Discover Internet of Things

Discover

Review

Use of Internet of Things in the context of execution of smart city applications: a review

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Received: 5 May 2023 / Accepted: 21 August 2023
Published online: 31 August 2023

Abstract
The Internet of Things (IoT) is rapidly becoming one of the most talked-about and essential components of any digitization process. The IoT is comprised of several key necessary components, the most important of which are sensors, communication (the internet), and user interfaces for data processing. IoTs are currently finding applications in virtually every industry, including healthcare, where they are known as the internet of medical things (IoMT), industry, where they are known as the industrial internet of things (IIoT), and interconnection between people, where they are known as the internet of everything (IoE). The challenge is to leverage the Internet of Things (IoT), technology, and data to create smarter and more sustainable cities that enhance the quality of life for residents. Therefore, in this article; we have demonstrated the use of the IoT in a variety of applications for smart communities. These applications include smart transportation, smart water management, smart garbage management, smart house illumination, smart parking, smart infrastructure, etc. This research also includes an explanation of the flow process of implementing the IoT in different applications of smart communities, as well as their characteristics and particular applications. Along with their flow illustration, the stages involved in the implementation of smart city applications and the components they consist of are also displayed here. We have also taken into consideration the instances of particular cases and their implementation utilizing IoT. Some of these cases include the automated water collection methods of smart water management systems as well as the condition of the water. Based on the findings of the research, we came to the conclusion that IoT devices play an essential role in each and every one of the smart city project implementations.

Keywords Smart city · Smart technology · Internet of things · Smart water management · Smart routing · Smart grid technology · Smart Electricity Meters · Smart home lighting · Smart parking · Smart waste management

1 Introduction

The concept of "smart cities" is one that is experiencing explosive growth right now and is expected to have a significant influence on people all over the globe, particularly those who live in metropolitan areas. Because of its term, one might assume that it encompasses all things clever, such as "smart houses," "smart roads," "smart industry," "smart hospitals and schools and colleges," "smart financial systems and payment platforms," "smart waterways," and many other forms of "smart" technology [1]. Adding intelligence to anything could potentially have both positive and detrimental repercussions. The term "smart technology" refers to the process of automating an entire system based on certain parameters

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[2]. For instance, the lights in a smart home will turn on and off automatically in response to the presence or absence of a person, and it will sound an alarm or make a phone call in the event of any unauthorized access. If we go back in time approximately fifty years, we will find that almost everything in India was done by hand, including the financial system, the educational system, the transportation system, and virtually everything else. There was no way to communicate wirelessly, the trains ran on coal, and people cooked their meals on coal stoves or homemade stoves that used wood and embers. These stoves were referred to as "chulhas." The exponential expansion of the automation industry was kicked off by the gradual adoption of semiconductors as a standard substance, which occurred as time went on. By the end of the year 2022, India will be ranked first in the world in terms of the total number of digital financial transactions, which is expected to be approximately 70 million transactions(Mahua [3]. India's real-time digital transactions reached 48 billion in 2021, which was nearly three times as much as its nearest competitor China's (18 billion) and 6.5 times as much as the total real-time digital transactions of the United States of America, Canada, the United Kingdom, France, and Germany combined[4]. In addition, on April 11, 2016, the "Unified Payments Interface," also known as UPI (which refers for "Unified Payments Interface"), was made available to the public. UPI stands for Unified Payments Interface, and it is a real-time immediate payment method that was established by the National Payments Corporation of India (NPCI). It is almost completely accountable for the operation of digital payment systems. This illustration demonstrates how India has significantly stepped up its mechanization efforts in the realm of digital payment systems.

The IoT plays a significant part in many of the smart city applications that have been developed. The internet of things incorporates a wide variety of sensors that are employed for the purpose of data collection [5]. These sensors include, but are not limited to, temperature sensors, humidity sensors, light sensors, and a great many others. Additionally, the IoT incorporates cloud storage that is utilized to save the information that has been gathered. Because it is impossible to make anything intelligent without a sensor, having sensors that are accurate and efficient plays an essential role in the process of automating things [6]. By decreasing reliance on conventional energy sources, smart cities can also play a significant part in promoting environmentally friendly practices that save energy and help preserve the planet's natural resources [7]. It is possible that the introduction of electronic vehicles will result in a reduction in the use of more conventional sources of energy, such as gasoline, diesel, and liquefied hydrocarbon vapors (LPG). In a similar vein, the idea of a smart city is not without its share of drawbacks, including the fact that every device relies on electricity and therefore uses a significant amount of the resource, that a greater quantity of internet will be required, that the demand for cloud storage will also increase, and that an increased number of electronic devices, such as robots, drones, intelligent vehicles, and a great deal more, will be introduced [8]. There are variety of smart city applications which uses IoT devices, in this work we have utilized some of them which is presented in Fig. 1.

1.1 Related works

Over the course of the last decade, a great number of studies have been conducted on smart cities, each of which has involved a substantial amount of labor and the application of a unique set of methodologies.

Hameed et al. [9] have proposed an IoT based traffic classification using deep learning models for smart city. To demonstrate their proposed work they first extracted the features performed such as device and packet level features, flow based features to describing the IoT for smart environment. In second stage, authors have applied preprocessing techniques based on weighting algorithm, and in third step the feature selection method was applied to provide the precise feature to the proposed model. At last, the multi-classification using two stage deep learning algorithm was applied to categorize the IoT devices in two distinct datasets. Their proposed model achieves 99.9% of accuracy on the first dataset and 899.8% of accuracy on 2nd dataset for classifying the IoT devices in smart city environment [10]. have presented the IoT use cases for analysis and evaluation of smart city using analytic network process (ANP). IoT are the main backbone of the smart city, so the ANP have been presented in this work to study the use cases of smart cities. Based on data and experimental outcomes using proposed ANP method, it can be said that proposed approach is effective for analyzing and evaluating the uses case of smart cities [11]. have developed the prototypes models for the various applications of smart cities using basic circuitry such as Arduino, Bread board and various sensors. In this work authors have implemented prototype modes for Smart Waste Management, Smart Gardening System, Automatic Fire Detection System, Automatic Air Pollution Monitoring, Automatic Accident Prevention System, Smart Parking System, and Smart Street Lighting system.

Klaina et al. [12] presented analysis of electric vehicle (EV) and communication between them using "Long Range Wide Area Network" (LoRaWAN) in vehicle to grid (V2G). The authors have used real time urban scenario for the measurement of wireless channel charging stations of EVs in Spain (Pamplona) using LoRaWAN. The experimental result shows that the wireless channel optimized the network designing of the LoRaWAN network in V2G services [13]. investigated the

