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# Smart cities implementing IoT applications for security technologies and future recommendations

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## Abstract

The rapid urbanization and escalating population growth are placing unprecedented pressure on urban infrastructure, prompting the necessity for smart city initiatives leveraging Internet of Things (IoT) technologies. This paper critically evaluates the integration of IoT applications within smart cities, emphasizing security and privacy as key challenges. By reviewing relevant research, it highlights the significance of maintaining robust cybersecurity measures to safeguard sensitive data generated by IoT devices, thereby enhancing user trust and service effectiveness. The study also explores the roles of visual communication, graphic technology, and photographic technology in supporting IoT applications, including multimedia surveillance and data visualization for improved decision-making and operational efficiency. It further identifies and discusses practical methodologies for ensuring cybersecurity and user privacy, recommending collaborative efforts among government entities, technology providers, and security specialists. The findings stress the importance of adaptable and secure systems capable of mitigating financial, informational, and reputational risks associated with cybersecurity incidents. Future research directions include refining AI-driven cybersecurity solutions and addressing emerging vulnerabilities in IoT-enabled smart city infrastructures.

**Keywords:** Adaptable systems, AI-driven security, Cybersecurity, Privacy protection, Data visualization, Graphic technology, Internet of things (IoT), Multimedia surveillance, Photographic technology, Smart cities, Urban infrastructure, Visual communication.

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## 1. Introduction

The rise of web-based technologies in the 1990s led to the 1999 coining of the phrase IoT. Social problems, ecological issues, healthcare, and user settings are just a few of the scenarios in which a network of physical objects may link and communicate with one another. In order to collect and share data, the IoT connects actual objects like cars, buildings, and even basic electrical appliances to one another. Major services and infrastructure are required to fulfill the needs of city dwellers because of the notable increase in population density in urban areas [1]. According to projections, the world's population will expand by over 10% over the next 30 years, particularly with 70% of the increase anticipated by 2050, meaning that the vast majority of people will reside in cities. As a result, nations are planning how to prepare their cities for the influx of people and the strain it will place on the existing infrastructure. The IoT apps required to enable such architecture are shown in Figure 1.

The use of electronic gadgets like actuators, sensors, and cell phones has increased significantly, as have the devices' connectivity and communication capabilities with the web and with each other. These "Things" can prioritize tasks, organize themselves, and communicate with other "Things" in the absence of human intervention. The goal of the IoT is to increase the Internet's immersion and extensive presence. By leveraging the enormous quantity and diversity of information generated by "things," the IoT will hasten the advancement of countless apps that offer fresh solutions for companies, shoppers, and governmental organizations.

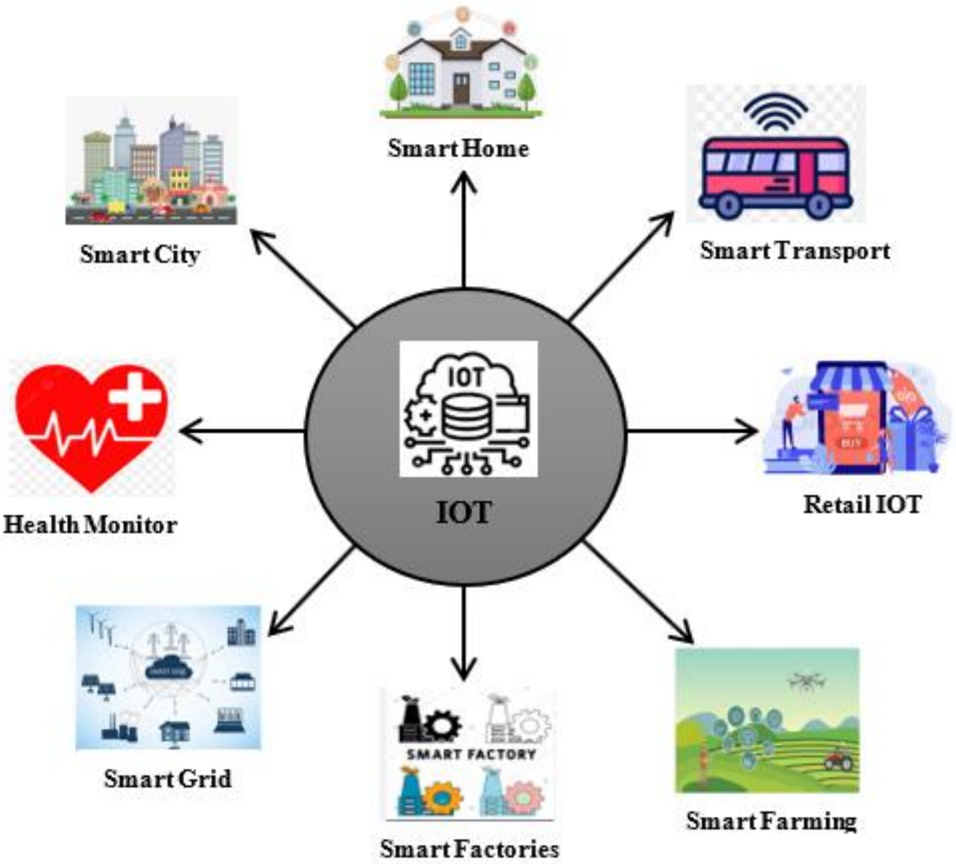


**Figure 1.**
IoT apps that help smart cities.

These sophisticated technologies are used in smart cities for a number of reasons, including traffic management, lighting, pollution control, energy usage, and traffic control. The main goal of smart cities has the potential to alter the way we now view the world. From basic daily tasks to intricate human emotions, we may say that the IoT is expected to influence every aspect of existence. Citizens frequently benefit most from smart city projects and the surrounding environment. Mega-city planners must therefore adopt a new analytical and conceptual technique due to dynamic development and complicated attributes. It must welcome technological advancements, moving from technology-driven to artificial intelligence and cognitive computing, as well as from being driven by the city administration, the public, and Industry 4.0.

