IOT Based Smart City

UNDER GUIDANCE OF
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ABSTRACT -This paper provides a comprehensive review of IoT-based technologies revolutionizing urban infrastructure through smart city concepts. Key features like smart parking, home automation, gas leakage detection, solar tracking systems, air quality monitoring, smart irrigation, garbage segregation, and street lighting are discussed with their implementation techniques and impact on sustainability and efficiency.

Keywords: IoT, Smart City, Home Automation, Smart Parking, LPG Gas Leakage, Air Monitoring, Smart Irrigation, Garbage Segregation, Street Lighting, Solar Tracking

1. INTRODUCTION

As cities grow rapidly, urban areas face increasing challenges such as traffic congestion, pollution, poor waste management, and energy inefficiency. To tackle these issues, the concept of a Smart City has emerged, integrating digital technologies and data-driven systems to enhance urban infrastructure, services, and the overall quality of life.The Internet of Things (IoT) plays a central role in smart city development. IoT connects everyday physical objects such as sensors, lights, vehicles, and appliances to the internet, allowing for real-time monitoring, data collection, and automation. These interconnected systems help city administrators and citizens to make informed decisions, conserve resources, and improve operational efficiency. The key applications of IoT in smart cities, includes smart car parking, home automation, LPG gas leakage detection, sun-tracking solar panels, smart street

lighting, air quality monitoring, smart irrigation, and automated garbage segregation. Each feature contributes to creating a more intelligent, secure, and eco-friendly urban environment.

2. IoT Architecture for Smart City

The architecture of an IoT-based smart city is a multi-layered structure that enables efficient communication, control, and automation of urban services. At the foundation there is a Perception Layer, which consists of a wide range of sensors and actuators deployed across the city that collects data from the physical environment. These include infrared sensors for vehicle detection in smart parking, MQ sensors for gas leakage, LDRs and PIR sensors for street lighting, air quality sensors for pollution monitoring, and moisture sensors for smart irrigation. The data from these sensors is transmitted through the Network Layer, which provides the communication backbone using technologies such as Wi-Fi (ESP32/ESP8266), Bluetooth, Zigbee, LoRaWAN for long-range low-power transmission, and GSM modules for SMS-based alerts. The Data Processing Layer serves as the core intelligence of the system, using cloud computing platforms like AWS, Azure, Google Firebase, or edge computing units to store, analyze, and process real-time data. This layer also supports data filtering, aggregation, and predictive analytics using AI or machine learning algorithms for smarter automation decisions..

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Fig 2 Architecture of Smart City

3. Applications And Features

3.1 Smart Car Parking

Smart car parking is a crucial IoT application in smart cities which helps you to reduce traffic congestion, fuel wastage, and time spent searching for parking spaces. This system uses IR or ultrasonic sensors installed in each parking slot to detect vehicle presence, with data processed by an ESP8266 or ESP32 microcontroller. This data is then sent to a cloud platform, such as Google Firebase, via Wi-Fi. A Flutter-based mobile application acts as the user interface, displaying real-time slot availability, navigation to free slots, and enabling features like slot reservation, booking history, and digital payments. Firebase handles real-time data syncing, authentication, and storage, ensuring accurate and instant updates for users and administrators. The admin panel in the app provides insights into parking usage and allows for system management. By combining IoT hardware with a Flutter-Firebase ecosystem, the smart parking system offers a scalable, cross-platform, and user-friendly solution that improves urban mobility and supports sustainable smart city development.

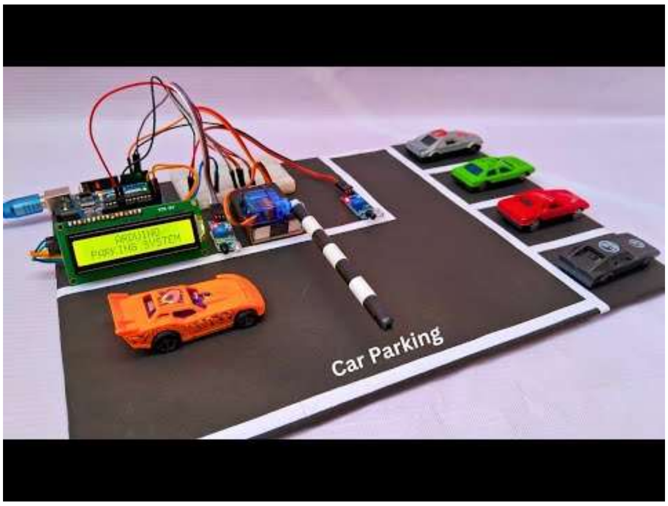

Fig 3.1 Smart Car Parking

3.2 Home Automation

Home automation in smart cities leverages IoT to provide users with remote control over home appliances, improving comfort, energy efficiency, and security. In this system, devices like lights, fans, and appliances are connected through relays controlled by a microcontroller, typically an ESP32 or ESP8266, which is connected to the internet via Wi-Fi. A custom-built Flutter application serves as the central control interface, allowing users to operate their devices from anywhere using their smartphone. The app communicates with a cloud platform such as Firebase, which stores device states, handles real-time data synchronization, and manages user authentication. Through the Flutter app, users can toggle switches, schedule operations (like turning lights on when its sunset), and receive notifications for events like motion detection or door access. The system supports voice assistant integration and can also include sensor-based automation, such as turning off lights when no motion is detected. By combining the power of IoT with a cross-platform Flutter app, this home automation solution offers a seamless, responsive, and user-friendly smart home experiences.

