $\Phi_{j,\,k}(r)$ vectors constitutes a more or less dense mesh of the Brillouin zone. In fact, the density of the mesh must be optimized using convergence tests on the total energy of the crystal structure such that the error introduced by this discrete set of values is negligible on the calculation of the total energy. Note that more important size of the crystalline mesh induced the smaller Brillouin zone, and thus the less the number of k-vectors are taken into consideration. In addition, for very large atomic groups (which corresponds to more than 100 atoms by ab-initio computing) we can usually be satisfied with the null vector, that is, the origin of the reciprocal space [16].

Although the ensemble of vectors k is now discrete and finite, the numerical computation of $\Phi_{j,\,k}(r)$ is impractical since the equation implies that the plane wave basis is infinite for each vector k. From a physical point of view, the coefficients $C_{j,\,kG}$ take negligible values when $|G| \to \infty$. Therefore, it is possible to limit the set of translation vectors of the reciprocal network by considering that the vectors of $C_{j,\,kG}$ are equal to zero when $|G| > |G_c|$, with $|G_c|$ is the cut-off modulus.

This value is associated with a kinetic energy of cut-off E_c defined by:

$$E_c = \frac{\hbar^2 \left|k + G_c\right|^2}{2m_e} \tag{25}$$

This implies that wave functions with low kinetic energies are more important than those high kinetic energies.

In the same way, density of the Brillouin zone [16] mesh and the kinetic energy of cut-off should be optimized so that the restriction of the number of plane waves within the bases necessary for the representation of the fictitious states does not constitute a significant error on the evaluation of the total energy [26].

This simplification imposes a limit on the size of the plane wave base for each $\Phi_{j,\,k}(r)$ in each vector k [20]:

$$\forall j \in \|\ 1; N\ \|, \forall k \in \left\{k\right\}_{MP}\ \Phi_{j,k}\left(r\right) = \sum_{|G| < |G_c|} C_{j,k,G^{e^{i(K+G).r}}} \tag{26}$$

By substituting equations, the Kohn-Sham equations are written:

$$\forall G \sum_{|G'|<|G_c|} \left[\frac{\hbar^2}{2m_e} |k+G|^2 \delta_{GG'} + V_{eff}(G-G') \right] C_{j,k,G'} = \varepsilon_{j,k} C_{j,k,G} \tag{27}$$

where δ is the Kronecker symbol.

Generally, the number of waves is limited by a cut-off energy E_{cut}, such as:

$$\frac{\hbar^2}{2m} |k+G|^2 < E_{cut} \tag{28}$$

where m is the mass of the electron [27].

The larger E_{cut} is the wider the plane wave basis for describing eigenstates. The large values of E_{cut} increase the precision of the calculation but also make it more expensive in terms of computing resources. Bloch's theorem allows to reduce the infinite system to the first Brillouin zone with a number of plane waves depending on the chosen of the cut-off energy.

In this paragraph, we recalled that for a crystalline solid, each fictitious wave function $\Phi_j(r)$ is represented in terms of the vector $\boldsymbol{k} \in \{\boldsymbol{k}\}_{MP}$ in the Brillouin zone by a Fourier series.

10 Choice of the Method of the Wave Function Basis and the Potential Form

Several methods for calculating electronic structures exist. Their common point is the resolution of the three equations of Kohn and Sham in a self-coherent way. Their respective specificities lie in the approach to represent the potential, the electron density and especially the single-electron orbitals of Kohn and Sham. The accuracy of the potential form can vary according to the pseudo-potentials considerations or the complete Muffin-tin potential.

Different levels of approximations for the exchange and correlation potential are therefore available. Calculations taking into account the spin state of the electrons can also be performed. Furthermore, the basis used to represent the Kohn and Sham orbitals can be very varied. It can be made of localized, delocalized, and mixed functions, but also entirely numerical. In the latter case, the wave functions are not built from the base and are defined on a numerical grid. The base is essential, since it conditions the scope of both investigations in terms of the systems studied and their properties. Generally speaking, the method is defined by its base.

As examples, we cite the following methods: Linear muffin-tin type orbital (LMTO), full potential linearized augmented plane waves (FPLAPW), and plane waves/pseudo-potential (PW/PP) methods.

In each of these methods, the Kohn and Sham orbitals are of the form:

$$\Phi_j(r) = \sum_G C_{j,k,G} \Phi_G(r) \tag{29}$$

where the $\Phi_j(r)$ are the basic functions and $C_{j,k,G}$ are the corresponding development coefficients. For a choice of functions of the given base, the resolution of the Kohn-Sham equations amounts to the determination of the coefficients $C_{j,k,G}$ for the occupied orbitals that minimize the total energy. The criteria qualifying the base are: its efficiency, ease of use, and accuracy. These three main characteristics will be found in the number of basic functions needed to achieve the convergence.

10.1 General Characteristics of the FP-LAPW Method

This method has its origin in the Slater's works. The APW (Augmented Plane Waves) method is based on the following observation: the solution of Schrödinger's equation for a constant potential is a plane wave [28], while for a spherical potential is a radial function. One way to describe a Muffin-tin type crystalline potential is therefore to divide space into two regions: a first region (I) consisting of spheres centered on each atomic site, in which the wave functions will be based on radial functions; a second region (II), referred to as interstitial, is between atoms and for which the basic functions will be plane waves. In this approach, the radial distribution functions used to construct the base are accurate only for the energy of the band considered. The difficulty of this type of method is that this function has a non-linear dependence on energy. It is therefore necessary to determine this energy precisely for each band before the secular equation which allows the determination of the orbitals energies of the Kohn and Sham.

A solution to overcome this lack of variational freedom has been proposed by Andersen, based on the use of linearized basic functions. The idea is to add in the construction of the base the first derivative of these functions with respect to energy, in order to build an orbital base independent of the first order. Their non-linear dependence on energy being neglected, the base functions are inadequate far from the energy of the considered band (a few tens of eV above the Fermi energy). Therefore, after defining the linearization energies (at the center of gravity of the occupied bands) [29], it is possible to solve the Kohn-Sham equation through a single diagonalization. These methods that have emerged from this approach are LAPW and LMTO. In the first case, the base is made up of linearized augmented plane waves, whereas in the second case the base is only made up of radial functions (Hankel functions). Each of these methods uses a Muffin-tin type potential description. On the other hand, for wave functions, the LMTO-atomic sphere approximation (ASA) method uses only one type of functions centered on atomic sites. The interstitial region is thus not described by plane waves.

This imposes to make the spheres overlap each other, in order to describe the whole structure. In the context of the FPLAPW (Full Potential Linearized Approximation Plane Wave) method, the base is made up of a set of plane-waves augmented by radial functions, multiplied by harmonics spherical (Y_{lm}) linearized.

$$\Phi_{j,k}(r)=\begin{cases}\dfrac{1}{\Omega^{\frac{1}{2}}}\sum_{G} C_{j,k,G^{e^{i(k,G).r}}} \\ \sum_{\mathrm{lm}}\left[A_{\mathrm{lm}}U_1(r,E_1)+B_{\mathrm{lm}}\dot{U}_1(r,E_1)Y_{\mathrm{lm}}(r)\right]\end{cases} \tag{30}$$

where Ω is the volume of the unit mesh and $C_{j,\,k,\,G}$ is the coefficients of plane wave development [30]. U_1 is the regular solution of the radial Schrodinger equation and its derivative $\dot{U}_1$. The linearized of the radial function is realized from a linear combination of these two functions. The coefficients A_{lm} and B_{lm} are determined so as to satisfy the conditions of continuity between zones (I) and (II). The LAPW method [31] in its full potential version goes beyond the Muffin-tin approximation: the potential is unconstrained to be spherical within spheres and constant between them. These so-called full-potential methods are very accurate for the calculation of the total energy. The LAPW-FP is therefore a method that has the double advantage of offering a description of the potential as well as the electrons. Thus, it will be a method of choice as soon as the targeted properties will involve extreme precision on core electrons and energy.

10.2 Characteristics of the Pseudo-Potentials

The pseudo-potential makes it possible to free oneself from the electrons of the core and "replace" the Coulomb potential of nucleus surrounded for its electrons and an effective ionic potential which will then act on the valence electrons of the studied systems (molecules, solids, ions, etc.).

The principle consists in replacing the nuclear potential (diverging in a coulomb manner by r = 0) with a potential whose first eigenvalues coincide with the valence states that would be obtained with an "all-electron" calculation. The use of a pseudo-potential allows us only to take into account core electrons without participating in the chemical bond, but also allows us in the case of methods based on plane wave development (such as the VASP code) of defining "Soft" potentials that require less plane waves in their Fourier series development. Many formulas have been proposed to obtain good pseudo-potentials digitally efficient and as accurate and transferable as possible. There are various classes of pseudo-potentials that we have listed below:

- Empirical pseudo-potentials.
- Pseudo-potentials with preserved standard.
- Ultra-soft pseudo-potentials.

The first pseudo-potentials were empirical, but a major improvement was made by the introduction of the conservation condition of the norm, which made it possible to define pseudo-potentials without adjustable parameters, and which had as a direct consequence a better precision. However, a major numerical problem persisted due to the "hardness" of these pseudo-potentials, which required a very large number of plane waves. The "ab-initio norm-conserving" approach was extended by David Vanderbilt, in 1990, with the creation of ultra-soft pseudo-potentials.

10.3 The Ultra-Soft/Ultra Pseudo-Potentials (US-PP)

In our work, we used the Ultra-Soft pseudo-potentials such as Vanderbilt. We will explain below what is an ultra-soft pseudo-potential (US-PP) [32].

Creating the pseudo-potential is a compromise between its precision and its "softness." The latter actually corresponds to the limit at which electrons are considered as valence electrons. From a practical point of view [19], this means that for plane wave calculations and the valence electrons obtained in Fourier components [19].