The idea of a "smart city" has become a widely accepted reason. First, because the majority of new positions are being created in urban regions, these areas are growing more quickly than ever before. Second, to improve their children's educational opportunities, a significant portion of rural families are relocating to cities. This trend has resulted in a number of serious issues. To accommodate this population growth, urban areas' facilities and amenities must be enhanced. Solutions also need to be developed for several problems, such as those pertaining to urban transportation and the environment. To address these issues, the smart city design was created.

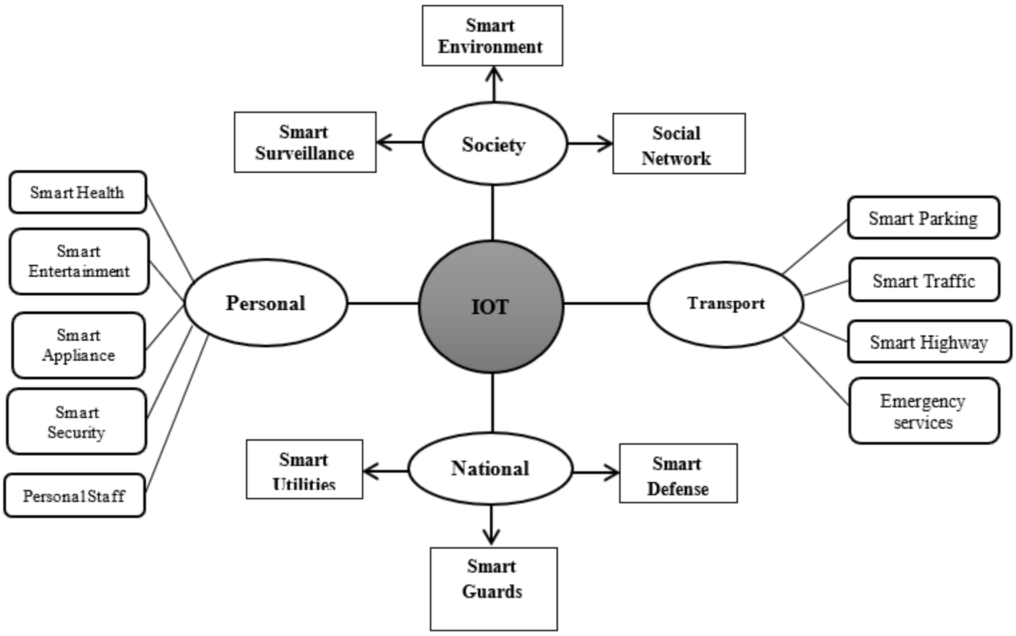


**Figure 2.**
IoT element integration in smart city concepts.

Numerous detectors, supporting technology, and city backdrop circumstances are needed and used by the basic framework of an intelligent city. Among the key elements for the effective deployment of a smart city is thought to be the IoT [11,12]. The goal of IoT applications is to guarantee the vital components of smart cities, which include the consistent functioning of vital city systems like alarm systems, water and energy supplies, and specialized manufacturing, among other production capacities. The integration of IoT elements pertinent to smart cities is depicted in Figure 2. Because of their socioeconomic and environmental effects on people's lives, cities are an essential part of modern civilization [2]. According to a recent United Nations (UN) report, cities today house 55% of the world's population. Nonetheless, the UN's predictions highlight the likelihood that 6.5 billion people or 68% of the global population, will reside in cities by 2050. This is brought on by urbanization, which is the slow movement of people's living patterns from pastoral to urban regions in line with the general growth of the world's population.

Furthermore, the research's primary importance stems from its dual focus on theoretical evaluation and real-world application. In order to provide insights into how these advances might be optimized for urban environments, it first explores the potential and challenges related to AI-driven computer safety in smart cities. Second, the study provides practitioners with an operational roadmap that outlines the steps and best practices that should be followed when applying AI models to actual smart city situations. With the help of this practical plan, communities will be able to improve their cybersecurity posture in the face of changing threats. It is expected that individuals in charge of safeguarding smart cities would gain valuable insights from this [3].

This paper's remaining sections are arranged as follows: The literature currently in publication is thoroughly examined in the section that follows, with a particular focus on the current level of AI in cyber security, specifically regarding smart city anomaly recognition in IoT networks. Relevant conceptual structures are then presented. The suggested conceptual model is then introduced in the article, along with an analysis of the connections and possible effects of the highlighted components within the smart city paradigm. Afterward, the focus shifts to the framework's consequences, taking into account both its theoretical and practical ramifications for those involved in technological and urban planning. Following a summary of the research's contributions to the advancement of AI-driven cybersecurity tactics in smart cities, an examination of its shortcomings and recommendations for further research are included.

## 2. Related Works

The lengthy lifespan of urban infrastructure has amplified the challenge of widespread data breaches, primarily due to the continued reliance on outdated technologies alongside cutting-edge security measures. Establishing comprehensive security protocols is vital for protecting the evolving infrastructure of intelligent cities and the IoT ecosystem, comprising numerous sensors and centralized data analytics capabilities [4]. The literature underscores critical strategies to bolster the security and resilience of AI-driven smart cities facilitated by IoT. Enhanced internet connectivity, particularly through advanced 5G and forthcoming network generations, is essential to secure smart urban environments by providing superior speeds, lower latency, and broad device interoperability. Nonetheless, the decentralized nature of these networks, alongside innovative technologies such as edge computing and network slicing, creates new security vulnerabilities that must be addressed.

Smart cities driven by IoT technologies rely on millions of interconnected devices, many with limited resources, functioning across heterogeneous networks (HetNets). Essential components of this IoT-based architecture include unified registries (UR), key management systems (KMS), trusted software-defined networking (SDN) controllers known as trusted third parties (TTP), and black networks (BNs). Each component fulfills specific roles, collectively ensuring secure connectivity and device authentication within HetNets [5]. Black networks particularly focus on safeguarding data integrity, credibility, privacy, and validation processes. UR maintains comprehensive records from diverse IoT equipment, such as nodes, sensors, and gateways, while TTP manages efficient routing among IoT nodes, with KMS overseeing the network's overall security.

