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Ai-Driven Sustainable Smart Cities: An Affordable Model for Viksit Bharat @2047

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***Abstract*—Urbanization in developing countries like India has created complex challenges in traffic management, waste disposal, air pollution and energy usage. It aims to develop an affordable and sustainable AloT framework that integrates these multiple urban sectors into single intelligent system. The proposed model uses low-cost loT sensors, lightweight edge-AI algorithm and open-source technologies to collect and analyse real time city data. Developed to meet the unique needs of Indian cities, such as Tier-2 and Tier-3 cities. It focuses on low- cost implementation and easy to use. Along with core urban services, the framework also introduces AI based smart parking detection which helps citizens to find available parking spaces in real time and reduces traffic crowding caused by vehicles searching. When someone enters the city or local residents, they can scan a QR board placed at different locations (ex. Bus stop, toll gates, railway stations etc.) The QR code displays nearly parking spots, real time parking availability (clearly highlighted as available or occupied), charges and navigation. Unlike existing system that target individual problems this system approaches to combine multiple domains like data analysis to support better planning and decision making. The framework also promotes citizen participation and environmental awareness contributing to cleaner and smart cities and ultimately improving the overall wellbeing and health of its residents. Through this work we aim to support national vision of Vikasit Bharat 2047 by presenting how an affordable AI technology can derive sustainable urban development in evolving economies.**

I. INTRODUCTION

India is experiencing very fast urban growth. According to the United Nations, by the year 2050, nearly 400 million more people will be living in Indian cities. This rapid increase in population will create serious challenges for city authorities, especially in areas such as transportation management, waste collection, air pollution monitoring, and efficient use of energy. These problems are more severe in Tier-2 and Tier-3 cities, where economical resources, technical expertise, and infrastructure that are often limited as compared to the large metropolitan cities. city can be defined as sustainable “if its conditions of production do not destroy over time the conditions of its reproduction” (Imperatives, 1987). Many smart city projects today use Internet of Things (IoT) technology to monitor city conditions. IoT systems collect data using sensors, such as traffic sensors, air quality sensors, and waste-level sensors, and send this data to centralized cloud servers for processing. this approach helps in data monitoring but it has several limitations. First, data processing happens far away in the cloud, which causes delays in decision making. Second, continuous data transmission requires high internet bandwidth, which increases operational cost. As a result, such traditional IoT systems are often too expensive and inefficient for smaller cities.

In this research, we use an AIoT architecture designed specifically for Indian Tier-2 and Tier-3 cities. The architecture uses low-cost scanner, lightweight AI algorithms to enable real-time analysis at the edge which will help in making affordable model for Vikasit Bharat @2047.The proposed system is tested in real-world conditions to evaluate its performance, reliability, and efficiency. this study discusses how such an AIoT-based approach can support sustainable urban planning, improve service delivery, reduce operational costs, and contribute to environmentally responsible city management.

The Government of India, through NITI Aayog’s National Strategy for Artificial Intelligence, encourages the use of low-cost and useful AI solutions to solve real problems in cities. This policy supports the use of AI and IoT technologies to improve services like traffic management, parking, energy use, and environmental protection, especially in small and medium Indian cities.

II. LITERATURE REVIEW

In 2013, Pescaru used traffic route data to predict traffic congestion. This study showed that data can help manage traffic better, but it was limited only to traffic control.

Later, parking became an important issue. In 2019, Praveen and Harini developed a smart parking system using NB-IoT technology. It helped in long-distance communication with low power use. In 2020, Dokania and others proposed a QR-code-based parking system to automate parking entry and exit. These systems improved parking management but worked only for parking and were not connected with other city services.

In 2022, Diop and Azmi studied how artificial intelligence can help in smart and sustainable urban planning. In the same year, Prasad and Pai discussed smart materials and manufacturing for sustainable development. These studies focused more on planning and infrastructure and not on real-time city monitoring.

In 2023, Sharma and others reviewed IoT-based smart city applications. They showed that low-cost sensors and open-source platforms are useful, but most systems are still designed for single applications.

