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Sagaya Aurelia
Sara Paiva *Editors*

Immersive Technology in Smart Cities

Augmented and Virtual Reality in IoT

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This humble work is dedicated to
the one who was with us
carried us,
guided us
and
led us
throughout this publication journey
the Almighty God of Supremacy!

Sagaya Aurelia
Sara Paiva

Preface

Immersive technologies refer to any technology that outspreads, matches and reinvents the reality we go through by the amalgamation of the virtual and physical worlds and offer a complete immersive involvement. These technologies are presently becoming mandatory and take the technological spectrum to the next level when implemented and used especially in smart cities. Immersive technologies play a vital role in smart cities based on the usage, application and human involvement.

Chapter 1 discusses augmented reality with mixed reality, and virtual reality integrates digital information with digital real-world objects and puts the student in a virtual world. It gives a shared understanding of the current and future applications of immersive technology in the education sector. Chapter 2 focuses on the field of education where internal combustion engine (IC engine) is considered. Using AR application, the learner will be able to have a 3D view of all the parts of the IC engine and interactively acquire a detailed knowledge about it with visual and audio information given with a real environment interaction. Chapter 3 presents a systematic review of Location-based Mobile Augmented Reality (LBMAR) system and outlines research issues that require more investigation. Chapter 4 explains in detail human-computer interaction (HCI), virtual reality (VR), various natural disasters, and the role and impact of VR environment in creating awareness and providing precautionary measures for preventing natural disasters. Chapter 5 discusses various technologies of IoT in health care and their numerous applications in the medical field. It also introduces the involvement of augmented reality that is acquiring a new dimension in the Internet of Things.

Chapter 6 addresses the implementation of a QMS that helps to correctly manage the information and knowledge that the organization obtains and generates to put in value and improve the services received by the citizen, reducing both salary costs and training of personnel. Chapter 7 proposes a framework of the computing and clustering mechanism that suits for the creation of the smart city application. Chapter 8 demonstrates the need for smart cities in our lives, the technologies available that support the applications needed for a smart city, aspects of the smart application for smart cities and the barriers to the transformation programme. Chapter 9 provides a survey of the IoT applications in smart cities and the analysed study is elaborated. Chapter 10 proposes the water quality and distribution monitoring system using IoT. This proposed system with Internet of Things together with the sensors for governing the quality and quantity of water improves the quality of water supplied and also avoids its wastage. Chapter 11 covers the real-time security tools and techniques to attack the IoT devices to defend against them by building a holistic view of the aggregated analytics layer.

This edited book mainly deals with the core ideas and application of immersive technologies in smart cities for various domains in detail, which is one of the main highlights of this book. Since it is an interdisciplinary book, we anticipate it will be beneficial to an extensive diversity of readers and will afford useful information to professors, researchers and students.

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"Every good and perfect gift is from above".

Above all, I concede my greatest educator of all and foundation of Wisdom, God Almighty, for all of His showers of blessings, strength and valour throughout this whole process.

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Sagaya Aurelia
Sara Paiva

Contents

Chapter 1
Exploring Immersive Technology in Education for Smart Cities

Jasmine Beulah Gnanadurai, S. Thirumurugan, and V. Vinothina

1.1 Introduction

Education is the foundation of our economic future. It is also the foundation for development for the initial economic and social well-being of any individual, and also the key to increasing economic and social consistency. 'Who we are and who we become, today, depends on what and how we learnt in school'. It becomes more important to provide the next generation with an excellent education to develop them as innovators and creative thinkers. In order to serve the students in a better way of teaching and igniting the passion for learning, the various teaching methodologies were introduced.

The effect of massive changes by technologies has been felt in many sectors including the education sector. Immersive technologies opened up new ways of learning with its ability to accelerate learning engagement and facilitate knowledge retention across various industries and applications. The success of educational outcomes depends on the digital technologies that they carried out so far in various disciplines and its ability to attract the learning towards them. When children are placed in supportive learning environments, the idea of justification can come naturally to them [1]. The observations and insights of the learners of such supporting environments with immersive technologies keep them stay focused and boost concentration on the learning. Immersive technologies are the right medium that helps the educational institutions to give the right directions to the students so that they can understand and imagine the things the way they wanted to teach. The rise of advanced digital technologies such as augmented reality (AR), virtual reality (VR),

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artificial intelligence (AR), cloud computing, immersive learning come into existence and it is undergoing a tectonic shift in terms of learning. Augmented reality is an enhanced system of reality that overlays virtual objects and information with the real-time environment. A new artificial environment will be made with some added information in the existing real environment. With the enhanced interaction with reality, this augmented reality technology has been used in various fields such as healthcare, entertainment and gaming, education, sales, design and modelling, military. It has become very popular among the software and hardware developers for building augmented reality applications.

Smart cities use various intelligent solutions to optimize infrastructure, with the engagement of citizens in managing the city. With the increased digital equity in smart cities, the AR technology has the potential to boost the effectiveness in many areas of education. Smart cities need education facilities and school systems which ensure student to acquire twenty-first–century skills, including digital literacy, creative thinking, effective communication, teamwork, and the ability to create high-quality projects. Most of the schools in smart cities are 'behind the curve' when it comes to technology adoption and implementation. According to [2], AR had been supporting the teaching among various educational stages such as preschool, high school, and higher education. The adoption of AR in the new learning methodology is still challenging with the existing traditional learning methodologies, and the continuous changes in curriculum are more challenging in developing and maintaining of the education system with AR [3]. Predicts AR will have a strong influence on all levels of education through 2021 and its capabilities. The horizon report of 2020, generated by EDUCAUSE, focuses on trends, technologies, and practices shaping the future of teaching and learning based on the expertise of horizon panel leaders in higher education. According to EdTech, Jason Osborne, Chief Innovation officer of Ector County Independent School District (ECISD), Texas, immersive technologies can even help the students to choose the career path, with the knowledge base that they gained with the simulation of real-world connection.

The education sector is one of the top industries for VR and AR investments, according to the '2019 Augmented and Virtual Reality Survey Report' [4] by Perkins Coie and the XR Association. Smart cities use various intelligent solutions to optimize infrastructure, with the engagement of citizens in managing the city. With the increased digital equity in smart cities, the AR technology has the potential to boost the effectiveness in many areas of education. It is the safest place to learn by making mistakes, taking risks, and solving the problems.

1.1.1 How Does the Technology Fit and What Are the Benefits?

There is a potential transformation in the way that universities deliver the course content with immersive technologies that enables the students to access space and connect with experiences that might otherwise be unavailable to them. There are a lot of pedagogical benefits to the students in the way that the technology not only helps them to visualize complex concepts but also helps to create creativity in the classroom activities as well.

Virtual reality is an artificial computer-generated modern technology in education that creates a learning environment for the learner to understand complex scientific concepts with fun and ease. Virtual reality creates a new pedagogy to learn scientific theories where the role of the teacher is transformed from a deliverer of knowledge to facilitator and helps the students to explore, innovate, and learn [5]. The abstract concepts can be visualized and experienced in a 3D space environment [6]. Also, the students feel empowered and engaged as they become indulged in a constructivist learning behaviour and control their learning process [7]. Virtual reality helps to improve the learning objectives of low-spatial ability learners through visualization by lowering the extraneous cognitive load [8, 9]. The user will be able to understand the systems of different scales. The virtual reality charcoal mini-blast furnace application helps the user to know the working of the system and walk through the small units of the system [10]. The virtual reality study of human anatomy gives a better understanding of the size of different organs along with the relative position of other parts of the body and enables the student to have more understanding rather than memorizing the names of the organs [11]. There is a widespread use of virtual reality in risky and exceptional situations like practicing surgery techniques and understanding to use machine tools safely [6]. The simulated environment further provides the students to learn the hazardous cost of failure from failing to track procedures or exceeding design conditions without physical harm to equipment or loss of life [12].

Virtual world plays an important role in the design and testing where digital prototypes can be created, modified, and tested without the price and period required to create physical prototypes. The students can thus redefine and test their design quickly and economically before creating a physical version [13]. It is important to remember that immersive technology does not reduce the magnitude of the teacher's responsibility in terms of lesson planning and class teaching. The guidance of the teacher has become more significant when using the technology and in fact the teacher has typically transformed to coach and mentor.

The twenty-first century has reshaped the education through technology because it is well-liked by students and teachers. A research study in the US shows that with technology in education, 87% of students are more likely to attend classes and 72% of them are more likely to take part. Another study proclaims that 96% of the teachers think that there is a positive blow on the way that children get involved and learn their lessons. New Jersey Institute of Technology (NJIT) reports 'augmented reality has the potential to revolutionize learning in primary and secondary schools more than any other technology has done in the recent past'. When a student wants to study in an international university, the biggest problem in education is a language barrier. He has to learn and speak the foreign language. Virtual reality solves the problem in the education plan of the student by implementing all possible languages within the software.

Immersive technology in learning can take hold a learner's interest and stimulate learning better than other learning management systems like Massive Open Online Course (MOOC)), e-learning, micro-learning. The traditional learning cannot be replaced by the technology but can enhance learner's learning experience as well as improve the training competence. With the advent of immersive learning, the greatest strategy of important learning goals can be achieved. Also the technology builds an interactive environment and acts as a tool for the students to experience the most practical learning situations without having reality constraints like a real-time failure, risks, and logistics. Following is the overall summary of benefits of immersive technologies in education.

- Accessibility

- The accessibility of learning content from anywhere and anytime.
- Understandability
- Minimizing the time spent on understanding even complex subjects.
- Nurturing the Learning Process
- Students will be more excited to learn than the normal learning process.
- Robust Learning Cycle
- Helps students improve and retain knowledge over a period of time by the increased curiosity of students.
- Increased Sensory Development

- The mind and senses work together as the students see, observe, and feel at the time of learning.

1.2 Augmented Reality in Education

AR highly motivates the students in the improvement of learning with the increased interaction and engagement. It is possible to describe and exemplify complex concepts, and it can be explained by the interaction and visualization. AR can be used in all age groups and also in all levels of education. AR provides a new way of learning with the rich educational contents through visualization. It allows to learn practically and improves memory retention of students by the new learning style. It increases the interest and involvement of students in learning. It helps students to acquire information easily and remember it. It has become very popular among the software and hardware developers for building augmented reality applications.

1.2.1 Remote Collaborative Classrooms

Immersive technology is advanced enough to provide remote collaborative classrooms in which a large group of students can be gathered virtually. It offers a multitude of ways to enable students to attend classes without physically being present.

It facilitates deeper and better learning in the core competencies of education in today's unprecedented situation. Educational institutions are redefining themselves to engage students and faculty for rich learning experiences without the participation in a traditional classroom.

1.2.2 Safer Experiments and Demonstrations

Most of the lab experiments and demonstrations help the students to understand more. Many schools limit the scope of practical demonstrations for many reasons such as safety hazards, unavailability of knowledgeable and trained instructor, budget limitations. The number of experiments and demonstrations increases with the adoption of AR technology. It solves many of the learning and teaching challenges in laboratories, especially if the laboratories contain inherent dangers and hazards.

1.3 Immersive Technology in Four Cs of Learning

There is a dramatic change in the skill sets that are required for success, over the period of time because the vast growth in the digital technologies. Learning is one of the core skills in the twenty-first century to help students to succeed in today's world. With the involvement of immersive technology, students need to master the 4Cs of learning to be competitive enough in the twenty-first–century global society. The skills critical thinking and problem solving, creativity and innovation, collaboration and effective communication are considered as the most important among the various other learning skills. Critical thinking is an imperative skill that involves reasoning effectively, problem-solving, and sound decision-making. Each individual should have the strong theoretical understanding with the study of creativity and followed by the training with help of creative tools and utilities will facilitate the ability of creativity [14]. 'Innovation resembles mutation, the biological process that keeps species evolving, so they can better compete for survival' [15]. 'Individuals are likely to learn more when they learn with others than when they learn alone' [16]. Immersive collaboration allows students from different places of the world to come together in a spatial environment and interact with each other to share ideas, opinions, and thoughts. Teaching basic annotation practices help students become more active and effective learners [17]. With the virtual annotation in immersive learning increases active learning and interaction in a particular discipline.

1.3.1 Critical Thinking and Problem-Solving

Immersive technology plunges the students into the environment that simulate the physical world and influence them in problem-solving and critical thinking. Immersive learning helps students to strategize themselves before making any decisions and experience the consequences of the decisions they made with the instant results. Immersive technology experience speeds up the learner's proficiency in making good decisions in critical incidents.

Problem-solving skills help the students to identify the problem, propose various solutions, choose the right one, and implement the successful solution. Immersive technology delivers an organized approach to problem-solving and decision-making. Nowadays, educators can integrate critical thinking into the classroom by using immersive technologies as one of the innovative ways. Students of Ector County Independent School District, Texas, can go in and trace neurons and brain cell tissue in their virtual solution that they rolled out using immersive technologies. ECISD also added that when some of the students leave the high school, they leave with the experience as a postdoctoral research student and they can be driven to research as they have exposure to high-level sciences.

1.3.2 Creativity and Innovation

Adding creativity to the learning process is important to design new products and innovate new products from the existing ones. Immersive technology presents promising opportunities in the creative economy. Creatives can use the immersive technologies to refine the content in a personalized and professional way and distribute it to a wider audience. Innovation in education involves a different way of looking at problems and solving them. It is actually allowing the imagination of students to flourish and try new things without any fear.

1.3.3 Collaboration

Immersive technology in education actually gives the students and teachers the real sense of presence in the classroom, no matter where they are in the world, and they can interact with each other even if they are not physically together, as if they are in a classroom. Also the interaction and involvement among the students will be more in the immersive learning, as they can annotate virtually on a specific learning activity. They can discuss together or in a small group as the annotations can be seen and read by others simultaneously.

Collaboration can promote conceptual understanding as students have the opportunity to share their ideas and make sense of various presentations or abstractions, and the true collaborative work is based on the each individual's goals and their capacity to choose among various alternatives and act on them without any constraints [17]. Students more likely to share representations, co-construct ideas and justifications during initial exploration on their learning activity with the limited role of teacher in the learning environment [1]. Collaborative learning is productive and it is not only assimilated others knowledge and practices and also produce their understanding [18]. Most of the learning happens during collaboration because of individual efforts with the contribution of all the individuals.

1.3.4 Effective Communication

Any communication is effective when the views that are presented by the sender in a way best understood by the receiver. It is the process of exchanging information, ideas, thoughts, and knowledge, such that the actual purpose of exchange is to be fulfilled in the best possible manner. As effective and quick communication with the streamlined collaboration is very much important for the current pandemic situations, immersive technologies give various opportunities to integrate the people and work together remotely. Digital platforms have enabled lots of creative approaches in communications.

Immersive technologies create an environment of communication where students can share their ideas and thoughts by exploring their creative and innovative side. The systematically framed contents and the proper flow of information make the learners disciplined and focussed on learning.

1.4 Applications of Immersive Technology in Education

In the centre of every aspect of modern society, technology has become entrenched in a great digital build out. From touch screens to real-life immersive experiences with virtual and augmented reality indicate a new way of learning, communicating, and collaborating across various institutions. Over the past two decades, rapid development in computing technology resulted in optimistic projections for the market opportunity and a growing list of applications in immersive technologies in campuses. The applications related to the education domain were explained in this section.

1.4.1 Engineering Education

To foster learning in engineering environments, effective self-directed learning-based education methods are deployed as engineering training simulators. The recognition of VR in this field has contributed to engage students in early design and thereby leading them to real-life industrial environment. Furthermore, it reduces the time and cost factor associated rather. Figure 1.1 shows the real engineering with its representation in VR.

In the discipline of Civil Engineering and Architecture, students are given support in the form of 3D didactic VR model for designing bridges and in various

Fig. 1.1 Real engineering labs with its representation in VR—Power Block, CRS Robotic Arm, Robotic Cell for Shoe-Sole Gluing, and Industrial Picking Robot

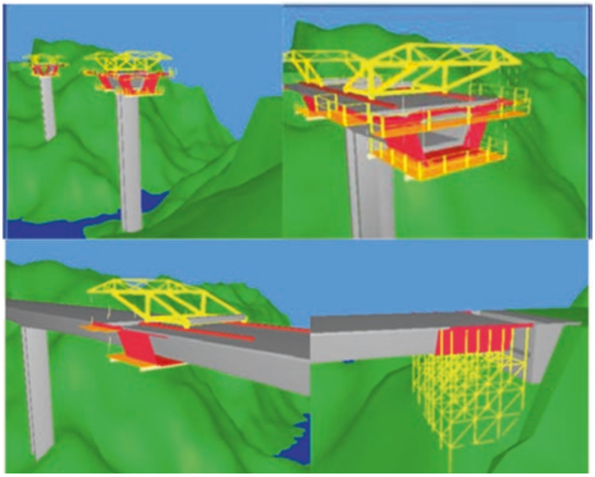

Fig. 1.2 Construction sequence of a bridge in Civil Engineering discipline

construction works. The model uses e-learning platform technology and supports class-based learning as well as distance training. Figure 1.2 shows the construction sequence of the bridge model and the student interacting with the virtual model.

1.4.2 Medical Education

Medical practitioners and clinical researchers have established that medical VR has great opportunities. Real-life scenarios assist physicians, nurses, and medical students and improve their quality of medical skills. Few VR medical, educational applications are depicted in the figure. The authors in [19] offer an interactive 3D real-time representation of heart structure which helps in understanding the complexity of heart structures. The model aims to clarify the students with true anatomical relations of parts of the heart in an interactive environment. Seo et al. in [20] have proposed a learning application to support canine anatomy education. The application aims to identify individual or group of bones. It also helps the students to assemble real skeleton of an animal in 3D space.

A 3D dental crown preparation training VR simulation system was proposed by Wang et al. [21] and was validated as a teaching tool for both Prosthodontics resident students and dental students. It allows students to have a realistic and interactive clinical environment. A time-sensitive and team-based guidance for VR-based training simulation system for advanced cardiac life support was presented in [22]. The system assisted the new clinical teams with clinical interventions during cardiac arrest and respiratory failures so that they can have an experience of saving the deceased life. A VR simulation system for students of nursing providing a hospital ward with avatars of demented patients along with their family members and hospital staff was presented in [23] with an intention to train them in a very realistic environment. To prevent post-surgical infection, an application to teach surgical hand preparation was developed in [24]. A realistic environment to acquire psychomotor skills was developed in [25]. To address novice ophthalmic surgeons in handling real-life cataract and vitreoretinal surgery VRmagic Eyesi Ophthalmic Surgical Simulator was developed to provide microsurgical spatial awareness and safe handling of the patient's eyes (Fig. 1.3).

Fig. 1.3 Screenshots of VR applications for medical education: a virtual reality heart anatomy system [19], Dental crown preparation training [21], Cardiac Life Support Training [25] and Anatomy Builder VR

1.4.3 Complex Concepts in Mathematics and Space Technology

VR resolves the complexity in tough courses. The authors in [26–28] have proposed that the understanding of geometry in mathematics can be made easier by the use of VR technology. An ED geometric construction tool, a collaborative augmented system, was proposed by Kaufmann et al. [29]. Astronomy and space technology have also been addressed by VR [30–32]. A dynamic 3D model of the solar system was developed by the authors in [33] where the learner operates the physical world in a virtual mode. Numerous tools were developed to showcase the space objects as the real world, and the tool provides an ability to travel in space and a unique learning experience is created.

1.4.4 General Education

VR may serve as a low-cost, easy-to-use user-friendly tool and resource [34–37]. There are a number of engaging projects that can be used in the classroom [38]. A great example is Google Expeditions, which allows the teacher to take an entire class on virtual trip. The application recreates an immersive experience of a real world with 360° video shots of different locations such as an underwater exploration of a coral reef in the South Pacific or the Louvre museum in Paris using Google Street View technology [39]. VEnvI (Virtual Environment Interactions) [40] is a visual programming tool that combines dance, computational thinking, and embodied interaction. The system was created for high school girls to increase the appliance of STEM fields. The application of VEnvI and the immersive, first-person interactions were carried out as an activity of a summer camp for middle school girls. The participants of the program (54 girls between the ages of 11 and 14) had to use computer science and programming concepts to program dance moves for avatars.

With the help of Oculus Rift HMD, the participants had the opportunity to be present with the virtual character they are programmed, have a first-person perspective of the choreographed performance, and make changes and correct mistakes. The use cases are shown in the Fig. 1.4. VRmagic Eyesi Ophthalmic Surgical Simulator was developed to provide microsurgical spatial awareness and safe handling of the patient's eyes.

The Covid-19 pandemic has changed the world to a new normal. The lockdown has provided an unprecedented platform to work virtually under some behavioural change. The pandemic has given rise to a new phenomenon of using tools like AR,

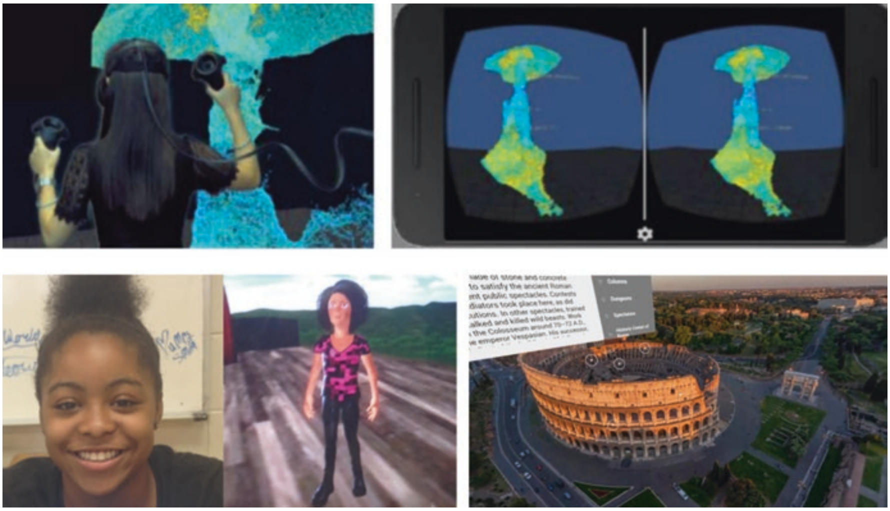

Fig. 1.4 Screenshots of VR applications for general education: Top: Thrihnukar experience in the HTC Vive [40]

VR, and mixed reality to learn, work, and shop. This behavioural change will last longer even after the lockdown ends, and the immersive platforms and technologies will allow online businesses to grow. To alleviate student's concerns, schools and colleges are likely to adopt technology that makes it possible for the students to innovate and learn through experiences. A system was developed to help primary students understand the concrete idea of the solar system with the immersive technology, which focuses on the learning outcome that each student should possess. With classrooms closed around the world, educators are moving towards online learning models. AstroSolar application helps students learn about the solar system in ways not possible otherwise. With access to the minutest details of the galaxy in 3D, the student's learning is not limited to 2D textbook illustrations.

1.5 Research Method

AR is a tool that can help students transform their immediate surroundings into learning spaces. Visualization, annotation, and story-telling are integrated through AR, and the outside world was brought in indoor spaces. An AR-based AstroSolar application was developed to help primary children enhance their learning skills and productivity by integrating digital information with the physical environment. The objective of the application was to evaluate and identify the user satisfaction of the school-going children at home using the AstroSolar application during the global pandemic.

1.5.1 Research Design

This study employed a mixed type of methods to collect and evaluate data. The reliability and validity of research depend on the way to collect data, measure, analyze, and interpret the data. Based on the problem statement, the required data will be collected through observations, interviews, and questionnaires. The data have to be collected from the users of the application. The data will be evaluated and analyzed using SUS. To gain insight into the views of the subject experts regarding the use of AR in AstroSolar, a short online interview using Google Forms was created. Testing the prototype was performed with the students. The observation was recorded as a video, when the student uses the AstroSolar application. When the children found it difficult to answer the survey questions, subject experts and parents could help the students to answer the questionnaire.

1.5.2 Sample of Study

The participants in the study are school students. The population (*N*) is a group of 30 students from a larger population of a specific class of group schools in India from various cities. Some of the students are from smart cities with better infrastructure.

1.5.3 AstroSolar Application

The AstroSolar application is developed in VR technology with more emphasis on the solar system. The interface of the application developed is shown in the Fig. 1.5. There is an option to select the language to view the text in the respective languages. The combination of immersive and language translator improves the usability of the application.

The virtual journey through the solar system with the relevant information helps the students visualize the solar system with the immersive technologies. There are many interesting facts about the solar system that were shown at the respective planets during the journey. AstroSolar is fully accurate model of our solar system with most of the known planets, moving in their orbits. Students who study and understand the solar system through this application are like boarding a spaceship and visiting the planets one by one. These kinds of applications could render the objects that are hard to imagine and making it easier to grasp abstract and difficult content (Fig. 1.6).

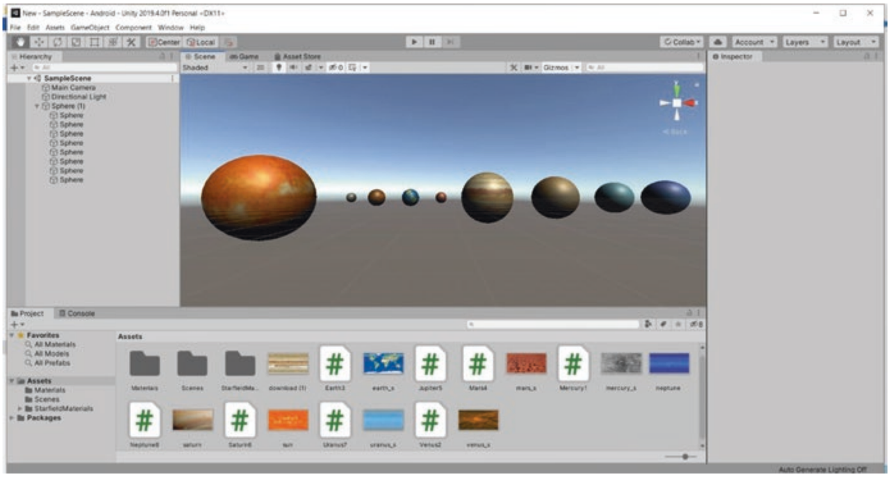

Fig. 1.5 AstroSolar application

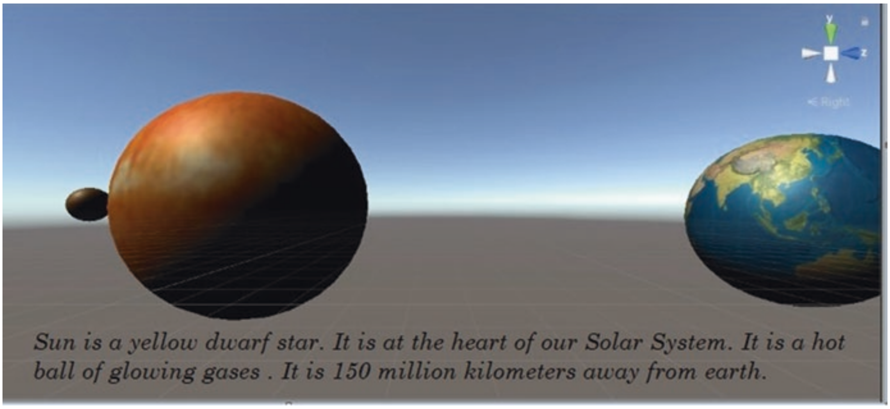

Fig. 1.6 AstroSolar application—with detailed information of each planet

1.5.4 Research Process

The research process was carried out in several steps. During the Covid-19 pandemic situation, where online teaching geared up across the globe, the AstroSolar application was introduced to the students in various cities and rural areas through webinars by the authors. Students from the various cities were allowed to use the applications, and they are provided with the steps for initial exploration. The objective of this research process is also to conduct the usability and understandability of students from smart cities, where the students have more facilities to learn through digital media.

1.5.5 Data Collection Utilities

The right technique of data collection is very important as the inaccurate and irrelevant data will impact the results of the study and it leads to invalid results. The three data collection techniques such as observation, interviews, and questionnaires were used as their suitability in evaluating the applications like AstroSolar. Interviews were conducted through the students through the Zoom app with the various questions given in Table 1.1. All the necessary and effective data were obtained through the interview process from each student even though reaching out to them individually is a time-consuming process. The various semi structured interview questions helped to explore the various factors related to background, infrastructure, usability, readability, etc. This method allowed for discovery of information that is more specific to students. The questions were correctly interpreted and understood by the respondents. Students were able to see the researcher and even can respond non-verbally. The Zoom, which is cost and time effective, is also very helpful in terms of data collection to reach out geographically remote participants.

SUS is a simple, widely used standardized questionnaire for the assessment of perceived usability in the foreseeable future. It is a ten-item scale with a degree of agreement or disagreement on five-point scale as a response. The students were asked to answer the SUS questionnaire based on their various experience with the application. The customized SUS questionnaire for the AstroSolar application is included in Table 1.2.

The questions 4 and 10 are related to learnability and all the remaining questions are related to usability. SUS provides the global measure of system satisfaction and subscales of usability and learnability. That means, we can track and report on the scales of the global SUS score as well as on subscales of usability and learnability (Table 1.3).

Table 1.1 Interview questions

SI no	Interview questions
1	How do you rate the AstroSolar application in AR?
2	Did the application meet your learning objective?
3	Does the application meet the manual procedure used to teach the solar system at school?
4	How do you think AR in online classes can help the students?
5	Are the basic devices suitable for students to access the AR application?
6	Is the present internet bandwidth enough to access the AstroSolar application?
7	How can the application be improved to enhance student's learning outcomes?
8	Does the student need to know a lot of things to access the application?
9	Is it necessary for a technical person to be around the student to use the system?
10	How likely would it be for you to recommend AstroSolar application to your friends?

Table 1.2 SUS questionnaire

Items	SUS questionnaire
Q1	I think I would like to use the AstroSolar application
Q2	I think the AstroSolar application is difficult to use
Q3	I think the AstroSolar application is easy to use
Q4	I required more technical assistance to use the AstroSolar application
Q5	I think the functionalities of the AstroSolar application are well integrated
Q6	I think the functionalities of the AstroSolar application are not organized
Q7	I think more users will be interested to use the AstroSolar application
Q8	I think most of users will have difficulties in learning, while using the AstroSolar application
Q9	I am confident when using the AstroSolar application
Q10	I may need to have more background on such technologies before I use the AstroSolar application

Table 1.3 SUS questionnaire—usability and learnability factor

Factors	Items									
Usability	Q1	Q2	Q3		Q5	Q6	Q7	Q8	Q9	
Learnability				Q4						Q10

1.6 Results

1.6.1 Expert's Interview

With the expert's interview, we can get great ideas that will be valuable to students. Their opinions are right when it is provided with scientific evidence. Their review can be thoroughly based on their experience and they can evaluate the contents, whether it will reach the students, and the teachers can use it as a teaching material. This gives a virtual trip through solar system to students. The student can explore the solar system in 3D virtual reality. Students are getting an immersive experience that takes them to the limits of our galaxy and beyond with informative documentary style. They can be able to fly through a fully accurate model of the solar system. These kinds of applications play an important role in sparking the interest in STEM objects as they bring a sense of fun and real connection to the science. It is difficult for teachers to teach such complex subjects without the right tools.

1.6.2 SUS Score

For each response for the item in the questionnaire ranging from 'strongly disagree' to 'strongly agree' on a point scale 1–5. The score contribution of each item Q1, Q2, Q3, etc., will range from 0 to 4. The score contribution of the items Q1, Q3, Q5, Q7, and Q9 is the scale position minus 1. The score contribution of the items Q2, Q4, Q6, Q8, and Q10 is 5 minus the scale position. The sum of each score from Q1 to Q10 of the respondents, multiplied by 2.5 to get the overall value of SUS score of each participant. The maximum value of the SUS score is 100. The calculated value of SUS score is shown in Table 1.4 along with Mean, Median, Mode, and Standard Deviation of each respondent's score. According to Sauro [40], SUS score above 68 would be considered above average. The average of the calculated SUS score for the 30 respondents is above 75.2 as in Table 1.4. There are four respondents who scored the below average SUS score 68. These are the students from non-smart cities in which certain factors influenced their dissatisfaction. The overall SUS score shows clearly that most of the participants were satisfied with the application and its usability. The single SUS score of each respondent estimates the overall usability of the application.

1.6.3 Usability and Learnability Factor

The usability can be the perceived 'ease of use', 'user-friendliness', or 'quality of use' of a system, interface, or product [41]. The usability of any application depends.

on its ability of users to achieve their objectives with efficiency, satisfaction, and effectiveness. The mean of subscale SUS score of the usability and learnability is 3 and 3.10, respectively as in Table 1.5. The usability involves the items Q1, Q2, Q3, Q5, Q6, Q7, Q8, and Q9 and its mean value is 3.0 and it is given in Table 1.6. The learnability involves the remaining items Q4 and Q10 and its mean value is 3.10 and it is given in Table 1.7. Both these values indicate both the usability and learnability are consistent among all the participants. Also, we can conclude the users of the application are positive in terms of their usability and learnability.

1.6.4 Feedback on Positive and Negative SUS Questionnaire

The items Q1, Q3, Q5, Q7, and Q9 are positively worded questions and its mean value is calculated and it is given in Table 1.7. The mean SUS score of positive questions is 2.97. The even numbered items Q2, Q4, Q6, Q8, and Q10 are negatively worded questions and its mean value is calculated and it is also given in Table 1.8. The mean SUS score of negative questions is 3.06. Here strongly disagreeing in a negative question is equivalent to strong agreeing with the positive question. The usage of both the positive and negative questions in the questionnaire increased the complexity. To keep the both scores of positive and negative questions in line, the scores were converted into the range of 0–4. When we analyze the SUS score of both the positive and negative questions individually, the mean value of negative questions is higher than the positive one (Table 1.9). The perceived usability and

Table 1.4 SUS score

Respondent	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Mean	Median	Mode	Std.Dev	SUS score
R01	3	4	3	4	3	3	4	4	3	4	3.5	3.5	3	0.53	87.5
R02	3	2	4	2	4	3	3	4	4	3	3.2	3	3	0.79	80
R03	3	3	3	2	1	2	4	4	3	3	2.8	3	3	0.92	70
R04	1	2	4	2	4	3	2	2	3	0	2.3	2	2	1.25	57.5
R05	1	3	4	3	2	4	4	2	4	2	2.9	3	4	1.1	72.5
R06	4	3	3	2	1	3	3	4	1	4	2.8	3	3	1.14	70
R07	3	2	2	1	3	3	1	3	2	3	2.3	2.5	3	0.82	57.5
R08	2	1	3	3	1	4	2	3	1	4	2.4	2.5	1	1.17	60
R09	1	3	4	2	2	2	3	2	4	3	2.6	2.5	2	0.97	65
R10	2	4	3	4	3	2	4	3	3	4	3.2	3	4	0.79	80
R11	3	2	3	4	4	1	2	3	4	4	3	3	4	1.05	75
R12	3	4	3	2	3	4	2	3	3	4	3.1	3	3	0.74	77.5
R13	3	4	4	2	3	4	3	4	2	3	3.2	3	3	0.79	80
R14	3	2	4	3	4	3	2	4	4	3	3.2	3	3	0.79	80
R15	4	3	4	4	3	4	3	3	4	4	3.6	4	4	0.52	90
R16	1	3	2	3	4	4	3	4	3	4	3.1	3	3	0.99	77.5
R17	3	2	4	2	4	1	4	2	3	4	2.9	3	4	1.1	72.5
R18	1	2	3	4	4	3	2	4	3	3	2.9	3	3	0.99	72.5
R19	2	4	4	2	4	3	4	3	2	4	3.2	3.5	4	0.92	80
R20	4	2	3	4	3	3	2	4	4	2	3.1	3	4	0.88	77.5
R21	4	3	4	3	4	2	3	4	3	3	3.3	3	3	0.67	82.5
R22	3	4	3	4	4	3	2	3	4	4	3.4	3.5	4	0.7	85
R23	4	3	4	4	3	2	4	3	4	3	3.4	3.5	4	0.7	85
R24	3	2	4	3	2	3	2	3	4	2	2.8	3	3	0.79	70
R25	3	2	4	3	4	4	1	3	4	3	3.1	3	3	0.99	77.5

(continued)

Table 1.4 (continued)

Respondent	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Mean	Median	Mode	Std.Dev	SUS score
R26	4	4	4	3	2	4	1	4	3	4	3.3	4	4	1.06	82.5
R27	2	3	1	4	2	3	3	4	3	4	2.9	3	3	0.99	72.5
R28	4	2	4	3	3	4	4	3	3	4	3.4	3.5	4	0.7	85
R29	0	2	3	3	4	3	2	3	4	4	2.8	3	3	1.23	70
R30	2	4	3	2	1	4	4	3	2	3	2.8	3	2	1.03	70
Average	2.6	2.8	3.4	2.9	3	3	2.8	3.3	3.1	3.3	3.02	3.07	3.2	0.9	75.42

Table 1.5 Usability and learnability—SUS score

Factor	*N*	Mean	Median
Usability	30	3.00	3.12
Learnability	30	3.10	3.10

Table 1.6 SUS score—usability

Respondent	Q1	Q2	Q3	Q5	Q6	Q7	Q8	Q9	Mean	Median	Mode
R01	3	4	3	3	3	4	4	3	3.375	3	3
R02	3	2	4	4	3	3	4	4	3.375	3.5	4
R03	3	3	3	1	2	4	4	3	2.875	3	3
R04	1	2	4	4	3	2	2	3	2.625	2.5	2
R05	1	3	4	2	4	4	2	4	3	3.5	4
R06	4	3	3	1	3	3	4	1	2.75	3	3
R07	3	2	2	3	3	1	3	2	2.375	2.5	3
R08	2	1	3	1	4	2	3	1	2.125	2	1
R09	1	3	4	2	2	3	2	4	2.625	2.5	2
R10	2	4	3	3	2	4	3	3	3	3	3
R11	3	2	3	4	1	2	3	4	2.75	3	3
R12	3	4	3	3	4	2	3	3	3.125	3	3
R13	3	4	4	3	4	3	4	2	3.375	3.5	4
R14	3	2	4	4	3	2	4	4	3.25	3.5	4
R15	4	3	4	3	4	3	3	4	3.5	3.5	4
R16	1	3	2	4	4	3	4	3	3	3	3
R17	3	2	4	4	1	4	2	3	2.875	3	4
R18	1	2	3	4	3	2	4	3	2.75	3	3
R19	2	4	4	4	3	4	3	2	3.25	3.5	4
R20	4	2	3	3	3	2	4	4	3.125	3	4
R21	4	3	4	4	2	3	4	3	3.375	3.5	4
R22	3	4	3	4	3	2	3	4	3.25	3	3
R23	4	3	4	3	2	4	3	4	3.375	3.5	4
R24	3	2	4	2	3	2	3	4	2.875	3	3
R25	3	2	4	4	4	1	3	4	3.125	3.5	4
R26	4	4	4	2	4	1	4	3	3.25	4	4
R27	2	3	1	2	3	3	4	3	2.625	3	3
R28	4	2	4	3	4	4	3	3	3.375	3.5	4
R29	0	2	3	4	3	2	3	4	2.625	3	3
R30	2	4	3	1	4	4	3	2	2.875	3	4

learnability is good in overall SUS score but not in the individual scores. As per the respondents list, this score indicates that the positive opinion of users from smart cities is higher than the users of non-smart cities.

Table 1.7 SUS score—learnability

Respondent	Q4	Q10	Mean	Median
R01	4	4	4	4
R02	2	3	2.5	2.5
R03	2	3	2.5	2.5
R04	2	0	1	1
R05	3	2	2.5	2.5
R06	2	4	3	3
R07	1	3	2	2
R08	3	4	3.5	3.5
R09	2	3	2.5	2.5
R10	4	4	4	4
R11	4	4	4	4
R12	2	4	3	3
R13	2	3	2.5	2.5
R14	3	3	3	3
R15	4	4	4	4
R16	3	4	3.5	3.5
R17	2	4	3	3
R18	4	3	3.5	3.5
R19	2	4	3	3
R20	4	2	3	3
R21	3	3	3	3
R22	4	4	4	4
R23	4	3	3.5	3.5
R24	3	2	2.5	2.5
R25	3	3	3	3
R26	3	4	3.5	3.5
R27	4	4	4	4
R28	3	4	3.5	3.5
R29	3	4	3.5	3.5
R30	2	3	2.5	2.5

1.7 Conclusion and Future Work

In this research study, SUS questionnaire and other data collection tools were used to analyze the student's satisfaction. The results of the test level satisfaction questionnaire reveal that the subject expert and the primary children show keen interest in using the AstroSolar application, and they were very much enthusiastic and satisfied with the application. The immersive technology used in this work helps in assisting the students by improving their learning knowledge along with innovation. Research hypotheses used in this study show that the subject experts are satisfied with the application based on the SUS score (SUS score > 68), as there are only four respondents recorded with SUS score below the average of 68. The total SUS score

Table 1.8 Positive questionnaire

Respondent	Q1	Q3	Q5	Q7	Q9	Mean	Median	Mode
R01	3	3	3	4	3	3.2	3	3
R02	3	4	4	3	4	3.6	4	4
R03	3	3	1	4	3	2.8	3	3
R04	1	4	4	2	3	2.8	3	4
R05	1	4	2	4	4	3	4	4
R06	4	3	1	3	1	2.4	3	3
R07	3	2	3	1	2	2.2	2	3
R08	2	3	1	2	1	1.8	2	2
R09	1	4	2	3	4	2.8	3	4
R10	2	3	3	4	3	3	3	3
R11	3	3	4	2	4	3.2	3	3
R12	3	3	3	2	3	2.8	3	3
R13	3	4	3	3	2	3	3	3
R14	3	4	4	2	4	3.4	4	4
R15	4	4	3	3	4	3.6	4	4
R16	1	2	4	3	3	2.6	3	3
R17	3	4	4	4	3	3.6	4	4
R18	1	3	4	2	3	2.6	3	3
R19	2	4	4	4	2	3.2	4	4
R20	4	3	3	2	4	3.2	3	4
R21	4	4	4	3	3	3.6	4	4
R22	3	3	4	2	4	3.2	3	3
R23	4	4	3	4	4	3.8	4	4
R24	3	4	2	2	4	3	3	4
R25	3	4	4	1	4	3.2	4	4
R26	4	4	2	1	3	2.8	3	4
R27	2	1	2	3	3	2.2	2	2
R28	4	4	3	4	3	3.6	4	4
R29	0	3	4	2	4	2.6	3	4
R30	2	3	1	4	2	2.4	2	2
Total						89.2	96	103
Mean						2.97	3.2	3.433

of 75.42 reveals that the users are satisfied with the application. Also, the observation shows that the primary students were very eager to use the application. From the results, we can infer that the mean of the usability study and the learnability study based on the questionnaire proves that the users have found the application very easy to use. SUS has proved that it is very easy to administer to participants.

The research study shows best analysis, although we could take bigger sample size for interviews and usability testing. Sample size can drastically affect the findings. Other parameters such as effectiveness and efficiency of the system can also be measured with detailed performance analysis. Tools like UMUX, UMUX-LITE,

Table 1.9 Negative questionnaire

Respondent	Q2	Q4	Q6	Q8	Q10	Mean	Median	Mode
R01	4	4	3	4	4	3.8	4	4
R02	2	2	3	4	3	2.8	3	2
R03	3	2	2	4	3	2.8	3	3
R04	2	2	3	2	0	1.8	2	2
R05	3	3	4	2	2	2.8	3	3
R06	3	2	3	4	4	3.2	3	3
R07	2	1	3	3	3	2.4	3	3
R08	1	3	4	3	4	3	3	3
R09	3	2	2	2	3	2.4	2	2
R10	4	4	2	3	4	3.4	4	4
R11	2	4	1	3	4	2.8	3	4
R12	4	2	4	3	4	3.4	4	4
R13	4	2	4	4	3	3.4	4	4
R14	2	3	3	4	3	3	3	3
R15	3	4	4	3	4	3.6	4	4
R16	3	3	4	4	4	3.6	4	4
R17	2	2	1	2	4	2.2	2	2
R18	2	4	3	4	3	3.2	3	4
R19	4	2	3	3	4	3.2	3	4
R20	2	4	3	4	2	3	3	2
R21	3	3	2	4	3	3	3	3
R22	4	4	3	3	4	3.6	4	4
R23	3	4	2	3	3	3	3	3
R24	2	3	3	3	2	2.6	3	3
R25	2	3	4	3	3	3	3	3
R26	4	3	4	4	4	3.8	4	4
R27	3	4	3	4	4	3.6	4	4
R28	2	3	4	3	4	3.2	3	3
R29	2	3	3	3	4	3	3	3
R30	4	2	4	3	3	3.2	3	4
Total						91.8	96	98
Mean						3.06	3.2	3.27

or SUPR-Q can also be used in lieu of SUS. In future, inferential statistics can also be used to perform quantitative analysis of the behavioural aspects and the better usability of the application.

This study has potential limitations. To set up a truly immersive beneficial environment, very good infrastructure and equipment are very much essential. Cost is one of the barriers for the massive adoption of immersive technologies within the educational systems. Because of the high cost and bulkiness of the devices, the immersive technologies are not yet fully utilized in the virtual world of education. Even the schools in smart cities are reluctant to invest in expensive gadgets. It is true that the devices can cause nausea, motion sickness, and eye strain. Also, the primary users are students, therefore very careful monitoring of schools, teachers, and parents is very much required.

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Chapter 2
Immersive Learning About IC-Engine Using Augmented Reality

K. B. Ashwini, H. D. GopalKrishna, S. Akhil, and Abhishek D. Pattanshetti

2.1 Introduction

AR is a technology that overlay's an image generated by the computer on a user's view of real world, thus providing a composite view. AR can be defined as a system that fulfils three basic features: (1) A combination of real and virtual worlds. (2) Real-time interaction. (3) Accurate 3D registration of virtual and real objects. AR alters one's ongoing perception of a real-world environment which means in AR the objects of the digital world blend into a person's perception of the real world. It is taken care that instead of just displaying the data, it penetrates through an enhancing sensation, which is recognised as a natural part of an environment.

AR is focused on many fields such as medicine, right from training the medical students till preparing them for surgeries. In military, its application is very huge for simulation of different equipment and usage. It can be widely used for industrial training and maintenance. AR plays an important role in the gaming industry. The AR apps create a mesmerising gaming effect for the player using his own surrounding environment. The most popular AR game till date is Pokemon Go which allows users to catch virtual Pokemon that is hidden throughout the map of the real world. One more important application of AR is in the field of construction and design as the user can have a feel of the entire structure and interact with it. AR apps can also be used to assist people in their repair work, public safety, navigations, marketing, entertainment, and sightseeing and are used in many other fields.

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This Chapter in the field of education put forward truly unlimited possibilities for teaching, learning, and working of IC-Engine. They are the most widely used heat engines for vehicles like boats, ships, airplanes, and trains. They got the name as IC-Engines because the fuel is ignited in order to do work inside the engine. The learner through the developed app will be able to interactively acquire detailed knowledge about the IC-Engine along with its internal parts and working in a real environment interaction.

The rest of the chapter is organized as follows: Sect. 2.2 highlights about the applications of AR in different fields. An explanation of the complexity of IC-Engine is discussed in Sect. 2.3 alone with the objective of the chapter. The methodology adopted in the development of IC-Engine application is discussed in Sect. 2.4 along with the languages and tools used for development of the application. Block diagram for marker-based AR application is represented in Sect. 2.5 followed by implementation and conclusion in Sects. 2.6 and 2.7, respectively.

2.2 Literature Review

AR applications as digital experiments in the field of education are increasing day by day. Some of the textbook image of the Earth is scanned and 3D models of Earth and moon are placed to implement in the system. It mainly aims in the 3D visualization and animation. A simple 3D animation can convey how a system works and thus this technology helps the students to understand complex topics and motivate them to learn more about them with digital experiments and visualization [1].

In higher education, students face difficulty in understanding and analyzing the mechanical machines, electrical circuits, or any other complicated system. Usually all the machines are represented as 2D images and it becomes very difficult to imagine that in 3D plan. In order to overcome these bottleneck situations, simulation models of the system have to be developed. AR can give a right answer to this problem, it can be used to visualize the image in the real world as shown in Fig. 2.1. AR is still a budding field with lot of opportunities to showcase, and, on the other hand, it also has equal number of challenges which have to be overcome [2].

It is a known fact that lot of time, money, and man power is invested in industrial training. The shortage of experts also gets added, keeping this in mind, a review is done in paper [3] as to how AR and other related technology can be used to record experienced persons' expert performance to train the trainers. This also reduces the time invested by the experts in training which helps them to focus on other productive work. Seventy-eight studies which have implemented AR and sensor technology for training purposes have been analyzed. The outcome is a tested methodology which can be used to design a learning environment for training using AR.

Many applications are developed using AR especially in medical field. These applications include training medical students and nurses with augmented images, to give a clear understanding of the medical images in the book. The most famous and appreciated application of AR is the device that helps in assisting the location

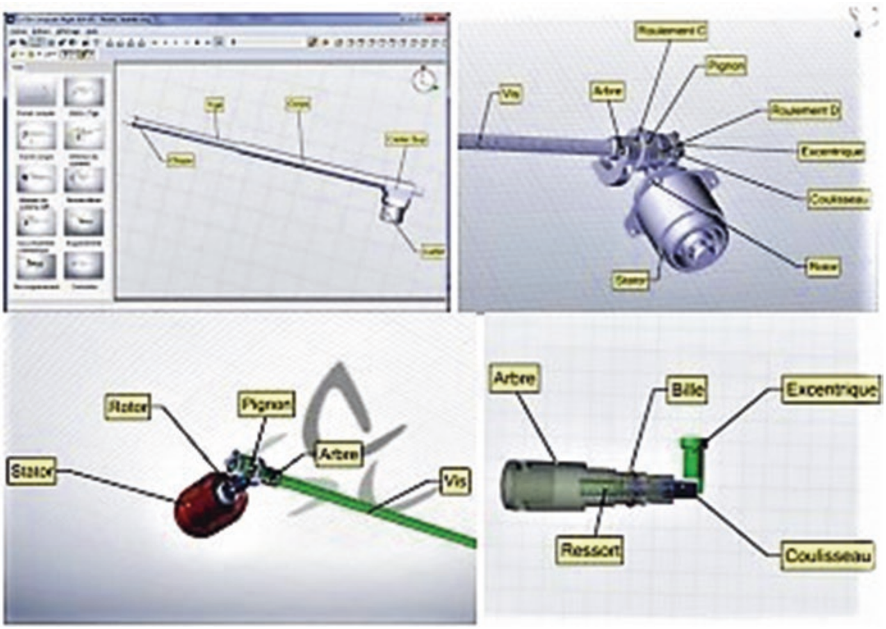

Fig. 2.1 Analysis outline of an electric actuator [2]

of veins which will be displayed on patient's hand using a projection-based AR system. A study was conducted in paper [4] where a group of nursing students had access to AR device to detect nasogastric tube in a mannequin. The nursing students who have access to the AR device were most satisfied with the training than the other group who had only video and audio training.

Application of AR in different fields has its own challenges, it is not an exception in Engineering Graphics (EG)) Education. The AR-based applications specially designed for EG instructions are very impressive as shown in Fig. 2.2. The main aim of this is to improve spatial awareness and interest in learning. The chapter proves the method to be a very effective aid for engineering graphics courses. A prediction is made where AR technology to support learning activity may become the future trend [3].

Applications of AR can also be extended for safety and rescue during natural calamities. Paper [5] uses AR apps to visualize the problems during the flood and advice a solution to manage the risk depending on the problem and the situation. It also gives an analysis from flood experts for a situation along with a solution. It is an important app as there is a need to develop many such apps to train people on a precautionary measure. AR techniques for learning and training of 3D printing process of Fused Deposition Modelling (FDM) are represented in Fig. 2.3.

AR apps are developed which can be used by a mobile phone for self-learning to know the basic operation of 3D printer. The developed apps can be repeatedly viewed to understand the operation of the 3D printer. The app also provides the

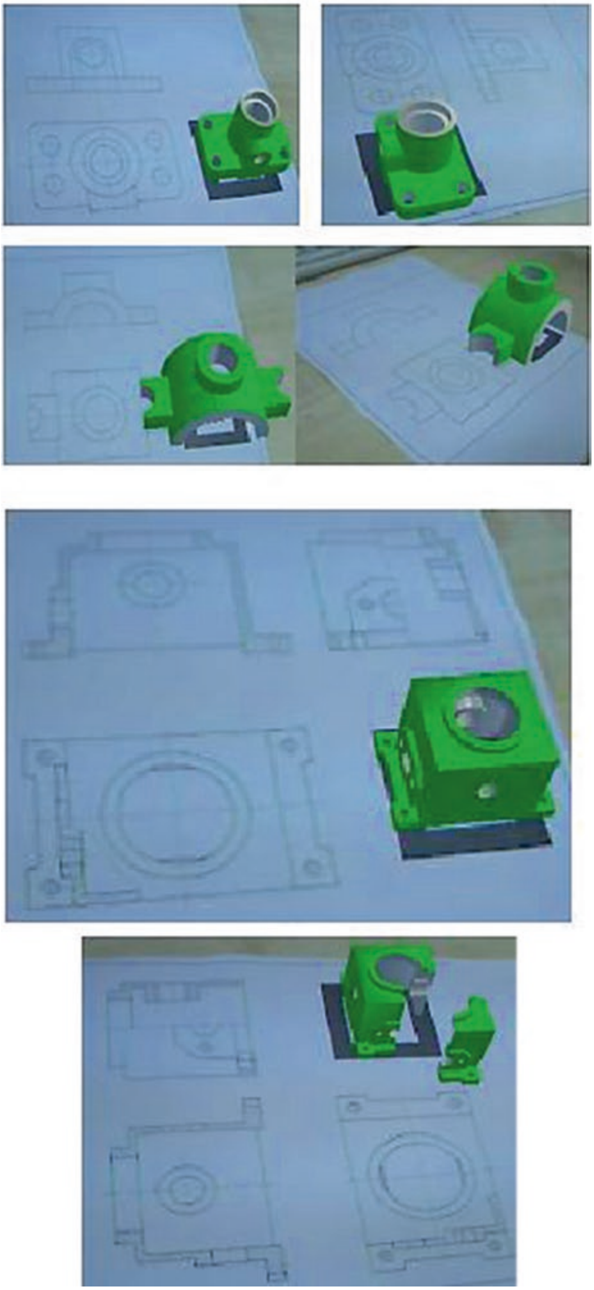

Fig. 2.2 Virtual 3D sectioning casing overlay on real page [3]

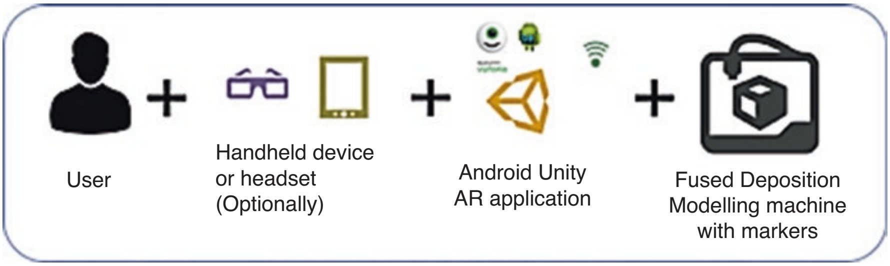

Fig. 2.3 AR apps for learning of FDM process [6]

option of selective view of the 3D printer operation. Efficiency of self-learning based on AR apps is compared with traditional learning methods with results of experts [6].

In manufacturing sector, polishing techniques are used in order to overcome minor corrections in geometric patterns of the parts manufactured. They are also used for specified surface polishing requirements. In order to enhance AR application from manufacturing to finished products, an effort is made in paper [7] to integrate real-world manufacturing sector from production to completion. The paper highlights important problems related to calibrations and tracking limitations in AR. An effort is also made to overcome the problem and to help the workers in judging the quality of the product after completing the product which includes final polishing processes. It is evaluated using robotic process as shown in Fig. 2.4, where the operator is supposed to enter the cell and check if the quality reached during the process satisfies the requirements or which parts of the surface require further polishing.

IC-Engine is considered as the heart of an automobile engine, which is used to produce the power required to propel the vehicle. Paper [8] explains about the different parts of IC-Engine. An analysis of different parts of IC-Engine like connecting rod, crankshaft, and piston is done using different methods like finite element analysis, multibody dynamic simulation, static analysis, dynamic analysis, numerical modelling and simulation.

Toys have a greater impact on child's imagination and learning. Paper [9] focuses on toys developed for education using AR. The outcome justifies that these toys can be an effective learning tool in early learning and fill the gap in the educational technology field.

Paper [10] presents the advantage of AR in training manufacturer of cherry pickers. The results show an improvement in learning time and reduced the number of errors. Microsoft HoloLens were used along with Unity and Vuforia software. The training involves sequential instructions through texts, images, and animations.