Indeed, during self-coherent iterations, the contribution of the charge that increases in the sphere changes according to the wave function and contributes to the potential used in the Kohn and Sham equations. Thus, the pseudo-potential evolutionary during the calculations. This allows the use of very soft pseudo-potentials (large values of the cutoff radius « r_c ») in the Vanderbilt scheme (Fig. 11) without affecting the accuracy of the calculations.

The US-PP achieves an accurate result, since the problem has been expressed in another way, as a smoothing function and an auxiliary function centered around each atomic nucleus corresponding to the rapidly varying part of the density [19].

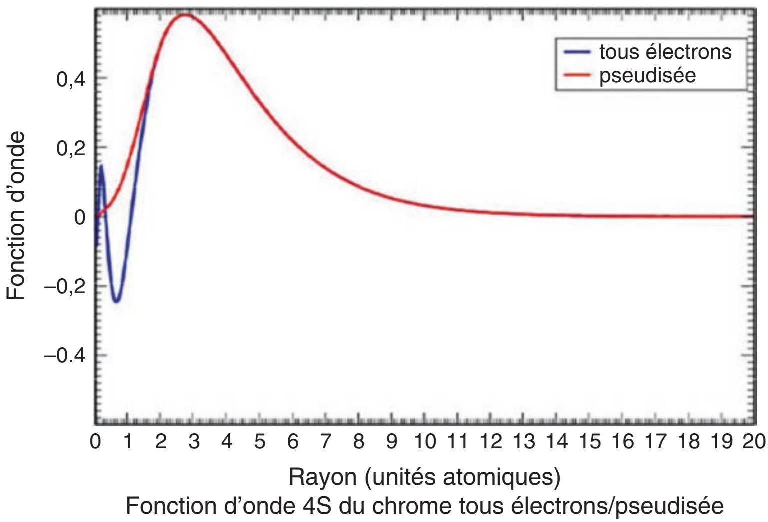

Fig. 11 Radial wave function r × R(r) 3 s (blue) and the pseudized (red) wave function of the aluminum atom (atomic units). Note that the function R(r) is non-zero in r = 0 for s functions

The variant part is replaced by the red part, which avoids the nodes of the function and thus the sign changes. At long range, the two curves become identical.

11 Modeling of Thermoelectric Materials

The transport theory deals both with load flow and heat flow that pass to through a solid material under the effect on an external field (electric field and/or gradient of temperature). The movements of the carriers (electrons or phonons) are driven by the external fields but resist by the processes of internal diffusion between them and among the other quasi-particles. There are exchanges of energy and moment within the interactions, resulting from finite electrical or thermal conductivity. On the other hand, the interactions have the consequence that the conduction of the carriers does not in their states of equilibrium. There are two approaches to such out of equilibrium state transport, namely Green Kubo's theory and Boltzmann semi-classical transport theory.

The first theory concerns the transport coefficients of the correlation function of the current flow or heat, the second theory considers the effect of the various diffusion in the mechanism of the transport properties in relaxation time.

The Boltzmann transport theory has proven its validity in many applications, where the calculated transport coefficients can be easly compared with the experimental results. In this section, it is shown how to merge the electronic structure from ab-initio approach by using the DFT in Boltzmann's transport theory to determine the electronic transport coefficients.

11.1 The Basis of the Semi-Classical Theory of Transport

The semi-classical transport theory is based on the direct or approximate solution of the Boltzmann transport eq. [33] determined by the semi-classical distribution function fn(r, k, t). It gives the probability of finding a particle in the region (r, r + dr) and (k + dk) at time t [34]. The moments of the distribution function give us the information about the particle density, the current density, and the energy density.

Boltzmann theory describes the electron system by introducing the distribution function, which is given by the Fermi function, where the electrons are in their equilibrium states. It is explicitly dependent on the band and the wave vector.

The distribution function can be changed due to the following mechanisms:

Diffusion: electrons of velocity $\nu(k)$ remain in the vicinity of adjacent regions, while the others leave, because of diffusion.

The external fields: the electrons are driven by forces generated by the external fields, which in this case are the electric field and the temperature gradient.

Collisions: electrons are scattered from one state to another by various interactions, including electron-phonon interactions.

The total rate of change of the distribution function is then:

$$\dot{f} = \dot{f}_{diff} + \dot{f}_{field} + \dot{f}_{coll} \tag{31}$$

In the state of equilibrium $\dot{f}$ becomes null:

$$\dot{f}_{diff} + \dot{f}_{field} = -\frac{df}{dt_{field}} \tag{32}$$

If we introduce the relaxation time $\tau(k)$ to describe the diffusion effects and assume that $f_n(r, k, t)$ approaches the equilibrium distribution $f^0(k)$, we obtain:

$$\frac{\partial f}{\partial t_{field}} = \frac{f(k) - f^0(k)}{\tau(k)} \tag{33}$$

Since f is a function of « r, k and t », the distribution rate is changed due to diffusion and external field. Then, external field can be written:

$$-\dot{f}_{diff+field} = \frac{\partial f}{\partial r}\frac{r}{\partial t} + \frac{\partial f}{\partial k}\frac{e\varepsilon}{\hbar'} \tag{34}$$

With

$$\frac{r}{\partial t} v(k) \frac{1}{\hbar}\frac{\partial E}{\partial k} \tag{35}$$

We replace f by f^0, thus we have:

$$\frac{\partial f}{\partial r} = -\frac{\partial f^0}{\partial E}\left(\nabla \mu + \frac{E-\mu}{T}\right)\nabla T \tag{36}$$

Then, the distribution function is written as:

$$f(k) = f^0(k) + \left(-\frac{\partial f^0}{\partial E}\right) v(k)\tau(k)\left\{e\varepsilon - \left(\frac{\sigma\mu}{\sigma T} + \frac{E-\mu}{T}\right)\nabla T\right\} \tag{37}$$

11.2 The Transport Coefficients

The displacement of charges under an electric field generates an electric current for which the density is given by:

$$J_e = \frac{2e}{8\pi^3}\int v(k) f(k) dk \tag{38}$$

where $f(k)$ is given by the equation (37) that constitutes the distribution function of Fermi- Dirac. In the same way, the current density of heat produced by the electrons is obtained by:

$$J_Q = \frac{2e}{8\pi^3} \int v(k)[E-\mu] f(k) dk \tag{39}$$

where μ is the chemical potential. Thus, substituting Eq. (37) in both Eqs. (38) and (39) with neglecting f^0 in Eq. (37) gives:

$$J_e = \frac{2e}{8\pi^3} \int v(k) v(k) \tau(k) \left(-\frac{\partial f^0}{\partial E}\right)\left[e\varepsilon - \nabla\mu + \frac{E-\mu}{T}(-\nabla T)\right] dk = \frac{e^2}{4\pi^3} \int v(k) v (k) \tau(k) \left(-\frac{\partial f^0}{\partial E}\right)\left[\mathcal{E} - \frac{1}{e}\nabla\mu\right] dk + \frac{e}{4\pi^3\hbar} \int v(k) v(k) \tau(k) \left[\frac{E-\mu}{T}\right](\nabla T) dk [20] \tag{40}$$

$$J_Q = \frac{2e}{8\pi^3} \int v(k) \int v(k) v(k) \tau(k) \left(-\frac{\partial f^0}{\partial E}\right)\left[e\varepsilon - \nabla\mu + \frac{E-\mu}{T}(-\nabla T)\right] (E-\mu) dk = \frac{e}{4\pi^3} \int v(k) v(k) \tau(k) \left[\varepsilon - \frac{1}{e}\nabla\mu\right](E-\mu)\left(-\frac{\partial f^0}{\partial E}\right) dk + \frac{1}{4\pi^3} \int v(k) v(k) \tau(k) \frac{E-\mu}{T}(-\nabla T)\left(-\frac{\partial f^0}{\partial E}\right) dk [20,21] \tag{41}$$

By defining now the integral:

$$K_n = \frac{1}{4\pi^3\hbar} \int v(k) v(k) \tau(k) (E-\mu)^n \left(-\frac{\partial f^0}{\partial E}\right) dk \tag{42}$$

Then, the equations can be expressed as a function of K_n:

$$\mathrm{J_e} = \mathrm{e}^2 \mathrm{K_0} \varepsilon + \frac{\mathrm{eK_1}}{\mathrm{T}}(-\nabla \mathrm{T}) \tag{43}$$

$$\mathrm{J_Q} = \mathrm{eK_1} \varepsilon + \frac{\mathrm{K_2}}{\mathrm{T}}(-\nabla \mathrm{T}) \tag{44}$$

When the temperature gradient is equal to zero ($\nabla T = 0$):

$$\mathrm{J_e} = \sigma\varepsilon \tag{45}$$

where σ is the electrical conductivity which takes the form:

$$\sigma = e^2 K_0 \tag{46}$$

In the case where no electrical current passes through the material, the relation $J_e = 0$ becomes valid, the electric field efficiencies gives:

$$J_Q = \kappa\left(-\nabla T\right) \tag{47}$$

where κ is the electronic thermal conductivity:

$$\kappa = \frac{1}{T}\left[K_2 - \frac{K_1^2}{K_0}\right] \tag{48}$$

If we suppose that there is a temperature gradient across the material, we will have a zero-electric current and an electric field is produced:

$$\varepsilon = \frac{K_1}{eTK_0}\nabla T \tag{49}$$

From the definition of the coefficient of Seebeck, we thus obtain:

$$S = \frac{K_1}{eTK_0} \tag{50}$$

12 Conclusion and Future Scope

The battery produces electricity through the thermoelectric effect. Even today's best thermoelectric material, bismuth telluride, is too inefficient to compete with other energy sources. However, thermoelectricity's strengths lie in the fact that it is irreplaceable in some applications by other types of electrical energy such as space exploration, and in its simplicity and reliability, both long and short term. Consequently, thermoelectricity can be profitable even at low efficiency because it makes use of the enormous amounts of energy lost and contributes to sustainable development.

These challenges help to explain the rapid and sustained increase in electricity storage innovation documented in this report, as well as the need for further innovation over the coming years. The data presented in this report show trends in high-value inventions for which patents have been filed on an international scale. They provide insights into which countries and companies are leading the way in developing electricity storage technologies and thus may be best placed to deliver much-need improvements in this area in the near future.