Recent studies in 2024 focused on advanced AI. Dos Santos and Vilela reviewed how AI improves smart city services but also mentioned problems like high cost and complex systems. Dadheech and others used deep learning and IoT sensors for traffic management and achieved high accuracy, but their system needs expensive hardware and strong internet.

Overall, most existing smart city systems either focus on only one service or require costly infrastructure. This shows the need for a low-cost, integrated, and edge-based AIoT system that can support parking, traffic, waste, and environmental monitoring together, especially for Indian Tier-2 and Tier-3 cities.

III. METHODOLOGY

Our research proposed AIoT-based system that aims to provide easy access to nearby urban services while keeping the solution affordable, scalable, and suitable for Indian Tier-2 and Tier-3 cities. unlike conventional system that depends entirely on cloud-based processing, the system uses edge artificial intelligence to process data close to the source.

By combining IoT sensing, Edge AI processing, cloud analytics and QR-based user access, the proposed methodology offers a low-cost, efficient, and scalable AIoT framework. The system is specifically designed for Indian Tier-2 and Tier-3 cities, supporting sustainable urban development and aligning with the vision of Viksit Bharat @2047.

Fig 3.1 shows a smart city system works. Sensors collect real-time data about traffic, parking, pollution, and waste. The data is processed using edge and cloud systems to make quick decisions. Finally, people can scan a QR code to see parking availability, charges, directions, and nearby services easily.

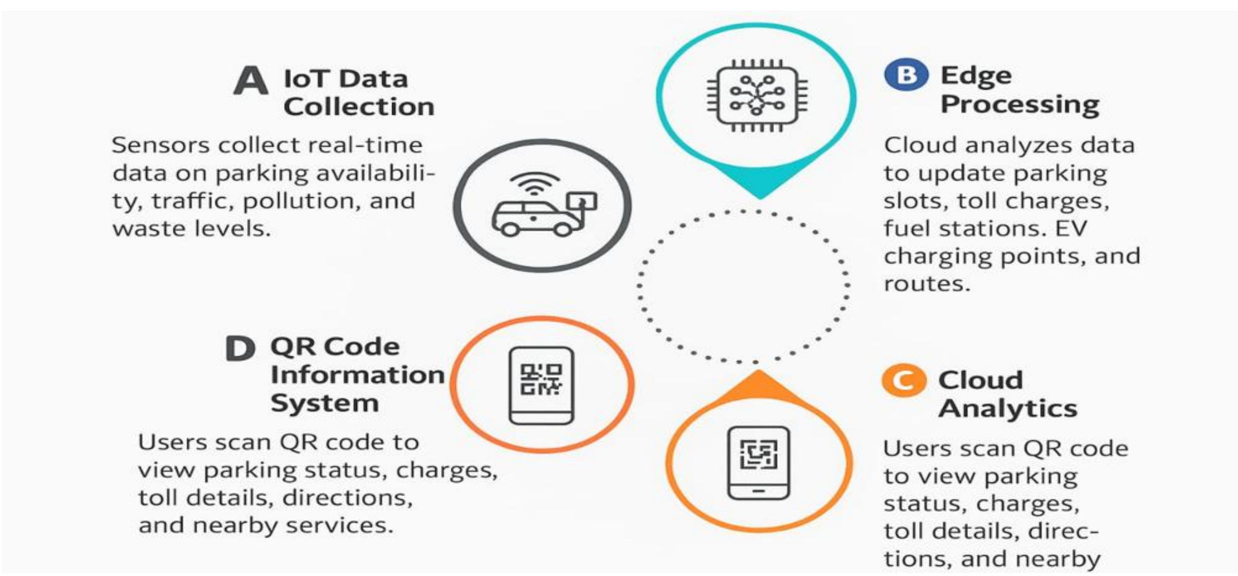

Figure 3.1. Smart Urban Services Model

A. Data Collection

- Low-cost IoT sensors are installed in parking areas and public places.
- The sensors collect real-time data such as parking availability, traffic conditions, and parking charges.
- ESP32 is used for low-cost and energy-efficient operation.
- Wi-Fi or LoRa is used to send data wirelessly.
- The collected data is transferred to a nearby edge device for processing