Protecting individual privacy remains a critical responsibility within smart city environments. Residents utilize various sophisticated technologies integrated across diverse networks, inherently exposing them to privacy violations and unauthorized access by cybercriminals [6]. Consequently, social networking's influence on information security and privacy warrants careful consideration, as risks depend significantly on the identifiable nature of shared data, intended recipients, and potential data exploitation. Despite assurances of anonymity from social networking platforms, sufficient information is often disclosed to facilitate user identification.

The emergence of advanced photographic and mobile graphic technologies significantly influences smart city developments, particularly in multimedia content management, real-time surveillance, and public safety initiatives. State-of-the-art photographic sensors and mobile graphics hardware embedded within IoT devices considerably enhance capabilities such as high-resolution video streaming, immediate event detection, facial recognition, and comprehensive traffic analysis [13]. These technologies enable urban areas to substantially enhance public safety, efficiently manage traffic flow, and provide rapid emergency responses through immediate visual data analytics.

Expanding their utility, photographic and mobile graphic technologies are increasingly leveraged by smart cities to improve environmental monitoring, maintain urban infrastructure, and enhance healthcare services. IoT-integrated high-resolution imaging supports the automatic detection of structural issues within infrastructure, the timely identification of environmental threats, and the provision of advanced telemedicine solutions via remote patient monitoring using mobile graphic devices [14]. Thus, the integration of photographic and mobile graphic elements significantly boosts the operational efficiency and responsiveness of smart cities, substantially improving the quality of life for residents.

Exploring the transformative potential of Metaverse technologies for transportation, emerging frameworks suggest transitioning traditional transportation infrastructure into augmented and virtual reality platforms. A conceptual model incorporating cloud computing, IoT devices, and artificial intelligence enables policymakers to prioritize and adopt sustainable transportation practices [7]. Blockchain-based decentralized cloud storage further secures digitized analytical outputs. Additionally, AI plays a pivotal role in addressing broader environmental sustainability challenges, including transportation management, biodiversity conservation, and optimized energy and water use, emphasizing the need for continuous oversight and iterative improvements.

Recommender systems, serving as advanced information filtering tools, streamline decision-making processes across extensive applications with numerous choices. Unlike conventional search engines reliant on explicit user queries, recommender systems proactively present relevant suggestions based on users' historical data and established preferences [8]. Nevertheless, challenges like the cold-start problem, where limited user data impedes personalized recommendations and rating sparsity issues persist as significant hurdles.

A detailed review of existing literature highlights extensive research on smart and sustainable cities aimed at optimizing sustainable development objectives through advancements in ICT [9]. Initial research in smart urban development traces back to the 1990s, catalyzed by the proliferation of electronic devices and internet technologies within urban contexts [10]. Global interest in smart cities notably intensified after major ICT corporations like IBM and Cisco, alongside international entities such as OECD and the European Commission, recognized and championed smart urban growth as a strategic global priority.

## 3. Methods and Materials

### *3.1. Smart City Overview*

To provide a cohesive environment and facilitate readers' comprehension of the survey's primary points, it is imperative to present the characteristics, architecture, and typical uses of smart cities [15]. This is due to the fact that the majority of the protection techniques introduced are based on particular scenarios of various intelligent applications, and the safety requirements and issues discussed in the following sections are directly tied to the characteristics of intelligent cities.

#### *3.1.1. IoT-Based Smart City Design*

The evolution of smart cities has led to the creation of several structures. There isn't a standard IoT architecture, though, as far as we know. This study focuses on security and privacy issues in intelligent cities, hence the design given here depends on the commonly known three-layer design and the widely approved structure proposed in. The construction is comprised of four layers, as illustrated in Figure 3; a synopsis is given below.

Perception layer, at the bottom of the framework level, is referred to as the edge layer, sensing layer, or recognition layer. In the actual world, the perceptual layers are predominantly used to gather data from objects (such as sensors, WSNs, and heterogeneous devices) and send the collected data to be processed further at the level of the network.