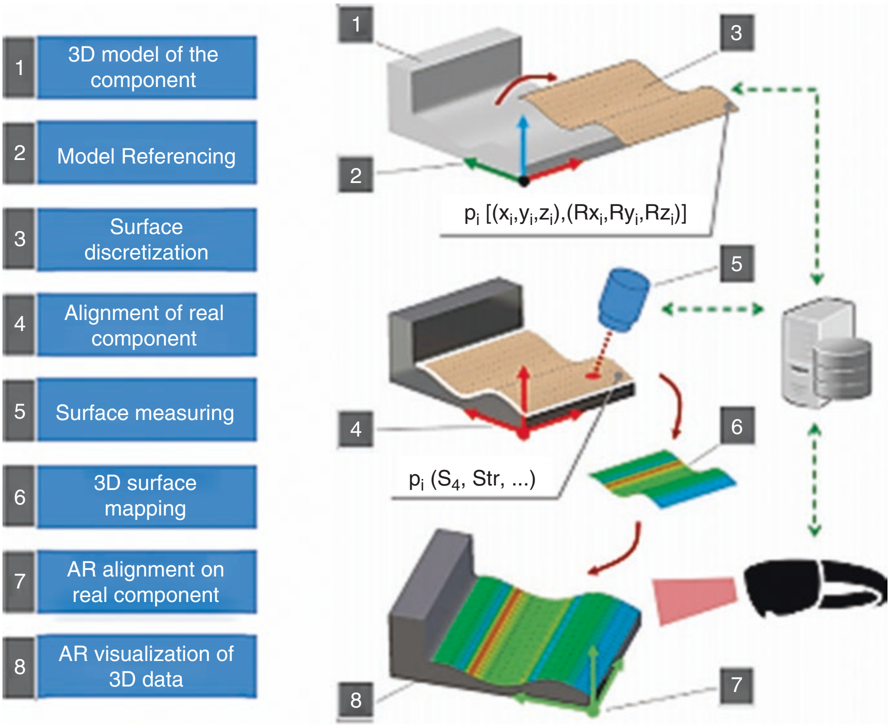

Fig. 2.4 Online visualize surface data related to the quality of the polished product by means of AR devices [7]

2.3 Problem Statement and Objective

IC-Engine is a mechanical component of a machine, and working of engine can only be viewed externally; therefore, it is difficult to view and learn all its individual part and its assembly in practical. The cost of the engine is also very high, around $5000. Installation and maintenance of engine is also risky. The objectives of the project are to show the working of IC-Engine using AR; to project 3D models of the engine with necessary information about it through AR and making an application which would convincingly provide details about the engine to the application user, so that the user would experience a better learning method than usual; to develop interactive learning platform for learner's with hands on experience; to deliver visual and vocal explanation of individual parts for better understanding; to provide in depth viewing experience of the IC-Engine both internally and externally; and to finally make it cost effective.

2.4 Methodology

In Fig. 2.5, the methodology followed in the development of IC-Engine application is explained. Further each step adopted is explained in further detail.

Development of 3D models: The required solid models are created using SolidWorks. It is a computer software tool that supports users in creating solid models and beyond. It has different modes like (1) SolidWorks part mode which is used to do different parts. (2) SolidWorks assembly mode which helps in assembling of part. Many such parts can be assembled and integrated to create more and more complex assembled components. Including a component to an assembly creates a link between the two. When SolidWorks opens the assembly, it finds the component file and brings the component to the assembly. Changes in the component are automatically reflected in the assembly, and vice versa. The document name extension for assemblies is SLDASM [3]. The first step in creating the models is conversion of 2D drawings available with dimensions into 3D parts. The dimensions of the 2D drawings can be selected according to design constraints and requirements.

SolidWorks: The different parts involved in IC-Engine assembly are noted. Proper 2D diagrams of various parts are selected with accurate dimensions. The 3D

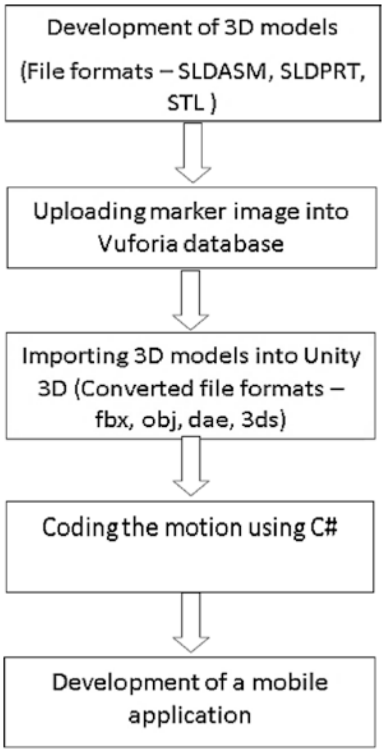

Fig. 2.5 Methodology adopted in the development of IC-Engine application

model of IC-Engine is build using SolidWorks 2014 software. The development of the 3D model in SolidWorks involves the following steps:

1. Open SolidWorks software, select new document and select Part design.
2. Using sketch command in sketch tab, the 2D diagram of the part is sketched in the prescribed plane.
3. Proper dimensions and constraints are provided to the 2D sketch, and the sketch environment is closed.
4. Solid features such as extrusion for stretching in the perpendicular plane or revolve for generating axis symmetrical solids are chosen according to the need.
5. Other features such as fillet, hole, slots are generated on the solid model wherever required.
6. The required model is compleated and the file is saved as. SLDPRT and proper material.
7. The above procedure is followed to model all the required parts.
8. A new assembly file is created using assembly design.
9. The generated parts are inserted into the assembly file.
10. Proper assembly constraints such as contact and coincidence are established between two parts by selecting the two parts and selecting the constraints in the constraints tab.
11. After all the required constraints are applied, the file is saved as. SLDASM. The Fig. 2.6 shows the final 3D model of IC-Engine.

Vuforia: It is a platform for AR that provides API in C++, Java, Objective-C, and the.Net languages over an extension to the Unity game engine. After logging into

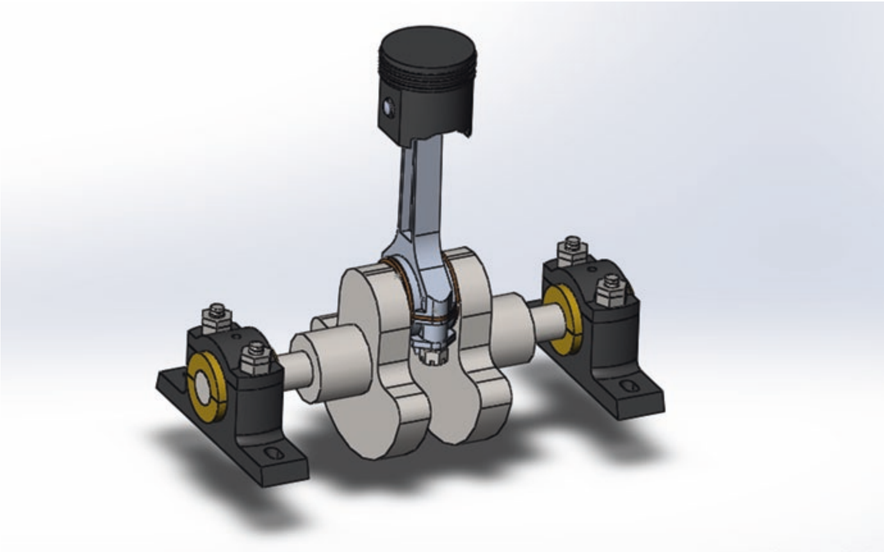

Fig. 2.6 3D model of IC-Engine

Vuforia engine developer portal, under license manager a free development key is added, then under target manager new database is created and target image is uploaded. A target image can be of multiple types single, cuboid, cylinder, and 3D object; particularly in our project, we work on single 2D target image and the following created database will be having the respective target image uploaded, this database is downloaded for its deployment in development of augmented reality app.

Unity: Unity is a cross-platform game engine developed by Unity Technologies. It can be used to create different type of 2D, 3D, VA, and AR games as well as simulations and other experiences. Using the real-time 3D platform, including film and automotive, Unity Technologies used this game engine for transition into other industries. The Unity Hub is a standalone application that streamlines the way we find, download, and manage our Unity Projects and installations. In addition, we can manually add versions of the Editor that we have already installed on our machine to our Hub, required Unity 3D version is downloaded (currently working on Unity 2018.4.17f1 (64-bit)) from installs option; after selecting the Unity version then certain tools required for development is included, platforms like Vuforia Augmented Reality Support and Android Build Support, dev tools (Microsoft Visual Studio Community 2017) with documentation for Unity is also installed. Later after completion of installation process, Unity application is opened to create a new project. Vuforia Engine—AR camera game object, Vuforia Augmented Reality, is enabled, and Vuforia engine image target is imported. Then downloaded database is imported. After importing 3D models, models are projected and simulated, coding of respective objects is done using C# programming language. Tested project is ready, now the working is played by showing the image target to the webcam, the coded and simulated objects will start its assigned task. Deployment of the working model into android compatible application is achieved by importing necessary unity file to Android Studio. Android Studio is the official integrated development environment for Google's Android operating system, built on JetBrains' IntelliJ IDEA software and designed specifically for Android development. The project can also be deployed into iOS, tvOS, PS4, Xbox One, WebGL, Facebook, Universal Windows Platform, PC, Mac, and Linux Standalone.

2.5 Block Diagram

Figure 2.7 represents a block diagram for marker-based AR application. The marker that has to be recognized is stored before in the database. The marker can be an image or an image descriptor. A camera is used with AR software to detect AR markers as the location for virtual objects. These markers have recognition library using which rotation and translation of the marker relative to the camera of the device in real world is calculated.

AR adds digital elements onto a camera. To show the relevant content to the user, AR uses computer vision, simultaneously localization and depth tracking; this allows cameras to collect, send, and process data in order to show digital content of

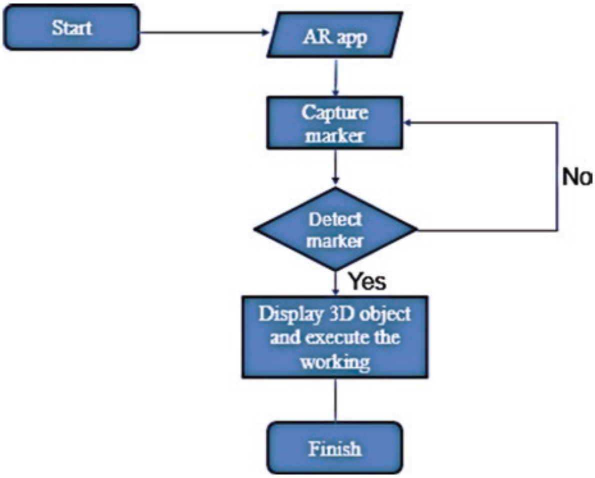

Fig. 2.7 Block diagram for marker-based AR application

Fig. 2.8 IC-Engine

IC-Engine. Computer vision processes the objects captured by the camera and recognizes it. Then, the program executes and the process happens every time the user holds a camera in front of the target image and so as the result output is viewed on a display device.

2.6 Implementation

The Fig. 2.8 shows the augmented 3D image of the IC-Engine. When the AR app is opened and the camera is focused on the target image, the 3D image pops up and a complete audio explanation about IC-Engine is given along with the working video.

Figure 2.9a–c are some of the internal parts of the IC-Engine. A complete audio and video explanation about all the parts of the IC-Engine is given along with assembly.

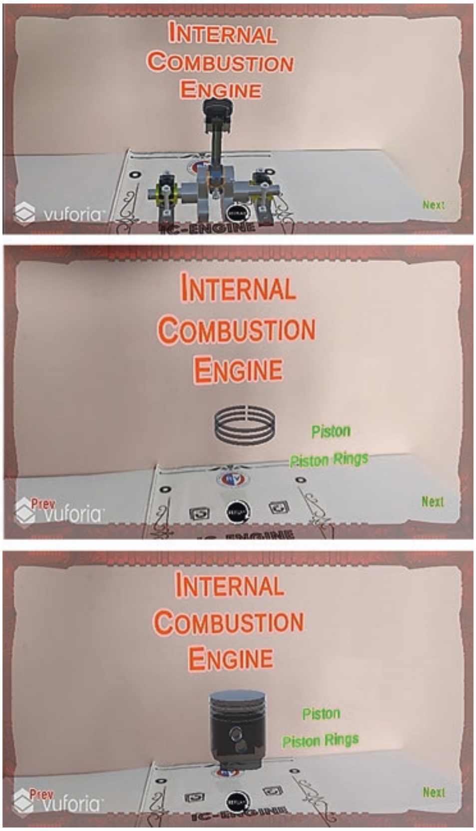

Fig. 2.9 (**a**) Piston, (**b**) piston ring, (**c**) connecting rod

Piston is considered as the heart of an IC-Engine. The parts of the piston are piston head and piston rings. The main purpose of piston is to firmly close the cylinder and glide freely inside of cylinder. Piston head is fixed to the cylinder and the gas pressure received is transmitted to the connecting rod. The piston is made out of aluminium alloy or cast iron so that it is light but strong enough to withstand the gas pressure. If the piston is tight, it will expand due to gas pressure and may stick tightly in the cylinder at the same time; if it is loose, it may start leaking due to gas pressure. At this situation, piston rings are used to provide best fit. They are made of cast iron which has high elastic material and is not affected by the working heat. These rings are fitted in grooves which have been cut in the piston. They are split at one end, so that they can expand or slip over the end of piston. A small two stroke engine has two piston rings to provide good sealing but a four stroke engine has an extra ring which is known as oil ring.

The connecting rod in Fig. 2.9c connects the piston to crankshaft and transmits the motion and thrust of piston to crankshaft. It converts the reciprocating motion of the piston into rotary motion of crankshaft. The two ends of connecting rod are known as big end and small end. Big end is connected to the crankshaft and the small end is connected to the piston by use of piston pin. The connecting rods are made of nickel and chrome. For small engines, it may be made up of aluminium. Connecting rod cover is used to cover the connecting rod. The big end of the connecting bar is attached to the crank pin on the crank of the crankshaft by a bearing. The main function of bearings is to reduce friction between these moving parts. In an IC-Engine, sliding and rolling types of bearing are used. The sliding type bearing which is sometimes called bush is used to attach the connecting rod to the piston and crankshaft.

2.7 Conclusion and Future Work

The existing models of IC-Engine are in the form of 2D drawings, 3D drawings, or 3D animations. The developed model of IC-Engine has working animations which support development of augmented reality–based application. The contribution of AR in providing the demonstration of IC-Engine helps in making the understandability much easier and interactive. Henceforth, this implementation leads to new opportunity to understand complex strategies into a convenient platform, reduces the difficulty in learning about the engine, and also provides better learning experience with detailed statistics. Further the model is open unlike closed in a cylinder which helps in better visualization of its working. The guided platform developed for demonstrating the complete engine will be a foothold tool for creating more such complex experiments. The 3D models are displayed on a particular target image, viewing of the output is enabled only with the presence of a target image. It is necessarily important to have the target image along with the application; hence, the portability of usage of the application is dependent. The output is confined to a certain limited view of boundary, where the application can only be used within the tracking area; hence, objects disappear when lost in contact with the image target. The 3D objects setup is fixed to the view and dynamically unscalable, and objects are not able to be resized or shift the position during the runtime of the application. The modules which are successfully completed as a base platform are introduction of the engine and development of android application with an interactive user interface. Modules which can be implemented as a further enhancement of the application would be assembly and working of IC-Engine which would contain the complete motions of the engine.

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Chapter 3
Location-Based Mobile Augmented Reality Systems: A Systematic Review

Arvind Ramtohul and Kavi Kumar Khedo

3.1 Introduction

During the last decade, mobile augmented reality (MAR) has only been fictitious until the recent developments in mobile devices have pioneered it as a state-of-the-art technology. The increasing demands of mobile devices have propelled industries and academia to focus on their research and further development. This has accelerated the developments of MAR since the latest mobile devices to have significantly more computing power. Furthermore, the advances in high-tech connectivity, cloud infrastructure and ubiquitous computing have supplemented the rise of MAR applications. The term MAR is similar to AR, it superimposes the live view of a mobile device with virtual computer-generated images and creates a real-time augmented experience of reality. The concept of virtual reality (VR) is alike to AR, except the surrounding environment in VR is virtual while in AR it is real [1]. Figure 3.1 shows the inline classification from reality to virtuality. According to Jupiter Research, the era of smart mobile devices will continue to bring new dimensions to new technologies such as MAR. These applications have widely been adopted by consumers and have generated more than $732 million [2]. MAR systems can further be extended into three subcategories namely: Marker-based, Marker-less and Location-based systems. In Marker-based applications, the objects are tagged to a marker (tag) which the systems identify the marker to provide the AR overlaid information. Marker-less systems take the physical characteristics of the object to inform on the AR experiences. Location-based MAR (LBMAR) applications require the inertial sensors (GPS, accelerometer, gyroscope and compass) of mobile devices to estimate

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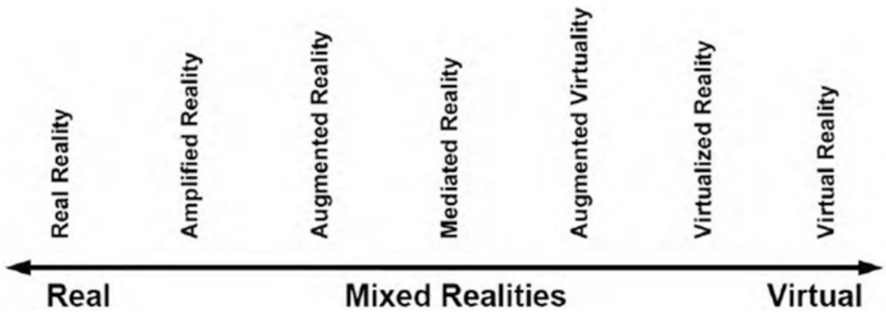

Fig. 3.1 Order of reality concepts

the users' location and geographical position and refine it to a more subtle real-time MAR experience.

The emergence of multitude sensory capabilities in mobile devices has widened the applicability of more LBMAR systems. Due to its portability, integration and infrastructure-free devices, industries are rethinking their conceptual model to adapt the basic MAR into a more robust LBMAR systems. Besides, context-aware services like positioning systems have also been integral part in our day-to-day activities, and this has undoubtedly benefitted LBMAR systems. Many studies have not referenced the term 'LBMAR' properly or it has not been identified as a subsection of MAR. Taking all the attributes into consideration, we can define LBMAR with the following characteristics:

1. Operates on a mobile device,
2. Employs the sensory capabilities of a mobile device for augmentation and positioning services and,
3. Is collaborative and real time.

To the best of our knowledge, most of the survey papers in the AR area were focussed mainly on Marker-based and Marker-less systems. In this chapter, we will carry out a systematic review of the recent literatures of LBMAR systems.

3.2 LBMAR Systems: A Walkthrough of Common Applications and Current State

The upsurge of LBMAR has been discussed in the introductory section; however, there is presently little literature in this particular domain that could differentiate the different LBMAR systems amongst others. In this section, we will present the recent works that have been carried out during the past 5 years. Table 3.1 provides an overview of the systems of some popular LBMAR systems.

Recently, *Pokémon GO* [3] has been a huge hit, generating millions of followers and denoting the notable expansion of LBMAR systems. The craze was everywhere

Table 3.1 Overview of system

Systems	Network technologies	Mobile sensory capabilities	Environment	Application field	Year published
Pokémon GO [3–5]	Cellular and Wi-Fi	GPS and digital compass	Indoor/ outdoor	Gaming	2016
Ingress [6]	Cellular and Wi-Fi	GPS and digital compass	Indoor/ outdoor	Gaming	2013
AREA [7, 8]	Cellular and Wi-Fi	GPS, compass, accelerometer and gyroscope	Indoor/ outdoor	Heritage	2016
MOIAR [9]	–	GPS, compass, accelerometer and gyroscope	Outdoor	–	2015
AR-based mobile learning [10]	Wi-Fi	GPS, compass, accelerometer and gyroscope	–	Educational	2014

in the world, some figures show that the application was installed in 10% of total smartphones in USA [4]. The game requires humans to roam the area to collect *Pokémon,* also referred as *PokeStop*. The *PokeStop* is tagged to distinct location places, and it uses mobile device's capabilities to guide the gamers during their play [5].

Ingress [6] has been conceived by Niantic, the same software company as *Pokémon GO*. It is based on a science fiction story to uplift humanity and is played in groups rather than individually. The game has *Portals* that represent specific landmarks such as monuments, squares, statues, parks, buildings that should be collected and linked during the gameplay. Moreover, the landmarks are attached in Google Maps and the location is tracked using GPS. Pryss et al. [7, 8] developed a location-based AR engine denoted as AREA. The engine identifies the predefined points of interest (POI) inside the camera view of a smart mobile device relative to the user position and the POI. Relative to the POI, additional information is overlaid and provided to the users. The readings from the mobile sensors are computed to determine the positioning of the users and the field of view. The first version of AREA was implemented in 2013 with its main focus on providing location-based AR services to users. AREAv2 was implemented in 2016 to address the following issues with the first kernel: the dynamic characteristics of mobile systems, the efficient management of increasing number of POIs and on-demand features. Tan and Chang [9] implemented a location-based adaptive mobile learning application, called MOIAR. The authors used AR as a prototype to model the location-based object identification algorithm. The system recognises the specific objects based on the users' current location, their orientation and the object's location information. In-addition, it has a mechanism whereby it can tailor the contents according to the users' learning profile and current position. Chiang et al., [10] developed an AR-based mobile learning system to innovate the learning approach of students. Mobile sensory capabilities such as GPS, camera, accelerometer, digital compass and Wi-Fi are used in their approach. The location tracking is done using GPS, camera is used to identify and capture the objects of interest and digital compass finds the relative direction and position of students and objects.

Nevertheless, there is a lack of systematic literature review studies focussing on LBMAR systems and its associated subordinates. Review papers on the different techniques used in LBMAR are missing. For example real-time positioning is an important aspect of LBMAR, it pinpoints both the user and object in interest (OOI) in a predefined coordinate respective to the real world at regular time intervals. A very small change in position would normally result to a significant change in the field of view; therefore, the system should be highly accurate and precise. This is one of the requirements that should be taken into consideration while designing an LBMAR systems. Many literature reviews have reported factors such as uses, benefits, limitations and challenges of these systems, but there is a research gap in the operating requirements of an IBMAR systems.

In this chapter, a number of research questions with respect to LBMAR are addressed and a systematic review of existing LBMAR systems is carried out. The rest of the chapter is structured as follows: Section 3.3 discusses the research questions addressed in this systematic review. Section 3.4 describes the methodology of the review. Section 3.5 presents the analysis jointly with the discussion of the findings. Section 3.6 highlights the research challenges and directions. Lastly, Section 3.7 is the conclusion of the study.

3.3 Research Questions

From previous literatures on mobile augmented reality, it is observed that LBMAR has not been fully evaluated and properly classified. As discussed above, most studies have focussed on only two types of MAR: Marker-less and Marker-based. With the likes of infrastructure-free devices, LBMAR is becoming more important than the two traditional types of MAR. Therefore, it is essential to study LBMAR comprehensively and its domino effect on the real world. The following research questions have been identified and studied in this chapter.

1. What is best classification and characterisation of LBMAR systems?
2. How the recent mobile computing technological advances have contributed to the growth of LBMAR systems?
3. What are the innovative application domains for LBMAR systems and their related challenges?
4. What are the latest advances in the techniques used in LBMAR for real-time positioning, AR object positioning and AR object retrieval?

3.4 Research Methods

In this chapter, a systematic literature review is conducted by identifying, evaluating and interpreting all the available research relevant to the topic area 'Location-based Mobile Augmented Reality Systems'. Based on the above research questions, the review is undertaken to report the recent existing works and further assists researchers in this field. The systematic review will carried out by following the guidelines proposed by Kitchenham [11], namely (1) planning the review, (2) conducting the review and (3) reporting the review. Each step is subdivided as follows:

Planning the review:

- Data sources.
- Search Terms
- Definition of inclusion and exclusion criteria
- Categories for analysis and data coding.

Conducting the review:

- Study selection.
- Content analysis method is applied.
- Data synthesis.
- Data coding.

Reporting the review:

Analysis of the results, discussion of findings, trends and conclusion of the review are elaborated in this step. The recommendation of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement is followed in this step [12].

3.5 Planning the Review

A predefined protocol is used to determine an appropriate strategy to undertake the review, which consists of (1) the data sources to be searched (including databases, specific journals and conference proceedings), (2) the search terms, (3) the inclusion and exclusion criteria considered in the review and (4) the definition of categories for analysis.

3.5.1 Data Sources

As LBMAR systems are now growing at an exponential rate into the market, however, very few research articles are available on the subject. Initially, a general exploration is carried out on reputed scientific journals and conference proceedings to shortlist the relevant scientific databases. The highest relevance of indexed papers was found in IEEE Xplore, ACM Digital Library, Springer, ScienceDirect, Elsevier and ERIC.

3.5.2 Search Terms

According to the research questions the review has been planned by determining the most appropriate search strategy. The query strings used during this phase included: 'Mobile Augmented Reality' AND (Location-based or Real-time or Smart) AND (Sensory capabilities or Embedded sensors). The search was limited from the years 2013 to 2018. The last update was on 18 October 2018

3.5.3 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria are refined based on the above formulated research questions. We considered the general criteria that define the type of study relevant to this review. The definitions of those criteria are as follows:

General criteria:

1. With respect to question 1, we considered all types of MAR (Marker-less, Marker-based and LBMAR) but it will be streamlined to LBMAR in the remaining questions.
2. By 'mobile computing technological advances', we are referring to all the advancement in the mobile technologies including computing resources and sensory capabilities.
3. By 'mobile sensors', we are referring all the inertial sensors in a smartphone such as: GPS, Wi-Fi, accelerometer, gyroscope, compass, Bluetooth and camera.
4. We shall consider all the studies which include MAR and use of mobile sensors for positioning.
5. All application domains of LBMAR will be considered and studied. The environmental or physical characteristics of LBMAR systems are not taken into consideration.
6. Studies published between 2013 and 2018.

Exclusion criteria:

1. All studies which mentioned the term 'MAR' but are related to 'virtual reality' or 'mixed reality'.
2. All studies which mentioned the term 'MAR' but are related to 'head-worn display' or 'smart-glass'.

3. All forms of studies which are book chapters, guest editorials, unpublished working papers, master's dissertations and article summaries.

3.5.4 Categories for Analysis and Data Coding

In this phase, the categories and sub-categories are defined for each research question (RQ). The categories will classify the studies based on their shared characteristics and will be useful during the systematic review process. The list of categories for each RQ is as follows:

RQ 1: What are the characterisation and classification of LBMAR systems?

- Distinctive properties of LBMAR.
- Reported advantages of LBMAR compared to Marker-based and Marker-less systems.
- The different environmental characteristics of LBMAR.
- Types of LBMAR.

RQ 2: How the recent mobile computing technological advances have contributed to the growth of LBMAR systems?

- The recent advances in computing power in mobile devices during the last 5 years.
- The evolution of embedded sensors in mobile devices during the last 5 years.
- The implementation of LBMAR systems with respect to evolution of embedded sensors in the last 5 years.

RQ 3: What are the innovative application domains for LBMAR systems and their related challenges?

- Field of study.
- Reported purposes of LBMAR.
- Target group.
- User's requirements.
- Mobile device requirements.

RQ 4: What are the latest advances in the techniques used in LBMAR for real-time positioning, AR object positioning and AR object retrieval?

- List of LBMAR systems by all its techniques and algorithms used for real-time positioning, AR object positioning and AR object retrieval.
- Categorisation of techniques and algorithms as per the mobile computing resources.
- Categorisation of techniques and algorithms as per the mobile sensors.
- The sensory capabilities of the techniques and algorithms.

3.6 Conducting the Review and Reporting the Review

In this section, the results of conducting the review are described and discussed. The review was conducted according to the planning phase. The key terms were searched in the data sources whereby a total of 589 non-duplicated articles were retrieved. The inclusion and exclusion criteria were thus applied based on title, abstracts and full texts, and as a result we selected only 35 articles. In the following subsections, our findings with respect to each research questions are presented.

RQ 1: What are the characterisation and classification of LBMAR systems?

At first glance, LBMAR systems can have a wide-range of characteristics that could differentiate amongst them. For example the functioning of the systems will vary in terms of the featured services, application domain, environment, technologies used or any factors that could have direct link with the workability of the system. Based on the reviewed studies, a list of key characteristics has been derived to rationalise the above-mentioned factors for carrying out a detailed categorisation. The Table 3.2 below presents the key characteristics together with their description. Moreover, a more eccentric classification of LBMAR system is presented in Table 3.3. The classification encompasses all the main attributes of the reviewed works to further categorise them into the four formulated types of LBMAR: Geostationary, Free-moving, Authoring and Gamification.

As shown in Table 3.4, all the related works have been reviewed thoroughly with respect to the defined characteristics. It provides an indication on the area of focus of each LBMAR system reviewed. Certainly, all the reviewed works are location-based thereof explaining the 100% mark percentile. The reactivity of such systems should be within a minimum time delay so that it does not disrupt the user experience. Developers have to take this aspect into consideration while designing the systems. Ninety-one percent of the works have considered the real-time factor,

Table 3.2 Characteristics of LBMAR

Characteristics	Description
Location-oriented	Superimposes the AR objects respective to the real world
Real-time	The perfect-inch augmentation at the right place and at the right time
Environment-free	The environmental characteristics are taken into consideration
Navigation	The ability to find and locate the routes to different interconnecting POIs
Immersive	Feeling of completely submerged by the various augmentation layers
Storytelling	A sense of exploring the POI by providing previous related information
Pervasive	Continuously augments the physical work with respect to the context of the user
Intuitiveness	Feeling of realness and naturalness in interacting with the AR information and how AR is overlaid on the real world
Liveliness	Contents are updated constantly thus making it feel more dynamic and vivid
Awareness and knowledge	Increased insight into objects surrounding in visually challenged environments

Table 3.3 Classifications of LBMAR

Types of LBMAR	Description
Geostationary	Identification of objects and superimposition are done in a fixed position
Free-moving	The systems overlay the AR objects in a real-time mode while the user is constantly changing position
Authoring	Ability to update the AR contents from users' AR experiences
Gamification	Creates a sense of play that provides the users' to search and connect with the AR objects

Table 3.4 Categorisation of LBMAR systems with defined characteristics

Sub-category	Related Studies	Percentage (%)
Location-oriented	All studies (35)	100
Real-time	32	91
Environment-free	2	6
Navigation	13	37
Immersive	5	14
Storytelling	5	14
Pervasive	7	20
Intuitiveness	10	29
Liveliness	9	26
Awareness and knowledge	23	66

whereby the flow of information changes as soon as the user's field of view changes. Storytelling and immersive have shared the same amount of percentiles, it can be viewed as the next generation of augmentation because of its complexity to implement. Until recently, awareness and knowledge are having utmost importance in the AR world and has accrued in its popularity in several fields such as education, marketing and tourism.

Table 3.5 classifies the systems into four different types of LBMAR namely: Geostationary, Free-moving, Authoring and Gamification. From year 2013 to 2014, six LBMAR systems were geostationary representing around 18%. At that time, LBMAR systems were in its preliminary stages, and designers were still improving on the initial conception thus explaining this figure. In the aftermath, many authors understood that a free-moving LBMAR would contribute towards a better user experience. Authoring is slowly incorporating on the LBMAR systems design to off-field large areas. It has been added so that users can create or update their own AR contents and share it with the public. Nonetheless, only 6% of the works have focussed on this area because it generates additional load to verify the customised the AR contents before it can be released to public. Gamification has gained momentum during the recent years, and it has enhanced the conventional method of LBMAR system into a new dimension that could potentially be viewed as the next-gen LBMAR systems.

Table 3.5 Classifications of LBMAR with related types

Types of LBMAR	Related studies	Percentage (%)
Geostationary	12	34
Free-moving	21	60
Authoring	2	6
Gamification	5	14

Table 3.6 LBMAR systems on year 2013

Year: 2013				
LBMAR systems	Application area	Brief overview	System services	Sensors
InfoSPOT [13]	AECO	A MAR application to assist facility manager on AECO industry and to help them on their decision-making	360-degree panorama, 3D object models	Wi-Fi, gyroscope, camera, compass, accelerometer
AREAv1 [7]	Cultural heritage	Location-based AR engine that identifies the predefined POI insider the camera view of a smartphone	POI, 2D images, text, map view	GPS, camera, accelerometer, compass
TARX [14]	Tourism	A novel storytelling application that provides historical information for the city of Lancaster by travelling back in time	2D images, text, map view, storytelling	Camera, GPS
Cultural Heritage Sites Visualization System Based on Outdoor [15]	Cultural heritage	A 3D model visualisation system of cultural heritage sites by using AR. They have used SIFT and SURF algorithms to process the video images and GPS for positioning	3D objects, 2D images, text	Camera, GPS

RQ 2: How the recent mobile computing technological advances have contributed to the growth of LBMAR systems?

Mobile technologies have known an exponential growth in the last 20 years. To support the increasing demands, various industries are reinventing their research and development programs to bring new innovations on their end products. One such innovation has been LBMAR systems. The tables below show the contributions of the recent advances in mobile technologies in support to these systems.

Table 3.6 provides an overview of the related LBMAR systems on the year 2013. The systems have been conceived in relation with the available mobile technologies at that particular time, thus explaining why authors developed simplified system services like 2D images, text and map view. Tarx [14] is the only work that has implemented a storytelling version of LBMAR, but authors have used GPS and camera as a means to trade-off between the proposed services and energy consumptions.

The Table 3.7 provides an overview of the related LBMAR systems on year 2014. During the transition of LBMAR, most of the authors concentrated their works on educational purposes and since then it has been a popular application to

Table 3.7 LBMAR systems on year 2014

Year: 2014				
LBMAR systems	Application area	Brief overview	System services	Sensors
BIM2MAR [16]	AECO	An efficient building information modelling (BIM) using MAR. It is the second iteration of InfoSPOT. In addition, they also addressed the interoperability issues between servers and improved the positioning services in the second version	3D object, 2D images, object identification, text	Camera, GPS, accelerometer, gyroscope
AuGeo [17]	Educational	The system is built to enhance the learning process of students through the use of AR. The objects are represented on a map view	3D object, map view, text	Camera, GPS, Wi-Fi, gyroscope
Historical time tunnel (HTT) [18]	Educational	A context-aware mobile learning platform using MAR for students. The HTT architecture comprises of the web layer, database layout and mobile device app	3D object, 2D icons, video clip	Camera, GPS
INSAR [19]	Research	INSAR is an indoor navigation system using AR using Wi-Fi fingerprinting technique. It is divided into two phases: The offline and online phases	POI, 2D images, text	Camera, Wi-Fi, compass
OUTMedia [20]	Entertainment	OUTMedia application is a context-aware music recommender system through an AR interface. It offers location-sensitive music content that is attached to places	POI, 2D images, text, music	Camera, compass, accelerometer
AR-based mobile learning [10]	Educational	An inquiry AR-based mobile learning system to innovate the learning approach of students. It allows students to learn on the AR objects, to annotate and to comment on the images	2D images, text annotation	Camera, gyroscope compass, GPS, accelerometer

Table 3.8 LBMAR systems on year 2015

Year: 2015				
LBMAR systems	Application area	Brief overview	System services	Sensors
LeeceAR [21]	Cultural heritage	An AR application implemented at the MUST museum in Leece, Italy. The application has two main functionalities: The matching and tracking module and the 3D rendering module	3D object model	Camera
MOIAR [9]	Research	A location-based adaptive mobile learning application, called MOIAR. The authors used AR as a prototype to model the location-based object identification algorithm	Collaborative, 2D images, text	GPS, camera, accelerometer, compass
CorfuAR [22]	Tourism	CorfuAR is a MAR travelling guide for the city of Corfu in Greece. It provides information on POIs and routing information to selected locations.	POI, 2D text	GPS, camera
The Buildings Speak About City [23]	Gaming	A game that is based on MAR to discover the historical buildings in a city of Greece.	Text, images, video, audio and questions	GPS, camera, Wi-Fi
BoreholeAR [24]	Resources management	An application to visualise borehole data using AR technology	3D view, 2D map view and text	GPS, camera, accelerometer, compass
IntelligShop [25]	Retail	This application provides intelligent shopping experience in malls. It provides reviews of particular retailers to customers	2D map, images and text	Camera, Wi-Fi, compass

showcase detailed information to students on complex objects. Gradually, it can be noted that 3D object service was emerging which added an additional layer of complexity and load on LBMAR systems.

Table 3.8 provides a brief summary of the works implemented on the year 2015. The proposed services on LBMAR systems have known a slight increase comparing with the previous years. This can be explained by the mobile technological advances which supported the implementation of the featured services.

Table 3.9 summarises the LBMAR systems developed on the year 2016. The systems have been spanned to various application fields, thereof showing its wide

Table 3.9 LBMAR systems on year 2016

Year: 2016				
LBMAR systems	Application area	Brief overview	System services	Sensors
AREAv2 [8]	Cultural heritage	The following issues in the first kernel: The dynamic characteristics of mobile systems, the efficient management of increasing number of POIs and on-demand features	3D view, POI text, images and tracks	Camera, gyroscope compass, GPS, accelerometer
VisAge [26]	Cultural heritage	The prototype is a web-based application with a map view of the POIs attached with an online database. Contents of POIs are stored in the database, and it may include text, images and audio	3D view, POI, audio, images and text	Camera
A client-server framework for the design of geo-location-based AR [27]	Resources management	The framework manages and visualises POIs through AR evolved that could be adapted to different contexts	2D, POI, text and images	Compass, camera, GPS
ReadMe [28]	Research	It detects and presents virtual objects based on the mobile users' context environment. A set of variables are collected by the device or can be inferred from neighbouring mobile devices to draw the MAR experience	Virtual objects	Camera, gyroscope compass, GPS, accelerometer
SlidAR [29]	Research	A 3D positioning based on SLAM algorithm. It uses 3D ray-casting and epipolar geometry to enable accurate 3D positioning of virtual objects to the real environment	3D, text and images	Camera and internal sensors
KioskAR [30]	Entertainment	An AR interface that allows art students to cooperate with each other in a real-time manner and present their artworks to other players	2D map view, 3D images and videos	Camera, compass, accelerometer, GPS

(continued)

Table 3.9 (continued)

Year: 2016				
LBMAR systems	Application area	Brief overview	System services	Sensors
Science spots AR (SSAR) [31]	Education	A story-driven learning approach for students on science education using AR and context awareness	Storytelling, AR map, 2D and 3D images, sound and videos	Smartphone sensors

spectrum of applicability in the real world. In the same vein, LBMAR is being applied to cultural heritage domains, and it has been a win-win situation for both the heritage industries and the visitors.

The Table 3.10 provides an overview of the related LBMAR systems implemented on the year 2017. Until recently, gamification and storytelling services are emerging to supplement the existing LBMAR systems. These innovative services are contributing on more collaboration and engagement aspects. For example a visitor experience can ultimately be enhanced by providing real-time user interactions between other visitors present in a cultural heritage site. Yet, these services require a mobile platform that can support the load and complexity without disrupting on the users' experiences.

Table 3.11 summarises the LBMAR systems developed on the year 2018 (January 2018–September 2018). Most of the authors have exploited the commonly available sensory devices present in smartphones to implement their systems. Authoring has featured recently in the system services, and it has been an innovative aspect in AR to share AR contents with other users.

The term 'location mobile augmented reality' has been searched in google scholar, and the figures of number of the unindexed search and filtered papers obtained are provided in the Table 3.12 below for the respective periods.

From Table 3.12, it is observed that the unindexed search in google scholar had an increase by 198% from year 2013 to year 2017. This growth can be explained by the widespread use of smartphones that were commonly available and the various advances in mobile technologies during this period. According to Statista [44], the overall number of mobile phone users has reached 4.43 billion in 2017, and this figure is expected to rise even more. Smartphones are contained to have more processing, memory and sensory powers compared to featured mobile phones. In this context, LBMAR systems have hugely been supported by the availability of smartphones to the general public thus making it practical for stakeholders to continue their research and developments on this subject. Table 3.13 and Table 3.14 below provide a breakdown of the LBMAR systems in terms of sensory devices, mobile computing power and proposed services.

From Table 3.13, it is observed that the most common combination of sensors is: camera, GPS, compass, accelerometer and gyroscope. Fourteen percent of the studies in LBMAR have used camera and GPS sensors, three out of the five studies have been published in the years 2013 and 2014. It can be inferred that other sensors were

Table 3.10 LBMAR systems on year 2017

Year: 2017				
LBMAR systems	Application area	Brief overview	System services	Sensors
CloudAR [32]	Research	A platform to offload AR applications to cloud servers using thin client design and explore its performances	2D and 3D images	Camera, gyroscope compass, GPS, accelerometer
LAGARTO [33]	Entertainment	An authoring tool to build location-based mobile games enhanced with AR capabilities	2D map view, 3D objects	Camera, accelerometer, GPS
Nobrega et al. [34]	Tourism	An AR application based on game mechanics to discover important locations in a city	Storytelling, game mechanics, 2D map view, 3D objects	Camera, gyroscope compass, GPS, accelerometer
de Oliveira et al. [35]	Navigation	An indoor positioning system for wheelchair users using MAR	Bluetooth positioning, 2D map, voice command	Camera, Bluetooth
Özcan et al. [36]	Navigation	An AR application for a smart university campus to visually aid students and enhance their user experiences with proactive services	2D icon	Camera, GPS
Arrowhead [37]	Research	An AR application that conceived on the basis of Wi-Fi positioning	2D icons, text	Camera, Wi-Fi, accelerometer, compass
Wang et al. [38]	Navigation	An MAR system that can detect and recognise multiple image targets and display corresponding 3D AR target	3D images, text	Camera, iBeacon (Bluetooth)
Neges et al. [39]	AECO	An AR system based on inertial measurement unit and live video feed to facilitate the task of maintenance operators inside a building	2D map, 3D images, navigation, text	Camera, compass, accelerometer, gyroscope

not yet introduced or the frameworks were providing limited support to the mobile sensory capabilities at that time. The introductions of compass and accelerometer have contributed to more advanced LBMAR systems, capable of measuring the direction and non-gravitation acceleration, respectively, thus rendering the systems more accurate. The opening of gyroscope on smartphones has further leveraged the quality of LBMAR systems, it has provided an extended support to determine the users' field of view. Fourteen percent of the works studied have included gyroscope

Table 3.11 LBMAR systems on year 2018

Year: 2018				
LBMAR systems	Application area	Brief overview	System services	Sensors
Svevo Tour [40]	Cultural heritage	The system has been built to enhance the visiting experience in a museum by focusing on several add-on features	2D map, 3D images, authoring tool, storytelling, audio	Camera and smartphone sensors
Dangkham [41]	Tourism	Identified POIs are augmented with geographical information and contact numbers that tourists can further use	2D images and text, dialling	Camera, GPS, compass, accelerometer
Yeh and Lin [42]	Research	An indoor AR system based on SLAM algorithm to provide a 3D structure environment	2D and 3D images	Camera, compass, accelerometer, gyroscope
MARBLE [43]	Research	MAR system that uses beacon devices for rendering 3D objects on mobile devices	2D and 3D images, text	Camera, Bluetooth

Table 3.12 Results of unindexed search and filtered papers

Year	Unindexed search	Filtered papers
2013	1030	4
2014	1300	6
2015	1470	6
2016	1610	7
2017	2000	8
Sep–2018	1320	4

Table 3.13 Categorisation of LBMAR systems with sensory devices

Sensors							Number of studies using the sensors	Percentage (%)
Camera	GPS	Wi-Fi	Bluetooth	Compass	Accelerometer	Gyroscope		
Y	Y	–	–	–	–	–	5	14
Y	Y	–	–	Y	–	–	1	3
Y	Y	–	–	Y	Y	–	5	14
Y	Y	–	–	Y	Y	Y	5	14
Y	–	Y	–	Y	–	–	2	6
Y	–	Y	–	Y	Y	–	1	3
Y	–	Y	–	Y	Y	Y	1	3
Y	–	–	Y	–	–	–	3	9

‘Y’ means sensor in mobile device is used. ‘-’ means no sensor in mobile device is used

Table 3.14 Categorisation of LBMAR systems with computing power

Released year	Samsung		Apple		Huawei		Key features
	Model	Processing power	Model	Processing power	Model	Processing power	
2013	Galaxy S4	Quad-core 1.9 GHz	iPhone 5S	A7,M7	Ascend Mate	Quad-core 1.5 GHz	2D images, 3D objects, storytelling
2014	Galaxy S5	Quad-core 2.5 GHz	iPhone 6	A8	Ascend P7	Quad-core 1.8 GHz	2D and 3D object, POI, music, video clip
2015	Galaxy S6	Octa-core 2.1 GHz	iPhone 6S	A9	P8	Octa-core 2.0 GHz	POI, collaborative, 3D view with 2D map
2016	Galaxy S7	Octa-core 2.3 GHz	iPhone 7	A10	P9	Octa-core 2.0 GHz	Tracks, virtual objects, storytelling, AR map, sound
2017	Galaxy S8	Octa-core 2.35 GHz	iPhone X	A11	P10	Octa-core 2.4 GHz	2D and 3D objects, storytelling, game mechanics, voice command
2018	Galaxy S9	Octa-Core 2.8 GHz	iPhone XS	A12	P20 Pro	Octa-core and micro core i7 2.36 GHz	2D and 3D object, authoring tool, Bluetooth (iBeacon) positioning, voice command, navigation

alongside with other available sensors, demonstrating that authors have exploited the mobile sensory capabilities in their works. Thirty-three percent of the works studied have included random combination of sensors that does not provide any further indication in this review.

The next subsection provides a high-level insight of the evolution of the computing power of the commonly used smartphones for MAR. In this review, the top three most used smartphones by brands are considered. As per latest survey report performed by Gartner [45] in 2018, the first three brands which have been dominant in the market are as follows: Samsung, Apple and Huawei. Table 3.14 below lists the common smartphones for each brands in increasing release year and computing power.

The above categorisation provides an inline view of the computing power of the top three dominant smartphones during the course of the year 2013–2018. Clearly, mobile industries have continued their vast developments in offering higher grade smartphones to consumers. Along with this transition, the key features in LBMAR systems during the same period are highlighted. It has been noted that the number of features have gradually increased, therefore demonstrating that new mobile technologies are more capable of handling new services concurrently and offering it to users at very high speed. These features have been conceived intelligently taking into consideration the digital evolution that could potentially augment the experiences of users and engage them more into AR technology. Additionally, the performance of these features significantly improved with the increasing computational power. For example storytelling feature requires a benchmarked processing power to support the load. Game mechanics is the trending feature in LBMAR, but it necessitate a good processing and memory power to execute.

Table 3.15 below provides a descriptive list of the common challenges of LBMAR systems. The challenges will be assessed with the above defined application domains for a full review.

The above list of challenges has been derived from the reviewed papers taking into considerations the factors that can affect the workability and functioning of LBMAR systems. Each of the reviewed application domains are assessed against the above list of challenges on Table 3.16 to provide a better understanding on the improvement that these systems can focus on and further enhance the fields of LBMAR.

RQ 3: What are the innovative application domains for LBMAR systems and their related challenges?

Table 3.16 provides a detailed evaluation of the application domains with the derived list of challenges. Accuracy and precision are the key drivers for an LBMAR systems, and the right information should be provided at the right place to keep the users interested. In fields like education and marketing, accuracy is not of high importance because their coverage area is subdivided into point of interests (POI), and they can afford a small margin of error. Given the nature of LBMAR systems, the processing should be near real time to continuously provide new information

Table 3.15 List of LBMAR challenges

Challenges	Description
Accuracy	Accurate registration and tracking between AR objects and real objects
Performance	The processing should be within a reasonable time-delay to allow a seamless AR experience
Interaction	The AR interfaces should be in constant change with respective to the dynamics of the environment
Visualisation	The computer-generated AR should reflect the resolution of the AR objects
Alignment	The proper alignment of the virtual object to the real world
Mobility	The ease to use the system in complex environments
Interoperability	Augmentation should be uniform taking into consideration the varying characteristics of mobile devices
Security and privacy	The authenticity of the generated contents should be validated. Location-based information should be handled with care
Flooding of information	The amount of AR-generated contents should be within a threshold to allow a more enhanced experience

Table 3.16 Application domains v/s challenges

Application domains	Challenges								
	Accuracy	Performance	Interaction	Visualisation	Alignment	Mobility	Interoperability	Security and privacy	Flooding of information
Construction	Y	–	–	Y	Y	Y	Y	–	Y
Training/education	–	–	Y	Y	–	–	Y	–	Y
Facility management	Y	–	–	–	Y	Y	Y	–	Y
Tourism	–	–	Y	Y	–	Y	Y	Y	Y
Navigation	Y	Y	–	–	Y	Y	Y	Y	Y
Medical	Y	Y	–	–	Y	Y	Y	Y	Y
Cultural heritage	Y	–	Y	Y	–	–	Y	–	Y
Marketing/ advertising	–	–	–	–	–	–	Y	Y	–
Entertainment/ gaming	Y	Y	Y	Y	Y	Y	Y	Y	Y

with respect to the users' contexts. In this perspective, the performance should be constant in following application domains: medical, navigation and gaming. Interaction and visualisation are the secondary features that can be proposed to extend the augmentation layers. They can be used in important fields such as education, tourism and cultural heritage to assist users to understand complex object easily. Recently, the construction and facility management sectors are increasing to adopt LBMAR in order to further improve the quality of their activities. In these scenarios, the proper alignment of the AR objects and real objects should be maintained so that correct management decisions can be taken. The portability and mobility of LBMAR systems are critical to their good functioning, their importance to almost all application domains. For example on a navigation case scenario, the system should work uniformly under varying environmental characteristics. Moreover, the accessibility of such system should not impact the consumer since it should work in commonly available smartphones. Interoperability ensures that the systems can function in different mobile devices having similar or dissimilar properties. Security and privacy is another challenge that developers are facing while dealing with users' data. Location information are very sensitive, and users may not desire to share it with everyone. It is an application domain where users may exchange information to the system to get personalised contents, for example in fields such as tourism, gaming, marketing and medical. Flooding of information is a new issue that many users have reported, a proper trade-off of textual information and AR contents should be achieved.

RQ 4: What are the latest advances in the techniques used in LBMAR for real-time positioning, AR object positioning and AR object retrieval?

In this section, the research question is broken into three subcategories. First of all, the recent techniques used for real-time positioning will be investigated. With the emerging sensory devices in smartphones, the recent positioning techniques are maximising on the use of available sensors to provide a more real-time positioning experiences to the users. GPS is used commonly in most of the LBMAR systems because of its simple and flexible integration to MAR applications. However, it also presents several limitations to work under different environments due to loss of signals and lack of accuracy [46]. For example the evolution of the work in AREA from version 1 to version 2 has brought improvement on its initial positioning design. AREAv1 used only GPS, whereas AREAv2 employed GPS with Earth-Centered, Earth-Fixed (ECEF) and East, North, Up (ENU) coordinates to achieve a more accurate and precise positioning system. The case is totally different in indoor environment, and some authors have reused existing infrastructure to locate users and objects. INSAR [19], The Buildings Speak About City [23], IntelligShop [25] and Ramtohul & Khedo [47] are among the studies that have exploited the fingerprinting technique using existing Wi-Fi infrastructure. The adaption of Wi-Fi and Bluetooth infrastructures to LBMAR systems is still in its infancy state, more investigation is required on their potential integration to such systems. In addition, pattern of movement is another potential subject that can be exploited in LBMAR system, a pattern is derived based on the users' past location histories and suggests interesting POIs to them. MOIAR [9] and ReadMe [28] are among the few studies that have modelled it, but there were no mention of how they could be implemented in different contexts.

Real-time user positioning is an important operation for LBMAR systems, but given the nature of LBMAR systems it is not sufficient to provide only user positioning and neglect other aspect such as AR object positioning. A perfectly inch-aligned AR objects would undeniably enhance the user experience. Many authors have added the concepts of orientation and direction in their works to provide a more real-time interaction. Basically, orientation will determine the user's field of view thus focusing on the subject area while direction will filter on the best candidate objects. Yeh and Lin [42] have used plane fitting method to attach AR contents to the object on its nearest point. Marble [43] has employed Kalman Filtering technique on both the user's position and user's field of view to achieve a more accurate AR layout. The human detection in MIRAR [48] was indeed challenging and complex, the authors have used a convolution neural networks that could identify human shapes in live video feed. In view to achieve this level of accuracy and precision, most of the reviewed works have fused mobile inertial sensors to work in LBMAR systems. However, mobile sensors consume high amount of battery and noise jitter can lead to many inaccuracies. These two challenges can further be exploited by researchers in this field to have a more fluid AR experience.

The database of an LBMAR systems can be very bulky since it contains the surrounding objects of interest. Special attention is required during the searching and retrieval process because a very minimal amount of time is allocated for this task. Users should feel a real-time interaction between the AR objects and the real objects. The term POI is referenced in many reviewed works, and this has assisted many designers of LBMAR to carefully build their database indexed with the POI field. Schickler et al. [49] have integrated POI and track features in their AR framework. The track functionality connects the POIs to form a path that the users can walk along the way. LeeceAR [21] has implemented the RANSAC algorithm to match the live camera feed with the offline data to retrieve the best-fit result. Readme [28] has twofolded techniques, it first assigns a weight to the filtered AR objects and then cancels the false matches with nearest neighbor search. Other systems have used SIFT, SURF and SLAM for searching and retrieving AR contents.

3.6.1 Future Research

The following existing gaps and needs in LBMAR research were derived from the findings of this research. The review was limited to only six databases because of their highest impact factor. As LBMAR is still in its infancy state, other databases can be included.

Lightweight: Advances in mobile computing have certainly supplemented the new implementation of the LBMAR systems, but the lightweight aspect is often neglected. New research should be carried out on the different lightweight strategies that can be employed in LBMAR. The introduction of new sensors has significantly enhanced LBMAR systems, but a review on the energy consumption by the inertial sensors can be carried out to see how to provide a much extended AR experience.

Real time: Most of the LBMAR systems have focussed in providing their localisation services at users' requests only. As a consequence, more manual intervention is required from users' side as they should locate themselves manually on the system. In addition, they will have limited time in their enjoyment and will not be able fulfil their AR experiences to their expectation. This will not only degrade their experiences but also take a huge leap against their engagement towards LBMAR technologies. On the other side, the reliability of such systems can be compromised if the users' locations are not tracked and the inputs are incorrect, thus heading towards to real-time positioning.

Accuracy and Precision: Together with real-time positioning, orientation is another area of subject that should be further exploited. Existing systems have not catered for orientation in their approach, but their presence is significant to the proper functioning of LBMAR systems. Orientation will take care of the users' field of view, and it is important with respect to the projection of AR images syncing the images correctly with the real objects.

Flexibility (Environment-Free): Most of the LBMAR systems have been conceived to a specific environment, therefore limiting on their own approaches of collections, groupings and arrangements. Therefore, more research should be carried out to achieve a flexible LBMAR system that could work in varying environmental characteristics.

Gamification and Collaboration: These two aspects can be further expanded on the current LBMAR landscapes to provide a real-time interaction between the users so that they can enjoy their AR experience.

In some literatures, the desirable characteristics of LBMAR conflict with each other. For example pervasive can be perceived as intrusive or vice versa. In this case, a more granular characteristics can be derived to categorise the systems. All the reviewed works in this chapter considered both indoor and outdoor environments, and further review can be carried out focusing on only indoor or outdoor environments.

3.7 Conclusion

In this chapter, a thorough review of LBMAR systems using a systematic approach has been carried out. Though LBMAR is still an emerging area, it can noted that it is growing and becoming very appealing to the general public. During the years, Marker-based and Marker-less MAR applications were dominant in the market because of their easy setup and configuration. However, they poised serious drawbacks in solving the resource-constraint issue of mobile and the varying environmental characteristics. Taking into consideration the localisation capabilities that have been phased in, LBMAR has significantly improved the AR experience of users. Additionally, with the rapid technological advances, it is expected that

LBMAR systems will continue to rise and will be more accessible. Summarising the review, it can be concluded that the number of LBMAR systems have increased from year 2013 to 2017. The increasing mobile computing power has made a positive impact on the accessibility of LBMAR systems. Openings of new mobile sensors have enhanced LBMAR and brought new features to assist users effectively. Recently, gamification has become a very popular application of LBMAR, and most of the authors are incorporating it on their systems. Furthermore, awareness and knowledge is among the characteristics that is most widely used. Cultural heritage is the application domain which adopted LBMAR mostly. Among the challenges, flooding of information should be urgently addressed.

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Chapter 4
Innovative Natural Disaster Precautionary Methods Through Virtual Space

S. Surya and Sagaya Aurelia

4.1 Introduction

Human–computer interaction, as shown in Fig. 4.1, is the study of human and computer interaction which creates an interface between human and computer in order to communicate, understand, and analyze and the feasibility to interact with the computer which changes the way of the usual lifestyle that can evolve the future generations according to the human's convenience.

4.2 Virtual Reality

Virtual reality technology is an insightful three-dimensional computer-made environment happening inside a replicated circumstance. It combines in a general sense sound-related and visual analysis, however, may moreover allow various types of precise info like haptic. This striking condition can resemble this present reality or an energetic environment. These frameworks of VR layer virtual information in a mobile phone with a head-mounted display or specialized head-mounted display specially designed for empowering the customer to see a virtual world in order to interact and learn [1–5].

