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Role of Cloud in Facilitating the Management of Smart City

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Abstract: *One of the most revolutionary trends in urban planning and development is the transformation of cities into "smart cities." Smart cities use cutting-edge technologies, like cloud computing and the Internet of Things (IoT), to improve the quality of life for their residents and maximize the effectiveness of municipal services. This paper examines how cloud computing enables smart cities and IoT solutions to create more efficient, sustainable, and citizen-friendly urban environments.*
Key Words: *Smart City, Cloud Technology, IoT, Big Data, Smart City Sustainability*

I. Introduction

The ever-changing digital landscape of today is being revolutionized by cloud technology. It significantly influences the growth of smart cities by improving sustainability, efficiency, and connectivity. Through scalable infrastructure, real-time data analysis, and seamless connectivity, cloud technology empowers cities to become more intelligent and citizen-centric. It promotes innovation and economic progress, enhances public services, and allocates resources as efficiently as possible. Cloud-based solutions facilitate data-driven decisions in public safety, waste management, energy efficiency, and traffic management by collecting and evaluating data from several sources, including social media and Internet of Things devices. Urban settings that are livable, sustainable, and inclusive are produced by this interconnection, which unifies infrastructure and improves coordination, procedures, and public engagement[1].

Urban regions where technology and data collecting enhance the sustainability and efficiency of city operations, as well as the quality of life, are referred to as smart cities. Local governments deploy ICT (information and communication technology) and IoT (the Internet of Things) as smart city technologies.ICT, IoT, and other smart technologies are becoming more and more significant in the transportation, energy, and infrastructure sectors of city operations. Incorporating these technology into a city's processes and buildings makes it smarter[4]. There is disagreement, nonetheless, over which towns are truly smart or deserving of the title of "smartest" city.

Emerging technologies are enabling cities to adapt to changes in their local urban contexts, much how the nervous system of the body controls how people react to their surroundings. Data collection technologies, notably real-time data collection technologies, are essential to smart city programs and the advantages they offer. Residents' quality of life is improved when local governments use data-driven insights to enhance urban planning and the implementation of city services, such as public transit and waste management[4].

In addition to improving local air quality, more effective city services can reduce carbon emissions and support international efforts to combat climate change. Furthermore, smart city solutions have the potential to stimulate economic growth by fostering job creation and commercial opportunities through improved infrastructure and technology innovation.Sensor networks collect and combine data that can be utilized for a number of purposes and municipal services. In addition to monitoring and managing civic infrastructure, connectivity allows municipal officials to engage directly with the community. The local government regularly makes operational and planning data available to the public as part of its commitment to an open data concept. In order to realize the full potential of smart cities, this paper explains how cloud technology is transforming them and influencing urban living in the future[15].

II. Literature Review

2.1 The rise of smart cities

Innovative urban areas known as "smart cities" use cutting-edge technology to greatly improve the standard of living for their citizens. Modern solutions like big data analytics, artificial intelligence (AI), and the

Internet of Things (IoT) are seamlessly integrated in these cities, allowing for sustainable development, effective citizen services, and superior resource management[10].

Smart cities may overcome innumerable challenges and open up numerous opportunities for urban growth, innovation, and connectivity by utilizing cloud computing. These intelligent cities' interconnected streets, buildings, and infrastructure form a harmonious ecosystem that optimizes sustainability, safety, and efficiency, ultimately forming a more promising and prosperous future for all. The transformation of cities into "smart cities" is one of the most revolutionary developments in urban governance. Smart cities maximize the efficiency of municipal services and improve the quality of life for their residents by utilizing cutting-edge technology like cloud computing and the Internet of Things (IoT). These sophisticated, data-driven ecosystems are made feasible in large part by cloud computing. This paper will discuss how cloud computing enables IoT solutions and smart cities to build more sustainable, effective, and livable urban environments[34].

Utilizing data, technology, and digital infrastructure, a smart city enhances everything from public safety and waste collection to energy and transportation management. Urban regions that have sensors and Internet of Things devices embedded throughout the city provide vast amounts of data that can be evaluated to yield useful insights. These insights assist city officials in making the most use of available resources, cutting expenses, and raising the general standard of services provided to citizens. Cloud computing is crucial for handling the massive volumes of data produced by these smart cities and making sure that every system is responsive and correlated[15].

Because it provides the flexibility, scalability, and processing power required to collect and analyze massive amounts of data in real-time, cloud computing forms the foundation of smart city infrastructure. Whether it's environmental surveillance, energy usage statistics, or traffic monitoring, the cloud enables smart cities to access a multitude of technical resources, such as machine learning (ML), artificial intelligence (AI), and data analytics. Cities can process data more effectively because to cloud computing's centralized architecture, which also eases the strain on local systems and makes service maintenance and updates easier. Cities can react quickly to possibilities and challenges since the cloud also facilitates real-time decision-making[18].In contrast to organizations that offer more conventional web-based services (like web hosting), cloud computing enables instant access to cloud delivery without the need for a drawn-out provisioning procedure. In cloud computing, every resource provisioning and withdrawal can be done as often as needed. Application programming interfaces, or APIs, facilitate communication between cloud applications and resource records as well as user access to cloud services. Payment options include invoicing and evaluating providers, which offer the aid needed to utilize rating assistance and make payments ahead of time[21].

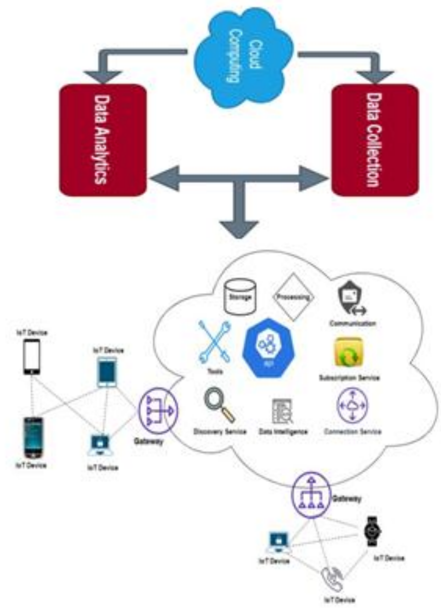

Figure1. Cloud-based IoT System Integration.