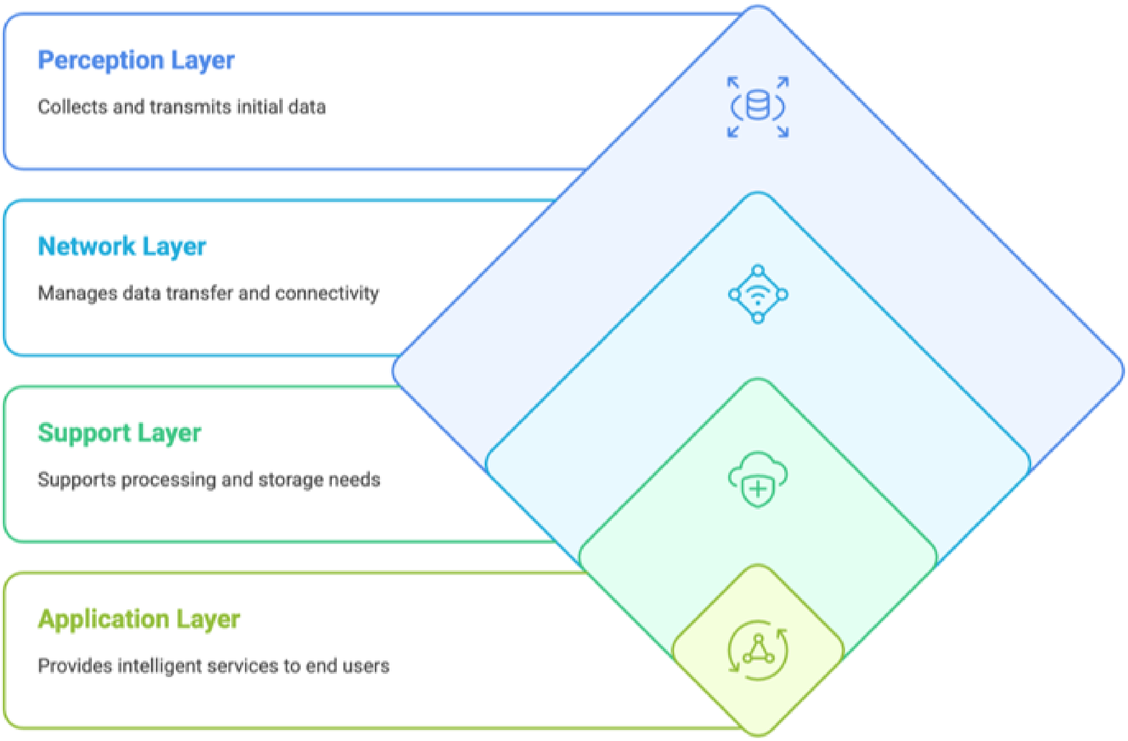


**Figure 3.**
IoT-based architecture for a smart city.

The network layer is the central layer of the IoT architectural design that is dependent on fundamental systems like communication networks, WSNs, and the Internet. This layer is responsible for connecting servers, transferring the information acquired by the sensory level, as well as intelligent objects and network components.

Support layer, it employs smart computing methods (such cloud, edge, and fog computing) and works directly with the software layer to support the needs of various applications.

Application layer, as the highest layer, it is responsible for giving users useful and intelligent services or apps according to their individual needs. In the next subsection, we give a thorough explanation.

*3.1.2. Applications*

Benefiting citizens in a variety of areas among the objectives of creating smart cities are those that are closely related to their standard of life, such as energy, the environment, business, real estate, and services. Figure 4 shoes the new intelligent uses of smart cities, which we go into further depth about below.

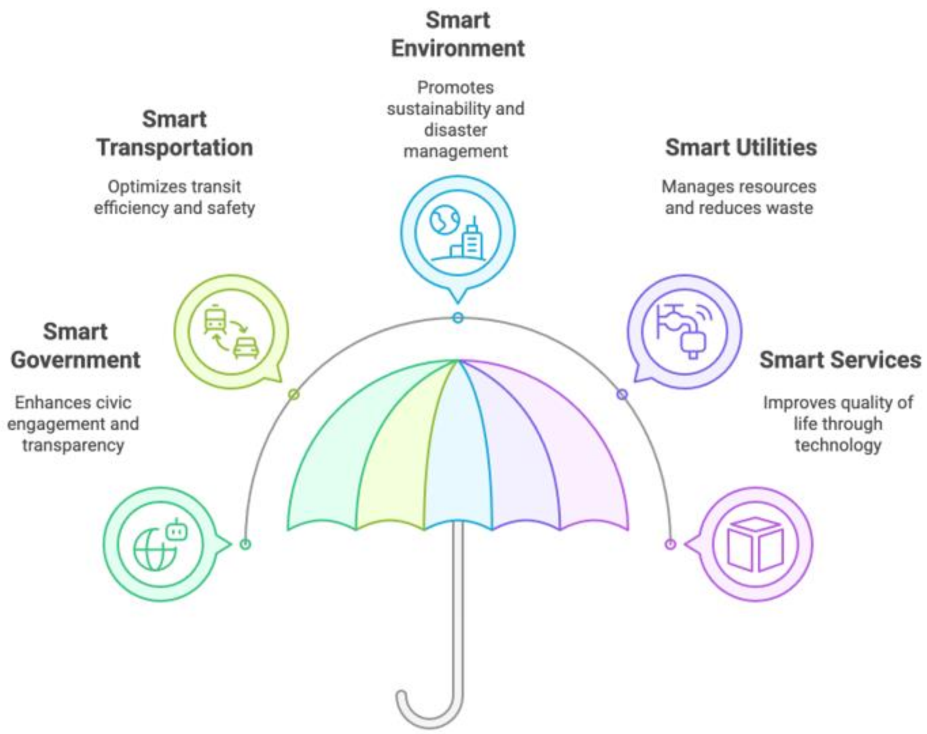


**Figure 4.**
Applications in smart cities.

*3.2. Smart Government*

A smart city is largely dependent on smart government. Smart government connects information technology-based physical infrastructures, institutions, data, and processes to better serve individuals and communities. Furthermore, residents can participate in city planning and public decision-making through smart governance, which can boost efficiency and information transparency at the same time. Electronic government, for instance, enables people to use Internet-based services for government, including submitting applications for conference centers, paying bills, and reporting issues.

*3.3. Smart transportation*

The goal of smart transport is to enable "smarter" use of transportation networks. In particular, through increasing reliability, speed, and security, intelligent transport networks can benefit the general population. Customers may quickly and affordably organize their schedules and identify the quickest and most efficient routes by using mobile applications that are focused on transportation. Driver passports, license recognition software, other commonly utilized functions for smart public transit include park search and forecasting.

*3.4. Smart environment*

The creation of a sustainable society can be greatly aided by smart environments. Specifically, Energy consumption, air pollution, structure quality, and congestion in traffic can all be tracked by a smart town, and effectively handle trash or pollution by putting technological management mechanisms in place. New ecological sensor networks could ideally even be able to predict and detect catastrophes in the future.

*3.5. Smart utilities*

Smart cities are able to boost economic growth, protect the environment, and lessen excessive use of resources like gas and water thanks to smart utilities [15,16]. A common smart utility use in smart grids for tracking dispersed energy supplies is smart metering. Additionally, to control sources and reduce energy waste, smart water gauges and light sensors save employed.

*3.6. Smart services*

In multiple ways, citizens benefit from smart services. Medical intelligence applications, for instance, can use medical sensors and wearable technology to promptly monitor people's health problems. Moreover, certain smart services, like the ability to remotely manage household equipment, can design cozy, intelligent, and energy-efficient living spaces. In conclusion, Smart purchasing goods, networking, recreation, and other clever services have significantly enhanced people's everyday ease.