Fig 3.1 Home Automation

3.3 LPG Gas Leakage Detection

LPG gas leakage detection is a critical smart safety feature implemented using the MQ-2 gas sensor. This system continuously monitors the environment for the presence of combustible gases. The MQ-2 sensor detects LPG levels and sends signals to the ESP32 microcontroller. When gas levels exceed a predefined threshold, the system automatically triggers an alert via the Blynk app and activates a buzzer or relay to shut off appliances. This enhances household and industrial safety in smart cities.
KeyComponents:MQ2GasSensor,ESP32,Buzzer,Relay,Bly-nkApp.Impact: Real-time detection, accident prevention, and remote alert system.

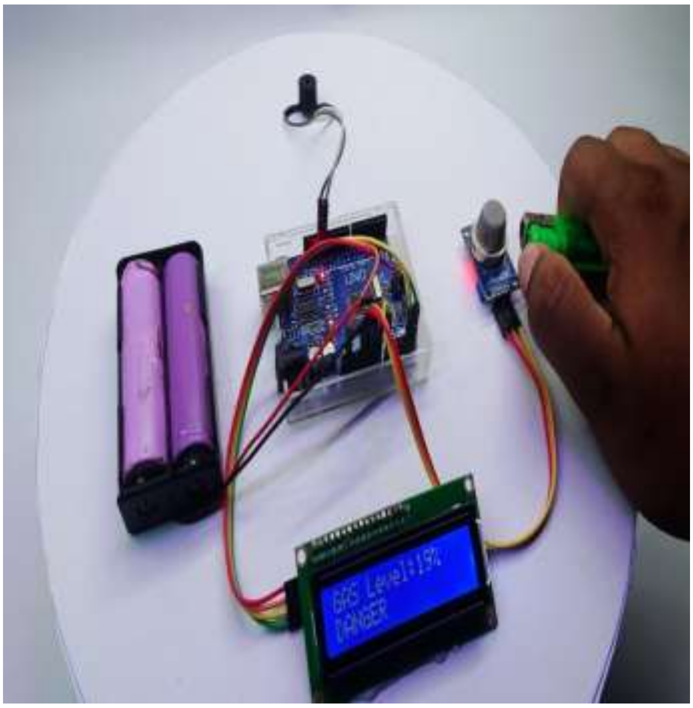

Fig 3.3 Lpg gas detection

3.4 Sun-Tracking Solar Panel System

The sun-tracking system increases the efficiency of solar power generation. It uses two LDR sensors and a servo motor to detect the direction of maximum sunlight. Based on the intensity difference between the LDRs, the servo adjusts the solar panel's angle. This ensures the panel remains perpendicular to the sunlight throughout the day, maximizing energy harvest.
Key Components: LDR Sensors, Servo Motor, ESP32, SolarPanel.
Impact: Increased energy efficiency and support for renewable energy sources.

Fig 3.4 Sun-Tracking Solar Pannel

3.5 Smart Street Light System

Smart street lighting automates the on/off behavior of lights based on ambient light levels. Using LDR sensors, the system detects darkness and automatically turns on the LED lights through a relay module. In daylight, the lights turn off automatically, reducing energy consumption. Motion sensors can also be integrated for further optimization.
Key Components: LDR Sensor, ESP32/Arduino, Relay, LEDs Impact: Energy savings, reduced manual effort, and environmental sustainability.

Fig 3.5 Smart Street Light

3.6 Air Quality Monitoring System

This system uses the MQ-135 air quality sensor to measure pollutants like CO2, ammonia, benzene, and smoke in real time. The ESP32 collects the sensor data and sends it to the Blynk app for monitoring. Alerts can be set for poor air quality levels, enabling authorities or citizens to take timely action.
Key Components: MQ-135, ESP32, LCD (optional), Blynk App
Impact: Real-time pollution tracking, public health monitoring, and environmental awareness.

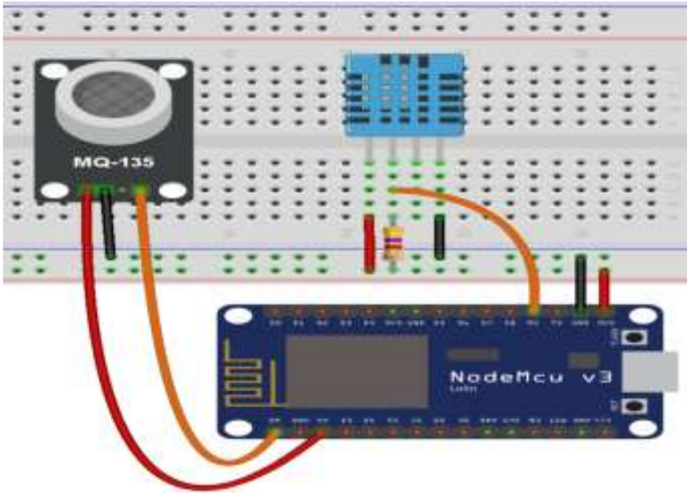

Fig 3.6 Air Quality Monitoring System

3.7 Smart Irrigation System

The Smart Irrigation System consists of moisture sensors inserted into the soil and connected to a microcontroller (Arduino). The system monitors the soil moisture levels and automatically activates a water pump or sprinkler when the soil becomes too dry. This automation helps conserve water by irrigating only when necessary, ensuring efficient water usage in urban gardening or agricultural areas of smart cities.