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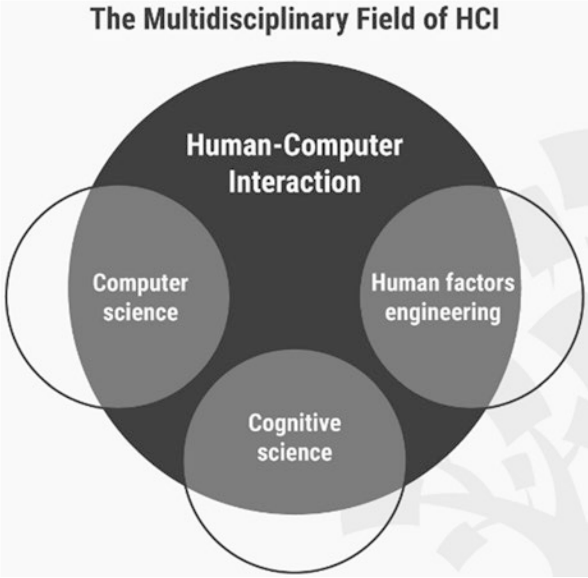

Fig. 4.1 The multidisciplinary field of HCI

Current VR development most typically uses computer-created reality head-mounted display or multi-foreseen conditions; the environment created is mostly on the physical, situational environments or experiments that provide the users an experience of realistic engagement with the surroundings, sounds, and eclectic vibes that turns a person's physically present experience in a virtual or non-existent condition. A person can experience VR-produced reality using a head-mounted display and can look around almost 360° and engage and interact with the virtual world environment. The block diagram of virtual reality is shown in Fig. 4.2. The effect is experienced only with the head-mounted display where the user can see through the display and experience in like manner that is made through by giving the user interaction with the virtual world with sound effects. These VR frameworks are enabled through vibrations and sensations; also, where the user experiences reality, this is mostly incorporated widely in video gaming applications [6–9].

4.2.1 Working of Virtual Reality

- Capturing:
- A multi-camera setup is done to capture the virtual reality video, which is raw to simulate a 360-degree view of the virtual world.
- Preprocessing:
- The virtual reality raw video is ready to preprocess in this stage. The raw video is now filtered by making what content to be shown in the 3D environment by

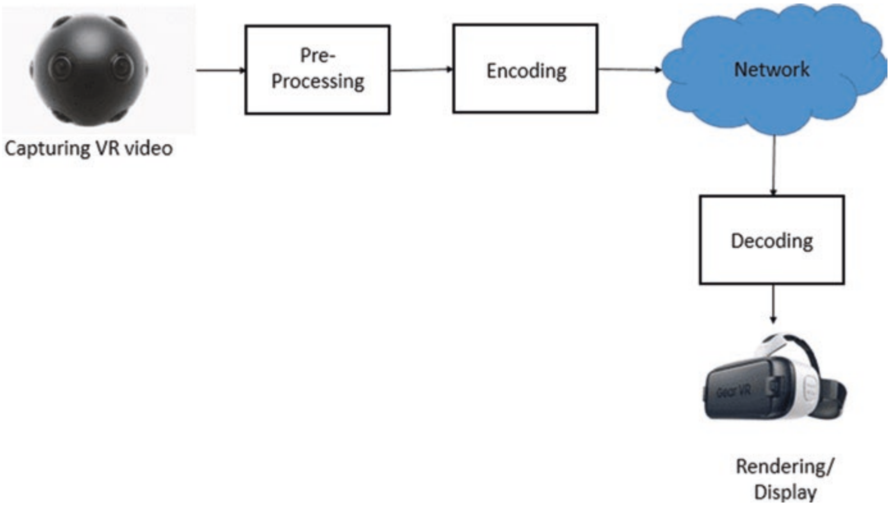

Fig. 4.2 Block diagram of virtual reality

editing and formatting concerning what content to be shown and many more operations in making the video.

- Encoding:
- After the virtual reality preprocessing, video is now made to compress or encode to efficiently store the data and stream the data for future use.
- Transmission:
- After the encoding process, the compressed data is transmitted through the network to the user, allowing the user to use the compressed data to interact with the virtual world through virtual reality devices.
- Decoding:
- After the transmission of the compressed data through the network, the data is now decoded with the decoder that is built in the virtual reality devices.
- Rendering:
- After decoding the data, the video is now rendered to the user's VR device by displaying the 3D environment's contents for the user to interact and perform actions based on the scenarios produced.

4.2.2 Key Features of Virtual Reality Technology

1. Virtual Environment

   A virtual environment is a three-dimensional environment created to interact with the computer-generated 3D environment where the participants can communicate with objects within the virtual environment and perform actions based on the scenarios. In a virtual world, it replicates the real world and allows the user to interact with the help of devices associated with the virtual world.

2. Immersion

   Virtual reality immersion assumes being present physically in a virtual world where the real world is replicated as a nonexistence environment. It includes a sense of touch, sound, and vibrations as well in order to make the user understand that, though the environment that is surrounded by the user is not real, by providing the senses of touch, sound, and vibration, we can make the user experience the environment as a real one by incorporating some interactions. Therefore, it is indispensable to create such an environment to make the user assume that it is a real-world replica. The immersion is divided into two types:

   - Mental immersion: A mental immersion makes the user immerse in the virtual world thoroughly so that the user is totally engaged with the environment surrounded by the user. Since it is authentic, the user mentally involves the environment and reacts accordingly.
   - Physical immersion: A physical immersion makes the user immerse in the virtual world thoroughly by enabling the user to interact with the virtual world with the sense of body movement where the user can move around as if he is actually inside the virtual world and react accordingly based on the scenarios that are produced in the virtual environment [6, 10, 11].

3. Sensory Feedback

   Virtual reality is not just about creating a user interface with the virtual world environment to interact; it is also about enabling the user to control the virtual world in which he/she is reacting according to scenarios produced in the virtual world. Therefore, it is essential to have sensors that give feedback on how the user reacts based on the scenarios that are produced in the virtual world. Hence, these sensors include senses such as vision, hearing, touch, vibrations, and many more. Incorporating such senses to the user makes the user engage in the virtual world and makes he/she feel that they are literally inside the virtual world and gives the user a thrilling experience of using virtual reality. This feedback can be sensed using some software and hardware like head-mounted display (HMD) and gloves.

4. Interactivity

Virtual reality can be made more exciting by incorporating interaction within the virtual world. Interaction is not just about moving the head and seeing the virtual objects present in the virtual world but also about interacting with the virtual world based on the virtual world environment's scenarios. Virtual reality makes the user more excited and enjoyable only when the user is wholly involved with the environment, and this could be made possible by allowing the user to interact directly with the scenarios provided inside the virtual world. This could sometimes be made verbally or using some input devices.

4.3 Natural Disasters

Natural disasters are sudden events that occur naturally due to some inconvenience in the Earth's natural habitat. Natural disasters destroy natural landscapes as well as cultural landscapes. These calamities are not preventable by humans though scientists can predict the upcoming calamity, sometimes it is not possible to predict, such dangerous are these natural disasters. The natural disasters cause damage not only to properties that comes in its way but also to the precious human lives. Because nature is not only meant for animals alone or humans alone but both. The primary reason for natural disasters is because of the human's involvement in the developmental activities resulting from this engagement of humans in the environment; humans neglect the consequences that are upcoming towards them. Because of deforestation, it causes floods, soil erosion, etc.

Similarly, the overutilization of resources, destruction of the natural landscape, and exposing harmful chemicals and gases to the atmosphere also result in natural disasters. They have witnessed that the major causes of natural disasters are due to global warming. Therefore, it is essential to balance both the natural landscape and cultural landscape equally. Though in the future generations of human development increases population and expansion, we need to control our natural environment as well to survive a peaceful life.

Different types of natural disasters, as shown in Figs. 4.3, 4.4, 4.5, 4.6, are:

1. Earthquakes
2. Tsunamis
3. Floods
4. Forest fires
5. Landslides
6. Volcanoes
7. Avalanches
8. Tornadoes, etc.

Fig. 4.3 Earthquake disaster

Fig. 4.4 Flood disaster

Fig. 4.5 Tornado disaster

Fig. 4.6 Tsunami disaster

4.3.1 Causes of Natural Disasters

Many disasters depend upon different landscapes and different reasons. The primary reason for natural disasters is basically because of the imbalance maintained in the Earth's environment, such as air pollution, soil pollution, noise pollution, and water pollution; even all these encompass the causes of natural disasters. Though humans are also one of the reasons in causing the natural disasters, they are not alone involved in the process of this cause; sometimes disasters like earthquakes, tornadoes, tsunamis, and floods occur naturally even when people are away from the natural landscape, so it is not possible to blame humans alone as well.

Natural disasters are because of the activities that happen inside the Earth's crust and the surface. The earthquakes are the seismic activity, which also provokes the volcanoes and other events such as typhoons. The other reason for natural disasters is that the continents sit on the plates that shift based on the Earth's movement. When such a shift happens, it causes increased pressure in the Earth underneath the surface, which can also result in disasters such as earthquakes. Even when there is a shift in the tectonic plates, there is a possibility of experiencing an earthquake. Sometimes an earthquake depends based on the moon's activity as well. It was witnessed that the Tsunami which occurred in December 2004 was also because of the full moon. The changing ocean currents are also reasons for natural disasters. The tornadoes are often because of the collision of high- and low-pressure winds, which cause a significant damage loss of lives and properties about that region or area. Though we can avoid natural disasters by staying away from the regions that frequently occur, the system cannot guarantee that the damages can cause the damages because these reactions with the environment are unpredictable and unavoidable. Due to such an imbalance in the natural environment, it was essential to preserve the natural resources by taking precautionary methods by just staying away from it and growing and maintaining a healthy environment [12–14].

The main objective is to provide precautionary measures in order to prevent natural disasters by engaging the user into a virtual space to interact and react according to natural disasters scenarios produced in the 3D environment so that the survivor will have an idea about how to react and protect themselves from the upcoming or ongoing devastation that causes for the damage of lives and properties. Though there are precautionary measures given manually because of the fear of the upcoming natural disaster, we sometimes forget to react correctly. Therefore, it is better to be prepared before the disasters rather than risking lives in a disaster situation.

4.4 State of the Art

For the community, a simulated calamity practice should clarify evacuation approaches and measures. Evacuation training via a simulated evacuation training system (SETS) is familiarized since everybody essential efficaciously vacates once a disaster occurs and is familiarized by Hiroyuki Mitsuhara [15].

In outmoded evacuation exercise, partakers simply trail a static path in normal circumstances. Nevertheless, this type of removal exercise includes slight immersion and fallouts in a negligible outcome since partakers barely had the impression that they are in a disaster state. It is indubitable that VR knowledge can be used to convincingly existing disaster circumstances and intensify the side by side of immersion.

For instance, Smith and Ericson [16] captivated on fire security for children and established a game grounded on a cave programmed virtual milieu that heartens players to take appropriate physical activities throughout the evacuation. Chittaro and Sioni [17] technologically advanced a VR-based desktop game in which cast lists can acquire how to relinquish extremist outbreaks while in receipt of directions about appropriate choices and intensify their effectiveness for existence.

Lovreglio et al. [18] deliberated an HMD-aided game that entails cast list to evacuate from an earthquake scratched hospital while networking with an altering atmosphere and numerous negotiators. VR-grounded calamity simulators that do not emphasize gaming fundamentals can also excellently assist individuals in being stayers. For illustration, Sharma et al. [19] established a VR-based fire simulator that imagines fire and troops in a subway position and generates a multi partaker SEE. Gong et al. [20] formed an earthquake simulator that uses motion-tracking instruments and generates an automatically operable SEE based on virtual reality.

A proportion of understandings with tall recital computing and calculating ordinary calamities submissions like big fires and landslides are instigated on a day-to-day basics [21]. 3D model of fire administration was formulated, and the claim is that computing in grid milieu was applied [22]. Subsequently, numerous web-service outlines (Kandaswamy) [23] (Krishnan) [24] have been premeditated and implemented in the edifice realm-precise science gateways.

4.5 Proposed Model

The model's proposal is a virtual reality framework that allows the user to access the training simulation with a head-mounted display using mobile technology that helps to access the virtual reality contents from the network to the virtual reality devices, the head-mounted display. The trainee or the survivor undergoes training by specific procedures; first, the trainee has to wear the head-mounted display on the head, next the virtual contents are produced in the head-mounted display from the network and allowed to project the virtual world contents through it and based on the scenarios that are produced according to the natural disasters. The reason behind bringing up mobile technology is the excessive use of smartphones in this generation. Though many of the applications are made manually, this generation and future generations are intended to use the trending technology as there is development in the technology that has made the users utilize such technologies by reducing human effort in cost and energy. The proposed model works with mobile technology over the network; its contents consist of six main components about the 3D environment in the head-mounted display as follows.

4.5.1 The Type of Natural Disaster

In this phase, the user can choose the natural disaster that the survivor wants to experience in a virtual world to learn and understand the precautionary measures that must be taken at a particular natural disaster situation.

4.5.2 Environment

In this phase, the environment is set according to the survivor's landscape, natural landscape, or human landscape. For example, if there is a flood, the environment could be anything that is; it could be either a natural habitat where the flood affects the nature such as plants, trees, and the soil of the forest or a city where the flood affects the buildings and other properties as well.

4.5.3 Training

When the natural disaster type and environment are set, now the survivor is instructed about how to go and interact with the natural disaster scenario with some precautionary measures. A demonstration of what needs to be done and how to react to such situations is explained in this phase.

4.5.4 Precautionary Measures

Since it is very much necessary to save the lives of the people, we need to understand and follow a set of instructions that are mandatory to follow in order to protect ourselves from the upcoming and the ongoing natural disasters which cause loss of lives and properties; therefore, such instructions and precautionary methods are demonstrated in this phase as shown in Fig. 4.7.

4.5.5 Scenario Simulation

After the demonstration of the training, precautionary measures, and instructions required to follow under the natural disaster situation, a replica of the actual natural disaster inside a 3D virtual world is generated to experience a scenario of a natural disaster react associated with it.

4.5.6 Trainee's Interaction

After completing the two phases of training and precautionary measures, the user can experience the natural disaster scenario, where the user can perform actions and react according to the scenarios produced in the virtual world.

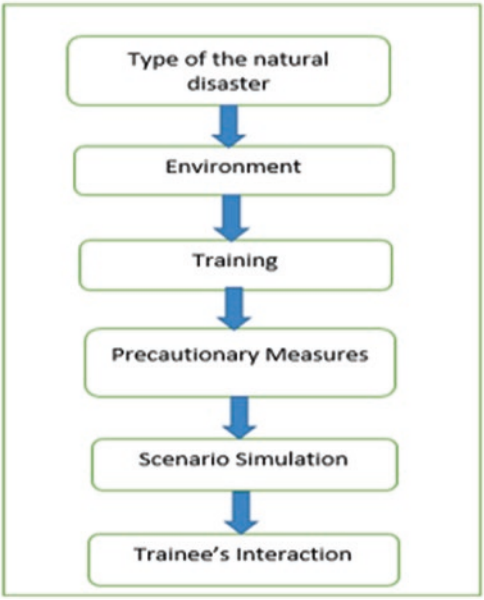

Fig. 4.7 Block diagram of the model

4.6 Result and Discussion

According to the International Disaster Database (IDD), the statistics about the various natural disasters recorded globally, depending on the type of natural disasters included concerning weather and seasons from 1970 to 2018, have been recorded. According to this statistic, the number of natural disasters that had occurred during the years has been noted to know the natural disasters' conditions over the year to be aware of the anyways upcoming disasters. This dataset describes about the various disasters that had occurred globally over the years concerning the number of occurrences and various natural disasters such as earthquake, flood, wildfire, extreme temperature, landslide, volcanic activity, drought, extreme weather, and mass movement, and the number of death rates occurred in natural disasters are shown in Figs. 4.8 and 4.9.

In the current generation, people are fond of using smartphones than any other technology, as everything is available within the smartphone. The only way to make people aware of technology is to bring about mobile technology as affordable and operable through the network. It is not just about having a smartphone; it is also necessary to use technology to the best. According to the statistics of smartphone users in the world from 2014 to 2020 and with the number of smartphone users concerning billions, it was predicted that smartphone usage would drastically increase by the people in the future in billions as new technologies are incorporated within the mobile technology itself.

We analyzed the results with nonparametric statistics by presumptuous and impulsive populace circulation. Table 4.1 shows the medians and means ranks of the partakers' evacuation times. For the first SETS, the medians were alike among the groups; variance analysis revealed no significant variances. For the second SETS, the medians of groups A and B were the highest and the lowest, correspondingly; on the root of numerous comparisons, a significant difference was found between group A and group B.

Table 4.2 shows the medians and mean ranks for requests on the survey. The opinion poll mostly asked about the partakers' immersion in the SETSs from the viewing platform of reality and pressure. If the pressure is felt, participants can be regarded as being immersed in the SETS.

4.6.1 Simulation Process

Table 4.3 shows the number of answers to the inquiry for each cluster and SETS.

In the post-disaster questionnaire stage, partakers were obligated to define the teachings they educated. Table 4.4 demonstrates their characteristic teachings and the number of partakers in each group who answered that they had educated the experience.

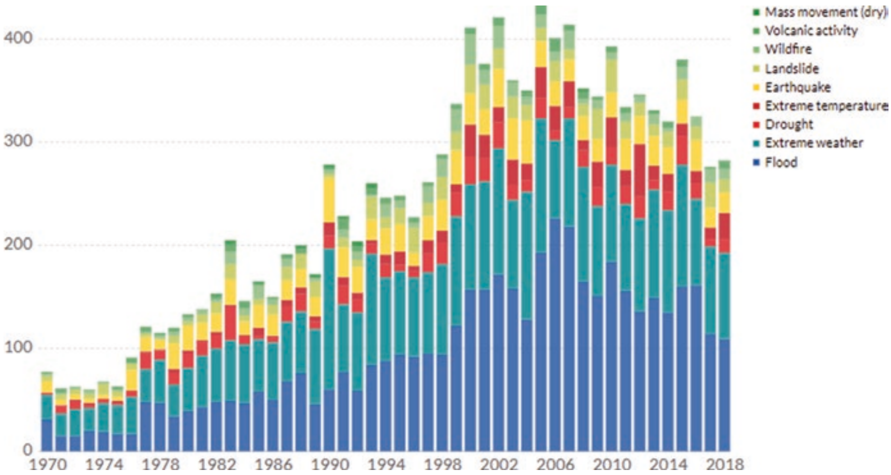

Fig. 4.8 Graph of the number of global natural disasters

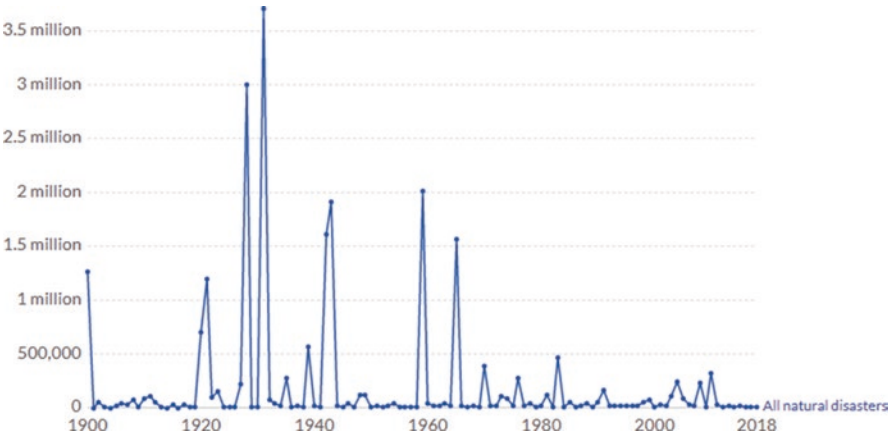

Fig. 4.9 Graph of the number of death rates in natural disasters

Table 4.1 Medians and mean ranks of evacuation times

	SETS-A	SETS-B
	Med., s	Med., s
Group A	108.5	153
Group B	122	96
Group C	118.5	114

Table 4.2 Medians and mean ranks for questions

Question: "Do you agree that …?"	Group A	Group B	Group C
Options: 1 = definitely no, 2 = no, 3 = neutral, 4 = yes, 5 = definitely yes	Med.	Med.	Med.
I felt the first replication was genuine	4	4	4
I felt stiffness in the first replication	3	3	3.5
I felt it was genuine during the second simulation process	4	4	4
I felt a bit nervous during the second simulation	3.5	3	3
I had very high inspiration in disaster management during both the two	4	4	4

Table 4.3 A total number of answers about reality during emptying in SETSs

Question: "In which SETS did you evacuate more dynamically?"			
	First SETS	Second SETS	Both SETS
Group A	7	3	0
Group B	3	6	1
Group C	7	1	2

Table 4.4 Distinctive teachings learned

Categorized lessons	Group A	Group B	Group C
We should not essentially trail others in adversities	3	3	4
We should relinquish instantly in infrequent circumstances	4	3	1
We should distinguish alternative exits and evacuation routes in prior	1	4	1
We should swiftly crisscross on disaster circumstances	3	1	0
Other	1	1	6

4.7 Limitation

The limitation of using virtual reality technology in natural disasters is that we need to create such a 3D environment for the survivor to interact with the environment freely by moving and pointing according to the scenarios produced in the virtual world. Though it has the advantage of training the survivor, it is also necessary to think about how it is used and who the users of this technology are. Though it can be used effectively, there is an age gap between the users who use it. The younger generations would be more excited about the new technology to use it. However, for the age groups of older generations, it would be more complicated because, for the younger generations, it would be more enthusiastic and excited to use, as this generation users are very much used to in using the trending technologies. However, when it comes to the older generations, it becomes hard for them to accept the new technology as they are not used to it. Sometimes it takes time to get used to it, or otherwise it is unacceptable because of the inexperience of using virtual reality technology.

4.8 Future Enhancements

The future is more exciting and helpful in understanding the concepts and experiments concerning virtual reality; therefore, to utilize such technology, we need to make it more interactive and improve the video's quality so that the user does not feel like he is just in a gaming world. Also, the most essential thing concerning technology is that we need to create a more expanded version of the 3D environment; that is, we need to expand the space in the virtual world to move freely and react to different situations that are upcoming in front of him/her because the survivor can learn more effectively by moving around the virtual world to experience more real-life experience that involves the user mentally into the world that engrosses the user more depending on the natural disaster scenarios that are produced to interact.

4.9 Conclusion

The agenda is to create a virtual reality framework for the natural disasters that are associated with mobile technology over the network, where the users can undergo training in order to prevent the loss of lives by providing precautionary measures through the 3D environment or the virtual world, where the user actually first experiences the virtual world by understanding what needs to done, instructions, and precautionary measures that are required to follow at the time of natural disasters. The trainee is next trained with the instructions, and then the scenarios are produced according to the type of natural disasters and environment and are projected through the head-mounted display so that the trainee reacts and interacts according to the scenarios that are produced inside the virtual world. By the help of virtual reality in such natural disasters, it can make people aware about how to react according to the situation based on the natural disasters and prevent them from the attacks of such natural disasters without risking their lives, which can also create a significant impact in the people's precious life by protecting and saving themselves from danger.

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Chapter 5
Internet of Things: Immersive Healthcare Technologies

A. Vijayalakshmi, Deepa V. Jose, and Sarwath Unnisa

5.1 Introduction to Internet of Things

Internet of Things is the emerging technology, a paradigm where objects and humans will be interconnected with the environment. The Internet of Things is growing rapidly as it is being used in several industries such as manufacturing, healthcare, service sectors. The Internet of Things is built on a simple concept of connecting all things to the internet. When a thing is connected to the internet, it can send and receive information which makes the things smart. The architecture of IoT is formed by three layers which is sensor layer that is responsible to take the information from the objects in environment. Next layer is the transmission phase which is done by network layer to communicate knowledge. The last layer is processing and utilization phase that interprets the data for final users. There are various communication technologies used in IoT. The most used technologies are RFID (Radio Frequency Identification), WSN (Wireless Sensor Networks), and NFC (Near Field Communication). RFID technology came into existence rapidly as it is used for identification of objects. RFID contains a tag to identify any object, when it is attached to the item. This happens in communication layer. There are two types of tags and they are active and passive. Active tags are equipped with battery and passive tags without battery. WSNs consist of a large number of sensors that can get and send the data along with processing it from an external environment. NFC is a technology that is known to be proximity specific, where communication takes place only by bringing two devices into contact. Lastly, the processing phase or the application layer will allow the information to flow and also it will be analyzed.

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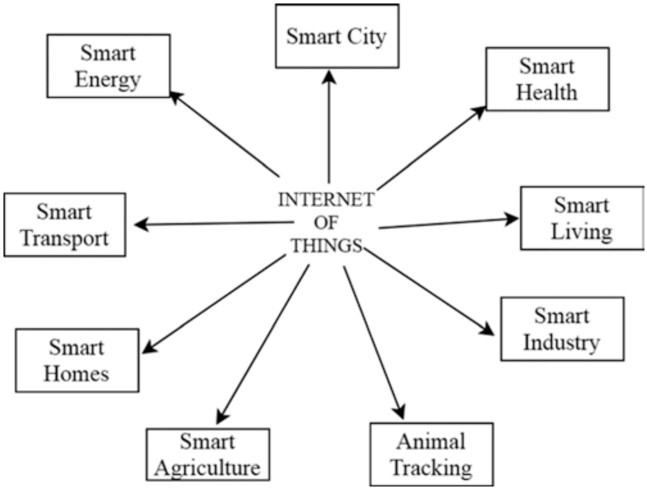

Fig. 5.1 Use cases of IoT [2]

Technologies at this phase are mainly oriented on software tool allowing managing data and extracting effective knowledge from them [1]. These IoT technologies are being used by many fields so as to reach maximum use. Figure 5.1 shows the various use cases of Internet of Things.

5.1.1 IoT Ecosystem and Its Components

The IoT ecosystem consists of components which allow all types of consumers, government, and businesses to connect to the IoT devices. The ecosystem is made of remotes, networks, gateways, analytics, security, dashboards, and data storage. Figure 5.2 shows various components in IoT.

The thing in the context of IoT is any physical object that holds a unique identifier and which can transfer data over a network. A gateway manages the traffic flow from protocols and networks. It acts as a bridge between the sensors and the cloud. It connects devices to sensors, preprocesses the data from sensors, and sends it to the next level. Good encryption is also provided by using new encryption techniques during data transmission. This provides an added amount of security as it acts as an extra layer between cloud and devices. It allows easy flow of data and this is very important in TCP/IP protocols. The data obtained from sensors and devices is in analog format. This data is then converted into an easy way that can be read and analyzed. One of the main highlights of this layer is that it provides real-time analysis of data which is done by checking if any irregularities are taking place, this will prevent further scam and loss. This helps in the prevention of attacks which enhances security as well as prevents from leaking of data. Analysis of data is used by

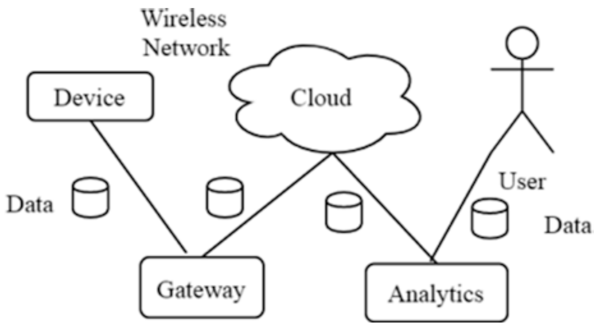

Fig. 5.2 IoT ecosystem [2]

companies to see their future opportunities. This helps the companies to set a future trend. Data is a very strong term that can either make or break a business.

The things connected in IoT generate a huge amount of data and cloud computing enables this data to travel and this can be stored for further analysis which is very crucial. Once data is collected from the devices and sent to the cloud, the data is processed by the software. This analysis of data can vary from simple temperature check to complex problems like video analysis using computer vision. The user interface plays an important role in interacting with the end user to delivering the information. Receiving spontaneous notification, monitoring information continuously, and controlling the overall system remotely are some of the ways in interacting with IoT solutions. Connectivity, simplicity, and performance are some of the important terms to be kept in mind while designing a UI for IoT. IoT is considered as the most recent progress in technology. The need for developing something new is growing rapidly with time [2].

5.2 Architecture of Internet of Things

As seen in Fig. 5.3, the IoT domain is spread across low-power network working protocols such as ZigBee, zwave, and Bluetooth. The protocols which are traditional in nature such as Ethernet and Wi-Fi are also part of the IoT domain. These protocols all have unique features and are designed according to the domain applications. The above figure is the basic present state scenario of any IoT working application or device [3].

There is a distributed architecture for IoT, in applications belonging to IoT, and numerous services are merged which contains no human/minimum human assistance. Similarly, in this IoT infrastructure, it has been grouped into three layers such as Virtual Object Layer (VOL), Composite Virtual Object Layer (CVOL), and Service Layer (SL) (Fig. 5.4). These layers help in object virtualization, service arrangement and implementation, and service formation and management separately.

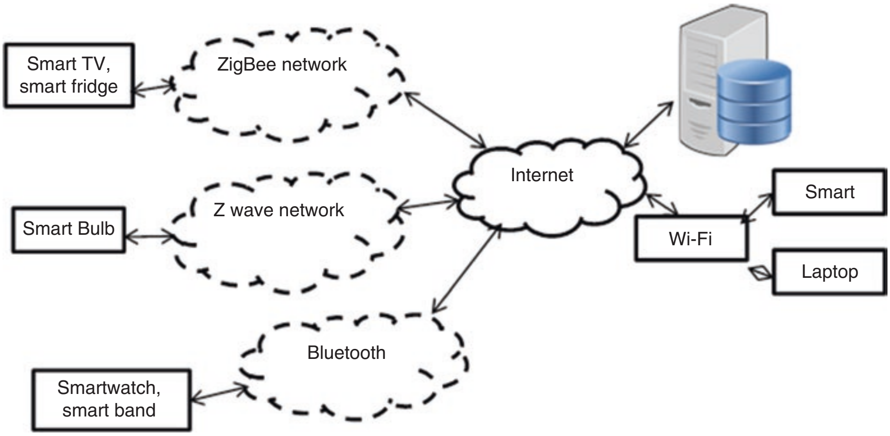

Fig. 5.3 Present state IoT network architecture [3]

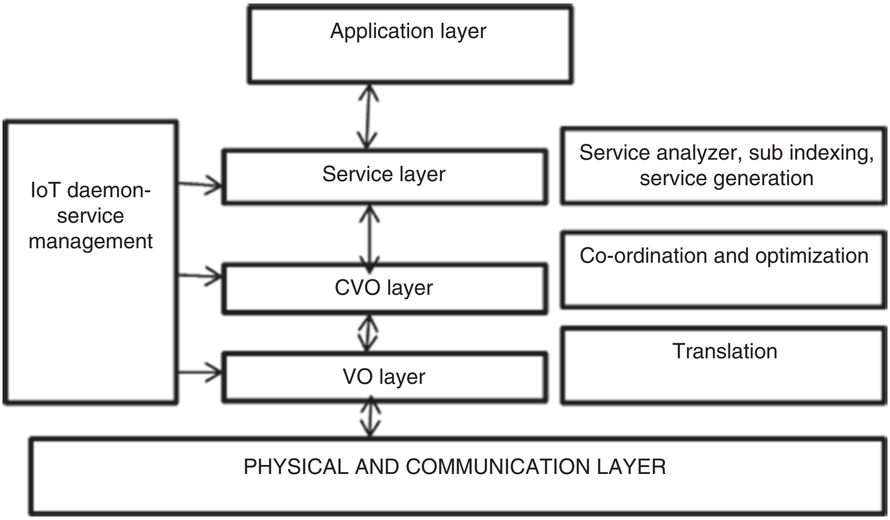

Fig. 5.4 Layered architecture of IoT [4]

The IoT daemon is responsible for performing security and privacy policy. This is handled by the security management (SM) [4].

- Virtual object layer (VOL)
  To virtualize the physical objects, VOL is in charge. It represents the physical objects from the real world; these are called as the virtual objects. It also closes the gap between the virtual and physical world [4].
- Composite virtual object layer

Since virtual objects' responsibility is limited to the particular physical object, CVOL will help to fulfill this gap as many physical objects come together to perform one task. This will help them to communicate with each other [4].

- Service layer
  This layer is held accountable for all the services and management of these services. It handles the services automatically and manually as well from the users. Whenever a task is obtained, it will divide this task into many sub tasks and also it will decide on how to assemble these sub tasks after results have been obtained [4].
- Security management
  This is used for addressing all queries regarding security and its management. The other main work of this module is to check the usage of the data and resources [4].
- IoT daemon
  All the layers together form the IoT daemon. It has cognitive abilities. A proper IoT daemon will contain all the above layers, but sometime some small devices such as few sensors cannot contain all the functionalities and hence some features may be missing [4].

Whenever a service request comes, data is obtained from many virtual objects and combined. This is done in CVO and service layer. Because of the layered architecture, lower layers are capable to communicate with the upper layers therefore establishing a good architecture [4].

5.3 Internet of Things in Healthcare

IoT in healthcare is applied to many fields which include elderly care, checking for chronic diseases in patients and maintaining personal health. To understand IoT in healthcare, this has been classified into services and applications. Further, the applications are divided into single and clustered condition which respectively means a condition for a specific individual and condition encountered by a specific group (Fig. 5.5).

5.3.1 IoT Services

There is no standard definition of IoT healthcare services as different healthcare providers provide varying services. These services incorporate notification administrations, resource sharing administrations, internet providers. The simple, quick, secure, and low-power disclosure of gadgets and administrations can be also be considered as essential IoT services.

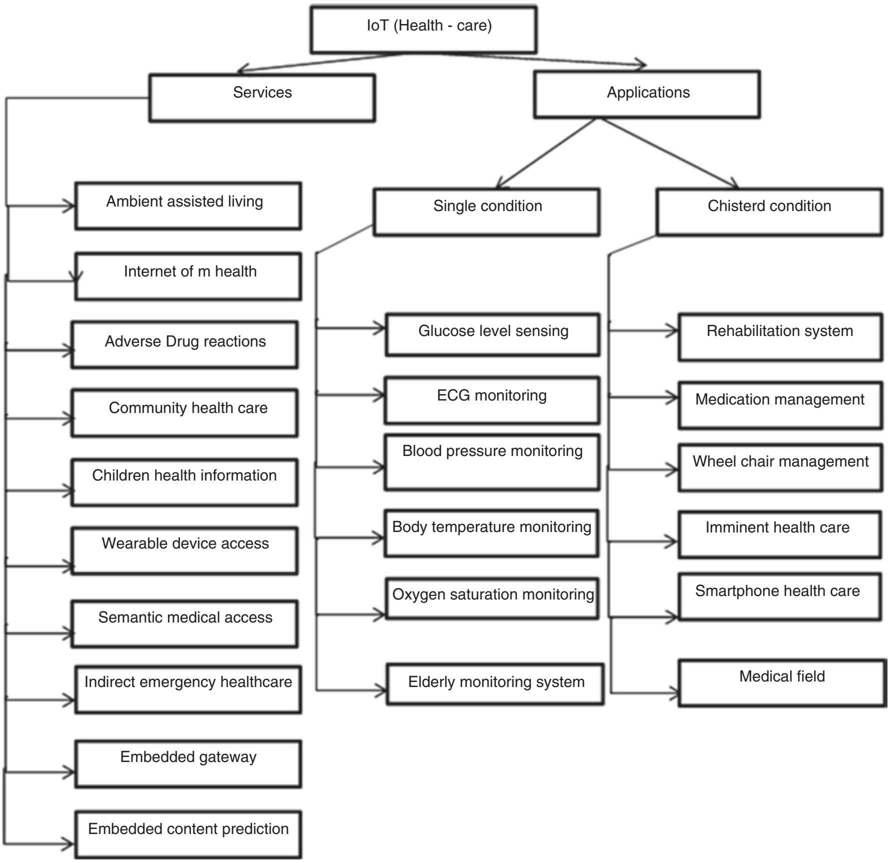

Fig. 5.5 IoT healthcare services and applications [5]

5.3.1.1 Elderly Assistance Through Ambient-Assisted Living Technology

Neither a smart home nor any assisted living is capable enough to offer full-fledged help to elderly people and to help them live longer, healthier [6]. This IoT platform which is backed up by the artificial intelligence can look into the matters of the elderly health and individuals who cannot take care of themselves. This process is called as AAL or ambient-assisted living. The main aim of this is to make the life of individuals easy and independent. This will make the elderly individuals confident [5, 7, 8].

5.3.1.2 IoMT (Internet of M Health)

M health is another word for mobile computing, medical sensors and technologies used for communications come under this. This technology is a revolution for the healthcare services which will connect with the 4G network. Since it has global mobility features, it can connect with mobile IoT services. This can be used for noninvasive glucose level check and other services [5, 9].

5.3.1.3 Assistance Provided for Adverse Drug Reaction Patients

This is a reaction which happens when a person consumes a drug and adverse effects of this medicine takes place. This can happen after continuous consumption or when a person takes same drug for two or more dosages. The IoT-based ADR will identify the drug by means of a barcode or scanner. And then this drug will be checked with the patient's record to see if it will cause him any reaction or allergy [5, 6, 10].

5.3.1.4 Health Concerns of the Public

Community healthcare monitoring means covering the entire community such as a government hospital, an area such as a rural area. This is a co-operative space which is used for monitoring the health of local community using the IoT-based network. In this structure, a virtual hospital is present which has all the health information of its residents, a technique for sharing this information among medical professional is used [11].

5.3.1.5 IoT Healthcare with the Integration of Wearable Devices

The integration of sensors, wearable devices, and IoT architecture has worked wonders as it delivers some immense technologies. But the heterogeneous behavior of sensors and devices causes many challenges. The activity recognition system to monitor the patients is a good example [5, 12].

5.3.1.6 Emergency Healthcare for Natural Disasters

Many a times in emergency situations such as accident, earthquake, and other issue with worst weather conditions require immediate attention and assistance. Therefore for this purpose, a dedicated service called as indirect emergency healthcare is introduced which addresses all these issues and keeps records of it [13].

5.3.1.7 Configuration of the Embedded Gateways

This IoT service will connect the nodes of the network to internet and this will be connected to the users through the internet. This is an automatic and intelligent monitoring of the devices which is connected to the internet such as the medical sensors [14].

5.3.2 IoT Applications

For the IoT in healthcare to work perfectly, in addition to the services, IoT applications also deserve close attentions as they have developed some commendable applications that can be directly used by the users without the consent of the medical practitioners. The IoT services are developer-centric whereas the IoT applications are more users specific and centric. Here numerous gadgets, wearables, and additional healthcare devices presently obtainable in the market are debated. These products can be observed as IoT inventions that can be prime reasons to numerous healthcare answers. The next subclasses talk about numerous IoT-based healthcare applications, containing both single- and clustered-condition applications.

5.3.2.1 Single Condition

- Elderly monitoring system
  Over the last few years, due to a fast increase in the number of old people, many efforts have been made to advance systems for watching the elderly behavior and for assisting them in daily life. IoT with its technology can easily make the life of the elderly less painful by providing smart environments that can assist them and monitor their health. IoT technology can be used for fall detection, emergency response mechanisms, generating reminders, and also it will allow the elderly to connect to medical assistance and their family. The infrared (IR) technology is widely used for indoor localization though it reduces accuracy. Alternative extensive technology for positioning system is Radio Frequency Identification (RFID), whose main benefit is the ability to work in nonattendance of Line of Sight (LOS). Lastly, Bluetooth (BT) technology signifies an effective substitute for indoor localization. Therefore, IoT technologies are used to capture positioning and motility data for repeatedly noticing behavioral variations in elderly people in an unobtrusive and less cost. This provides two services. The first service is the indoor positioning service that runs on wearable devices and relies on BLE devices. It will detect the user's current location and help them to communicate in the cloud. Along with this, it will detect the user's body state and identify the activity performed by the user with high accuracy. Also, IoT gadgets can help make independent seniors residing more secure. For instance, the caregiver could opt to set up a movement sensor that signals a responder if no motions

been detected over a long period. This indicates assistance will arrive quickly after a fall or illness. IoT gadgets can also tune modifications in air quality, temperature, humidity, or carbon monoxide, notifying the house owner or caregiver if levels fall under a suitable degree [5, 15].

- Monitoring of the glucose levels among the patients
  Diabetes is considered as one of the dangerous metabolic diseases that contain high glucose levels in the body. Therefore, monitoring this can help the patient to achieve normal glucose levels. This can be monitored by checking the intake of the food and planning meals adequately. This can be done by placing sensors which are linked via internet to monitor noninvasive glucose rise in blood [16].
- Monitoring ECG among heart patients
  ECG monitoring is the checking of the heart rate and rhythm of the heart which if not done can lead to various ailments of heart. Therefore, use of IoT in this can give the medical professionals maximum information about the heart of the patient. This contains a wireless transmission and receiver which can detect any abnormal heart activities using IoT [5, 17].
- Monitoring blood pressure in patients
  Blood pressure is another disease which needs to be regularly monitored. The main issue is how to connect the BP apparatus with the mobile device which uses the IoT technology. This can be done by connecting a BP module and communication module through an intelligent channel [5, 18].
- Monitoring body temperature of people using IoT healthcare
  The maintaining of body temperature is very vital in all healthcare applications as this is very decisive in nature. The details of the body temperature can be obtained by using sensors which are embedded and with the integration of M-IoT [5, 19].
- Monitoring of oxygen level using noninvasive process
  This is a noninvasive process that needs regular update of the pulse oximeter. The integration of this device with IoT is very helpful for all the technology driven applications [18, 20].

5.3.2.2 Clustered–Condition Applications

- Medical field
  NFC also plays a great role in observing an individual's health. It has information and data about the health of the patient and sends it to the health monitoring center. By examining this data at the health center, important information is provided to the individual. It will also help doctors to transfer the former health record of patients, which would result in accurateness of the medication given by the doctor [21]. IoT is certainly reworking the healthcare enterprise by redefining the distance of gadgets and people's interaction in handing over healthcare solutions. IoT has packages in healthcare those advantage patients, families, physicians, hospitals. IoT for patients is in the form of devices that are wearables like fitness bands and other wirelessly connected gadgets like blood strain and heart

charge monitoring cuffs, glucometer. IoT has modified humans' lives, especially aged people, via allowing steady monitoring of health conditions. This has a chief impact on people living on their own and their households. On any disturbance or changes within the ordinary activities of someone, an alert mechanism sends alerts to family individuals and concerned health companies. IoT for medical professionals is through using wearables and different domestic tracking device embedded with IoT, physicians can preserve details of patients' fitness successfully. They could track the patient's adherence to treatment plans or any need for fast clinical attention. IoT enables healthcare experts to be extra watchful and connect with the sufferers proactively. Facts gathered from IoT devices can assist physicians to discover the fine treatment manner for patients and attain the predicted effects. IoT for hospitals is that other than tracking patient's fitness, there are numerous different regions where IoT devices are very beneficial in hospitals. IoT devices tagged with sensors are used for tracking real-time regions of a clinical system like wheelchairs, defibrillators, nebulizers, oxygen pumps, and different tracking equipment. Deployment of the scientific workforce at different locations also can be analyzed in actual time. The increase of infections is the main situation for sufferers in hospitals. IoT-enabled hygiene monitoring devices help in preventing patients from getting inflamed. IoT devices also assist in asset management like pharmacy inventory control, and environmental tracking, for example, checking refrigerator temperature, and humidity and temperature management [22]. For instance, patient registration and control in hospitals is done by using an RFID band that is a bracelet-like strip, given to the user for use during the clinic procedures. On this strip, in line with the utility infrastructure, there exists best RFID unique identifier, or occasionally the owner's records [23].

- IoT healthcare integration with rehabilitation systems for people with disabilities
  People experiencing physical disabilities wish to enhance the quality of living and this can be done with the help of medicine and IoT. Since IoT technology helps in designing wearable and non wearable devices that can monitor the health of a patient for timely indication on changes in the health parameters, it is well accepted by everyone. This can also be used to treat autism in children [24].
- Managing the medicines using wireless technology
  Because of non-compliance, there is a serious issue as this can lead to financial loss as well as health loss of patients. To avoid this, with the help of IoT, medicines are packed with wireless communication technology, so that medicines can be tracked and controlled using RFID [5, 19].
- IoT healthcare integration for wheelchair patients
  Many research works have aimed to develop smart wheelchair for the handicapped, with the help of IoT this process can speed up. By means of WBANs and sensors embedded in the wheelchair, this can be achieved. By checking the vibrations of the wheelchair, the status of the person sitting on the wheelchair can be detected and so on [25].
- Use of smartphone to provide healthcare resolutions to existing problems

Recent years have witnessed the emergence of electronic devices with a smartphone-controlled sensor, which highlights the rise of smartphones as a driver of the IoT. Various hardware and software products have been designed to make smartphones a versatile healthcare device [5, 19].

5.4 More Details on the Applications in Healthcare

5.4.1 IoT Applications in Healthcare

5.4.1.1 Sensors and Technology Used for the Diseases

- Advance care for diabetic patients
  For this purpose, a smart camera is used. Techniques used are compression of images and segmentation. With the help of IoT, the app can be shown on a smartphone [5]. In some cases, such as diabetes 1, a breath test will be able to monitor the patient. This is a noninvasive method [26].
- Monitoring of blood pressure in patients
  For this purpose, a wearable sensor is used. The techniques used are oscillometry and automatic check of inflation and deflation. With the help of wearable body area networks, this can be connected to the smart devices using proper gateways [5, 27].
- Detection of cough using IoT
  A built in microphone is used for this purpose. Rainforest algorithm is used to detect the cough in human body through spectrograms. Apps integrated with IoT running on smartphone are used for this purpose [5, 28].
- Skin cancer detection
  A smartphone camera is used for this purpose. The images of the skin are used to match with predefined images from the library of cancerous skin. Apps integrated with IoT running on smartphone are used for this purpose [29].

5.4.1.2 Apps in Use for Healthcare

- Fuel band
  Tracks the activities of a person daily and can measure the body movements of the entire body. Also measure the amount of calories burnt. This was developed by the company Nike. Also using this application in smartphone, the person will be able to monitor and compare himself to other people anywhere in the world [5, 30].
- Sync Smartband and iBitz
  Sync Smartband is a band which can track the steps, calories, eye movement for sleep and also synchronizes and notifies the family about the activities [31]. IBitz is a wearable device which does not only track the steps of the person but also is

waterproof and durable, it can sync to family's profile so that they can be aware of the activities of the person wearing it [32].

- Reemo
  This controls user's environment with the help of gestures from hand. Its main initiative is to aid aged people and to provide remote care initiatives by connecting, communicating, providing service and insights in IoT healthcare and life science [5, 33].
- Health tracker
  This is used to track a person's health. These health trackers will have many features such as tracking a person's sleep, alarm time, maintain calories, step intake, water intake, alarm alert if no exercises are done. Apps such as Haloband [34], Samsung Gear Fit [35], Olive [36] are wristbands designed mainly as health trackers.
- Vessyl
  This is a smart cup which is capable to track user's intake of liquids automatically. This is a 13 ounce cup which is capable of sinking the water intake information with the smartphone so that a person is capable to know how much water he has consumed [5, 37].
- Owlet
  This is the first ankle sock that keeps track of a new-born's health. It tracks oxygen levels, rate of heart beat, temperature, and quality of sleep. If everything is normal, the parent will receive a safe message and if something is amiss the parents will receive an unsafe message [38].
- Proteus discover
  Proteus discover is a combination of smart ingestible sensor, smart patch, smartphone, and IoT technology that keeps track of the patients health that has never been heard before. The patients are able to monitor the medicine intake, and the healthcare professional is capable to see if the medicine is doing changes in the patient's body and whether or not to continue the medicine [39].
- Tracking devices for dementia patients
  GPS locator watch and pocket finder are some of the devices which keep track of dementia patients using GPS sensors. Since aged people are not capable enough to remember everything and patients suffering from dementia may arise concerns in their family members, this tracking devices such as pocket finder are very necessary as they will track the location of the patients using sensor technology [40].
- Leaf monitoring system
  An electronic sensor with an accelerometer is connected. This product is developed by leaf healthcare systems. This product helps to understand if the patient is at the risk of developing pressure ulcers just by sensing its motion [41].
- An intelligent monitoring and caution system for pressure ulcer prevention
  An intelligent remote monitoring and caution system is designed and developed for prevention of pressure ulcer. The developed system uses a ZigBee network infrastructure with pressure sensors to monitor pressured positions for mobility-impaired persons on the bed [42].

- Wearable ultrasonic and force sensors
  This device is used to measure the pressure under the foot while walking, if there are changes in the pressure, and then the patient will be alerted. This is very small in size and can be worn easily under the shoes [43].
- Noninvasive smart bandage for early detection of pressure ulcers
  This is a noninvasive smart bandage that is used to detect pressure ulcers before it comes in the human body. Even when the damage is not visible, this device is capable enough to map the tissues which are damaged in the human body to the system [44].
- Smart gown
  This smart gown is capable to sense the calorie intake in a person, breathing feedback is also provided using this smart gown. This gown is worn by the concerned patient and this can also check temperature and also has an emergency push button in case of emergencies [45].
- Wearable sensing system
  This technology is used for adults and individuals who are not capable to take care of themselves. This is a shirt which has integrated itself with latest IoT technologies that are capable to measure temperature, pressure, and humidity in a patient [46].

5.5 Architecture for Healthcare-Based Internet of Things

The IoT architecture in healthcare is basically a group of devices and objects which are connected with each other that can observe, analyze, and control these devices (Fig. 5.6). Edge computing technology has made getting the wireless devices connected to the internet seem very effortless. To process any data, IoT devices are totally dependent on the middleware layer of the IoT architecture. Basic three layered IoT architecture comes with layers which comprise of perception, network, and application layers. These are further extended to middleware and business layers.

5.5.1 Perception Layer

This layer tells about all the devices and objects which are used. This layer identifies and senses these objects and collects information about them. Then the collected information such as the temperature, humidity, name of the location, changes in the chemicals are processed based on the sensor type. This data is then transferred to the next layer for processing.

For an instance, if a woman is wearing a set of smart earrings, then this is capable to detect the position and other conditions of the woman. This is then passed to the network layer for processing [18].

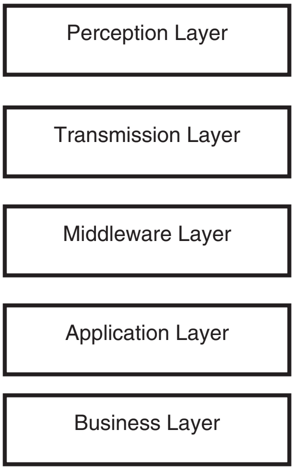

Fig. 5.6 Architecture of IoT healthcare [18]

5.5.2 Network Layer

The main aim of this layer is to connect to various servers and smart objects, network devices. This then obtains the data from the perception layer. The transmission happens through mediums such as infrared, Bluetooth, ZigBee, Wi-Fi, UMTS, and 3G. This is then passed on to middleware layer.

This will combine the data from earring and send it to middleware layer for further processing [18].

5.5.3 Middleware Layer

This layer is used as the main processing layer which can store and analyze huge amount of data which has been obtained from the network layer.

Its main responsibility is connection of the database and managing the services. Because it is in between the middle layer, it also provides many services to its below layers. It has the capability of connecting to cloud and big data so that large data can be processed easily.

The data collected from smart earrings can be analyzed and many features like temperature of the body can be found. If any variations in temperature is noticed then it can be sent to the patient [18].

5.5.4 Application Layer

The main aim of this layer is to deliver its services to the user. This layer is capable of communicating with the user. This is done by using some protocols of the application layer.

For instance, if they notice any raise in temperature in the woman, then the information is communicated to her by means of notification in a smartphone [18].

5.5.5 Business Layer

The business layer handles the full IoT ecosystem with good business proposals. It helps the end user to make choices for future actions.

For instance, if a person suffers from high fever then the close by clinics or hospitals will be listed down for the patient [18].

5.6 Challenges in Deployment of Healthcare System

There are several challenges when the device integrated with IoT in healthcare arises. These challenges have been addressed in the below section.

5.6.1 Rules Regarding Standardization of Merchants and Sellers of Medical Devices

In the medical services, there are numerous merchants that make many items and devices, and new sellers keep on joining this innovative race. Nonetheless, they have not kept standard principles and guidelines for interfaces and conventions across devices. This raises interoperability issues. To address this, prompt actions are needed. First step is to standardize the layers with protocols from the communication to the media access control layers. Second step is to introduce a management team which can handle this services [5] For example, the standardization of medical devices in the USA is done by Food and Drug Administration (FDA), Centers for Medicare and Medicaid Services (CMS), and Federal Communications Commission (FCC) [6].

5.6.2 Analyzing the Cost Effectiveness

Investing in IoT healthcare may look like very low cost in nature as it does not require many devices and services. But in real, no research has been done on this and hence validation of cost cannot be done [5, 19].

5.6.3 The Process of Developing the Application

For maintaining and developing an application, the steps are setup, developing, debugging and testing, deploying. When it comes to healthcare, this also requires the same steps but difference is that there should be a healthcare professional who manages this process and quality [5, 19].

5.6.4 Low Power Requirements

The IoT devices tend to be heterogeneous in nature when it comes to sleep, receiving and transmitting data. Each layer will face new challenges when it comes to power requirements. For an instance, finding a device which uses less power is very difficult [5, 19].

5.6.5 Types of Network: Data Centric, Service, and Patients Centric

When it comes to how an IoT can be viewed, it can be seen through three different types. One is data centric, service centric, and another is patient centric architectures. İn data centric, the structure is separated according to the data whereas in service centric the structure is allocated according to their characteristics. In patient centric, it is divided according to the patients and their needs. Therefore this is an open issue because of its variedness [5, 19].

5.6.6 Issue of Reducing Scalability

The IoT database and services need to be scalable, as when the IoT devices increase then the scalability comes down [5]. The major issue is how the users will be able to access the services using the portable devices such as mobile phones [6].

5.6.7 Arise of New Conditions and Diseases

With the rise of new diseases and ailments, alerting the common people is very necessary. As it is already known that smartphone plays a major role in IoT healthcare industry, new research should be carried on to find and alert the people of new diseases [5].

5.6.8 Identification and Managing Resources

Since IoT healthcare and medical field deal with multiple patients, identification of patients and their caregivers is very crucial to dissipate information to the correct patient [5]. Because of multiple users, identifying and distributing resources also is very crucial [47].

5.6.9 The Issue of Quality of Service

Healthcare services in IoT are highly time oriented, and they require quality of service for maintaining and reliability. Therefore, system availability and robustness should be offered to maintain Qos [5, 47].

5.6.10 Managing and Protecting the Data

Since IoT data captured for healthcare purposes is very crucial, establishing security is very important. Therefore, proper algorithms should be implemented so that leaking of data and attacks of various kinds do not take place. This can be provided by data transparency, secure routing, physical security, and resource efficient security [5]. Also the data formats are separate for different diseases and hence managing them is an issue [6].

5.6.11 Mobility and Heterogeneous Nature

Even if the patients have different environment, mobility should be supported as assistance to the patient should be available anywhere and at any time [5]. Because of the heterogeneous nature of the devices, mobility is also difficult [47].

5.7 Security in IoT Healthcare

IoT is an ever-growing technology which keeps integrating with many applications to make human life easier. The healthcare industry deals with high-level confidential data as a result of which having proper security becomes important [48]. For this purpose, the requirements needed by any application are listed below:

5.7.1 Analyzing the Security Requirements in IoT

For any IoT device to function, there are six main components which need to be maintained, and they are IoT network, platform, service, user, attacker, and the cloud. The necessary requirements for any IoT device to function in these components are explained briefly.

IoT network has three important features, and they are sensors, gateways, and communication protocols. Therefore, the basic security requirement in any IoT network is that there is maximum privacy and security provided while bootstrapping and multicasting. Also introducing embedded security will provide proper isolation of devices so that privacy can be obtained. The next component is cloud; critical data is usually saved in the cloud such as CCTV footages or in the case of healthcare important patient data, and if by any chance cloud service goes out of order then it will be a serious problem; hence the basic requirement of cloud is to provide good authorization techniques so that data cannot be stolen, encryption of data and data anonymity. The next component is the user. This is the most vulnerable component when it comes to IoT security. Hence no carelessness should be taken while implementing security requirements at user's side and hence user should follow all security rules. The next component is the attacker, although user may follow all rules, this component is very difficult to handle as there may be many threats obtained from the attacker side, and hence proper protocols need to be implemented to avoid each threat. The next component is the IoT service; here trust and compatibility are the basic requirements. Finally for a device to work properly and to avoid getting attacked, all requirements need to be working together [49].

5.7.2 Security Issues in IoT Healthcare

Some of the security issues while encountering the completion of security requirements are the computational limits of the CPU and low memory capacity of the low devices. Low energy operated batteries in the devices make it difficult for the tasks to take place. Some devices such as heart monitor used by the person needs continuous monitoring and this can be interrupted by the different network configurations in different settings, getting a stable scalable scheme is difficult as many devices are connected to the IoT healthcare network daily, and physical security is also very important and tampering of the devices needs to be avoided. These are some of the issues which take place when getting the requirements in order as seen in Fig. 5.8 [5].

The IoT as a paradigm is continuing to evolve, and many devices are getting added to it. The attacker may find new methods to attack the system. The threats are divided into three parts. They are classified as network based, information based, and host based. Attacks on information system occur when the data is compromised when it is in the transit. Such attacks are interruption attack which causes denial of services and communication will be lost, interception attack which makes the attacker to eavesdrop on the crucial information, modification of data, fabrication of the messages, and replay attacks [50]. Next are the attacks on the host properties which include user compromise where the devices of the users are at risk and hardware and software compromise [51]. Then is the attack on the network properties which include standard protocol compromise and network protocol stack attack [5].

5.7.3 Secured IoT Healthcare

An attacker may exploit each layer of the IoT architecture and hence a secured layered architecture is necessary as seen in Fig. 5.7. And security needs to be provided as seen in the figure at each layer [5].