*3.7. Smart City Components*

The four main parts of data gathering are receipt and delivery, preservation, and evaluation that are usually included in uses for smart cities. Application-specific data collection has played a significant role in the advancement of sensors across a range of industries. The data exchange, which includes sending data from the information collection equipment to the cloud for analysis and storage, is the second component. Many smart city initiatives have implemented citywide WiFi networks, 4G, and 5G technologies, and different kinds of local networks that can transmit data locally or globally. These are some of the ways that this task has been accomplished. Various storage strategies are employed to structure and organize data in order to make it usable for the fourth step, which is the analysis of data. The third stage is cloud storage. Data analysis is the process of drawing conclusions and trends from collected data in order to inform choices. In certain cases, basic analysis, such as simple decision-making and aggregation, would also be effective. When it comes to making more complicated decisions, the cloud's accessibility enables not just the collection, storing, and processing of diverse data, but also real-time analysis using statistical techniques and machine and deep learning algorithms.

*3.8. Smart Agriculture*

The UN's 2030 Sustainable Development Goals include food safety as a major objective. As the world's population increases and warming intensifies, causing severe weather in agricultural centers worldwide, countries are rushing to ensure that the food supply is sustainable and that limited resources, such as water, are used effectively. The application of sensors incorporated into crops and farms to measure a variety of characteristics in order to aid in decision-making and keep pests, illnesses, etc. at bay is known as smart agriculture. Accurate farming is a component of the intelligent farming concept that uses sensors inserted into plants to provide precise measurements, enabling the implementation of specific care methods. Precision agriculture is crucial to the struggle for sustainable food production since it will be required for future food security. Data-driven crop care and decision-making, as well as crop monitoring and disease detection, are the main uses of AI in IoT for agriculture.

*3.9. Smart City Services*

The activities that maintain a city's inhabitants are covered by the services offered by intelligent cities; these include municipal duties like water delivery, waste management, environmental monitoring, and control, among others. Water quality sensors can be installed to identify leaks and continuously offer data regarding water's condition utilized in the city. One prevalent feature of smart city projects is handling waste., and it has been incorporated into many of the previously mentioned projects, such as Barcelona's chutes and bins equipped with sensors and online connections that, in addition to notifying the proper authorities when they must be emptying use artificial intelligence (AI) to identify the most cost-effective route. Moreover, sensors can be utilized to guide residents to the next available parking spot to reduce gasoline expenses and track pollution levels in a city.

*3.10. Smart Energy*

Common electrical systems rely on a primary generating source, typically a fossil fuel or hydroelectricity plant, to supply energy in a one-way fashion. Although substation feedback controls power generation, Since the user does not enter data, the power generation strategy utilized with these systems requires that the power generated by these sources significantly exceeds the demand in order to ensure a consistent supply of electricity. Furthermore, locating errors in these systems and implementing fixes take time. Additionally, modern users have the option to produce their own energy in addition to obtaining it from the main utility as renewable energy technologies become more accessible. The phrase "smart grid" describes the use of ICT technologies to make both new and old networks more observable, let customers and utilities generate energy in other locations, and give the system the capacity to fix itself. The transmission of real-time power data to utilities at various grid locations via supply lines all the way to the customer is one feature of smart grids. Smart grids provide improved oversight of power generation through the use of prediction models created from collected consumption data, the integration of various energy sources, and network self-healing to guarantee a steady supply, since they give real-time data about demand from customers.

*3.11. Smart Health*

The term "smart health" describes how ICT is used to increase the accessibility and quality of healthcare. Due to the growing population and rising healthcare costs, researchers and healthcare professionals have been focusing heavily on this topic. The population's growing demand cannot be met by the overburdened health systems of today. Through telemedicine services and better diagnostic support for physicians using AI, smart health seeks to ensure that healthcare is accessible to as many people as feasible. The widespread use of mobile phones and health trackers that record daily activities, detect abnormal movements using inertial sensors, and capture real-time health data (temperature, body oxygen saturation, ECGs, and other biosensors) has made it feasible to use cloud processing capabilities to process this data and improve healthcare decisions. Consequently, the overall costs and strain on medical institutions are decreased.

*3.12. Smart Home*

The smart home is a key element of smart cities since it is essential to the residents' daily lives. Sensing units placed throughout a person's house are used in "smart homes" to gather data about the house and its residents. Motion trackers, environmental sensors, power/energy consumption, and other user activity monitors may be among these sensors.

*3.13. Smart Industry*

Globally, industries are constantly working to become more cost-effective, productive, and efficient. The idea of a linked factory with all of its intermediary functionaries seamlessly interconnected and cooperating with one another is part of the Industry 4.0 concept. The Internet of Things makes this possible. The industry has benefited from the use of IoT in manufacturing and production processes, cyber-physical systems that integrate workers and machines, and improved and faster innovation, as well as improved product quality, safety for factory workers, and optimization of manufacturing schemes (resources and processes). However, there are a number of obstacles to IoT use in smart industries. For example, managing a collection of diverse machines and devices presents unique difficulties, necessitating cyber-physical systems with adaptability, connectivity, and speed for use in IoT services for smart industries. IoT and AI have worked together to promote the creation and implementation of Industry 4.0 services. Data from these sources offers the chance to use AI approaches to boost automation, carry out business intelligence operations, and more because sensors are integrated into machines and other manufacturing processes. Indeed, scholars have proposed frameworks for incorporating AI into the Internet of Things for Smart Industry. Production management, monitoring/fault detection (machine health), and predictive maintenance are the three main uses of AI in the sector.

*3.14. Smart Infrastructure*

The quality of life in a city is greatly influenced by its infrastructure; municipal governments must develop new roads, bridges, and buildings for the benefit of its citizens and maintain existing ones to ensure continuous use. Through the use of accelerometers, smart materials, and sensors to measure the structural state of buildings and bridges, smart infrastructure assists communities in making sure their infrastructure is functional and in good condition. The information gathered by these sensors enables predictive repair of these crucial components to preserve the city's regular operations.

*3.15. Smart Transport*

Traffic difficulties, such as congestion, pollution, and challenges with public transportation planning and cost reduction, plague many urban areas. Communication between vehicles, infrastructure, and pedestrians has become widespread due to the quick development and deployment of new information and communication technologies. These technologies, whether they are Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), Vehicle to Pedestrian (V2P), or Pedestrian to Infrastructure (P2I), have enabled the development of intelligent transportation systems. Considering that all drivers own cellphones and that cars are equipped with GPS devices, numerous methods employ GPS data to monitor traffic patterns and driver behavior. Applications like Google Maps and Waze already use this real-time data for route planning, and public transportation already uses it for trip scheduling. Sensor-enabled parking systems can also direct cars to the closest available space.

