

The Role of IoT in Shaping Smart Cities with Architectural Perspective

Md Shahbaz Alam^{1*}, Mukesh Asati², Rakesh Kumar Tiwari³

Abstract

The integration of IoT in smart cities is revolutionizing the development of cities through interconnected systems that enhance efficiency, sustainability, and quality of life. Real-time data collection, communication, and processing are facilitated by IoT technology through its layered architecture: sensing, network, and application layers. These interlinked ecosystems help solve such serious problems of urbanization as the efficient allocation of resources, smooth flow of traffic, efficient utilization of energy, and the handling of waste, apart from services to citizens. Solutions in the form of smart grids, intelligent traffic systems, and IoT-based waste management systems are examples of the influence IoT has on the architecture and public services. Nonetheless, there are challenges about interoperability, scalability, security, and real-time processing when IoT is applied to the smart city. Emerging technologies such as artificial intelligence, edge computing, and blockchain will play an important role in IoT, giving advanced analytics, low latency, and secured data sharing. In addition, IoT contributes to sustainable and resilient urban environments through predictive maintenance, disaster preparedness, and environmental monitoring. The study therefore puts forward the potential of IoT as the backbone of future smart cities in developing adaptive, efficient, and inclusive urban ecosystems. Through advanced technologies and architectural challenges, IoT promotes sustainable urban growth and enhanced living standards for citizens worldwide.

Keywords: Internet of Things (IoT), smart cities, urban development, IoT architecture, smart infrastructure, sustainability, scalability, interoperability, edge computing, artificial intelligence (AI), blockchain, real-time data processing, public services, resource optimization, citizen engagement, environmental monitoring, disaster preparedness

*Author for Correspondence

Md Shahbaz Alam
E-mail: myselfalamshahbaz15@gmail.com

¹M.Tech. Scholar, Department of Computer Science and Engineering, Technocrats Institute of Technology and Science, Technocrats Group Campus, Anand Nagar, Bhopal, Madhya Pradesh, India

²Assistant Professor, Department of Computer Science and Engineering, Technocrats Institute of Technology and Science, Technocrats Group Campus, Anand Nagar, Bhopal, Madhya Pradesh, India

³Head, Department of Computer Science and Engineering, Technocrats Institute of Technology and Science, Technocrats Group Campus, Anand Nagar, Bhopal, Madhya Pradesh, India

Receiving Date: March 22, 2025

Accepted Date: March 24, 2025

Published Date: May 16, 2025

Citation: Md Shahbaz Alam, Mukesh Asati, Rakesh Kumar Tiwari. The Role of IoT in Shaping Smart Cities with Architectural Perspective. Journal of Control & Instrumentation. 2025; 16(2): 1–10p.

INTRODUCTION

This can be described as the system of connected devices, sensors, and systems through the internet for communication with themselves and exchanging information without humans. IoT includes everything, from simple appliances in homes, to more complex industrial machinery and components of urban infrastructures. IoT enables data collection, analysis, and automated responses in real time, thus creating an intelligent ecosystem that enhances efficiency and functionality across various domains [1]. It acts as a foundational technology to achieve automation, integration, and advanced decision-making in various sectors, such as healthcare, transportation, and urban management. Smart cities, instead, are smart urban communities that utilize state-of-the-art technologies, especially the Internet of Things, for the betterment of their citizens' lifestyles, maximize resource usage, and drive

sustainable development. A smart city is thus an entity that integrates its infrastructure using digital solutions: IoT-based smart grids, intelligent transport systems, connected public services, and much more, to make its urban area more efficient, livable, and environmentally friendly [2]. Smart cities enable better governance, reduce operational costs, and provide citizens with innovative services that respond dynamically to their needs by embedding IoT in their architecture.

IoT is transforming the function, operation, and delivery of services to citizens by the cities. The rapid rate at which the world is undergoing urbanization brings about such challenges as overcrowding, resource depletion, inefficient public services, and environmental degradation. However, IoT addresses all this by ensuring that the cities work smarter using data-driven solutions to improve planning, governance, and sustainability. With the implementation of IoT technologies in the infrastructure of cities, water, electricity, and transportation resources can be monitored and managed in real-time for better use and wastage control [3]. It gives a boost to the efficient operation and saves money simultaneously as the quality of service increases for the citizens. Public services and infrastructure management are some of the huge contributions that can be done by IoT towards the urban transformation. For example, smart grids along with IoT-powered solutions assist the city in becoming smart through the connection of traffic systems. For instance, a smart grid monitors energy consumption patterns and adjusts its supply to the demand side as this minimizes energy wastage [4]. Similarly, IoT-based smart intelligent traffic systems collect information from sensors, cameras, and connected vehicles to help mitigate congestion, optimize the flow of traffic, and increase road safety. In the same vein, IoT assists in waste management through smart bins and collection systems that alert authorities when the bins are full, allowing collection schedules to be adjusted for less environmental impact. All these innovations illustrate how IoT can transform cities into efficient, responsive, and citizen-centric environments.