B. IoT Data Collection

- Ultrasonic sensors are placed at parking locations to detect vehicles.
- The sensor measures the distance between the vehicle and the sensor.
- If the distance is less than the set value, the parking slot is occupied.
- If the distance is greater, the slot is free.
- The system collects parking status, location ID, time, and nearby service details.
- ESP32 collects the sensor data and sends it for local processing

C. Cloud Analytics

After initial processing at the edge only the essential and processed data is sent to the cloud for long-term storage and advanced analysis. The cloud layer maintains and updates information such as:

- Available parking slots
- Toll gate locations and applicable toll charges
- Nearest petrol pump
- EV charging points
- Route recommendations and navigation support

The cloud also manages variations in parking charges, including differences in privately owned parking spaces. All processed information is made accessible through secure cloud APIs, ensuring data integrity and controlled access.

D. QR Code–Based Information System

QR codes area installed at key locations such as parking areas, toll gates, petrol pumps, bus stops, and stations. Only the QR code is displayed on the information board to keep the system simple and with low-maintenance

When a user scans the QR code using a mobile phone:

1. The system detects user's current location
2. The latest data is fetched from the cloud
3. The mobile interface displays parking availability and applicable parking charges
4. Toll gate details and distance are shown
5. Nearby petrol pumps and EV charging stations are listed
6. If parking is full, alternative parking locations are suggested
7. Charges for privately owned parking spaces are also displayed where applicable

This QR-based access removes the need for a dedicated mobile application while making the system easy to use for all citizens.

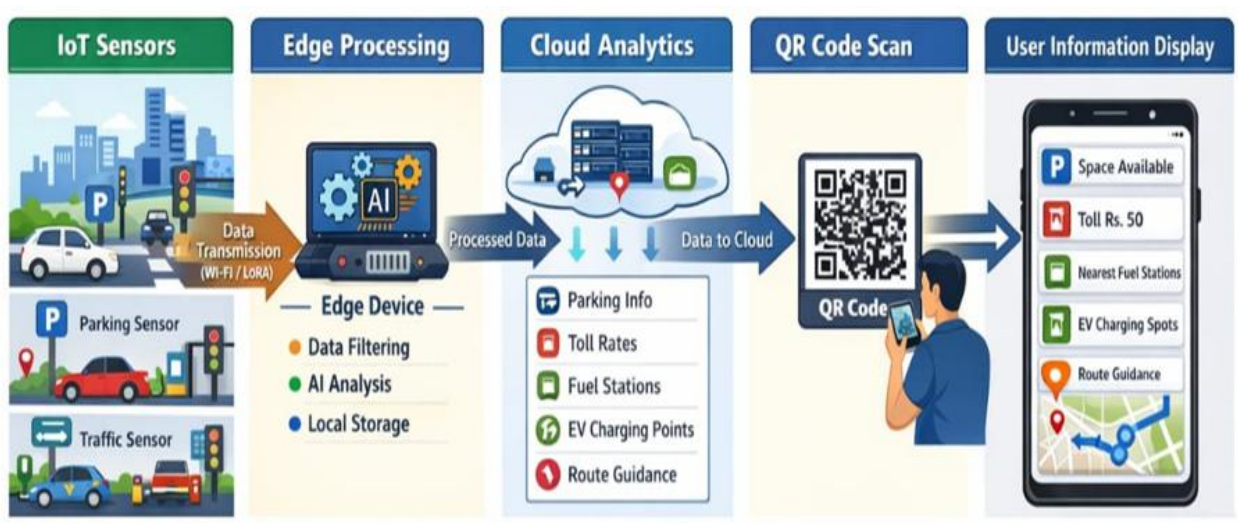

Figure 3.2. IoT-Edge-Cloud Based Methodology for QR Code Enabled Smart City Services

Algorithm 1:
QR Code-Based Parking Information Access
Step 1: User scans the QR code displayed at the parking area or nearby location.
Step 2: Extract the unique Parking Zone ID from the scanned QR code.
Step 3: Request the latest parking status from the cloud database using the Zone ID.
Step 4: Retrieve parking details such as free slots, charges, and navigation route.
Step 5: Display the information to the user in a clear format.
Step 6: Suggest alternative parking zones if no slots are available.