## 4. Implementation and Experimental Results

*4.1. Technologies for Networking*

Data collected by individual sensor units positioned across the smart city environment is what makes the Internet of Things in smart towns work. For many years, there have been technologies that can use such measurements separately to automate small-scale tasks. But what makes a smart city "smart" is how the data from these separate sensing units is used together to make complicated decisions and provide services to the public. When this data is used collectively, it may be analyzed more broadly than when it is used at the individual level, allowing for the identification of long-term trends and the provision of insightful information to support services. Currently, there are several times as many of these IoT devices worldwide as there are people. Wireless technologies must be utilized to allow these devices to share data since physical connections would be too expensive (anywhere they can be used) and would not meet the mobility requirements that are common in many applications for smart cities. By connecting computers, smartphones, and other electronic devices worldwide, the Internet has made it possible for information to be sent instantly between them.

**Table 1.**
Sensing Technologies by Smart City Module for IoT Smart Cities.

| Smart City Component | Sensor Type |
|---|---|
| Smart Agriculture | Ambient, chemist, hydraulic, other sensor |
| Smart City Service | Ambient, Chemical, Hydraulic, Presence, Other sensors |
| Smart Energy | Ambient, Electric, Motion |
| Smart Health | Biosensors, identification, Motion, Other Sensors |
| Smart Home | Ambient, Chemical, Electric, Hydraulic, Identification, Motion, presence, Other Sensor |
| Smart Industry | Ambient, Biosensor, Electric, Hydraulic, Identification, Motion, Other Sensor |
| Smart Infrastructure | Ambient, Motion, Electric, Other Sensors |
| Smart Transportation | Ambient, Chemical, Identification, Motion, Presence, Other Sensors |

Working with various sensor kinds, which may have distinct output data types, is a task that must be handled while dealing with several sensor types, as mentioned in the difficulties. An overview of the sensors utilized in each smart city element is shown in Table 1.

**Table 2.**
Network Technology Comparisons for IoT Smart Cities.

| Architecture | Technology | Frequency Medium | Data rate | Range | Topology |
|---|---|---|---|---|---|
| Home Area Network (HANs) | NFC | 125 KHz, 13.56 MHz/860 MHz | 106 Kbps, 212 Kbps or 424 Kbps | 10 cm | Point to point |
| | RFID | 125 KHz, 13.56 MHz/902–928 MHz | 4 Mbps [77] | 3–10 m | Point to Point |
| | Li-Fi | LED light | 1–3.5 Gbps [80] | 10 m | Point to point, Star, Mesh |
| | Bluetooth | 2 4 GHz | Up to 2 Mbps | 240 m | Star |
| | Z-wave | 868 MHz/900 MHz | 40–100 Kbps | 30 – 100 m | Mesh |
| | Zigbee | 868 MHz/915 MHz/2.4 GHz | 250 Kbps | Up to 100 m | Mesh, Star, Tree |
| | Wi-Fi | 2.4 GHz/5 GHz | 54 Mb/s, 6.75 Gb/s | 140 m 100 m | Tree |
| | 6LOWPAN [77] | 868 MHz/915 MHz/2.4 GHz | Up to 250 Kbps | 10 – 100 m | Mesh, Star |
| Field/Neighborhood Area Networks (FANs/NANs) | Wi - SUN | 868 MHz/915 MHz/2.4 GHz | Up to 300 Kbps | Up to 4 km | Star, Mesh |
| Wide Area Networks (WANs) | NB- IOT | Licensed LTE bands | 200 Kbps | 1–10 km | Tree |
| | LoRa WAN | 433 MHz/868 MHz/915 MHz | Up to 50 kbps | 5–20 km | Star of Star (nested Star) |
| | Sigfox | 433 MHz/868 MHz/915 MHz | 100 bps | 10–50 km | One-hop Star |
| | 3G | 1.8–2.5 GHz | 2 Mbps | - | Tree |
| | 4G | 600–5.925 GHz | up to 1 Gbps | - | Tree |
| | 5G | 600–80 GHz | Up to 20 Gbps | - | Tree |

However, since many applications lack edge devices with internet connectivity, the internet might not be the only way for IoT users to communicate. An application might be a local network of detectors that can communicate with one another and relay data to a hub, gateway, or central node using a multi-hop communications method. The gateway could be fixed and linked to the internet, sending any data that is monitored to the cloud for use or additional processing. A typical example of architecture of this kind is the smart home, where manufacturers create devices using proprietary or incompatible procedures for which a hub may be used. An example of such a system has been provided in, and several hubs are freely accessible. It may also be possible for devices throughout a program to use a variety of different protocols, yet the main hub may be able to connect with all of them. This section covers the various network topologies, kinds, and protocols utilized in Internet of Things programs for smart cities, as shown in Figure 5. Table 1 presents a comparison of various methods.