Performance monitoring and assessment: Cloud computing infrastructure offers a carrier management environment for performance monitoring and assessment, in addition to the integrated system of physical computing and its techniques[4].

Security: The architecture of cloud computing provides safe operations with the goal of safeguarding private data. Cloud computing and related services are being adopted primarily for two business reasons: (1) commercial enterprise. Two benefits of cloud computing are (1) cost savings and (2) flexible, timely, and necessary access to computer resources as needed to achieve corporate goals. By transforming capital expenditures (CapEx) into operating costs, cloud computing promises to save costs. This is due to cloud computing's preference for pre-existing management and its ability to provide more flexible scheduling and resource allocation[4].

2.2 IoT and Cloud Convergence

Integration with cloud computing infrastructure can be cost-effective because IoT applications produce vast amounts of data and incorporate several computational add-ons (such as real-time processing and analytics procedures).The following situation is a great illustration. Spreading product specifics (such as sensors and WSN data) in the cloud can be an uncomfortable and costly way to fulfill the expansion goals of a small to medium-sized business that produces a power control device utilized in smart homes and buildings.Small and medium-sized businesses (SMEs) may gather and use more data as their customer grows and their product becomes more publicly visible. Additionally, SMEs can handle and maintain massive data volumes collected from multiple sources thanks to cloud integration[21].

Cloud-based building and system distribution can help a smart city. The smart city is anticipated to include smart power management applications, smart water controls, smart transportation controls, urban mobility, and other IoT packages. They might also offer greater data volumes. By evaluating the cloud integration, the smart city can now manage these records and applications.

Furthermore, the cloud can help expedite the deployment of new packages and the growth of the previously stated ones, which have hitherto raised serious problems regarding the availability of the required computer resources. By allowing third parties to utilize its infrastructure and integrate IoT data with computer resources running on IoT devices, a public cloud computing provider can broaden the IoT ecosystem[34].

The business can offer Internet of Things data for service and access. This demonstrates how IoT infrastructure and cloud computing modification are applicable and desired. The conflicting cloud and IoT architectures have, however, always made integration difficult. IoT devices are often unstable (based on resources and access), have limited support, are region-specific, and are costly to estimate (based on upgrade/shipping costs) [34].

In contrast, cloud computing resources are usually situated in a practical and effective location that offers flexibility and speed. They can be distributed throughout any cloud resource and minimize discrepancies by establishing sensors and devices prior to integrating data and their offers into the cloud[15].

In order to provide real-time service and sensor availability, sensor gathering and service implementation are also done in the cloud. Integration of IoT and cloud can send WSN and sensory data to the cloud. During Japan's earthquakes, this extensive infrastructure was one of the first developments and was widely used for radiation maps and detection[15].

However, dozens of well-known clouds exist, such as cloud-sensor, ThingsWorx, ThingSpeak, and real-time cloud services. Customers can pay as they go with these public cloud providers if they want to store IoT packages in the cloud. Cloud systems that are similar to IoT services in the cloud are enhanced by the majority of providers' sophisticated development tools[34]. IoT/cloud infrastructure, cloud computing infrastructure, and related services may also be referred to as follows:

1. Infrastructure as a Service (IaaS)

Users can connect to sensors and actuators in the cloud through IoT/clouds. IaaS is a big calculation that keeps a solution and sends it when someone asks for it. A cloud computing service is offered by it. IaaS provides IoT management to control things as a requirement for providing suitable services[40].

2. Platform-as-a-Service (PaaS)

The IoT/cloud public infrastructure outlined the high-performance PaaS concept for IoT/cloud services. PaaS is a comprehensive cloud-based development and deployment architecture that includes the ability to provide services ranging from the most basic cloud-based services to complex, cloud-capable businesses[40].

3. Software-as-a-Service (SaaS)

SaaS products enable consumers to access comprehensive software packages based on the cloud and the Internet of Things. The SaaS packages are comparable to regular cloud-based packages that employ IoT sensors and devices. The claim is that SaaS IoT packages are often built on top of PaaS infrastructure and allow for business models that rely on IoT software and services. It provides a general grasp of IoT and cloud connections, as well as why they are important and beneficial[40].

These days, more and more IoT devices are cloud-based, enabling users to take use of their total functionality, business acumen, and payment capabilities. By guaranteeing the interoperability of IoT data and contributions within the cloud, the advantages of the IoT cloud are maximized, allowing for high records for analytical purposes in areas related to smart energy, smart transportation, smart cities, and communications. Additionally, IoT/cloud integration can benefit IoT components with IoT-based wearable computing[17,18].

Without requiring human or computer interaction, the Internet of Things (IoT) connects computer devices, machine tools, and virtual objects, animals, or people that have been given indicators and the ability to change records on a network. Anything created by people or by machines that can be identified by an IP address and have the capacity to transmit data across a network is included under the Internet of Things umbrella. The Internet of Things has grown as information technology has advanced[17,18].

Communication between sensors is made possible by IoT devices, and billions of linked devices are probably going to be a part of people's lives in the future. IoT has essentially taken over a number of local sectors, including building management, transportation, energy, health care, and agriculture. More ways to connect to the IoT through a cloud network are being sought after by experts and active developers. The development of IoT applications is an exceptional strategy to support further advancement[17,18].

The socially relevant devices that people gather from IoT networks are now more beneficial to them than the increased connectivity of devices. Cloud-enabled communication can benefit from the useful information that machines can offer regarding appearance and performance in the field. Not only can related devices verify the devices of enterprises, but they can also use network cloud solutions to help everyone move away from personal devices. Reality helps manage the timing of things through closed storage, processing power, energy, and other fast connections. It is still difficult to gather, store, and use IoT efficiently because of the large number of sensors and the volume of data they generate[17,18].