To provide more protection, secure data transmission needs to take place as seen in Fig. 5.8 [52].

As seen in Fig. 5.8, the source medical data is transmitted to the destination. In between some high-level applications of algorithms are done. First, the source medical data is encrypted using RSA and AES algorithms; here the source plain text

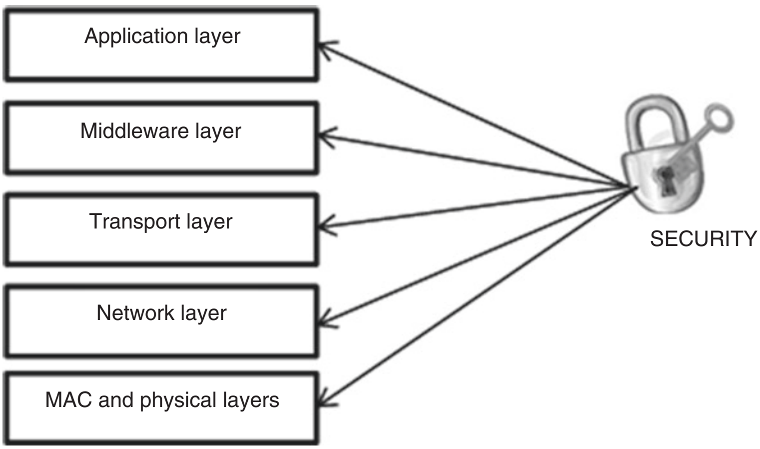

Fig. 5.7 A protected architecture with high security in IoT healthcare

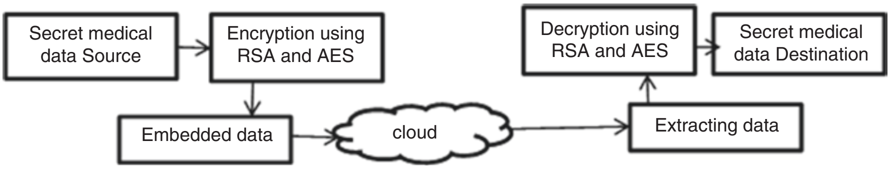

Fig. 5.8 Data transmission with high security in IoT healthcare

medical data is converted into cipher text. Then this data is also embedded with some other data so that the attacker would not be able to decipher it. This then is safely passed to the cloud. At the destination node, the embedded data is first extracted and then the original data is decrypted using RSA and AES. Then the secret medical data is obtained at the destination node [52].

5.8 Conclusion

The world has changed due to internet and its various applications. The main reason for this change is IoT. Interacting with the world seems nearly impossible without IoT. This has helped ease human life by helping them communicate with the smart objects, which does not only save time but also energy and cost. In the above chapter, there is a vast description about all the technologies which can be embedded into our surroundings with the help of IoT in healthcare field. This will make a dream into a reality which will provide comfort of life for many patients and medical staff.

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Chapter 6
Implementation of an Intelligent Model Based on Big Data and Decision-Making Using Fuzzy Logic Type-2 for the Car Assembly Industry in an Industrial Estate in Northern Mexico

José Peinado, Alberto Ochoa, and Sara Paiva

6.1 Introduction

The administration is structured by specialized departments, in case of the functional organization, this type of structure poses a series of problem when developing transversal projects throughout the organization as a Knowledge Management System (QMS), given its low agility in coordinating the different activities, the low authority of the project management over the heads of the different areas, the shortage of staff that will be assigned full-time to the project and the organizational service structure itself, reluctant to change.

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6.1.1 Proposal Methodology

The knowledge management system to be applied will take as a model the one developed by Nonaka and Takeuchi (or model C) that affects the way people create knowledge and promotes the generation of organizational knowledge by supporting individuals and the processes of knowledge creation and transformation. Nonaka and Takeuchi [1] classify knowledge tacitly and explicitly. Explicit knowledge is that which can be structured, stored, and distributed, and the tacit is one that is part of everyone's personal learning experiences and that is extremely complicated, if not impossible, of structuring, storing, and distributing. It is close to talent, art, or a certain mental model and is made up of attitudes, abilities, and most of the abstract, complex, or sophisticated knowledge of people. Special attention should be paid to the processes that govern the transformation of knowledge from one type to another, since it is the key route for both transmission and consolidation of knowledge within the organization and abroad. Let us not forget that knowledge is an intangible asset that has a value that should not be wasted. The spiral of the knowledge process proposed by Nonaka and Takeuchi describes the four processes that give rise to the different transformations of knowledge. The SECI spiral (Socialization, Outsourcing, Combination, and Internalization) is called (Fig. 6.1):

- Socialization of knowledge: from tacit to tacit, knowledge is shared and created through direct experience, for example, personal conversations, demonstrations, etc.
- Outsourcing: is the step from tacit to explicit. Through dialogue and reflection, knowledge is codified.

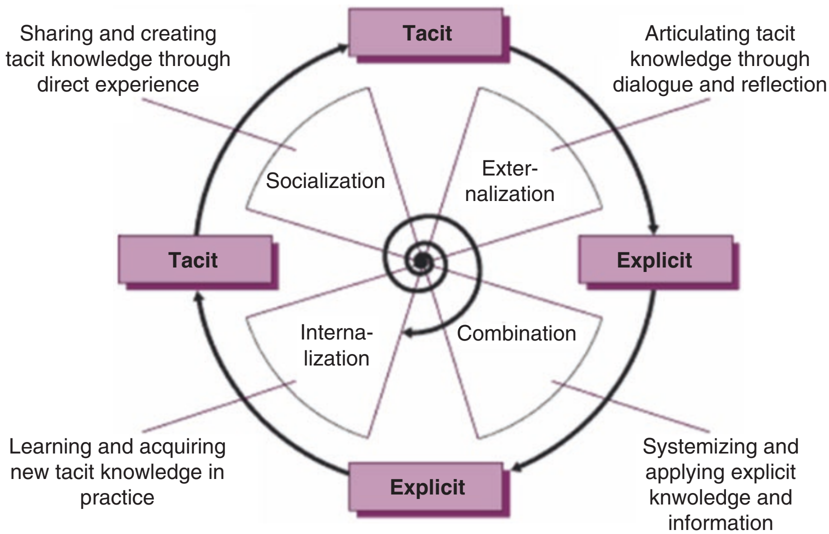

Fig. 6.1 SECI spiral. (Excerpted from [2])

- Combination: from explicit to explicit, structuring of multiple explicit knowledge and information in new knowledge.
- Internalization: from explicit to tacit, is the learning and incorporation of new tacit knowledge by the members of the organization.

In order to create the spiral of knowledge in an organization [2], it is necessary that conversions and synthesis or combinations be made between: (1) tacit and explicit knowledge, (2) levels (individual, collective, organization) within the organization, (3) functions, departments, divisions within the organization, (4) layers (senior management, middle managers, and grassroots workers) within the organization, and (5) internal knowledge to the organization and external, provided by suppliers, customers, competitors, universities, government, or stakeholders.

Main intellectual capital assets of the Organization With the Intellect model [3], a series of elements, determined by each organization depending on the strategy, can be used to measure the three blocks of intellectual capital: human, structural, and relational capital. It also establishes that the indicators will try to give an image of the organization both in the present and in the future. The following indicators are defined for the organization:

Human Capital
- Workforce
- Number of workers
- % of new annual contracts
- Replacement of people
  - % key people
  - % people with low substitutability
- Staff turnover
  - Number of incorporations/number of departures
- Personnel qualification
  - % graduates
  - % graduates
  - % with secondary education
  - % with primary education
- Worker training
  - Hours training person/year

Structural Capital
- Procedures
- Number of procedures
- Duration x procedure

- % documented procedures
- % automated procedures
- Quality
  - Certifications obtained
- Technology
  - Number of computers/templates
  - Number of printers/templates
  - % Broadband access
  - Number of databases
  - % of staff with internal email

Relational Capital

- User base
- No. of users
- Loyalty of users
  - % of users who repeat in the use of services
- Satisfaction of users
  - Satisfaction index (through surveys)
- Feedback
  - Number of claims
  - Number of suggestions
- Agreements
  - Number of agreements signed with other organizations
- Reputation
  - Number of positive references in the media
  - Number of negative references in the media
- Notoriety in social networks
  - Number of contacts in social networks
  - Number of messages received/sent in social networks
- Web
  - Search engine positioning
  - Number of visitors/years
  - Average bounce rate
  - Average return percentage
  - Media page views/visit

6.1.2 Main Stakeholders or Interest Groups

AI will study the actors that use and produce information in the organization. The audit will identify where each of them is, to whom they report, and from whom they obtain information, their area of specialization, what level of information culture they have, and their training in this regard, what is their network of contacts, how and for what purpose the information is used, the added value that it provides, and what relationship they have with the information managers. In this organization, 27 functional areas have been identified, the main roles in each area will be:

1. Service chiefs (group A, according to the classification scale of public officials): they are responsible for the proper functioning of the assigned area or areas. They organize the area, control budget execution, issue reports, write strategic plans in the short, medium, and long term, and supervise daily work. They are the ones who use and generate the most information in the organization.
2. Team leaders (group B): coordinate the work of their subordinates and write reports. They collaborate in tasks of superior administrative management and operational management.
3. Administrative staff (group C): This category includes staff who perform administrative tasks of management, processing, and collaboration with the higher level.
4. Auxiliary personnel (group C1): registration tasks, calculations, handling of basic machines, and the like.
5. Junior staff (group C2): includes tasks such as concierge, reprography, manual transport, correspondence. Which makes this the level that handles the least information.

On the other hand, the following were identified as political profiles:

1. Councilors: They are the policy makers of the assigned areas and decide on which projects the budget money will be invested.
2. Mayor: This is the maximum political responsible of the administration, evaluates the proposals of the councilors and proposes initiatives of political character.

6.2 Business Simulators as Knowledge Manager

The business simulator is a tool that allows establishing a virtual business environment to have the opportunity to participate, through a set of decisions, in the management process of a company or a specific area of it [4].

For the creation of the business simulator, PHP programming has been used, an application in a study program (based on the Adobe Flash study form) that is intended for the construction, design, and editing of sites, videos, and web applications based on standards [2].

PHP programming has support for both image editing and animation through integration with others. In addition, it is characterized by the ease of use and web development. The implementation of the business simulator offers the following benefits [5]:

- Evaluate and choose the best decision that leads to the best result.
- Foresee the consequences to which the company is exposed because of the decisions taken.
- The simulation will allow the company to position itself in the first places and generate competitiveness.
- The results of the decisions taken can be positive or negative. However, the analysis of these results will expose the mistakes that have been made, allowing feedback on this.
- The interpretation of the results in the simulator will contribute to the development of the company's vision.

Three different approaches were used to solve our research, including:

6.2.1 Industry 4.0

Industry 4.0 (I4.0) is the latest standard for data and computation-oriented advanced manufacturing [6], The term "Industry 4.0" originated from a project initiated by high-tech strategy of the German government to promote the computerization of manufacturing. Industry 4.0 is considered as the next phase in the digitization of the manufacturing sector, and it is driven by four disruptions: the astonishing rise in data, computational power, and connectivity, especially new low-power wide-area networks [7]; the I4.0 was so named because throughout history it was the fourth industrial revolution, the first one (I1.0) refers to the first revolution that occurred in the 19th century where the most important change was mechanical manufacturing, then in the 1900s take place the second revolution which has as main chance the assembly line and it means an increase in mass production; before the I4.0 occurs the third revolution, this happened around 1970 when the industry introduced the use of robots get better in the production, and finally the I4.0 being the current stage within the evolution of the industry, all this information was taken from the Table 6.1.

This emerging concept of Industry 4.0 is an umbrella term for a new industrial paradigm that encompasses a range of future industrial developments in relation to

Table 6.1 Technology evolution from Industry 1.0 to Industry 4.0 [6]

Time	Evolution transition	Defining technology
1800s	Industry 1.0	Mechanical manufacturing
1900s	Industry 2.0	Assembly line (mass production)
1970	Industry 3.0	Robotic manufacturing (flexible manufacturing)
2010	Industry 3.5	Cyber physical systems
2012 forward	Industry 4.0	Virtual manufacturing

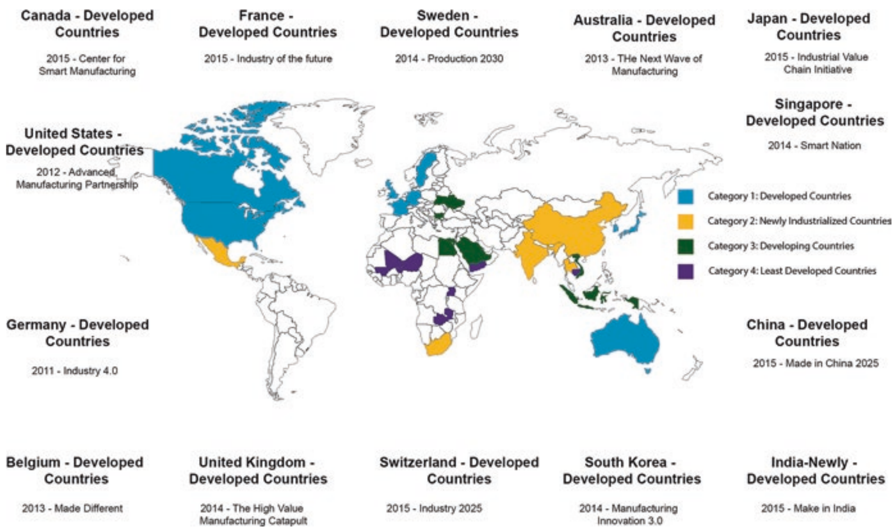

Fig. 6.2 Industry 4.0 initiatives around the world [10]

Cyber Physical Systems (CPS), the Internet of Things (IoT), the Internet of Services (IoS), Robotics, Big Data, Cloud Manufacturing, and Augmented Reality. The adoption of these technologies is fundamental for the development of more intelligent manufacturing processes, which include devices, machines, production modules, and products capable of exchanging information independently, triggering actions and controlling each other, enabling an intelligent manufacturing environment [8]. The term industry 4.0 has been used throughout the world, both academically and in industry, although this term has been handled in different ways, for example, in China the term "Made-in-China 2025" was introduced; in the United States of America it is called "Re-industrialization"; in Japan they refer to the "New Robotics Strategy" to methods that allow manufacturing fully customized products with the help of integrating the entire supply chain and production system [9], as is possible shown in Fig. 6.2.

As it mentions before, the I4.0 is based on nine pillars; this was described by Rüßmann et al. [11] and they are:

1. Big Data and Analytics
2. Autonomous Robots
3. Simulation
4. Horizontal and Vertical System Integration
5. The Industrial Internet of Things
6. Cybersecurity
7. The Cloud
8. Additive Manufacturing
9. Augmented Reality

Intelligent supply chains will be highly automated and integrated and, again, made possible through the integration of software and communications in the industry. CPS generates real-time data on their position and status, which allows to automate processes in the supply chain and identify products throughout the production process allowing manufacturers to identify changes in orders, in addition, and recognize inefficiencies, increase reliability, and reduce costs [12].

6.2.2 Big Data

One of the most important part of I4.0 is the Big Data and Analytics, normally is associated with the result of the use of internet, sensors, management systems, but big data is not about a big group of data, it is a model named "Model of 3vs," Volume, Velocity, and Variety [13]. Then this model was increased with a new "V," variability [14] for the "Model 4vs," the next suggest for the "Model 5vs" was value, and along the time this model has been increasing to the last model named "3v^2 Model" and is mentioned by Wu, Buyya, & Ramamohanarao [15], and they show us the next Venn Diagram (Fig. 6.3):

Some of the authors like Zhang, Zhan, and Yu [16] talk about the use of big data in the industry of car. He proposes that the use of big data helps determine the characteristics that a user searches for in a car, in addition to predicting how sales will be in the coming months. Otherwise, Kambatla, Kollias, Kumar, and Grama [17], talk about the future to big data, and they give us an idea of what the use of big data implies, from the type of hardware that is needed to apply this technology, be it the use of memory, the hierarchy of memory that this implies, to the types of network and systems distributed that allow the application of big data for companies. On the other hand, Philip Chen and Zhang [18] mention that in order to be competent, the use of big data is a big part for innovation, competition, and production for any company and that the use of big data should include the use of cloud computing, quantum computation, and biological computation, besides that the development of tools is an important part of the use of these technologies. With the origin of new advances in technology, a huge amount of organized and unstructured data is delivered, collected from different sources such as social media, audios, websites, video among others, which makes the task of monitoring and processing such information difficult [19].

The decision-making in a company is one of the biggest problems, the use of the techniques of the science of the data allows to take decisions in massive scale depending on the technologies of big data that is applied, in addition to the storage and the engineering that the company is able to have, nevertheless, the processing of this information to scale continues being the privileges of a few with the capacity to integrate and to deploy the great tools of data processing [20].

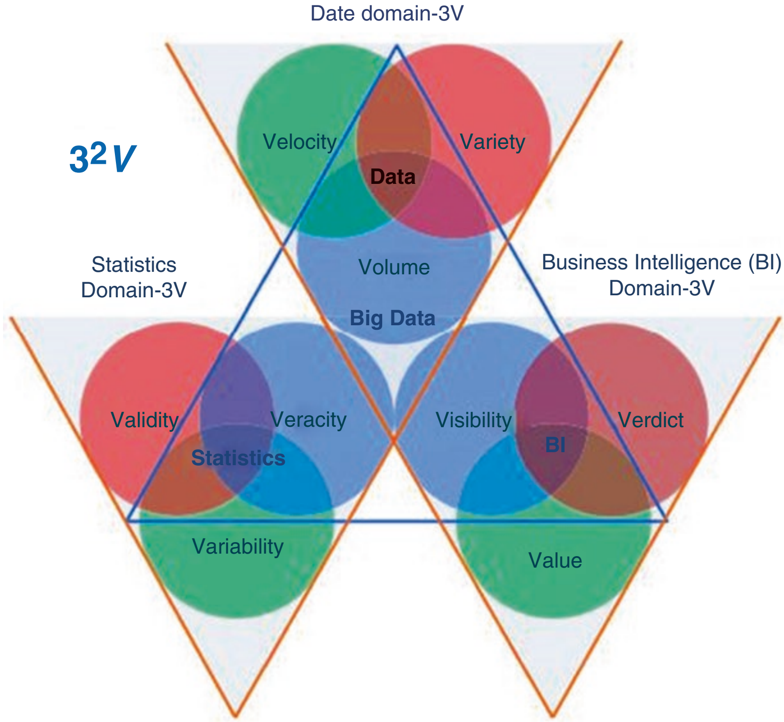

Fig. 6.3 3^2Vs Venn diagrams in hierarchical model [15]

6.2.3 *Fuzzy Logic Type-2*

Type-2 fuzzy sets were originally proposed by Zadeh in 1975 and are essentially "fuzzy–fuzzy" sets in which the degrees of belonging are type-1 fuzzy sets [21]. Fuzzy algorithms have the common feature of not requiring a detailed mathematical model, the type-2 fuzzy logic system (FLS T2) can give robust adaptive response to a drive that has parameter variations, disturbance loading, and non-linearity [22]. Fuzzy logic has obtained attention of researchers for last couple of decades. It has opened new horizons both in the academia and the industry site; although conventional fuzzy systems (FSs) or the so-called type-1 FSs are capable of handling input uncertainties, it is not adequate to handle all types of uncertainties associated with knowledge-based systems [23]. The type-2 provide additional design degrees of freedom fuzzy logic systems, which can be very useful when such systems are used in situations where lots of uncertainties are present. The resulting type-2 fuzzy logic systems (T2 FLS) have the potential to provide better performance than a type-1 (T1) FLS [24]. Even in the face of these difficulties, type-2 fuzzy logic has found applications in the classification of encoded video sequences, the elimination of co-channel interference from time varying nonlinear communication channels, connection

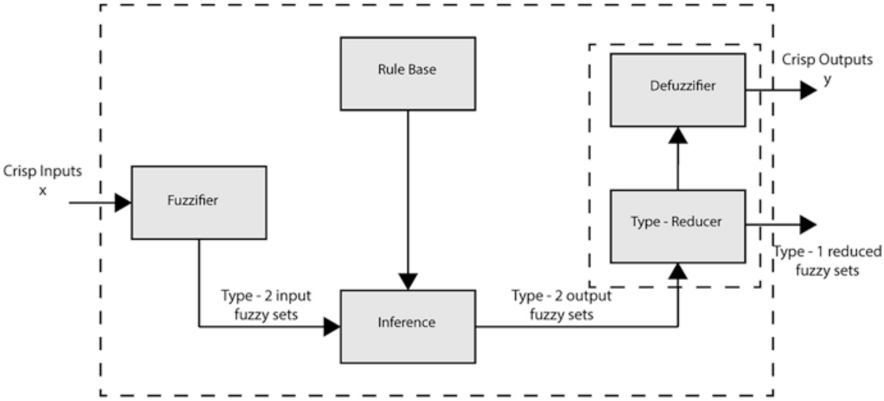

Fig. 6.4 Shows us the diagram of a fuzzy logic controller

admission control, knowledge extraction from questionnaire surveys, time series forecasting, function approximation, radiographic image preprocessing, and transport scheduling [25].

A type-2 fuzzy set is characterized by a fuzzy membership function, i.e., the membership value (or membership grade) for each element of this set is a fuzzy set in [0,1], unlike a type-1 fuzzy set where the membership grade is a crisp number in [0,1] [26]. Membership functions of type-1 fuzzy sets are two-dimensional, whereas membership functions of type-2 fuzzy sets are three-dimensional. It is the new third dimension of type-2 fuzzy sets that provides additional degrees of freedom that make it possible to directly model uncertainties [24] (Fig. 6.4).

6.3 Simulation Execution Methodology

The following information is considered for the execution of the business simulator:

- Market data: Market segmentation, consumer preferences, effective demand, potential demand, characteristic of the industry, initial situation of the company ($75,000.00) [1].
- Decisions: Decision-making in different key areas of the simulation model.
- Results: The application of a survey helped determine the degree of user satisfaction once the selected strategies were implemented.

The main purpose of the business simulator is to create an improvement plan for the correct decision-making that helps to improve the self-cleaning service. For this, various proposals and scenarios are presented in which companies can analyze their current and future situation in case of implementing any of the strategies. It should be noted that the proposals arose from the results obtained through a survey in which questions were asked about the needs that the client needs to meet. Finally, the selected strategies will appear loaded together with the respective investment; in addition, the suggestions issued by the simulator will be displayed.

6.3.1 Measure Knowledge Management

Five guidelines can be used to create a successful GC measurement system [27]:

1. Start with a model that links the GC with the needs of the organization. A GC system should incorporate the results of the organization's activity as the starting point for establishing a GC strategy and a way to measure its effectiveness.
2. Choose metrics that are appropriate to the GC approach of the organization, its objectives, and its development status.
3. Understand the relationships between the inputs, changes in the processes, and the desired results.
4. Use a measuring system that works. Measuring indicators are not enough; processes are needed to collect, organize, report, and use metrics to improve the GC strategy.
5. In addition to performing metrics, give convincing examples of success to the organization's management.

Sometimes illustrating with practical examples is necessary to justify the investments made and give managers a vision of what can be done. The management indicators must measure both the different types of knowledge and the conversion processes. For example, it is difficult but valuable to convert tacit knowledge to explicit. The consolidation of a standard for valuing knowledge assets is an issue still not resolved, much less standardized. We can find in the literature various measurement methods: The Navigator method, Intellect, Balanced Scorecard, Direct Intellectual Capital, Performance on assets, etc. The process to measure knowledge is very problematic given the intangible nature of these assets, as is shown in Fig. 6.5.

Fig. 6.5 GUI associated with the representation of knowledge management in an organization of the manufacturing industry associated with car assembly

Fig. 6.6 Proposed stratagems in our intelligent knowledge management system

6.3.2 The Intellect Model

The Intellect model [3] responds to the interest of measuring the intellectual capital of organizations. It offers managers relevant information for decision-making and providing information to third parties about the value of the company or organization. In the case of a Public Administration, it is not interesting to obtain the market value of it, but the model is still useful because it informs about the organization's ability to manage knowledge, generate sustainable results, and constant improvements. The model structures intellectual capital into three blocks, according to its nature.

- Human capital: Knowledge (explicit or tacit) useful for the company that people and teams possess, as well as their ability to regenerate and learn it. It belongs to people and the organization can only "rent it."
- Structural capital: Knowledge that the organization manages to explain, systematize, and internalize and that may be latent in the company's people and teams. It is owned by the organization.
- Relational capital: The value that the set of relations with the outside world has for an organization. The model considers within each block a series of intangible assets, which it calls elements, determined by each organization based on its strategy and its critical success factors. To measure each element, a series of indicators will be established. One of the great difficulties of the Intellect model, which it has in common with other models such as the Balanced Scorecard [28], is that it must be defined for each organization. This does not mean that it is split from a blank sheet because, in principle, points can be found in common with other organizations that have already implemented it, as is shown in Fig. 6.6.

6.4 Results

The analyzed organization in Juarez City is of good quality; however, the business simulator analyzes the information and operation of the company to offer a better customer service. Among the main suggestions thrown by the simulator are the following:

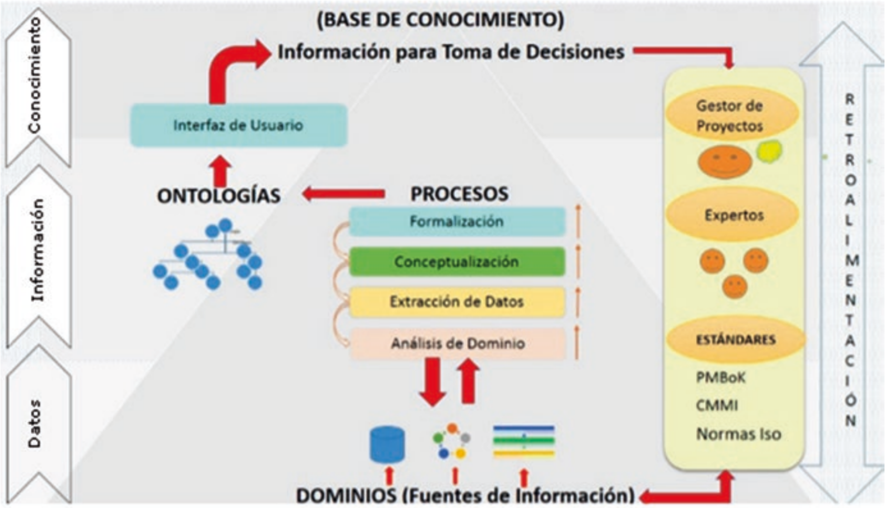

Fig. 6.7 Graphical representation of the proposed model

- Segment the washing process for the optimization of the operating time.
- Make use of strategic alliances to consolidate the business and attract more customers.
- Hire services that allow the customer greater satisfaction.

In general, the simulator helps clients or investors to make decisions about their company, either to start a new one or improve if it exists. In addition, it involves a defined process whose objective is to contribute to the self-cleaning service.The strategies implemented determine an investment determined according to the magnitude of the same; however, they represent a very acceptable proposition for the client, the company has a higher recognition than the competition and an increase in the sale of the service, as possibly analyzed below Fig. 6.7.

To specify, the previous image shows the process that must follow an investor supported by the business simulator; part of the business idea and the economic resource, in this case, the initial investment is $75,000.00 to be considered microenterprise. The investor consults the expert so that the business simulator processes and analyzes the required information. Once the business idea has been consolidated, the personnel and material resources necessary to formally start the company are hired. By performing this procedure correctly, the manufacturing organization in Ciudad Juarez has been successful.

6.5 Conclusions and Future Research

Through the investigation, an overview of the customer service in self-cleaning companies in the municipality of Juarez City is presented. In addition, the feasibility of the strategies that are applicable in strengthening the companies of this line of business is projected. For this, a business simulator was created that considers the operation of the company based on real information, which was obtained through surveys applied to users of the service, as well as to those in charge. The business simulator contains various strategies to develop for the growth and consolidation of the company. Part of the washing process, strategic alliances and added services. Among the strategic alliances are agreements with hardware companies and advertising companies, which are viable to carry out an advertising campaign. On the other hand, in aggregate services, it is sought to give complete satisfaction to the clients based on the needs that were expressed in the survey; within the aggregate services the waiting room, internet service, and snack and beverage service are considered. The business simulator is a very useful tool because it allows predicting the success or failure of the decisions made without having made any type of investment. In addition, with the development of the strategies suggested by the simulator, those in charge of the car washes will be able to provide a better customer service.

6.5.1 Future Research

The implementation of a knowledge management system in a local administration is a complex task. The rigid, bureaucratized and, in general, reluctant organizational culture itself makes it difficult to implement new developments. To overcome these barriers, the involvement of both the high political levels and the key individuals of the organization is necessary. This project is both a challenge and an opportunity to improve the management of a resource, knowledge, which is used intensively in administrations. A City Council is the closest administration to citizens, which solves their most immediate problems. Therefore, the implementation of a knowledge management system will result in an improvement of the services offered to them from the institution and a reduction in the medium term of the cost associated with them. The set of proposed objectives covers in a global way the key aspects that a knowledge management system must have: Identification of knowledge, both the one that has and the one that does not; how and where knowledge is generated; how it is represented; its classification, structuring and storage; how it is transmitted; and how it is assimilated and applied. In addition, through the Communities of Practice, their transmission and a collaborative culture in the organization are actively promoted, which may improve other important aspects such as the work environment and productivity, as is shown in Fig. 6.8.

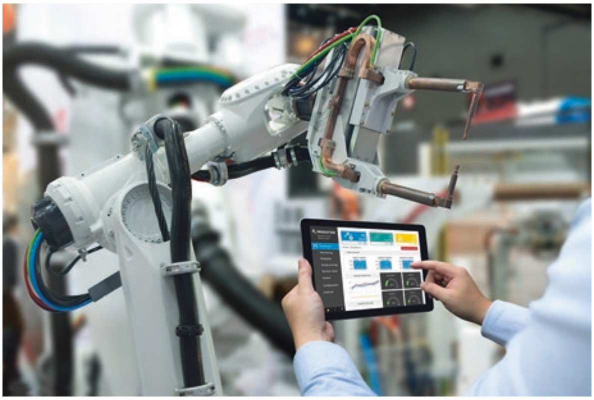

Fig. 6.8 Implementation of an intelligent knowledge management system in a mobile device to improve the competitiveness of an organization within the manufacturing industry

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Chapter 7
Cloud Computing Model on Wireless Ad Hoc Network Using Clustering Mechanism for Smart City Applications

S. Thirumurugan and Jasmine Beulah Gnanadurai

7.1 Introduction

The implementation of modern technology is essential in creating smart cities. The implementation of IoT helps the home network to link with the global network. The implementation of the smart city is carried out as a result of effective utilization of computing technology with the communication network. The smart city application includes the manifestation of smart healthcare [1], smart water management [2], smart lighting [3], smart transport [4], smart home [5], smart grid [6], and smart irrigation [7] with the help of 5G networks [8]. The network address has to be upgraded to IPV6 [9] for the identification of objects in the world. The generation of data in the smart city creation approach will grow continuously, and the literary analysis has to be done with the help of advanced tools, computing methods, high-end data storage mechanism, and resources systematically. Figure 7.1 indicates the various units of the smart city project.

Implementation of smart healthcare gives a boost to the fast-growing healthcare industry. Implementation of smart healthcare will help the healthcare services to obtain better results both in time and efficiency. The goal of this cloud computing technology is to make the healthcare facilities available to nook and corner of the city without any delay or with an acceptable level of delay in treatment. The healthcare services include a secured patient detail management system, remote doctoring, and artificial intelligence-based solution to assist the patients and doctors in providing the right treatment at the right time. The implementation of cloud

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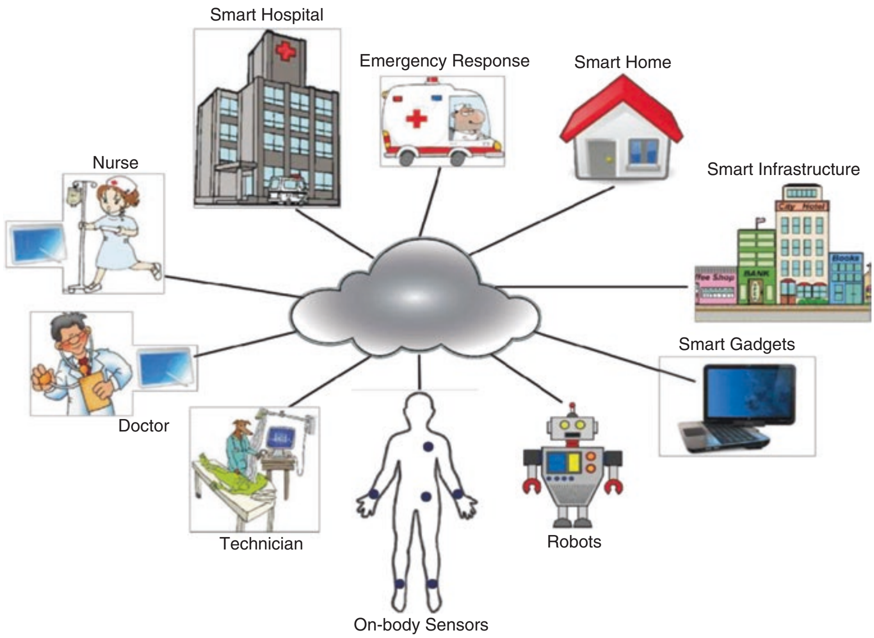


Fig. 7.1 Smart healthcare

computing services with IoT may affirm continuously monitoring and alerting systems to sustain the patient life under critical circumstances. It has been analyzed how the death rates have fallen drastically due to the introduction of smartness in healthcare services. In a smart healthcare system, the affordability of treatment to economically different status is considered a challenging phenomenon. Figure 7.1 depicts various elements of the smart healthcare system.

Water is one of the precious resources in this world. The technology should be supportive and alert the people before the water scarcity happens. It is well understood that the groundwater level is getting down and water storage bodies are drying up due to global warming. Thus, the steps should be taken right from the city level to improve the situation. Smart water management will provide a solution by planning the water distribution for the houses and industries within the city. It is an undeniable fact that if the water management system is not improved from the present state, then the people will have to face the clutches of water scarcity.

The following steps include identification of sources of a water body, establishment of storage, implementation of the desalination plant, purification, sewage treatment plant, recycling, and distribution of water to households and industries. Further, water contamination by factory effluents would be measured, controlled, and monitored with the help of modern networks. The smart water metering system will give clear details to the people about the utilization of water in an efficient manner, and the billing details would be generated based on water consumption.

Smart lighting is one of the indispensable needs in smart cities to reduce power consumption and at the same time to ensure proper utilization of technology to handle the lighting system within the house as well as outside of the house; for example, street lights and IoT-enabled devices provide the best solution to control the lighting devices within the house as well as metropolitan area networks that cover the city region, thereby controls the lighting facilities outside the house. In energy sources, renewable energy sources, for instance, solar power could be integrated with this smart lighting to support climate change resolutions.

Smart transport system controls the traffic which is filled with constantly growing vehicles. The traditional methods available for man-induced traffic are confined to certain restrictions. Thus, this scenario needs legacy methods to give a contemporary touch. This approach utilizes machine learning algorithms for real-time applications to take decisions based on the present scenario in the given context. For instance, the static approach in the signaling system within the city will put the system to a halt due to the dynamic nature of the situation. The static approach will have to be changed while taking decisions to control the traffic within the city. Further, the transport system should be capable of facing unprecedented situations, for instance, a mishap occurring at someplace will create havoc to the city traffic. So, the smart transport system should address those difficult situations and provide the necessary solution for an effective traffic mechanism. A good transport system will motivate the people to follow traffic rules while they are driving their vehicles so that they can handle the real-time situation effectively. In an emergency, a priority-based decision must be added to help the people. The ultimate goal of this system is to ensure the city transport function even in the worst-case scenario with the aid of smart computing technology.

The smart home is the project where the electronic, electrical, and mechanical devices, ambiance, internet, and appliances of the home will be brought under a single network and managed by service providers, owners, or end-users that can be controlled remotely by computer or smartphones. The security systems like burglar alarm, door passcode, CCTVs, automated systems like water level indicators, watering the plants, remote monitoring, and control systems are the essential parts of the smart home. In advance, the present generation prominent fields such as machine learning, artificial intelligence, and data science could be added to make AI-based smart home projects which will make decisions and recognize human behavior.

Figure 7.2 shows a smart grid system scenario. The above system shows how technological adventure has been utilized for the generation and distribution of power efficiently. This system has ensured the distribution of the power on a demand and supply basis within the city. The utilization of renewable sources such as wind, water, and solar energy for power generation has given a significant reduction in pollution control. Since the world is moving toward green computing, the power grid would give solutions based on green energy.

Smart irrigation is another primary necessity of the smart city project since agriculture will no longer be handled as in old tradition. The present-day resources are inadequate to meet out the demand, hence pumping and watering of paddy and other food grains has to be done more smartly. The smart irrigation system will help

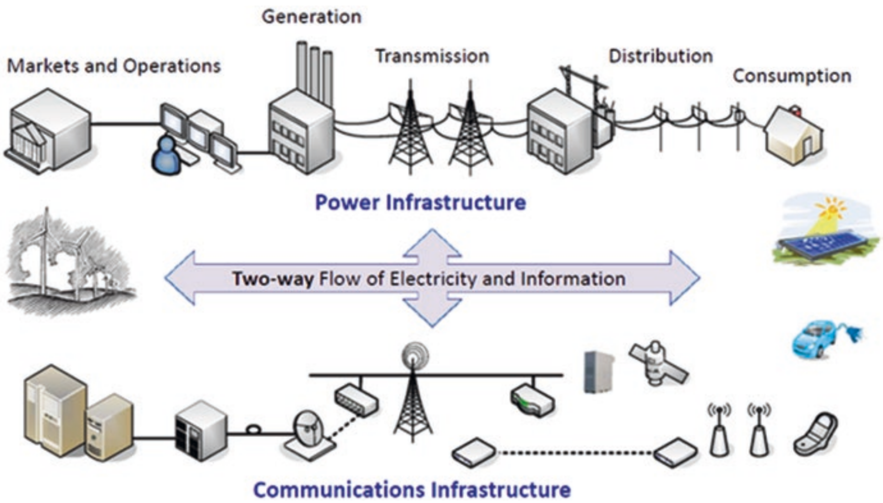


Fig. 7.2 Smart grid

to achieve water utilization and conservation with the aid of smart networking technology such as wireless networks and mobile communication systems.

Big data [10] is a field that contains a huge volume of multimedia data of different contexts grows exponentially and has to be considered for the analysis and make decisions based on the result. This activity has created a prominent field called data science [11]. Since automation and computerization have become important growth factors, the smart city project will make use of this stored data for taking decisions in a specific context. Big data has a dynamic nature of growing data which needs to be addressed using distributed systems like Hadoop to improve the processing capability.

In this twenty-first century, the world is facing a severe economic and health crisis due to the coronavirus pandemic [12]. In the worst case, technology would be used as a remedial tool to solve the problem to a greater extent. If artificial intelligence [13], machine language, and computing concepts did not exist, the world could have been crippled. In this adversity, the communication networks help to perform the people to work from home and make most of the business to run through online. The digital mode of transactions makes the business convenient and accessible. Thus, various elements help the city to function effectively. Those elements indeed made the smart city by providing services to the people with the help of smart applications. The forthcoming part of this description deals with elements such as cloud computing, ad hoc scenario network, and mechanism for efficient clustering. It is very well understood that the blend of the technology and mechanisms is the core thing in developing an efficient application for the smart city.

7.1.1 Cloud Computing

Cloud computing is a distributed computing system that ensures the availability of various system resources, mainly computing power and cloud storage, with indirect interaction by the end-user. Cloud computing is the best-developed technology in the IT industry and a new delivery technique for the services on pay-per-use basis.

The term “cloud” indicates that the group of machines involved are meant for services over the network on demand and charged on a utilization basis. The term computation describes the processing or job handling mechanism that makes use of the network to task effectively and efficiently. Cloud computing has become one of the fastest-growing technologies embraced by both industry and academics. Figure 7.3 describes the components and types of services of cloud computing.

The cloud provides a centralized data storage and maintenance mechanism where the service is available for the users based on their demand. It delivers a flexible and effective way to store and retrieve the data. The primary issue here is to plan the incoming request in such a way that it takes minimum response time [14] and gives assurance to efficient resource utilization.

Cloud computing systems profoundly depend on the virtualization [15] concept to improve the job handling approach effectively. The virtual machines are created from physical servers and are configured based on requirements specified by the end-users or clients. This type of computing approach delivers all services through the internet and handles user requests which are neither static nor the same. For

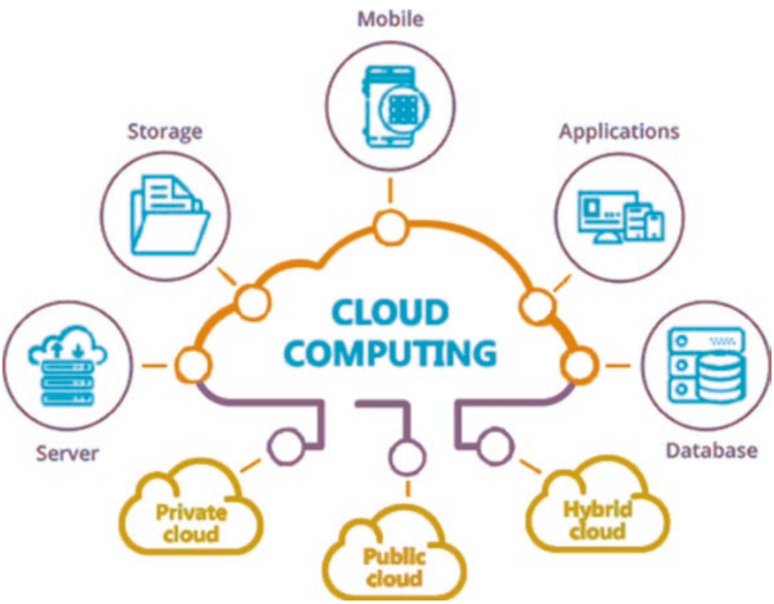


Fig. 7.3 Cloud computing

instance, the users may require an operating system, network, storage, software, hardware, and resources.

The role of cloud computing is indispensable in this century which makes the underutilized resources be outsourced based on requirements. This technology reduces the investment cost, ensures effective utilization of resources, and lays the path toward green computing. In green computing, the utilization of the resources would be minimized by sharing surplus resources over the network. Further, the cloud computing technology also suits very well for medium-scale industries to run their business with less liability since the service providers will take all the legal responsibility and adhere to the safety standards. The vision of smart city creation will not be completed without giving green computing touch. Thus, the implementation of cloud computing within the city will be used to maintain the data about the region as a part of the smart city project.

7.1.2 Clustering Mechanism

The term 'cluster' represents a group of objects which are similar in their characteristics. This concept has been imbibed into various domains such as data mining, image processing, and networking. The fruitfulness of this concept improves the situation and helps to reap out various unbounded benefits in different domains. The smart city project makes use of the cloud computing approach to achieve the goal of computing. Figure 7.4 shows an example structure for cluster computing.

The network that interconnects various devices and components will always grow. Thus, there should be some mechanism to address this modular growth factor

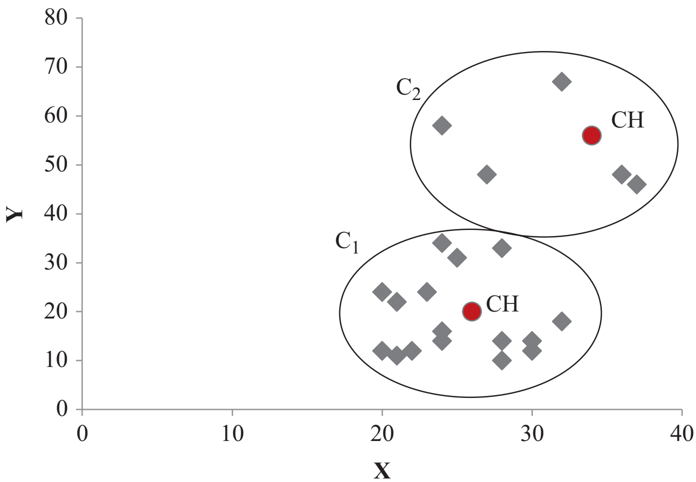


Fig. 7.4 Clustering mechanism

of the network. The prominent clustering technique takes that issue into account and provides a viable solution. This method selects the representative object to handle the objects which are under its control. In this way, the burden of nodes could be reduced, and the responsibility of the objects is decided based on the role that they play in the given scenario. The clustering method also ensures the reusability of resources like frequency in the case of wireless networks. In wireless networks, this technique speeds up the communication process, reduces the bandwidth consumption, and also makes the networks carry out their functionality in an efficient manner. Clustering methods are divided into two broad categories, namely hard clustering and soft clustering. In hard clustering also known as exclusive clustering in which each object belongs to only one cluster, and the boundaries are defined clearly for each cluster. In soft clustering, the object can belong to more than one group known as the overlapping cluster technique. Fuzzy logic-based solutions will identify the objects and their respective clusters in a soft clustering approach.

7.1.3 Clustering Mechanism in Cloud Computing

The implementation of clustering in cloud computing improves the result and provides various services over the network. The clustering could be attained by grouping the physical servers in the data center or grouping virtual machines created from the server machines. These servers are generally used to store the data that belong to the users, and the virtual machines are meant for providing the working environment for the user-defined tasks. This working environment includes operating systems, software, application development framework, and smart tools.

The clustering mechanism in cloud computing helps to maintain the data in a distributed way. This type of data would be ever-growing and hence popularly known as big data. The clustering mechanism provides an improved solution by identifying the tasks to be handled within the cluster and among the clusters in a systematic manner. The formation of clusters is attained by a divide-and-conquer scheme where the problem is divided into pieces and attains the goal of processing big data quickly with the help of a distributed system. The cluster head ensures inter-cluster communication while handling the distributed database. Each head node of the cluster is meant for controlling member nodes that contain the data. The processed results from all cluster heads are integrated to obtain the final result. Here the cluster head acts as an effective load balancer where the data storage among the member nodes of the cluster will be properly decided by the cluster head. Thus, the member nodes are considered as lightweight nodes, whereas the cluster head is considered as heavyweight since it needs to take care of member nodes. A good clustering scheme will rotate the cluster head to reduce the burden of playing the cluster head role for a long time.

7.1.4 Ad Hoc Networks

Ad hoc networks are wireless networks without infrastructure similar to Bluetooth technology at the macro-level. The transmission and reception functionalities have to be integrated with each communicating device. The member nodes of ad hoc networks will be mobile nodes such as laptops, mobile phones with high energy levels for data transmission. The uniqueness of the network is to create the tentative network quickly and dismantle the network when it is no longer needed. It provides a cost-effective solution for carrying out various tasks. This dynamic scenario network which is unprecedented in nature suits for network creation in terrain and tunnels. The modular growth of this network could be efficiently handled with the help of a clustering mechanism to improve bandwidth utilization and frequency reusability effectively. Mobile ad hoc network (MANET) and vehicular ad hoc network (VANET) are two major classifications of ad hoc networks that should be included in the creation of smart cities.

7.2 Related Works

7.2.1 Cloud Computing

In a cloud computing environment, data centers and load balancers are highly needed since the workload increases continuously. It is a very challenging phenomenon for the cloud service provider to optimize the resources [16, 17].

7.2.2 Ad Hoc Networks

The role of ad hoc networks is ever-growing and challenging since the present communication system needs an ad hoc-based network to handle unprecedented scenarios. As long as the nodes are mobile, the ad hoc network formation is unavoidable in forming a simple network that will support IoT applications [18].

7.2.3 Clustering Mechanism in Cloud Computing

The role of clustering in cloud computing shows plenty of benefits in handling the resources in an efficient manner [19]. For instance, applying data mining techniques that make use of clustering algorithms on cloud storage will help to make the right decision. The clustering mechanism ensures proper utilization of resources, reduces the burden of nodes that are playing a specific role, and handles the workload in a well-decentralized way without any hassles.

7.3 Clustering in Cloud Computing

In a cloud environment, each datacenter will be handling a bunch of servers with the help of a load balancer. The user request reaches the datacenter at the initial stage, later this will be given to the load balancer to allocate the resources. In this approach, a single load balancer to handle all the servers and the VMs created from them will be a challenging task. Thus, the clustering concept has been added to create a group of servers where each group or cluster will have a representative called cluster head (one of the server nodes) and member nodes (server nodes). In this concept, the cluster size and election of the cluster head will be vital. The cluster size is decided based on boundary values. The cluster head is elected based on cluster formation algorithms. This work focuses on the cluster formation and cluster head election based on W-PAC (Weighted Partitioning Around Clusterhead) algorithm.

7.3.1 Pseudocode: Cluster Creation

{NonC$_n$: Non-cluster nodes or outlier nodes}.

```
1. Let Y be the set of nodes such as Y = { MN1, M N2, MNn }
2. Calculate the degree of the node.
3. Let assume that degree (MNp) is initially zero for p = 1,2,3…..-
Size of (Y).
4. If p and q are unequal then
5. q = 1.
 begin
  Manhattan distance between MNp and MNq = MOD{(U2 —U1) + (V2
—V1)}
 If ( Manhattan distance between MNp and MNq < boundary )
 begin
 Include MNp to cluster Cm. // add to cluster
 Increment degree of MNp by 1.
 Increment q by 1.
 end
 else
 Add ( MNp , NonCn) // add to Non cluster
 end
6. Repeat step 5 until q = Y.
7. p =0.
8. Repeat steps 5 and 6 until all the nodes in the non-cluster get
examined.
```

The cluster creation algorithm considers Manhattan distance parameters to create clusters. The size of the (number of nodes) cluster is decided based on boundary values. The nodes are included in cluster C_p as long as they are satisfying the membership criteria specified in step 5. The nodes that fall outside the criteria will be included in non-cluster $NonC_n$ and are called outlier nodes. Then, cluster formation is tried again among outlier nodes; hence, many clusters are made possible.

7.3.2 Pseudocode: Clusterhead Election

1. Call W-PAC to create the clusters based on Manhattan distance parameters.
2. Cluster = CL_p, NCnt = Number of nodes in CL_p.
3. q = 1; $MN_p = (U_x, V_x)$; $MN_q = (U_{x-1}, V_{x-1})$;
4. If p is not equal to q

    begin

      If (Manhattan distance between MN_p and MN_q < boundary)

        begin

          Calculate the Mobility speed of Node $Mob(MN_p)$ belongs to CL_p.

$$Mob(MN_p) = \frac{1}{T}\sum_{x=1}^{T} MOD\{(U_x - U_{x-1}) + (V_x - V_{x-1})\}$$

          Calculate the $Dist(N_p)$ Distance between nodes MN_p and MN_q using Manhattan distance metric.

          Increment q by 1.

        end

    end

5. Repeat the step 4 until q = NCnt.
6. Let assume the Energy of nodes $E(MN_p)$ for all the nodes.
7. The weight of node $Weight(MN_p)$ is calculated as follows,

    $Weight(MN_p) = k_1 * degree(MN_p) + k_2 * Mob(MN_p) +$
    $k_3 * Dist(MN_p) + k_4 * E(MN_p)$

8. Repeat step 7 for all nodes belonging to CL_p.
9. $CH_z = Min\{ Weight(MN_1), Weight(MN_2), Weight(MN_3), Weight(MN_M) \}$.
10. Repeat the step 2 through 9 for p = 1….. no of clusters.

The W-PAC cluster head election algorithm takes clusters that are created using a distance metric. As W-PAC is a multi-parametric type, the election of the head node happens based on other parameters such as degree, mobility, and energy. The parametric values are computed for every node that belongs to the cluster CL_p and the weight value of each node is computed based on parameter values. The constants k_1,

k_2, k_3, and k_4 are the weightage percentage or value of the parameters and will be decided based on the context.

In-line with cluster head selection, the node with the least weight is chosen as cluster head. This process is done among all the clusters to elect their respective cluster head. The energy level of nodes is assumed or fixed to standard values for the simulation.

The energy level of nodes will go down as the time passes. The node which plays the cluster head role will get quickly exhausted than member nodes. Thus, the re-election of cluster heads is unavoidable to sustain the lifetime of the clustered ad hoc network. This re-election takes less time since the cluster creation part is segregated. The re-election of cluster heads indeed saves the network from re-clustering. The re-clustering step includes the addition of overhead of the network that has to be decided at the appropriate time. W-PAC has made the cluster head re-election as simple as possible by considering the local minimum for re-election. In local minimum, the nodes belonging to clusters are only considered to re-elect the cluster head of the cluster.

7.3.3 Experimental Results

The ad hoc scenario network is considered for applying the clustering mechanism. The node's position at a particular instant is considered for the analysis. After the clusters are formed, they have to be monitored periodically or continuously for the re-clustering or re-election to happen when the clustered network performance goes down.

The cluster formation in an ad hoc network is done with an example scenario. For instance, it is considered to take 100 nodes as the sample set for implementation using the C++ programming language. Table 7.1 shows the simulation parameters for the experimental study. The energy threshold indicates the re-election level of the cluster head when the cluster head energy goes below the energy threshold value. The weighing factors k_1, k_2, k_3, and k_4 are decided based on the specific context.

Table 7.2 shows a data sample considered for the W-PAC algorithm for electing the cluster head. The table shows the values that were assigned for the data sample considered for the experimental study.

Table 7.1 Simulation parameters

Particulars	Values
N (number of nodes)	100
Boundary	10 units
Threshold (energy)	500 units
Weighing factors (k_1, k_2, k_3, k_4)	0.7, 0.2, 0.05, 0.05
Parameters	Distance, degree, mobility, and energy

Table 7.2 Data sample and values for W-PAC algorithm

S. No.	*X* (m)	*Y* (m)	*E* (mW)	*M* (recorded value)
1	10	12	1000	1
2	11	14	1001	2
3	12	16	1002	1
4	13	18	1003	3
5	14	20	1004	1
6	15	22	1005	2
7	16	24	1006	1
8	17	26	1007	3
9	18	28	1008	1
10	19	30	1009	2
11	20	32	1010	1
12	21	34	1011	3
13	22	36	1012	1
14	23	38	1013	2
15	24	40	1014	1
16	25	42	1015	3
17	26	44	1016	1
18	27	46	1017	2
19	28	48	1018	1
20	29	50	1019	3
21	30	52	1020	1
22	31	54	1021	2
23	32	56	1022	1
24	33	58	1023	3
25	34	60	1024	1
26	35	62	1025	2
27	36	64	1026	1
28	37	66	1027	3
29	38	68	1028	1
30	39	70	1029	2
31	40	72	1030	1
32	41	74	1031	3
33	42	76	1032	1
34	43	78	1033	2
35	44	80	1034	1
36	45	82	1035	3
37	46	84	1036	1
38	47	86	1037	2
39	48	88	1038	1
40	49	90	1039	3
41	50	92	1040	1
42	51	94	1041	2

(continued)

Table 7.2 (continued)

S. No.	*X* (m)	*Y* (m)	*E* (mW)	*M* (recorded value)
43	52	96	1042	1
44	53	98	1043	3
45	54	100	1044	1
46	55	102	1045	2
47	56	104	1046	1
48	57	106	1047	3
49	58	108	1048	1
50	59	110	1049	2
51	60	112	1050	1
52	61	114	1051	3
53	62	116	1052	1
54	63	118	1053	2
55	64	120	1054	1
56	65	122	1055	3
57	66	124	1056	1
58	67	126	1057	2
59	68	128	1058	1
60	69	130	1059	3
61	70	132	1060	1
62	71	134	1061	2
63	72	136	1062	1
64	73	138	1063	3
65	74	140	1064	1
66	75	142	1065	2
67	76	144	1066	1
68	77	146	1067	3
69	78	148	1068	1
70	79	150	1069	2
71	80	152	1070	1
72	81	154	1071	3
73	82	156	1072	1
74	83	158	1073	2
75	84	160	1074	1
76	85	162	1075	3
77	86	164	1076	1
78	87	166	1077	2
79	88	168	1078	1
80	89	170	1079	3
81	90	172	1080	1
82	91	174	1081	2
83	92	176	1082	1
84	93	178	1083	3

(continued)

Table 7.2 (continued)

S. No.	*X* (m)	*Y* (m)	*E* (mW)	*M* (recorded value)
85	94	180	1084	1
86	95	182	1085	2
87	96	184	1086	1
88	97	186	1087	3
89	98	188	1088	1
90	99	190	1089	2
91	100	192	1090	1
92	101	194	1091	3
93	102	196	1092	1
94	103	198	1093	2
95	104	200	1094	1
96	105	202	1095	3
97	106	204	1096	1
98	107	206	1097	2
99	108	208	1098	1
100	109	210	1099	3

Table 7.3 W-PAC results: cluster head coordinates of clusters

Clusters	*X* (m)	*Y* (m)	Nodes
C_1	32	56	40
C_2	82	156	43

The coordinates of the nodes are marked as *x* and *y* positions in meters. The energy level of nodes is assumed to be in milliwatt (mW). The mobility factor value is chosen based on the historical records of the movement of the nodes for the specific period. The least value specifies the low mobility of a node, and the higher value of mobility represents the high movement of the nodes. The election of the cluster head is based on the node with minimum weight factor and minimum or least mobility node. Those sample sets of data will be fed to the W-PAC algorithm as input to form the clusters and also identify the cluster head based on the weight value computation.