The data also show not only how the types of electricity storage application attracting the most interest from companies and inventors have changed, but also which applications and technologies are gathering momentum and could be poised to play breakthrough roles in the future.

Thereby, the technological innovation in this chapter is proposing the theoretical mean to optimize the transport properties of the materials that make up the batteries of smartphones, laptops, electric vehicles, and satellites, in order to encourage environmental protection, by using green energy to build a new clean society where there is no pollution and no greenhouse gas emissions realized from fossil fuels. The batteries proposed in this chapter can be used in multiple fields. The most relevant of these domains is that of smartphones, which are very important for processing medical information by means of a smartphone under the l'IoT framework. Indeed, the IoT have a very wide range of smartphones that can be utilized for healthcare purposes, battlefield, underwater or underground usage, space application, etc. The subjects of this chapter are presented in more details in advanced textbooks on Green Technological Innovation for Sustainable Smart Societies, environment and challenges and opportunities. Most recent researches are focusing on bio-batteries because of the worldwide priority concerning the human health. The first bio-battery is based on the utilization of carbohydrates, amino acids and enzyme materials, recent bio-batteries using Blood and sweat and the latest bio-battery using virus (bacteria). A bio-battery or a biofuel cell is an energy storage device that is powered by organic compounds, especially glucose. It generates electricity from renewable fuels providing sustained, on-demand portable power sources.

Compared to conventional batteries, such as lithium batteries, bio-batteries [35] are less likely to retain most of their energy. This causes a problem when it comes to long-term usage and storage of energy for these batteries. However, researchers are continuing to develop the battery in order to make it a more practical replacement for current batteries and sources of energy. The bio-batteries have a very promising future ahead of them as third industrialization and the specialized scientific research have been increasing over recent years. They serve as a new form of clean (green) energy that is proving to be environmentally friendly as well as successful in production and storage of energy. This energy may be used in the ecological houses as a source of electrical energy to power household appliances and electronic devices (smartphones, laptops, games, cars) and design the sustainable smart society. Also, in the medical domain [36], these bio-batteries power mobile devices such as the defibrillators and portable blood pressure monitors, for example. Indeed, the sustainable smart society built from clean energy uses the innovation in batteries and electricity storage [37].

Nevertheless, energy storage – which is a critical technology – is currently not on track to achieve the levels called for in the Sustainable Development Scenario, in terms of both its deployment and performance. This means that we are failing to put in place the infrastructure that will be needed for renewable energy to expand more rapidly. Clean energy innovation policy will have a crucial role to play in reconciling these divergent trends. But for it to be effective, it needs to be based on robust data. This timely report is an excellent example of the value of reliable numbers and rigorous analysis on new technologies for which claims and counterclaims can sometimes obscure the reality. For example, it provides important statistics on countries' technological advantages that can support critical decisions about funding for energy storage projects. In synthesis, the bio-batteries are environmentally friendly as they did not use harmful chemicals or metals. With that in mind, scientists seem to be exploring every possible option in bio-battery and fuel-cell technology. The technological innovation focuses on the discovery of new materials that possess a compromise between the physical and chemical properties depending on the field of battery application to build a sustainable smart society.

Our work focuses on the optimization and prediction of new intelligent materials through the methods of simulation and machine learning. A complementary combination between experiments is very interesting which we consider as future perspectives.

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An Integrated Constructed Wetland System for Society

J. S. Sudarsan and S. Nithiyanantham

Abstract A constructed wetland is used to treat wastewater. It involves free water surface flow and subsurface flow. The subsurface system has two types of flow: horizontal flow and vertical flow. For treatment, wastewater and sewage from houses, industries, agriculture, etc. flow through the constructed wetland for removal of pollutants through the processes of sedimentation, filtration, and some chemical processes. This work describes pollutant removal using *Typha latifolia* and *Phragmites australis* with soil and sand. Samples were tested and their chemical oxygen demand, biochemical oxygen demand, and levels of total suspended solids, total nitrogen, and total phosphate were determined. Further, computations in MATLAB software were used to validate hydraulic retention time coefficients of 96–144 hours for total phosphate and total nitrogen. The analysis revealed that the integrated wetland design is suitable for forming constructed wetlands in developing countries.

Keywords Constructed wetland · *Typha latifolia* · *Phragmites australis* · Wastewater · Pollutant

1 Introduction

After air, water is the second most important substance in the world. It is the "divine amrita" that sustains human life in the universe. Water is a scarce and essential natural resource, and it plays an important role in all kinds of activity. Conservation and maintenance of water quality are very important for the welfare of humans and

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other living beings. Prevention and reduction of water pollution protect water quality and are essential for maintaining the health of our environment and our quality of life. Demand for water is based on its usage and disposal of used water, which deserve equal importance and awareness. With rapid increases in urbanization and industrialization, more and more wastewater is being produced and must be treated before it can be disposed of safely. In the European Community alone, more than 21 million tons of toxic waste needs to be treated every year.

Treated sewage effluent may be disposed of in a running body of water or may be used for irrigation purposes. However, the provision of services—including wastewater collection, treatment, and disposal—has not kept pace with rapid population explosion and industrialization [1]. The use of conventional treatment plants is very costly and adds to the financial burden on the public, particularly in developing countries. In most developing countries, such as India, a huge quantum of wastewater is discharged into water bodies without proper treatment. For small communities in particular, the cost of wastewater treatment represents a high percentage of their budgets and is thus unaffordable. The total amount of wastewater that is produced in major cities in India is 38,354 million liters per day. However, the sewage treatment plants throughout the country have a total throughput capacity of only around 11,786 million liters per day; thus, there is a treatment capacity deficit of 26,568 million liters per day. The kinds of techniques used in such treatment plants provide a very effective secondary treatment process, which has been proven to be effective in treating wastewater (especially community wastewater) in developed countries. The economic feasibility of utilizing local labor and materials is an added advantage. The need for cost-effective treatment of wastewater in an eco-friendly manner is urgent in countries such as India.

Many aquatic plants exist in wetlands and perform numerous functions. They remove or convert large quantities of pollutants—as well as suspended solids (SS), metals, and excess nutrients—through processes such as filtration, sedimentation, plant uptake, and microbial degradation. Physical, chemical, and biological processes that occur in wetlands treat waste matter. These wetlands are wet during rainy seasons and dry during nonrainy seasons. Wetlands are generally considered the "kidneys" of the landscape. Wetlands used for wastewater treatment conform more to the definition devised by Coward et al. than to the Ramsar convention. The processes that occur in both natural and constructed wetlands are similar, and there should be no functional difference between natural and constructed wetlands. A constructed wetland is designed to change in the same way as a natural wetland does.

From the dawn of civilization, drains were considered to be a symbol of advancement in a social setup. Primitive civilizations employed drains for sewage disposal. Wastelands have received wastewater discharges in many situations and on many occasions over many years, but for the past few decades, they have been recognized as a low-cost and cost-effective water treatment and purification system. Constructed wetlands (CWLs) work similarly to natural wetlands for treatment of wastewater, but their advantage is an absence of the constraints associated with discharging waste into a natural ecosystem. The intention of a constructed wetland is to modify the land for pollution control and waste management at a specific location. Artificial and man-made wetlands benefit human life. For a long time, people were unaware of the mechanism of treatment of wastewater; thus, in the initial stages of wetland research, there was little documentation on the subject. A handwritten note dating from 1904 is the earliest document focused on this concept, and it is on that basis that further research has progressed [2, 3].

The concept of using wetlands for wastewater treatment which was subsequently developed further [4]. It was found that contaminated water supports the life of specific plants. Common bulrushes were used in an experiment on aquatic macrophysics for improvement of water quality. This analysis showed that this plant species not only removed organic and inorganic substances from water but also purified and enhanced soil. The experiment was further extended to treatment of water containing phenol, dairy wastewater, and livestock wastewater [5]. In 1976, the first free water system (FWS), known as the Kneford system, was developed in the Netherlands [4]. This type of system contains four or five parallel basins planted with emergent macrophytes in gravel media. The first and second stages have vertical flow beds; the upper layer of sand is planted with the macrophytes and the bottom layer contains gravel. There is then a horizontal cell with several species of macrophytes planted in sand and gravel. This type of alternating arrangement of sand and gravel results in better performance, as an integrated wetland unit, with clogging being its only limitation.

Two kinds of constructed wetland systems are available for treating wastewater: (1) free water surface systems and (2) subsurface flow systems [1, 6]. A free water system contains parallel basins and, in some cases, channels with suitable watertight bottom soil, planted with vegetation in shallow water depths ranging from 0.1 to 0.6 m. It needs to be used carefully and monitored for the efficacy of the wastewater treatment because of the potential for the spread of pathogens and vectors [7]. A subsurface flow system is constructed with the aim of an advanced type of water treatment, using the root zone, a vegetated submerged bed, and rock reed filters. Its channels restrict the flow of water, which moves slowly through the lower part filled with sand and rock media, and enhances the growth of the vegetation.

The subsurface flow method can be further characterized as a horizontal subsurface flow (HSF) system; here, the wastewater flows horizontally between the substrate and the vertical subsurface flow (VSF) system [8]. Constructed wetlands have been used widely for treatment of household sewage wastewater, industrial wastewater, agricultural runoff, heavy rain, and snowmelt water. The pollutant removal process in a constructed wetland uses physical processes such as sedimentation and filtration; chemical processes such as adsorption, absorption, and precipitation; and biological processes of metabolism by bacteria and plants (e.g., *Typha latifolia*) [9, 10].

The removal efficiency of a constructed wetland depends on the interactions of several parameters, such as (1) the temperatures of the water, soil, and air; (2) the solar radiation; (3) the humidity; (4) the volume and frequency of rainfall; (5) the presence of pollutant concentrations; (6) the hydraulic and soil characteristics; and (7) the vegetation. These parameters influence the supply of nutrients, the movement of chemical substances, and the biological activities of the plants [11, 12].