IoT also supports sustainability and resilience in cities through enablers such as active decision-making and preparedness for disasters. Sensors embedded in the critical infrastructure, such as bridges and buildings, monitor the structural integrity and detect potential failures and allow for timely intervention that would prevent catastrophic events [5]. Moreover, IoT technologies can predict and manage environmental risks such as flood or air pollution through weather station data, water level sensor data, and air quality monitor data. Real-time insights and actionable intelligence in IoT empower city administrators to take proper decisions for promoting urban resilience, protecting citizens, and achieving long-term sustainability objectives. This all-round approach to urban transformation places IoT at the heart of building smarter, more livable cities for the future.

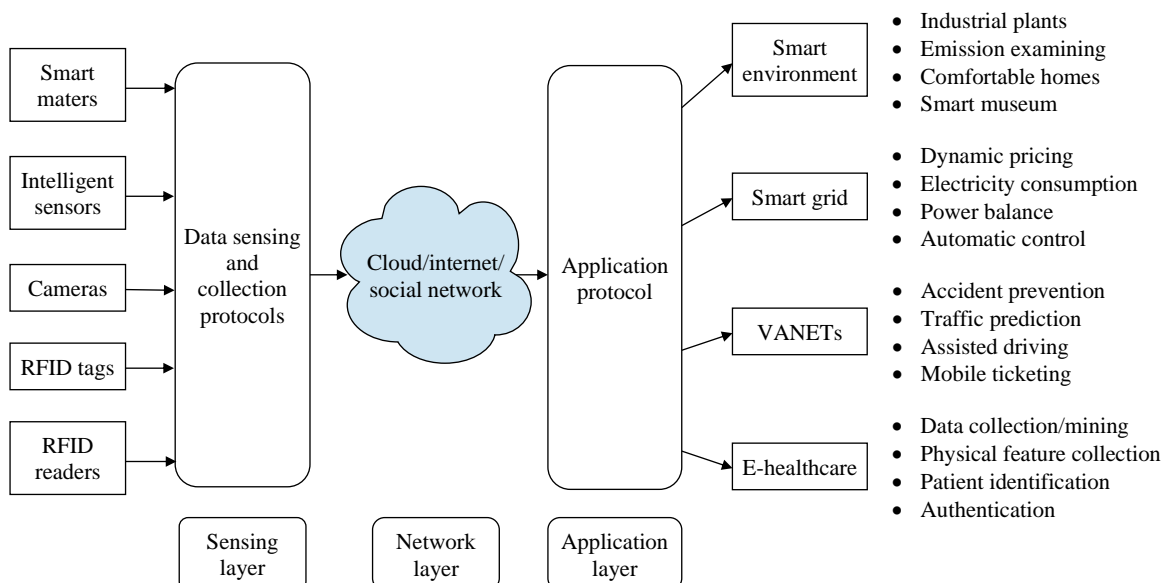


Figure 1. Cloud-based IoT architecture [6].

Figure 1 shows the typical structure of an IoT architecture for smart cities, divided into three tiers: the sensing layer, the network layer, and the application layer [6]. The information from devices, such as smart meters, intelligent sensors, cameras, RFID tags, and readers, is garnered by the sensing layer. That information is sent to the application layer over the network layer using clouds, internet, or even social networks. In processing this data, the application layer is used for very specific use cases, namely smart environments (industrial plants, emission monitoring) and smart grids (dynamic pricing, power balance); vehicular networks (traffic management, accident prevention); and e-healthcare with patient identification and data mining as very popular services. This layered architecture catches the interconnected and dynamic nature of IoT in enabling smart, efficient solutions for areas in cities.

IOT ARCHITECTURE IN SMART CITIES

The three interconnected layers making up the IoT architecture for smart cities include the sensing, network, and application layer, which collectively enable seamless collection, communication, and smart decision-making. The devices that constitute the sensing layer capture real-time data from the urban space, such as cameras and sensors, as well as smart meters [7]. All the above information is communicated by the network layer, based on cloud platforms, internet protocols, and social networks to maintain safe and efficient communication. The application layer processes the above information to support all various applications of an urban environment including: smart environments (emission control, smart homes), smart grids (energy optimization, dynamic pricing), vehicular networks (traffic management), and e-healthcare (patient monitoring). This architecture creates a cohesive IoT ecosystem that addresses urban challenges, optimizes resource usage, and enhances the quality of life in smart cities.