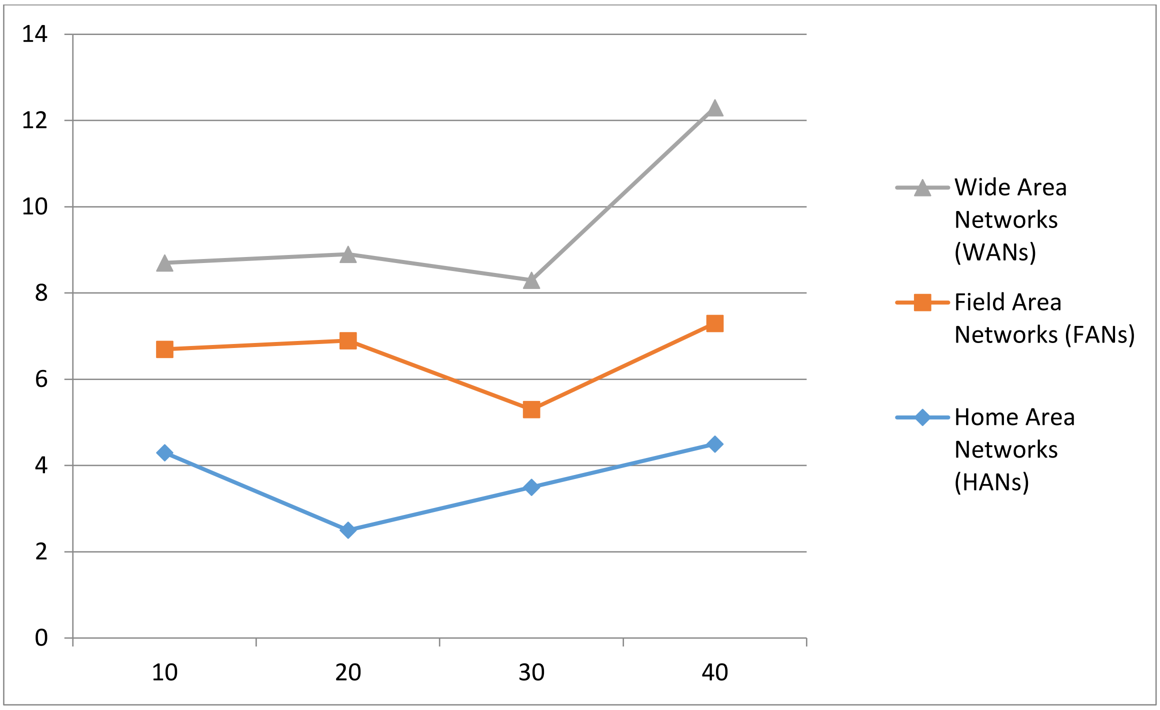


**Figure 5.**
IoT Smart City Network Technologies

Forecasting load and energy consumption is a crucial duty for keeping an eye on and managing the electrical grid's power supply and guaranteeing proper demand-side management. In order to assess load up to 24 hours in advance, the authors of the study used data gathered from smart grid users. They handle this as essentially a clustering problem, forming groups of similar load patterns and calculating future energy use using distance functions. The authors also employ a cloud-based clustering technique, utilizing past power data to identify the most closely related historical records using K-Means clustering. These records are then combined to forecast energy consumption 24 hours ahead of time. Using energy power data, the load prediction problem has been tackled as a regression using an SVM and an RNN. Those that utilize power usage along with environmental data for load forecasting using deep learning techniques (DNN and a combination of autoencoders and RNNs (GRU)) also employ a regression methodology.

**Table 3.**
Using AI in Smart Energy.

| Network | System Architecture | Task | Data Type |
|---|---|---|---|
| k-Means | Cloud | Clustering-Determine Clusters of Similar Power Consumption | Homogeneous (Electric Power) |
| K-NN | | Regression- predict consumption of electricity ahead of time | |
| SVM | | | |
| RNN {LSTM} | | | |
| DNN | | | Heterogeneous (Electric power, Temperature, Humidity, Time, Holiday) |
| SAE+RNN (GRU) | | | |
| CNN | Edge | | |
| RNN {GRU} | | | Homogeneous (Electric Power) |
| RNN {LSTM} | | | |
| DT | Cloud | Classification-Different Powerline events | Homogeneous (Electric Power) |
| CNN | Cloud | Classification- Theft detection for abnormal patterns of Consumption | Homogeneous (Electric Power) |

Another essential use in this field is smart grid management/monitoring, in addition to load forecasting. To distinguish between various smart grid issues, the authors employ decision chains in a cloud-based approach. Using a cloud-based approach, the authors analyze power usage data from Chinese consumers to identify instances of electricity theft. They demonstrate the suitability of their network for detecting electricity theft by employing deep and wide convolutional neural networks to extract the periodic and nonperiodic elements from kWh data. A framework for energy system surveillance based on edge computing is presented by the authors. There are a number of benefits to edge computing in the smart grid, including decreased latency and data privacy protection. Table 3 gives an overview of the application of IoT-based AI in Smart Energy.

**Table 4.**
Using AI in Smart Health

| Application | Network | System Architecture | Task | Data Type |
|---|---|---|---|---|
| Human activity recognition/Fall detection | DT | Cloud | Classification- different Activities, fall/non-fall | Heterogeneous |
| | RF | | | Homogeneous |
| | CNN | | | |
| | RNN (LSTM) | Fog Edge | | Heterogeneous |
| | CNN | Fog | | |
| | RF | Edge | | Heterogenous |
| | SVM | | | |
| Patient Health Monitoring | DT | C<br><br>loud | Classification- Recommendation about diet, etc | Heterogeneous |
| | SVM | | Classification—Different emotions | Heterogeneous |
| | RNN(LSTM) | | | Heterogeneous |
| | CNN- SAE | | Classification—Abnormal/normal heart sounds | Homogeneous |
| | RF | | Classification—Epileptic Seizure Detection | Homogeneous |
| | SVM | | Classification—ECG arrhythmias | Homogeneous |
| Disease diagnosis | DT | Cloud | Classification—Different heart diseases | Heterogeneous |
| | K-Means | | Classification—Kidney, Heart and Liver disease | Heterogeneous |
| | RF | | Classification—Detection of various diseases | Heterogeneous |
| | DNN | Fog | Classification | Heterogeneous |
| Parkinson detection | RF | Cloud | Classification—Parkinson detection/stroke has happened/seizure detection | Heterogeneous |
| Seizure monitoring | SVM | | | Homogeneous |
| | K-NN | Fog | | |
| | NB | Edge | | Homogeneous |

The two main uses of IoT and AI in health are disease diagnosis and health monitoring, and the recognition of activities and fall detection. Table 4 provides an overview of the IoT-based AI systems utilized in Smart Health. Recognition of activities uses movement sensors, like accelerometers, gyroscopes, and magnetometers, to help give the user feedback on how healthy they are, including whether they are getting enough exercise. It is also used for sports therapy, fall detection, and the monitoring of various diseases, including Parkinson's disorder and other motor degenerative disorders. Utilizing a variety of deep and machine learning methods, inertial sensors are the most widely utilized detectors for identifying activities in cloud-based environments. Using the DT as their classifier, Castro et al. incorporate mobility data and vital sign data for the purpose of identifying human activity in a cloud setting.