Explanation:
This algorithm allows users to access parking information instantly.
QR code scanning makes the system simple and user-friendly.
Real-time cloud data ensures accurate parking status.
Alternative suggestions improve user convenience.

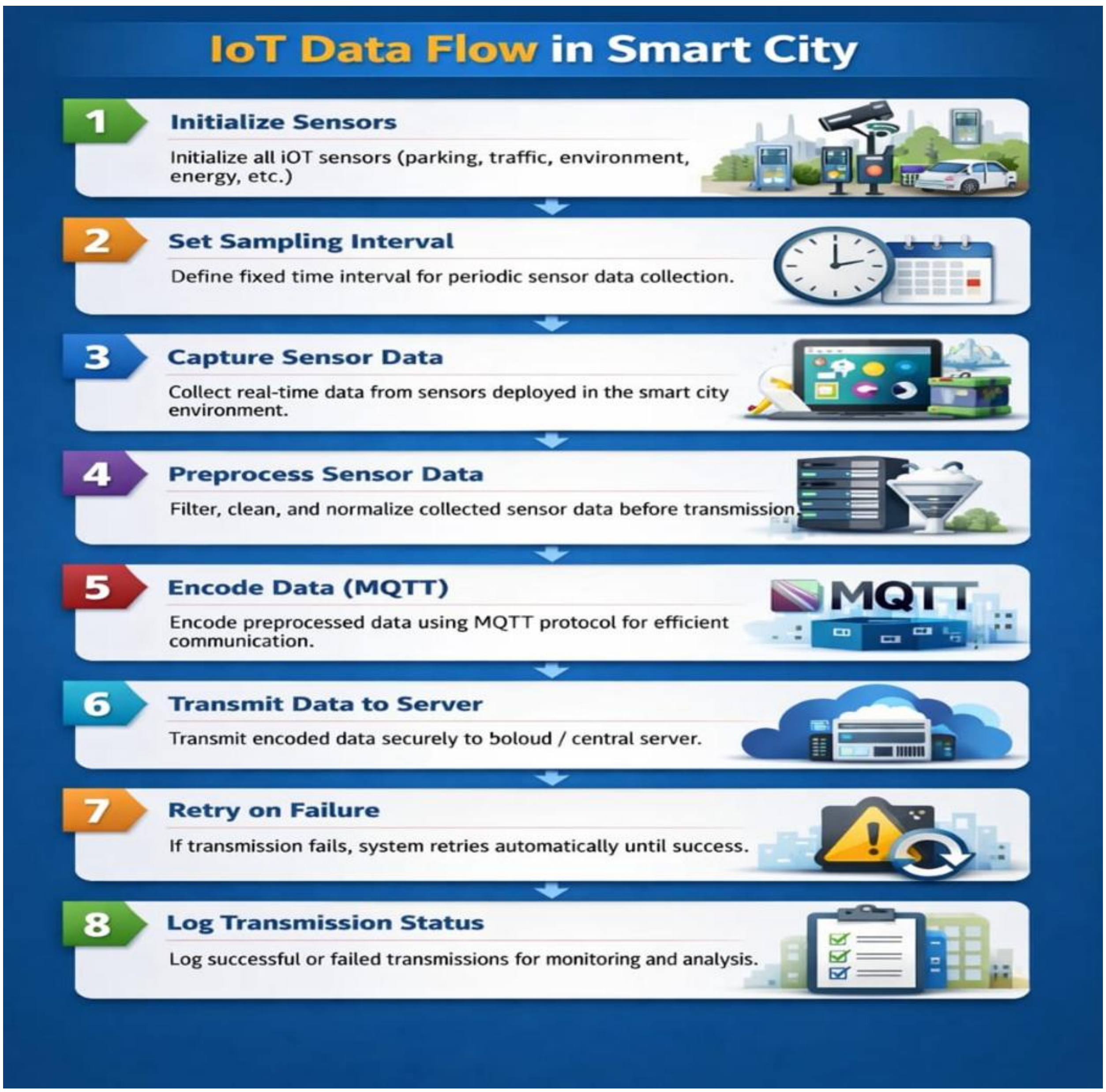

Figure 4.1. Iot Data Flow in Smart city

IoT Data Flow in Smart City

- First, all IoT sensors are started. These sensors are used for parking, traffic, environment, and energy monitoring.
- The system sets a fixed time gap to decide how the sensors will send data.
- Sensors then collect real-time data from different locations in the city.
- The collected data is cleaned and filtered to remove errors and unwanted values.
- After cleaning, the data is converted into a format suitable for communication using the MQTT protocol.
- The encoded data is sent safely to the central server or cloud.
- If data transfer fails due to network issues, the system automatically tries again.
- Finally, the system records whether data transmission was successful or failed for future monitoring.