IoT architecture is divided into four primary parts: sensors, networks, cloud infrastructure, and data analytics. All these elements work hand in hand to facilitate the IoT systems for smart cities. Sensors are the heart of IoT architecture. It is the source from where data is collected from the environment. These devices are temperature sensors, motion detectors, RFID tags, cameras, and smart meters that track traffic flow, energy consumption, levels of pollution, and waste management. Sensors are the physical interface between the IoT system and the real world. Therefore, it is ensured that there is availability of accurate and real-time data for analysis and decision-making. This information, as collected by sensors, is transmitted through networks to centralized or distributed processing systems [8]. Technologies such as Wi-Fi, 4G/5G, LoRa, ZigBee, and Bluetooth are used to enable seamless communication between IoT devices in networks. The information that reaches the cloud infrastructure is stored, managed, and processed on scalable platforms able to process large volumes of data. This is then followed by data analytics in which advanced algorithms and machine learning models are applied to arrive at actionable insights. Raw data, through data analytics, gets transformed into meaningful outputs [9]. This allows smart applications like predictive maintenance, energy optimization, and real-time traffic management, making the IoT systems the backbone of smart city functionality.

Architectural Frameworks for Smart Cities

These architectures in a smart city take a layered approach and mainly involve three elements: perception, network, and the application layer; each takes on an indispensable role in operating the IoT system smoothly. Undergirding this architecture lies a sensing layer composed of sensors, actuators, and any other form of devices with internet enabled that senses and captures data of what goes on physically around the environment in real time [10]. The layer basically allows interaction between the two dimensions through sensing important information on things like temperature, quality of air, traffic movement patterns, consumption of energy and the waste levels. In addition to data gathering, these sensors and devices are able to provide control functionalities, such as changing the lighting, sounding alarms, or opening smart infrastructure gates with the preconditions. The function of the perception layer ensures real-time and accurate data are given to underpin smart city systems. It ensures the digital infrastructure is an exact reflection of the state of the physical environment.

Information at the perception layer is collected and transmitted across the IoT framework's communication backbone; that is the network layer. The data transmitted by these layers is guaranteed

to arrive accurately and securely and processed afterwards through centralized cloud infrastructure or other distributed systems. Technologies with smart communication protocols which are associated with the use in this layer include ZigBee, Wi-Fi, 5G, Bluetooth, LoRa. On top of this framework is the application layer, where data is analyzed and transformed into actionable insights for end-users and administrators [11]. It allows for applications such as intelligent traffic management systems, dynamic energy grids, predictive maintenance of urban infrastructure, and improved public services like healthcare and waste management. By converting raw data into meaningful outputs, it enables the application layer, which makes responsive, adaptive, and citizen-centric solutions capable of making smart city ecosystems efficient, scalable, and well-equipped to address complex challenges in urban areas. Together these layers form a comprehensive and modular IoT framework that is in fact required to manage the resources effectively, which goes on to ensure the sustainability and livability of modern cities.

Integration Challenges in IoT Architectures

Interoperability is one of the major challenges in IoT architecture. Interoperability pertains to the interaction of disparate devices, systems, and protocols working well together under a harmonized IoT ecosystem. The nature of deploying IoT devices from more than one manufacturer with different standards and communication protocols makes this challenging. Devices often come incompatible due to proprietary designs which make them hard to piece together into a coherent whole [12]. For example, a smart city can have its traffic management network using one protocol and its energy grid using another, therefore creating fragmentation and inefficiency. To ensure smooth and seamless data exchange and communication between these heterogeneous devices necessitates the adoption of some universal standards or middleware that acts as a translator of different systems [13]. Without interoperability, the potential of IoT systems is severely limited, since siloed data and fragmented networks fail to deliver the holistic insights necessary for smart city operations.

Another important challenge is scalability, especially in smart cities where IoT systems need to support exponential growth in the number of connected devices and volumes of data. With increasing urban areas and increased technology adoption, IoT architectures must scale to support millions of interconnected devices without performance degradation [14]. However, the rapid expansion often fails traditional network infrastructures, causing bottlenecks, latency, and decreased efficiency. In addition, managing the storing and processing of such an enormous amount of data generated by IoT devices is straining cloud infrastructure and local servers. Scalable architectures must have strong network designs and edge computing to distribute close data processing to the original source in order to remove the load from centralized systems [15]. Failure to consider scalability may cause system breakdown, reduced reliability, and an inability to fulfill the needs of growing smart city applications.