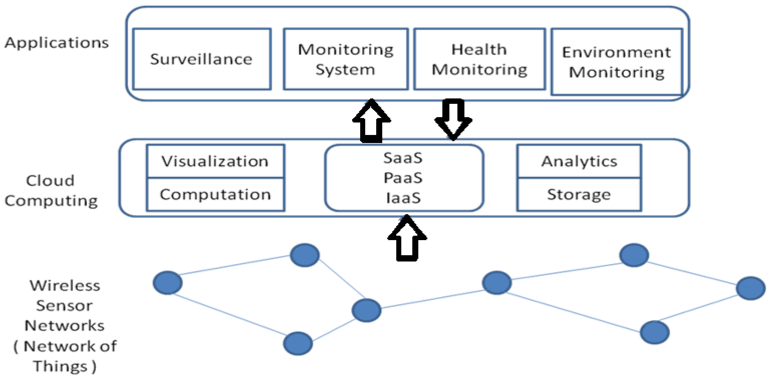

Figure 2: IoT and Cloud Convergence

IoT generates vast volumes of data and connects people and things. It might be challenging to obtain information through organizations because of complex systems, common connection agreements, and legacy application compliance. Sensors, WSNs, RFID, and other IoT infrastructure are either unique or widely used, and the resources needed to develop and provide access are limited and frequently costly. The productivity of IoT devices often results in a limited budget and inadequate processing and storage capacity[17,18].

In addition to being energy-efficient, cloud computing offers infinite storage. Through an Internet connection, the cloud gives users access to data and resources. Cloud infrastructure allows easy access to less expensive resources in a self-contained or ubiquitous area (resources that may be accessed from anywhere). Cloud virtualization is the outcome of the resource base's independent work. When using cloud computing, the IoT-cloud connection is a means to experience the resources that are always available. IoT and cloud computing technology integration is encouraged by the need for IoT systems for cloud compression, availability, and performance[10].This link enables user mobility, the integration of points from various devices and users, the processing and storing of gathered facts, and identical data in various contributions. There have been multiple initiatives to incorporate cloud and IoT technology into the commercial community and research network. Because of this combination of capabilities, the ability to move data to the cloud is exceptional for working, monitoring, regulating data dissemination, and managing systems[17].

The cloud can utilize dependable retrieval packages and restoration and processing equipment for IoT packages. IoT systems on a large scale are by nature vulnerable. Numerous dispersed sensors in large IoT systems generate data that needs to be handled. The cloud can create complex systems using IoT technology and provides an enormous output service. Additionally, a delivery system that is mostly based on cloud infrastructure and concentrates on setting up and delivering IoT systems can be advantageous for many IoT services. Networks of cloud-based IoT devices can be designed, deployed, operated, and managed by an IoT platform, which is mostly hosted on the cloud. In addition to their interactions with the three cloud computing styles (i.e., IaaS, PaaS, and SaaS), this illustrates the IoT platform's and architecture's initial capabilities[1].Every IoT gadget will establish a connection with a cloud-based universal resource pool. Devices may easily access, gather, organize, display, store, divide, and search through large amounts of sensor data from several applications that use this platform[17].

Sensor data can be generated, analyzed, and stored using the cloud's processing and storage capabilities. Additionally, a cloud-based IoT platform enables users and programs to receive sensor data percentages under various usage scenarios, allowing sensor devices to fulfill certain processing tasks. Customers can purchase sensor devices from this platform, which is a long-term cloud computing solution for sensor control. It uses a web browser to change services for clients and provide sensor monitoring[15].

Moreover, the cloud facilitates data collection and processing for IoT information, taking into account simple setup and integration of new issues while maintaining low deployment costs and complicated data processing. Clients can run any application on cloud hardware using the cloud infrastructure provided by this platform. It simplifies application development, removes the requirement for infrastructure, reduces the difficulty of manipulating issues, and lowers refurbishment costs[1].It gives users access to special tool control features, direct device communication, storage to gather problem-related data, and event transition. Sensor data can be processed, stored, and analyzed using the processing and service resources of the cloud. The developer suite for creating Internet of Things application is installed on sophisticated and quick cloud carrier devices.[4].

Open service software programming interfaces are a part of this technology, which gives developers extensive deployment and enhancement capabilities. The system, which is a collection of cloud products that aid in the deployment and specialization of processing services, includes subscription administration, network coordination, subjects' connection, issues discovery, statistics intelligence, and things composition.In cloud-based IoT structures, such as a home community, IoT devices are frequently combined into IoT networks[17,18].These networks are linked to the cloud via a specific gateway, which is typically a mobile phone or a home router. The detected data is sent to the cloud by the dedicated gate-manner from the networks. Data is continuously stored in the cloud and made available to contribute to apps. With authorization to access and control the data via cloud processing assets, the provider can offer particular cloud services[17,18].

The cloud acts as a bridge between problems and IoT application, hiding all of the features and complexity of execution. This platform can enhance destiny software because it will provide a new solution for data collecting and record transfer[15].The goal of the fully IoT, cloud-based platform's architecture is to optimize the availability of data and services. Cloud-based IoT apps link to the cloud-based IoT platform, as shown in Figure 1.A web browser or application can be used to store and visualize the cloud applications, allowing the user to access, monitor, and control them at any time and from any location.

III. Related Work and Discussion

3.1 Phases for Building a Smart City Model

Information management is becoming increasingly crucial in smart cities, where systems are connected by energy or information linkages. and the particular cyber-physical systems, which are coupled virtual (software) and actual (hardware) worlds.The following is a six-phase model for the formation of a smart city[6].

Phase 1: A fully Smart City Platform

A basic design should be the first step in implementing smart cities. Future development will be built around it, and you can add new services without sacrificing overall speed[5].Four requirements make up the core solution for smart cities.