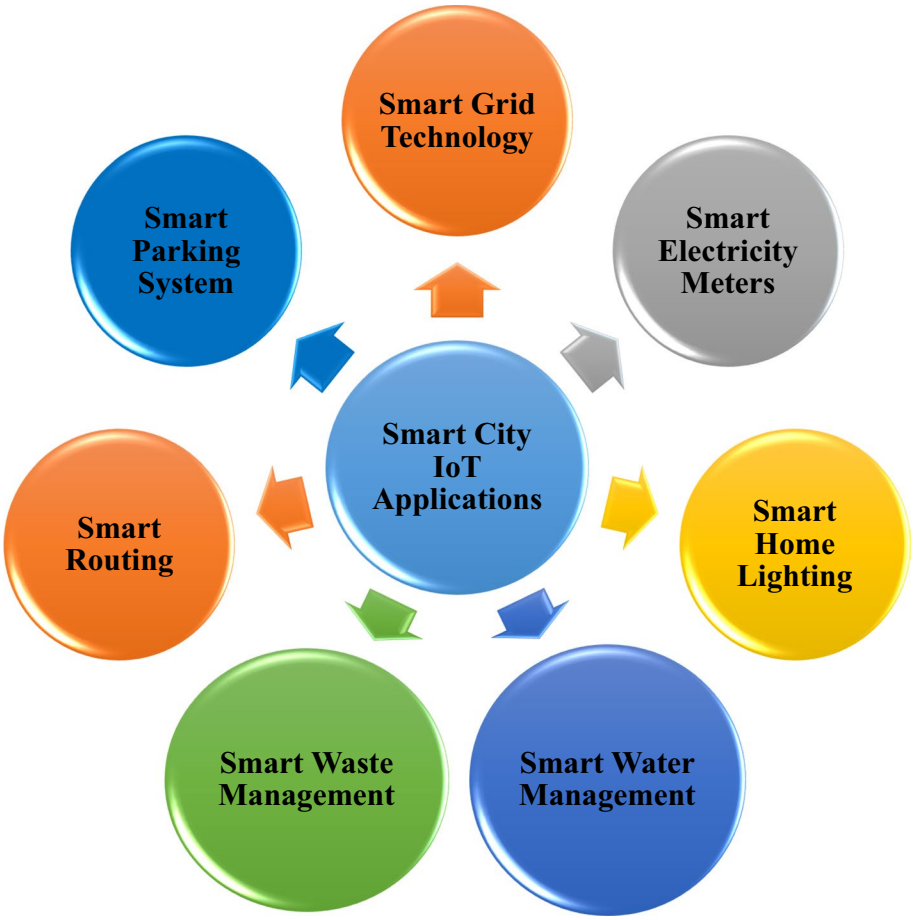

Fig. 1 The flow architecture of IoT applications of smart city

impact of global positioning system (GPS) signal on the power consumption which shows the relation between strength of GPS signal and energy consumption of mobile applications. Smart cities should have the greener and smarter mobile phones which should less affect the environment. In this work authors have performed the experimentation to derive a mathematical model which measures the power consumption of mobile application in terms of signal to noise ratio (SNR). The result shows that the higher the SNR values lesser the energy consumption also the GPS signal reduces more battery power approximately 38% as compared to 13% [14]. have studied the smart and intelligent routing system in smart city using IoT for smart routing system. Tthe Wireless sensor networks (WSN) have been utilized and the due to WSN the energy consumption have been analyzing while communication with each other, works on battery in order to communicate with each other. For smart city project the various types of energy consumptions networks which is used in smart routing system and how it can be minimized is studied in this work [15]. have presented the best routes recommendation for smart waste management system using IoT. Artificial Intelligence based technique is utilized for throughout analysis and compare their corresponding outcomes. The intelligent route recommendation using AI approach is based on a multi-level decision-making approach in which the coordinates (locations) and status of the dustbins in smart waste management system is considered. The smart routing for trash vehicle is modeled using two different scenarios where the authors have used continuous and discrete optimization technique. The results of both the methods were compared and also validated its effectiveness using case study.

Rahman et al. [16] have formulated the case study for chain of retail stores in Dhaka, Bangladesh. In this research, the scheduling of orders are divided into two regions, these orders are brought from various stores and grouped together. The shortest path algorithm is designed using Dijkstra algorithm through smart route optimizer from android application. Authors have obtained the improved result in terms of reduced travel distance for both the regions by 8.1% and 12.2% and similarly obtained reduced time by 20.2% and 15%, respectively. Hence a mobile based application was designed in this research to enhance the order distribution which can be utilized for smart vehicle routing system in real time traffic [17]. have proposed the use of IoT for the adoption and monitoring of smart city applications mainly traffic management system. The authors have developed the new and effective technology for monitoring the possible

losses and smart traffic management system using IoT for innovating the smart city in fast and effective way with the help of integrated, digitalized and software approach [18]. proposed the smart solid waste management system and monitoring the dustbin using IoT devices. The problem arises of the distribution of solid waste in smart city is solved using this approach. The collection and distribution of solid waste and also proper monitoring of dustbin utilized by Municipal Corporation is addressed using IoT devices. Authors have presented the effective and eeficient technique for the collection of solid waste, predicting the generation of solid waste and also the detection of fire in waste materials. The IoT-based device performs the controlling and monitoring of the electric bins. These devices are wirelessly connected with the central hub to transmit the information about the bins filling level with the existing location. The significant advantage of the system is to collect waste material on time in order to avoid the overflow of bins that would help in saving the environment from pollution.

Barcik et al. [19] presented the security issues and its future possibilities in developing the smart city especially digitization. The Future Possibilities and Security Challenges of various smart city project have been discussed and also the framework utilized for data processing from different sources have been presented. The uses of military in cotext of smart city project for the safety and security of the public have been discussed in this paper. The authors have also presented the various examples of consumption of lighting for public uses and air quality dataset availability [20]. presented the direction of evolution toward sustainable Smart Cities using smart city diagnosis plans. In this work, the diagnosis parameter and evaluation parameters have been derived in aspects of indicators of the sustainable smart city. Authors have used cities such as Incheon, Gyeonggi-do, Goyang-si from the republic of korea for their case study [21]. proposes the internet of medical things (IoMT) Based autoimmune diseases diagnosis using Artificial Intelligence based multistage classification scheme (MSCS) for smart sustainable city. In this appears authors have utilized MSCS technique for the classification and detection of the autoantibodies which uses antinuclear antibody (ANA). The artificial neural network (ANN) provides better detection and classification result as compared to Support Vector machine (SVM) classifier using 24 features.

Chopade et al. [22] discussed the shift in the healthcare system towards a distributed, patient-centric approach due to the Internet of Things (IoT). The review focused on IoT-enabled intelligent health monitoring systems by analyzing papers reported between 2016 and 2023. The review concentrated on sensors and smart devices used in IoT-based health monitoring systems, highlighting their merits and demerits [23]. introduced the VitalSense model, which provided a hierarchical multi-tier remote health monitoring architecture in smart cities by combining edge, fog, and cloud computing. The article explored adaptive data compression and homomorphic encryption at the edge, a multi-tier notification mechanism, low latency health traceability with data sharding, a Serverless execution engine to support multiple fog layers, and an offloading mechanism based on service and person computing priorities [24]. discusses the important role that new technologies and the Internet of Things (IoT) play in the design, construction, and maintenance of Smart Cities. The article highlights the need for a broad discussion on the characteristics, use, applications, and challenges of IoT and Smart Cities. The main contribution of the article is a systematic assessment and synthesis of the critical applications and challenges of IoT in the development of Smart Cities [25]. proposed a smart water meter prototype that used narrowband internet of things technology for automatic metering readings. The authors introduced a flexible power management design that enabled the use of an energy harvester to recover energy from the surrounding environment and charge the internal battery. The integration of energy harvesting technologies in commercial SWM applications was found to be feasible and could create business advantages by reducing the size and capacity of internal batteries, reducing operation costs, and mitigating long-term ecological problems associated with battery use and disposal.

Through an extensive review of various research studies, it is evident that significant attention has been given to the concept of smart cities and the integration of Internet of Things (IoT) technologies. However, despite the progress made, there is still ample scope for further advancements in this field. In light of this, the present study aims to contribute to the existing knowledge by investigating the role of IoT in the implementation of smart cities.

Specifically, we focus on exploring and analyzing the application of IoT in key areas of smart city development. These areas include Smart Grid, which involves the integration of advanced technologies to enhance the efficiency and reliability of electricity distribution. Smart Electricity Meters are another important aspect, enabling real-time monitoring and control of energy consumption in households and businesses. Moreover, we delve into the implementation of IoT in Smart Lighting systems, which optimize energy usage by dynamically adjusting lighting levels based on occupancy and natural lighting conditions. Smart water management solutions are examined, involving IoT-enabled sensors and networks to monitor and conserve water resources efficiently. Additionally, we explore the application of IoT in smart waste management, where connected devices and data analytics enable optimized waste collection and recycling processes. Lastly, we investigate the utilization of IoT in smart parking systems, which leverage real-time data and automated processes to enhance parking availability and reduce congestion.

By examining these specific instances of IoT implementation in smart cities, we aim to identify gaps and potential areas for improvement. This research provides valuable insights into the current state of IoT-enabled smart city technologies and offers recommendations for future enhancements and advancements. Ultimately, our study contributes to the ongoing efforts towards creating more sustainable, efficient, and livable urban environments through the effective utilization of IoT in smart city applications.

2 Smart grid technology

A smart grid is an advanced electricity network that integrates digital technologies to efficiently manage electricity generation, transmission, and consumption. IoT helps us create or handle a connection between the smart sensors, devices control, or with a network that gives the greatest control or helps to make a smart control using an IoT device [26]. The concept of the "Smart City" continues to be recognized as one of the IoT's implementations with the most potential and public visibility [27]. The concept of "smart cities" has gained momentum with the advancement of technologies, enabling cities to be efficiently managed using IoT and various devices for enhanced urban management [10]. IoT technology plays a vital role in establishing smart cities by enabling intelligent management through the use of information and communication technologies. It facilitates the creation of a network that enhances control and enables real-time data analysis for improved decision-making and cost reduction [11]. These technologies also allow for the creation of new systems. The use of the IoT in smart cities significantly reduces the amount of effort that humans put into controlling and monitoring the system. It is necessary for urban neighborhoods to become more shrewd, more compact, and more connected [28]. The IoT is playing a crucial role in the development of highly populated cities worldwide by enabling autonomous system monitoring and operation. Smart cities are built on information and communication technologies to improve the quality of life while reducing costs. Key applications include smart networks, roadways, lighting, public transport, safety, environmental surveillance, parking, and waste management. The concept of a smart city aims to address the challenges posed by urban expansion by implementing smart designs for transportation, parks, residences, and healthcare. The infrastructure of a smart city operates as a network, ensuring the privacy and security of citizens' personal information. The IoT has the potential to make communities more advanced, enhancing energy efficiency, reducing traffic congestion, improving public transportation, monitoring air quality, enhancing public safety, and elevating the overall quality of life in smart cities [29].