Lastly, real-time processing is the final challenge of IoT architectures for many applications, especially when an instantaneous decision-making application exists. For example, several smart city systems rely on the capacity to process data in real time as generated to act in a matter of minutes [16]. The required computing capability for such operations includes low-latency networks, edge computing, and optimized algorithms. While all of these issues are complex, the massive quantity and speed of data emanating from IoT devices may drown many existing systems, causing inefficiency and delay. Moreover, this system calls for real-time processing of data with accuracy, security, and privacy, thereby adding complexity to the whole challenge. This can be overcome by adopting technologies like 5G for speed communication, AI-driven analytics to provide rapid insights, and distributed processing to offload computations [17]. Without effective real-time processing, critical applications of IoT may not have the desired impact, affecting the effectiveness of smart cities.

APPLICATIONS OF IOT IN SMART CITIES

The applications of IoT in smart cities are broad and transformative, solving the critical urban challenges and improving the quality of life for citizens. One prominent area is the management of smart infrastructure. It optimizes the performance and efficiency of the key services such as

transportation, energy, and waste management using IoT-enabled systems [18]. For example, IoT sensors placed within roads and traffic signals can help reduce congestion and enhance road safety through intelligent traffic management systems. In a similar manner, smart grids that use IoT devices, monitor and optimize energy consumption to ensure balanced supply and demand with reduced wastage. IoT further facilitates waste management systems through the use of smart bins, which send alerts to relevant authorities whenever they are filled up. This enhances schedules for collections and reduces their impacts on the environment [19]. These applications do not only make operations efficient but also contribute to developing a more sustainable and environmentally-friendly urban landscape.

Public safety and citizen services have been another critical application of IoT in smart cities, such as IoT surveillance system with smart cameras and sensors, which improves the efficiency of security by giving space for real-time emergency responses [20]. Healthcare through IoT devices is done remotely to monitor patients, trigger alert signals, and data capture for better access and healthcare infrastructure decongestion. Furthermore, IoT enables citizen engagement by providing real-time information through mobile applications and service platforms on public transport, parking availability, and weather updates. IoT also helps in disaster management by incorporating sensors that monitor environmental risks, such as floods or earthquakes, to give early warnings and better preparation. Together, these applications show how IoT fosters safer, more connected, and resilient urban environments, making cities smarter and more livable.

Smart Infrastructure Management

IoT-enabled solutions revolutionize transportation infrastructure in smart cities by enhancing the flow of traffic, reducing congestion, and making roads safer. The IoT sensors installed in the roads, traffic lights, and vehicles collect real-time data on the traffic patterns that are analyzed to optimize signal timings, reroute the vehicles, and reduce bottlenecks [21]. ITS also equips commuters with live information about the traffic situation, parking spaces, and schedules of public transportation through mobile applications to help make smarter choices in travel. IoT-enabled vehicles and Vehicle-to-Everything (V2X) communication contribute to accident prevention by sharing vital information about road hazards and speed limits [22]. All these innovations help make the journey smoother, safer, and more efficient for urban mobility while reducing the environmental footprint of transportation systems.

Correspondingly, the infrastructure for energy and waste management in smart cities depends very much on IoT. For instance, with its sensor systems, smart grids constantly measure energy consumption patterns for immediate and dynamic pricing, more efficient energy distribution, and swift identification of outages [23]. Likewise, with IoT, renewable sources, like solar panels and wind turbines, are incorporated into a network that can power smart cities without relying much on non-renewable resources. In waste management, IoT-enabled smart bins are equipped with sensors that detect when they are full and notify collection services, thereby ensuring timely and efficient waste disposal [24]. By analyzing data from these systems, city administrators can optimize waste collection routes, reduce operational costs, and minimize environmental pollution. All these IoT-powered solutions enhance the efficiency, sustainability, and resilience of urban infrastructure to pave the way for smarter and more livable cities.

Public Safety and Security

IoT plays a very crucial role in the enhancement of surveillance and crime prevention in smart cities through real-time monitoring and intelligent response systems. IoT-enabled security cameras using AI and facial recognition capabilities will be able to identify suspicious activities, potential threats, and immediately notify the appropriate law enforcement agencies. Smart sensors in public parks and streets monitor unusual sounds, movements, or changes in the environment, for example, broken glass or shots. These sensors raise alerts immediately to the authorities involved [25]. These advanced surveillance systems deter criminal activities and support critical evidence gathering for proper investigations. In addition, streetlights connected to IoT, equipped with motion sensors, automatically change brightness to improve safety and visibility in risky locations.