## 5. Conclusion

Security and privacy issues have grown in importance because of the deployment of numerous smart technologies, and they require quick fixes. Furthermore, when designing and implementing new smart systems, it is crucial to take privacy and security risks into account. The security and privacy concerns in the applications of information-centric smart cities have been examined and discussed in this study. Additionally, we offered several privacy and security options for different information-centric smart city applications. Finally, we discussed a few unresolved research questions that need to be carefully considered to improve the security and privacy of smart cities.

Information security in a smart city is a complex topic that encompasses social, economic, structural, and governance elements. To support much-needed research in tackling the problem areas in smart city security, this paper offers a thorough analysis of the risks, weaknesses, and viable solutions. The implementation and upkeep of a smart city heavily relies on technology. Technology is what creates and sustains smart cities to provide the promised benefits.

However, the importance of researching a smart city's security in relation to socioeconomic and governance aspects aids in determining the security needs and issues of the relevant stakeholders. The benefits of the promised amenities and features of a smart city could be undone by the severe consequences of inadequate security. If there are security flaws in the system, the great functionality of smart solutions would be rendered useless. The security of a distributed system must be guaranteed by the decision-making authority and smart solution manufacturers, who are both stakeholders.

## References


[1] C. Ma, "Smart city and cyber-security; technologies used, leading challenges and future recommendations," *Energy Reports*, vol. 7, pp. 7999–8012, 2021. https://doi.org/10.1016/j.egyr.2021.07.028

[2] H. Omrany, K. M. Al-Obaidi, M. Hossain, N. A. Alduais, H. S. Al-Duais, and A. Ghaffarianhoseini, "IoT-enabled smart cities: A hybrid systematic analysis of key research areas, challenges, and recommendations for future direction," *Discover Cities*, vol. 1, no. 1, p. 2, 2024. https://doi.org/10.1007/s44280-023-00002-0

[3] H. Zeng, M. Yunis, A. Khalil, and N. Mirza, "Towards a conceptual framework for AI-driven anomaly detection in smart city IoT networks for enhanced cybersecurity," *Journal of Innovation & Knowledge*, vol. 9, no. 4, p. 100601, 2024. https://doi.org/10.1016/j.jik.2024.100601

[4] J. Ali *et al.*, "A deep dive into cybersecurity solutions for AI-driven IoT-enabled smart cities in advanced communication networks," *Computer Communications*, vol. 229, p. 108000, 2025. https://doi.org/10.1016/j.comcom.2024.108000

[5] F. Al-Turjman, H. Zahmatkesh, and R. Shahroze, "An overview of security and privacy in smart cities' IoT communications," *Transactions on Emerging Telecommunications Technologies*, vol. 33, no. 3, p. e3677, 2022. https://doi.org/10.1002/ett.3677

[6] D. Ahlers, "Making sense of the urban future: Recommendation systems in smart cities," in *CEUR Workshop Proceedings*, 2020.

[7] M. Batty *et al.*, "Smart cities of the future," *The European Physical Journal Special Topics*, vol. 214, pp. 481-518, 2012. https://doi.org/10.1140/epjst/e2012-01703-3

[8] L. Quijano-Sánchez, I. Cantador, M. E. Cortés-Cediel, and O. Gil, "Recommender systems for smart cities," *Information Systems*, vol. 92, p. 101545, 2020. https://doi.org/10.1016/j.is.2020.101545

[9] S. E. Bibri and J. Krogstie, "Smart sustainable cities of the future: An extensive interdisciplinary literature review," *Sustainable Cities and Society*, vol. 31, pp. 183-212, 2017. https://doi.org/10.1016/j.scs.2017.02.016

[10] T. Singh, A. Solanki, S. K. Sharma, A. Nayyar, and A. Paul, "A decade review on smart cities: Paradigms, challenges and opportunities," *IEEE Access*, vol. 10, pp. 68319-68364, 2022. https://doi.org/10.1109/ACCESS.2022.3184710

[11] A. S.Syed, D.Sierra-Sosa, A. Kumar, and A.Elmaghraby, "IoT in smart cities: A survey of technologies practices and challenges," *Smart Cities*, vol. 4, no. 2, pp. 429-475, 2021.

[12] A.Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of things for smart cities," *IEEE Internet of Things journal*, vol. 1, no. 1, pp. 22-32, 2014.

[13] M. Talebkhah, A. Sali, M. Marjani, M. Gordan, S.J. Hashim, and F.Z. Rokhani, "IoT and big data applications in smart cities: recent advances, challenges, and critical issues," *IEEE Access*, vol. 9, pp. 55465-55484, 2021.

[14] M. Janssen, S. Luthra, S. Mangla, N.P. Rana, and Y.K. Dwivedi, "Challenges for adopting and implementing IoT in smart cities: An integrated MICMAC-ISM approach," *Internet Research*, vol. 29, no. 6, pp. 1589-1616, 2019.

[15] L. Belli, A. Cilfone, L. Davoli, G. Ferrari, P. Adorni, F. Di Nocera, and E. Bertolotti, "IoT-enabled smart sustainable cities: Challenges and approaches," *Smart Cities*, vol. 3, no. 3, pp. 1039-1071, 2020.

[16] Y. Alshamaila, S. Papagiannidis, H. Alsawalqah, and I. Aljarah, "Effective use of smart cities in crisis cases: A systematic review of the literature," *International Journal of Disaster Risk Reduction*, vol. 85, pp. 103521, 2023.

[17] M.N. Kamel Boulos and N.M. Al-Shorbaji, "On the Internet of Things, smart cities and the WHO Healthy Cities," *International journal of health geographics*, vol. 13, pp. 1-6, 2014.