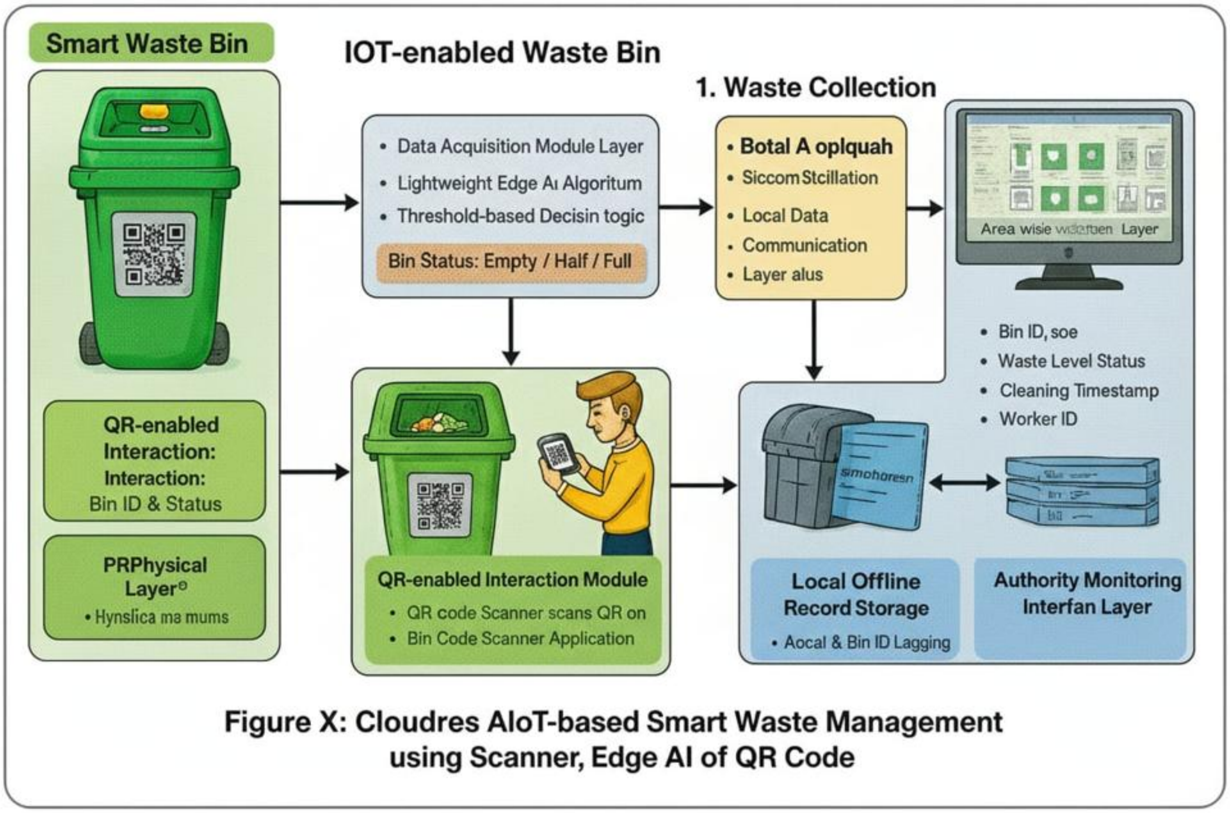

Figure 4.3 QR Code-Based Smart Waste Bin System

This image shows an IoT-enabled smart waste bin where QR codes and edge AI are used to monitor bin status, store data locally, and support efficient waste collection without cloud dependency.

Algorithm 2:

Waste to energy algorithm:

1. Waste Collection

- IoT-enabled waste bins send fill-level notifications to the central server.
- Machine learning algorithms optimize waste collection routes and schedules.
- Waste collection vehicles receive optimized routes and collect waste.

2. Waste Processing

- Waste is transported to the processing facility.
- Sensors monitor waste input, processing, and energy output.
- Energy generation is optimized based on waste composition and quantity.

3. Energy Distribution

- Generated energy is fed into the energy grid.
- Energy distribution is optimized based on demand and supply

IV. DISCUSSION

Our research presents a low-cost and integrated AIoT-based framework which will help in recent challenges in tier -2 and tier 3 cities. The proposed system effectively bridges an important gap in existing literature, where most smart city solutions rely heavily on high-cost infrastructure and continuous cloud connectivity. By combining edge AI, IoT sensors, and a user-centric mobile interface, the framework demonstrates a practical and scalable approach for sustainable urban management.

Following architecture shows the working of the smart parking system. First, the driver logs into the mobile application and checks for available parking slots. The request is sent to the central parking management system (CPMS). The local parking management system (LPMS) checks the parking area and finds the available slots. The parking information is then sent back to the server and displayed in the mobile app. After selecting a slot, the driver sends a booking request, and the system sends a booking confirmation to the user. This system helps users easily find and reserve parking spaces using a mobile phone.