Since its initial conception and development, this technology has gained widespread use in the USA, Europe, and Australia, It has also recently been extended to most countries in Asia. A constructed wetland is a potentially low-cost treatment technology, making it particularly advantageous for wastewater treatment in developing countries [3]. These constructed wetlands are usually built using local materials and any type of labor. This is their main advantage in developing countries such as India. However, there has been only limited research on the setup of constructed wetlands in India [13].

Use of a constructed wetland to decrease (1) biological oxygen demand (BOD), (2) chemical oxygen demand (COD), (3) nitrogen content, (4) phosphorus content, and (5) pathogen content in primarily treated water was carried out by Juwarkar et al. in 1995 [14]. *Typha latifolia* and *Phragmites australis* were the emergent macrophytes used in that study. They were grown in cement pipes, which covered an area of 1256 m^2 and were 0.8 m deep, filled with 30% soil and 70% sand. The hydraulic loading was 5 cm day^{-1}. BOD was reduced by 78–91%, the nitrogen content was reduced from 30.8 to 9.5 mg L^{-1}, and the phosphate level in the treated effluent was 9.6 mg^{-1}.

In India, the first constructed wetland, measuring 90 m by 30 m in size, was established at Sainik School in Bhubaneshwar, Odisha, using *Typha* and *Phragmites* as the vegetation. BOD and N content were found to be reduced by 67–90% and 58–63%, respectively [15].

A field-scale constructed wetland with an HSF design was built over a period of 4 years in Ujjain (Madhya Pradesh, India), with a surface area of about 41.82 m^2 and a water retention capacity of 18 m^3. Its efficiency in reducing BOD and the levels of total suspended solids (TSS), ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), total nitrogen (TN), and phosphorus (P) in municipal wastewater was evaluated. The emergent plant species used was *Phragmites karka*, planted in gravel. In the reported findings, BOD_5, NH_4-N, TN, and P were each reduced by more than 50%.

Use of ornamental plants as vegetation in a constructed wetland with an HSF design was shown to achieve good reductions in all parameters in an experiment using a combined subsurface wetland to treat river water in Taiwan [15, 16]. A small-scale constructed wetland with a free surface flow unit and a subsurface flow unit (planted with *Pennisetum alopecuroides*, *lpomoea reptans*, and *Phragmites communis*) was used to purify highly polluted river water. On average, COD was reduced by 13–51%, ammonia-N (NH_3-N) by 78–100%, and organophosphate (OP) by 52–85%.

A field study was performed in small towns in South India, using low-cost wastewater treatment and collection technology. It was found that in rainy seasons and in the summer, this form of municipal wastewater treatment was efficient, low cost, and easy to operate [17, 18].

Municipal wastewater was treated in a subsurface flow wetland in Spain, using two hydraulic application rates and plant species. Both species reduced BOD, COD, and TSS by >60% [19]. However, a free surface constructed wetland with three cells (marsh–pond–meadow) planted with cattails and bulrushes was found to have low efficiency for removal of phosphorus.

The biological and chemical processes that occur in a wetland are responsible for the nutrient transformation that takes place in it [20]. Constructed wetlands have been used to treat both municipal and industrial wastewater. In one study, use of a constructed wetland to treat municipal wastewater from five treatment plants resulted in good TSS, BOD, COD, and NH_3-N reductions. An earthen channel was used to pretreat the wastewater. Average NH_3-N and TSS reductions of 78% and phosphorus, BOD, and TN reductions of 58–65% were reported [21].

A pilot constructed wetland was built in Warangal (Andhra Pradesh, India) and monitored for about 1 year to evaluate seasonal effects on the efficiency of removal of different constituents in municipal wastewater. As a result of this study, this system for treating wastewater has been extended and established in all parts of the city [17].

The fast pace of economic growth since the 1980s has also led to a serious water pollution problem in India. Many towns and municipalities lack the money and technology to install advanced wastewater treatment systems. There is vast potential for use of constructed wetland systems in India. The advantages and disadvantages of constructed wetlands for wastewater purification are shown in Table 1.

Constructed wetlands can purify a variety of different types of wastewater (runoff, landfill leachate, swine effluent, etc.) in rivers. A global perspective on constructed wetlands shows a promising picture of design developments and modifications to improve treatment and substance removal efficiency. Many research findings have highlighted that treatment of wastewater in constructed wetlands after primary treatment is very effective.

The survival of different plant species was monitored in an HSF constructed wetland receiving tannery wastewater in Portugal. In this study, *Phragmites australis* and *Typha latifolia* were the only plants that were able to be established satisfactorily.

The treatment performance of compost-based and gravel-based wetlands to treat wastewater from a refinery in Pakistan was evaluated. *Phragmites karka* was the vegetation used, with a hydraulic loading rate of 0.100 m^3 day^{-1} at irregular intervals. TSS content was reduced by 51–73% and 39–56% in the compost- and gravel-based wetlands, respectively; COD was reduced by 45–78% and 33–61%, respectively; and BOD was reduced by 35–83% and 35–69%, respectively. These results showed that the compost-based wetland performed better than the gravel-based one.

Table 1 Advantages and disadvantages of constructed wetlands

Advantages	Disadvantages
Lower capital costs and construction costs than those of conventional systems	Larger area required
Consistent compliance with permit requirements	Reduced performance during the vegetation establishment period
Operational and maintenance simplicity	For subsurface flow systems, mosquito control may be necessary
Aesthetics may be greatly enhanced	Potential odor problems
Habitat for wildlife	Possible groundwater contamination
High levels of wastewater treatment	Standardization of designs requires input from engineers

In a constructed wetland planted with *Typha* species in Thailand, an analysis of the effect of soil-to-sand ratios of 75:25, 50:50, and 25:75 on treatment of domestic wastewater with three different hydraulic retention times (HRTs) (3, 1.5, and 0.75 days) was conducted. The study revealed that an HRT of 3 days with a 75:25 soil-to-sand ratio achieved the greatest efficiency, reducing BOD, COD, suspended solids, TN, and total phosphorus (TP) by 92%, 91%, 76%, 90%, and 95%, respectively.

Septic tank effluent from eight locations in Texas was used to assess reductions in pollutants over a period of 1 year. Subsurface constructed wetlands were designed in accordance with US Environmental Protection Agency (EPA) guidelines. The types of vegetation planted were *Canna flaccida* (canna lily), *Cyperus alternifolius* (umbrella palm), *Sagittaria lancifolia* (arrow heads), *Scirpus* sp. (bulrush), *Typha latifolia* (cattails), and *Colocasia esculenta*. The system reduced BOD by 80–90%. This work confirmed that use of constructed wetlands is a promising method for advanced treatment of onsite domestic wastewater. It can also be inferred from various research findings that this type of system is quite good for organic pollutant removal. Todorovics et al. (2005) indicated that use of reeds contributes to the wastewater cleaning process in many ways [22], increasing the permeability of the sand and the porosity of the substrate, and creating oxygenated microsites within reducing conditions by releasing oxygen from roots. Different operation strategies have been reviewed to ascertain whether they improve performance, such as reaeration and aeration, tidal flow operation, flow direction reciprocation, earthworm integration, and innovative designs and configurations such as circular flow corridor wetlands, hybrid tower wetlands, and baffled subsurface wetlands.

From 1991 to 2010, the annual number of journal articles published and the number of articles cited regarding wetland research increased dramatically. The USA produced the greatest number of these publications, followed by Canada and the UK. The journal *Wetlands* is a highly active publication.

The main issues in wetland research in the future may be wetland biodiversity and constructed wetlands [23]. India now faces serious water pollution problems. Along with the growing interest in India regarding constructed wetlands for treatment of both domestic and industrial wastewater, there is also an increasing realization of the need for tertiary treatment of effluent from conventional treatment plants before its discharge into surface waters. Three wetland plant species—*Phragmites karka*, *Scirpus litoralis*, and *Typha angustata*—were evaluated for their efficiency in tertiary treatment of wastewater from a milk-processing unit. Analysis of all of the pollutants showed that *Typha* achieved the greatest reductions (>90%) in NH_4-N and NO_3-N. The superiority of *Typha* in wastewater treatment was partly due to its greater uptake and accumulation of nutrients in its biomass.

Constructed wetlands can assist nature by providing protection for shore life; flood reduction; control over geochemical sinks; traps for harmful elements such as carbon, sulfur (from acid rain), and heavy metals; and food and habitats for wildlife. They can also provide suitable environments for human recreational pursuits. As has been discussed by different groups, they also provide free treatment for various type of water pollution, removing or otherwise transforming large quantities of pollutants from point sources and nonpoint sources (including organic matter, TSS, metals, and excess nutrients) by natural filtration, sedimentation, and other processes. By mimicking natural processes of sedimentation, natural filtration, etc., use of constructed wetlands is a promising green technology for wastewater treatment.

Cost-effective constructed wetlands have been considered a viable future technology for a developing country such as India. A review of design considerations, construction, operation, and application of root zone treatment in tropical and subtropical countries was conducted by Patnaik's group. That review concluded that a root zone treatment system (RTZS) was the most suitable technology to deal with domestic wastewater, as a low-expense, maintenance-free, and efficient method of treatment. This technology is presently gaining momentum in India and has the potential to help address the country's water scarcity.

Construction of the wetland units: based on natural and artificial (man made).

1. *Wetlands:* The more conventional definition of the term "wetland" is relatively restrictive. Wetlands are classified into two main categories: natural wetlands and constructed wetlands.

   (a) *Natural wetlands:* Natural wetlands (such as marshes, swamps, and bogs) have been traditionally used all over the world for disposal of wastewater. Their attributes—high primary productivity; brisk microbial activity in the sediment and in the sediment–water interface; and stabilization of waste and removal of nutrients, facilitated by macrophytes—all combine to make wetlands efficient assimilators of biodegradable wastewater. Waste stabilization pond treatment systems are largely favored for application in developing countries, mainly those located in tropical climates. These wetlands exist near seashores, riverbeds, and lake-beds. Over the past few decades, several functions of wetlands and their importance have been recognized by scientists, farmers, and field workers. In many cases, these wetlands significantly reduce suspended solids, BOD, pathogens, etc. [24].