Table 7.3 shows that there are two clusters, namely C_1 and C_2 where C_1 contains 40 nodes and C_2 contains 43 nodes and the remaining nodes are outliers. Cluster C_1 contains the cluster head node at the position (32, 56) and cluster C_2 has the cluster head node at the position (82, 156). After the formation of clusters, the cluster management happens to decide re-election and re-clustering steps in an ad hoc network. The re-election happens when the cluster head energy level goes below the energy threshold value. As the W-PAC algorithm adheres to local minimum policy, the re-election of cluster head is done by considering the nodes within the same cluster. This process helps the network to sustain and also eliminate the exploitation of nodes by the addition of more responsibility. The re-clustering is handled and should be considered as the extreme level step implemented specifically when the cluster has become so weak. For instance, re-clustering is considered when the movement of nodes is high.

7.4 Cloud Computing Model on Clustered Wireless Ad Hoc Networks

The data center is a collection of nodes (servers) that are communicating in wireless mode, which is managed by the cloud service providers. In general, the server nodes are very high-end machines to handle the user's request, and they are housed in a single place. For instance, the Facebook data center has a bunch of servers to handle user's requests, and they are interconnected using optical fibers to provide high-speed communication among the nodes.

A novel approach is considered in this chapter on housing and handling the data centers. This approach proposes to combine the dynamic nature of an ad hoc network with the static nature of cloud servers. In this method, the data centers will no longer be housed in specific areas to provide services such as SaaS, PaaS, and IaaS. Since the ad hoc nature eliminates the need for infrastructure, the cloud services are provided without the infrastructure to the end-users. The data centers are formed based on the demand and availability of nodes (high-end server machines).

After ensuring the availability of nodes under the data center, the nodes are clustered and cluster heads are fixed for each cluster to optimize the resource utilization.

The clusters and cluster heads are identified using W-PAC cluster creation and cluster head selection algorithms. The server system is a node that could play the role of either cluster head or member. Cluster head works as load balancer together with clusters form a distributed load balancing system to simplify the task handling mechanism. The cluster head maintains the list of member nodes and their status in a table form.

Table 7.4 shows the data structure which is maintained by the cluster head node. The member nodes are server machines that will handle the task. The cluster head checks the status of the member node before allocating the task. If the server node status is idle, then the task which is waiting in the queue will be assigned to the server node. If the server node is busy with some other task, then it will not be disturbed for a while.

When the task queue is ready with the list of tasks, the cluster head will get the task from the queue and distribute them to the member nodes for speedy execution.

Table 7.4 Format of cluster head data structure

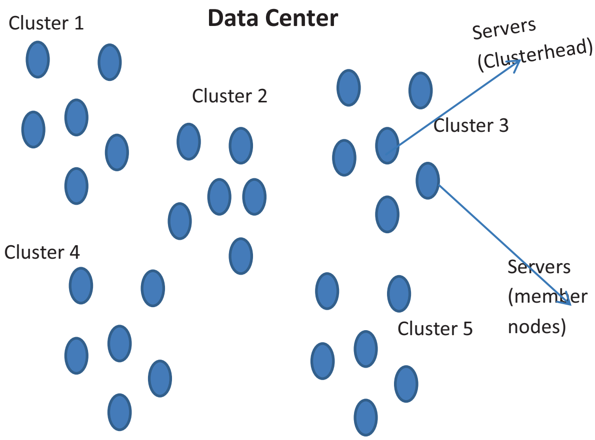
Particulars	Value
Member nodes	MN_1, MN_2, MN_3, MN_n
Status of member node	Idle or busy
Task queue	T_1, T_2, T_3, T_n

This proposed scheme of task allocation will improve the task handling mechanism. If the node moves, then this would be known by the cluster head, and the communication is possible between cluster head and member node as long as the member node falls within the coverage of the cluster head node.

Figure 7.5 shows the structure of a cloud data center using a clustered ad hoc network. The data center is viewed as a collection of clusters where each cluster has a cluster head node (server). In general, the data centers are managed by cloud service providers. The proposed approach avails the data center under the control of a person who has sufficient resources (servers) or capable of bringing the resources from some other means. The ownership of the cloud is tentative since the resources will be withdrawn after the requirement gets over in that region. The functionality of the clustered wireless ad hoc network on cloud computing technology will be clearly understood with the help of the framework as shown in Fig. 7.6.

The basic cloud architecture is viewed as a two-level model such as client and server. The proposed model recommends the modification which has to be incorporated at the second level. The cloud data center contains the nodes (servers) which are ad hoc in nature and are clustered with representatives (cluster head) for each cluster. The cluster formation is done with the help of the W-PAC cluster formation algorithm. This method reduces the burden of each node within the network, and the workloads are easily distributed and handled in an enhanced way than in a non-clustered environment. The re-election is decided based on a continuous or periodical check on the energy level of the cluster head. The re-clustering will be based on the validation of cluster's strength using validation parameters like Silhouette index, Dunn's index, and Davies–Bouldin index. The Silhouette index value decides how far the member nodes are strongly tied up with the cluster head. The Dunn's index and Davies–Bouldin index values reveal the strength of inter-cluster communication in data centers.

Fig. 7.5 Cloud data center using clustered ad hoc network



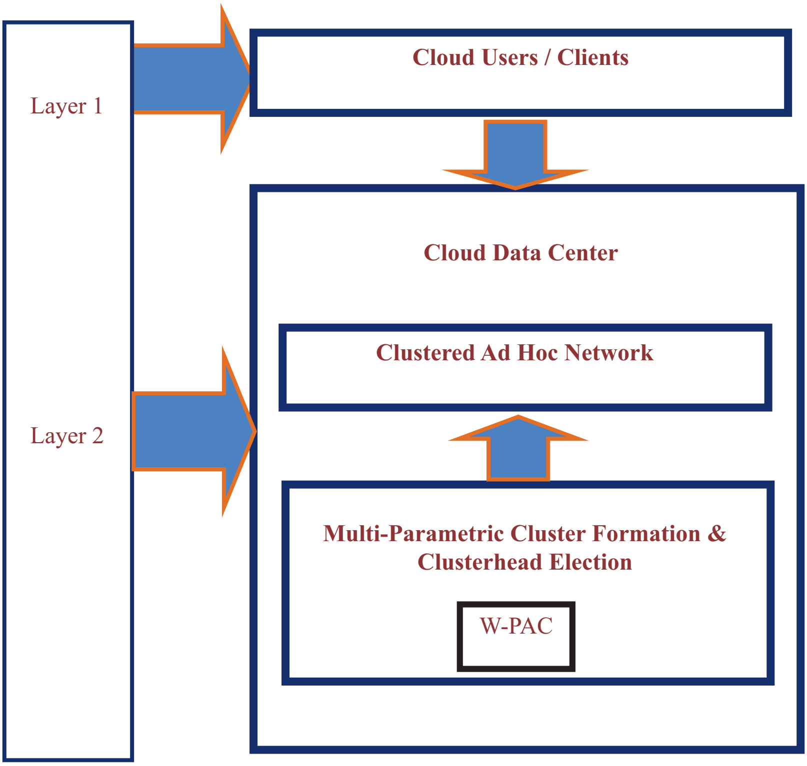


Fig. 7.6 Framework of cloud computing model on clustered wireless ad hoc networks

7.5 Clustered Wireless Ad Hoc Cloud Network for Smart City Applications

The model proposed in this chapter with a clustering mechanism has played a vital role in various smart city applications like storage, resource sharing, and data analytics. Cloud computing has laid the road to green computing and edge computing. Further, the Internet of Things (IoT) will provide enhanced service when combined with cloud computing technology. It is very well clear that the future will be reigned by IoT with advanced technologies like cloud computing to store and analyze the data about smart cities. The following are the smart city applications and the emergence of computing methods using cloud computing technology.

7.5.1 Storage and Resource Sharing

Figure 7.7 shows the cloud data center that contains clusters that contain various server nodes. The database is a platform that stores data about real-world objects. Presently, small-scale industries, retailers, and wholesalers within the city are

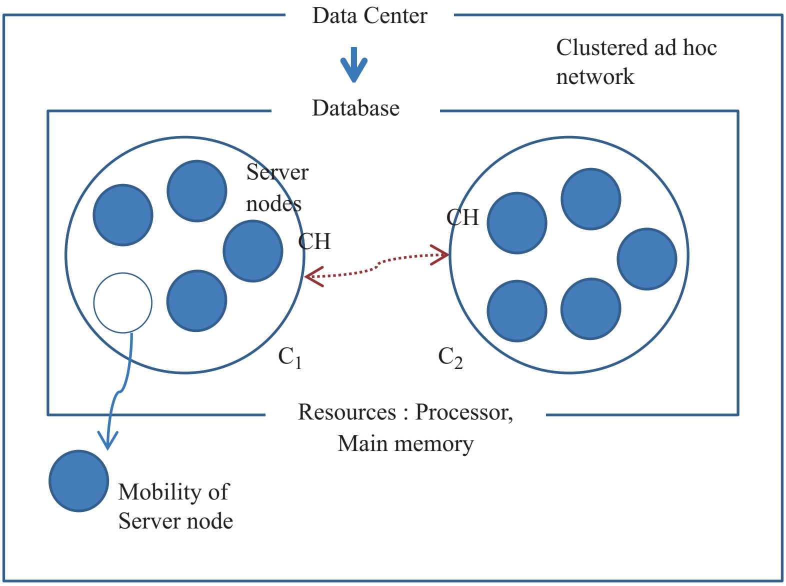


Fig. 7.7 Data center for storage and resource sharing

outsourcing their data maintenance to run their business successfully. Cloud service providers are providing better options for the data outsourcing field. As the gaming field is growing at a rapid pace, the available resources will become obsolete, making the replacement cost more. The implementation of cloud service in this approach would cut down the cost by hiring resources tentatively.

7.5.2 Data Analytics

Figure 7.8 gives details of the data center for data analytics. Modern-day cities generate a huge amount of data related to various functions handled by the people. The functions are broadly classified into home-based tasks and non-home-based tasks. In home-based tasks, handling the electric and electronic appliances, online mode of transactions, working from home nature of the job, and technology-aided learning methodologies are possible with the support of IoT and cloud computing. In non-home-based tasks, handling of higher-end wireless devices, emergency healthcare services, technology-enabled security systems, and demographic details of the people are implemented using IoT, cloud computing, and distributed software systems. The data generation based on the tasks mentioned earlier will be dynamic and continuously grows multimedia data for analysis and various applications.

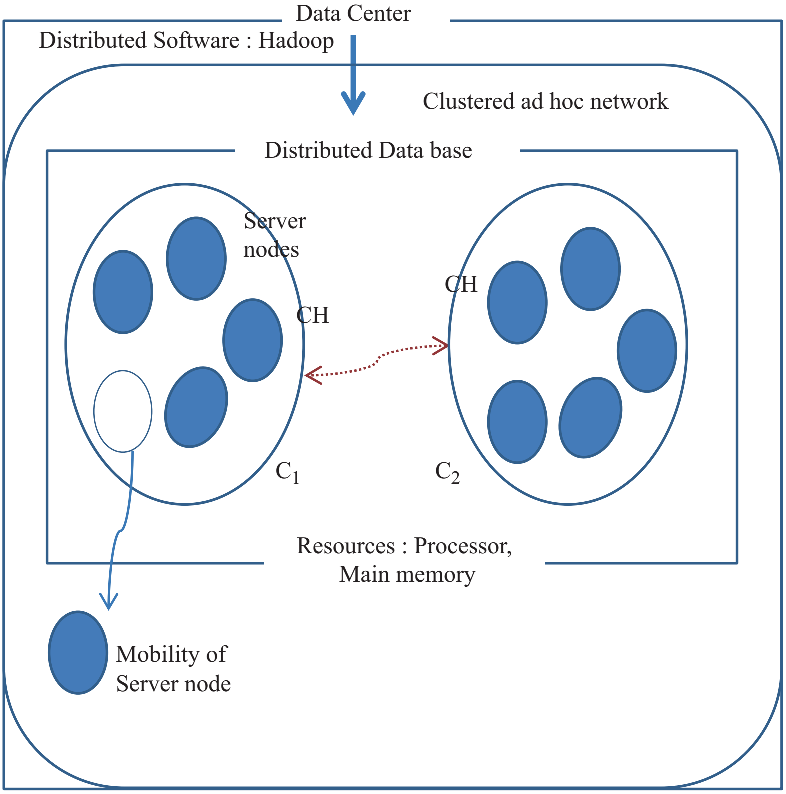


Fig. 7.8 Data center for data analytics

7.5.3 Virtual Machine Clustering

The optimization principle is attained with the help of the virtualization of resources in cloud computing. Figure 7.9 shows the clustering phenomenon on virtual machines to store the data and share the resources for the end-users. The virtual machines are configured based on user requirements such as operating system, memory, and software resources or tools. The server nodes are clustered, and members of ad hoc networks and virtual machines (VMs) are created from them. The virtual clusters are having a virtual cluster head to maintain the status of nodes for the task allocation.

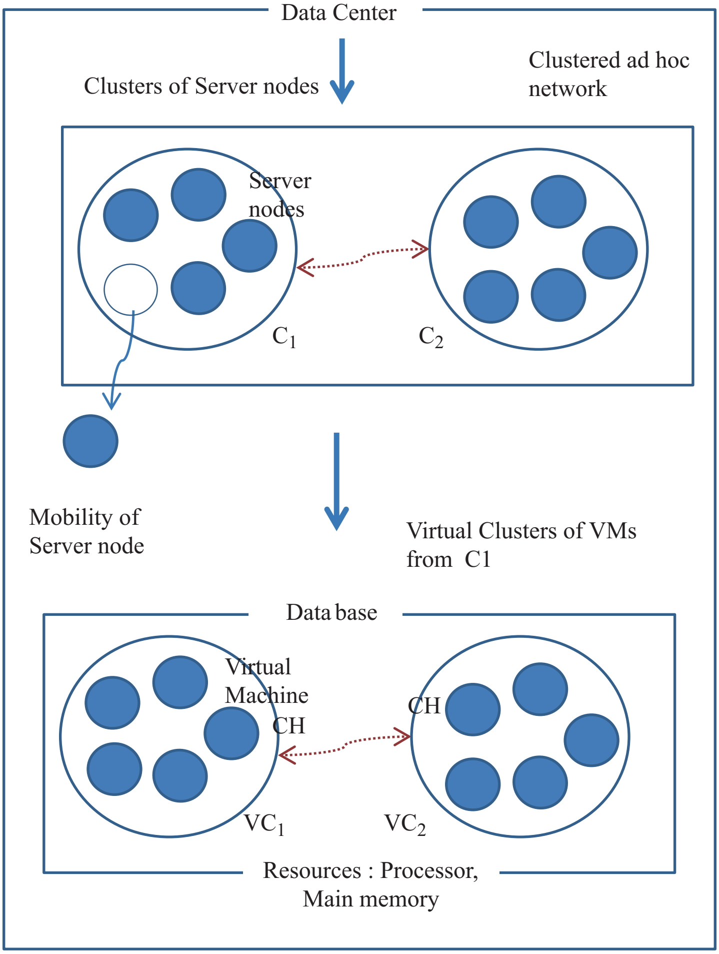


Fig. 7.9 Data center contains clustered servers and VMs

7.5.4 Fog Computing or Edge Computing

The integration of ad hoc clustered cloud, fog network, and IoT devices will yield a distinct smart city application. The fog network or edge network consists of fog nodes or edge nodes to communicate directly to IoT devices. This middle-level network reduces the burden of the clustered ad hoc cloud network which stands uniquely much closer to IoT devices than the cloud. The data generated as a result of functionalities of devices will be stored in clustered fog nodes and analyzed for making decisions. IoT devices would behave as electrical appliances, electromechanical devices, electronic gadgets, and also as hardware. In general, any device which can communicate with systems or other devices over the network will be known as IoT devices. These devices can communicate in either wireless mode or wired mode. The processing capabilities of fog nodes are slightly lower than server nodes in the cloud. Having two levels of networks, namely cloud networking and fog networking, would improve the data handling mechanism within the city. For instance, crime investigation details in a city create a huge volume of multimedia data and are processed in a distributed way. Figure 7.10 shows the data center nodes, cloud computing, and fog networking link with IoT devices.

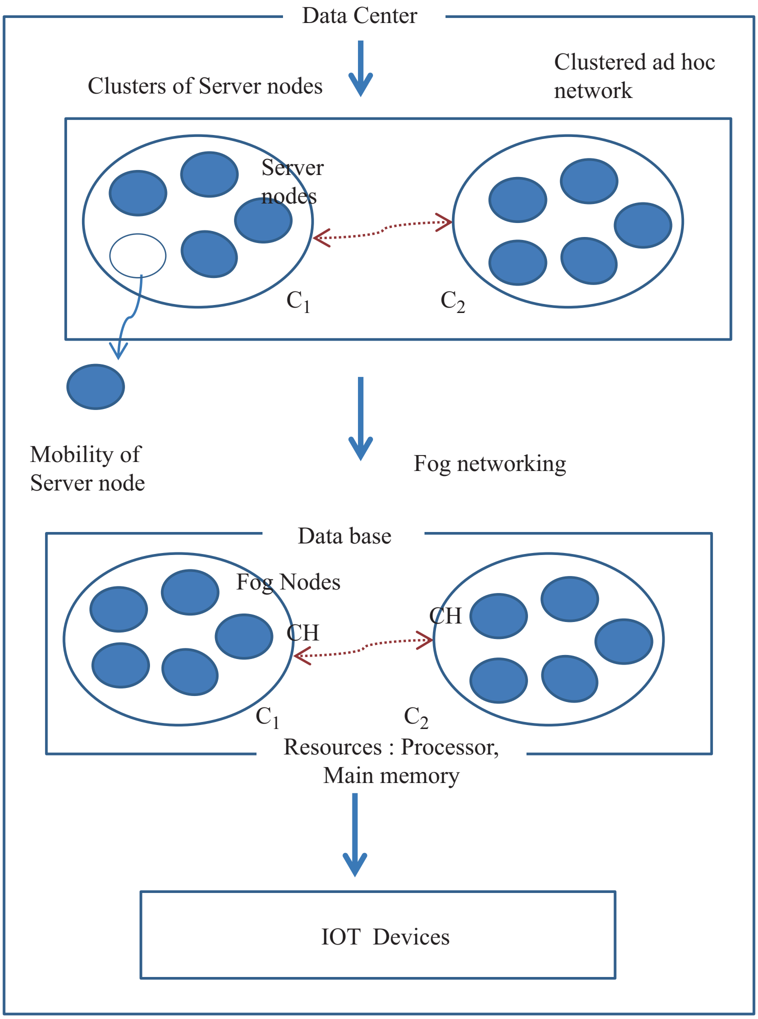


Fig. 7.10 Data center implements fog computing for data from IoT devices

7.5.5 Green Computing

As people move toward high tech on one side, the world experiences global warming and greenhouse effects on the other side. It is well experienced that manufacture of more products would lead to more pollution. Since the scrap or waste handling mechanism is not much efficient, the recycling would not give fruitful results. Thus, the technology must yield environment-friendly products, thus optimizing resource handling capability and effectively reducing product manufacture. The rapid growth of technology should be nature-friendly and also ensures the reduction of resources for cost-effective production. This drives the computing world to give a green touch to safeguard the world. This would be successful when it is handled at the micro-level for instance and city-level applications. The utilization of cloud and fog networks in smart city projects which are part of green computing will affirm the intention of living closer to nature.

7.6 Conclusion

This chapter describes the essence of pollution-free and the effectiveness of smart technology in the creation of the smart city. It is well understood that the applications which are meant for smart cities should make use of technologies such as cloud computing, fog computing, ad hoc network, and clustering. This work describes various smart city applications that ensure the generation of huge amounts of data.

The literature study shows the existing technologies that are generally meant for improving the top-level industries' data rather than putting them on a diverse platform to expand the horizon. Thus, the focus of this study has been aligned to provide a solution with a high vision that could address various entities under a single roof. These entities include households, industries, and institutions within the city. It is understood that the various elements of smart city projects have been developed by the implementation of smart technology and mechanisms which would be either nature-friendly or in-line with green computing. In the path of identifying such technology, this proposed work describes the cloud, fog, and clustering mechanism as one of the integrated solutions toward green computing.

The role of clustering in cloud computing is explained in this study with an example scenario. W-PAC is a multi-parametric clustering algorithm used to form clusters in the cloud. Later, the integration of clustering and advanced technology will reap out better energy-efficient solutions.

Further, this work describes the ad hoc network scenario-based data center to provide cost-effective solutions. The smart city applications based on smart technology and the vital role of virtual machines (VMs) in the data center are explained. The link between cloud computing and fog computing in providing services to IoT devices has been discussed. Eventually, "cloud computing is a path towards green computing" has been visualized and realized.

To conclude, here the elaborated study reveals the importance of smart technology implementation and supportive techniques on the manifestation of smart cities. It has been concluded that the implementation of smart technology has made better survival for all species of the present and future generation.

Acknowledgments I am extremely thankful for the management of Ramakrishna Mission Vivekananda College, Mylapore, Chennai, for showing their immense blessing and support toward carrying out this study and also toward me in all my endeavors.

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Chapter 8
Smart Cities New Paradigm Applications and Challenges

Ossama Embarak

8.1 Introduction

Smart city is managed with intelligent technologies to improve the quality of services provided to citizens as well as to increase the efficiency of all processes. More than 4.0 billion people today live in urban areas, which account for approximately 55% of the world's population, which is expected to increase over the coming decades. As a result, demand for intelligent systems would increase not only in terms of capacity but also in the quality of services. Meanwhile, urban areas accounted for around 76% of waste production, 72% of global energy consumption, and more than 80% of greenhouse gas emissions. As a result, strong demand is being made for sustainable, reliable, and efficient urban services and, thus, urban infrastructure. Digitalization offers a powerful platform to solve these problems and develop models for moving into intelligent cities using smart urban solutions. Governments and policymakers must, therefore, understand and address the challenges of this transition from the heritage of city infrastructure and application to more smart cities meeting welfare requirements and maintaining high productivity [1]. The purpose of this chapter is to explore the digital applications of smart cities and smart city transitions. By completing this chapter, the reader should be able to:

1. Understand the progress from the Push services model into the ecosystem service model.
2. Explore the fourth industrial revolution's pillars.
3. Find out the current state of intelligent services.

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4. Distinguish between smart city services and smart connected giant technology and services (SCGTS).
5. Recognize the proposed collaborative ecosystem for smart cities.
6. Explore smart-oriented solutions focusing on intelligent urban energy systems and smart urban transport systems.
7. Explore the properties and challenges of the smart city transition plan.

The concept of intelligent cities has several interpretations, but each definition includes various views and perspectives. Solanki [2] defines the smart city as "the use of smart computer technology to make the components and services of critical city infrastructure smarter, more interconnected, and more efficient, including municipal management, education, healthcare, public security, property, transport, and utilities." Over recent years, the word "smart city" has been used by various technology companies. It is defined as a compound technology to automate the functioning of urban infrastructure and services, such as housing, traffic, electricity, water, and public safety. Mora et al. [3] state that a smart city could be described as a society allowing:

– To capture and analyze real-world urban knowledge through technology, server substructure, network infrastructure, and consumer devices.
– To apply technology with the assistance of instrumentation and interconnection sensor, actuator, and mobile device in all services.
– The production of services with an intelligent environment that exploits accessible information in its activities and decision-making and adopts information flows between the services providers and the urban or business community.

In recent years, there has been a growing trend, with large numbers of people heading into urban life. As expected in [4] by 2030, more than 60% of the world will be living in an urban climate. Any of the technologies that can solve the rising population problem would lead to the growth of the smart city. The smart city paradigm exists in a diverse urban environment that incorporates a variety of complex structures such as architecture, human activity, innovation, social and economic variability [5]. Smart city provides an insightful way to handle components such as transportation, wellness, electricity, accommodation, infrastructure, and climate control. Data created and obtained from wireless sensor networks are available in a number of fields, such as health tracking, smart home devices, water tracking, and environmental monitoring [6]. In smart city, sensor nodes from different sectors generate large amounts of data that are currently underused. With the use of existing ICT resources, heterogeneous data for improved software processing and service delivery can be incorporated. Some of the latest wireless communication systems 5G, LTE, and Wi-Fi can be used to achieve this convergence of data. The Internet of Things (IoT) includes PCs and other digital devices for the use of linked applications and existing Internet infrastructure. Henceforth, the vision of smart city depends on the infrastructure from a shared location with billions of IoT devices. The recent introduction of low-power wireless network technologies for actuator sensors has made it possible for authorities to monitor and control a wide range of sensor networks and actuators remotely. Hence, this imposes the need to maintain a robust smart city architecture to facilitate the interaction of wireless sensor networks with ICTs.

8.2 The Service Delivery Progression from Push Model into the Ecosystems Model

The world's services are evolving realistically, due to the innovative technology and solutions available worldwide. The outbreaks and revolutions of many countries reflect the huge gap between services offered to citizens and the services offered through online technology the citizens can receive, using social networking, MOOC education, e-commerce systems, etc. Many governments failed to implement transition processes and changes from the Push (the 1950s), Pull (1970s), Coupling (1980s), Integrated (1990s), Integrated System Network (2000s) to Open Ecosystems (2010 +) [7].

1. Push (in the 1950s): When insight into services offered by service providers is not as important, little exposure has been paid to people's experience, no networked connections, and little technological tools used to deliver services.
2. Pull (1970s): Service companies rely on people's needs but do not pay heed to feedback, networked experiences, and digital resources platforms.
3. Coupling (1980s): Providers rely mainly on the needs of the people to take care of their input so that service quality to upgrade reviews are received. It is a mix of Push and Pull method and it is twofold. However, there are no networked connections and no interventions into technology tools networks.
4. Integration (in the 1990s): Both Push and Pull service providers use the modalities for their optimized business services. However, without the introduction of technical resources, the degree of sophistication has risen.
5. System-integrated network (2000s): Service providers use advanced technological tools to provide services and maintain integrated network infrastructure. However, isolated service packages have led to high complexity and delays in the provision of services.
6. Open ecosystem (2010 +): Emphasis of service providers on coordinating and combining systems linked internally and externally with other third-party service providers. This offers an exchange (chain) of interconnected systems between government, semi-government, and private businesses leveraging high-tech platforms to deliver relevant services.

Many countries still have at first or at most the third-level form. Nonetheless, few countries are beginning to realize the need to shift towards the sixth-tier system that matches in with the new concept of globalization and that utilizes advanced technologies. Smart cities use the six-tier model, and decision makers and policymakers on the one side should recognize the services they need to operate in such a distributed and exchangeable fashion. On the other hand, they should be conscious of smart cities'fourth industrial technology that could be used in its governmental regulations and policies.

8.3 Pillars of the Fourth Industrial Revolution

The fourth industrial revolution is all about emerging technology that would shift the processes of human–machine interaction, the way resources are distributed, the relationship between manufacturers, distributors, and consumers. As a result, people will be more open to exchanging and collecting data from everywhere in the world through space technology engagement rather than only central earth broadcasting.

The following shows the nine pillars of the fourth industrial revolution technologies that will transform the way we think and function in every field of life [8] (Fig. 8.1).

1. **Advanced simulation**: Relation is made to the use of simulation in industries to test and optimize facilities and procedures in order to enhance results and job quality and to mitigate or demolish associated threats and hazards prior to actual implementation.

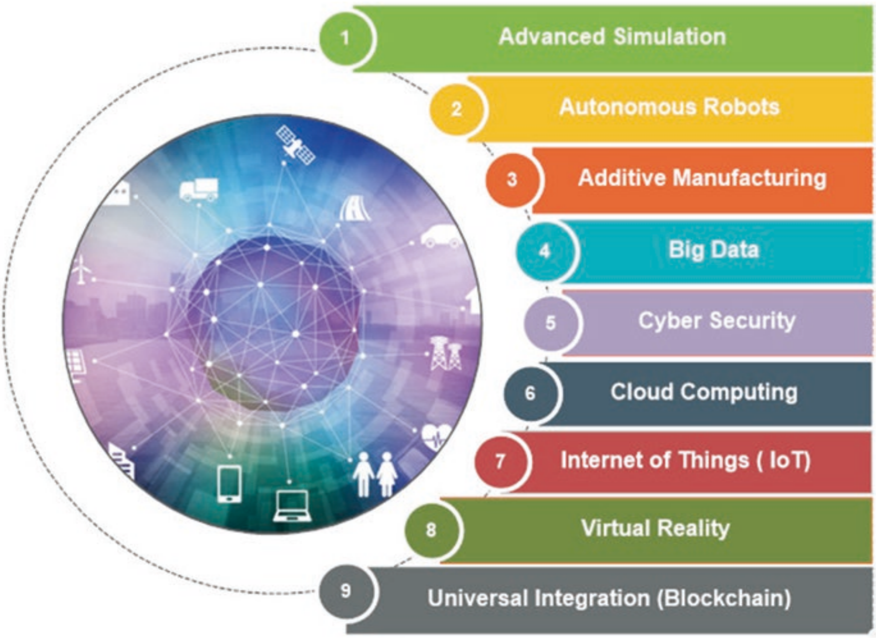

Fig. 8.1 Pillars of the fourth industrial revolution

2. **Autonomous robots**: It concerns the use of robotics in manufacturing to enhance the productivity, quality, and profitability of the business.
3. **Additive manufacturing**: Use computer-aided design (CAD) applications or 3D object scanners to direct hardware to deposit material, layer by layer, in complex geometric shapes.
4. **Big data**: It refers to the enormous data collected by vast active devices every second; this data processing requires to identify patterns and trends, enabling real-time decision-making.
5. **Cyber security:** Hazards and threats to the Internet have arisen in data storage, network processes, and distribution. This calls for large, effective, and comprehensive data monitoring mechanisms to be placed in place to inspect, detect, and deter cyberattacks.
6. **Cloud computing**: It refers to the use of cloud services to store, handle, and process data from remote resources to speed up operations.
7. **Internet of Things (IoT)**: It refers to devices that connect all Internet accessories, making hybrid individuals to individual connections or individuals to company/governmental entities connections, enabling real-time responses—saving business resources, time, money, risk reduction, and production time.
8. **Virtual reality**: It refers to technologies that enable us to present goods to the real world in an artificial shape without bearing the costs of creating a physical one.
9. **Universal integration(Blockchain)**: Where processes are distributed globally, facilitating data sharing and process management in the global business sector.

8.4 The Current State of Smart Services

Moving from conventional cities to smart cities would not entail starting from scratch, it can take advantage of the available infrastructure that is digital or can be digitized. Many cities around the world have been seen as smart cities like New York, Shanghai, Paris, Stockholm, Toronto, and Tokyo. Several cities have already initiated programs for the transition from legacy structures to smart cities, such as Barcelona (Spain), Stockholm (Sweden). There are several cities on the queue, such as Dubai, Abu Dhabi, Ahmedabad. There are several communities focused on IoT multi-hub backbone technologies that make it easy to connect new infrastructure to plug-in and play mode. Mobile nodes, for example, are built on a public bus transit network, a taxi fleet, police vehicles, cliffs, beaches, etc. Present systems also rely on the Push and Pull service models as seen in Fig. 8.2.

The main goal of smart cities is to make better decision-making possible with the use of data obtained by all residents, authorities, companies, individuals, etc. A smart city should provide its people with the best available facilities and give its visitors a greater quality of life. Sustainability of industry to retain quality and entrepreneurship. Smart cities rely on automated data-gathering technologies to offer facilities to which the government and the public are active in city

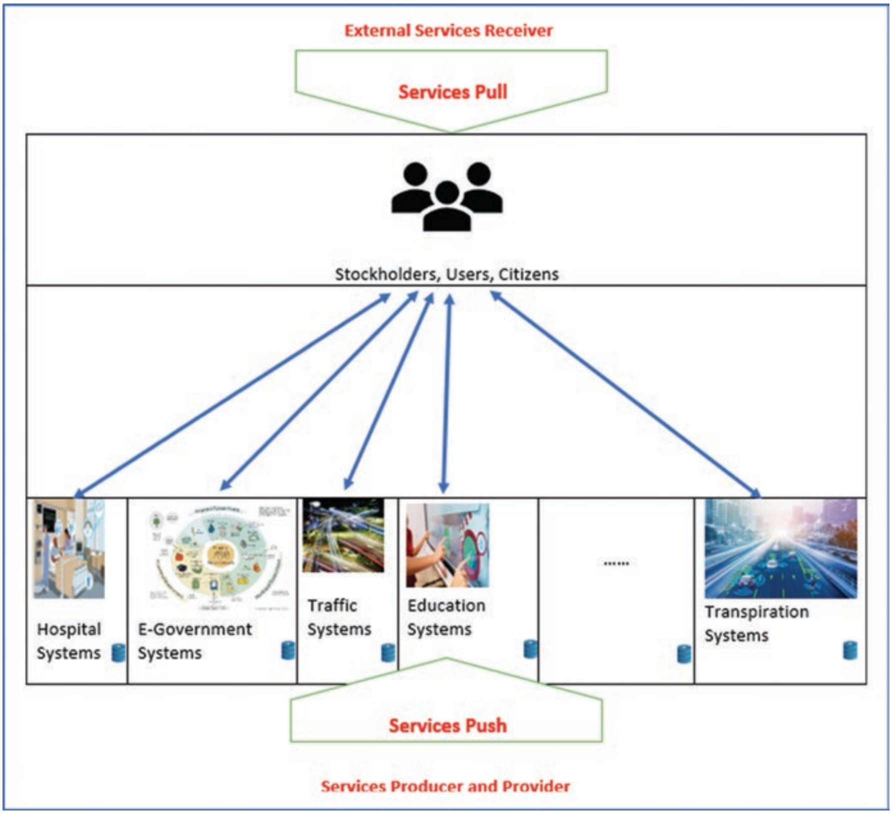

Fig. 8.2 Smart services current state

management. These data are used by the government to optimize the community, including traffic, housing, facilities, climate, amenities, public services, etc.

External service receiver: Represents the top layer that refers to external individuals such as citizens, tourists, and other consumers who require access to the service(s) provided. An external agency may be a service user or a supplier who wants to receive services from another organization, e.g., an industrial company that provides and offers services to producers, etc., also from the e-government system.

Service producer and provider: This is the lower layer in which all resources are produced and provided to external recipients upon request. Service providers refer to business organizations, manufacturers, telecommunications companies, universities, government officials, financial organizations, etc. The facilities' suppliers have their systems for collecting data, processing, and production services in a specific field. They sometimes rely on IoT sensors and other data-gathering mechanisms to produce services based on user requests.

Many smart city frameworks also suffer from certain pitfalls, such as:

1. They have not provided sustainable services due to a restricted degree of standardization.
2. They provide different service bundles that are not compliant with other systems.
3. They provide limited intelligence capabilities where customers need to conduct ad-hoc analysis to obtain specific knowledge from service providers.
4. They lack of standardization and policy consistency.
5. They lack of protection and privacy considerations.
6. They lack of awareness among users due to low levels of training and restricted usability.

The smart cities model would focus on ecosystems rather than the traditional Push and Pull aspect to ensure effective flexible and interconnected services.

8.5 Smart Cities Services Vs. Smart Connected Giant Technology and Services "SCGTS"

The planet is becoming a small village where an incident in a single country might have a direct/indirect effect on the people of other nations, such as Typhoon Haiyan, which has had a major economic, social, and environmental influence on vast areas such as Micronesia, the Philippines, South China, Vietnam, and Taiwan. Suppose we had a smart grid that is integrated across a transparent global network, we might have saved a lot and managed to do so in a different way. As a result, delivering smart services to a city within a nation remains inadequate until it is combined with other smart cities across the globe. As a result, service suppliers and service providers should be organized in a manner that is open to all people, and this contributes to the creation of a global unification structure. The smart city will not succeed and prosper if it offered smart services to its tiny population isolated from other smart cities across the globe. This leads to what we called a smart hybrid integrated system (SHIS) that needs Smart Connected Giant Technology and Services (SCGTS) that impose applying normalization of policies from different nations adapted to different cultures to provide global services. The following are some of the expected obstacles that represent real challenges for deploying worldwide smart integrated systems.

1. Different nations have different practices and customs that lay down different guidelines for the provision of services.
2. Countries have varying basement structures, some countries have strongly integrated structures for their states, whereas some may have no systems at all.
3. Security and privacy concerns extend to automated programs that allow those entities to monitor nonresidents.
4. Taxes and exchange of money that are varied and have a negative effect on service evidence.

5. Discrimination between stakeholders would remain a challenge as developing countries offer high-quality services to their nations that differ from the level of services offered to other recipient nations.
6. These models may lead to the dominant role of the giant service providers and the devastation of medium and small organizations.
7. Abrupt Internet services will pull all networks down during any upheaval, uprising, or war. This will contribute to the effect of events on the population.
8. Technology illiteracy, there are still a significant number of people who are not consumers of smart devices due to technical illiteracy or financial problems that discourage them from owning smartphones.

Though smart cities will make considerable strides in the provision of utilities and healthcare, they require rules and legislation that are obligatory to all regimes in times of peace and conflict.

8.6 Proposed Smart Cities Collaborative Ecosystems

Present urban cities have centralized networks (tier four) or, at most, centralized network services (tier five) as set out in Sect. 8.2. Exiting systems are aged compared to more recently established developments and developments in technology, including digital modeling, stand-alone robots, big data platforms, cloud computing, artificial intelligence, deep learning, etc. This has caused cities to become massively deficient in functionality compared with the expectations of its citizens. There is a significant need to shift to smart urban systems that are transparent and massively interconnected and deliver services to any customer request. However, this creates a requirement to build a smart city model system as proposed in Fig. 8.3.

Legacy communities have only two layers, the network and the user layer. The Push and Pull demand models, or at most the pairing method, relate to the production and delivery of the service. In the meantime, the infrastructure layer does not focus on 4G technologies, but still depends on traditional classical techniques. As a result, the hug fund inefficiently invests in reclaiming issues.

In order to make a realistic change from a legacy city to a smart city, policymakers and service providers should establish and implement the ecosystem approach rather than the other services demand approaches set out in Sect. 8.2. The suggested general architecture for smart cities as shown in Fig. 8.3 can specifically be explained as follows:

8.6.1 Infrastructure Layer

The infrastructure layer is the foundation for smart city services that interact with the physical components of a system in which the added value or resources produced by industries, towns, education, transport, and other institutions have been

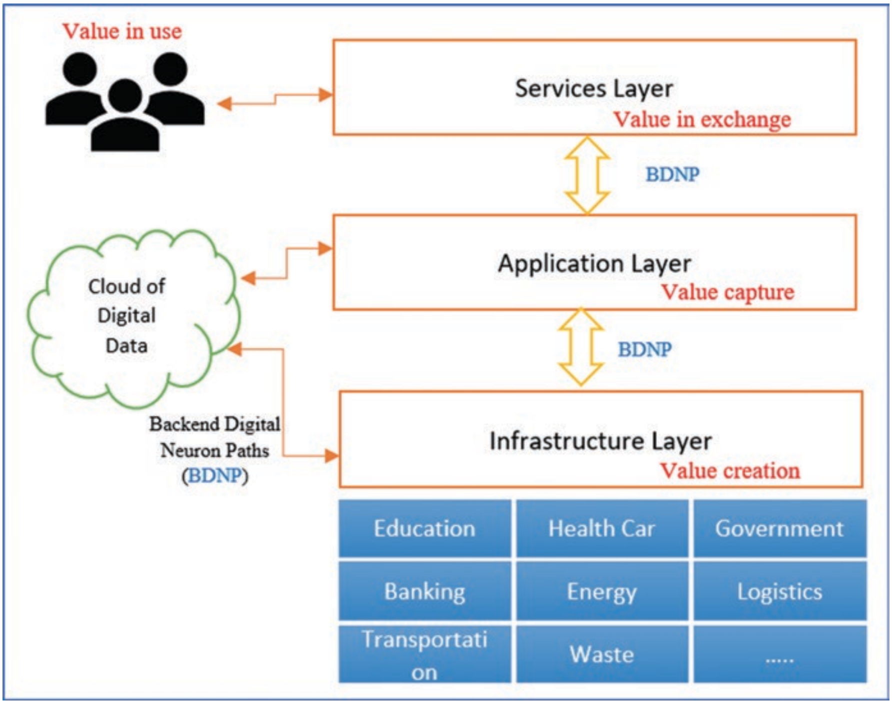

Fig. 8.3 Smart cities general framework

incorporated. In this case, it includes communication infrastructures (satellites, landlines, etc.), networks, IoT devices, and all medium-term applications for value creation and production. There are two essential forms of infrastructure:

1. New installations, which not only draw on 4G technology but will need to be expandable and compatible with the existing system.
2. The legacy infrastructure, which should either be merged with the new setups or be replaced instead of being retained as an obstacle to any modernization project.

As seen in Fig. 8.4, this layer comprises all government agencies, private sector institutions, semi-governed agencies providing services to people, consumers, and other stakeholders of smart devices who also provide inputs for processing applications. However, all policies and regulations that govern the values produced at this point must be monitored by the authorities. User devices (smartphones, wearable technologies, cameras, etc.) are part of the infrastructure layer where they can be used to produce some information and exchange resources with subsystems such as tourist sites, human health monitoring, education subsystems.

All hardware devices that operate on the infrastructure layer must migrate their data to their respective cloud zone, where programs in the application layer will retrieve data for analysis and produce additional values that will be transmitted through the services layer. The digital data exchanged may pose several concerns

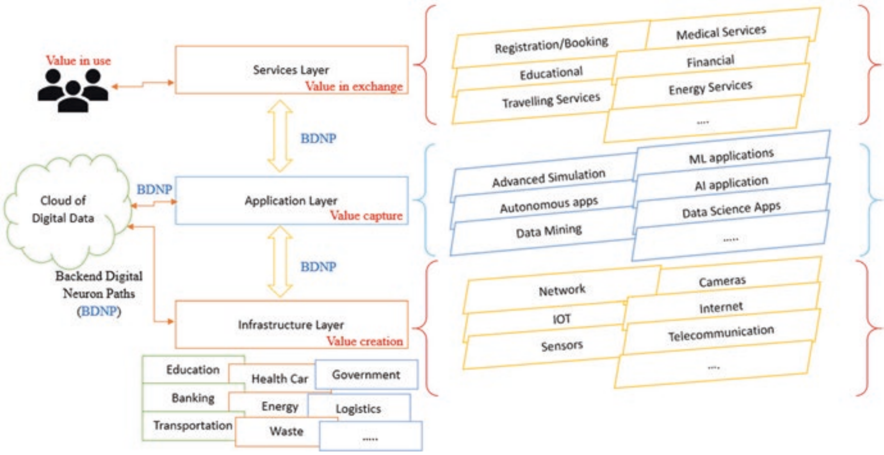

Fig. 8.4 Layered hardware, applications, and service mapping

that will be addressed later in this chapter. This paradigm looks at the entire image of smart cities as an ecosystem with a huge, transparent, distributed service called by end users and tight to legitimate person authentication.

8.6.2 *Application Layer*

All subsystems residing in the infrastructure layer are interconnected through the application layer and cloud data zones, as shown in Fig. 8.5.

Figure 8.5 shows how the healthcare subsystem works by linking the subsystem architecture (base), subsystem software, and its cloud zone, which maintains digital health data. Other subsystems, such as the education subsystem, insurance subsystem, banking subsystem, can capture value through their respective application in the application layer with the authorization. It should be clear that applications that exist on the application layer can communicate directly to other applications within the application layer and can collect data from a digital data zone from what we call the Backend Digital Neuron Paths (BDNP). The BDNP represents the backend digital connectors responsible for linking all subsystem elements. This links subsystem devices located in the networks, applications, the service layer, and the network field. It would also be responsible for feeding the other subsystems with their needs from the subsystem of which it belongs.

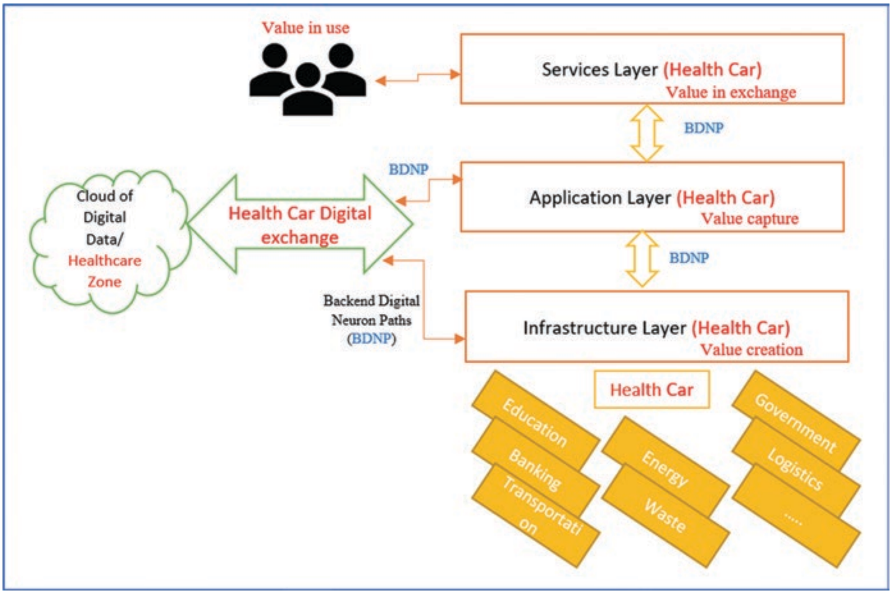

Fig. 8.5 Healthcare subsystem

8.6.2.1 Application to Application Exchange

All applications run on the application layer that should be able to work together and share application resources if they are called by each other. This requires a degree of integration, standardization, and protocol for application-to-application operations. The key problem here is who will be responsible for controlling and maintaining the activity of the services produced. The solution to this question is very clear if we introduce decentralization and privatize services that are based on efficiency and competition. Governments could, however, track the provision of services and the processing of citizens' data that may have been used for the provision of services.

8.6.2.2 Application to Data Zone Exchange

Applications can store all generated data in the dedicated zone and extract all necessary data from the cloud data zone. The data zone might represent a pool of thousands of specialized zones in which all applications using the data as input for processing should be able to access the zone and be allowed to modify the data. Data zones should be isolated from each other and could only be exchanged through the processing of applications.

8.6.2.3 Application to Grade Service Exchange

End users should be able to access the services offered by the applications. As a result, apps not only provide services to the platform but also obtain feedback from users on the services they offer. Applications can apply machine learning mechanisms to the input received by the end user to optimize and customize the services provided to the end user.

8.6.2.4 Application to Infrastructure Exchange

The physical layer is the main layer where all services are actually produced and distributed by applications. Applications can access specific ad hoc infrastructure. In the main time, the infrastructure layer updates the resources generated on the basis of requests obtained from the application layer. There should be a continuous relationship between the physical layer and the application layer where the services are respectively created and processed.

8.6.3 Services Layer

The services layer is the main tier where users can call all utilities. Figure 8.6 shows a sample of services that could be produced by an application layer using smart technologies and algorithms and rely on cloud-based data. The service layer acts as an interface for the distribution and management of services that should be expandable.

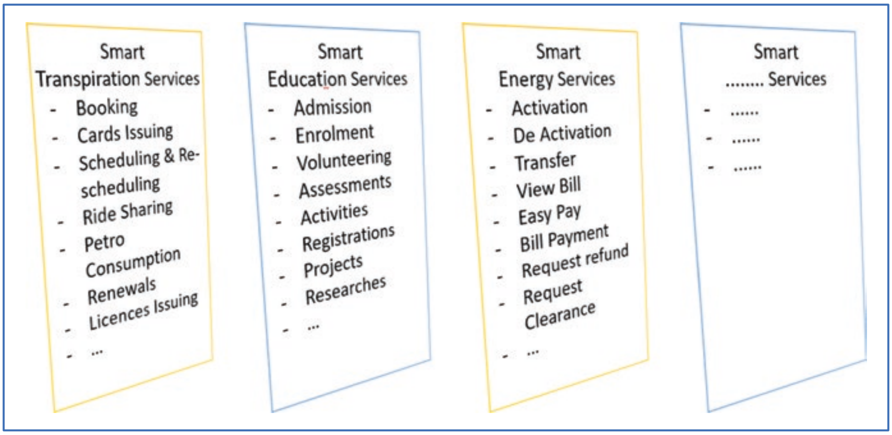

Fig. 8.6 Sample smart services

As discussed above, the output of the services delivered relies on the expertise of its respective application in the application layer, which is also affected by the quality of the input data obtained from the cloud sector, which we referred to as services tuning. However, there are three major barriers to the development of utilities in smart cities.

1. Services integration refers to:
   (a) Services coordination across different sectors.
   (b) Data integration across applications.
   (c) Service coordination between the legacy systems and the modern ones.
2. Services obligation guarantees:
   (a) Accountability by entities that will take the lead and responsibilities.
   (b) Affordability, which refers to the class-based tariff of provided services.
   (c) Accessibility, which refers to grant access to segmentation of users.
3. Services quality refers to the level of provided quality and loop feedback for updating.
   (a) Regulatory issues to make sure the competitions are works without service interruptions.
   (b) Legal issues that guarantee the system liability to provide services as per the commitments.
4. Services normalization refers to the services design pattern where applications guarantee that services that are part of the same service inventory do not contain any redundant functionality.

8.6.4 Cloud of Digital Data

The data generated by the infrastructure layer should be migrated to the cloud digital data storage that can be accessed by the application layer. The data collected is expected to grow dramatically across a vast range of data collection sources in cities such as sensors, wearable technology, cameras, GPS, smartphones. These data generation systems can be seen at considerably smaller prices and sizes, making them very easy to use. In fact, their storage capacity has improved significantly, meaning that an unprecedented volume of data is generated.

The data sources are:

1. Current legacy systems, namely the telecommunications infrastructure (both cables and wireless), which allow for the physical transmission and storage of information.
2. The government, semi-gov, and private entities that produce data through their normal functioning.
3. The individual devices that generate data that echoed back to the systems.

All data sources are deemed IoT once they have a device that links them to the internet and the worldwide web. Smart cities should also assign high priority to IoT sensors and connectors, which should serve as enablers to relay all data collected from various sources to the cloud for application layer connectivity and processing.

All users living within the borders of a smart city should be able to connect their devices automatically through the plug and play through the city's wireless network, which introduces the need to retain wireless connectivity anywhere. Every IoT data collected must be sent to the cloud for standardization and sharing. Once the data is cleaned and processed in a standard form, it should be appropriate for accessing the data using proper security, and the device authentication methods exist on the application layer.

According to the model mentioned in Fig. 8.7, data collection in smart cities has the following capabilities.

1. Collect data from various IoT devices.
2. Data sending and receiving, sending by IoTs devices and receiving by respective cloud zone.
3. Data standardize, where all data should be structured by means of data protocols, which place it in the proper form for processing.
4. Data storage, where the data put into its respective specialized zone such as medical zone, economic zone, education zone, energy zone.
5. Data exchange, where the data resides in each specific zone, could be shared with apps that resides in the application layer and the infrastructure layer.

At this stage, it should be obvious that only the data are generated in the infrastructure layer. The outputs of any subsystem could be viewed as input for another subsystem, in which case the data could be sent directly from the application layer to the data cloud areas, or if the network IoT devices were intermediate between the apps and the cloud data region, the domain being monitored through blockchain technologies.

The massive amount of data stored on the cloud poses several additional challenges and concerns, as pointed out below.

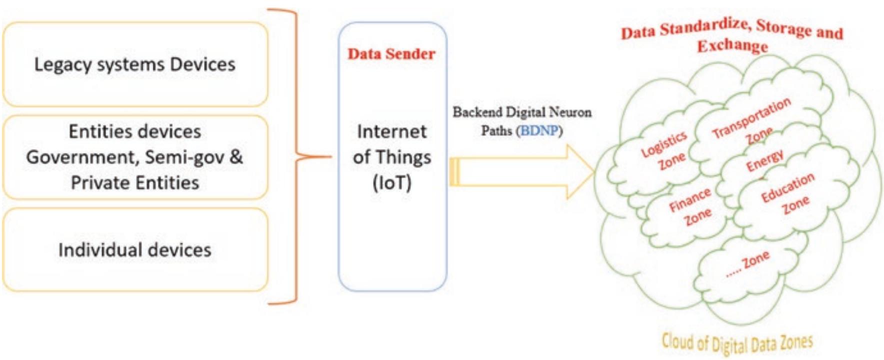

Fig. 8.7 Smart city IoT data collection and processing

1. **Security issues** that depend on data protection, encryption, and decryption processes in cloud areas.
2. **Privacy issues**, users'data are also aggregated in cloud areas, which raise privacy concerns and how users'accounts can be monitored, and a malicious attack avoided.
3. **Continuity,** representing concerns about data access and how smart cities can continue to operate their systems with any cloud disconnects from any location.
4. **Mirroring and backups**, how the data are replicated and maintained and who will be responsible about the replication operations.
5. **Standardization,** which focuses on the development of data standardization and exchange protocols.
6. **Control,** refers to taking control of each data zone and how authorization access will be given.
7. **Pricing**, who will be responsible for data pricing or it will be funded by each zone government entity, for instance, the medical zone responsible from the ministry of health.
8. **Storage**, where the cloud zones that use used to maintain data will be located within the smart city, or it could be globally through remote servers.

These are challenges that need more work to ensure the smooth running, productivity, and uninterruption of all intelligent city infrastructure.

8.6.5 End Users

End users in smart cities can access any application that resides on the service layer by means of unique authentication. Services are developed using unique cutting-edge technology, including artificial intelligence, deep learning, virtual reality, etc. In this paradigm, consumers are not only service consumers in the proposed smart cities model but also data providers, so they are required to connect their smartphones, wearable devices, etc., to the infrastructure layer where data value is produced. Consumers should be able to provide feedback and information on the services they offer, which could include three different aspects.

1. Individual feedback leads to changes in the facilities offered.
2. Public reviews on smart city services and how it impacts people's health positively or negatively.
3. Cross-feedback expressing feedback on cross-services between separate subsystems.

As shown in Fig. 8.8, users can access the service grid by means of authentication methods controlled and supervised by authorized agencies.

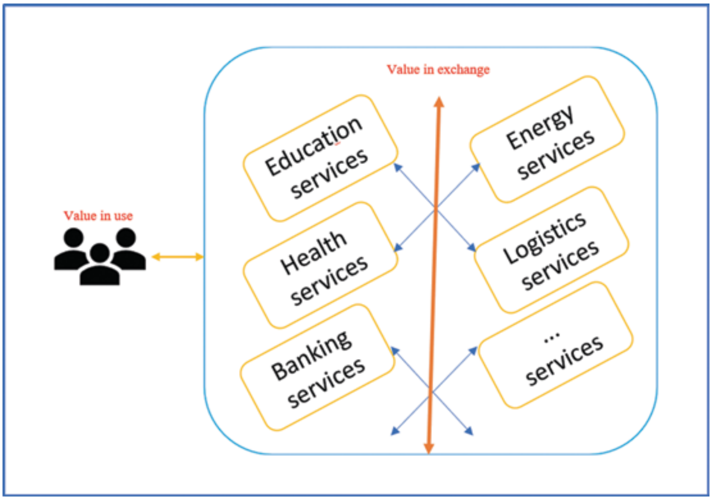

Fig. 8.8 Service exchange in smart cities

8.7 Smart Applications

Today, technology is moving from a digital infrastructure to a smart system. As a result, cities will transition from being a modern community service provider to a smart city service provider where the networks maintain the following functions:

1. Interconnected and selective, where the systems maintain connections heterogeneously, and users can pick which services they want anytime, anywhere.
2. Adaptive, through applying AI, data processing, machine learning, etc., methods/algorithms for adapting to any new integration.
3. Autonomous, where the system provides services that do not mimic certain subsystem resources.
4. Learn to add new features via ML algorithms.
5. Self-repairing by using deep learning algorithms to patch any glitches.
6. Robust, where systems maintain strong security, privacy, and direct services to targeted and real stakeholders.

Smart cities' networks and amenities are digitally integrated and configured using ICT to provide services to their residents and other stakeholders. Smart cities theory is known from the perception of technologies and components that have the exact properties within the larger sense of cyber, digital, smart, and ecosystems apps that rely on the fourth industry revolution technologies [9]. A society wants smart apps that not only offer one-way services but also collect feedback and adapt to better and tailored services.

Smart technologies include all human/animal life facilities, e.g., smart electrical systems, smart marine systems, waste control, health care, water storage, smart education systems, smart animal tracking systems. Smart sustainable cities require high-tech smart applications, including computer simulation, stand-alone robotics, automated manufacturing, big data, cyber protection, cloud computing, virtual reality, unified convergence technologies, and the Internet of Things apps. Smart applications include facets of ecosystems with capacity for interconnection, engagement with feedback, self-organization, and adaptation to represent the increasing demands, activities, and evolution of cities performance. There are currently a number of smart applications available, such as smart infrastructure, smart operation, smart service and smart industry, smart education systems or smart security systems, and smart weather forecasting. However, these applications are also isolated from convergence and are not in-line within the grid structure.