- *A Network of Intelligent Objects:* Smart devices for sensors and actuators are used in IoT-enabled smart cities. The sensory equipment's job is to gather information and transmit it to a reliable cloud control system. Actuators enable devices to function, such as light control, lowering water flow in a leaky pipe, and more[34].
- *Gateways for Secure Transmission:* The hardware and the applications are the two components that are combined in any IoT device. Applications are necessary for the transfer of data between objects. Gateways for data control should exist. Before data is sent to the cloud, these gates filter it, making data collection and compression easier. In addition to being a component of the city's smart solution, the cloud gate guarantees safe information flow between local gates[2].
- *Pool Facts:* Keeping records is the primary purpose of the information pool. Data sets provide evidence for smart city claims. Requests for data are taken out of the pool and sent to the intended location[2].
- *Large Record Warehouse:* We refer to an enormous records warehouse as an enormous database. It has extremely structured data, in contrast to statistical pools. Once the real data has been identified, it is fed into a sizable data warehouse after being extracted and transformed[2].

Phase 2: Data Tracking and Analytics

The procedure for data tracking and analytics entails gathering, identifying, and categorizing data items throughout the network system for use in data analysis. Data tracking includes the technologies that businesses use to manage their data as well as the legal guidelines they follow to protect the security and privacy of their customers. Cities can, for instance, create digital valve rules to open or close at the determined humidity level based on data from soil moisture sensors placed in parks. Customers may view any area of the park thanks to the dashboard of a single platform that displays the data gathered by the sensors[45].

Phase 3: Analyze Data

Communities, transportation networks, and digitization generate an astounding amount of data that keeps growing at a breakneck pace. The production process is greatly accelerated by new IoT devices and cloud services. By analyzing, modeling, and extracting information from this data, one can enhance the efficacy of urban movement and contribute significantly to our understanding of city environments[45].

In order to assess progress and develop dependable models, machine learning (ML) algorithms examine historical sensory data that is kept in a large database. Actuators of IoT devices receive commands from models utilized by control packages. As opposed to standard traffic modes, which are intended to show a chosen sign for a set amount of time, astute visitors are able to modify the entry times based on traffic conditions. To detect visitor styles, regulate signal timing, facilitate average vehicle speed acceleration, and prevent traffic jams, machine learning algorithms were created using outdated sensory systems[2].

Phase 4: Smart Control

By instructing the actuators of smart city equipment, control systems guarantee a high level of automation. To address a specific problem, they "tell" the appropriate staff members what to do. Rule-based management systems, which are primarily ML-based, exist. Manual explanations are provided for standards for deceptively based systems, but ML-controlled applications make use of models developed using ML techniques. Based on statistical testing, those patterns are identified, and they are frequently tested, authorized, and updated[7].

Phase 5: Automatic Traffic Control

It should always be possible for users to regulate smart city programs (for instance, in an emergency) in addition to the option for automatic control. This job is done by user programs. Through user programs, citizens can connect to the municipal administration platform, identify and control IoT devices, and get alerts and warnings[5].An intelligent traffic control system, for instance, uses GPS information from drivers' smart phones to detect a visitation gridlock[45]. An automated message asking local drivers to look for other routes is sent out by the response. The smart city area implements a tourist control system to identify traffic jams in real time and to implement visitor guidelines to decrease the number of tourists in busy regions. Moreover, the smart city combines a visitor management response with an intelligent air tracking technology to guarantee that site visitors do not negatively impact the environment. A computer program can be used to alert visitor center employees about congested areas[5].The robot detectives receive an instruction to handle the alerts in order to relieve and reroute traffic congestion.

Phase 6: Integrating Multiple Solutions

In order to increase the number of features and, more significantly, the variety of sensations, it is necessary to integrate the IoT-based diverse solutions[10].

3.2 Functions of Cloud Computing in IoT

Cloud computing and the Internet of Things are two platforms that have shown numerous advantages. Most people are aware of IoT regulations pertaining to smart homes, smart cities, etc. IoT is essential for incorporating smart city answers into business tools and opening the door for high-caliber input in a variety of industries, including energy, logistics, healthcare, and transportation. Not far behind is the cloud.Cloud computing has many advantages in the Internet of Things[17].To put it another way,cloud computing and the Internet of Things are quite complementary and both aim to make daily tasks more efficient. IoT generates a lot of data even though it integrates with smart cities. On the contrary, cloud computing opens up new possibilities. IoT and cloud computing work together to improve integration in areas like service offerings and remote data access[17,18].Although they offer affordable and easily accessible storage, there are numerous ways to examine how IoT and cloud computing differ from one another. Individual applications and business service solutions have changed significantly as a result of cloud computing. The power and intensity of cloud response statistics also make it possible to make data remotely accessible. It has therefore shown itself to be a solution for information transfer via network channels and hyperlinks that are given directly according to corporate demands[17,18].