Device that monitors, controls, and optimizes the movement of electricity throughout a metropolis by utilizing various instruments and communication technologies. The quantity of energy that is lost due to inefficiency can be decreased by utilizing smart networks. A "smart grid" is an electrical network that incorporates intelligent digital communication technology into an existing electrical network. This type of network is commonly referred to by its acronym, "smart grid." A smart grid is able to obtain its supply of electricity from a wide variety of decentralized sources, such as solar arrays, wind generators, and potentially even plug-in hybrid electric vehicles [30]. The smart grid is also an main components of smart city, the various application of smart grid technology is shown in Fig. 2.

2.1 Apparatuses of smart grid technologies

In order to accomplish a more contemporary and sophisticated infrastructure, it will be necessary to develop and implement a broad variety of different technologies. These technological solutions are typically sold in packages together. Many different types of technology are available for Intelligent Home Appliances Intelligent home appliances are able to determine when they should use energy based on the preferences that the user has previously set [31]. This has the potential to lower high demands, which in turn can lower expenses associated with electricity production. For instance, sophisticated devices, such as the temperature sensor utilized in heat stations for the purpose of controlling the temperature of the furnace in accordance with a set of predetermined temperature levels [32].

2.2 Benefits of smart grid technology

2.2.1 Enhancing electricity reliability

Smart meters improve electricity reliability by enabling utility companies like PG&E to quickly detect and resolve service disruptions, eliminating the need for physical visits and minimizing inconveniences for customers [20].

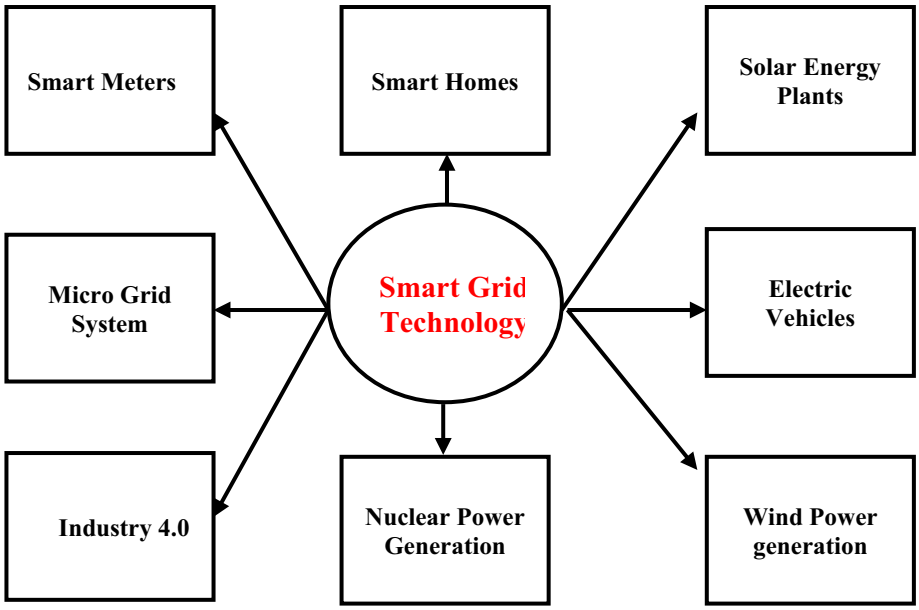

Fig. 2 Applications of smart grid technology

2.2.2 Improving sustainable power generation efficiency

Installing smart meters is a crucial step in building a smart infrastructure. Smart meters enable quick detection and resolution of service disruptions, reducing the need for physical visits. Our goal is to provide efficient solutions to customer issues without the need for on-site visits [32].

2.2.3 Diversifying energy sources

PG&E utilizes an energy blend consisting of eco-friendly sources like solar, wind, hydro, geothermal, and biofuels. Over half of the electricity supplied in our coverage region comes from carbon-free sources, reducing our ecological impact. With a diverse energy portfolio, PG&E aims to be a leader in environmental preservation within the American energy industry [33].

2.2.4 Home automation and smart technology

The installation of Smart Meters is the initial step in establishing a connected energy grid. PG&E envisions the next phase to involve connected homes and smart devices, forming a wireless network within the house (HAN). This network enables programmable management of energy consumption and real-time data exchange between smart devices. The goal is to leverage internet connectivity to enhance control over energy usage, enabling better optimization and responsiveness to changes in the power grid.

2.2.5 Reducing carbon dioxide emissions

Electricity is the type of energy that is the least complicated to control. Unfortunately, the generation of carbon dioxide is the primary contributor to the planet's greenhouse gas pollution. Because of the Smart Grid, we have the capability of substantially reducing our pollution of carbon. Our dependence on nonrenewable energy sources, such as natural fuels, is one of the primary goals of the Smart Grid's comprehensive design [34].

2.2.6 Promoting electrified transportation infrastructure

In India, the adoption of electric cars remains robust, contributing to reduced reliance on fossil fuels and lower atmospheric pollution. To meet the increasing demand for electric vehicles, a more advanced infrastructure is required. PG&E is actively involved in research and development of innovative charging technologies, aiming to establish guidelines and

standards. Collaboration with manufacturers, dealerships, customers, and domestic/international organizations ensures uniform communication and charging standards for all electric vehicles [35].

2.3 Smart grid characteristics and functions

- The primary capabilities required to perform real-time monitoring of a smart infrastructure.
- Also helps automate administration, which results in a quicker recovery time.
- In order to be utilized in dynamic pricing strategies.
- Additionally, it should be utilized in the management of a battery.
- To carry out with the help of web platforms and smartphone applications.

2.4 Various applications of the smart infrastructure

- Reaction to Customer Requests for Sophisticated Metering Infrastructure
- Electrically propelled automobiles and trucks (EVs).
- Maintaining Environmental Knowledge Across a Large Region
- Transportation Grid Administration for Distributed Energy Resources and storing

3 Smart Electricity Meters (SEM)

Smart Electricity Meters (SEM) facilitate for two-way information exchange between power suppliers and end users. This makes it possible for accounting intelligence gathering to be automatic, for device malfunctions to be recognized, and for maintenance personnel to be dispatched to the precise location much more quickly. Smarter distribution systems are distribution lines that can observe and regulate both non-critical and essential management information, such as the status of the power, the power factor performance, the circuit, the security, and the status of the transformer, amongst other things [36]. To ensure the distribution of energy in a manner that is both secure and dependable, voltage must be transformed multiple times across a wide geographic area by means of substations. In order to control the movement of electricity in a number of different directions, intelligent substations are necessary [37]. To carry out their functions, substations need to be outfitted with a variety of massive and pricey pieces of machinery, including transformers, switches, capacitor banks, circuit breakers, and network protected relays, amongst other things[16]. The incorporation of integrated communications into smart grid technology is essential to its success. The real-time requirements of the system dictate that it must operate at a speed high enough to satisfy those demands. Communication over smart grids can make use of a wide variety of different technologies, such as cellular, cordless, SCADA (Supervisory Management and Data Acquisition), BPL, and Programmable Logic Controllers (PLCs). These technologies are used contingent on the requirements of the task at hand. Significant Factors to Take Into Consideration Regarding Consolidated Communication [38]. The flow diagram of smart electricity meter is visualized in Fig. 3.

3.1 Benefits of SEM

3.1.1 No manual measurements

Digital meters eliminate the need to recall submitting monthly measurements by transmitting them immediately to your provider. The weather will no longer be an issue, nor will the need for flashlights.

3.1.2 Monitor the utilization and rates with ease

The price of your monthly energy bill and how much energy you've used can be viewed on the In-Home Monitor. Some households have seen savings of up to 20% on their energy costs thanks to the system's ability to track and promote good energy practices. Ideal for financial planning [39].