IoT also helps strengthen emergency response and disaster management by facilitating faster and better-coordinated responses to emergencies. Sensors and IoT devices monitor environmental conditions such as air quality, water levels, or seismic activity, giving early warnings of natural disasters like floods, wildfires, or earthquakes. IoT systems can guide evacuation efforts during emergencies by sharing real-time information through connected devices, such as mobile apps or digital signboards, to help people reach safe zones. IoT-enabled healthcare systems contribute to public safety by providing real-time patient monitoring and ensuring timely medical assistance during emergencies [26]. Furthermore, IoT solutions integrate into emergency response services, whereby first responders can access key information such as building schematics or where trapped victims are located to enable quick and efficient rescues. This application is one of many that illustrate how IoT creates resilient and safe urban areas, hence smart cities can be better secured and able to respond to issues more appropriately.

Citizen Engagement and Services

IoT greatly enhances public services by providing real-time, data-driven solutions that benefit citizens directly and optimize urban operations. Connected systems update residents in real-time on public transport schedules, parking availability, and road conditions, making it easier for them to plan their commutes. Mobile applications powered by IoT provide users with access to a wide range of city services, such as reporting infrastructure issues, accessing utility bill information, or reserving public facilities. The smart city platform also integrates feedback mechanisms where citizens can share their complaints or suggestions, promoting mutual collaboration between the public and local authorities [27]. The instruments improve the efficiency and responsiveness of public services as well as the general experience for people living in cities. IoT is equally important as it enhances urban standards of living by offering more convenience and sustainability with ease of use in everyday life. One can control the smart home connected to the IoT system even from another town by remoting in through lighting heating and security. In such public places, IoT-integrated lights and energy efficiency systems ensure that resources are used without overusing in order to minimize both energy wastes and environmental pollution. IoT also gives rise to cleaner urban environments through applications like smart waste management, air quality monitoring, and water conservation systems [28]. Such applications make sure that the urban spaces are functional as well as healthy and sustainable for lifestyle.

The IoT fosters an open and inclusive citizen participation due to its transparency in showing the gaps between city government and residents. Real-time updates of public programs can be shown through IoT-powered apps and sites on events occurring soon, emergency alerts, or many others [29]. Residents can also interact with their local governments through digital platforms, accessing services or contributing to decision-making processes. This level of interactivity empowers citizens, enhances trust in public administration, and ensures that urban development is aligned with the needs and preferences of the population. Overall, IoT enables a citizen-centric approach to urban management, fostering a sense of ownership and shared responsibility in the development of smarter cities.

ARCHITECTURAL CHALLENGES AND INNOVATIONS

Architectural challenges within IoT systems in smart cities include interoperability, scalability, security, and real-time processing, and all these are taken care of to deliver efficient and robust urban solutions. The variability of the devices and protocols with which these devices communicate results in massive interoperability problems. This therefore calls for a standardized framework or middleware. One key point is scalability as IoT devices have to sustain the high explosion growth of connected items and, indeed the volumes of information that correspond thereto as cities expand in size [30]. Robust security and strong privacy are necessary because systems become a prime cyberattack candidate, compromising personal data while degrading services to an alarming level. Applications such as traffic management and disaster response require real-time processing, which requires the use of advanced computing solutions such as edge computing and 5G networks. Blockchain technologies that enable secure data sharing, AI-driven analytics that help in predictive decision-making, and modular architectures that allow flexible scaling are addressing these challenges to make way for more resilient, adaptive, and efficient IoT ecosystems in smart cities.

Security and Privacy in IoT Architectures

Security and privacy are a major concern in IoT architectures, particularly in smart cities, where massive amounts of sensitive data are collected, transmitted, and processed. Due to the large number of devices connected and the heterogeneity of communication protocols, IoT systems are inherently vulnerable to cyber threats, which can be used to compromise data integrity, disrupt services, or gain unauthorized access to critical infrastructure [30]. For example, a breach into a smart grid or traffic management could cause widespread disruptions and put the public at quite a risk. It is achieved through robust encryption protocols; secure authentication mechanisms; and constant monitoring for potential threats or vulnerabilities. Blockchain technology might be used to enhance security, as blockchains provide decentralized and virtually tamper-proof data storage. AI-powered anomaly detection systems can identify and automatically respond to cyberattacks.

Privacy is another major challenge because IoT systems often collect highly sensitive personal and behavioral data from citizens. This includes information from surveillance cameras, health monitoring devices, and smart home systems, which, if mishandled, can lead to privacy violations or misuse. Data protection ensures that there are strict access controls, anonymization of sensitive data, and compliance with regulations such as GDPR and CCPA [31]. Trust among citizens is established by the transparency in data collection, storage, and use. Privacy-by-design in IoT architectures needs to be inculcated, wherein privacy measures are integrated within the system at the conceptualization stage rather than becoming an afterthought. The security and privacy of the smart city's IoT system can be taken care of by ensuring proper working and ethical operation to build confidence among users while making urban innovations successful.