1. One of the best IoT tools for addressing the problems caused by commercial corporate data is the cloud. As a technology, the cloud offers a dynamic platform for creating essential applications to improve the utilization of internet data[1].
2. IoT offers mobility and connection, and the two primary cloud computing techniques—velocity and scale—combine in a way that is unmatched. As a result, the combination of cloud computing with IoT improves their capacities.Additional characteristics demonstrate the significance of the cloud for IoT access[4].
3. With the extensive usage of IoT devices, maintaining a large number of devices and controlling over-speed takes a considerable amount of time, depending on the building infrastructure. The cloud offers the advantage of a high-quality service environment in this situation[15].
4. IoT data security and privacy are enhanced via the cloud. IoT devices are portable and can incorporate important security features, upgrades, and discoveries when the cloud is involved. By offering complete security measures, the cloud empowers users with strong authentication and encryption agreements[17].
5. How cloud services are presented and connected to IoT devices. Plug-and-play cloud hosting services frequently require a significant amount of infrastructure, which can be costly for both people and businesses. IoT and cloud computing work together to eliminate any barriers to access for IoT and cloud service providers, negating the need for this infrastructure expenditure[17].
6. Improved device connectivity: because to its robust IoT APIs, the cloud acts as a communication hub. These APIs facilitate both the communication between intermediary tools and the pure networking of smart devices[17].
7. While offering sufficient resources, cloud technology spares businesses from the need to build infrastructure[1].
8. By safeguarding against unexpected issues that can occur during the process, cloud computing guarantees business continuity. There is no chance of data loss because the data is kept on different servers, especially in infrastructure that is very well-supported[17].
9. Secure and trouble-free solutions are necessary for IoT development.Thus,the ideal option is cloud computing on the Internet of Things. IoT devices can leverage distant statistical settings through applications after cloud computing is implemented. Financially speaking, cloud computing on IoT is a great option since users successfully comply and future costs are significantly reduced. Consequently, companies might be able to make use of more extensive IoT systems. As a result, high-level IoT-based enterprises have less access[17,18].
10. Strong API connections between connected devices and smart devices are made possible by cloud computing on the Internet of Things, which facilitates smooth communication between IoT devices. In this sense, cloud computing facilitates the proliferation of connected technology in the Internet of Things[1].

How Does the Cloud Allow IoT Applications?

Cloud-based Applications for the Internet of Things are expanding and interacting with one another. Cloud-based IoT applications, service deployment, and hosting are made possible via the cloud. Furthermore, cloud computing is a suitable Internet platform for processing and storing data from smart devices, including Wi-Fi, sensors, actuator networks, smart grids, smart cities, and linked automobiles.It is possible to set up network setups efficiently and rapidly. However, software is used for backend operations, which enables performance monitoring, location tracking, content labeling, and rolling back[15].

Furthermore, cloud computing strengthens IoT systems. Technologists can create backups of cloud-running devices and apps by integrating the cloud and IoT, which increases the devices' error tolerance. They can also be utilized for offline data tracking. To support their IoT response, developers can also establish a database, execute apps, and set up digital servers[1].

3.3 Issues and Cchallenges

(i) Data Management and Storage at Scale

Managing the massive volumes of data produced by IoT devices and sensors is one of the main issues smart cities face. Cities can manage growing information volumes without experiencing infrastructure constraints thanks to cloud computing's scalable and affordable data storage solutions. Since data from smart cities frequently ranges from historical data needed for trend analysis to real-time sensor readings, this scalability is essential. The cloud offers a single platform for data management, making it possible to integrate with several analytics tools, store data securely, and make it easily accessible to stakeholders. Through real-time data processing, cloud solutions optimize resource allocation and improve citizen services by enabling cities to respond immediately to traffic situations, public safety issues, or energy demands[2].

(ii) Interconnectivity and System Integration

To operate effectively, a smart city's transportation, electricity, water, emergency services, and other systems must cooperate. By facilitating smooth integration and connectivity across various municipal departments and systems, cloud computing dismantles organizational silos and promotes teamwork. Cities can guarantee seamless data transfer between all systems and enable more thorough activity coordination by utilizing cloud-based solutions. Traffic management systems, for example, can be linked to emergency services and public transportation networks, enabling improved route optimization and speedier emergency response times. Additionally, cloud computing facilitates device interoperability, which guarantees that legacy systems and new IoT technologies may function together efficiently [15].

(iii) Scalability and Flexibility: Growing with the City

More connected devices and smarter infrastructure will become more and more necessary as cities continue to develop and expand. The ability of cloud computing to scale easily is one of its main benefits. In order to accommodate the expanding network of IoT devices, cities may swiftly scale up or down their computing capabilities as needed without having to make large hardware-investments. In order to manage a dynamic urban environment, this adaptability is essential. Cities are able to easily incorporate new technologies into their current infrastructure as they become available, which keeps them flexible and robust as technology advances[10].

(iv) Enhanced Citizen Services and Operational Efficiency

The enhancement of citizen services is among the most obvious effects of cloud computing on smart cities. Cities may provide their citizens with more individualized, effective services by utilizing cloud-based technologies. For instance, energy networks can better balance supply and demand, lowering energy waste and expenses, while smart transportation systems can adapt in real-time to ease traffic. Because cloud computing makes it possible to automate repetitive operations, it also improves operational efficiency. For instance, information from Internet of Things sensors that track bin capacity can be used to optimize waste collection systems, allowing for the scheduling of pickups only when required. Cities save money and citizens receive better services as a result of this type of optimization[3].

(v) Security and Privacy in Smart Cities

Ensuring the security and privacy of this data is crucial since smart cities depend on data-driven processes and networked technology. Because they understand these difficulties, cloud computing companies provide strong security frameworks that incorporate threat detection, encryption, access control, and adherence to global standards. Sensitive data is protected by advanced encryption techniques while it is in transit and at rest, guaranteeing the security of personal data. Furthermore, in order to guarantee that their solutions meet demanding security certifications like ISO/IEC 27001, prominent cloud service providers frequently adhere to these standards. This helps cities uphold public confidence and guarantees the responsible handling of sensitive data, including personal information from Internet of Things devices[16].

(vi) The Collaborative Ecosystem

Collaboration is the key to smart cities. Because cloud computing offers open data platforms, it facilitates collaboration amongst various stakeholders, including people, citizens, private companies, and educational institutions. These platforms enable stakeholders to create new applications, services, and solutions that tackle urban concerns by fostering an innovative and collaborative culture. For instance, open data projects enable programmers to create apps that help optimize energy use, strengthen emergency response systems, or improve public transit. Cloud-based smart cities foster continuous innovation, drive sustainable growth, and enhance the general quality of life for their residents by establishing a collaborative environment[21].