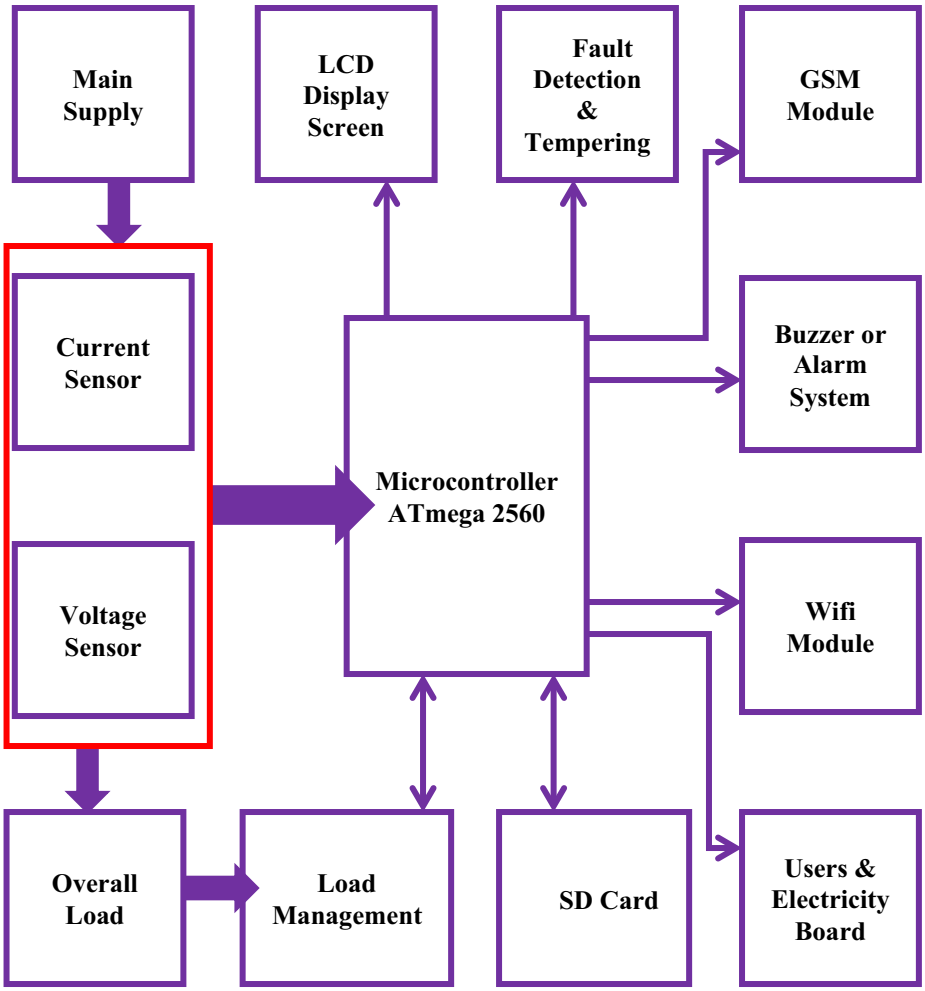

Fig. 3 The flow diagram of Smart Electricity Meter used in smart city

3.1.3 Precise expenditures

No more guesswork with the account is required in case of smart electricity meter, it provides accurate and precise price calculations as per the rate charges by the electricity providers.. A smart meter can send measurements instantly, guaranteeing accurate billing for energy consumed. Your energy provider is obligated to make an approximation of your consumption if you have a normal (non-smart) meter and neglect to send a measurement. They speculate on how much energy you will need in the future based on how much you have used in the past. When vendors don't have enough knowledge about your consumption, their estimates can be off.

3.1.4 Detects malfunctioning equipment

Timely identification of malfunctioning devices causing sudden energy consumption increases is crucial for effective energy management. The In-Home Monitor provides information that helps detect such issues promptly, enabling proactive measures to address them.

3.1.5 Environmental safety

By altering consumer behavior and providing data to guide the purchase of more energy-efficient equipment, strain on the electrical infrastructure is reduced. Smart Energy GB predicts that by 2030, pollution from households and businesses will have decreased by 24 percent.

3.1.6 Wider selection of prices is offered

As we progress toward a more advanced future, we will see a rise in the use of smart meters. Smart meters are preferred by many utilities, and those homes that have them can often get special rates. Smart meter rates are available in a wide range of price points, providing you with a great deal of flexibility. The energy industry is your gilded treasure.

3.2 Features of SEM

- An abundance of energy databases and pricing structures exist.
- Processing a number of documents simultaneously
- Supply quality incidents have been recorded frequently.

3.3 Application of SEM

- Provision of Electrical Current in the Conference Room
- Electricity production from wind Metallurgy sector Factory
- DC Management System

4 Smart home lighting system

When a smart lighting system detects that it is not being used, it can be programmed to automatically tone down the brightness of the lights or even turn them off entirely. This helps save energy. The increased accessibility afforded by the installation of intelligent lighting technologies can also contribute to the enhancement of public safety. Universal communication connections, advanced management, and advanced illumination are the three major characteristics of solid state lighting (SSL) technology solutions that are connected through the concept of smart lighting, which is a technology-driven concept. However, this paradigm is continuously changing to fulfill the demands of the next generation of gadgets that will be functioning in an IoT atmosphere. Those requirements are becoming more complex [18]. Light-emitting diode (LED) technology is at the heart of today's sophisticated and energy-efficient smart lighting systems, which also make use of the most recent advances in technology drivers. Illumination systems are currently undergoing an evolution to support a variety of wireless communications connections that are ideally adapted to the IoT environment. The market proclivity for SSL systems forecasts accelerated development of networked IoT lighting management systems in a variety of industries, spanning from smart residences to advanced manufacturing lighting systems. These systems come with a variety of cutting-edge features, such as the capability to regulate the spectrum output of the illumination and numerous communication connections [40].

A lighting system is considered to be smart if it incorporates energy-efficient LED controllers, sophisticated control algorithms, illumination sensors, and communication interfaces, all of which collaborate to create a lighting network. In its most basic form, a smart lighting system is an adaptable lighting system designed with the intention of enhancing both the aesthetic pleasure and the energy efficiency of the space [41]. Smart home lighting system is the part of smart home automation system; in this study we have presented the block diagram of smart home lighting system in Fig. 4.

4.1 Advantages of smart home lighting system

4.1.1 Remote control adjustment of the brightness of lights

Smart lighting offers significant advantages, including remote control and voice command functionality, enhancing convenience and accessibility. The ability to control lights from distance benefits individuals with mobility issues, while also providing added safety and security by simulating occupancy when away from home.

4.1.2 Adjust the color of the illumination to different levels

Smart lighting offers the entertaining feature of controlling the color of the light source using a mobile device. This allows for personalized and customizable lighting experiences, including adjusting the tone, color scheme, and color

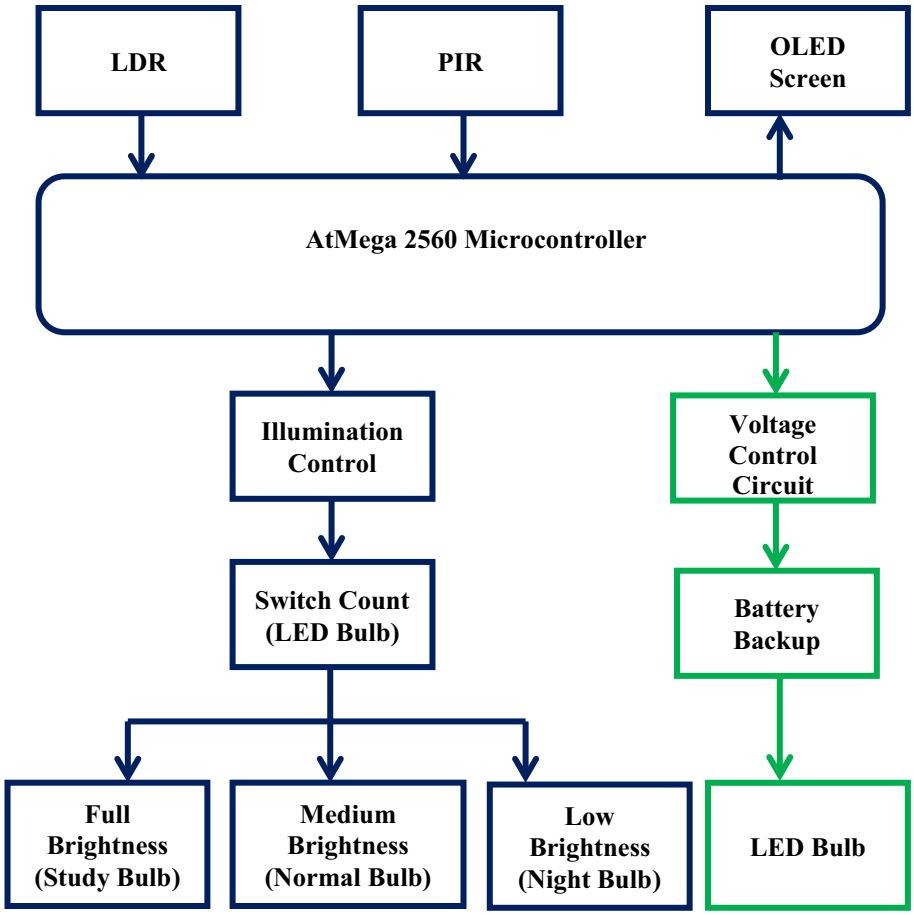

Fig. 4 The block diagram of smart home lighting system

temperature. People struggling with sleeplessness can benefit from lights that change color throughout the night, gradually transitioning to warmer tones. By avoiding blue light before bed, it can promote better sleep and synchronization of circadian patterns.