Scalability and Interoperability Solutions

Scaling issues also appear within the architecture as smart cities are extended to accommodate an increasingly growing number of connected devices, generating significant data volumes. In the meantime, traditional centralized architectures will struggle to accommodate these needs in relation to network congestion, latency, and diminished performance [32]. Innovation, in this regard, is through edge computing and fog computing, that helps in the distribution of processing near to the source of data, so it is not overburdened on the centralized cloud system, and it also has to provide faster response times. The other important role is scalable cloud platforms with elastic capabilities that allow resources to be dynamically allocated based on demand. Furthermore, 5G networks ensure high bandwidth and low latency that is necessary to enable high-density devices in smart cities. The solutions help ensure that IoT systems scale effortlessly without efficiency or reliability losses.

Interoperability is the critical component in the integration of all the various devices and systems used in IoT ecosystems. Fragmented networks, due to lack of standardization in communication protocols and device frameworks, make it less effective for IoT applications. Therefore, open standards and frameworks such as MQTT, CoAP, and IoT are being implemented to enable seamless communication across heterogeneous devices. Middleware solutions translate among different protocols to allow integration with minimal modification to previous systems [33]. One of the new emerging technologies is the digital twin technology, which further supports interoperability through the virtualization of physical assets. With all of these innovations, smart cities would be able to construct an interconnected, scalable, and interoperable IoT network capable of delivering a unified and effective urban solution.

Emerging Technologies Enhancing IoT Architectures

The use of emerging technologies like Artificial Intelligence and edge computing is changing the architectures of IoT in smart city systems to be more efficient and intelligent. AI is playing a key role by analyzing the huge amount of data that IoT devices produce to find patterns, predict outcomes, and make decisions autonomously. For example, in the area of traffic management, algorithms which depend on AI can shift signal-timing accordingly, keeping into mind real-time flows and consequently reducing congestion, while it boosts mobility. Similarly, predictive maintenance improves owing to

data interpretation by an AI-driven process from sensors set in bridges or pipelines for prevention before failure [34]. In the system reliability, it guarantees, at the same time, cost is decreased. With this comes the closeness of processing data closer to where they are needed, making the occurrence of real-time decisions along with reduced latency. Such instances, where milliseconds count, for example, in autonomous vehicle or disaster response, with Edge Computing ensure that the core operations of critical nature can be executed without any latencies, so overall efficiency and responsiveness of an IoT system is enhanced.

Another emerging innovation working through IoT architecture is Blockchain Technology. Blockchain ensures safe data sharing between IoT devices and stakeholders through a decentralized and tamper-proof ledger. This is highly valuable in applications such as energy trading in smart grids where blockchain can facilitate transparent and secure peer-to-peer transactions [35]. Moreover, with blockchain integrity, unauthorized amendments are out of question, making it extremely fit to applications that require strong trust values, such as a healthcare or public safety system record. When combined with AI and edge computing, it represents a robust IoT-based ecosystem. Data is efficiently processed not only but also protects it from cyber threats. These technologies empower smart cities to implement scalable, secure, and intelligent IoT architectures, which help innovate and improve sustainability in the urban ecosystem.

CONCLUSION

Smartness in integrating IoT in city spaces enables its ability to improve the quality of resource management in cities, quality in public service delivery, as well as increased value of citizen's life standards. A city's various interconnected layers of sensing and communication architecture plus application layers equips a city to adequately solve various problems such overcrowding and resource scarcity or lack, inefficient public service, or environmental degradation all of which are real time with bases of decision making. It focuses on architectures that optimize infrastructure in transportation, energy grids, and waste management, enhance public safety, and citizen engagement in the urban system. However, interoperability between different devices, scalability in support of rapid growth in IoT networks, security vulnerabilities, and real-time processing requirements are serious challenges. Emerging technologies, including AI, edge computing, and blockchain, are pivotal to helping overcome such challenges since they facilitate analytics in making predictive decisions, cut down latency, and secure tamper-proof data. Collectively, these advancements form an integrated, dynamic IoT framework that contributes to sustainable growth of the city; further, these enhance citizen involvement as transparent processes, guaranteeing safe cities, interconnected and vibrant for citizens to live, marking IoT as the very fabric of future smart cities.