   (b) *Constructed wetlands:* Constructed wetlands have been defined as "engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewaters" [20, 25]. Several kinds of processes occur inside the system at the same time and thereby minimize pollutant levels in the wastewater. Pollutants and other waste in the water are removed by filtration, sedimentation, and biochemical interactions [8]. Constructed wetlands can be classified on the basis of the types of plants that are grown in them. Most constructed wetlands include the following five main components:

      (i) Conductive substrates
      (ii) Types of plants taken as water saturated anaerobic substrates
      (iii) A water column
      (iv) Vegetation
      (v) Microbial populations (aerobic and anerobic)

2. *Benefits of constructed wetlands:* Constructed wetlands have many inherent advantages over natural wetlands. They are inexpensive, with low operational and maintenance expenses. Only periodic maintenance is required, and they do not require continuous onsite monitoring. Constructed wetlands can treat different types of wastewater containing varying concentrations of substances and can tolerate large fluctuations in flow. They also facilitate water reuse and recycling, and blend in well with nature. They are both eco-friendly and economical.
3. *Need for this research:* Because of its fast economic growth and population explosion over the years, India now faces serious water pollution problems, which mandate eco-friendly and cost-effective water treatment systems. Constructed wetlands are a tangible and viable option for this purpose.
4. *Significance of this research:* This research focused on the use of integrated or hybrid constructed wetlands employing integrated flow to treat domestic wastewater. The objectives were approached analytically to fulfill that aim.
5. *Novelty of this research:* This study combined both vertical and horizontal flow construction into a single unit and achieved both flow patterns in it. Most other researchers have studied horizontal and vertical flow systems separately and established that they are effective for wastewater treatment. In this study, through provision of baffles and holes in the baffles, it was possible to achieve an integrated flow pattern in a single chamber. This integrated setup was fabricated in accordance with design calculations and design procedures based on the EPA guidelines. Another important highlight of this study was that the plants used in it were native wetland plants that were readily available in the local area.
6. *Objective of this research:* This study was performed to examine the efficiency of an integrated constructed wetland system using the emergent macrophytes *Phragmites australis* and *Typha latifolia* to treat domestic wastewater.

2 Methodology

First, we collected plant samples from a natural local wetland for use in the treatment process. In the design of a constructed wetland, the choice of a vertical flow system, a horizontal flow system, or a hybrid system depends on the requirements. The selected plants were then transplanted into the constructed wetland, and wastewater was introduced into it. The level of wastewater treatment achieved was assessed by sampling and analysis. Figure 1 provides a pictorial representation of the project methodology.

2.1 Project Site

The project site, SRM University, is located at Potheri Village in Chengalpat District, Tamil Nadu, South India (Fig. 2). The site is situated at 12° 42′ N and at 80° 02′ E, at an average altitude of 33 m, with a temperature range of 19–42 °C and yearly

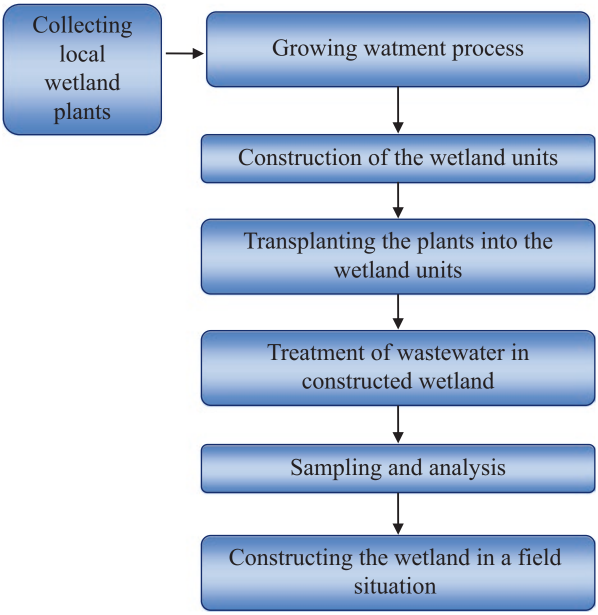

Fig. 1 The project methodology

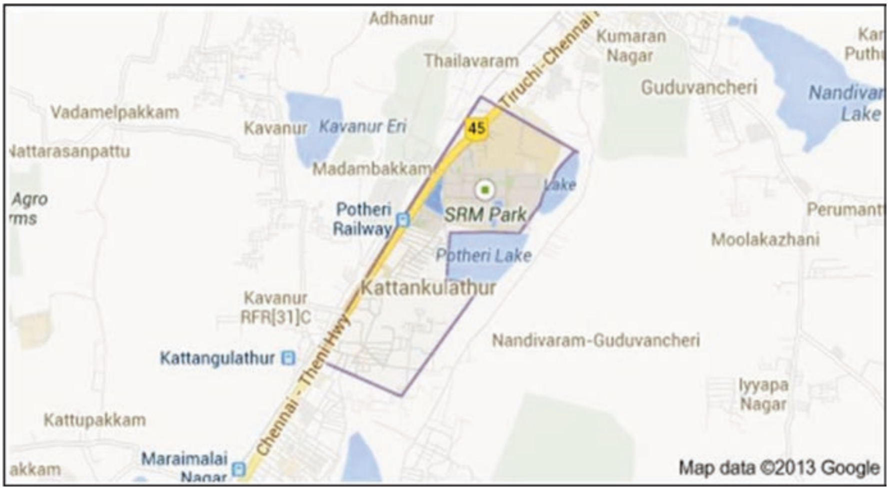

Fig. 2 The project site

rainfall of 1330 mm [26]. Six experimental units in the integrated subsurface flow constructed wetland were created in unused space near an existing conventional sewage treatment plant (STP) on the SRM University property so that wastewater from its pretreatment chamber could be utilized for the study. A final pilot unit used for testing community wastewater was set up behind the Dental College, where a mixture of campus and community wastewater was available [27].

2.2 Wetland Plants

1. *Collection of local wetland plants:* Stems of *Phragmites australis* and small *Typha angustata* plants were collected from local fields surrounding the campus and transplanted in polyethylene bags containing natural soil [15].
2. *Growth of wetland species prior to the treatment process:* The *Phragmites* stems were watered with fresh water on alternate days for initiation. The *Typha* plants were kept in standing water. After 1 month, the plants were transplanted from the bags into a natural bed and maintained there. Wastewater was added slowly once the plants were well established, in order to acclimatize them. The plants were monitored often, and weeds were removed immediately [28].

2.3 Experimental Setup

Initially, six units were built to fulfill the study objectives. Two units were designed for vertical flow and horizontal flow, respectively, and the other four were integrated systems. Vertical flow and horizontal flow were achieved by using baffles to allow only vertical flow or horizontal flow. Each wetland unit was a rectangular channel with an inlet chamber, wetland chamber, and outlet chamber. The inlet and outlet chambers were fitted with facilities for entrance and exit of wastewater. The middle chamber was separated into three zones by use of stone baffles [29].

In the case of the integrated wetland units, eight holes were made in each baffle (Fig. 3). This arrangement helped to adjust the water levels in the horizontal and vertical units in order to confirm that both horizontal and vertical movement occurred. The plants were grown in a two-layered medium of sand and gravel in one case, and in sand and hollow polyethylene tubes embedded in gravel in the other [29].

1. *Transplantation of plants into the wetland unit:* The plants were transplanted into the wetland units and, again, were given time to become acclimatized there before the treatment started. The photos below show the *Phragmites* and *Typha* plants in the initial stages of their growth [13].
2. *Treatment of wastewater in the constructed wetland:* The wastewater was subjected to primary treatment (skimming and primary sedimentation) prior to being let into the constructed wetland. A design of discharge of wastewater was let into the input chamber. The wastewater was allowed to stay in the wetland chamber for the planned HRT corresponding to the unit's capacity, after which it exited to the outlet chamber [30, 31].
3. *Design procedure for actual inflow:* A design procedure specified by the University of New Hampshire Stormwater Center (UNHSC) was used to formulate a complete hydrological design for the wetland for typical inflow into one of the treatment plants on the campus [32].
4. *General design procedure:* To ensure drainage when required, a slight slope was provided and the depth was the maximum downward length that the macrophyte

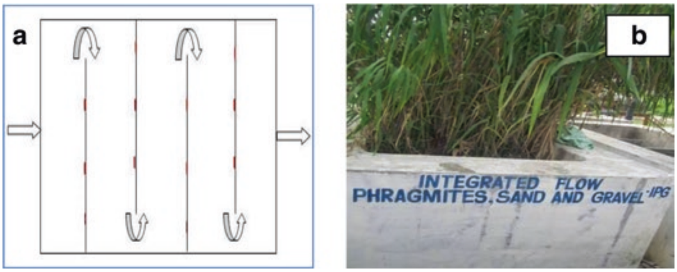

Fig. 3 (**a**) The plan of the integrated wetland unit. *Red lines* indicate holes in the baffles. (**b**) The units built at the site (the integrated wetland unit)

roots could reach. *Phragmites australis*, whose roots can reach a depth of 0.6–0.8 m in a constructed wetland bed, was used to determine the depth of the bed. A slope of less than 2.5% was used for the coarse filtration medium, and for the finer medium, it was less than 1%. It was decided that a water depth of 0.27 m with a bed depth of 0.8 m would be good for refining efficiency and for higher rates of nitrification/denitrification with increased oxygen flux from plants at a shallower water depth, so that more efficient treatment could be achieved. The ideal requirements of a filtration medium are as follows:

(a) It should facilitate macrophyte growth.
(b) It should provide a high filtration effect.
(c) It should maintain high hydraulic conductivity flow.

Further, with regard to the internal hydraulics, it is important to have suitable incoming and outgoing structures for the bed to ensure suitable distribution and collection of flow and utilization of the area provided in the bed. This standard has been reported in the literature on wetlands. The percentile efficiency increases with inflow concentrations and nothing else. The design was planned for total discharge into the wetland of 1200 m^3 day^{-1}, which was the volume entering one of the treatment plants in the campus.