4.2 Features of smart home lighting system

a) Make the switch to LED light lights, which have a lower impact on the environment and save money.
b) When you are away from home or out of town, it is a good idea to take extra precautions to protect your property by turning off the lights according to predetermined timetables or by using a remote control to adjust the illumination schedules.

4.3 Smart water distribution and management (SWDM)

Smart water distribution and management (SWDM) system uses sensing and networking technologies to track and optimize water demand in communities. Smart water control devices can decrease water loss while improving water purity. Effective water management requires the merging of systems and a set of measures to watch, control, and govern the use and purity of groundwater sources, as well as the upkeep of related machinery. Sensors, meters, information processing and visual analytics tools, controllers, and mobile and web-based commands constitute the variety of both software and hardware devices that link people to water networks. Water supply systems presently offers openness and better management throughout the overall water distribution network, from a freshwater pool to effluent gathering and disposal. This category covers IoT water management technologies, platforms, and applications tools that help optimize water output, transportation, and usage, alongside efficient water purification practices [41].

Instruments, due to their flexibility and purpose, have a broad variety of uses in efficient water management. Instruments in a fundamental water supply chain monitor the purity of natural source water, the chemical makeup of purified

water and effluent, and the shifting amount in storage. Demand on distribution network pipelines, damage on the apparatus and machinery that handles and delivers water to end consumers, and other variables. Administrators at different places anywhere along water distribution chain can use data gathered by IoT water devices to obtain crucial insights into the shifting states of water supplies and machinery, which allows them to implement data-driven remedial steps on demand [5]. The smart water management system is one of the important section of the smart city, the block diagram of Smart water distribution and management system is presented in Fig. 5.

4.4 Applications of SWDM

4.4.1 Decrease the total quantity of water

SWDM (Smart Water and Data Management) is an innovative approach that minimizes water wastage in sectors like manufacturing, agriculture, and electricity generation. It employs advanced farming practices, IoT applications, and real-time monitoring to optimize water usage. Learn more about our agricultural software development services.

4.4.2 Work to enhance the water's quality

The IoT-based system enhances water quality and protects against contamination from chemical waste and natural pollutants. Real-time monitoring and management devices are utilized to improve and preserve water conditions, ensuring its safety and quality.

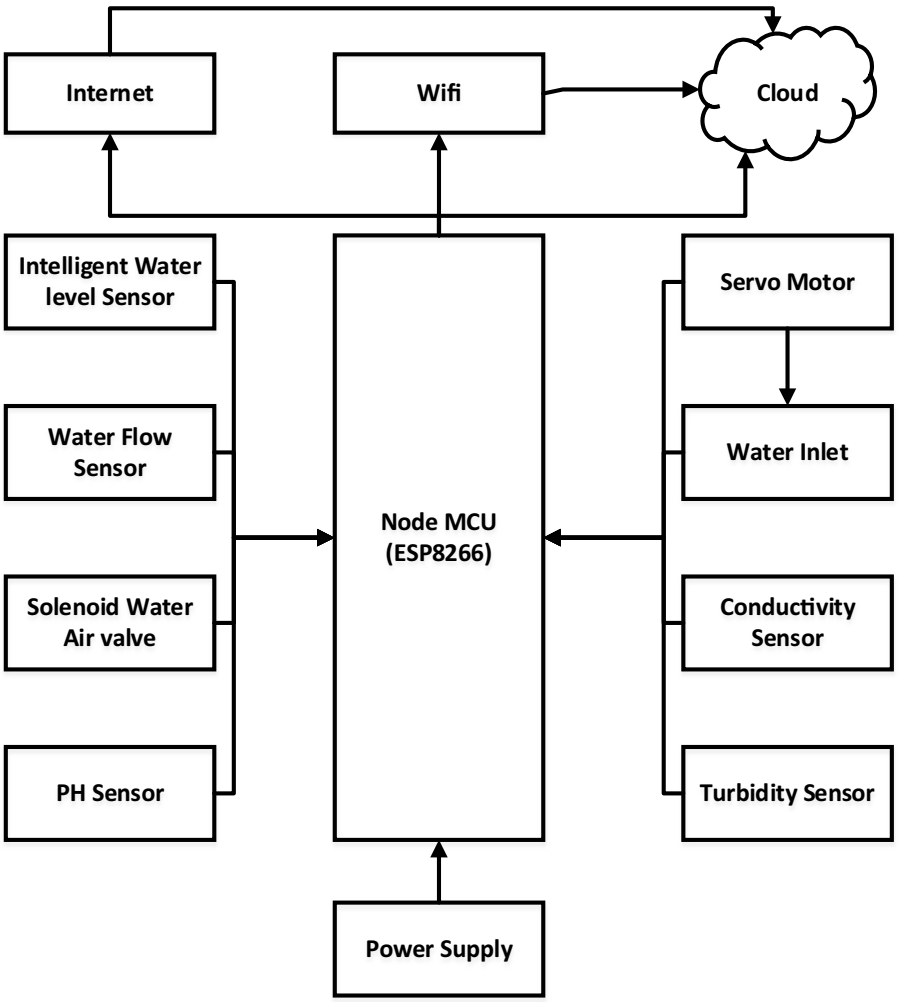

Fig. 5 The block diagram of Smart water distribution and management system

4.4.3 Increase the effectiveness of water distribution networks

IoT and data solutions enhance the efficiency of water networks, including collection, purification, transportation, and wastewater reprocessing. Businesses utilizing these technologies can effectively manage assets, monitor crucial measurements such as water pressure, temperature, and flow, implement proactive maintenance, and prevent equipment failures and operational downtime.

4.4.4 Employ innovative tools for water management

For the purpose of controlling leaking, SWDM makes use of clever water management devices that are fitted with leak and dampness monitors. Leakage management is essential for the protection of both water resources and finances given the annual expense of nearly $3 billion in repairing the damage caused by leaking.

4.4.5 Engage in the practice of consumption monitoring

Monitor water usage with administration systems based on the IoT. It helps in optimizing and controlling the use of water resources at different stages, including residences.

4.5 Effective SWDM features

- Elimination of trash produced by businesses that use large amounts of water
- Monitoring of the water quality is currently taking place as part of an effort to battle illness and contamination.
- Enhancing the productive capacity of existing water systems
- The use of smart meters is helping to increase people's knowledge of the amount of water that is consumed in their homes.

4.6 SWDM applications

- Utilizing IoT-based water management devices, keep track of how much water is being consumed. It is useful for optimizing and exercising control over the use of water resources on multiple levels, including in residences.
- Elimination or diminution of waste in businesses that use large amounts of water
- Monitoring of the water quality is currently taking place as part of an effort to reduce contamination and illness.
- Efficacy improvements to be made to the water distribution infrastructure.
- The population is becoming more conscious of the amount of water that is being consumed in their homes thanks to smart meters.

5 Smart waste management system (SWM)

SWMS utilize devices and various communication technologies in order to observe and improve the process of refuse collection and dispersal in urban areas. The generation of garbage can be cut down with the help of intelligent waste management systems, which can also improve the effectiveness of refuse collection and dispersal. An innovative strategy for the dispersal and collection of garbage is known as "smart waste management." The IoT technology that underpins smart garbage management enables the collection of information on the behaviors and patterns associated with trash production [18]. This enables municipalities, communities, and garbage collection to increase their level of sustainability, optimize their refuse operations, and make more educated business decisions [42].

Throughout its entire existence, the garbage business has been characterized by a lack of change. And it has only been in the most recent decades that we have started about seeing technical improvements in the procedures that are used for handling waste. Waste management organizations are increasingly turning to intelligent approaches for dealing with financial deficits and aggressive real-life environments as a result of the commercialization of IoT technology and other new developments.