REFERENCES

1. Dahmane WM, Ouchani S, Bouarfa H. Smart cities services and solutions: A systematic review. *Data and Information Management (DIM)*. 2024; 100087. <https://doi.org/10.1016/j.dim.2024.100087>
2. Okonta DE, Vukovic V. Smart cities software applications for sustainability and resilience. *Heliyon*. 2024; 10(12): e32654. <https://doi.org/10.1016/j.heliyon.2024.e32654>
3. Khemakhem S, Krichen L. A comprehensive survey on an IoT-based smart public street lighting system application for smart cities. *Franklin Open*. 2024; 8: 100142. <https://doi.org/10.1016/j.fraope.2024.100142>
4. Alam T. Metaverse of Things (MoT) applications for revolutionizing urban living in smart cities. *Smart Cities*. 2024; 7(5): 2466–2494. <https://doi.org/10.3390/smartcities7050096>
5. Nguyen H, Nawara D, Kashef R. Connecting the indispensable roles of iot and artificial intelligence in smart cities: a survey. *Journal of Information and Intelligence*. 2024 May; 2(3): 261–285. <https://doi.org/10.1016/j.jiixd.2024.01.003>
6. Bera Tanushree, Kar Anwesha, Chandra Pretam, Nag Anindya. A Review on Cloud-Based Smart Applications. *Cham: Springer*; 2023; 387–403. 10.1007/978-3-031-27440-4_38.

7. Kanellopoulos D, Sharma VK, Panagiotakopoulos T, Kameas A. Networking architectures and protocols for IoT applications in smart cities: Recent developments and perspectives. *Electronics*. 2023; 12(11): 2490. <https://doi.org/10.3390/electronics12112490>
8. Nikpour M, Yousefi PB, Jafarzadeh H, Danesh K, Shomali R, Lonbar AG, Ahmadi M. Intelligent energy management with iot framework in smart cities using intelligent analysis: An application of machine learning methods for complex networks and systems. *arXiv preprint arXiv:2306.05567*. 2023. <https://doi.org/10.48550/arXiv.2306.05567>
9. Olaniyi OO, Okunleye OJ, Olabanji SO. Advancing data-driven decision-making in smart cities through big data analytics: A comprehensive review of existing literature. *Curr J Appl Sci Technol*. 2023; 42(25): 10–18. <https://ssrn.com/abstract=4546193>
10. Alahi MEE, Sukkuea A, Tina FW, Nag A, Kurdthongmee W, Suwannarat K, Mukhopadhyay SC. Integration of IoT-enabled technologies and artificial intelligence (AI) for smart city scenario: recent advancements and future trends. *Sensors*. 2023; 23(11): 5206. <https://doi.org/10.3390/s23115206>
11. Rafiq I, Mahmood A, Razzaq S, Jafri SHM, Aziz I. IoT applications and challenges in smart cities and services. *J Eng*. 2023; 2023(4): e12262. <https://doi.org/10.1049/tje2.12262>
12. Moudgil V, Hewage K, Hussain SA, Sadiq R. Integration of IoT in building energy infrastructure: A critical review on challenges and solutions. *Renew Sustain Energy Rev*. 2023; 174: 113121. <https://doi.org/10.1016/j.rser.2022.113121>
13. Abed SE, Jaffal R, Mohd BJ. A review on blockchain and IoT integration from energy, security and hardware perspectives. *Wirel Pers Commun*. 2023; 129(3): 2079–2122. <https://doi.org/10.1007/s11277-023-10226-5>
14. Adam M, Hammoudeh M, Alrawashdeh R, Alsulaimy B. A Survey on Security, Privacy, Trust, and Architectural Challenges in IoT Systems. *IEEE Access*. 2024. <https://doi.org/10.1109/ACCESS.2024.3382709>
15. Nguyen T, Nguyen H, Gia TN. Exploring the integration of edge computing and blockchain IoT: Principles, architectures, security, and applications. *J Netw Comput Appl*. 2024; 226: 103884. <https://doi.org/10.1016/j.jnca.2024.103884>
16. Rane N, Choudhary S, Rane J. Artificial Intelligence (AI) and Internet of Things (IoT)-based sensors for monitoring and controlling in architecture, engineering, and construction: applications, challenges, and opportunities. Available at SSRN 4642197. 2023. <https://dx.doi.org/10.2139/ssrn.4642197>
17. Elhanashi A, Dini P, Saponara S, Zheng Q. Integration of deep learning into the iot: A survey of techniques and challenges for real-world applications. *Electronics*. 2023; 12(24): 4925. <https://doi.org/10.3390/electronics12244925>
18. Salman MY, Hasar H. Review on environmental aspects in smart city concept: Water, waste, air pollution and transportation smart applications using IoT techniques. *Sustain Cities Soc*. 2023; 94: 104567. <https://doi.org/10.1016/j.scs.2023.104567>
19. Chataut R, Phoummalayvane A, Akl R. Unleashing the power of IoT: A comprehensive review of IoT applications and future prospects in healthcare, agriculture, smart homes, smart cities, and industry 4.0. *Sensors*. 2023; 23(16): 7194. <https://doi.org/10.3390/s23167194>
20. Hassebo A, Tealab M. Global models of smart cities and potential IoT applications: A review. *IoT*. 2023; 4(3): 366–411. <https://doi.org/10.3390/iot4030017>
21. Pandiyan P, Saravanan S, Usha K, Kannadasan R, Alsharif MH, Kim MK. Technological advancements toward smart energy management in smart cities. *Energy Rep*. 2023; 10: 648–677. <https://doi.org/10.1016/j.egy.2023.07.021>
22. Papastefanopoulos V, Linardatos P, Panagiotakopoulos T, Kotsiantis S. Multivariate Time-Series Forecasting: A Review of Deep Learning Methods in Internet of Things Applications to Smart Cities. *Smart Cities*. 2023; 6(5): 2519–2552. <https://doi.org/10.3390/smartcities6050114>
23. Hashem IA, Siddiq A, Alaba FA, Bilal M, Alhashmi SM. Distributed intelligence for IoT-based smart cities: a survey. *Neural Comput Appl*. 2024; 36(27): 16621–16656. <https://doi.org/10.1007/s00521-024-10136-y>