5. *Pretreatment chambers:* Pretreatment chambers are basins that can hold 10% of the total influent volume. These are provided to hold the initial inflow and let it into the treatment cells [33]. Hence, the basin volume was 120 m^3.
6. *Treatment cells:* These were designed to hold 45% of the volume in each of the two cells above ground. Thus, each treatment cell could hold 540 m^3 of influent. The travel distance through the gravel was designed to be a minimum of 4.6 m. The minimum aspect ratio (length to width) was ≥ 2. Taking an influent depth above ground of 0.3 m, the surface area of each cell was 1800 m^2. Assuming an aspect ratio of 2:1, each cell was 60 m long and 30 m wide.
7. *Media:* The top layer was 30 cm of local wetland soil in which the wetland plants would grow. The second layer was 60 cm of 0.75-inch crushed stone. In this type of design, a compact soil liner or high-density polyethylene (HDPE) liner is used at the bottom if the permeability of the underlying soil is more than 10 cm day^{-1}.

8. *Additional design details:* The primary outlet invert was located about 10 cm below the elevation of the wetland soil surface and was used to control the groundwater elevation. The minimum space between the distribution line and the collection drain at the subsurface level of the gravel in each treatment cell was 4.6 m. Slots were provided to deliver water from the surface to the subsurface. These risers had a maximum spacing of 4.6 m. The minimum diameter of the central riser was 30 cm, and that of the end risers was 15 cm.

In this combined horizontal and vertical flow wetland unit, eight holes were made in every baffle (Fig. 3). In this type the plants were kept in the center of the chamber. To avoid the possibility of backflow, a slope arrangement from the inlet to the outlet was used. The plants were grown in a two-layer medium of sand and gravel in one case, and in sand in hollow polyethylene tubes embedded in gravel in the other.

2.4 Sampling and Analysis

The wastewater was subjected to primary treatment (skimming and primary sedimentation) prior to being let into the constructed wetland. A design in discharge of wastewater was let into the input chamber. The wastewater was allowed to stay in the wetland chamber for the planned HRT corresponding to the unit's capacity, after which it exited to the outlet chamber.

The samples were tested for TSS, COD, BOD, TN, and TP, mainly because the study was focused on domestic and institutional wastewater, in which organic content is predominant. Samples were collected at both the inlet and the outlet. These samples were collected at 24, 48, 72, 96, 144, and 192 h, in the morning. Twelve samples were collected at each inlet and outlet over a course of 12 months from March 2012 to April 2013. The samples were analyzed for TSS, COD, BOD, TN, and TP, using methods for examining water pollution and purification [34].

The observations and analytical findings provided information on the constructed wetland and its use. Treatment efficiency was calculated as the percentage difference between the inlet and outlet concentrations. Statistical analyses were performed on the observations to assess the effects of the different treatment methods, different species, and different media [35].

Construction of a wetland in nearby Panchayat Village: Once it was proved that the wetland plants were able to treat campus wastewater efficiently, a final experimental unit was built to accommodate a mixture of campus and community wastewater on the outskirts of the campus [36]. The procedures used earlier were followed in this unit too. After establishment of the plants, mixed wastewater was let into the unit and subjected to treatment, and the results were analyzed.

3 Results and Discussion

Influent characteristics: The influent that flowed into the initially constructed wetland units was taken from a primary sedimentation tank, where wastewater from nine different areas was collected for treatment. The influent to the wetland units was also taken from the same, so that there would be no discrepancies in the characteristics of the wastewater. The characteristics of the influent were observed in different months, as reported in Fig. 4. The parameters of the influent fell within normal domestic wastewater limits. No striking trends or variations were seen that were due either to seasonality or to the population. The absence of a trend may also have been due to the limited number of samples that were taken; daily samples might have given a better indication of any variations, but such a detailed analysis would have been difficult to perform in this study [14, 37].

Preliminary tests conducted on the two control units (with the vertical and horizontal flows) using gravel and the (hollow tubes + sand) mixture indicated that the horizontal flow unit had a very short HRT for both media. The vertical flow with hollow tubes performed better than the other tests like horizontal flow types. It was thus decided to opt for integrated flow by using a series of perforated baffles, as shown in Fig. 3a. Two units were filled with gravel + sand + soil (GS), while the

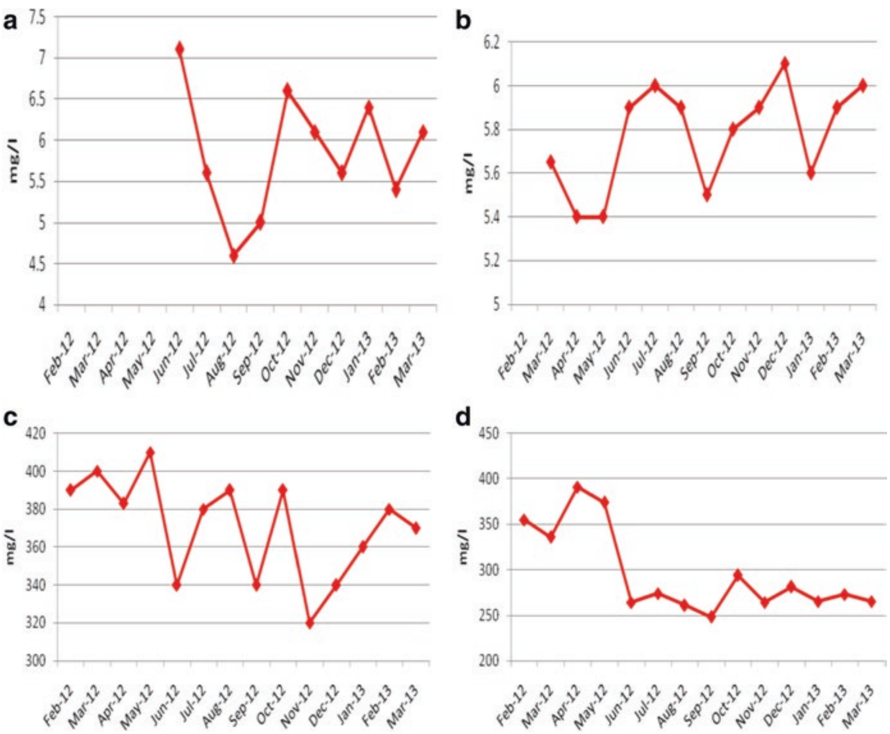

Fig. 4 (**a**) Total phosphorus (TP), (**b**) total nitrogen (TN), (**c**) chemical oxygen demand (COD), and (**d**) biological oxygen demand (BOD) variations in the influent during treatment

other two were filled with gravel + (sand + hollow tubes) + soil (GPS) [38]. The average percentage reductions in TP, TN, COD, and BOD achieved in the six units after 2 days of HRT are shown in Fig. 4. It was clear that the integrated wetland units performed better than the units with purely horizontal or purely vertical flows [39]. The *Typha* GS unit had low efficiency at the start of the treatment. As shown in Fig. 5, it was also clear that addition of hollow plastic tubes to the sand layer increased the treatment efficiency in both units, especially with regard to the inorganic constituents.

A final set of experiments was performed, using only the *Phragmites australis* GPS and *Typha latifolia* GPS units with integrated flow. These tests were done to assess the importance of the wastewater retention time in the wetland units. The HRTs that were used were 1, 2, 3, 4, 6, and 8 days, and the treated wastewater from the two units was tested. Although the plastic tubes had no significant effect on the treatment, the designs of the units were retained as such, as removing them would have led to loss of time for filling up and replanting the units. This was considered acceptable, as the percentage reductions achieved in the units were not impaired by the presence of the plastic tubes [40–42]. The average percentage reductions in the individual constituents TP, TN, COD, and BOD with HRTs of 24, 48, 72, 96, 144, and 192 h (corresponding to 1, 2, 3, 4, 6, and 8 days) are shown in Fig. 6.

Good reductions in all constituents were achieved by day 8 of the HRT: around 80% for the inorganic constituents and close to 90% for the organic constituents. Also, *Typha* seemed to perform marginally better than *Phragmites*, but the difference did not reach statistical significance [23, 41]. The performance of the wetland units as the plants matured can be observed by looking at the monthly reductions in the constituents shown in Fig. 7.

It can be inferred from Fig. 7 that with both *Phragmites australis* and *Typha latifolia*, there was some variability in treatment with use of 96 h and 144 h HRTs. At 192 h, there was some stability in comparison with the other HRTs. There was greater variability with *Typha latifolia* than with *Phragmites australis*. This was

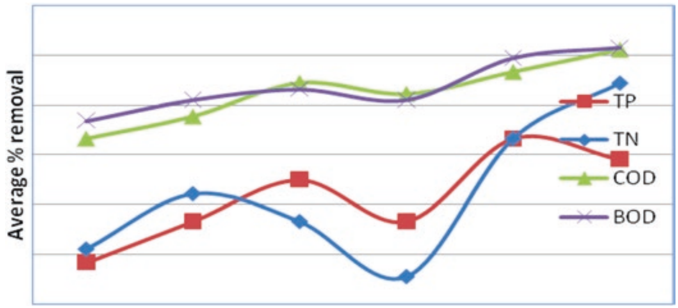

Fig. 5 Treatment efficiency in the test units. Control1 denotes purely horizontal flow; Control2 denotes purely vertical flow; *Phragmites australis* with gravel + sand and integrated flow; *Typha latifolia* with gravel + sand and integrated flow; *Phragmites australis* with gravel + hollow plastic tubes + sand and integrated flow; *Typha latifolia* with gravel + hollow plastic tubes + sand and integrated flow