The United Nations estimates that more over 50% of the global total resides in urban areas [43]. In addition, as urban areas continue to expand, the environmental, societal, and infrastructural difficulties they confront call for innovative

approaches to the execution of public services, such as those pertaining to garbage management. Waste disposal that is both efficient and effective is very much an essential element of smart cities, and it has a significant impact in ensuring that our cities will continue to be habitable and sustainable in the future.

Sensors for Intelligent Receptacles IoT clever sensors are utilized in intelligent garbage management. Intelligent sensors keep track of how full refuse containers get. They are controlled by a network called the IoT, which uses the internet to connect various electronic gadgets [44]. Every 15 min, smart bin sensors collect data on the fill volume, direction, and temp of the contents of the bin, and then use this data to generate 3D topography models of the bin's contents [45].

Cloud storage receives information from intelligent devices that capture data on the patterns of garbage production. A smart waste solution performs analysis on these data and makes them accessible to users. It provides an infrastructure for efficient processing of garbage and also best utilization of homemade waste on timely manner. A smart garbage management solution can help you improve someone garbage assistance by using analytics to transform the data collected from your receptacles into actionable insights [46]. These insights can then be used to improve your trash services. There is a possibility that you will obtain information on measures such as "overflow-prone locations". It provides the information about the minimum amount of containers which are necessary to prevent refuse from spilling over. Also it informs about the quantity of solid waste collection which might be sidestepped altogether. Furthermore, the smart waste management solution provides the quantity of gasoline that could be saved if certain measures were taken. It also provides the number of hours spent behind the wheel that could be saved. These data insights have the potential to assist you in transitioning your trash management practices to ones that are greener, more environmentally friendly, and more effective. Make changes to your method of trash disposal that are more environmentally friendly, hygienic, and resourceful. The smart waste management system which also uses the garbage vehicle tracking and dustbin status is visualized in Fig. 6.

5.1 Benefits of smart waste management system

5.1.1 Shortens the time required to travel

In smart communities, garbage vehicles optimize their routes to reduce traffic congestion and minimize travel time. This benefits both the efficiency of waste collection and reduces delays for other road users. Leveraging IoT technology for remote monitoring eliminates the need for on-site inspections, saving time and resources previously spent on dispatching employees to distant locations.

5.1.2 Cost saving

As a result of the significant increase in garbage, additional resources are being allocated to the collection and management of rubbish. It is possible to reduce the amount of money spent on garbage management if collections that serve no purpose are discontinued.

5.1.3 Sustainability

Efficient garbage collection methods in smart communities prevent environmental pollution and health hazards caused by overflowing containers. By improving waste management, air quality is enhanced, and CO2 emissions are reduced, aligning with the Sustainable Development Goals (SDGs) for a lower carbon footprint.

5.1.4 Effectiveness

The smart cities movement focuses on achieving more with less effort by efficiently utilizing available resources. Real-time data enables quick decision-making, including proactive measures to prevent waste overflow. Smart communities promote responsiveness and challenge traditional waste management practices, leading to cost savings and increased productivity.

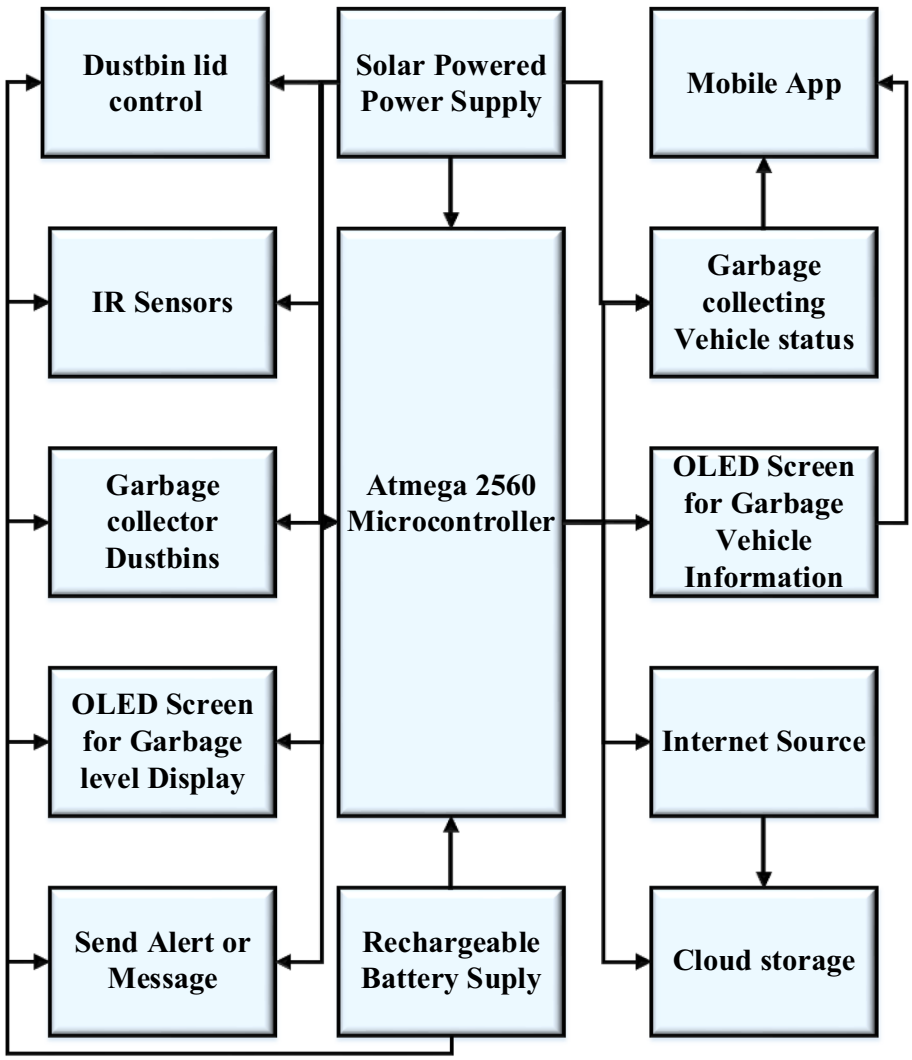

Fig. 6 The block diagram of smart waste management system

5.1.5 Effective monitoring

Through meticulous route monitoring, smart communities can eliminate any possibility of asset misappropriation. Transparency in waste management processes is being encouraged by cities as a means to build trust with their residents. Making statistics more accessible can enhance credibility and foster a sense of community involvement. It is crucial for smart communities to be supported in their pursuit of sustainable development, allowing them to explore innovative procedures and solutions beyond their current implementations.

5.2 Smart waste management system's applications

- The primary application for its use is in the rubbish collection system of governmental corporations.
- In a community with metropolitan dwellings, the garbage management system can also be utilized for the collection of refuse from individual households.
- Recycling and refuse collection in industrial settings are both possible with the use of SWM devices.
- This strategy can be utilized by new businesses that are just getting their feet wet in the field of refuse reprocessing technology.

6 Smart routing system

The information on the container full levels makes it feasible to implement intelligent navigation. Trash collectors are able to enhance their collection process with the help of the innovative material management software. The software provides a digital snapshot of the refill quantities of receptacles [17].

Instead of following the predetermined collection routes, waste collectors can use the data insights to transition to traveling along dynamic collection routes instead. Because of this, they are able to save several hours that would have been spent traveling also before the garbage collection and picking up each and every receptacle, regardless of how full the bins were, so that they can instead pick up only the containers that necessitate care[14]. Smart Transportation: 'intelligent transportation systems utilize sensors as well as various communication methods to monitor and enhance a city's public transportation in order to make it more user-friendly. By utilizing innovative transportation technologies, one can lessen the severity of traffic congestion while simultaneously improving the effectiveness of public transportation. The term "Smart Transportation Systems" (STS) refers to a category of systems that observe, evaluate, and handle existing transportation networks in an effort to increase both productivity and safety. This description can be simplified into the following concepts for what constitutes intelligent transportation: administration, productivity, and safety [47]. To be more precise, smart transportation is the utilization of cutting-edge technology to enhance the security, convenience (for both the community and the individual), and convenience of navigating metropolitan areas. The most important contributors are the proliferation of IoT devices and indeed the advancement of 5G networks. By incorporating relatively inexpensive instruments and controls, the earlier allows users to exercise distant control and management over virtually any physical equipment. The latter provides the high-speed communication that is necessary for real-time control and operation of mass transit with a minimum amount of latency time [6].