(vii) Sustainability and Smart Resource Management

In smart cities, cloud computing is also essential for advancing environmental projects. Cities can maximize resource management with the capacity to process and analyze enormous volumes of data in real time. Water management systems can monitor usage and cut waste, smart grids can balance energy loads, and environmental regulations can be informed by air quality sensors. Cities may use the cloud to make better informed decisions that support environmental sustainability over the long run[10].

3.4 Benefits of Cloud Technology in Smart Cities

Cloud technology has several distinct features that make it an excellent fit for smart city initiatives. Cloud technology, with its scalability, flexibility, and cost-effectiveness, lays the groundwork for the creation and deployment of novel solutions to improve smart city life style[10].

(i) Scalability: Scalability is a significant advantage of cloud platforms. Cities with the flexibility and ability to scale can easily extend their infrastructure to meet growing demand. As cities expand and place greater demands on its technological systems, the scalability of cloud platforms becomes critical for guaranteeing efficient and successful operations. This versatility enables cities to effortlessly incorporate new technology and services, supporting innovation and sustainable development[10].

(ii) Cost Efficiency: Cloud services offer a highly cost-effective approach for implementing smart cities. Cities can save money on hardware and software by using cloud-based infrastructure. Instead, they can take advantage of the massive resources available from cloud providers, paying just for the services they need. This flexibility not only reduces initial costs, but also enables communities to smoothly scale their operations as their needs change. Smart city efforts can be carried out more efficiently and cost-effectively via cloud technologies[10].

(iii) Real-Time Data Analysis: Cloud technology's extraordinary capabilities enable the seamless capture, secure storage, and efficient processing of massive amounts of data created in real time by IoT devices and sensors. This essential data can be rigorously evaluated to yield profound insights, resulting in significant increases in efficiency, optimal resource allocation, and more informed decision-making processes. With cloud technology at the forefront, businesses can fully realize the promise of their data-driven strategies, changing operations and paving the path for unparalleled development and success[7].

(iv) Enhanced Connectivity: In a smart city ecosystem, cloud-based technologies are essential for facilitating smooth connectivity. These platforms enable communities to effectively manage and optimize their infrastructure by promoting real-time communication and coordination amongst several components, such as public safety agencies, utilities, and transportation networks. Cities can improve service delivery, make well-informed decisions, and give their citizens a sustainable and connected urban environment by securely gathering, analyzing, and sharing data[10].

(v) Improved Services: The delivery of services is being completely transformed by cloud technology, which offers a platform for individualized and incredibly effective solutions. Cloud-based solutions are revolutionizing the experience for both locals and tourists, whether it's through online portals for government services, intelligent parking apps that maximize your trip, or real-time public transportation updates that keep you informed[10].These cutting-edge technologies use the cloud's power to provide better accessibility, convenience, and seamless integration, making daily living easier and more connected than before.

3.5 Deployment of Cloud Computing in Managing Smart City Utility Services

Utilizing technology to complete activities with little or no human involvement is known as automation. Automation makes cities more responsive to real-time data sent by Internet of Things sensors in smart city projects. For example, automation can be used to turn on and off streetlights based on input from motion and light sensors. By automatically turning off streetlights when not in use, these technologies support sustainable city operations and energy efficiency[40].

Deployment applications in smart cities are strongly related to a number of ICT (information and communication technology) ideas, such as the widespread use of connected physical things, gadgets, etc. When implementing intelligent city applications that comprise multiple networked items, it can be regarded as a system of systems. In order to improve and preserve urban functions and resources for the improvement of environmental performance, the system is being made simpler by the spread of sensor technologies that enable object identification, data collection, communication resources, and the facilitation of data distribution, information processing, computational analysis, and connection systems. Thus, under digitalization, a new digital layer is positioned between the city's service layer and the infrastructure conceptualization[17,18]. .

(i) Smart City Governance: When it comes to smart governance, if citizens actively participate in the decision-making process, the government acts transparently. Through an interconnected governance system, citizens can effectively receive the city's functions through new technology[24].

(ii) Smart Mobility: Smart cities are characterized by their promotion of sustainable urban mobility. Providing cutting-edge transportation services via intelligent traffic management is one of the primary objectives of smart cities. By supplying users with the necessary information, it enables safer and more intelligent decisions regarding the usage of the transport network. To enhance traffic management, for example, a variety of technologies can be used to support services like parking guidance, car navigation, surveillance, and traffic control[13].

(iii) Smart Utility: Applications that help lower energy use include smart streetlights, which may function based on traffic and weather conditions. This can help the smart city develop an environmentally friendly and sustainable ecosystem. People's everyday grievances, individual social affairs management, help requests, and other issues pertaining to city management and market operations can all be handled by a social service system. A platform that facilitates various services requires a single integrated system[5].

(iv) Smart Living: The delivery of affordable, high-quality healthcare services is a major problem for the present health system. These difficulties are made worse by an aging population, which results in a chronic plague of illnesses and an increased need for medical care. Due to a shortage of resources, it might be challenging to obtain quality healthcare in some cities as well. These factors make it imperative that the current healthcare system be transformed into an intelligent one[15].The idea of "smart health" encompasses a number of technologies and entities, including sensors, ICT, portable devices, and many more.Emerging in-body sensors, intelligent hospitals, and intelligent emergency response are some of the components that make up smart healthcare. A variety of technologies, such as cloud computing, ICT information technologies, sophisticated data analysis methods, and smartphone applications, are utilized in smart hospitals. Offices can receive patient data in real time from many smart city hospitals or hospitals. This enables test data to be shared among multiple doctors, technicians, and nurses, enabling real-time decision-making regarding patients' ailments and related prescriptions[6].

(v) Smart Environment: By keeping an eye on environmental changes, smart services are thought to be able to deliver real-time information regarding pollution in urban areas. Governments and citizens may understand the negative consequences of altering their behavior with regard to public utilities like water, gas, and electricity[21].