There is a wide range of services and applications, as shown in Fig. 8.9. These systems are spread through fields such as smart road and public transit networks, smart public energy, public water and gas delivery, smart school, medicine and healthcare, and public security. Smart systems for emergencies and daily business, disaster management, smart buildings, logistics, intelligent procurement, weather forecasting, and hurricanes predictions and monitoring. The massive use of smartphones offers new opportunities for continuous control of human well-being and wellness. Smart home monitoring, smart grid monitoring, and payments apply machine-to-machine processing, etc. However, these applications follow the Push and Pull paradigm instead of applying an ecosystem that maintains integrated and high-dimensional connectivity with users acting as the receiver and participants of service in the creation of the service. The smart application must have a range of attributes, as seen below.

Smart Application Attributes

1. Act smartly by integrating sensing, actuation, and control functions to identify and evaluate a situation and make analytical or proactive decisions based on available data.

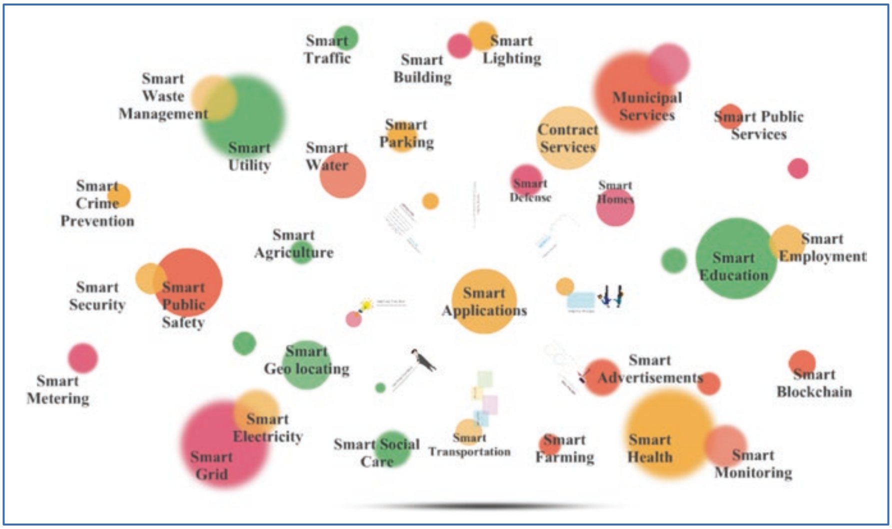

Fig. 8.9 Forms of smart services

2. Prone to be cloud-based systems due to the continuous and tremendous connectivity of devices.
3. Work as an agent who acts to change part of the environment or of its status and influences what is sensed.
4. Adaptive in response to information changes or due to any evolve in the goals and requirements.
5. Interact easily with users so that users can define their needs comfortably, as well as such systems interact with other processes, devices, and cloud services.
6. Contextual based as they may understand, identify, and extract contextual elements such as meaning, syntax, time, location, drawing on multiple sources of information, structured and unstructured.
7. Learning by reasoning on data to create new information and use closed-loop feedback to rapidly iterate and learn from the output and hence get smarter.

In the following sections, we are going to demonstrate two ad hoc smart systems in smart city.

8.7.1 Smart Urban Energy Systems

The smart urban energy subsystem can be seen within the proposed smart city model where the application layer is connected with the infrastructure layer, services layer, and the cloud zone (Fig. 8.10). The policies and protocols that govern all-inclusive operations and exchange should be standardized and controlled by authorities' entities. The transition from legacy energy system towards smart energy systems becomes a necessity due to current motives which are:

1. The evolution of energy infrastructure technologies such as decentralized generation, renewable generation, housing technology, district heating, electric mobility such as electric vehicles, electric busses, electric bicycles, charging stations.
2. Climate change, which imposes a need for effective and less polluting usage of natural resources.
3. The possibilities of digitization that serve as a vehicle for the transition to smart urban energy systems.

These causes make it possible to have a fully integrated energy infrastructure that allows the end user to generate, deliver, and trade resources smartly. In addition, it would help to apply state-of-the-art technology, such as ML, AI, to allow the requisite reliable and effective data for decision-making. Smart urban energy grids can experience major energy-saving improvements and help solve much of the present and potential challenges that can be outlined below.

1. Decentralization and collaborative energy production, where houses, factories, etc., will generate the energy they need and pump the surplus back into the electric system.

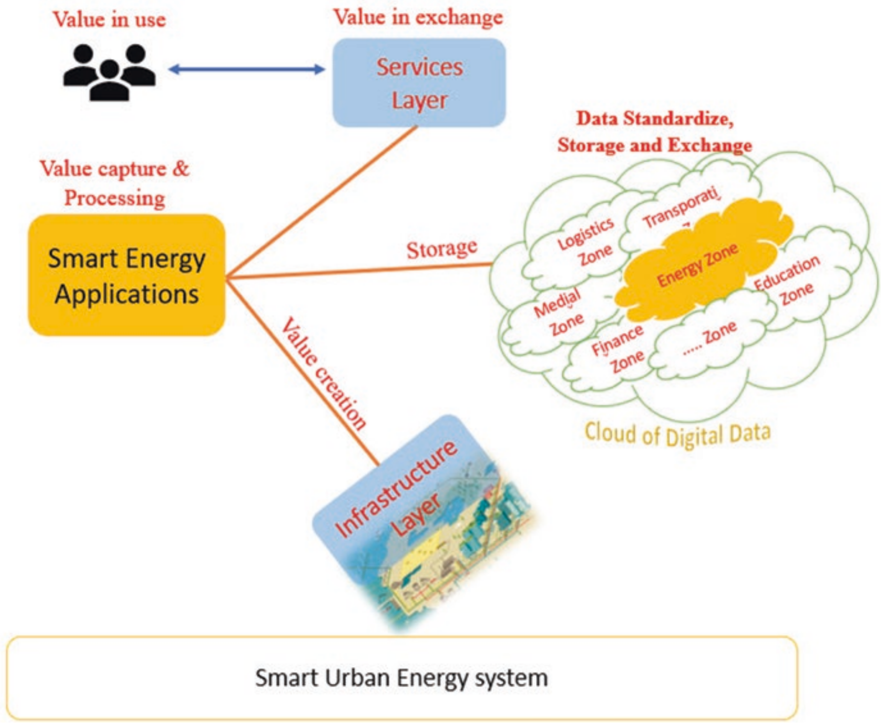

Fig. 8.10 Smart urban energy layered subsystem

2. Moving to intermittent productions that rely on solar and wind rather than the planned energy that relies only on petrol.
3. Fluctuated prices depend on consumption; they can be monitored by smart devices mounted on electrical appliances such as sensor refrigerators for threshold factors or freezing temperatures.
4. Auto reacts to changes in rates and demand levels.

There are a lot of challenges for the transition into smart energy systems.

1. Financial challenges.
2. Regulatory challenges.
3. Competences challenges.
4. Collaboration between systems actors and stakeholders' challenges.
5. Security and privacy challenges.
6. Standardization challenges.
7. Technology illiteracy.

8.7.1.1 Energy Infrastructure

This layer refers to all services producers and providers where all electrical devices are planted for energy value creation or work as an intermediary for distribution such as:

1. Electricity distributors who offer demand side management and smart integrated energy services such as charging stations.
2. Electricity urban utilities refer to all companies that offer integrated services with energy such as waste systems, transportation systems.
3. Electricity intermediary refers to companies that produce devices or units that have information about the consumptions and sell energy-related services.

8.7.1.2 Energy Applications

This applies to all applications that can be accessed and used to process energy data and offer end user services. It may be an application on the part of energy suppliers, intermediate applications, or even end user applications.

8.7.1.3 Energy Cloud Zone

All electricity data related to the usage by consumers, energy grid data, and energy providers should be stored in a standard format in the cloud energy region.

8.7.1.4 End Users

There are four major categories of consumers for such smart urban energy systems.

1. Householders.
2. Buildings.
3. Commercial or industrial areas, for instance, airports, shopping malls, etc.
4. The distributors grid operators who will buy and redistribute or balancing energy.

8.7.1.5 Energy Services

There are three types of smart energy services:

1. The balancing of energy services, which refer to all services that keep the grade stable.
2. The demand side services that refer to users' demand, pricing, metering, etc., that is being offered to households, buildings, commercial, and industrial units.

3. The smart and integrated energy services work as intermediate and link the electricity system with other systems such as the water system, the transport system, the waste system, the recycling system.

8.7.1.6 Energy Standardization and Protocols

As stated earlier, the model is based on the produced digital data on energy production, consumption, and distribution. Data must be standardized to ensure the longevity and expandability of systems for potential operation demands. Therefore, all accessing data and resources should be governed by regulations, specific guidelines for exchange and dissemination, and the data should be controlled by users and service providers. Many problems require the attention of decision makers and policymakers to make the transition to smart systems effective, as seen in Table 8.1.

8.7.2 Smart Urban Transportation Systems

Urbanization has led to major relocation from rural areas to towns. This causes a lot of challenges, beginning with traffic jams and pollution. Many cities around the world are overwhelmed with legacy traffic networks, such as Cairo City, the capital of Egypt, where some 20 million people live in a small area, creating a number of problems with the legacy transport system, which has a detrimental influence on health and other facets of life in the community.

The model of moving transport from the legacy transport system to smart transport systems is becoming a must due to the existing following incentives:

1. Urbanization, urban cities are projected to cross 55% or more by the middle of this century, which means more congestion and demand on transport networks.
2. New technologies that make it possible to transition towards smart transpiration and make it possible to use creativity to solve the problems of legacy transport systems.
3. Sustainability and the use of green energies in transport are an incentive to combat climate change and reduce global CO_2 emissions from traditional transport.
4. Customized systems that allow people to use the transport they need at a cheaper cost and more convenient time. This leads to a shift in citizens' behaviors from ownership to users, which interprets the success of emerging companies, such as Uber network, which provides services such as peer-to-peer ride-sharing, ride hailing.
5. Flexible availability of 24/7 cloud services.

The transition from legacy transport systems to smart interconnected transport systems would become inevitable and will have many benefits for society. There are, however, many barriers to this change, such as (Fig. 8.11):

Table 8.1 Key issues for smart energy systems

	Infrastructure layer level	Application layer level	Service layer level	The digital clouds of data zones	End users
Decision makers	– The technology for intermittency and grid stability – Required costs for upgrading from legacy into smart	– Who will develop the applications and maintain the control on it? – Who will give the privilege to access the related cloud data zones? – How are the applications integrated directly with the infrastructure layer devices?	– What type of services? – Who will have the authority to access such services? – How to pay for the services and to whom? – Users requirements – Users collaborations	– Data standards and quality – Data security – Data storage capacity and costs – Where will the data be located, centrally of on each city? – Data mirroring and replications authorities – Data availability and disruption issues	– Security implementations – User's collaboration forms – Fund required for keeping accurate data
Policymakers	– Infrastructure interconnection levels, is it countywide or metropolitan?	– How to conduct auditing to the developed and integrated applications? – Polices to guarantee integration between the ad hoc system and the other subsystems	– Service regulations and pricing – Universal service obligations	– The right to access data – The cost coverage of data and its maintenance – Data ownerships	– Privacy regulations – User's participation levels – Data reliability – Data standardization – Data ownership – Data accessibility

1. Integration of the legacy transportation system with the smart cities transportation system.
2. Data reliability, completeness, standardization.
3. Service customization.
4. Security and privacy challenges.

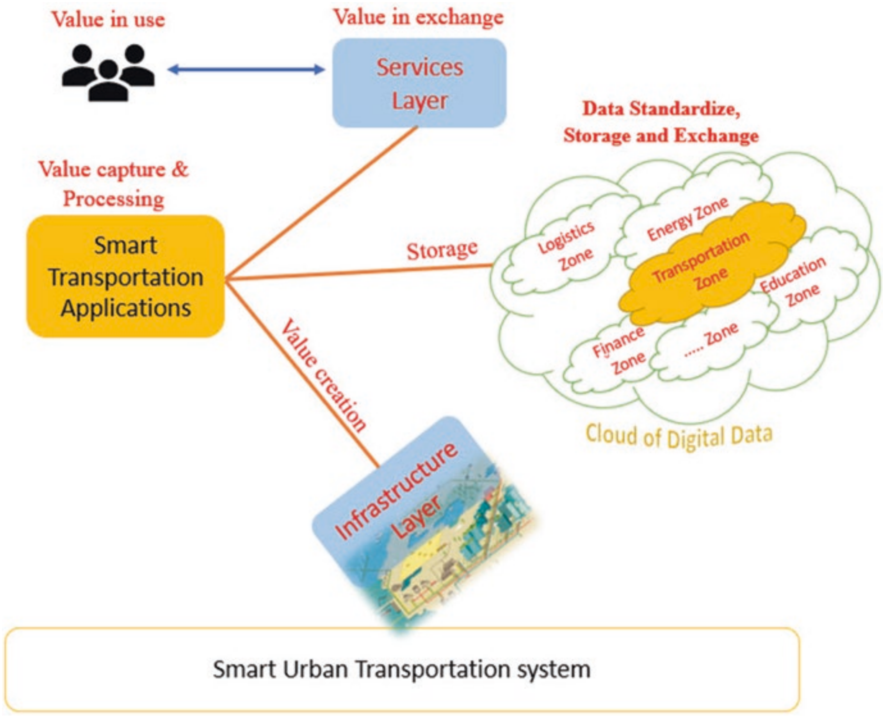

Fig. 8.11 Smart urban transportation layered subsystem

5. Service optimization.
6. Data ownership and distribution.
7. Data storing and processing costs.
8. Accountability, for instance, in case of a car accident, then who will be responsible, the car owner, manufacturer, the insurance company, etc.
9. Community acceptance for the automated driving either private cars or public busses.

8.7.2.1 Transportations Infrastructure

This layer applies to all transport systems and relevant hardware, including surveillance monitors, speed detectors, alarms, gas stations, repair facilities, etc. The existing infrastructure is not ideal for smart transport systems. Therefore, following precautions must then be taken:

1. Vehicles must be connected to each other by means of sensors and chip units.
2. Vehicles must be connected to the equipment of the infrastructure layer.

3. Traffic signals, traffic signs, speed limits, and other public transport facilities could be injected with chips in order to be able to communicate with cars and to provide information on road conditions.

8.7.2.2 Transportation Applications

Applications that can be accessed and used to process transport data and deliver services to end users. It may be the implementation of an automated ticketing scheme for travel, traffic signs, mobility as a service (MaaS), charging stations, auto driving, accessibility facilities, analysis of traffic conditions, smart parking, vehicle-sharing, shifting batteries, etc.

8.7.2.3 Transportation Cloud Zone

All transport data relating to the usage of customers, the transport networks, and the data of the internet service provider should be stored in the cloud internet zone in the regular format.

8.7.2.4 End Users

Various consumers can benefit from smart city transit networks, as seen below.

1. City users have to use smart urban highways, subways, or commuter trains.
2. Users that are dependent on private cars.
3. Industry service companies offering door-to-door facilities.
4. Intermediate agencies delivering transport-related services.

8.7.2.5 Transportation Services

There are several services that could be offered by smart transport networks such as:

1. Carpooling (also vehicle-sharing, ride-sharing, and lift-sharing) refers to sharing car journeys on the same route from origin to destination.
2. E-hailing refers to ordering a cab, a taxi, a limousine, or some other mode of transport to pick up using virtual devices like a computer or mobile device.
3. Smart traffic E-light service focused on cameras combined with a network of tariff light nodes.
4. Road speed limit detectors that transmit data to vehicles and read vehicle speed.
5. Smart transpiration services for ad hoc purposes such as medical transport services, colleges and university students, staff and workers transportation, petroleum transfer.
6. Electrical vehicles charging.

7. Smart parking management and valet parking.
8. Logistics services.
9. Technical inspection and maintenance services.
10. Accidents repair and rehabilitation services.
11. Mobile smart tires services.

8.7.2.6 Transportation Standardized and Protocols

As discussed above, the model used digital data generated from the infrastructure layer and stored in cloud data fields. Data must be transparent to ensure that networks are efficient and expandable to fulfill future demand expectations. Therefore, all data and communication systems should be regulated by rules, specific guidelines for transmission and data sharing, as well as the data of service providers should be controlled by them. Many problems need attention from decision makers and policymakers in order to make the transition to smart applications feasible, as seen in Table 8.2.

8.8 Transition Plan Properties and Challenges

Present infrastructure networks are not tailored to today's and future smart cities, presenting a massive market and a big challenge for infrastructure transport players. In order to adapt to the new smart environment, legacy transport operators must strive for excellence in their core business. Improve and deepen the knowledge of their customers to enhance user experience. Build a complete mobile ecosystem that aims to extend the spectrum of mobility applications and provide new services.

There are three critical stages for a smooth transition to smart cities.

1. Implement a digital transformation focused on the nine concepts of the fourth industrial revolution, taking into account consumer engagement, employee experience, and organizational efficiency.

   In this strategy, all model layers must be transparent in an extensible manner.

   (a) Infrastructure layer producers and devices for the sector (energy, transpiration, healthcare, education, etc.).
   (b) Application layer, all listed concerns should be cleared by decision makers and policymakers also, how the application of a specific field integrates with the other systems apps.
   (c) Services layer, it should be clear to whom the services will be directed and the interconnection between services.
   (d) The system digital data cloud zone, the plan should cover all related concerns with solutions, and how accurately and smoothly link cloud zones with dedicated applications for services.

Table 8.2 Issues need attention in smart transportation systems

	Infrastructure layer level	Application layer level	Services layer level	The digital clouds of data zones	End users
Decision makers	– The financing for transformation from legacy into smart systems	– Who will develop the applications and maintain control? – Who will give the privilege to access the related cloud data zones? – How are the applications integrated directly with the infrastructure layer devices? – How are transpiration applications integrated with other smart systems such as energy smart systems?	– What type of services? – Who will have the authority to access such services? – How to pay for the services and to whom? – Users requirements – Users collaborations	– Data standards and quality – Data security – Data storage capacity and costs – Where will the data be located, centrally of on each city? – Data mirroring and replication authorities – Data availability and disruption issues	– Security implementations – User's collaboration forms – Fund required for keeping accurate data
Policymakers	– Interconnection of transport modes – Upgrading the legacy system and digitization	– How to conduct auditing to the developed and integrated applications? – Polices to guarantee integration between the ad hoc system and the other subsystems	– Services regulations and pricing – Universal services obligations – How different services are interconnected and levels of coordination?	– The right to access data – The cost coverage of data and its maintenance – Data ownerships	– Privacy regulations – User's participation levels – Data reliability – Data standardization – Data ownership – Data accessibility

(e) End user's involvement and collaboration levels, and how to protect user's privacy and apply robust security for any communications.

2. Accelerate innovation; authorities need to concentrate on introducing technologies instead of improving existing processes by implementing applied technological innovation. The goal should be to build and introduce new digital technology to speed up conversion by improving innovation ability via qualified expertise to launch big innovation initiatives such as AI and ML systems, robotics, energy storage, drones, and so on.
3. Create an urban ecosystem that hosts innovative interconnected business models and creates alliances with both major groups and start-ups.

It should be clear that the transformation proposals need to be ***holistic***. It must deal with each subsystem (energy, transpiration, healthcare, etc.) as an entire system with integrated features to the other systems in the smart cities. These integrated systems should be ***highly obliged*** to the regulation as any changes in one system will have a direct impact on the performance of the other integrated systems and ***flexible*** to changes could happen inside each sector. System ***integration*** with other smart city systems should be stated clearly. A transition plan must **applicable** and focus on building up ***innovative*** systems rather than rectifying the legacy systems (Fig. 8.12).

Table 8.3 lists the important challenges for smart cities, regardless the industry, which should be addressed by decision makers and policymakers.

The smart city implementation will pose many obstacles. Some of these challenges are listed in the table above. However, there will be several more challenges to come, as well as options for practical execution.

Fig. 8.12 Transition plan properties

Table 8.3 Transportation plan challenges

	Infrastructure layer level	Application layer level	Services layer level	The digital clouds of data zones	End users
Decision makers	– Integration between the legacy and the smart infrastructure – Expansion	– Interconnection – Development entities	– Integration – Competition – Cooperation – Liability – Criteria for delivery	– Standardization – Continuity –Storage – Prices	– Security – Collaboration
Policymakers	– Startups (local domain or global) – Interconnection rules – Upgrading and digitization – Sustainability	– Auditing – Distributed application interconnections	– Regulations – Pricing – Obligations – Interconnection	– Accessibility – Maintenance – Ownerships	– Privacy – Reliability – Accessibility

8.9 Conclusion

Smart cities are now a must, not for developing nations but for all countries around the world. Sooner or later, smart cities would be the only realistic living place where residents can attain greater efficiency. Governments have no choice but to develop smart cities. It is said that the young generations are born with the technology at hand. Understanding and incorporating the current emerging technologies into the community would then lead to a revolution in education, healthcare, electricity, transpiration, etc. The age of Novel Coronavirus (COVID-19) showed that humans could run business by technology and overcome what was considered to be stubborn problems. This chapter discusses various approaches to service delivery, from the Push to the ecosystem that has not been applied anywhere to date. Then we discussed the nine foundations of market transformation followed by smart cities' latest state-of-the-art solution that responds to Push or Pull or, at most, the coupling type. We also seen how smart connected giant technology and services are far better than the metropolitan smart city aspect. We then illustrated a new smart cities framework in conjunction with its three layers and five facets, namely infrastructure layer, application layer, services layer, cloud of digital data, and end users. We have demonstrated two smart systems, the smart urban energy system and the smart urban transport system. Finally, we discussed the properties and problems of the transformation process that should be answered by decision leaders and policymakers.

8.10 Exercises

8.10.1 Short Answers Questions

1. Define smart city?
2. What are the services delivery forms?
3. List the nine pillars of the fourth industrial revolution?
4. What are the challenges for deploying smart integrated systems worldwide.?
5. Draw the illustrated smart city paradigm.
6. List five concerns raised by maintaining data on the cloud.
7. Contrast between digital systems and smart systems.
8. List the five attributes for a smart application.
9. What are the of challenges for the transition into smart energy systems?
10. List the energy infrastructure services producers and providers.
11. Explain in details type of services that could be provided by energy smart systems.
12. What are the energy standardization and protocols that should be addressed by decision makers?
13. What are the energy standardization and protocols that should be addressed by policymakers?

14. List transition plan properties for smart cities.
15. What are the of challenges for the transition into smart transportation systems?
16. List the transportation infrastructure services producers and providers.
17. Explain in details type of services that could be provided by transportation smart systems.
18. What are the transportation standardization and protocols that should be addressed by decision makers?
19. What are the transportation standardization and protocols that should be addressed by policymakers?

8.10.2 True/False Questions

State which of the following is true and which is false, provide your justifications for the false ones.

1. Smart city definition is clearly stated.
   F: The smart city definition still unmatured.
2. Push service delivery mode is the best approach for services delivery.
   F: The ecosystem services delivery mode is the latest and best form.
3. Cloud computing is one of the nine pillars for the fourth industry revolution?
   T.
4. The current smart services have two layers, the services producers and services receivers layers.
   T.
5. Smart cities need no connection with other international or regional smart services.
   F: For better smart services, a smart city should not be isolated from the other worldwide cities integrated services.
6. Smart cities could easily integrate worldwide.
   F: There are many obstacles such as privacy, culture, etc.
7. Illustrated smart city paradigm has three layers and five interconnections.
   T.
8. Application layer is responsible for services exchange.
   F: The service layer.
9. Cloud services maintain a separate zone for each subsystem.
   T.
10. Users are only service receivers in smart cities.

F: They are collaborative, they receive services and participate in services creation.

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Chapter 9
A Survey on IoT Applications in Smart Cities

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9.1 Introduction

The Internet of Things (IoT) is an innovative communications standard that will facilitate communication from machine to machine. In recent times, humans control devices using computers, mobile phones, and tablets with internet access. The interface of the Internet with each sort of device including sensors and smart tags in different domains leads to the development of technology. With the upgradation of internet connectivity, any devices can be controlled by anybody at all places at any time [1, 2].

Pena-Lopez characterizes the IoT as a concept of connecting all things in the world with the internet [3]. The development of Information and Communication Technologies (ICT) in urban areas is the fundamental foundation for a smart city. The IoT is viewed as one of the most significant perspectives for an effective accomplishment of a smart city. Security is one of the major challenges in the IoT concept [4].

In 2017, a 39% increase in the utilization of IoT components in smart cities was observed compared to 2015. The usage of IoT components in 2018 increased to 43% [5]. At present, the percentage of people living in urban areas is 54%, and this is expected to reach 66% by 2050.

As urban areas develop and grow, smart and new technologies are needed for improving profitability, improving operational efficiencies, and lessening the

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executive costs [6]. By interconnecting devices with the internet, smart services are provided to the environment [7].

The innovations in ICT in modern societies help people to control devices and effectively utilize resources. With the advancements in IoT technology, the sustainable urban development concept came into existence. The quality of life of citizens is improved by the IoT approach [8]. The IoT is one of the most significant technologies, which provide smart solutions for solving critical issues in various domains. Smart services to urban citizens are achieved by embedding sensors and electronics with the internet [9].

This chapter is organized as follows: Sect. 9.2 includes a comparative study of existing surveys. The various applications of IoT in smart cities are discussed in Sect. 9.3. Finally, Sect. 9.4 concludes the chapter.

9.2 Related Work

The goal of this survey chapter is to provide an inclusive literature review on IoT applications in smart cities from different aspects. This survey gives an overview of the technological innovations developed to make a city smart that provide services to the citizens for the betterment of their lives. There is a comparative analysis of various IoT applications with innovative technologies which enables the correct choice according to the requirement. This survey chapter is different from the existing surveys as it gives a concept on the methodologies developed with IoT for different smart city applications, and analysis is done on current research techniques that were published from 2010 to 2019.

Parvaneh Asghari et al. [10] focused on IoT applications including environmental monitoring, healthcare monitoring, smart city, commercial, and industrial aspects. Some of the IoT applications are not discussed in this paper.

Zakir Ullah et al. [11] discussed the most essential and key features of IoT technological development which had been accomplished and will be accomplished in the future. Recent innovations in IoT development in smart cities by wide researchers were also discussed. Different types of IoT sensors and applications in smart cities were discussed in the paper [12] by Jegathesh Amalraj et al. Sunitha Cheepurishetti and Mohana Roopa [13] gave a brief explanation of data transmission from sensors to the cloud with various communication protocols. The advantage of this paper is that it provides analyses of various applications such as shadow analysis and smart estates.

A review of the motivation and applications of the IoT paradigm in smart cities is presented. The insights and challenges of using IoT technologies in smart cities such as assuring data quality and integrity, management and coordination, and energy efficiency had been presented by Husam Rajab and Tibor Cinkelr [14].

Amir Alavi et al. [15] emphasized the significant features and applications of IoT standards that aid in the development of smart cities. The advantage is that the statistical analysis was exhibited on the world population and the number of smart devices and Gartner's cycle of innovative technologies.

Ashwini Khairnar and Dhiraj Birari [16] explained the basic IoT components with their functionality and the uses of IoT in different applications for the development of a smart city. The disadvantage of the paper is an insufficient survey of applications of IoT paradigms in smart cities. IoT frameworks and architectures were presented in the paper by Ahmed Samy Nassar et al. [17]. A detailed survey on smart city applications is missing.

A brief description of the view of IoT and statistical information of IoT devices concerning various countries of the world is given by Mahmood Hussain Mir and Ravindran [18]. Some listed applications of IoT were not explained in the paper. Saber Talari et al. [19] presented a review on a large portion of the conceivable IoT advancements and their potential development that leads to the emergence of smart cities.

IoT technologies and smart city requirements were discussed in the paper by Gokulnath et al. [20]. The key barriers to the implementation of smart city and various applications of IoT had been explained in this paper. The literature review is insufficient all over the paper. Arasteh et al. [21] covered the concepts and motivations of IoT-based interconnections and their technologies for smart cities such as RFID, WSN, addressing, and middleware.

In particular, the urban IoT system was concentrated by Andrea Zanella et al. [8]. A brief description is given of the services done to the citizens based on IoT technology for the emergence of the smart city concept, and the analysis of services and specifications for the Padova smart city project was tabulated. Kehua Su et al. [23] give a general overview of smart cities and their applications. The framework on IoT applications of smart cities and the key aspects that make the construction of smart cities difficult were explained. The disadvantage of this paper is inadequate literature survey and analysis of the review is absent.

A comparative study of the existing surveys from 2011 to 2019 is provided in Table 9.1.

9.3 Applications of IoT in Smart Cities

Enormous applications using IoT with innovative technologies are used to make a city smart. It is intriguing to consider the use of the IoT worldview in an urban system. Without a doubt, numerous national governments widely are executing ICT advancements for the welfare of citizens to understand the smart city ideas. Some of the smart city projects developed worldwide are SONGDO IBD (South Korea), LAVASA (India), PLANIT VALLEY (Portugal), MEIXI LAKE (China), SKOLKOVO (Russia), and MASDAR CITY (Abu Dhabi) [22].

The organization of IoT applications in smart cities is shown in Fig. 9.1. Table 9.2 provides some of the smart city projects in the world with IoT applications.

Table 9.1 Comparative study of the existing surveys

Discussed applications	This paper	2019 [10]	2019 [11]	2019 [12]	2019 [13]	2018 [14]	2018 [15]	2018 [16]	2018 [17]	2017 [18]	2017 [19]	2017 [20]	2016 [21]	2014 [8]	2011 [22]
Services	✓	✓	✓	✓	✓	✗	✓	✓	✗	✓	✓	✗	✗	✗	✓
Security	✓	✓	✗	✓	✗	✗	✗	✗	✓	✗	✓	✗	✓	✗	✗
Infrastructure	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Homes and buildings	✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Environment	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✓	✓
Waste management	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗
Grid	✓	✓	✗	✗	✓	✓	✓	✗	✓	✓	✗	✗	✓	✓	✗
E-Governance	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
Commercial aspects	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Agriculture and Animal farming	✓	✓	✗	✓	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗

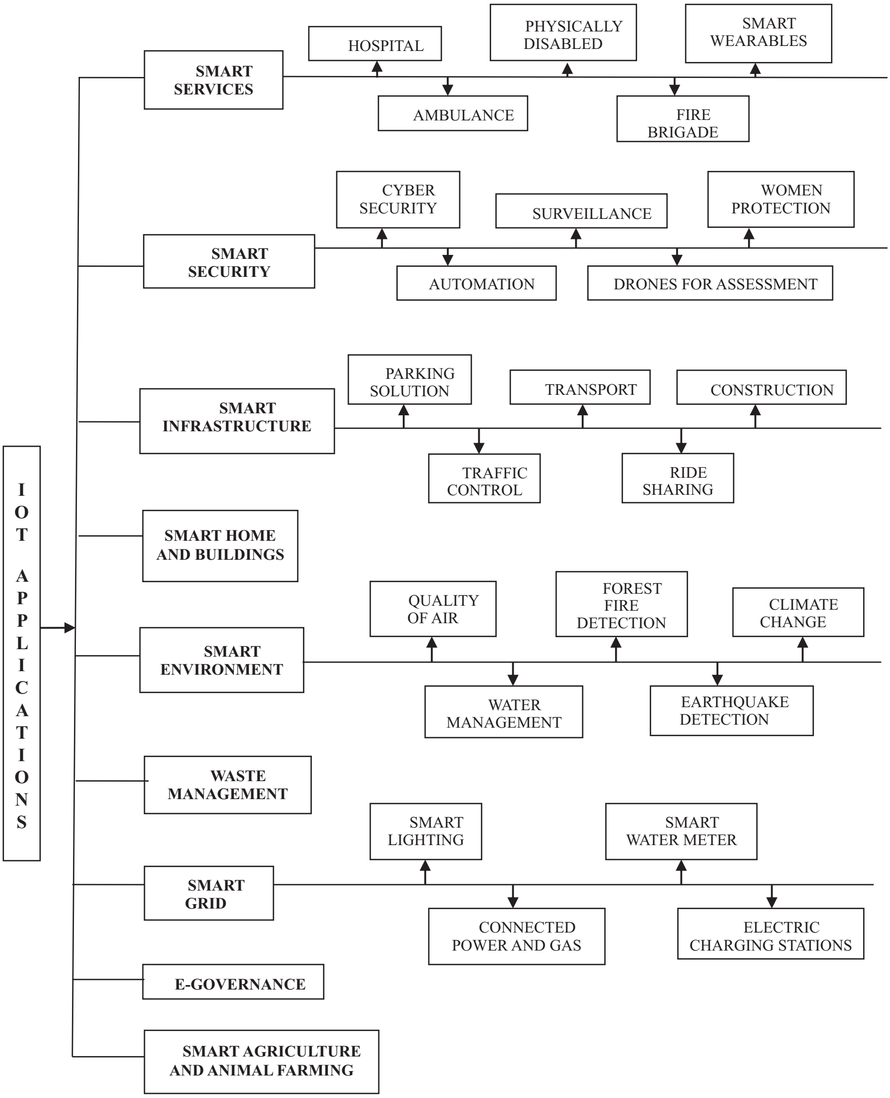

Fig. 9.1 Organization of IoT applications in smart cities

9.3.1 Smart Security

The current and future developments of IoT applications in various fields extend a rising level of convenience, capability, and safety for people. With increasing innovations in the world, it is necessary to ensure high privacy, security, surveillance, and retrieval from cyberattacks. Table 9.3 provides a comparative survey of smart

Table 9.2 Worldwide smart city projects [19, 22]

City	Results
Amsterdam	Smart governance, security level development, saving energy, smart traffic, smart transport, smart environment, smart healthcare
Barcelona	Advancement in sensor technology, smart traffic, smart road, smart governance, smart transport, smart environment
Stockholm	Smart grid, smart environment
Songdo	Smart buildings, smart grid
PlanIT Valley	Numerous sensor deployment
Fujisawa	Smart environment
Norfolk	Smart commercial services
Santander	Smart parking
Vienna	Smart environment, smart environment
Malaga	Smart governance, smart transport, smart environment
Santa Cruz	Smart security
Paris	Smart transport, smart healthcare, smart living
Toronto	Smart transport, smart environment, smart living
Groening	Smart transport
New York	Smart governance, smart transport, smart living
Hong Kong	Smart governance, smart living
London	Smart governance, smart transport, smart living
Rio De Janerio	Smart transport, smart security
Vancouver	Smart transport, smart environment, smart agriculture

security which includes cybersecurity, women protection, unmanned vehicle, and surveillance.

9.3.2 Smart Services

Health monitoring systems with IoT technology had developed vastly in recent times and aid to monitor the health conditions of patients. Emergency services help disabled and elderly people to keep track of abnormal conditions, and ambulance robots are designed and developed which are accessed to save lives. Table 9.4 provides a comparative survey of smart services, which include monitoring physically disabled people, healthcare, emergency services, and wheelchair users.

Table 9.3 Comparative survey of smart security

Paper	Research topic	Case study	Outcome	Remarks
Sidra Ijaz et al. [24]	Smart Cities: A Survey on Security Concerns	Security problems and solutions	Performance analysis on security breaches with solutions	Security is the weakness criteria in smart cities development
Moez Krichen et al. [25]	Towards a Model-Based Testing Framework for the Security of Internet of Things for Smart City Applications	Security of IoT	Model-based testing framework	Extended work will be done for validating the framework
Zubair A. Baig et al. [26]	Future Challenges for Smart Cities: Cybersecurity and Digital Forensics	Cybersecurity	Identification of security threats	New findings of cybersecurity threats
Navya R. Sogi et al. [27]	SMARISA: A Raspberry Pi Based Smart Ring for Women Safety Using IoT	Women protection	Smart ring using raspberry pi	– Fast process – Low cost – Accurate tracking – Not powerful to prevent crimes
Edwin Vattapparamban et al. [28]	Drones for Smart Cities: Issues in CyberSecurity, Privacy, and Public Safety	Drones for assessment	Representative results on cyberattacks using drones	Future work on drones such as jamming and GPS spoofing
Aislan Gomide Foina et al. [29]	Drones in Smart Cities: Overcoming Barriers through Air Traffic Control Research	Drones for assessment	A prototype integrated with cloud server	High transmitting frequency and maneuver distance is 200 m
Ling Hu and Qiang Ni [30]	IoT-Driven Automated Object Detection Algorithm for Urban Surveillance Systems in Smart Cities	Surveillance	Algorithm	Reduce the big data volume
Prince Waqas Khan et al. [31]	A Data Verification System for CCTV Surveillance Cameras Using Blockchain Technology in Smart Cities	Surveillance	Blockchain-based system	– Cost-effective – Good fault tolerance – More reliable

(continued)

Table 9.3 (continued)

Paper	Research topic	Case study	Outcome	Remarks
Andrey Giyenko and Young Im Cho [32]	Intelligent UAV in Smart Cities Using IoT	Surveillance	Open-source intelligent IoT platform	– Cost-effective – Crime reduction – Covers more area
Deeraj Nagothu et al. [33]	A Microservice-Enabled Architecture for Smart Surveillance Using Blockchain Technology	Surveillance	Architecture	Highest level of data encryption for efficient and secure communication

9.3.3 Smart Infrastructure

Smart parking is accomplished using IoT innovations to benefit advancement in sensor technology and to provide service to citizens to park vehicles effectively. Drastic growth in the development of Internet of Vehicles and systems for traffic reduction provides smart transport to users. Table 9.5 provides a comparative survey of smart infrastructure which includes construction, traffic system, ride-sharing system, charging stations, and parking system.

9.3.4 Smart Home and Buildings

Smart homes and buildings were emerged with innovative IoT technology incorporated with embedded services such as sensors, integrated devices, and mobile phones with smart nature for the city residents. Table 9.6 provides a comparative survey of smart homes and buildings which include smart homes, buildings, campuses, hotels, and schools.

9.3.5 Smart Environment

The smart environment is an important application of IoT in smart cities which addresses pollution monitoring and air quality, water management, earthquake detection, protection of the forest, climate change, etc. Table 9.7 provides a comparative survey of the smart environment which includes quality of air, water, earthquake detection, and monitoring environment.

Table 9.4 Comparative survey of smart services

Paper	Research topic	Case study	Outcome	Remarks
Musaed Alhussein et al. [34]	Monitoring Parkinson's Disease in Smart Cities	Monitoring disease	PD monitoring framework	97.2% accuracy
Zulfiqar Ali et al. [35]	An Automatic Health Monitoring System for Patients Suffering from Voice Complications in Smart Cities	Monitoring disease	Automatic voice disorder detection system	Accuracy for a sustained vowel is 99.94% ± 0.1, for running speech is 99.75% ± 0.8
Kahtan Aziz et al. [36]	Smart Real-Time Healthcare Monitoring and Tracking System Using GSM/GPS Technologies	Healthcare monitoring	Real-time health monitoring and tracking	– Limits patient mobility – Immediate rescue in case of illness is done
Rajat Chaudhary et al. [37]	LSCSH: Lattice-Based Secure Cryptosystem for Smart Healthcare in Smart Cities Environment	Healthcare monitoring	Lattice-based secure cryptosystem	– Low computation – Low communication costs
Shamim Hossain Chaudhary et al. [38]	Smart Healthcare Monitoring: A Voice Pathology Detection Paradigm for Smart Cities	Healthcare monitoring	A cloud-oriented smart healthcare monitoring framework	Accuracy is 93%
Aamir Hussain et al. [39]	Health and Emergency Care Platform for the Elderly and Disabled People in the Smart City	Monitoring physically disabled people	People-centric-sensing framework	– Efficient – Cost-effective
Mofijul Islam et al. [40]	Mobile Cloud-Based Big Healthcare Data Processing in Smart Cities	Healthcare monitoring	Ant colony optimization technique	Task computation time is more
Sarfraz Fayaz Khan [41]	Health Care Monitoring System in the Internet of Things (loT) by Using RFID	Healthcare monitoring	Complete monitoring using IoT and RFID tags	Robust output
Jay Lohokare et al. [42]	Emergency services platform for smart cities	Emergency services	Back-end architecture	23,000 messages transfer per second using MQTT protocol

(continued)

Table 9.4 (continued)

Paper	Research topic	Case study	Outcome	Remarks
Ghulam Muhammad et al. [43]	A Facial-Expression Monitoring System for Improved Healthcare in Smart Cities	Healthcare monitoring	Feature-selection technique	Accuracy is 99.95%
Thaha Muhammed et al. [44]	UbeHealth: A Personalized Ubiquitous Cloud and Edge-Enabled Networked Healthcare System for Smart Cities	Healthcare monitoring	Healthcare framework	– High performance – Latency is 37%
Alex Adim Obinikpo and Burak Kantarci [45]	Big Sensed Data Meets Deep Learning for Smarter Health Care in Smart Cities	Healthcare monitoring	Deep learning techniques	Exhibited deep learning solutions for healthcare
Armando Papa et al. [46]	E-health and wellbeing monitoring using smart healthcare devices: An empirical investigation	Healthcare monitoring	Investigation	Work extended for investigating other countries with longitudinal analysis
Hooman Samani and Rongbo Zhu [47]	Robotic Automated External Defibrillator Ambulance for Emergency Medical Service in Smart Cities	Ambulance	Automated external defibrillator	– Health status directly at home – Work extended for improving more flexible AmboBot
Divya Saxena, Member and Vaskar Raychoudhury [48]	Design and Verification of an NDN-Based Safety-Critical Application: A Case Study With Smart Healthcare	Healthcare monitoring	Human and data-centric smart system	– High reliability and robustness – Performance optimization in future work
Lin Yang et al. [49]	A Home Mobile Healthcare System for Wheelchair Users	Services for wheelchair users	Home mobile healthcare system	– Improves the portability and flexibility – Remote interaction is possible

9.3.6 Waste Management

The demanding issue in the environment is waste management. This results in technological development in the IoT framework for efficiently collecting garbage to make the city smarter. Table 9.8 provides a comparative survey of waste management,

Table 9.5 Comparative survey of smart infrastructure

Paper	Research topic	Case study	Outcome	Remarks
Saba Latif et al. [50]	Intelligent Traffic Monitoring and Guidance System for Smart City	Traffic system	Graph model using Vienna Development Method	– More accuracy – More effective compared to the manual system
Sivadi Balakrishna and Thirumaran [51]	Semantic Interoperable Traffic Management Framework for IoT Smart City Applications	Traffic system	A smart real-time traffic monitoring system	– Low cost – Emergency detection – Traffic reduction – More accurate
Anurag Saikar et al. [52]	TrafficIntel	Traffic system	Real-time traffic management system	– Minimizes traffic congestion – Avoids wastage of resources – Saves time
Fangxin Wang et al. [53]	Demystifying the Crowd Intelligence in Last Mile Parcel Delivery for Smart Cities	Ride-sharing system	The IoV-enabled intelligent ride-sharing-based delivery system	Time-precise, elastic, and cost-efficient
Arunkumar and Vijith [54]	IoT Enabled Smart Charging Stations for Electric Vehicle	Smart charging stations	IoT with V2G system	– Saves time and money – Future work for multiple users
Li Minn Ang et al. [55]	Deployment of IoV for Smart Cities: Applications, Architecture, and Challenges	Internet of Vehicle	Architecture for IoV	The success rate for termite hill and ad hoc on-demand distance vector
Mohd Helmy Abd Wahab et al. [56]	IoT-Based Battery Monitoring System for Electric Vehicle	Electric vehicle monitoring	Prototype	Detects degraded battery performance and sends notification messages to user
Abdulkadir Adamu et al. [57]	An Integrated IoT System Pathway for Smart Cities	Road system	Smart patient health management system framework	Quick and efficient healthcare delivery
Durga Devi et al. [58]	Smart City: IOT-Based Prototype for Parking Monitoring and Management System by Mobile App	Parking system	Prototype	– Minimizes vehicle parking problem – Future work is planned to perform experiments
Kalpana and Nagaraju [59]	Advances Reservation and Smart Parking System for Smart Cities Using IoT Network	Parking system	IoT-based cloud-integrated smart parking system	Reservation for the parking lot is done

(continued)

Table 9.5 (continued)

Paper	Research topic	Case study	Outcome	Remarks
Antoine Bagula et al. [60]	On the Design of Smart Parking Networks in the Smart Cities: An Optimal Sensor Placement Model	Parking system	Smart parking sensor placement model	More nodes in a bigger area are the future work
Rosamaria Elisa Barone et al. [61]	Architecture for Parking Management in Smart Cities	Parking system	Intelligent parking assistant architecture	Increases the quality of life and mobility
Abhirup Khanna and Rishi Anand [62]	IoT-based Smart Parking System	Parking system	IoT-based cloud-integrated smart parking system	Enhances the quality of life of people
Felix Jesus Villanueva et al. [63]	Crowdsensing Smart City Parking Monitoring	Parking system	Real-time map using a magnetometer	More feasible to detect parking spaces

which includes management of solid in manholes and dustbins.

9.3.7 Smart Grid

Smart lighting systems, smart meters, and electric charging stations lead to the development of smart grids in urban cities. These systems with IoT measure various parameters of the grid and utilize less energy. Table 9.9 provides a comparative survey of smart grids which include smart lighting, water meter, charging stations, and power and gas connections.

9.3.8 E-Governance

E-governance is the main application of IoT in smart cities that creates an intelligent government with advanced ICT utilization and beneficial policies for the welfare of the citizens. Table 9.10 provides a comparative survey of E-governance which includes an analysis of roles and dimensions of governments.

Table 9.6 Comparative survey of smart home and buildings

Paper	Research topic	Case study	Outcome	Remarks
Terence Hui et al. [64]	Major Requirements for Building Smart Homes in Smart Cities Based on Internet of Things Technologies	Smart home	Requirements for smart home	Save energy and help in remote health monitoring
Skouby and Lynggaard [65]	Smart Home and Smart City Solutions Enabled by 5G, IoT, AAI, and CoT Services	Smart home	ICT-based infrastructure	– Intelligent way by deploying AI – Good scalability
Magdi Amer and Ahood Alqhtani [66]	IoT Applications in Smart Hotels	Smart hotels	IoT architecture that uses intelligent agents and fuzzy rules	– Improves the guest's satisfaction and retention rates – Inexpensive
Minoli and Occhiogrosso [67]	IoT Applications to Smart Campuses and a Case Study	Smart campus	Survey	Describes a real-life use case of an IoT/M2M/SCADA application
Anna Mavroudi et al. [68]	Designing IoT Applications in Lower Secondary Schools	Lower secondary schools	Case study	Increases the motivation aspect for the teacher and the students
Chi-Sheng Shih et al. [69]	WuKong: Secure Run-Time Environment and Data-Driven IoT Applications for Smart Cities and Smart Buildings	Smart buildings	An intelligent virtual middleware	Prevents illegal memory access
Neeraj Kumar et al. [70]	A Multi-Tenant Cloud-Based DC Nano Grid for Self-Sustained Smart Buildings in Smart Cities	Smart buildings	Cloud-assisted DC nanogrid	– Performance is good – Future work will be exploring machine learning models
Daniel Minoli et al. [71]	IoT Considerations, Requirements, and Architectures for Smart Buildings – Energy Optimization and Next Generation Building Management Systems	Smart buildings	Architecture	Facilitates global optimization and appropriate data mining, trending, and forecasting
Chi-Sheng Shih et al. [72]	Designing CPS/IoT Applications for Smart Buildings and Cities	Smart buildings	Cyber-physical system and IoT	– Reduces energy consumption – Ensures safety – Increases comfort

(continued)

Table 9.6 (continued)

Paper	Research topic	Case study	Outcome	Remarks
Chi-Sheng Shih et al. [73]	Data-Driven IoT Applications Design for Smart City and Smart Buildings	Smart buildings	Data-driven programming model	Cloud-based model is best for asynchronous data exchange

Table 9.7 Comparative survey of smart environment

Paper	Research topic	Case study	Outcome	Remarks
Ali et al. [74]	A Real-Time Ambient Air Quality Monitoring Wireless Sensor Network for Schools in Smart Cities	Quality of air	Solar-powered air quality monitoring system	Provides high quality of air over a wide range of CO and NO_2
Saba Ameer et al. [75]	Comparative Analysis of Machine Learning Techniques for Predicting Air Quality in Smart Cities	Quality of air	Pollution prediction using advanced regression techniques	Random forest regression was the best technique
Vaishnavi Daigavane and Gaikwad [76]	Water Quality Monitoring System Based on IoT	Water quality	Design and development of a real-time monitoring system	– Low cost – Good flexibility
Bart Braem et al. [77]	Designing a Smart City Playground: Real-time Air Quality Measurements and Visualization in the City of Things Testbed	Quality of air	Architecture demonstration	GPS inaccuracy
Yiheng Chen and Dawei Han [78]	Water Quality Monitoring in Smart City: A Pilot Project	Water quality	Water quality monitoring system of Bristol Floating Harbour	Future work in the urban water management system
Sarun Duangsuwan et al. [79]	A Study of Air Pollution Smart Sensors LPWAN via NB-IoT for Thailand Smart Cities 4.0	Quality of air	Development of smart sensors LPWAN	Air Quality Index level is not above 100, which is secured for location zone for the people
Mohannad Ibrahim et al. [80]	Internet of Things Based Smart Environmental Monitoring using the Raspberry-Pi Computer	Environmental monitoring	Development of environmental monitoring device using Raspberry-Pi	– Cost-effective – More accurate

(continued)

Table 9.7 (continued)

Paper	Research topic	Case study	Outcome	Remarks
Jangsoo Lee et al. [81]	A Smart IoT Device for Detecting and Responding to Earthquakes	Earthquake detection	Earthquake alert device	Low-cost acceleration sensor and least computing resources to detect earthquakes
Goncalo Marques et al. [82]	Indoor Air Quality Assessment Using a CO_2 Monitoring System Based on Internet of Things	Quality of air	Air CO_2 system on IoT architecture	– Modularity – Scalability – Low cost – Easy installation
Federico Montori et al. [83]	A Collaborative Internet of Things Architecture for Smart Cities and Environmental Monitoring	Environmental monitoring	SenSquare architecture	– More accurate – Future work with a high volume of data
Jalpa Shah and Biswajit Mishra [84]	IoT-Enabled Environmental Monitoring System for Smart Cities	Environmental monitoring	Customized design of an IoT-enabled environment monitoring system	– Low power consumption – More reliable
Vijender Kumar Solanki et al. [85]	Conceptual Model for Smart Cities: Irrigation and Highway Lamps Using IoT	Water management	Prototype	– Conservation of water and energy was done

Table 9.8 Comparative survey of waste management

Paper	Research topic	Case study	Outcome	Remarks
Praneetha Surapaneni et al. [86]	Solid Waste Management in Smart Cities Using IoT	Solid waste management	Survey	Properly organized sectors for reuse and recycling of waste should be evolved
Nalavadi Srikantha et al. [87]	Waste Management in IoT-Enabled Smart Cities: A Survey	Waste management	A comprehensive survey of ICT-enabled waste management models	This paper reveals the need for a novel framework for waste management
Theodoros Anagnostopoulos et al. [88]	Robust Waste Collection Exploiting Cost Efficiency of IoT Potentiality in Smart Cities	Waste management	Dynamic routing algorithm	– More cost-efficient – More robust

(continued)

Table 9.8 (continued)

Paper	Research topic	Case study	Outcome	Remarks
Digiesi et al. [89]	A Cyber-based DSS for a Low Carbon Integrated Waste Management System in a Smart City	Waste management	Decision Support Systems (DSS) for a Social Cyber Physical framework	Integrated waste management system performance assessment will be done as future work
Behzad Esmaeilian et al. [90]	The Future of Waste Management in Smart and Sustainable Cities: A Review and Concept Paper	Waste management	A conceptual framework for a centralized waste management system	Extensive work will be done across urban planning
Haribabu et al. [91]	Implementation of a Smart Waste Management system using IoT	Waste management	Mobile application system associated with a smart trash bin	– Waste management done effectively – Automated system will be developed as future work
Viral Rambhia et al. [92]	Smart Dustbins Automatic Segregation and Efficient Solid Waste Management Using IoT Solutions for Smart Cities	Solid waste management	An IoT-based smart dustbin monitoring system	Developed an application based on the android platform
Patric Marques et al. [93]	An IoT-based Smart Cities Infrastructure Architecture Applied to a Waste Management Scenario	Waste management	Multilevel IoT-based smart cities infrastructure management architecture	COAP protocol supports the higher amount of concurrent users
Alexey Medvedev et al. [94]	Waste Management as an IoT-Enabled Service in Smart Cities	Waste management	Advanced Decision Support System	High quality of service
Sai Rohit et al. [95]	Smart Dual Dustbin Model for Waste Management in Smart Cities	Waste management	Smart dustbin model	User-friendly and cost-effective
Mahajan et al. [96]	Smart Waste Management System Using IoT	Waste management	An embedded device on public dustbins	– Efficiency was increased – Low cost – Increased hygiene
Hesham Ali et al. [97]	Towards a Fully Automated Monitoring System for Manhole Cover	Waste management	Survey	This paper evaluates the use of automated and non-automated systems

Table 9.9 Comparative survey of smart grid

Paper	Research topic	Case study	Outcome	Remarks
Iman Khajenasiria et al. [98]	A Review on the Internet of Things Solutions for Intelligent Energy Control in Buildings for Smart City Applications	Energy management	IoT hierarchical architecture model	Secure, reliable, and user-friendly IoT system
Giuseppe Cacciatore et al. [99]	Cost Analysis of Smart Lighting Solutions for Smart Cities	Smart lighting	Comparison methodology for new smart lighting techniques	– Low power consumption – Long life
Miguel Castro et al. [100]	Smart Lighting Solutions for Smart Cities	Smart lighting	Interoperable smart lighting solution over the emerging M2M protocols	– Low power consumption – Reduction of greenhouse gases
Leonardo Gabrielli et al. [101]	Smart Water Grids for Smart Cities: A Sustainable Prototype Demonstrator	Smart grid	Prototype	– Wide coverage and robust – Limited use of resources
Dong Jin et al. [102]	Smart Street Lighting System: A Platform for Innovative Smart City Applications and a New Frontier for Cyber Security	Smart lighting	A wireless networked LED street lighting system	– Reduces energy – Low cost – Ensures public safety
Jaime Lloret et al. [103]	An Integrated IoT Architecture for Smart Metering	Smart meter	The architecture includes electricity, water, and gas smart meters	– Reduces waste of energy, water, and gas – Consumption efficiency and leak detection were addressed – Detects electricity and water theft
Danielle Meyer and Jiankang Wang [104]	Integrating Ultra-fast Charging Stations within the Power Grids of Smart Cities: A Review	Charging stations	Survey related to ultra-fast charging technology	Increases power quality and grid stability
Nabil Ouerhani et al. [105]	IoT-Based Dynamic Street Light Control for Smart Cities Use Cases	Smart lighting	Dynamic street light control and management	The proposed system permits an energy-saving of about 56% compared to classical methods

(continued)

Table 9.9 (continued)

Paper	Research topic	Case study	Outcome	Remarks
Suresh et al. [106]	A Novel Smart Water-Meter based on IoT and Smartphone App for City Distribution Management	Smart meter	Automated water meter reading system	Tampering in pre-paid water meters was avoided
Francesco Brundu et al. [107]	IoT Software Infrastructure for Energy Management and Simulation in Smart Cities	Energy management	Infrastructure	Infrastructure will be extended and complemented with a Big Data Analytics modules
Andreas Spanias [108]	Solar Energy Management as an Internet of Things (IoT) Application	Energy management	Solar energy IoT system	– Provides mobile analytics – Enables solar farm control – Detects and remedies faults – Optimize power
Fortes et al. [109]	Deployment of Smart Metering in the Buzios City	Smart meter	Smart metering systems	Losses are minimized, provides control, and allows monitoring different customer profiles

9.3.9 Smart Agriculture and Animal Farming

Control and monitoring of agriculture parameters like quality of crops, soil moisture, temperature, water level, humidity, and carbon dioxide level with IoT technology in urban cities lead to smart agriculture and farming. Table 9.11 provides a comparative survey of agriculture which includes many automotive technologies that measure soil parameters.