There are currently ongoing projects to implement intelligent transportation in a variety of locations, and both the achievements and shortcomings of previously carried out projects are being utilized in the development of new transportation systems in different geographical locations [48]. The basic block diagram of smart routing system which uses the IoT components is shown in Fig. 7.

6.1 Advantages of utilizing a smart transportation system

- Automated transportation systems, incorporating machine learning, IoT, and 5G wireless networking, have shown to reduce accidents by minimizing the human aspect. Algorithms used in these systems do not get fatigued, frustrated, or distracted like humans do.
- Smart transportation enables effective data acquisition, providing managers with comprehensive data points for every component of the transportation system. This allows for constant monitoring of operational processes, identification of service requirements, and analysis of the root causes of problems that need to be addressed.
- Intelligent transportation improves efficiency through better administration, leading to increased utilization of resources. By utilizing high-quality data, transportation systems can identify areas for improvement, such as optimizing bus routes or adjusting train timetables to increase passenger usage.
- Implementing intelligent transportation systems can also result in cost-effectiveness. By employing preventive maintenance, reducing energy consumption, and allocating resources efficiently, costs can be minimized. Users can benefit from affordable and efficient public transportation as an alternative to personal vehicle ownership, leading to potential cost savings[44].
- Intelligent transportation is more cost-effective since that makes greater benefit from the assets that are currently available to it. Users will be able to save money when there is public transportation that is both reasonable and efficient enough to contend with personal automotive possession[49].

6.2 Features of smart routing system

- Instant insights and alerts for city transportation management centers
- Quick and efficient response to traffic issues
- Optimization of traffic flow and signal timings
- Real-time information for drivers
- Enhanced transportation efficiency
- Reduction of congestion

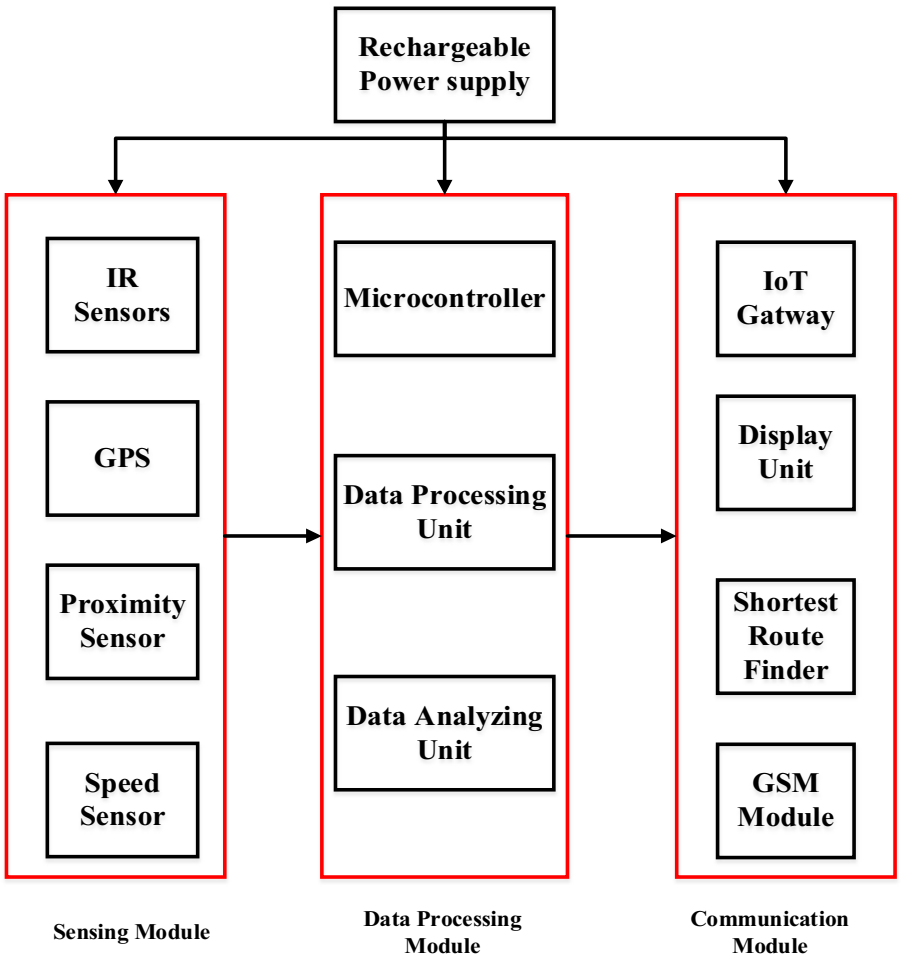

Fig. 7 The basic block diagram of smart routing system

The flow chart of smart routing system is shown in Fig. 8. The flow chart describes the automatic "chalan" system for over speeding also vehicle tracking and information sharing with traffic department. If the driver is sleeping or his eye is closed for more than 5 s, the vehicle stopped will be automatically slow down and automatic breaks will be applied.

7 Intelligent vehicle parking system

The lightning-fast society of today makes the utilization of clever parking techniques an absolute requirement. The implementation of an IoT application known as smart parking really does have the opportunity to significantly improve the quality of life for all individuals. The challenges that people face when trying to find parking in this volatile environment are significantly reduced as a result of the implementation of smart traffic technology as well as IoT connectedness[46]. The IoT devices that have been successfully implemented are able to identify parking spots that are vacant. The information that was gathered in the parking structure is uploaded to a computer that is located in the cloud. The user will then be able to receive the essential instructions through the use of smart phones or other forms of communication tools. In the intelligent parking system, the closeness, ultrasound, and distance detecting devices are utilized in a significant way. This system not only displays the parking area as well as the appropriate distance for the automobiles to be stored, but it is also capable of recognizing the arrival as well as departure of the automobiles. This device is capable of communicating with an android smartphone using whatever app or online access. This not only helps save time but also makes parking a relatively straightforward process [15].

This method does not require any complicated or pricey infrastructure in order to function properly. Message Queuing Telemetry Transport, or MQTT for short, is a straightforward messaging protocol that transforms communications between various devices, platforms, and software applications. The cloud computer is responsible for