24. Alam T. Cloud-based IoT applications and their roles in smart cities. *Smart Cities*. 2021; 4(3): 1196–1219. <https://doi.org/10.3390/smartcities4030064>
25. Ali K, Nguyen HX, Vien QT, Shah P, Raza M, Paranthaman VV, Rodrigues JJ, et al. Review and implementation of resilient public safety networks: 5G, IoT, and emerging technologies. *IEEE Netw*. 2021; 35(2): 18–25. <https://doi.org/10.1109/MNET.011.2000418>
26. Razmjoo A, Gandomi A, Mahlooji M, Astiaso Garcia D, Mirjalili S, Rezvani A, Memon S, et al. An investigation of the policies and crucial sectors of smart cities based on IoT application. *Appl Sci*. 2022; 12(5): 2672. <https://doi.org/10.3390/app12052672>
27. Al-Ansi AM, Garad A, Jaboob M, Al-Ansi A. Elevating e-government: Unleashing the power of AI and IoT for enhanced public services. *Heliyon*. 2024; 10(23): e40591. <https://doi.org/10.1016/j.heliyon.2024.e40591>
28. Kangana N, Kankanamge N, De Silva C, Goonetilleke A, Mahamood R, Ranasinghe D. Bridging Community Engagement and Technological Innovation for Creating Smart and Resilient Cities: A Systematic Literature Review. *Smart Cities*. 2024; 7(6): 3823–3852. <https://doi.org/10.3390/smartcities7060147>
29. Rodríguez Bolívar MP, Alcaide Muñoz L, Morales Marín M. The use and theoretical support of emerging technologies for citizen participation in cities. A Systematic Literature Review in DGRL. In *Proceedings of the 25th Annual International Conference on Digital Government Research*. 2024 Jun; 295–304. <https://doi.org/10.1145/3657054.3657255>
30. Alhaidari F, Rahman A, Zagrouba R. Cloud of Things: architecture, applications and challenges. *J Ambient Intell Humaniz Comput*. 2023; 14(5): 5957–5975. <https://doi.org/10.1007/s12652-020-02448-3>
31. Alabdulatif A, Thilakarathne NN, Lawal ZK, Fahim KE, Zakari RY. Internet of nano-things (iont): A comprehensive review from architecture to security and privacy challenges. *Sensors*. 2023; 23(5): 2807. <https://doi.org/10.3390/s23052807>
32. Magara T, Zhou Y. Internet of Things (IoT) of Smart Homes: Privacy and Security. *J Electr Comput Eng*. 2024; 2024(1): 7716956. <https://doi.org/10.1155/2024/7716956>
33. Dave DMK, Mittapally BK. data integration and interoperability in Iot: challenges, strategies and future direction. *International Journal of Computer Engineering and Technology (IJCET)*. 2024; 15(1): 45–60. <https://iaeme.com/Home/journal/IJCET>
34. Umoh AA, Adefemi A, Ibewe KI, Etukudoh EA, Ilojiana VI, Nwokediegwu ZQS. Green architecture and energy efficiency: a review of innovative design and construction techniques. *Engineering Science & Technology Journal*. 2024; 5(1): 185–200. <https://doi.org/10.51594/estj.v5i1.743>
35. Rehman Z, Tariq N, Moqurrab SA, Yoo J, Srivastava G. Machine learning and internet of things applications in enterprise architectures: Solutions, challenges, and open issues. *Expert Syst*. 2024; 41(1): e13467. <https://doi.org/10.1111/exsy.13467>