9.4 Conclusion

In this literature review chapter, we inclusively presented the survey of enormous applications of IoT in smart cities as of 2019. Moreover, a comparative analysis of different IoT applications is tabulated. The Internet of Things attributes to another sort of world where practically all the devices and machines are connected to a network. We can utilize them cooperatively with a higher degree of intelligence to accomplish difficult tasks. There are numerous activities that happen in our day-to-day lives that combine IoT devices with innovative technologies leading to a favorable condition that promotes cities to a safer, ecological, and sustainable one. The ruling administrators of cities can implement the technological development of IoT

Table 9.10 Comparative survey of E-governance

Paper	Research topic	Case study	Outcome	Remarks
Manuel Pedro Rodriguez Bolivar [110]	Characterizing the Role of Governments in Smart Cities: A Literature Review	E-Governance	Survey	Analyzes the role of governments in smart cities
Krassimira Antonova Paskaleva [111]	Enabling the Smart City: The Progress of City E-Governance in Europe	E-Governance	A comprehensive survey study in 12 European cities	Assesses the conceptual landscape for the city e-governance
Manuel Pedro Rodriguez Bolivar [112]	Governance in Smart Cities: A Comparison of Practitioners' Perceptions and Prior Research	E-Governance	Analysis of dimensions of governance	Future work should be made on efficient and inefficient patterns of governance of smart cities
Amanda Coe et al. [113]	E-Governance and Smart Communities	E-Governance	New information and communications technologies	Provides some preliminary mapping of intelligence of the communities
Rama Krushna Das and Harekrishna Misra [114]	Smart City and E-Governance: Exploring the Connect in the Context of Local Development in India	E-Governance	Architectural framework	Future study is planned to undertake qualitative methods
Olga Gil et al. [115]	Citizen Participation and the Rise of Digital Media Platforms in Smart Governance and Smart Cities	E-Governance	Thirteen digital media platforms are surveyed, mostly in cities across countries	More work is needed to understand what drives a large number of people to participate in e-platforms
Albert Meijer [116]	Smart City Governance: A Local Emergent Perspective	E-Governance	Local emergent perspective on smart city governance	Further work is based on empirical studies
Gabriela Viale Pereira et al. [117]	Smart Governance in the Context of Smart Cities: A Literature Review	E-Governance	Survey	Developed a framework for building new, smart governance models
Robert Wilhelm Siegfried Ruhlandt [118]	The governance of Smart Cities: A Systematic Literature Review	E-Governance	Survey	Substantial variances in contextual factors, measurement techniques, and outcomes
Vinod Kumar [119]	E-Governance for Smart Cities	E-Governance	Survey	Innovation in the decision-making process and implementation

Table 9.11 Comparative survey of smart agriculture and farming

Paper	Research topic	Case study	Outcome	Remarks
Ricardo Alonso et al. [120]	An Intelligent Edge-IoT Platform for Monitoring Livestock and Crops in a Dairy Farming Scenario	Smart agriculture	IoT platform	Reduction in data traffic and an improvement in the reliability of communications
Tran Anh Khoa et al. [121]	Smart Agriculture Using IoT Multi-Sensors: A Novel Watering Management System	Smart agriculture	Architecture	Inexpensive and highly efficient components
Hemlata Channe et al. [122]	Multidisciplinary Model for Smart Agriculture Using Internet-of-Things (IoT), Sensors, Cloud-Computing, Mobile-Computing & Big Data Analysis	Smart agriculture	Multidisciplinary model for smart agriculture	Increase in agricultural production and for cost control of Agro-products
Pallavi et al. [123]	Remote Sensing and Controlling of Greenhouse Agriculture Parameters Based on IoT	Smart agriculture	Remote sensing of agriculture parameters and control system	Increase of yield and to provide organic farming
Prathibha et al. [124]	IoT-Based Monitoring System in Smart Agriculture	Smart agriculture	IoT and smart agriculture using automation	This system can be improved by modern techniques like irrigation methods and solar power source usage
Xiaojie Shi et al. [125]	State-of-the-Art Internet of Things in Protected Agriculture	Smart agriculture	Literature review	Enhanced versatility, reliability, expansibility, endurance
Gero Strobel [126]	Farming in the Era of Internet of Things: An Information System Architecture for Smart Farming	Smart agriculture	Architecture	This presented architecture offers insights and information on smart farming

into practice for the welfare of citizens and the environment. The innovative technologies of IoT will emerge and create changes in human life in unimaginable ways throughout the following decades.

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Chapter 10
IoT-Based Water Quality and Quantity Monitoring System for Domestic Usage

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10.1 Introduction

Water pollution has received global attention in recent years due to undermining economic growth as well as the physical and environmental health of people. In particular, it has terrible effects on environment. It occurs due to mixing up of contaminated substances with subsurface groundwater, lakes, stream, rivers, and oceans. These pollutants can be from a variety of sources like sewage, discharge of toxic chemicals, radioactive materials, thermal pollution, food processing waste, insecticides, pesticides, drugs, and many more. Water pollution causes change in physical or biological properties of water which will create a detrimental effect on living organism. High concentration of BOD and TDS in the pollutants can cause depletion of oxygen present in the water. Furthermore, these pollutants can travel through food chain and get into human bodies, causing various diseases and death. Contaminated water creates waterborne diseases like dengue, cholera, diarrhea, and malaria. Conventional method of water monitoring involves manual collection of water sample from different locations in a regular period of time to provide the details of each location. These conventional monitoring techniques are lengthy, expensive, and time consuming. Manual monitoring system does not provide the exact values, and it needs more processing time. The frequent maintenance and repairing of instruments increase the operating cost too in this system. Furthermore, significant amount of resources get wasted when the instruments fail or when data go missing or erroneous. So an alternate technique, much simpler and a powerful

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and an efficient one, is needed for water quality and quantity monitoring in today's scenario.

In order to collect the data on temperature, pH, and turbidity, the water quality monitoring system employs sensors. These parameters are measured in real time with suitable sensors and directed to the monitoring station in the remote location. Smart water quality monitoring through Internet of Things (IoT) is proposed to efficiently keep track on water characteristics. The usage of Internet of Things (IoT) with sensor nodes that have networking capability provides a better and suitable solution to the water monitoring system.

The water quality and quantity monitoring system through IoT involves three main subsystems: (1) data gathering subsystem, (2) data carrying subsystem, and (3) data governing subsystem. The water quality and quantity monitoring system through IoT is presented in Fig. 10.1.

Water parameter monitoring subsystem involves various sensors for monitoring water metrics and a data transmission device to transmit the collected information from sensors to the controller. The controller collects and processes the data received from the sensor. The processed data from controller is transmitted to the cloud

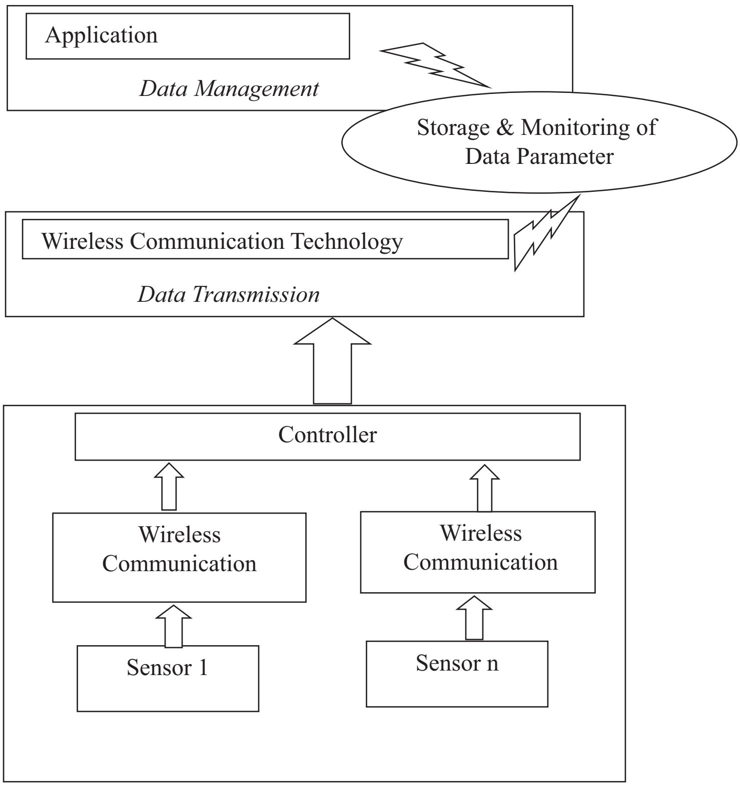

Fig. 10.1 Process of real-time water monitoring system

storage using wireless communication device in the data carrying subsystem. The data governing subsystem uses an application to acquire the information from cloud and displays it to the end user.

Sensors are typically used to detect the changes in an environment or a system and transmit the data for processing. In this work, the sensors are placed inside running or stored water source. The sensors convert the measured parameter into its equivalent electrical quantity. The converted physical parameter is processed by a controller and sent to the suitable application using appropriate communication technology. The technology used for communication can be chosen based on the type of application used. The application can be data governing system, data inspection system, or warning system based on the parameter to be monitored.

Sensors involved in the proposed system are (1) sensor for pH monitoring, (2) sensor for turbidity monitoring, (3) sensor for temperature monitoring, and (4) level and flow monitoring sensor.

pH scale for liquid generally varies from 0 to 14. In general, if the pH of water is less than 7, it can be treated as acidic, and if it is more than 7 pH, it can be considered as alkaline. So, measurement of pH in water is treated as an important indicator of water purity. pH is generally considered as measure of free hydrogen and hydroxyl ions in the liquid. It generally changes with the chemicals present in the pollutants. The solubility and biological availability of chemicals present in water are also determined by measuring the pH of water. pH of water is measured with pH sensor and sent to the controller for further processing.

Turbidity monitoring is important in water resources as it affects the growth of aquatic plants in the water stream. Increase in the turbidity of water reduces the amount of light for photosynthesis and also increases the temperature of water. Turbidity in the water occurs due to the suspended particles like clay, slit, tiny organic and inorganic organisms, and organic compounds that are soluble. Increase in the turbidity in the water is caused mainly due to human activity in industries and agriculture that causes the movement of suspended particles which get mixed into the water. During transportation of water through broken water line and rusted water pipes, the turbidity of water gets increased. The amount of light scattered by the suspended particles in the water is measured by turbidity sensor. If the level of turbidity in the water gets increased, the risk for gastrointestinal diseases in the human also increases. The World Health Organization (WHO) suggested that the turbidity measure in the water should not be more than 5 Nephelometric Turbidity Units (NTU) and that the ideal value of turbidity in water must be below 1 NTU.

Thermal pollution increases the temperature in water that in turn affects the reproductive system of human beings and metabolism of aquatic animals. Thermal pollution occurs when the heat gets released from coolers and heat exchangers in industrial processes that get exposed into water. Pollutants in the water become more toxic when the temperature increases, and the dissolved oxygen in the water also reduces when water becomes warmer. At the same time, when the temperature increases, $H+$ ions in the water also increase, and this makes the pH of water to get dropped. Water temperature can be measured with temperature sensor, and the electrical signal from the sensor is given to the controller in data processing subsystem.

Next, the proposed water quantity monitoring system comprises sensors like (1) level sensor and (2) flow sensor. Water distribution system generally has an infrastructure that collects, treats, and stores water and efficiently distributes it through the network of storage tanks and pipelines. The function of water distribution system is to supply appropriate quantity of water to customers with sufficient pressure, with minimal loss, safe, and in an economical way [1]. There are a wide variety of water sources like river extractions and ground water extractions, and it can be extracted from alternative sources like wastewater treatment process and desalination process also. Water flow through pipeline must be with sufficient pressure to avoid the contamination with underground water leakage and other user requirements. About 60% of population depends on the public water supply. There is a wide gap between demand and supply of water to the common people. The major issue in India is the sanitation facilities and safe access to water in both urban and rural areas. A large part of India falls under water scarcity where the availability of natural resources is not sufficient, so the efficient usage and distribution of water are necessary in current scenario.

Generally, water is stored in overhead tanks and underground reservoirs having inlet and outlet pipes fitted with the valves that are opened and closed for a scheduled time to manage the supply of water. Monitoring and control of this must be automated for the efficient distribution of water. Measurement of leakage of water is also quite important to avoid the wastage of water during distribution of water in pipelines. Wastage of water due to leakage in pipelines while transporting water from one place to another also paves the way for water scarcity in many places, and so it should be monitored and repaired shortly for further usage. While transporting water, there is also a chance for the quality getting affected due to the external parameters; therefore, this should be monitored and corrected before it is given to the public. In primitive method, water leakage in a rural area is located manually which took more time that leads to more loss of water and increases the demand in the receiving area. So, the sensors, meters, and analytical tools are required for monitoring and controlling the transmission and distribution of water.

Water quantity measurements include an ultrasonic sensor that measures the amount of water in the storage tank, and the flow of water in pipeline is measured with flow sensor that helps to know about the amount of water flowing through the pipelines. Water leakage is detected with the wireless sensor network that helps to keep tracking the location that has more water leakage through the data given by the sensors.

So this work proposes a system that monitors the water quality and also distribution of water for the domestic usage using IoT for a single home, and this can be extended to any civil structure.

This proposed work is organized as follows: Sect. 10.1.1 gives the review of existing system, Sect. 10.2 explains the proposed system, Sect. 10.3 gives results and discussion, and Sect. 10.4 elaborates the results obtained.

10.1.1 Overview of the Existing Systems

The existing water level monitoring system monitors the level of water, quality of water, and GSM module for sending the messages to the user. In this method, the water quality is measured by testing the water samples from the water tank. In these methods, water level is monitored by water level sensors. The water level sensors are made of plastics and may have the chance to be deposited by algae. The conventional method involves the collection of water samples from different locations manually. The water quality in the storage tank is usually measured in laboratories. These methods fail in identifying losses occurred in transmission lines and also get affected by the leakage problems. Lag in leakage monitoring system leads to the wastage of water in the unwanted places which in turn affects the people by water scarcity in the needed areas. In older methods, the leakage is identified manually and then the workers search hard to locate the leakage. This leads to loss of huge water from the pipelines and also increases the period of water scarcity in the terminal area.

Other method includes monitoring of water in the stored level in the large quantities like lakes, tanks. This method does not offer full functionality when the water is lost while transporting. Water level monitoring is done simply using electronic components which does not give the exact reading. In some methods, the water level is measured by calculating the water quantity input and output measurements. In this technique, any blockage in the outlet pipeline leads to misreading of the water level. In former methods, the deposits in the water tank are not considered, but they also contribute more in the water quantity and quality in the tank. Moreover, these methods allow knowing the level of water alone.

Smart water quality monitoring system deals with the data management subsystem that acquires, transmits, and analyzes the data [2]. Particularly, it deals with the subsystem that acquires the data and selects the parameters for water quality measurement, the techniques currently used for water quality monitoring through online, the locations for placing collecting stations, and interval of time for collecting the samples. In this work, the data network architecture chosen for data transmission and management system for the data communication involved is also studied. In this work, the techniques involved for water quality analysis and methods for data storage are also dealt.

Water quality monitoring using a smart sensing system deals with the design of new smart sensor used for monitoring water quality [3]. This new introduced technique measures the physical and chemical properties of water sample to calculate the water pollution parameters by utilizing the spectroscopic techniques. This is done by using a multisensor fusion approach, by utilizing artificial neural network algorithms. A set of water samples are tested successfully with the proposed smart sensor to estimate the value of chemical oxygen demand (COD). The estimated COD with this proposed smart sensor technique equals the value measured with a conventional technique.

Remote monitoring and smart sensing for water meter system and leakage detection speaks about the devices utilized for remote monitoring of quality and quantity of water. These electrical meters waste the energy significantly as they must be turned ON and OFF periodically [4]. This proposed work introduces a new metering scheme that uses the traditional mechanism by combining traditional mechanical devices with electronic water meters. This proposed method is a low-cost method, utilizing noncontact-type sensor with capacitive signal sensing method; moreover, in this method, the device is supplied with power only when the server requests for measured signal, so it consumes only less power. This method also includes a water quality monitoring technique that uses wireless network to detect the water leakage by performing software analysis done through a control center placed at the server. This system efficiently performs water management and has low power consumption, low human errors, and minimum wastage of water resources.

10.2 Proposed System

The proposed work involves sensors for the measurement of quality factors of water like pH, turbidity, temperature, and also the water level in the storage tank [5]. The flow diagram of the process of real-time monitoring system is presented in Fig. 10.1. The controller processes the values that are measured by sensor, and the processed data is transferred through Internet to the authorities. Arduino is used as a core controller in this proposed water quantity and quality metrics monitoring system.

The quantity of water in the storage tank is measured continuously with an ultrasonic sensor [6–8]. Measured value from the sensor is compared with the standard value, and if the water reaches the value below the standard, the Arduino interfaced with the ultrasonic sensor alerts the municipal authorities about the water level. The municipal authorities get alerted about the water level in the tank with the available data. Since the water level is monitored continuously, any sudden drop in the water level alerts the municipal authorities. This makes the municipal authorities to know about the leakage or any overuse of water in the particular area.

Flow sensor is connected to the outlet of the water pump from the lake or water resources and interfaced to an Arduino board along with a GPS module. Arduino is also connected to the RF module which transfers data to the next RF module placed after certain interval. This RF module is interfaced to another Arduino which receives and stores the data and sends it along with the data obtained from the flow sensor and GPS module to the next RF module. These data are then finally transferred to the Arduino placed in the last stage of the process, and from there, these processed data are transferred to the municipal authorities. Therefore, the information regarding the leakage of water in the pipelines from the tank will be intimated to the municipal authorities immediately by comparing the flow rate of the sensors. Along with this, the information regarding the leakage of water in the pipelines in different location can also be identified. This helps the municipal authorities to repair the leakage in short span of time that reduces the wastage of water and avoids water scarcity.

Turbidity sensor reads the amount of turbidity in the stored water. It also helps to know about the amount of dissolved particles deposited in the lower level of the tank. This deposition decreases the amount of water quantity in the tank and also leads to the development of many small parasites in the water which deploys the quality of water. Voltage output from the turbidity sensor varies in a linear manner to the amount of the suspended particles in the water. The voltage output from the sensor is coupled to the Arduino. This output from the Arduino is sent to the municipal authorities, so that they can know about the turbid nature of water in the tank. This makes the authorities to recheck the filters in the water reservoir pumps and make the water pure.

pH sensor helps to know the alkalinity of the water stored in the storage tank [9]. pH sensor with BNC connector interfaced to the analog input of Arduino can sense the change in pH value. The humans have high tolerance for the values of pH, but when the pH value become higher than 11, it causes problem in the skin, irritations in eye, and minimal gastrointestinal irritations. Any variation in the pH value of water in the storage tank from the standard value can be reported to the municipal authorities.

Negative temperature coefficient (NTC) thermistor measures the temperature of water in the stored tank. The resistance of NTC thermistor reduces when the temperature increases. Change in resistance for the change in the temperature cannot be measured directly with Arduino, the changes can be measured only as voltage. The voltage at a point between the thermistor and a known resistor is measured with an Arduino. If the temperature of the stored water increases above the desired level, the information about the change is given to the municipal authority.

The municipal authorities can access the data using smartphones, personal computer, and tablet from server module placed in the remote place. The service is available to the end users through the network, usually the Internet. This system stores the data, and this stored data can be accessed by the end user from any location through the Internet. A web page is created that allows the user to monitor and control the system. The web page gives information about pH value, turbidity, temperature variations, and amount of water in storage tank of a particular region. Through the IP address of the server placed for monitoring, the web page of particular area can be accessed [10].

The sensors and the modules utilized in the proposed water quality and quantity system are discussed below. Figure 10.2 presents the block diagram of the proposed water quality and quantity metrics monitoring system.

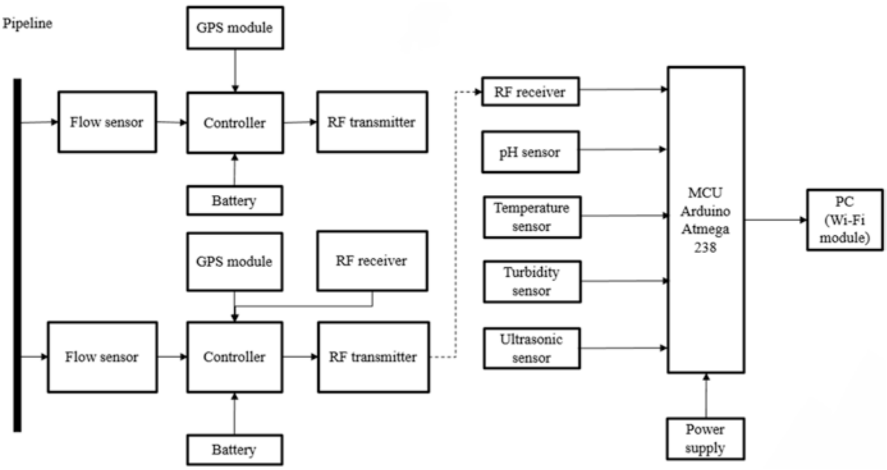

Fig. 10.2 Water quality and quantity metrics monitoring system

10.2.1 Ultrasonic Sensor

Ultrasonic sensor works by the principle of "time of flight" using the speed of sound. It sends the short and high-frequency sound pulses at regular interval of time in the direction of medium. These pulses strike an object and reflect back from the object as an echo signal to the sensor. The distance to reach the target is calculated as the time interval between transmitting signal and receiving signal. The distance and level are calculated using Eqs. (10.1) and (10.2).

$$\text{Distance} = (\text{Speed of sound in air} \times \text{time delay}) \div 2 \tag{10.1}$$

$$\text{Level} = (\text{Tank height} - \text{Distance}) \tag{10.2}$$

In this work, ultrasonic sensor is placed on the top of the storage tank, and it sends an ultrasonic signal down to the bottom of the tank. These signals travel at the speed of sound and get reflected back to the transmitter. The time delay between transmitted and received signal is calculated using ultrasonic transmitter. This time delay changes linearly based on distance between the target surface and the transducer mounted on the surface, and it can be used to calculate the quantity of water in the storage tank. The medium of transmission of sound signal is usually air. The speed of the sound wave gets altered with medium temperature, and the presence of dust or any other environmental factors can also affect the signal transmission. A beam guide can be attached to the transducer for enhancing the performance of the system where dust and temperature affect the sound signal.

Advantage with the usage of ultrasonic sensor for liquid measurement is that of the technique used for measurement is a noncontact type that will not get affected

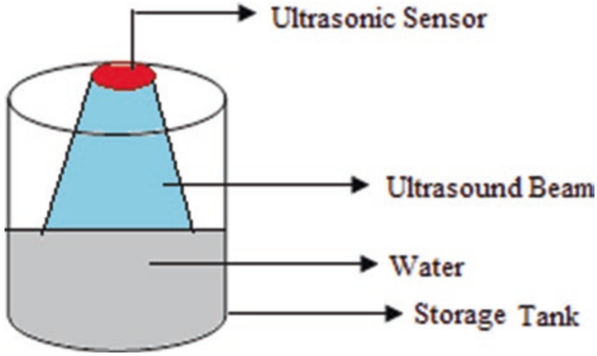

Fig. 10.3 Principle of level measurement using ultrasonic sensor

by liquid density and pressure. Installation of ultrasonic transducer on the empty tank or tank with liquid is very easy and easily configurable.

The disadvantage of using ultrasonic sensor for water quality monitoring system is that it can be only used for measuring minimum liquid distance. Moreover, reading the reflections from smooth and curved surface is difficult and sensitive to temperature variations.

Principle of level measurement of water storage tank using ultrasonic sensor is presented in Figs. 10.3 and 10.4 shows the ultrasonic sensor used for the proposed work.

10.2.2 Turbidity Sensor

Turbidity measurement is performed to check for the water clearness. Water cleanliness generally gets affected by clay, soil, and slit entering into the water from distributed places. Suspended particles adversely affecting the ecosystem can be the pollutants like chemicals, pesticides, and heavy metals. The historic data of the turbidity of water in different areas at different instant time can be maintained, and the occurrence of drastic change in the turbidity will be reported. The turbidity sensors work by transmitting a beam of light into the water to be tested. The suspended particles scatter the transmitted light, and the quantity of light reflected back determines the density of suspended particles. More the light gets scattered more the suspended particles in the stored water. Figure 10.5 shows the arrangement for principle of turbidity measurement, and Fig. 10.6 shows the turbidity sensor used in the proposed work.

Fig. 10.4 Level measurement using ultrasonic sensor. (Source: IndiaMart)

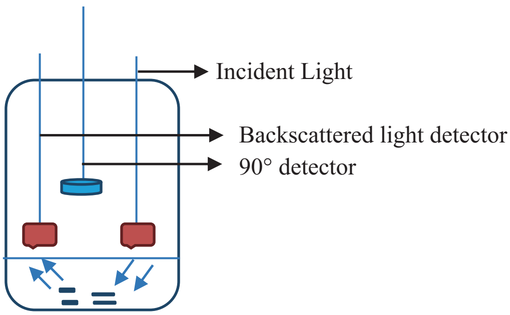

Fig. 10.5 Principle of turbidity sensor

10.2.3 pH Sensor

In water quality monitoring, high or low pH values will be an indication of water pollution. pH sensor is used to measure the hydrogen ion activity in water, indicating its acidity or basicity. pH meter estimates the difference in electric field potential between the reference and pH electrode and displays the pH value. This arrangement comprises electronic amplifier, glass electrode, and reference electrode or a combination electrode. The electrodes are placed into the water that is to be examined for the quality and quantity metrics. Glass electrode used for pH measurement is designed specifically for measuring hydrogen ion concentration. The hydrogen ions in the stored water exchange the positive ions with glass bulb and create an electrochemical potential across the bulb. The reference electrode is made of

Fig. 10.6 Turbidity sensor. (Source: Thomson Electronics)

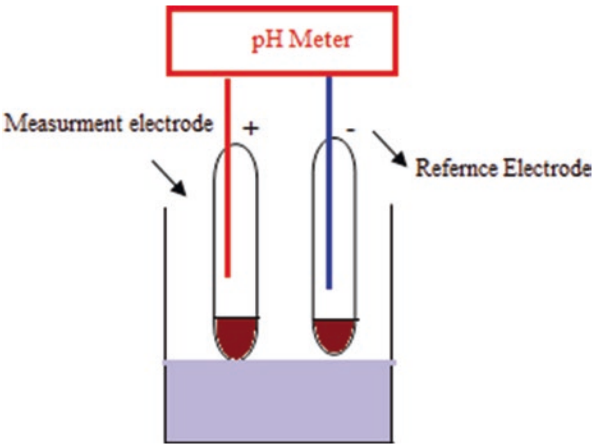

Fig. 10.7 Principle of pH sensor

metallic conductor and must be insensitive to the pH value of the water. On the immersion of reference and glass electrode in the water, the electric circuit gets completed. The difference in electrical potential created between electrodes is measured, amplified, and displayed as a pH value. The potential difference developed across the electrode is detected by the voltmeter. The Nernst equation gives the relation between ion movement and measured voltage.

The electrodes are sensitive to the contaminants, and cleanliness of electrode is essential to derive more accurate and precise results. Calibration must be done for glass electrode, as it will not produce a reproducible output over long span of time.

Fig. 10.8 pH sensor. (Source: Robokits)

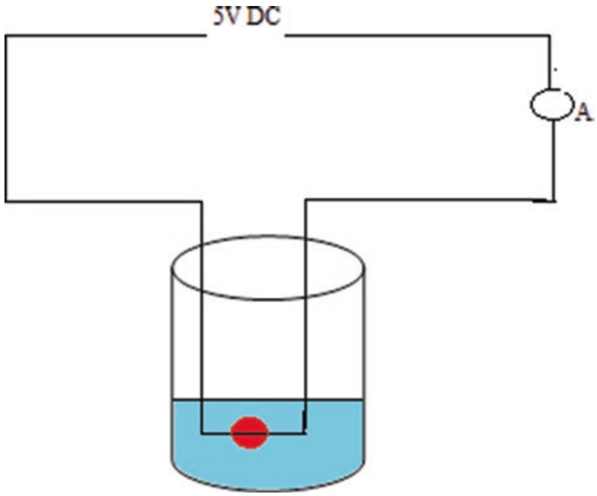

Fig. 10.9 Principle of NTC thermistor

The response of pH electrode is temperature dependent, and pH values of buffer solutions greatly depend on the temperature. Some electrodes have in-built temperature coefficient correction, so the calibration process correlates the voltage produced by the electrode with pH scale.

The principle of working of pH sensor is shown in Fig. 10.7, and pH sensor utilized in this proposed work is shown in Fig. 10.8.

10.2.4 NTC Thermistor

Thermistor is a thermal-sensitive resistor that produces high, precise, and predictable variation in resistance for the small variation in temperature. The resistance of NTC thermistor increases as the temperature decreases and the resistance value

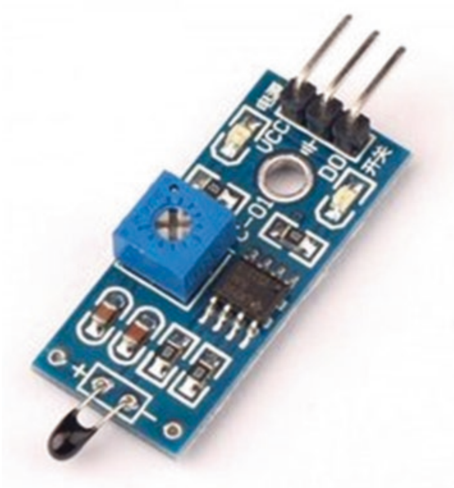

Fig. 10.10 NTC thermistor. (Source: IndiaMart)

decreases as the temperature increases. As NTC thermistor provides a larger variation in resistance for °C change in temperature, and a small change in temperature can also be revealed very faster with higher accuracy. The effective operating range for NTC thermistor is −50 to 250 °C. Unlike other resistors, these are made of ceramics and polymers that are composed of metal oxides that are processed to get the desired form factor.

The principle of working of NTC thermistor is shown in Figs. 10.9 and 10.10 gives the NTC thermistor module used in the proposed work.

10.2.5 Flow Measurement

The orifice plate is used for the measurement of water flow in a storage tank. It is made of stainless steel of various grade and is a thin metal plate of diameter 1.5–6 mm in thickness with the hole bored at the center of plate. The bore diameter in the plate will be in the range of 30–75% of the inside diameter of pipe.

Principle of orifice plate is that when an obstruction is placed in the pipeline, a difference in pressure results. This difference in pressure measured with the upstream and downstream side of partially obstructed pipe gives the amount of fluid flow in the pipe. This pressure drop can be measured with a pressure gauge and varies based on the flow rate. The differential pressure measured with pressure gauge is directly proportional to the flow rate as per Bernoulli's equation, and hence the pressure gauge can display the flow rate instead of differential pressure.

Orifice plate has no moving parts and is mechanically stable, simple, reliable for many years, and inexpensive. But it has less discharge coefficient and produces inaccurate results when the plate gets eroded. Moreover, its accuracy is dependent on density, viscosity, and pressure of fluids.

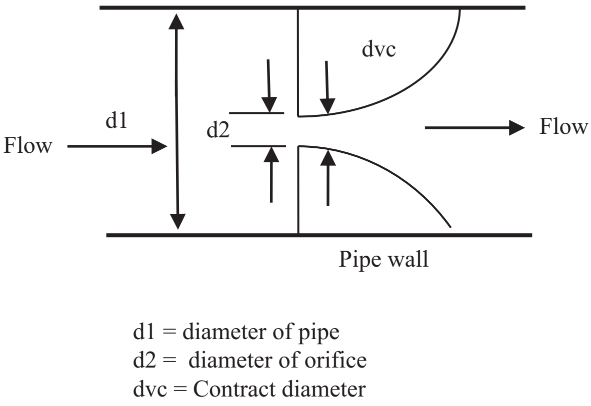

Fig. 10.11 Flow measurement

Fig. 10.12 Flow sensor. (Source: Electronics hub)

The principle of operation of orifice plate is shown in Fig. 10.11, and the flow sensor module utilized in the work is shown in Fig. 10.12.

The process of flow for the proposed work is shown in Fig. 10.13, starting from interfacing of sensors to Arduino and final intimation given to the user is shown.

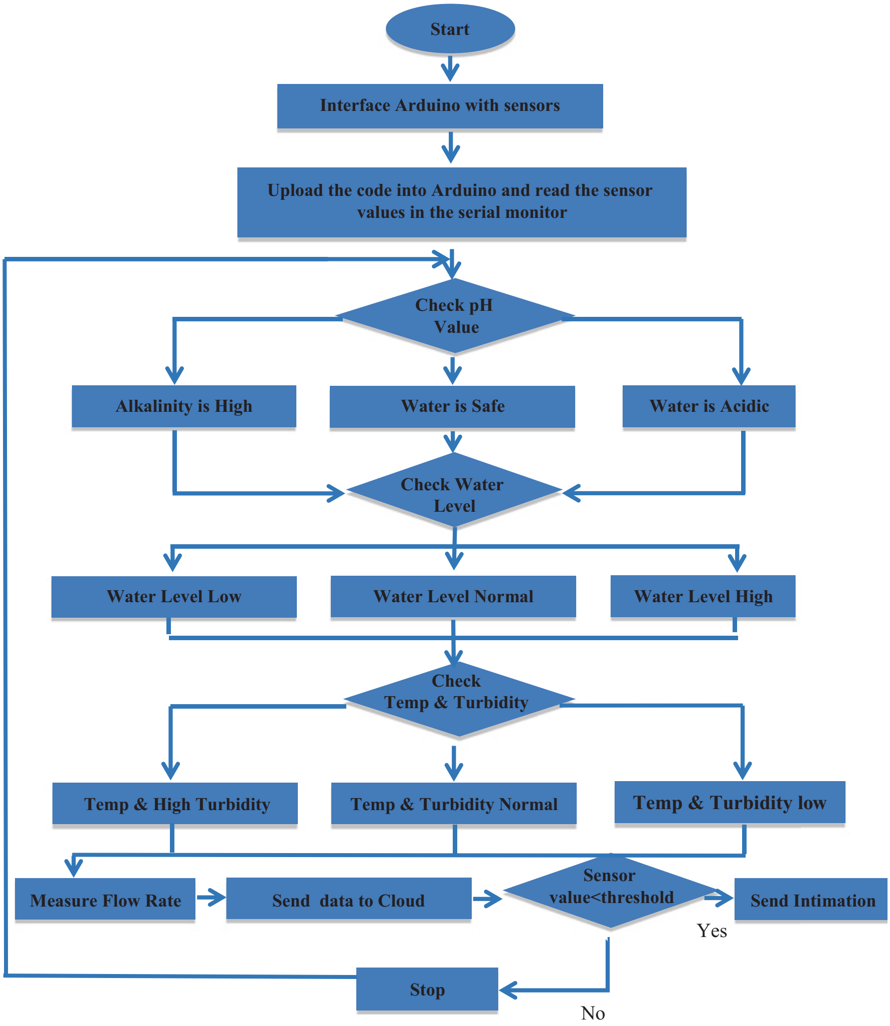

Fig. 10.13 Flow diagram of the proposed system

10.2.6 Arduino UNO

Arduino UNO is an open source platform that is used to develop IoT-based products. It consists of ATMega 38 microcontroller. The board has a set of digital input and output pins that can be interfaced to various expansion boards and circuits [11, 12]. Arduino can be powered with personal computer through USB or with external power supply. Processor utilized in Arduino is based on Harvard architecture. In Harvard architecture, program code can be stored in a flash memory and can be reprogrammed for any number of times, and the data is stored in data memory.

It has 14 digital input and output pins and six analog input and output pins. Arduino UNO can be programmed with Arduino IDE (integrated development environment) via USB cable. Some pins in Arduino have some specialized functions like UART (universal asynchronous receiver transmitter) for transmitting and receiving the data serially. External interrupt pins can trigger an interrupt on change in value, rising or falling edge and low value, PWM (pulse width modulation) pins, SPI (serial peripheral interface) pins, and AREF (analog reference) pins. By connecting a sensor to an Arduino board, the sensor values can be read and processed. The Arduino can be connected to Internet so that the sensor data can be monitored from remote place. The sensors can be connected directly to Arduino pins or using Arduino shield pins.

Arduino shield provides three-pin interface for connecting different sensors and output devices to Arduino. It is an easy way of connecting input and output devices to Arduino. It is a passive circuit that connects the Arduino pin to many connectors. The connector allows to connect various sensors, servos, relays, and buttons to Arduino. There are 13 ports for digital input and output and six analog ports for analog input. The digital port has 5 V power and TTL level signal (0 or 1), and analog input accepts 0.5 V DC input voltage and gives output voltage in the range 0.5 V. Arduino sensor shield system is connected to a 5 V system and to a 3.3 V system also.

The Arduino can be programmed directly by loading the program into it without the need of hardware programmer for doing programming or burning the program. This can be done with Arduino bootloader that programs the flash memory for any number of times.

In this work, five sensors like flow sensor, level sensor, turbidity sensor, temperature sensor, and pH sensor are connected to the five analog/digital pins of Arduino.

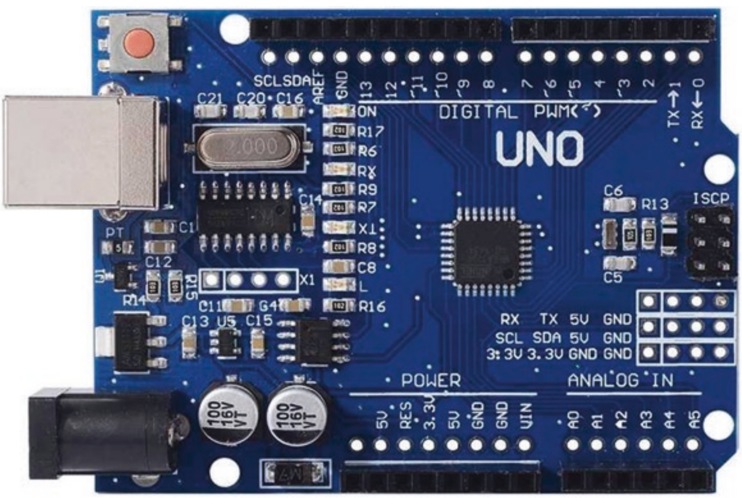

Fig. 10.14 Arduino UNO. (Source: Amazon)

The Arduino UNO has in built TCP/IP protocol stack that made Arduino to have access to Wi-Fi network. This collected data about the status of water quality and quantity from different sensors is given to municipal authorities. The RF module is used for communication between Arduino and sensors. Arduino UNO used in this work is shown in Fig. 10.14.

10.2.7 RF Module

RF (radio frequency) module is the cheapest mode of wireless communication. Communication between two Arduino modules can be done with RF module. RF module is made of transmitter and receiver pair that works at a radio frequency. It is based on amplitude shift keying (ASK) or of hook keying (OOK) modulation. In these RF modules, the carrier frequency is fully suppressed and consumes low battery power. Usually, the operating frequency range of RF module is 315 or 434 MHz. RF transmitter part has four pins: VCC, GND, data, and antenna. VCC and GND pins are connected to +5 V pins and GND pin, respectively, and the data pin is connected to digital input/output pin of Arduino. Antenna pin in the RF transmitter module can be connected to the antenna through a wire wound in the form of coil. RF transmitter transmits the data from Arduino to the receiver through the antenna. The receiver receives the data through the antenna and transmits it to the Arduino

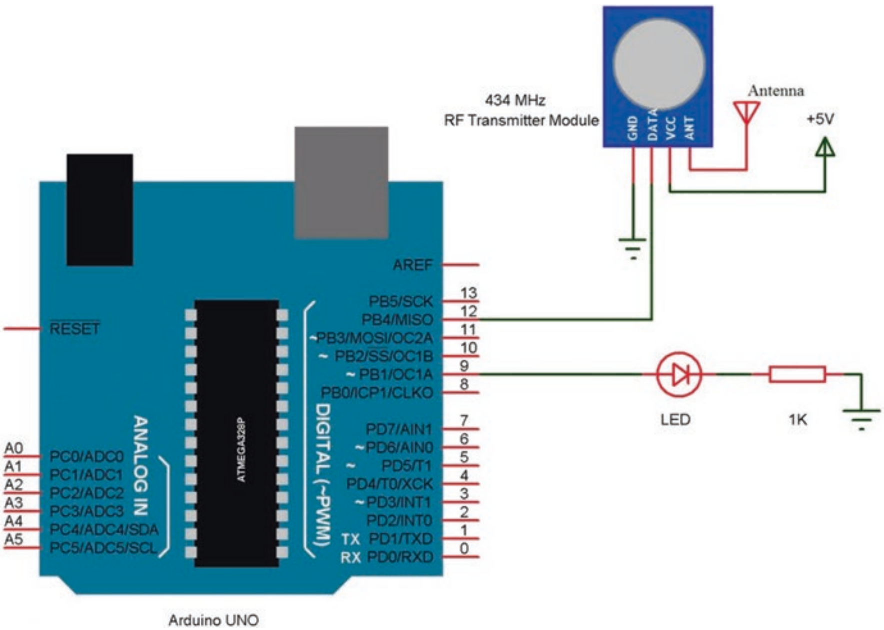

Fig. 10.15 Arduino UNO with RF transmitter module. (Source: Electronics Hub)

connected to it. This can be done with VirtualWire Library. It is a library used for communication between two Arduino using RF module. The library consists of several functions to configure the modules, transmit the data with the transmitter module, and receive the data using receiver module. Arduino UNO connected with RF transmitter module is shown in Fig. 10.15.

RF receiver part has four pins: VCC, GND, data, and antenna. VCC and GND pins are connected to 3.3 V pin and GND, respectively, and the data pin is connected to digital input/output pin of Arduino. Antenna pin in the RF receiver module is connected to the antenna through a wire wound in the form of coil. In this work, Arduino board can communicate with each other using RF transmitter and receiver module. RF receiver module connected to Arduino is shown in Fig. 10.16.

10.2.8 LED

In this work, three LEDs are used. Green, red, and orange LEDs are used to indicate the values of sensor low, moderate, and high condition.

10.2.9 LCD

It is an electronic display module that uses liquid crystal to display the values. 16 × 2 LCD is used in this work for displaying the measured values. The LCD is interfaced with Arduino to display the measured values. LCD is connected to

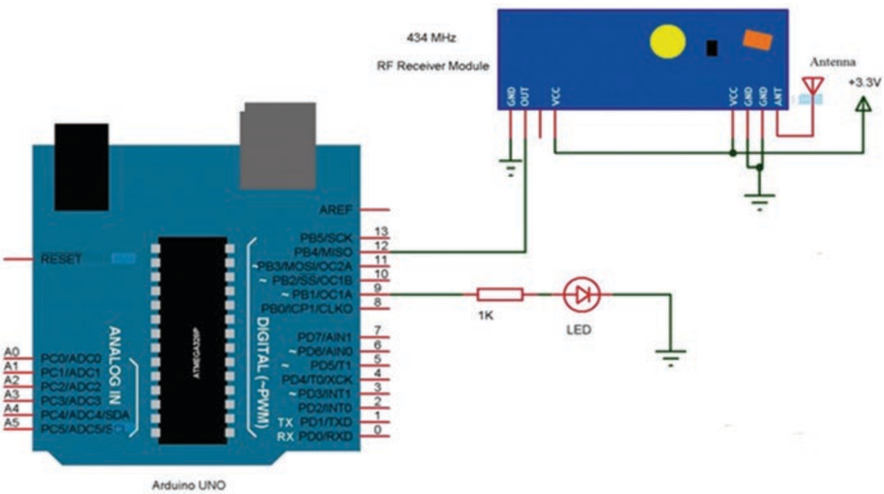

Fig. 10.16 Arduino UNO with RF receiver module. (Source: Electronics Hub)

Arduino by connecting RS pin of LCD to pin 12 of Arduino. Operating voltage of LCD is 4.7–5.3 V.

10.3 Results and Discussion

The source code is written in C language in Arduino IDE environment. The sensors are tested individually and integrated into a single whole system. The code was uploaded to Arduino through the USB connected to the Arduino. The Arduino has several analog input pins that help to get analog input from sensors. These signals have multiple range of input; Arduino scales it to the range of 0–255.

In this work, multiple sensors can communicate with the Arduino through a single serial port of Arduino expanded using serial port expander. The sensors must be changed to UART mode before it gets connected to the expander board. The sensor readings are monitored continuously, and the results are displayed on a serial port monitor. The steps to interface sensor with Arduino are given below.

10.3.1 Steps for Connection

1. Ezo_uart_lib, a zip folder was downloaded from GitHub to the computer.
2. Arduino IDE is opened in the computer.
3. In the IDE, select sketch --→ include library--→add ZIP library-→Ezo_uart_lib folder.
4. Code Serial_port_expander_example is copied on to IDE work panel.
5. Compile and upload the Serial_port_expander_example code on to Arduino UNO.
6. Channel communication can be done with serial monitor.
7. Serial monitor is opened in the Arduino UNO, go to Tools ---→Serial Monitor.
8. Baud rate is set to the rate of 9600.
9. Readings of sensors are displayed on the serial monitor.

In this work, two water samples are tested from two different water sources. Water samples from normal tap water and industrial water are taken. pH value of wastewater from industry is in the range of 6.5–8.5 and that of tap water in the range of 6.5–9.5. The temperature of tap water is around 13 °C. The ultrasonic sensor outputs are obtained and checked by varying the water level in the sample water tank. The output of ultrasonic sensor is measured in centimeters. The ultrasonic sensor output is monitored continuously during each and every fixed duration of time, so that sudden changes in the level of water can be found, which indicate that there is a leakage of water in the tank. The flow sensor reads the amount of water flowing through the storage tank. The flow sensor is fixed to the small pump outlet, so that

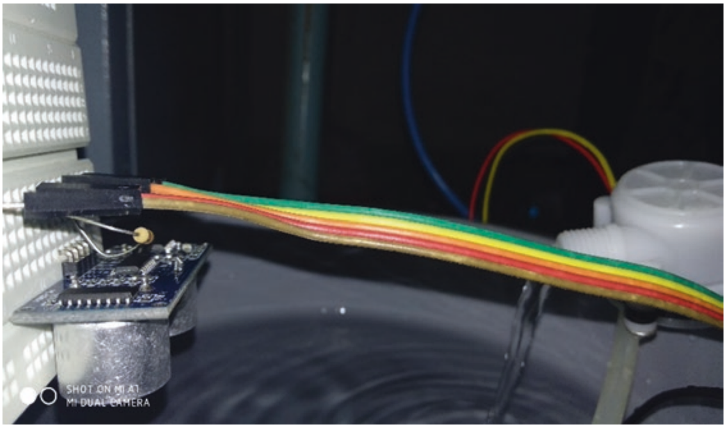

Fig. 10.17 Arrangement of ultrasonic and flow sensor

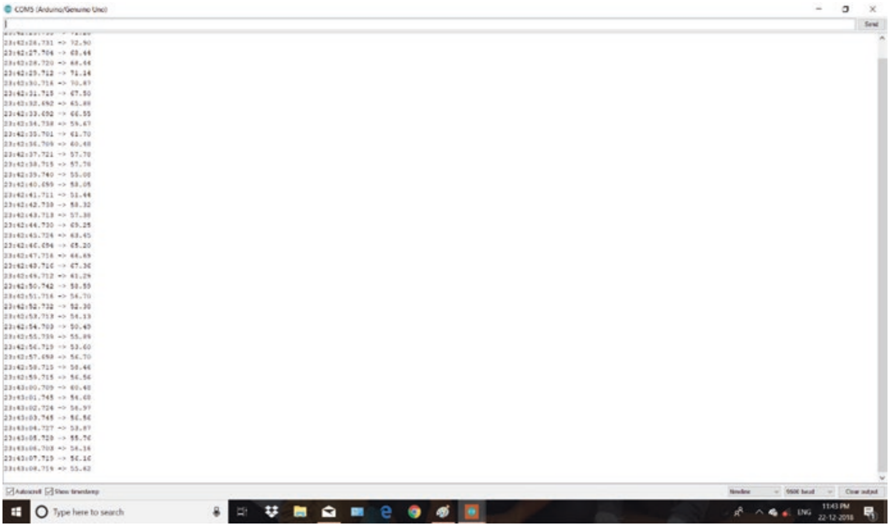

Fig. 10.18 Output of sensor displayed in the serial monitor of Arduino

the sample outputs are taken from the sensor. The sample outputs are collected and displayed in the serial port monitor.

The arrangement of flow and ultrasonic sensor is shown in Fig. 10.17, and the serial monitor that displays the sensor values is shown in Fig. 10.18. The snapshot of the proposed system for water quantity and quality monitoring is shown in Fig. 10.19. Tables 10.1 and 10.2 list the sensors with the specifications that are interfaced with Arduino.

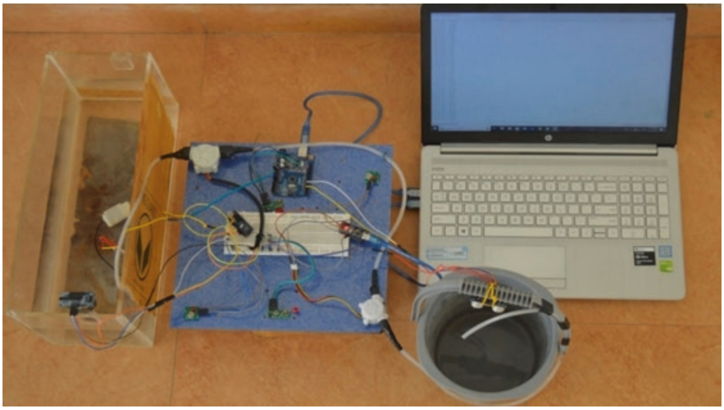

Fig. 10.19 Experimental setup of water quality and quantity monitoring system

Table 10.1 Sensors interfaced with Arduino

Sensor	Pin of sensor	Pin of Arduino
Ultrasonic module	VCC	5 V
	GND	GND
	Echo	PWM 5
	Trigger	PWM 6
pH sensor	VCC	5V
	GND	GND
	P0	A0
YF-S201	Black probe	GND
	Red probe	5 V
	Yellow probe	PWM 9
Ds18b20	VCC	5 V
	GND	GND
	DQ	D3
SEN0189	VCC	5 V
	GND	GND
	DQ	D4

Table 10.2 Summary of the sensor with the specification used in the proposed work

Sensor	Manufacturer	Range
pH	Robot	0–14
Flow	Unknown	1–30 L/min
Ultrasonic	Texas	2–4 cm
Temperature	HEL	−45 to +85 °C
Turbidity	Tomson Electronics	<500 ms—Response time

10.4 Conclusion and Future Scope

IoT-based water quality and quantity monitoring system is proposed in this work. In this work, quality and quantity of water are monitored using various sensors with web server through the Internet. Parameters are displayed on the web page so any variations from the certain level can be monitored easily. Monitoring of turbidity, pH, and temperature of water is done using various sensors with unique advantage of utilizing existing GSM network. The flow and level of the water in the storage tank is also monitored continuously. The system can monitor water quality and quantity automatically with less human intervention. So, the water testing with the proposed method is likely to be cheaper, easier, and flexible. This system can also be extended to monitor other parameters of water by including different sensors and also by using the appropriate resources. This work can also be extended to monitor pollution in air and soil contamination also. Using the embedded devices with suitable sensors for monitoring, different environmental parameters make the environment to be pollution free. To implement this, it is necessary to deploy the suitable sensors for measuring various parameters and doing analysis. By deploying different sensor devices, it can interact with other gadgets through the network for monitoring the environmental parameters. This method of collecting the data and performing analysis on the data will be made available to the authority through the Wi-Fi.

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Chapter 11
Threat Modeling and IoT Attack Surfaces

S. Raja, S. S. Manikandasaran, and Rajesh Doss

11.1 Introduction

IoT technology refers to the combination of hardware and software designed with various features such as establishing Internet connectivity between remote devices. In digital adoption, the IoT technology stack is growing rapidly. The disruptive IoT innovation creates a revolution in various industries such as aerospace, manufacturing, water, sewage, and health care. The Internet has considered one to many relationships between Internet gateway and devices until the last decade. The technologies have been innovated to many to one relationship between multiple IoT devices and Internet gateway. The recent advancement decouples the IoT and cloud computing to operate autonomously and efficiently. IoT devices are nothing but a web-enabled computing device with the capabilities of sensing, collecting, sending data, communicating with the hardware, and building in processors embedded within the device. The networking capabilities of machines are used in different sectors, such as offices, homes, industries, transportation, buildings, and wearable devices. Its key features are connection, sensors, artificial intelligence, small appliances, and active engagement. Figure 11.1 shows the typical IoT ecosystem architecture

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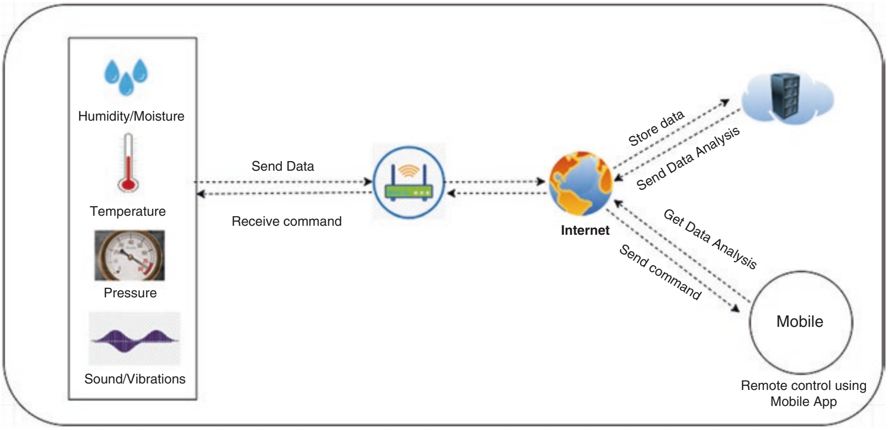

Fig. 11.1 Typical view of IoT ecosystem architecture

IoT ecosystem technology includes three primary systems. They are:

- IoT devices: These devices play a virtual role in the working of an IoT ecosystem. These devices are tightly coupled together to make the communication between two endpoints possible.
- Sensing technology: Sensors that are embedded in the devices sense a wide range of information from their surroundings, such as temperature, gases, and location, working on some industrial machine as well as sensing health data of patients.
- Gateway systems: Gateways are the devices that act as a bridge between IoT devices (internal network) and end-users (external system). It permits the user to connect and communicate with each other. The data collected by the IoT sensors that are available in the IoT devices send the collected data to the concerned user or cloud through the gateway.
- Data storage systems: The collected data after flowing through the gateway reaches the cloud intended to be stored. It is made available for data analysis. The processed data are then transferred to the user when the support person takes the necessary measures according to the information collected.
- Remote control using mobile app: The end-user controls the data using mobile phones, tabs, laptops, etc. This installed mobile app helps the user monitor, retrieve data, and take specific IoT devices from remote locations.

It is prophesied that the quantity of attached Internet of Things (IoT) devices are risen to 38.6 billion by 2025 and an expected 50 billion by 2030 [1]. The enlarged deployment of IoT devices in assorted areas of people's life has provided substantial assistance, such as enhanced quality of life and job automation. Conversely, each time a new IoT device is connected, new and matchless security dangers emerge or are hosted in the environment on which the device is operated. Instantaneous detection and mitigation of every security threat introduced by different IoT devices deployed can be very challenging. The reason is that many IoT devices are manufactured with no consideration of their security implications.

Many published research did a survey related to IoT security and challenges facing IoT devices. For example, Sicari et al. [2] presented solutions to IoT's main security issues, such as authentication, confidentiality, privacy, and access control. The survey concluded that many security issues with IoT is an open problem and need to be addressed to find a solution to these security problems. Andrea et al. [3] studied the type of IoT attacks and introduced some steps to improve IoT security. Al-Omary et al. [4] presented a survey focused on hardware-based security support that enhances the IoT and Cyber-Physical Systems (CPS) security. The study of IoT security and addressing the IoT environment's security issues and challenges are most significant.

The remaining chapter is organized as follows, discussed adequate IoT architectural components for the ecosystem, various IoT technologies, and protocols for connecting various devices. It covers the various IoT OS flavors that support industries and environments, discussed IoT communication models and IoT issues and challenges, covered IoT security problems and attack surfaces, discussed various attack techniques, and covered defensive techniques in the overall IoT ecosystem.

11.2 IoT Layered Architecture

Figure 11.2 depicts the multilayered Internet of Things architecture, such as the application layer, the middleware layer, the Internet layer, the access gateway layer, and the edge technology layer [5, 6]. The motivation here to discuss the IoT architecture is to derive the IoT threat vector and attack surfaces. These elements have foundational components to build any use cases using IoT.

- Edges Technology Layer: This layer consists of all the hardware parts such as sensors, RFID tags, readers or other soft sensors, and the device itself. These entities are the first part of the data sensors deployed to monitor or sense various

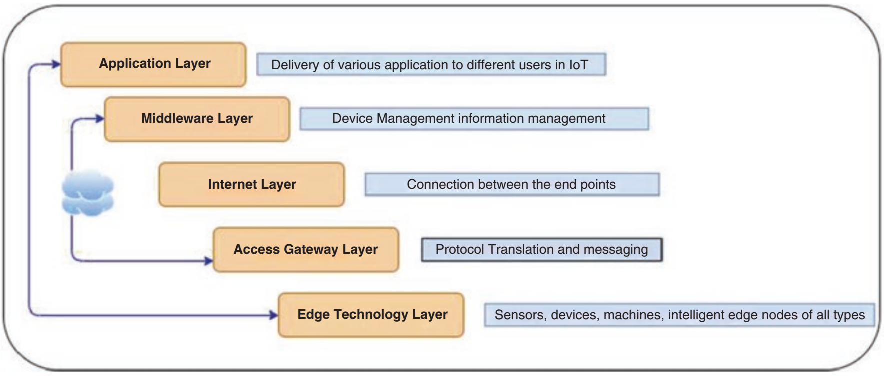

Fig. 11.2 Internet of Things layered architecture

phenomena. This layer plays an important role in data collection, connecting devices to the network and server.

- Access Gateway Layer: It acts as a bridge between two endpoints like device and client. It handles the data on the first layer and responsible for performing the routing, message identification, and subscribing.
- Internet Layer: It is responsible for carrying out communication between two endpoints such as device-to-device, device-to-cloud, device-to-gateway, and back-end-data sharing.
- Middleware Layer: It is the most critical layer that operates in two-way mode. It sits in the middle of the application layer and the middleware layer. It is responsible for important functions such as data management, device management, and various issues such as data analysis, data aggregation, data filtering, device information discovery, and access control.
- Application Layer: It has positioned at the top of the IoT stack and responsible for delivering services to the respective users from different sectors such as building, industrial, manufacturing, automobile, security, and healthcare.

11.3 IoT Technologies and Protocols

The IoT includes a wide range of new technologies and skills. This IoT technology stack has challenges because of the immaturity of technologies associated with its services and the vendors providing them. The key challenges for organizations to exploit the IoT. Hackers use standard networking protocols when there is successful communication between two endpoints. There are two types of network protocols categorized with IoT, such as wired technologies and wireless technologies. Wireless communication methodology is split into short range, medium range, low range, and wired communication. This section describes the comprehensive methodology of IoT.