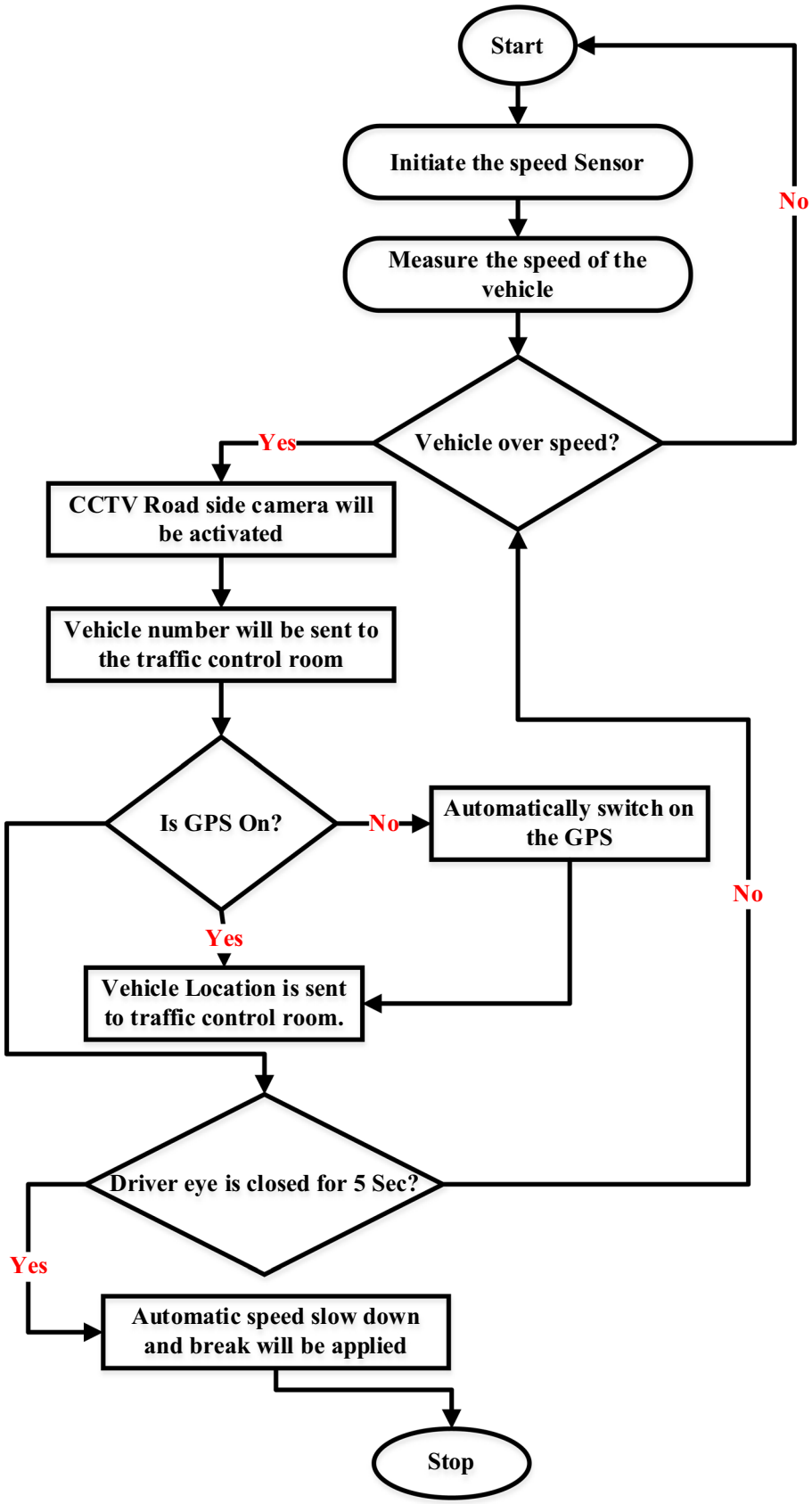

Fig. 8 Flow chart of smart routing system

managing the information on each available parking spot (Fig. 9). Last but not least, customers now have the ability to get the instructions they need by using communication devices that are connected to online platforms. groups and emergency medical technicians and volunteers [45].

7.1 Advantages of using IoT for automated parking

7.1.1 Environment

One of the goals of the Smart Parking system is to cut down on the amount of time and energy that is spent searching for a parking spot. Being able to accurately direct a vehicle to an open place has many positive effects on the surrounding environment, including a reduction in CO2 pollution, noise, and other contaminants. When intelligent parking and strategies resulted technologies are combined, it is possible to evaluate both the air quality and the availability of parking spots.

7.1.2 Convenience

Getting parking in the metropolis can be difficult, particularly during peak hours of traffic congestion. In the event that a person is unable to locate a parking space, they run the risk of losing their business or opting to make their purchase elsewhere. When a consumer or tourist can immediately recognize a location, both the difficulty and the experience are diminished, and the interaction is improved. Ease of access is of the utmost importance in places that are reserved for drivers with disabilities, municipal vehicles, or emergency vehicles.

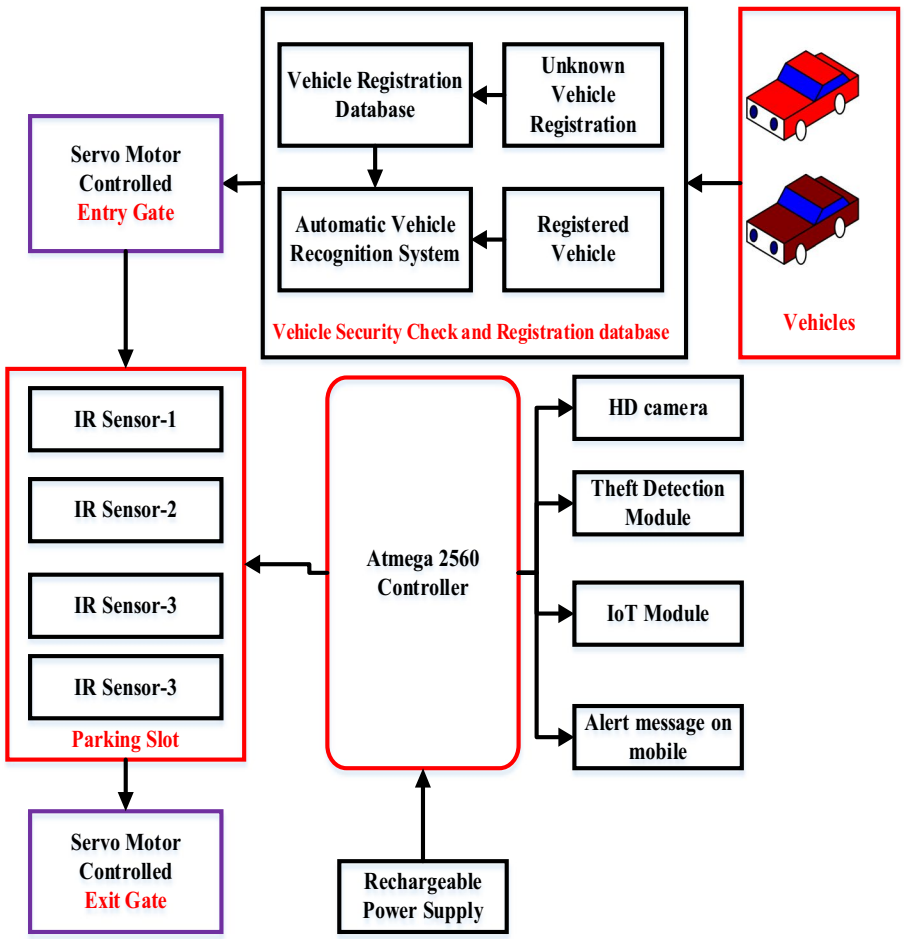

Fig. 9 The block diagram of Intelligent Vehicle Parking system using IoT

7.1.3 Information and statistics updated in real time

Whether you are a municipality, a parking lot provider, or a business, Smart Parking can provide you with extensive data sets that can be used to identify patterns, busy periods, and other measures that can be used in forecasting and reporting. These data sets are available to you through Smart Parking. With the help of specialized software, the data and devices can be incorporated into municipal administration systems or made a part of MI reports.

7.1.4 Decreased amount of traffic

When drivers are able to avoid stopping and traveling when it is not essential, the result is an improvement in the flow of traffic in areas that are already densely populated.

7.1.5 New marketing strategies

Smart Parking enables the realization of novel business strategies which can only be accomplished through the application of technology. There are many examples of this, such as loyalty programs, purchases made through apps, and changing parking fees.

7.1.6 Decreased expenses as well as bureaucracy

The more traditional method of parking on the street may have necessitated the purchase of parking meters or the hiring of parking inspectors. These expenses can be reduced thanks to the automation of parking procedures and more targeted enforcement that is made possible by smart parking technologies.

7.1.7 Effectiveness of law enforcement

New, technologically based business strategies are made feasible by the implementation of smart parking systems. Some examples of this are membership programs, purchasing options within apps, and changing parking costs.

7.1.8 Protection

It is possible to reduce the number of incidents that occur as a result of space searching if drivers are reminded to pay attention, refrain from making rash maneuvers, and do not look for open places.

7.1.9 Purchases that are consolidated

When using a mobile application or a website, users of smart parking systems are able to make payments in real time using computerized methods. The parking procedure will be considerably simplified as a result, and the info regarding revenue sources will be more systematic.

7.1.10 Intelligent city

It won't be long before smart parking is a necessity in any town or jurisdiction that aspires to implement "Smart City" advanced technologies or specifications like ISO 37122. The government of the United Kingdom and a number of other organizations are currently working to establish standards for intelligent parking.

8 Conclusion

This research study presented a comprehensive exploration of the various applications and purposes of smart cities in conjunction with the Internet of Things (IoT). Throughout the research process, meticulous attention was given to the implementation of each application and the selection of appropriate components. To facilitate a better understanding of smart city applications, the study employed visual aids such as block diagrams, flow diagrams, and flow charts,

which effectively illustrated the fundamental applications and demonstrated their potential utilization. While smart cities encompass a wide array of applications, this investigation specifically focused on several key cases that exemplify the capabilities and potential of smart city technologies. These cases included smart grid technology, which enables efficient energy management and distribution; smart electricity meters, which provide real-time consumption data for optimized energy usage; smart lighting systems, which offer intelligent control and energy savings; smart water management systems, which enhance water conservation and distribution; smart waste management systems, which streamline waste collection and disposal processes; and smart parking systems, which enable efficient parking space management and reduced congestion.

In the future, we intend to apply these research findings to real-world scenarios and evaluate the benefits and drawbacks associated with their implementation. Additionally, we will investigate concerns related to the safety and security of smart cities as part of this project. By addressing these aspects, we aim to contribute to the development of efficient and secure smart cities.

Author contributions HMR: Wrote Main Manuscript, Prepared the Figures. A-U-R: Prepared the raw draft of the manuscript. AP: Prepared the raw draft of the manuscript. SM: Reviewed the manuscript, KKS: Reviewed the manuscript

Declarations

Competing interests The authors declare no competing interests.

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