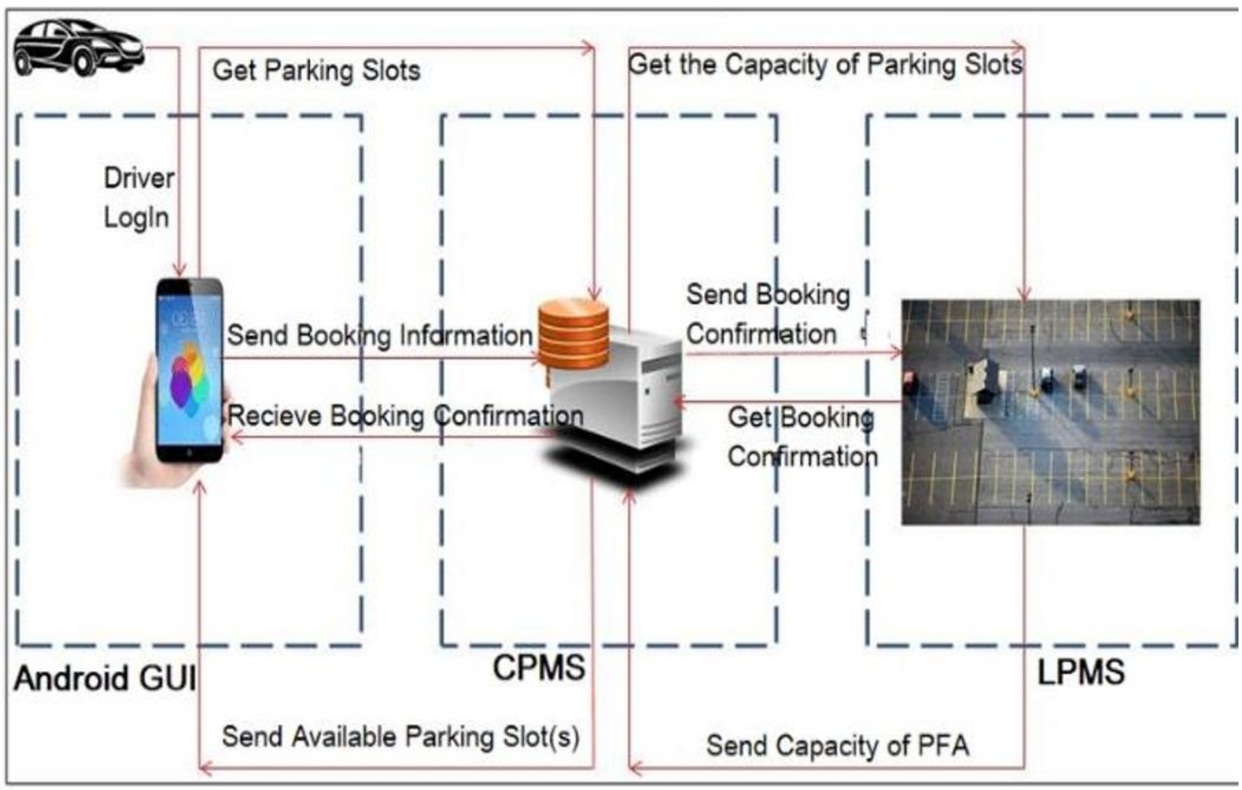

Figure 5.1 Smart Parking System Architecture

This local processing reduces delay and improves data privacy. Sensitive data is not always sent to cloud servers, which helps keep user data safe and secure.
Another important feature of this system is the QR-based interface for citizens. It makes the system easy to use and encourages more people to use it. Since users do not need technical knowledge, interaction becomes simple. This ease of use increases public participation and helps the system succeed in real-world smart city applications.

Compared to existing smart parking and IoT systems, this proposed framework is more affordable, flexible, and suitable for sustainable cities. Most current systems are designed for big, developed cities and are difficult to use in Tier-2 and Tier-3 cities. In contrast, this system uses low-cost hardware, open-source software, and simple AI models, which makes it practical for large-scale use in developing regions.
However, the current system also has some limitations. It has been tested in controlled environments, so its performance may change in very busy cities with

heavy traffic. Also, using a centralized system for AI training may create issues related to scalability and data privacy when many devices are connected.
To overcome these limitations, future work will focus on using federated learning. This method trains AI models locally on devices without sharing raw data, which improves privacy and system performance. Future improvements may also include testing the system in multiple cities, studying energy usage, and connecting it with other smart city services such as traffic control and environmental monitoring.