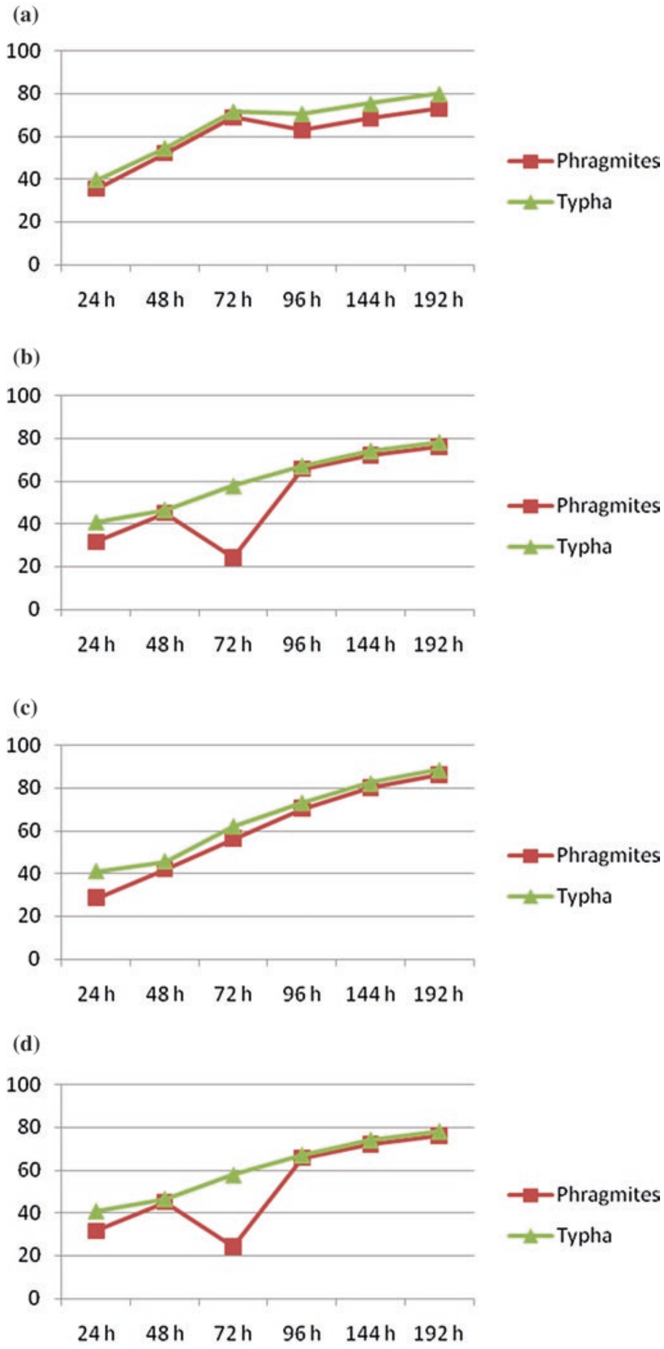

Fig. 6 Average percentage reductions in (**a**) total phosphorus (TP), (**b**) total nitrogen (TN), (**c**) chemical oxygen demand (COD), and (**d**) biological oxygen demand (BOD) with use of *Phragmites australis* and *Typha latifolia*, and with hydraulic retention times (HRTs) of 24, 48, 72, 96, 144, and 192 h

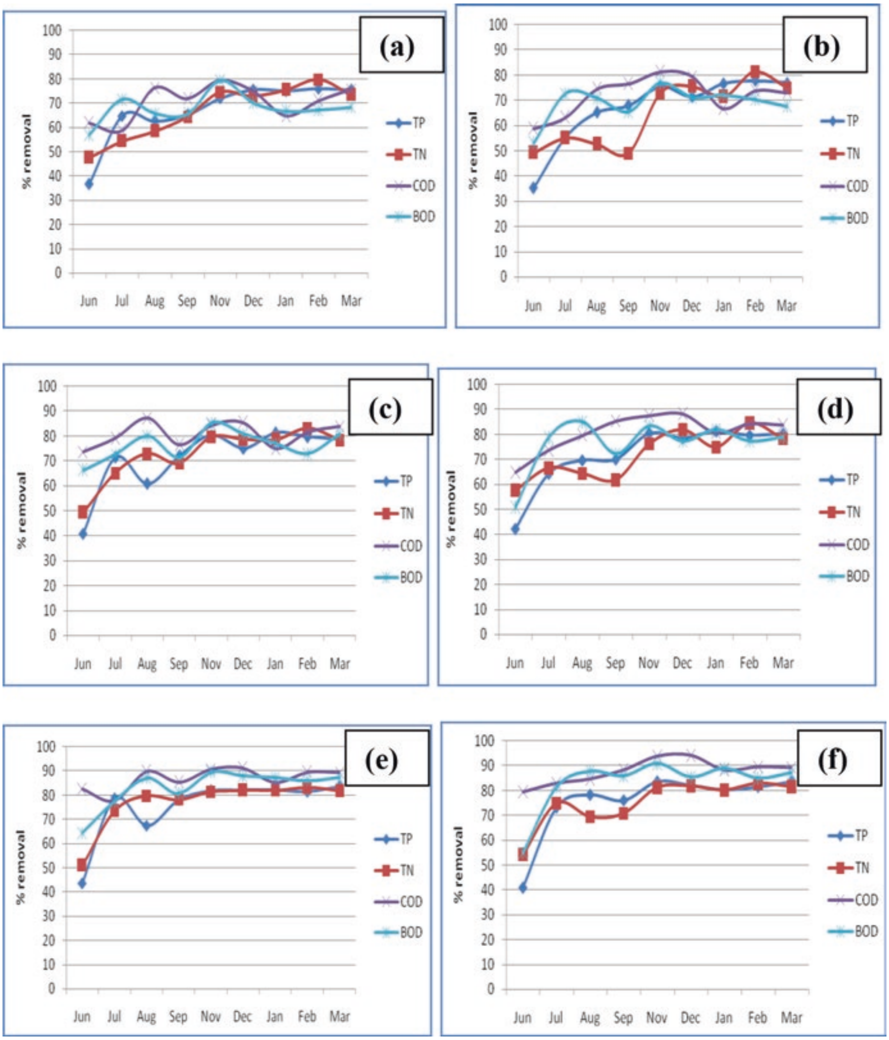

Fig. 7 Percentage reductions in total phosphorus (TP), total nitrogen (TN), chemical oxygen demand (COD), and biological oxygen demand (BOD) with use of *Phragmites australis*, measured at (**a**) 96 h, (**c**) 144 h, and (**e**) 192 h; and with use of *Typha latifolia*, measured at (**b**) 96 h and (**d**) 144 h. (**f**) Hydraulic retention times (HRTs) over an 8-month period

also proved by analyzing the variances in the measured constituents (Table 2). As can be seen in Table 2, there was greater variance with use of *Typha* than with use of *Phragmites australis*. This finding supports the concept that it is better to plant *Phragmites australis* than *Typha latifolia* in field conditions.

Test for normality: Monthly-averaged samples were tested for normality, using the MATLAB normplot function. The results are shown in Fig. 8. TN, BOD, and COD appeared to be normally distributed, with the sample results being distrib-

Table 2 Variances in percentage reductions in total phosphate (TP), total nitrogen (TN), chemical oxygen demand (COD), and biological oxygen demand (BOD)

HRT	Species	Variance in percentage reduction %			
		TP	TN	COD	BOD
96 h	*Phragmites*	158	124	51	36
	Typha	194	167	56	46
144 h	*Phragmites*	169	111	24	36
	Typha	160	91	57	105
192 h	*Phragmites*	168	104	20	64
	Typha	181	88	23	114

HRT hydraulic retention time

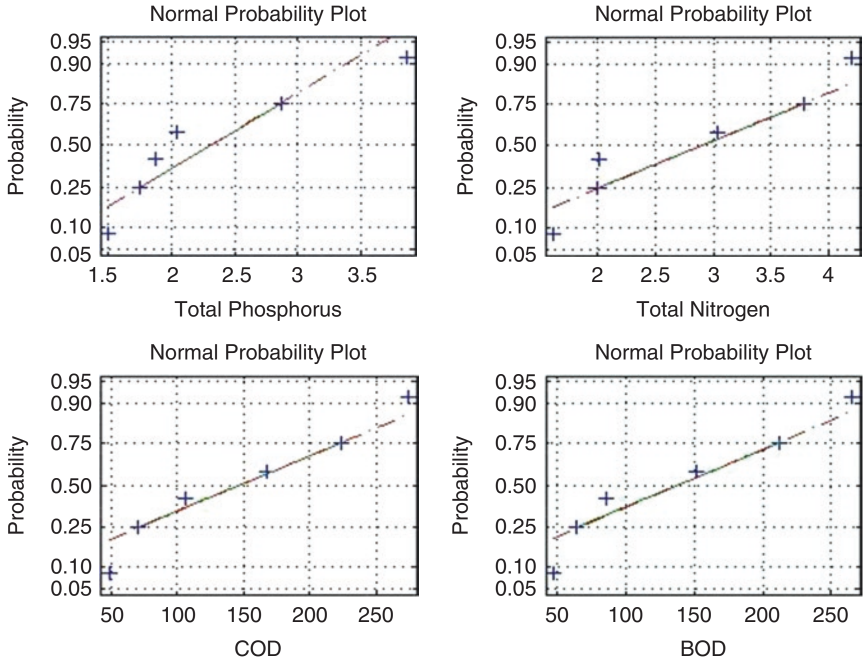

Fig. 8 Testing for normality of the samples

uted in almost straight lines. The TP results were not fully normally distributed but could be taken to be approximately normally distributed [33].

Multicomparison: The MATLAB multicomparison routine was implemented to check the results that were obtained. The results regarding the differences in use of various HRTs with *Phragmites australis* and *Typha latifolia* for both organics (BOD and COD) and inorganics (TP and TN) are shown in Fig. 9. The blue, green, and red colors indicate the results at 192 h, 144 h, and 96 h (8, 6, and 4 days), respectively.

Figure 9a and b indicate that with both plant species, there was a clear difference in treatment between 96 h and 192 h for the contaminants TP and TN [1, 42]. Thus, the importance of a longer HRT for efficient treatment of TP and TN was validated by this test.