(vi) Cloud Based Smart Transportation: The foundation of smart city planning is smart mobility. Local governments and commercial sector partners may gather data in real time thanks to technologies like geo-location, artificial intelligence, and the Internet of Things. The quality of life for both city dwellers and commuters is enhanced by this data, which also helps to reduce carbon emissions and relieve traffic congestion and public transportation. By using smart city technology with smart transportation systems, officials can proactively request repairs and identify which city vehicles are most likely to break down[15].

(vii) Smart Parking Systems: These systems determine the parking availability and notify drivers are powered by these technologies. By employing real-time traffic data to ascertain the timing of signal changes at intersections, they enable an effective, AI-powered approach to traffic management. In order to further reduce carbon emissions and enhance traffic flow, smart transportation systems also encourage the usage of electric and driverless vehicles[15].

(viii) Cloud based Smart Energy Management: AI and other smart city technologies can assist energy providers in managing smart grids, which are electrical networks that have sensors and software installed. In order to anticipate future energy use and spot trends in energy use, advanced software and analytics tools may evaluate data from connected devices[13This helps providers anticipate outages and satisfy consumer demands. Climate change can be lessened by integrating energy-efficient technologies and renewable energy sources with smart energy. Additionally, waste and resources used in oil and gas operations, as well as carbon dioxide emissions, can be decreased with smart energy technologies. Some examples are as follows[5,6]:

- Using AI and IoT in predictive asset optimization to increase asset longevity and lower maintenance and monitoring costs.
- In order to improve the time migration to digital systems, upstream and midstream operations should be optimized with an emphasis on systemic asset performance. Additionally, underperforming or excessively consuming equipment should be investigated.
- Reducing energy use and improving health, safety, and environment (HSE) issues by utilizing environmental monitoring systems.

(ix) Cloud Based Smart Infrastructure: Smart transportation and smart energy are both included in smart infrastructure. It also covers intelligent use of utilities like water and upkeep of buildings and machinery that facilitate transit, such decks and cables. Decision makers may identify and proactively solve possible issues with the use of data gathered from sensors and linked devices, much like with other smart technologies. In this instance, the data improves efficiency and the standard of living for locals while also assisting in the early detection and resolution of issues pertaining to infrastructure assets[13].

(x) Cloud Based Smart Waste Management: As technology may increase waste management's effectiveness and environmental impact, smart waste management is a crucial component of smart cities. Smart waste management systems monitor and regulate the collection and processing of garbage using a range of technologies, including sensors and Internet of Things devices. This enables communities to increase the overall effectiveness of the waste management system, minimize the negative environmental effects of trash management, and optimize waste collection routes. The efficiency and sustainability of waste management systems can be increased through the use of cloud computing in smart trash management[3,5,6].Using cloud-based monitoring systems to track and manage waste collection, transportation, and disposal in real-time is a significant use of the cloud in smart waste management. Route optimization, fuel economy, and waste management system performance can all be enhanced using these solutions. To establish a waste management system that is more sustainable and effective, cloud-based monitoring systems can also be integrated with other systems, such recycling facilities. Using cloud-based analytics to track and improve waste management system performance is another way that the cloud is being used in smart waste management. The cloud can be used to examine patterns and trends in the creation, collection, and disposal of garbage by gathering data from sensors and other Internet of Things devices in the waste management system. Utilizing this data, plans for reducing waste, increasing recycling, and enhancing the general sustainability of waste management systems may be developed, as well as areas where performance can be enhanced[3,5,6].Furthermore, any maintenance problems can be anticipated and preventative maintenance can be scheduled appropriately using cloud-based data. This may also help lessen the negative effects of waste management on the environment. Compared to conventional trash management systems, cloud-based smart waste management technologies give cities an extra degree of control and flexibility. Cities can easily adapt the waste management system to changing conditions thanks to these technologies, which enable remote monitoring and control of garbage collection and processing from a central location. Cities may greatly lessen the environmental impact of trash management with the use of cloud-based smart waste management technologies. [3,5,6].These solutions enable cities to minimize waste management-related emissions and optimize waste pickup routes. The ability of cloud-based smart waste management systems to increase system efficiency is another advantage. Cities can monitor and address possible waste management concerns in real time by integrating these systems with other systems, such recycling facilities. Smart waste management systems that are cloud-based also offer more flexibility and scalability. It is simple to scale up or down cloud-based systems to suit the demands of the city as waste management requirements change and cities expand. Cities can now more readily adjust to shifting waste management needs and guarantee that the waste management system is constantly running as efficiently as possible[3,5,6].

3.6 Emerging Technologies for Sustainable Smart City

(i) 5G Networks

In order to facilitate smooth communication between devices and systems in smart cities, 5G networks will be deployed, offering incredibly fast and dependable connectivity. Innovative services, IoT installations, and real-time data analysis will all be made possible by this high-speed, low-latency network infrastructure[16].

(ii) Digital Twins

Virtual copies of real assets, systems, or procedures are called digital twins. Digital twins can offer significant insights into the operation, upkeep, and optimization of smart city infrastructure by fusing real-time sensor data with advanced modeling and simulation methodologies. For the management and analysis of the enormous volumes of data needed for digital twin implementations, cloud-based solutions will be crucial[16].

(iii) Citizen Engagement and Participation

In order to encourage citizen participation and engagement in smart city initiatives, cloud technology will remain essential. Residents will be able to access information, offer feedback, and actively participate in determining the future of their communities using online platforms, mobile applications, and cloud-powered interactive dashboards[16]

(iv) Integration of Edge Computing, Blockchain, AI, Software-Defined Networking (SDN), and Big data Analytics

The implementation of edge computing, blockchain, artificial intelligence, software-defined networking, and big data analytics technologies in a smart city setting describes the data issues and solutions that arise there[45].A new approach to address a number of urban problems, including urban aging, traffic jams, energy scarcity, pollution, and crime, is the smart city. Finding converged new industries that will dominate the fourth industrial revolution through data, networks, and artificial intelligence (AI) is made possible by smart cities[7].Attempts to use network technology to alleviate urban problems have increased recently, both locally and globally. By leveraging ICT like artificial intelligence (AI), big data, 5G, and networks, the smart city platform is becoming a cutting-edge growth engine focused on energy, transportation, and security. By 2050, according to a UN assessment, 70% of the world's resources would be used in cities, and 66% of the population will live in metropolitan regions[11].