The proposed system supports the goals of NITI Aayog by showing how affordable AI and IoT technologies can be used in real city environments. The system improves access to urban services while keeping the cost low, which helps smaller cities adopt smart technologies easily.

V. CONCLUSION

This research introduces a practical, affordable, and AI-based Internet of Things (IoT) system designed to support smart city services in Indian Tier-2 and Tier-3 cities, in line with the vision of Viksit Bharat.
Many Tier-2 and Tier-3 cities face challenges such as traffic congestion, parking shortages, inefficient waste management, and rising environmental pollution. At the same time, these cities often have limited budgets and technical infrastructure. This research addresses these issues by proposing an affordable and low-cost smart city architecture that uses inexpensive sensors and lightweight artificial intelligence models, making it suitable for wide adoption.This ensures that citizen data is protected and secured in this system.
Main advantage of this research is that one common platform supports multiple urban services such as smart parking, traffic monitoring, waste management, and environmental monitoring. This approach reduces the need for separate systems, lowers overall deployment and maintenance costs, and improves operational efficiency for municipalities.
The results clearly show that affordable AI and IoT technologies can play an important role in building smart, inclusive, and sustainable cities. By enabling cost-effective and scalable solutions, this researchsupports the Viksit Bharat vision by helping smaller cities adopt digital innovation, improve the public services, and enhance quality of life.

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