Figure 9c and d indicate that with both plant species, there was a clear difference in treatment between 96 and 192 h for the contaminants BOD and COD, but there were no differences between 96 and 144 h and no differences between 144 and 192 h. Hence, for treatment of organic constituents, an HRT of 144 h (6 days) was deemed sufficient. This was consistent with findings from earlier studies [13]. The difference between *Phragmites australis* and *Typha latifolia* in terms of treatment of the various constituents was analyzed and is shown in Fig. 10. These findings clearly indicated that there was practically no difference in treatment between *Phragmites* and *Typha* for treatment of any of the constituents that were considered.

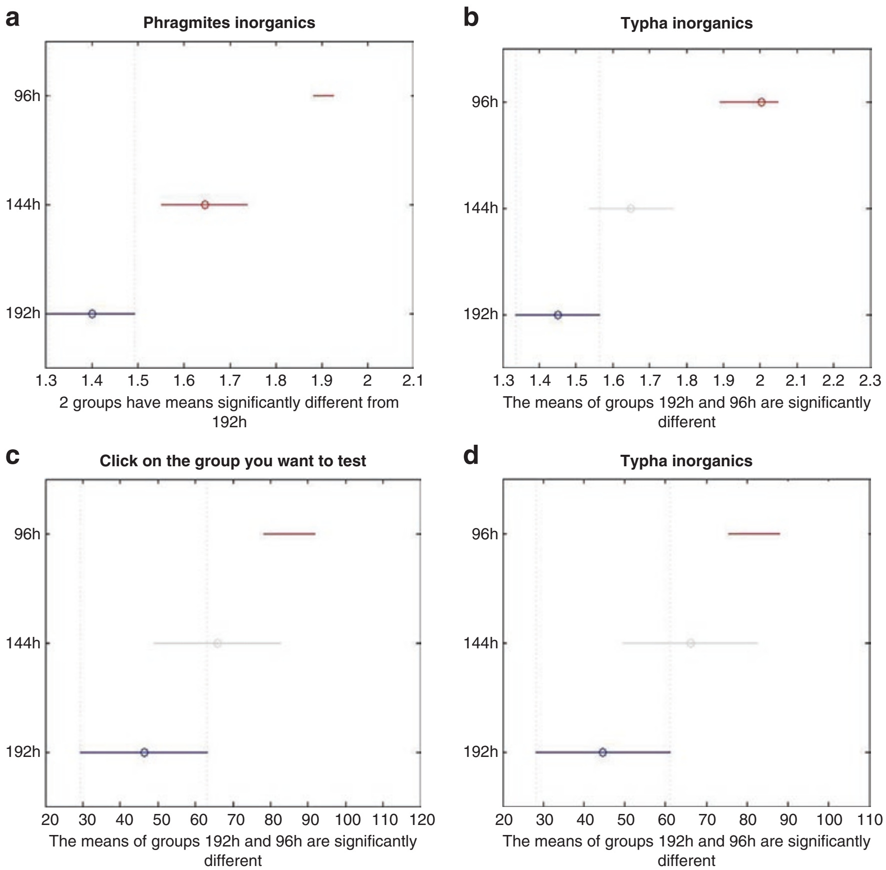

Fig. 9 Effects of hydraulic retention time (HRT) differences on reductions in (**a**) total phosphorus (TP), (**b**) total nitrogen (TN), (**c**) biological oxygen demand (BOD), and (**d**) chemical oxygen demand (COD) with use of *Phragmites australis* and *Typha latifolia*

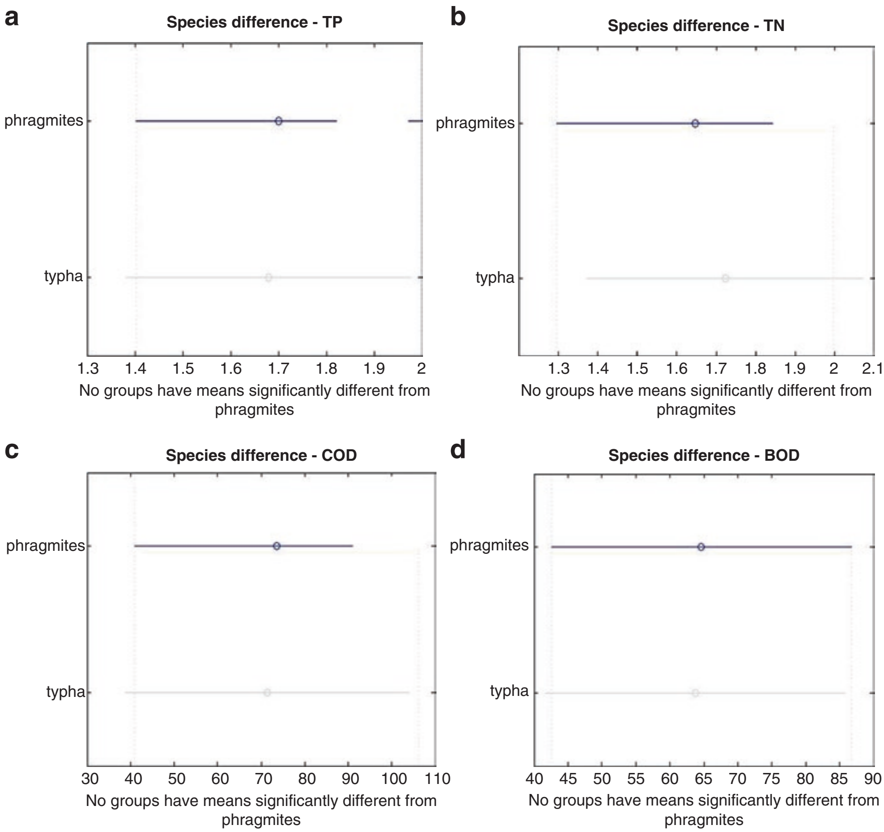

Fig. 10 Differences in reductions in (**a**) total nitrogen (TN), (**b**) total phosphorus (TP), (**c**) chemical oxygen demand (COD), and (**d**) biological oxygen demand (BOD) with use of *Phragmites australis* and *Typha latifolia*

A multicomparison test of the long-term impact did not show any difference in treatment over the months, with the exception of the first month. However, this result cannot be taken as significant, because of the smaller number of data points involved.

Implementation of wetland treatment for community wastewater: One of the objectives of this project was to replicate the treatment in a field situation. A wetland unit was built near the outlet of pipes carrying a mixture of campus and community wastewater. This unit was built for partial capacity only, as the total cost for complete treatment exceeded the budget allowed for year 3 of the project. The unit was planted with *Phragmites australis* because it was easier to maintain than *Typha latifolia* and had achieved good results in the earlier experiments [19, 40]. The results are shown in Table 3.

Table 3 Percentage reductions in total phosphate (TP), total nitrogen (TN), chemical oxygen demand (COD), and biological oxygen demand (BOD) achieved with use of different hydraulic retention times (HRTs)

	Reduction (%)			
HRT	TP	TN	COD	BOD
24 h	28.83	30.32	24.13	18.80
48 h	41.67	40.56	40.75	35.54
72 h	60.00	55.02	55.78	55.71
96 h	60.42	59.81	70.24	67.47
144 h	65.89	67.15	78.23	75.39
192 h	71.35	71.74	86.69	82.17

This wetland unit exhibited treatment results similar to those seen in the previous experiments.

4 Conclusions

It was proved conclusively in this work that both *Typha latifolia* and *Phragmites australis*, which are local wetland plants, are capable of treating domestic wastewater successfully to within standard discharge limits. Although *Typha latifolia* achieved marginally greater percentage reductions in the specified wastewater constituents, the differences were not statistically significant. Moreover, it was difficult to maintain the growth of *Typha latifolia*, as it requires continuous standing water. Hence, we concluded that it was better to use *Phragmites australis* instead, which needs only a wetted surface to survive. An HRT of 8 days was sufficient to treat the wastewater to within the required limits. The reductions in inorganic constituents were greater at 8 days, whereas the organic constituents required an HRT of only 6 days. The same degree of treatment could be achieved in a larger unit with a shorter HRT because of the longer distance provided for the flow.

Integrated flow units (with provision of baffles) perform better than purely horizontal or vertical flow units. The inclusion of hollow plastic tubes did not affect the performance of the units; the smooth surfaces of the tubes probably did not provide a suitable surface area for bacterial communities to adhere to. It is possible to exhaustively design a constructed wetland unit by using established design standards. The Tennessee Valley Authority (TVA) method is suited to the design of small units, and the UNHSC specification gives reasonable sizes for typical wastewater inflows. A recent study on a constructed wetland revealed that it could be used for industrial wastewater treatment and was capable of treating inorganic wastewater too. Some research studies have highlighted that constructed wetlands can also treat persistent organic pollutants (POP) and the presence of *Escherichia coli* bacteria in the wastewater.

Scope for Future Work

Instead of hollow plastic tubes, coarse materials could be added to the sand matrix. This might provide better adherent surfaces for bacterial communities. One option would be to use broken coconut shells. Being biological in origin and abundantly available in India, this material could work well for both adhesion and absorption. This possibility needs to be studied further. Natural coarse fibers could also be added and tested to ascertain whether they would improve treatment efficiency. Artificial inclusion of microbial communities might also help to improve treatment of wastewater.

In our study, it was not possible to test the units for continuous flow, because the wastewater reached the outer end of the unit within a few minutes as a result of the small length of the units. Now that wetlands have been shown to be capable of wastewater treatment equivalent to that achieved by a conventional treatment plant, a single unit of larger size could be tested with continuous flow to assess its performance.

At the very least, a study focusing on the role of microorganisms in treatment of wastewater in a wetland unit is needed. If such a study were carried out, it would improve understanding of the exact roles of substrates, plants, and microorganisms in a wetland unit. A mass balance study in a constructed wetland unit is also needed to extend our recent research. Moreover, a study on the role of constructed wetlands in treating wastewater contaminated with COVID-19 could improve understanding of the role of wetland plants in treating pathogenic impurities.

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Index

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