(v) Edge Computing

Applications in smart cities must offer citizens real-time services, which is difficult to accomplish when IoT nodes connected directly to the cloud layer cause a bottleneck in data flow. The field of smart mobility is growing, embracing new applications of data to facilitate our daily lives[11]. All forms of movement are made cleaner, safer, and more pleasurable by the efficient and quick use of data. However, the offline and real-time capabilities needed to guarantee a seamless, safe experience for mobile users are absent from the current cloud computing paradigm. In the face of rising regulatory requirements, edge computing is a vital tool for reducing excessive cloud costs, enhancing user experience, guaranteeing real-time reaction times, and protecting personal data. Assure Offline Capability and Reliability: You will occasionally be without an Internet connection when you are traveling. Offline functionality is necessary for many mobility use cases, such as when traveling, in isolated locations, or in underground garages. Sync Data and Save Money: Although edge computing offers a lot of advantages, many projects require centralized access to some of their data, such as through an on-premise server or the cloud[7].As projects grow, this technology allows you to control which sections of your data to synchronize and when, providing you with dependable access to the data you require while lowering networking and cloud expenses[45].Enhance Sustainability with Edge Computing: As the number of IoT and mobile devices increases, consider the possibilities of using these devices for data processing and storage instead of sending all of our data to data centers. This reduces the quantity of inactive data retained in data centers and not only increases energy efficiency (by lessening the strain on overburdened data centers), but it also creates computing architectures that are intrinsically more sustainable[11].

(vi) Artificial Intelligence

The technology that gives smart cities its name is artificial intelligence (AI). Common applications of AI include voice and facial recognition, network security against foreign incursion, device profiling for authentication, analytics to maximize the operation of IoT devices in smart cities, and more. The field of cognitive science is acknowledged as the next frontier in artificial intelligence, where intelligent systems may offer tailored answers based on the way the human brain thinks[7].Machines are trained to think and act like humans by using human characteristics including brain activity, emotions, spatial-temporal data, gestures, etc. Experts recommended merging Deep Reinforcement learning algorithms with brain activity like perceptual and logical thinking[7].

The same methods that humans use to detect and analyze objects may be applied to applications. One drawback of traditional machine learning techniques is their inability to distinguish items other than those they have been trained to recognize. AI that is based on cognitive computing makes it possible to create a mapping relationship between an object's logical concept and its figure. In Jammu, an AI-based ITMS is already in place. A system called Jammu ITMS uses artificial intelligence to evaluate traffic in real time. When put into effect, it should alter the city's traffic situation. Violations are currently being automatically detected. Commuters will be provided with real-time traffic information next. Depending on traffic volume and average speed on the road, traffic lights will function automatically throughout the day and the human contact in road management will be eliminated. In order to analyze traffic patterns, high-resolution video cameras are deployed as part of ITMS. After the system is put into place and the comprehensive project report is prepared, traffic cops anticipate seeing changes by the following year[27].

(vii) Blockchain Technology

In applications related to smart cities, blockchain's decentralized and transparent structure may improve privacy, security, and trust. Cities may simplify transactional procedures, facilitate safe data sharing among stakeholders, and guarantee the validity and integrity of data by utilizing blockchain technology in combination with cloud platforms[45].

(viii) Big Data Analytics

In order to better serve their inhabitants, smart cities produce vast amounts of data. With the use of big data, smart cities may gain insights from the information gathered from numerous IoT devices located throughout the city. Through the utilization of this data, useful insights are obtained to optimize machine performance in smart city sectors including energy, industrial IoT, residences, buildings, etc[11].A useful four-tier paradigm for big data analysis in urban planning was put out by experts. In smart city sectors including automobile networks, smart parking, weather, pollution, surveillance, etc., data is taken from IoT devices to enable decision-making by authorities that are then put into action instantly. MongoDB is a novel and widely used database these days. It is a provider of document-based, non-relational databases[7]. It is too soon to predict that it will completely replace the conventional RDBMS, despite the fact that it is 100 times quicker than the standard database. However, in terms of performance and scalability, it might be quite helpful. Whereas MongoDB lacks the concept of a relationship, relational databases have a standard schema design that displays the number of tables and the relationships between them[11].

IV. Conclusion

The planning, administration, and general experience of smart cities are being completely transformed by cloud computing. Cloud platforms' scalability, affordability, and real-time data analytic capabilities are enabling cities to improve citizen services, allocate resources more efficiently, and promote sustainability. Cities can monitor energy use, improve transportation systems, and manage infrastructure more effectively by utilizing cloud computing. Nevertheless, it is imperative to handle a number of issues as towns integrate cloud technology into their smart city development[3]. For IoT devices and data streams to integrate seamlessly, connectivity must be strong and dependable. To protect sensitive data and defend against online attacks, security measures must be put in place. To close the digital divide and guarantee that everyone has access to the advantages of cloud computing, digital inclusion programs should also be given top priority. The future of cloud computing and smart cities is quite promising as long as technology keeps developing[4]. Cities may build more connected, effective, and sustainable urban landscapes by utilizing cloud computing. In order to manage energy efficiently, smart grids must be deployed; intelligent transportation systems must be put in place to ease traffic; and data analytics must be used to inform urban planning decisions. In terms of smart city development, cloud technology is revolutionary, providing cities with previously unheard-of chances to prosper in the digital era. By adopting cloud platforms and tackling related issues, cities can fully utilize cloud technology to create a better urban living environment in the future[15].

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