- *Bluetooth Low Energy (BLE):* Bluetooth LE or Bluetooth Smart is a wireless personal area network. It is designed to provide applications in various sectors such as healthcare, security, entertainment, and fitness.
- *Light Fidelity (Li-Fi):* Li-Fi is similar to Wi-Fi. It has two different modes of communication and speed. Li-Fi is a visual communication system that uses common household light bulbs for data transfer at a very high rate of 224 Gbps.
- *Near Field Communication (NFC):* NFC is a type of short-range communication that uses magnetic field induction to enable communication between two electronic devices. It uses connectionless mobile payment, social network, and the identification of documents or objects like books in a library or some product.
- *QR Codes or Barcodes:* QR codes are machine-readable tags that contain information about the product or item to which they are attached. An instant response code or QR code is a two-dimensional code that stores product information. It

can be scanned through smartphones or any specific device. The barcode comes in two formats: one dimensional and two-dimensional code.

- *Radio Frequency Identification (RFID):* RFID stores data in tags that are read using electromagnetic fields; RFID is used in many sectors such as industrial, offices, companies, automobile, pharmaceuticals, livestock, and pets.
- *Thread:* Thread is an IPV6-based networking protocol for IoT devices. Its main aim is home automation, so that devices can communicate with each other through a local Wi-Fi network.
- *Wi-Fi:* Wi-Fi is a technology that is widely used in wireless local area networking or LAN. The most common Wi-Fi standard used in homes or companies is 802.11n, which offers a maximum speed of 600 Mbps and range approximately 50 meters.
- *Wi-Fi Direct:* It is used for peer to peer communication without the need for a wireless access point. The direct Wi-Fi devices start discussion only after deciding which method is to act as an access point.
- *Z-Wave:* Z-Wave is a low-power, short-range communication designed primarily for home automation. It gives a simple and reliable way to wirelessly monitor and control household devices such as HVAC, thermostat, garage, and home cinema.
- *Zigbee:* It is a short-range communication protocol based on the IEEE 203.15.4 standard. Zigbee is for the device's data infrequently at a low data rate in a restricted area and within a range of 10–100 meters [7].

Medium Range Wireless Communication

- *HaLow:* It is another variant of the WiFi standard that provides extended Range. It is useful for communication in rural areas. It offers low data rates, reducing power and cost for transmission.
- *LTE-Advanced:* LTE-Advanced is a standard for mobile communication. It provides an enhancement to LTE, thus focusing on delivering higher capacity in terms of data rate, extended rate, efficiency, and performance.

Low-Range Wireless Communication

- *LPWAN:* Low Power Wide Area Networking (LPWAN) is a type of wireless telecommunication network, designed in such a way to provide long-range communication between two endpoints. LPWAN protocols and technologies have three classes.
- *LoRaWAN:* Low Power Wide Area Network (LoRaWAN) is used to support various applications such as mobile, industrial, machine-to-machine, and secure two-way communication for IoT devices, smart cities, and healthcare applications.
- *Sigfox:* It is used in devices with small battery life and needs to transfer low data levels.
- *Neul:* It is used in a small part of tv white space spectrum to deliver high-quality, high-power, high-coverage, and low-cost networks.
- *Very Small Aperture Terminal (VSAT):* It is one of the communication protocols used for data transfer using small antennas for broadband and narrowband data.

- *Cellular:* It is another type of communication protocol used for communication over long distances with high-quality data, but it is expensive and high power.

Wired Communications for IoT

- *Ethernet:* Ethernet is a significant type of network protocol used today. It is a type of LAN (Local Area Network), which refers to a wired connection of computers in small buildings, offices, or campuses.
- *Multimedia over Coax Alliance (MoCA):* MoCA is the type of network protocol that provides a high definition video of home and content related to it over the existing coaxial cable.
- *Power-Line Communications (PLC):* It is a type of protocol where electrical wires transmit power and data from one endpoint to another. PLC is required for applications in different areas like home automation, industrial devices, and broadband over power lines (BPL).

11.4 IoT Operating Systems

IoT devices can be used in different operating systems in real-time. Table 11.1 describes the operating systems which are supported by the IoT environment.

Table 11.1 Flavors of IoT operating systems [8, 9]

IoT OS	Description and use
RIOTOS	Required less resource and used energy-efficient. It can run on embedded systems, actuator boards, sensors, etc.
ARMmbed OS	Low-powered devices like wearable devices
RealSense OS X	Intel depth-sensing technology since its implemented in cameras, sensors, etc.
Nucleus RTOS	It is used in aerospace medical and industrial applications
Brillo	It is an android-based embedded OS used in low-end devices such as thermostats
Conkiti	Low-power wireless devices such as street lighting and sound monitoring systems.
Zephyr	It is used in low-power and resource-constrained devices
Ubuntu Core	Also known as Snappy, it is used in robots, drones, edge gateways, etc.
Integrity RTOS	Primarily used in aerospace or defence, industrial, automotive, and medical sectors
Apache Mynewt	Supports the devices that work on Bluetooth Low Energy protocol

11.5 IT Communication Model

IoT technology uses different technical communication models, each having its characteristics.

11.5.1 Device-to-Device Model

Figure 11.3 describes the device-to-device communication model; devices connect to interrelate through the Internet in this type of communication. It uses Zigbee, Z-Wave, or Bluetooth device-to-device connection which are most commonly used in the smart home device like a thermostat, light bulb, door locks, CCTV, cameras, fridge, etc., where these devices transfer small data packets to each other at a low data rate. This model is also popular in communication between wearable devices.

11.5.2 Device-to-Cloud Model

Figure 11.4 describes the Device-To-Cloud Model; In this type of communication, devices communicate with the cloud [10] directly rather than directly communicating with the client to send or receive the data or commands. It uses communication protocols such as Wi-Fi or ethernet and sometimes uses cellular as well.

11.5.3 Device to Gateway Model

Figure 11.5 represents the Device-to-Gateway Model. In device-to-gateway communication, the Internet of Things device communication with an intermediate device called a gateway communicates with the cloud service [10]. The gateway device could be a smartphone or a hub that is acting as a primary point and provides

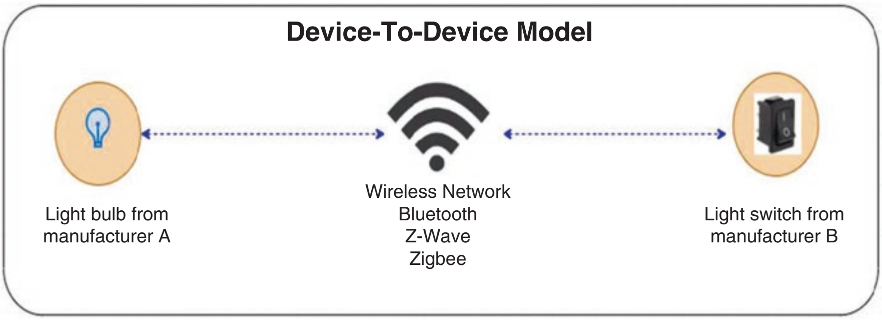

Fig. 11.3 Device-to-device communication model

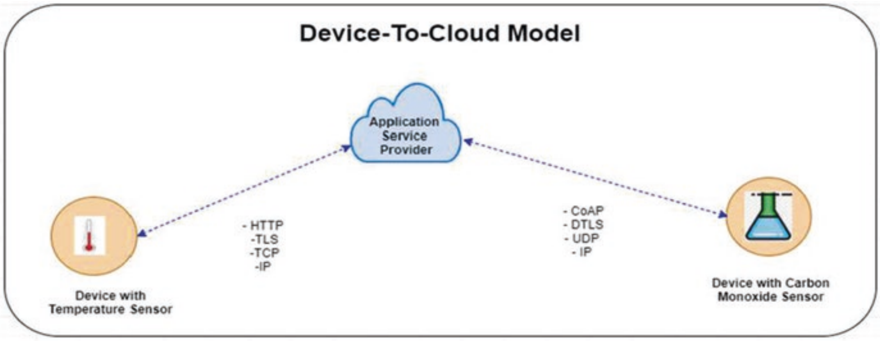

Fig. 11.4 Device-to-cloud model

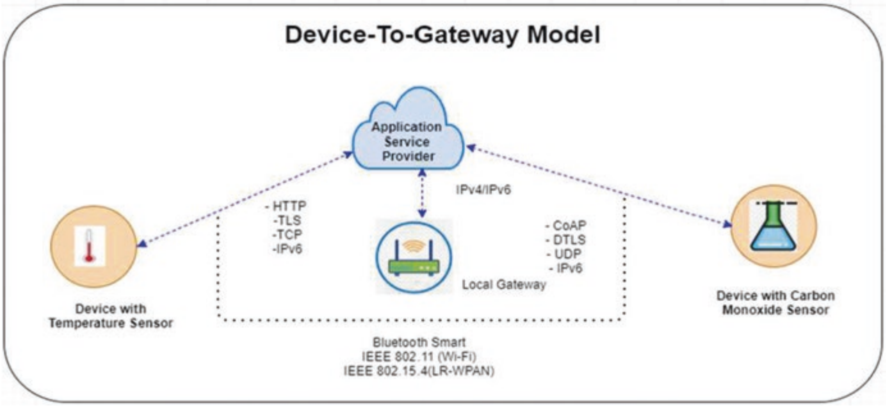

Fig. 11.5 Device-to-Gateway Model

security features and data or protocol translation. The protocol uses Zigbee and Z-wave communications.

11.5.4 Back-End Data Sharing Model

Figure 11.6 demonstrates Back-End Data Sharing Model; this type of communication model extends the device to a cloud communication type in which authorized third parties can access the IoT device data. Devices upload their data onto the cloud, which is later accessed or analyzed by third parties.

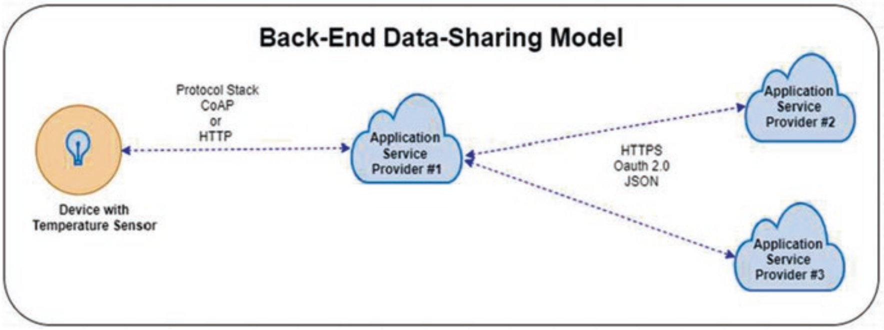

Fig. 11.6 Back-End Data Sharing Model

11.6 IoT Issues and Challenges

IoT technology growth is exponential and becomes ubiquitous. IoT has various challenges in a broader manner, such as security, privacy, interoperability standards, legal, regulatory and rights, emerging economies and development [11]. In these five areas, security is the top contributor to look at the IoT ecosystem. The security pillar is required to protect the entire system. When you choose the security, it is a broader element in cybersecurity. There is a main difference between information security and cybersecurity. Information security covers the corresponding element in the perimeter zone, which does not have connected to the Internet or is exposed to the outside public world. Cybersecurity refers to the adverse option of information security. Security has three pillars namely confidentiality, integrity, and availability. Authentication, authorization, and accounting are also the part of information security elements. Figure 11.7 presents the major requirements for enhancing data security in the IoT environment.

Figure 11.7 shows the IoT Environment's data security components in detail, confidentiality, integrity, authentication, authorization, non-repudiation, privacy, and availability.

Confidentiality: It guarantees the authorized entities to access and modify data. Authorization is given not only to the users but also to objects. Privacy needs to address two important concepts in the IoT environment. It must define an access control mechanism and an object authentication process to determine a related identity management system.

Integrity: It is nothing but openness, honesty, and reliability. An opponent cannot alter the data in the transaction without the system detecting the change. The device identity is complex, and it is very difficult to determine the data source. Trusted computing solutions are to be established to maintain the integrity of data and devices.

Authentication: Authentication is the procedure for defining someone or something who or what it is declared to be. It works with integrity, confidentiality, and authorization. Scalability posts a big thread to the authentication of devices. It is

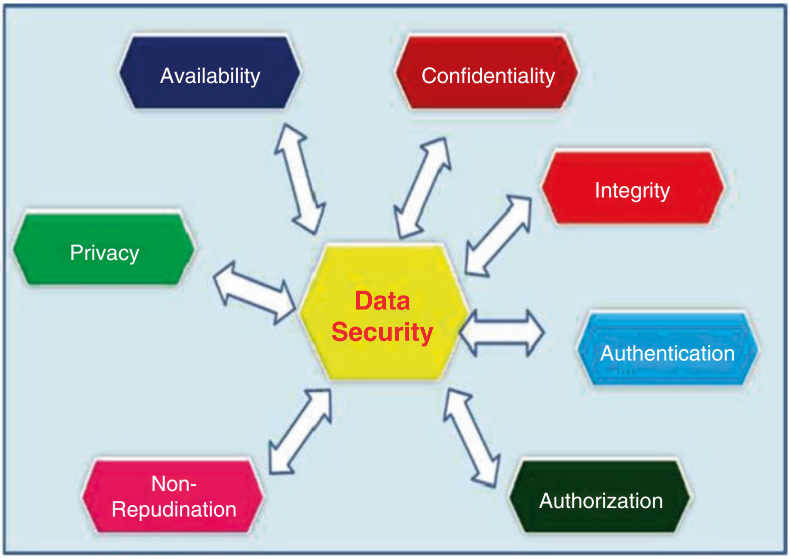

Fig. 11.7 Data security components in IoT

necessary to prepare a mechanism or an architecture that securely handles the scalability of tools in the IoT environment.

Authorization: Permitting any user or device to avail the information from the IoT environment is called authorization. Permission is delivered with the equipment or users' identity. Therefore, an efficient authorization mechanism is a need for the IoT environment, and tightening of identity verification is another challenge posed to the researchers.

Non-repudiation: The assurance that someone cannot deny anything. A node cannot dismiss its message or information sent to the other node or the user into the IoT environment. Data ownership has become a serious issue in the IoT environment.

Availability: By the highly distributed nature of the IoT environment, an explosive amount of data is available everywhere. Every device can generate data when they connect to the Internet and try to store it anywhere. Though power loss, failures, and denial of service (DOS) are part of information exchange, proper algorithm must be developed to ensure the availability of data and services in the IoT environment.

Privacy: A lot of earmarks information of a person can be composed without the person's awareness. Control of the dissemination of all such information is terrible in the current scenario. So, the IoT users need to manage their data and know who is handling their data and how and when they use it. In this section, let us see common challenges in complete IoT ecosystems. It has built a lot of applications and features, but a lack of basic security policies. Hackers can easily break the IoT devices, and upgrading these IoT devices has introduced new security flaws that hackers can easily exploit. Many manufacturing companies should consider security the topmost priority to mitigate this big issue, from planning to design until the deployment, implementation, management, and maintenance.

Here are the points some challenges of IoT devices that make them vulnerable to many threats.

- *Lack of Security and Privacy:* The IoT devices today, such as household devices, industrial devices, healthcare devices, automobiles, and so on, are connected to the Internet, and these devices contain important and confidential data. These devices lack even basic security and privacy policies so that the hackers can exploit this lack to carry out some malicious activity.
- *Vulnerable Web Interfaces*: Many IoT devices come with embedded web server technology that makes them weak attacks.
- *Legal, Regulatory, and Right Issues*: When interconnection of IoT devices, certain security issues are raised with no existing legal laws that address these issues.
- *Default, Weak, and Hardcoded Credentials:* One of the most common reasons for cyberattacks is its authentication system. These devices usually come with the default and weak credentials, which an attacker can easily exploit to gain unauthorized access.
- *Clear Text Protocols and Unnecessary Open Ports*: IoT devices lack encryption techniques during data transmission, making them use certain protocols that transmit data in the clear text besides having open ports.
- *Coding Errors (Buffer Overflow):* Most of the IoT devices today has embedded web services subjected to the same vulnerabilities commonly exploited on web service platforms. As a result, updating such functionality may rise to a buffer overflow, SQL injections in technology infrastructure.
- *Storage Issues:* IoT devices generally come with a smaller data storage capacity, but the data collected and transmitted by the apparatus is limitless.
- *Difficult to Update Firmware and OS:* Firmware is the fundamental component of operating a normal state for IoT devices. It is essential to update this system software periodically to counter the vulnerability. The device functionality may break device functionality.
- *Interoperability Standard Issues:* In the complete IoT ecosystem, interoperability is an issue for long-term growth. Especially the device manufacturer does not meet the requirement to integrate with multiple devices.
- *Physical Theft and Tampering*: Physical attacks on the IoT devices include tampering with IoT devices to inject malicious code to make the device physically fail state. In most scenarios, protecting these devices from physical tampering is the biggest challenge.
- *Lack of Vendor Support for Fixing Vulnerabilities*: Best practices to upgrade the firmware periodically to overcome certain weaknesses and protect them. Some vendors are hesitant to provide third-party access to the device for updating firmware.

11.6.1 IoT Security Problems

Security represents that any unknown or known person breaks the system intentionally. Security elements are categorized into three types, such as confidentiality, integrity, and availability. Table 11.2 demonstrates that the weakness of the IoT system has been mapped into IoT layers. When you deal hardware or software components, threats are entry points or blueprint to come and attack any infrastructure Threats can be categorized as in Table 11.3. Based on these categories, hacker plans to derive attack surfaces before entering to IoT infrastructure premises. It has various processes and techniques included before the hacker launches the attack against these targets IoT devices. Table 11.3 represents the threat vector mapped into various IoT system streams.

Attack surfaces [13] and techniques can be planned based on these categories, such as DDoS attacks [14], attacks on HVAC systems, rolling code attack, BlueBorne attack, and jamming attack. This threat category is applied to the IoT ecosystem into various layers based on the vulnerabilities. Most attacks happen in the IoT system based on the device vulnerabilities of the application layers. This section discusses top application-based weaknesses in the OWASP framework and tabled the obstacles in the IoT ecosystem.

11.7 IoT Vulnerabilities and Attack Surfaces

IoT systems can be exploited through potential vulnerabilities, resulting in a major problem for organizations. Most IoT devices come with security issues such as improper authentication methods or default credentials, missing encryption schemes, invalid key management systems, and inadequate physical security. Open web application security project often releases potential security issues in the system is categorized and released to the world for the reference. Table 11.3 discusses the vulnerabilities and obstacles.

IoT Attack Surfaces: OWASP top 10 vulnerability leads to what security issues and challenges occur in IoT devices. This top 10 vulnerability is constantly updated

Table 11.2 Weakness of IoT system layers

IoT layers	Description
Applications	Validation of the inputted strings, AuthN, AuthZ, no automatic security updates, default passwords
Network	Firewall, improper communication encryption, services, lack of automatic updates
Mobile	Insecure API, lack of communication channels, encryption, authentication, lack of storage security
Cloud	Improper authentication, no encryption for storage and communications, insecure web interface
IoT	Application + Network + Mobile + Cloud = IoT

Table 11.3 Security threat vector categories [12]

Threat category	Description
Spoofing	Threat action designed to unlawfully access and use another user's credentials such as username and password
Tampering	Threats aim to change/modify persistent data in the database maliciously and alter data in transit between two computers over an open network
Repudiation	Threat action intended to achieve illegal operations in a system that cannot trace the prohibited operations
Information disclosure	Threat activities to read data that one was not granted access to or read data in transit
Denial of service	Threat directed to reject access to valid users, such as by making a web server temporarily unavailable or unusable
Elevation of privilege	Risk sought to gain privileged access to resources for gaining unauthorized access to information

on the website. In this chapter, we can derive attack surfaces for IoT devices. Let us discuss the possible attack surfaces that occur based on OWASP.

Device Memory

1. *Clear-Text Credentials:* Most important components of the IoT ecosystem. Device memory is required to store important information about certain events. One of the most common mistakes is everyone stores clear-text credentials. Unencrypted credentials or clear-text credentials may lead to credentials and information leak from the device, mitigate these vulnerabilities, and keep the device and information security. The credentials are used to access some equipment. Communication between two endpoints should be established in an encrypted form not to be easily located to compromise or get unauthorized access to the platform.
2. *Third-Party Credentials:* Third-party application requires connectivity to perform a certain activity on the target IoT devices. When third-party apps initiate the connection request to the target devices, only limited functionality should be exempted from third-party applications. It is highly suggested to practice a strong encryption mechanism when the authentication process initiates.
3. *Encryption Keys:* When hackers tried to gain access to the target device. There is a high possibility to capture the encryption keys to gain unauthorized access to the target device. Ensure to have the proper key management system to protect the encryption keys from hackers. The best practice is that encryption keys should not be stored with the data that they decrypt.

Ecosystem Access Control

1. *Implicit Trust Between Components:* Enabling implicit trust between source and destination endpoints in the IoT ecosystem results in a malicious trusting element and leads to the items' malfunction. Best consideration is to mitigate this attack from the hacker: Before the interaction, each component required to

establish strong authentication is required. There should be a strong mechanism and procedures to ensure that trust cannot be abused in any situation.

2. *Device Enrolment Security:* Enrolling devices are an adequate phase of establishing IoT ecosystems. When enrolling the IoT device, the absence of certain restrictions or authentication mechanisms results in injecting malicious devices that can put entire network security at risk. Each device should be authenticated before the device enroll process starts.
3. *Decommissioning System:* Any single device may put into whole networks at risk in entire IoT ecosystems by compromising it. When the moment is identified, the compromise should be handled carefully by analyzing the problem and developing methods to counter it. Certain techniques should also be adopted to prepare the system if some unwanted situations arise, like clearing the data, resetting the device from the cloud, debugging, and decommissioning system.
4. *Lost Access Procedures:* Process and procedures to be defined precisely and clearly, lack of explaining it, each device and its access level may result in the situation known as the right escalation. The initial phase of onboarding the device procedures should be handled properly. Access to control list and network levels should be implemented to overcome these difficulties and decrease the security gaps. It may help us to improve control over the devices.

Device Physical Interfaces

1. *Firmware Extraction:* Firmware is the base component for any IoT device in the complete ecosystem. There may be hidden vulnerabilities in the system that can be exposed if the firmware allows access to the hacker. To avoid this, a strong recommendation to use the firmware in an encrypted form.
2. *User CLI:* Users can be categorized into normal and admin users. A normal user should not be permitted to access all parts of a device. If a normal user has administrative rights, the device is exposed to high-security risk. The preferred approach is to limit users' access to the core part of the invention, and certain changes in the tools should be allowed.
3. *Admin CLI:* Access to the administrative console, performing administrative tasks, or access to the data received by the device may be exposed to the outside world. It can be easily compromised. A recommended approach to these loopholes is that administrative rights should be limited for the devices, and live device debugging ports should be blocked.
4. *Privilege Escalation:* Physical access to the device configuration not being proper may result in elevated access to the system resource, usually not allowed for a user. It is easily exploited in the device functions. Proper design of firmware is required so users cannot access that part of the device, so hackers have less possibility of exploiting it.
5. *Reset to Insecure State:* Enabled physical access to the devices can reset the equipment's storage memory and unwanted or undesired state. The firmware needs to design by secure that access to resetting the device should be denied.
6. *Removal of Storage Media:* Access to the device physically leads in to access the storage media, which can expose firmware, data stored in the device, and the

credentials. Additional hardware security to be enabled or hardware encryption should be implemented to overcome these situations.

Device Web Interface

1. *SQL Injection:* It is the type of code injection where malicious code is injected into the application to extract and modify the database content. Recommend using the strategy against SQL injection, which includes prepared statements with parameterized queries rather than static or hardcoded queries.
2. *Cross-Site Request Forgery:* Cross-site scripting or XSS is a type of attack used in web applications where an attacker can vaccinate malicious code into the app to gain unauthorized access through the web application. These activities are monitored and all the inputs are validated before being processed by the system. The applications should be capable of discarding insecure or untrusted data coming from an unknown source.
3. *Username Enumeration:* Enumeration is the technique to gather information about the targeted user. The attacker tries to collect the user information based on the guessing or social engineering attack. If the hacker finds the valid usernames and password, it can gain access to their accounts. There are best practices to be followed that application should specify their usernames, and they should not be predictable. A CAPTCHA can also be avoided to the enumeration of user accounts to overcome this scenario.
4. *Weak Passwords:* Weak or easy to guess passwords can be brute forced by an attacker to access users' personal and confidential data. Recommendation insists the user set strong passwords having a combination of uppercase, lowercase, and alphanumeric characters. In many cases, also avoid using dictionary words as their password as they are easy to crack.
5. *Account Lockout:* It is a mechanism used to prevent the system from brute force password guessing attack. Missing of lockout mechanism can allow an attacker to brute force the password and gain access to the user accounts. Considerably, a proper lockout mechanism should be implemented, which locks out a report of individuals over 3–5 unsuccessful login attempts for a certain period.
6. *Known Default Credentials:* Every device has default credentials to set up the device. Suppose the default credentials are not changed. It can be easily cracked, and the machine goes into the compromised state. Users should change the credentials of any device they buy to prevent it from unauthorized access.

Device Firmware

1. *Hardcoded Credentials:* Most of the devices that the customer buys come with default credentials set by the manufacturer during the machine making process itself. End-users normally do not reset the default credentials that make them vulnerable to unauthorized access. Hackers can turn them into an automated program upon a successful attack. To mitigate the situation, as a first step, the user should change the default credentials.
2. *Sensitive Information/URL Disclosure:* Most of the time, information and sensitive or confidential data leaked via URLs may make the devices exposed to

attacks. Information transmitted through the URLs must be properly encrypted. The firmware should be designed so that the apparatus's information is in a strongly encrypted form.

3. *Encryption Keys:* Access to the encryption keys may lead to decryption and obtaining confidential data. An encryption key is used to decrypt the data in the cloud rather than directly from the device memory.
4. *Firmware Version Display and Last Update Date:* Sensitive information about the device such as credentials, control keys, and update information should not be visible publicly. It should be encrypted or should not be shared between devices. The preferred approach is to separate control keys and credentials. Always recommendation to use different security keys for different methods provides an additional level of security against threats.

Device Network Services

1. *Information Disclosure:* Information disclosure can happen in any form. The leak of sensitive or confidential data may make the devices exposed to attacks. The firmware should be designed to enable strong encryption, and the message should not be in plain text.
2. *Denial of Service:* The DoS attack may impact the services offered by the cloud. Recommendation to use the intrusion detection mechanism should be deployed to handle different denial of service attacks.
3. *UPnP:* Unwanted ports like universal plug and play (UPnP) are enabled by default in the devices, putting the device security at risk as it allows the malware to enter and destroy the device and the local network. Manufacturers should design the instruments that these types of vulnerable ports should, by default, become disabled.
4. *Vulnerable UDP Services:* Vulnerable UDP services can put the security of the system at high risk. Some unwanted or malicious files can be transferred using such services, which can even destroy the system and important data. The manufacturer should be designed to disable default ports such as user and admin CLI, injection and unencrypted services, and poorly implemented encryption.

Local Data Storage

1. *Unencrypted Data:* Clear text or unencrypted communication in the IoT ecosystem network results in data interception. Strong encryption mechanisms that encrypt data should be adopted. Security operation center engineering should be monitored continuously to avoid misuse.
2. *Data Encrypted with Discovered Keys:* Ransomware attacks where an attacker who has encrypted the data and has the keys can ask the ransom to decrypt the data. To mitigate this situation, update the service regularly and avoid opening emails from unknown sources since it might contain a malicious attachment.
3. *Lack of Data Integrity checks:* Weakest encryption mechanism may result in data interception and loss of important information. Security consideration for such an issue is to use strong encryption techniques like Transport Layer Security (TLS)

Cloud Web Interfaces

1. *Transport Encryption:* Transport encryption is an essential step toward device security, lacking and resulting in loss of important information, loss of privacy, and compromise of the device. Proper transport encryption techniques should be implemented to keep the data encrypted and protected when in transit.

   - SQL Injection
   - Cross-site Scripting and Cross-site Request Forgery
   - Username Enumeration and known default Credentials
   - Weak passwords and Account lockout
   - The insecure password recovery mechanism
   - Two-factor Authentication

Update Mechanism

1. *Update Sent Without Encryption:* Security update transferring mechanism to the endpoints, which opens the door for cyberattacks. It is recommended to test and enable strong encryption mechanisms to secure updates to the devices.
2. *Update Not Signed:* Security updates that are not signed from a trusted or reliable source might contain malicious files that can harm the device. Verify whether the updates to be installed are approved and are from a trusted source.
3. *Updated Verification:* The verification mechanism verifies the updates that are installed in the device. If this decision does not turn on, the system does not distinguish between malicious and genuine updates that can eventually harm the appliance. It is recommended to keep the update verification option disabled if some malicious update or update from an unknown source pops up.
4. *Malicious Update:* If the device update provides unauthorized access to attackers, using he/she can perform malicious activities utilizing the equipment. If the update is from a confidential source, if it is not, it should be discarded.
5. *Missing Update Mechanism:* Patching updates remove system vulnerabilities, and it prevents various attacks. An absent update mechanism can make the device or the system prone to multiple online and offline attacks.
6. *No Manual Update Mechanism:* Some updates are not automatically installed in the target system. The absence of a manual update mechanism can make your device vulnerable to certain attacks. Updates usually include various security patches to update the device software and remove all existing vulnerabilities. The device should be capable of manual update mechanism.

Third-Party Back-End APIs

1. *Unencrypted PII Sent:* User sending unencrypted personal identifiable information (PII) can identify a specific individual. It contains important information that can distinguish one person from another. If hackers access this information, they can carry out malicious activities like identifying, stealing, and accessing the device illegitimately. Always PII should be kept and sent in encrypted form.
2. *Device Information Leaked:* Lack of information storage security policies can lead to an information leak, the consequences of which could be the loss of sen-

sitive and confidential data that, in turn, could help the hackers get unauthorized access to the device. The firmware should incorporate certain security policies that keep personal as well as the device information protected.

3. *Location Leaked:* Leak of a device's site could result in physically accessing the device and the information possessed by it or compromising the device. The firmware should ensure that sensitive information such as location, identity, and device banner. It should be kept in an encrypted form to become inaccessible to the attacker through debugging or physical level.

Mobile Application

1. *Implicitly Trusted by Device or Cloud:* Trusting each device connected to the network or the cloud without doubts about it leads to high risks. The device connected to the system may be a fake or an infected one. As a result, the whole network gets infected. To overcome this, implementing trusted policies is a perfect step to counter this problem. Strategies should be analyzed (identity, location, not infected, etc.) before making the device trusted.
2. *Username Enumeration:* Some web applications have a security loophole where they expose the system's username. Exploiting this vulnerability, an attacker can guess and find out the username and then, using the brute force attack, can gain access. The best practice to overcome this issue is to design a system in which the application should stop responding or providing service to the user for a certain period.
3. *Account Lockout:* Unavailability of the account lockout mechanism after a certain period of inactivity on a system can result in unauthorized access to the device by hackers. Account lockout techniques should be combined in the device locks whether the user is out after a defined period. So, hackers cannot get unauthorized access and obtain important information.
4. *Known Default Credentials or Weak Passwords:* Having improper authentication mechanisms or known default usernames and passwords may increase credential leak, putting the device at risk. In the cloud's side, the authentication mechanism should be used rather than transferring credentials to the cloud every time. Best practices to use the token within a short period can automatically increase the security level.
5. *Insecure Data Storage:* Unsafe data storage can lead to leakage or exposure of sensitive or confidential data. Firmware design should be for the protection of data storage. Transport encryption, insecure password recovery mechanism, and two-factor authentication should be implemented to mitigate this situation.

Vendor Back-End API

1. *Inherent Trust of Cloud or Mobile Application:* Trusting each mobile application and simple cloud connectivity lead to high risks. A mobile device with malicious mobile apps that may be fake could result in the whole network being infected. It is highly recommended to implement the trust policies which is a perfect step to consider this problem. Policies should be reviewed and analyzed between cloud and mobile applications.

2. *Weak Authentication:* Entire security layers are completely dependent on the strength of the authentication mechanism and the credentials used. The soft authentication mechanism results in the device's security issues such as loss of privacy, unauthorized access, change of device settings, and infecting components of the invention. It is highly recommended to implement two-factor or multifactor authentication mechanisms that would increase the device security level.
3. *Weak Access Controls:* Lack of defining each device's proper implementation and access level may result in the right escalation situation. A mandatory access control mechanism should be implemented, which eventually reduces security gaps. It improves control over the devices.

Ecosystem Communications

1. *Health Checks:* Hackers can exploit vulnerabilities present in healthcare devices that can put a patient's life at risk. Vulnerable medical devices are also connected to many monitors and sensors, making them potential entry points to the larger network. To overcome this security loophole, the manufacturer should focus on tightening its security rather than improved functionality.
2. *Heartbeats:* Security flaws in the pacemaker or the features that make it accessible from a remote location can be exploited by the potential hacker, resulting in killing the patient.
3. *Ecosystem Commands:* If unable to verify the system's command, expose it to exploitation or attacks. System alteration commands required additional verification, whether it is coming from a legitimate source.
4. *De-Provisioning:* Devices are not in use, but connected to the Internet entry point for various attacks on the device and the network. Always unused devices are recommended to detach or terminate from the system.
5. *Pushing Updates:* Malicious updates from the attackers through document attachment in the email or compromised third parties can heavily impact the system security by installing unwanted or malicious files. IoT devices should discard all the unwelcome links and files from unknown resources.

Network Traffic

1. *LAN:* Lack of network segregation between IoT devices and cloud network results in connection interceptions, jamming signal attacks, the man-in-the-middle attacks, etc. Before the network deployment, network engineers should properly segregate and keep the hackers away from the network.
2. *LAN to the Internet:* Not having proper security infrastructure between LAN to Internet connectivity. Ensure that it has been secured and adequate security policies and practices are followed to enhance the networking security.
3. *Short-Range Devices:* Short-range devices like Bluetooth devices are vulnerable to various pass-through frequent attacks and difficulty in identifying the intruder. Good security design should be implemented that hardens device security.

Fig. 11.8 Threat modeling for IoT ecosystem

4. *Non-standard:* Non-standardized network traffic might contain malicious files that could harm network security and devices. Each network device should be standardized and checked before leaving or coming to the IoT network.

According to Top 10 OWASP [15], vulnerabilities derived common threat and attack trees [8], how an attacker can inject into the IoT ecosystem (Fig. 11.8).

11.8 Tools and Techniques

The above sections have described the top 10 vulnerabilities and possible attack vectors in each IoT layer, like network, application, cloud, storage, and IoT (Fig. 11.9). This section discusses the tools and techniques of the IoT system based on the attack surfaces. IoT devices have very few protection mechanisms against various emerging threats.

1. *DDoS attacks:* Distributed Denial of Service attack is a type of attack that has multiple infected systems tightly coupled into a single online system that makes the server useless, slow, and unavailable for a legitimate user for a short period. The attacker initiates the attack by exploiting the devices' vulnerabilities [8] and installing malicious software in their operating systems. Once an attacker device the target, the process begins the botnets or zombie agents to send a request to the target server. The objective is attacked with a large volume of requests from

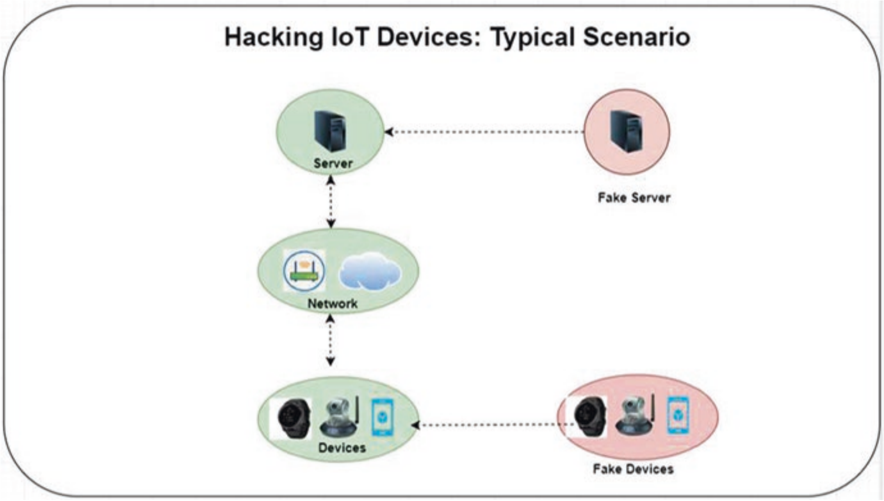

Fig. 11.9 Hacking IoT devices: typical scenario

multiple IoT devices from different locations. As a result, the target systems are flooded with many applications than they can handle. When the device is exhausted, it goes offline or suffers a loss in performance or shut down completely (Fig. 11.10).

The below steps are to be followed by an attacker to perform DDoS attacks.

- The attacker gains remote access to vulnerable devices.
- After gaining access, the attacker injects malware into the IoT devices to turn them into botnets.
- The attacker uses the command and control center to instruct botnets and send multiple requests to the target server resulting in a DDoS attack.
- The target server goes offline and becomes unavailable to process any further requests.

2. *Exploiting HVAC:* Many organizations use Internet-connected Heat Ventilation and Air Conditioning (HVAC) systems without implementing security mechanisms. It gives way for attackers to gain access to the gateway for hacking corporate systems. The HVAC system has many security vulnerabilities.

   The steps used by an attacker to exploit HVAC systems are as follows (Fig. 11.11):

- An attacker using Shodan and searches for vulnerable ICS systems [16].
- Based on the vulnerable ICS systems found, the attacker then tries for default user credentials using online tools.
- The attacker tries default user credentials to access the ICS system.
- After gaining access to the ICS system, the attacker tries to access the HVAC system through the ICS system remotely.
- After gaining access to the HVAC system, an attacker can control HVAC's temperature or carry out other attacks on the local network [17].

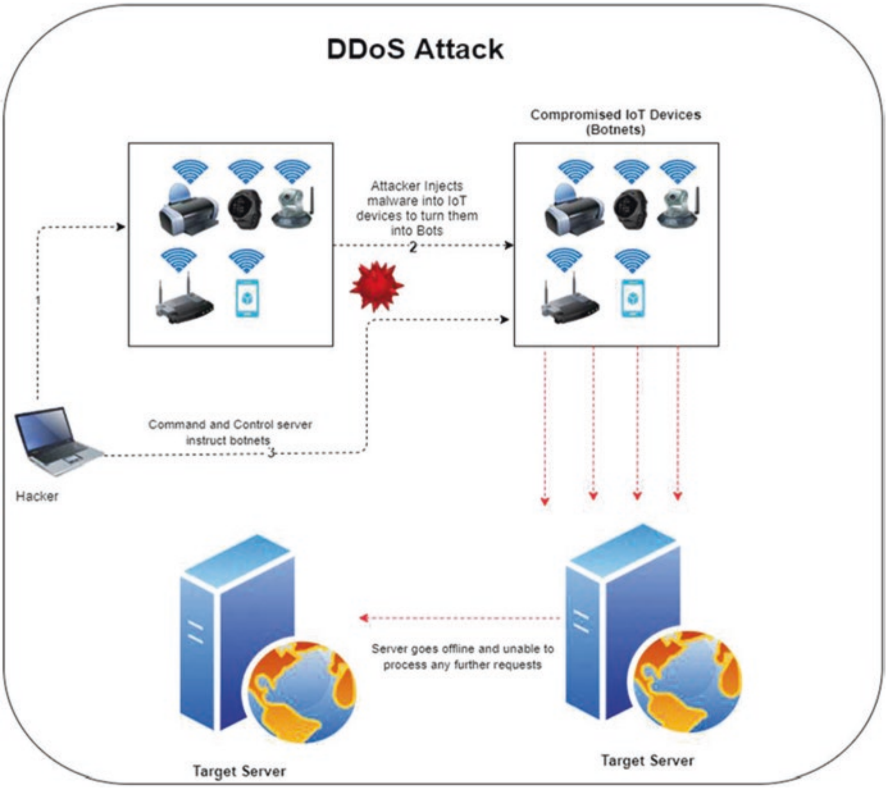

Fig 11.10 DDoS attack

3. *Rolling Code:* Modern trend is that every car comes with smart locking systems that include RF signals transmitted in code from a smart key fob that locks or unlock the vehicle. This code closes or opens a car, or a garage called a Rolling code or Hopping code. It is used in a keyless entry system to prevent replay attacks. An eavesdropper can capture the code transmitted and later use it to unlock the garage or the vehicle.

   The steps used by an attacker to perform a rolling code attack are as follows:

- The victim presses the car remote button and tries to unlock the car.
- An attacker uses a jammer that jams the car's reception of rolling code sent by the victim and simultaneously sniffs the first code.
- The car does not unlock; the victim tries again by sending a second code.
- The attacker sniffs the second code.
- On the second attempt by the victim, an attacker forwards the first code that unlocks the car.
- The recorded second code is used later by an attacker to open and steal the vehicle.
- Attackers can make use of tools such as rfcat-rolljam and RFCrack to perform this attack (Fig. 11.12).

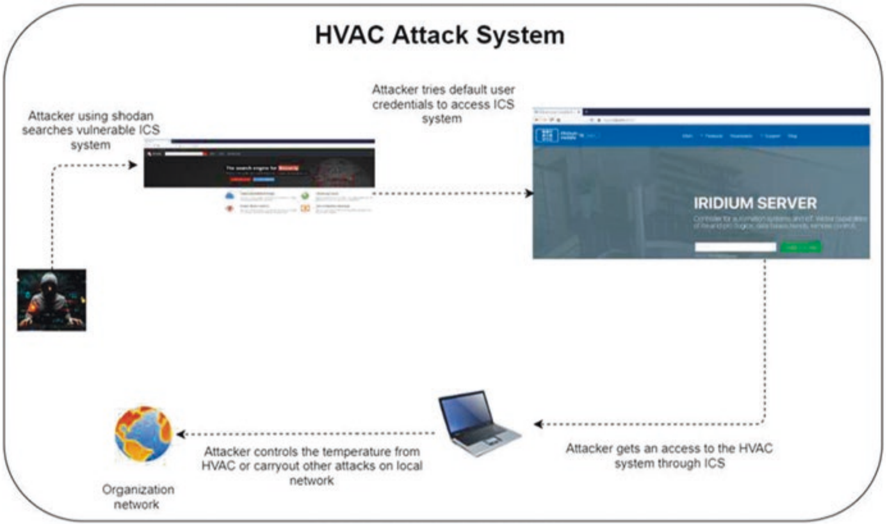

Fig. 11.11 HVAC attack system

4. *BlueBorne Attacks:* A BlueBorne attack is performed on Bluetooth connections to gain access and take full control of the target device. Attackers can connect to nearby devices and exploit the vulnerabilities of the Bluetooth protocol to compromise the devices. BlueBorne is a collection of various techniques based on the known weaknesses of the Bluetooth protocol. This attack can be performed on multiple IoT devices, including those running OS such as Android, Linux, Windows, and older versions of iOS. The Bluetooth process has higher privileges. After gaining access to one device, an attacker can penetrate any corporate network using that device to steal the organization's critical information and spread malware to the nearby devices. BlueBorne is compatible with all software versions and does not require any user interaction or precondition or configuration except that the Bluetooth being active.

   The steps used by an attacker to exploit BlueBorne attack are as follows:

- The attacker discovers the active Bluetooth-enabled devices around him/her. All the Bluetooth-enabled devices can be located even if they are not in discoverable mode.
- After locating any nearby device, the attacker obtains the MAC address of the invention.
- Now, the attacker sends continuous probes to the target device to determine the operating system.
- After identifying the OS, the attacker exploits the Bluetooth protocol's vulnerabilities to access the target device.
- The attacker can perform remote code execution or a man-in-the-middle attack and fully control it (Fig. 11.13).

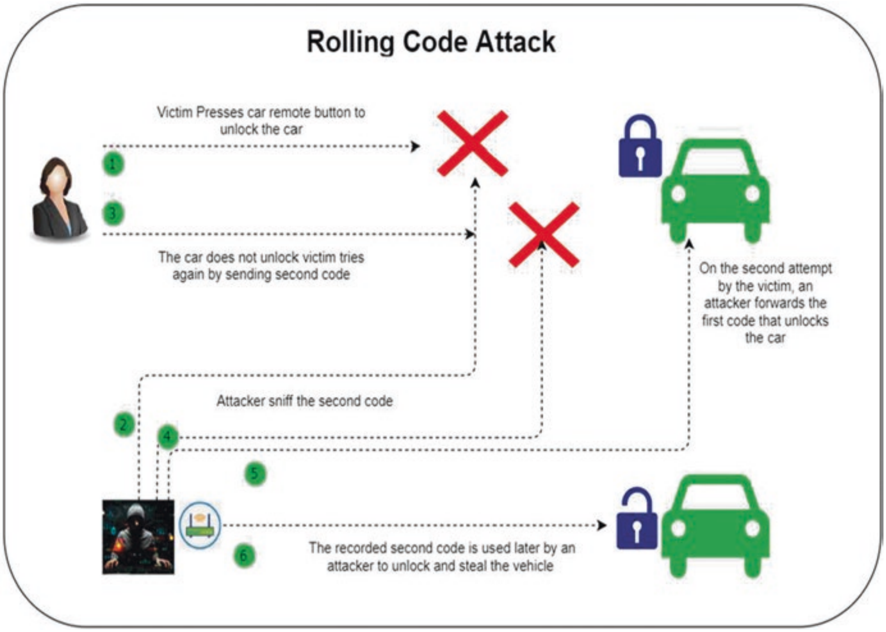

Fig. 11.12 Rolling code attack

5. *Jamming Attack:* Jamming is a type of attack in which the communication between wireless IoT devices is jammed to compromise it. During this attack, an overwhelming volume of malicious traffic is sent, which results in DOS attacks to authorized users; thus, obstructing legitimate traffic and making the endpoints unable to communicate with each other. Every wireless network is prone to this attack. Attackers use special types of hardware and transmit radio signals randomly with the same.
6. *Remote Access Using Backdoor:* Attackers gather basic information about the target organization using various social engineering techniques. After obtaining information, such as email IDs of the employees, an attacker sends phishing emails to the employees with a malicious attachment. In such type of attack, after gaining access to the private network, an attacker can access SCADA (supervisory control and Data acquisition network) that controls the grid. After gaining access to the system, the attacker replaces the legitimate firmware with a malicious firmware to process the attacker's commands. Finally, the attacker can disable the power supply to any place by sending malicious commands to the SCADA's substation control systems.
7. *Sybil Attack:* Vehicular communication plays an important role in safe transportation by exchanging safety messages, but even the VANETs are not safe from the attackers to reach. An attacker uses multiple, forged identities, nodes, and networks.

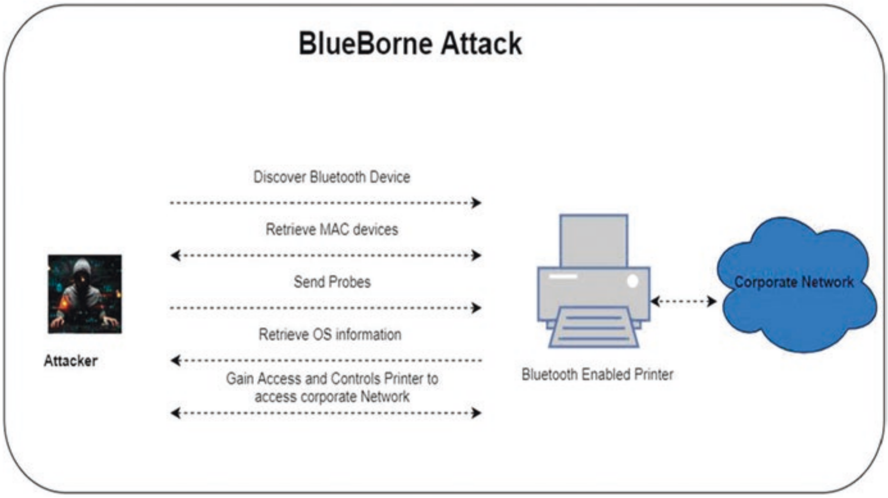

Fig. 11.13 BlueBorne attack

8. *Exploit Kits:* Exploit Kit is a malicious script used by the attackers to exploit poorly patched vulnerabilities in an IoT device. These kits are designed so that new ways of exploitation and add-on functions to be added to the device automatically whenever there are new vulnerabilities.
9. *Man-in-the-Middle Attacks:* In man-in-the-middle attack, the attacker pretends to be a legitimate sender, intercepts all the communication between the sender and receiver, and hijacks the conversation. Any malicious user can pose a valid sender and send a malicious request to the device to control the invention.
10. *Replay attacks:* In the replay attack, attackers intercept legitimate messages from persuasive communication and continuously send the intercepted note to the target device to perform a denial of service attack or delay it. They manipulate the news or crash the target device.
11. *Forged Malicious attacks:* Adversary replaces an authentic IoT device with malicious devices once successful physical access to the network. It is hard to discover such kinds of attacks because the forged instrument resembles the legitimate one.
12. *Side-Channel Attack:* Attackers perform side-channel attacks by extracting information about the encryption key by observing the emission signals, i.e., “side channels” from IoT devices. All devices emit these signals that provide information about the internal computing process either by power consumption. Attackers carefully observe the side-channel emissions to acquire knowledge about the varying power consumption to access and duplicate encryption key non-evasive.
13. *Ransomware Attack:* Ransomware is a thread that uses encryption to block users’ access to its device by locking the screen or closing users’ files. It stays stuck until a ransom is paid that allow a user again to access his/her device.

11.8.1 Defend IoT Security Issues

To protect the IoT ecosystem requires management systems to monitor end-device activities in various stages such as authentication, authorization, device onboarding and offboarding, network monitoring, and intrusion detection system monitoring. These multiple layers should collect the report in a centralized place to co-relate the events in case of an incident and proactive monitoring systems. When an IoT device is implemented, the tools should start reporting with the legitimate data, and connectivity monitoring must be enabled as per the standard [18] (Fig. 11.14).

The diagram illustrates how typical enterprises should consider implementing security monitoring systems to defend themselves from exploitation and attack. System surveillance is important. When IoT systems are performed, resources should be planned to handle security monitoring and mitigation of threats [19].

Real-Time Event Correlation

- *More Sources:* Real-time relationship and analysis with support for logs and user identities, as well as network flows, vulnerabilities, asset profiles, and device configurations
- *More Intelligence:* Sophisticated threat analytics and compliance automation, including analytics of network activity data (using deep packet inspection) for enhanced visibility and insight.
- *Highly Scalable:* Hundreds of thousands of events per second, fully correlated and stored in real-time.
- *Improved Ease of Use*: Common reporting, searching, and unified administration across products and appliances—integrated, no-hassle, high availability.
- *Rapid Time to Value:* Deployment options ranging from all-in-one appliance to highly distributed deployments with multiple devices spanning geographies.
- *Logfile Integrity:* Using hashing to ensure log data has not been tampered with.

Identity and access management: password vaulting

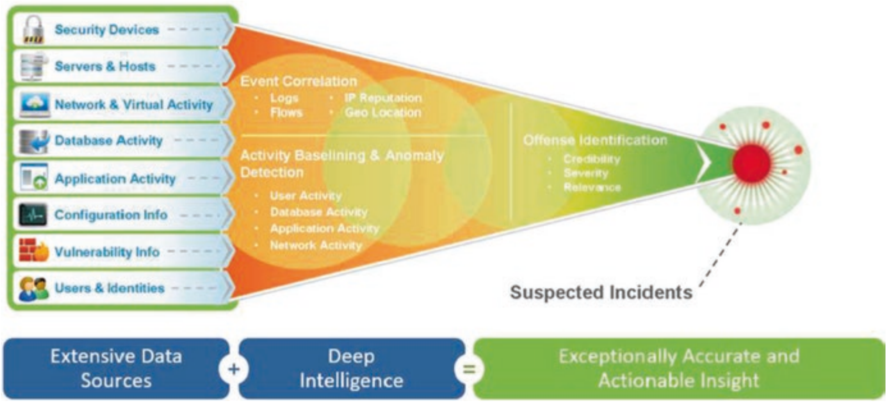

Fig. 11.14 IoT Aggregated IoT ecosystem

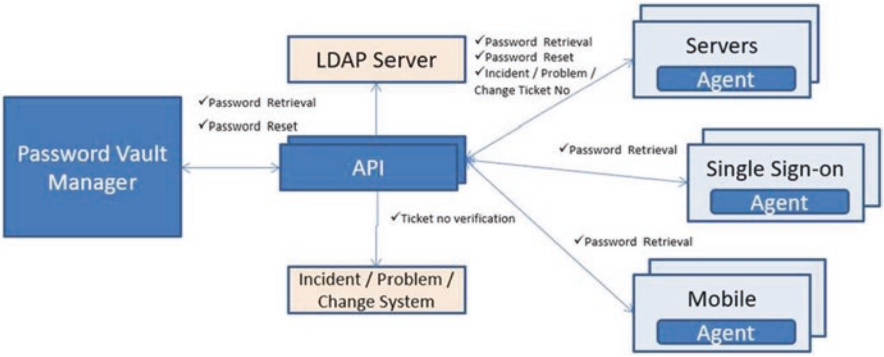

Fig. 11.15 Identity and authentication systems in IoT [20]

- Password Vault centralizes the organization's privileged user IDs and passwords into one secure repository (Fig. 11.15).
- The servers' agent collects the valid ticket no and verifies with the IPC system via API interface, and releases the password online to manage it.
- API-based integration helps validate the given ticket number with the IPC system, retrieve the vault's password, and release it to the server agent.
- The same approach can be used in single sign-on and mobile applications to get the password from the vault for the privileged user ID access.
- This solution helps to govern all the privileged user access.
- 2FA authentication can be achieved by using a token-based, password generation + user password. The agent on the endpoint validates the password of 1FA, and its 2FA password can be verified on the back-end token manager. In this section, the picture represents how strong the authentication mechanism must be implemented in the IoT ecosystem. Furthermore, the steps to be carried out to defend the IoT system (Fig. 11.16).

Disable "guest" and "demo" user accounts when activated. Use the "Lockout" feature to lockout accounts for excessive invalid login attempts and implement a strong authentication system. It is recommended to facilitate and implement a strong authentication system with 2FA enabled and highly encouraged to disable default ports vulnerable services. Remediate the Vulnerabilities and update the device firmware regularly. Maintain data confidentiality using symmetric key encryption.

When designing the IoT devices, security issues should be properly considered; most consideration is developing a secure IoT framework for building the machine. The default framework should provide security by design, ensure each stage of the application development, and validate it. Edge is the main physical device in the IoT system, which interacts with its surroundings and contains various components such as sensors, actuators, operating systems, hardware, and network communication capabilities. Edge devices must configure properly encrypted SSL communication and storage encryption, no default credentials, strong passwords, and use the

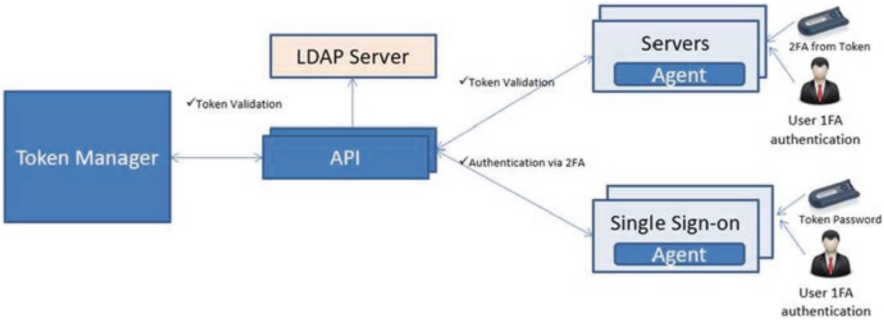

Fig. 11.16 Secure two-factor authentication system

latest up-to-date components. Another layer gateway acts as the first step for an edge into the Internet world as it connects the smart devices to the cloud components. It is often referred to as a communication aggregator that allows communication with secure and trusted local networks and a secure connection with an untrusted public network. A gateway must incorporate strong encryption techniques for the secure transmission of endpoints. The authentication mechanism for the edge components should be as strong as any other component. When designing the gateway system in the IoT ecosystem, it is confirmed that it authenticates multidirectional to carry out trusted communication between the edge and the cloud. The IoT ecosystem's cloud platform is referred to as the main central aggregation and data management point. Access point to the cloud platform should be restricted. Often hackers try to hack the cloud systems rather than endpoint devices. Cloud platforms should include encrypted communication, strong authentication, secure web interfaces, encrypted storage, and automatic updates of tools.

11.9 Conclusion

This chapter discussed detailed IoT architecture, communication models, and various operating system flavors, and it is useful based on the industry perspective. The details of attack vectors and surface techniques in the IoT ecosystem have been discussed. Various attack techniques have been discussed in this chapter, and various proposed IoT security approaches capable of authentication, availability, encryption, and integrity for secure communication have been dealt. This chapter has focused on the review of emerging security approaches of IoT. IoT devices have power constraints and limited processing capabilities; hence, IoT devices are highly prone to security attacks like DoS and DDoS. Secure communication and authentication are essential requirements for IoT models. Security attacks like DoS and DDoS have been mitigated through the models mentioned above and also improved IoT secure communication. Authentication and confidentiality are two important parameters to be addressed in the IoT security approaches. Researchers should concentrate more on security services like authentication, confidentiality, and integrity and propose lightweight mechanisms to address the IoT environment's security challenges.

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