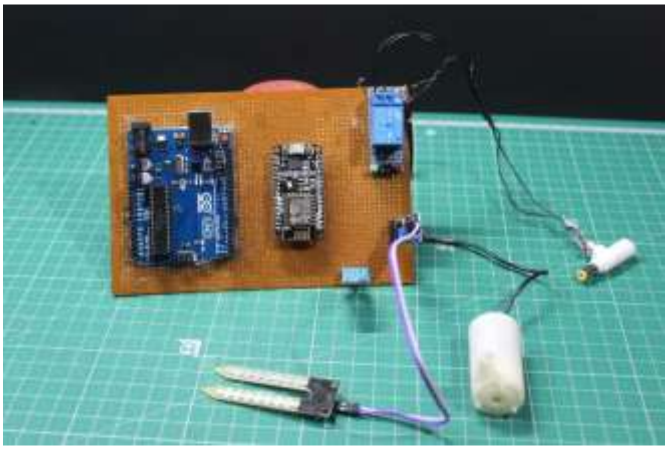

Fig 3.7 Smart Irrigation System

3.8 Garbage Segregator

The Garbage Segregator contains two labeled bins—"DRY WASTE" and "WET WASTE"—along with sensors (such as IR or moisture sensors) and actuators. When waste is inserted, the system detects the type of waste (dry or wet) and uses a servo motor to direct it into the appropriate bin. This feature aims to automate waste classification at the source, making recycling and waste management more efficient in smart urban environments.

Fig 3.8 Garbage Segregator

4. *Communication Technologies Used*

1. **Wi-Fi (ESP8266 / ESP32):**

Wi-Fi is the main communication technology used in this Smart City IoT project. Modules like Air Monitoring System, Smart Irrigation, Smart Car Parking, and Smart Home Automation use ESP8266 or ESP32 microcontrollers to connect to the internet. These devices send real-time sensor data (such as air quality, soil moisture, parking slot status) to cloud platforms like Firebase. Wi-Fi allows remote access and control from mobile apps or dashboards, making the system efficient and user-friendly.

2. **Bluetooth (HC-05):**

Bluetooth is used for short-range communication between devices and smartphones. In this project, it is applied in modules like Smart Home Automation and the Sun Tracking Solar Panel to control appliances or movements locally without internet access. The HC-05 module enables simple and low-power wireless communication within a range of 10 meters, ideal for indoor or nearby control.

3. **Zigbee (Recommended for Future Use):**

Zigbee is not currently implemented in the model but is highly recommended for future scalability. It can be used in modules like Smart Street Lighting and Smart Irrigation, where multiple nodes need to communicate wirelessly over a larger area. Zigbee provides low-power, mesh networking capabilities, allowing devices to relay data among themselves and extend coverage efficiently.

4. **LoRa (Recommended for Long-Range Use):**
5.

LoRa is suitable for modules that need to operate over long distances with minimal power consumption. In a real-world deployment, modules like Air Quality Monitoring or Remote Garbage Monitoring can benefit from LoRa to transmit data up to 10 kilometers away. Although not used in this prototype, LoRa is ideal for expanding smart city features to rural or wide urban areas.

6. **NB-IoT (For Commercial Expansion):**

It is useful for devices like Smart Parking sensors or Garbage Bins that need to send small amounts of data over mobile networks. NB-IoT ensures reliable connectivity even in underground or hard-to-reach areas, making it a strong candidate for future upgrades.

7. **Cloud Platforms (Firebase):**

Firebase is used in this project for real-time data storage, device control, and syncing between modules and mobile applications. It supports Wi-Fi-enabled microcontrollers like ESP8266 and ESP32. This platform enhance the user interface and provide easy access to system information.

5. *Future Scope*

The concept of Smart Cities powered by IoT has immense potential for future development. With the continuous advancement in sensor technologies, cloud computing, and AI integration, the scope of this project can be significantly expanded. Some of the key future enhancements include:

- **AI Integration**: Implementing machine learning algorithms for predictive analytics to optimize city operations such as traffic management, pollution control, and water usage.
- **Real-time Data Visualization**: Use of dashboards and visual tools to display live sensor data for authorities and citizens.
- **Scalability**: Expanding the system to accommodate a broader range of sensors and devices to monitor other aspects like smart lighting, smart parking, and energy consumption.
- **Edge Computing**: Reducing latency and improving response time by processing data closer to the source using edge devices.
- **Security Enhancement**: Implementing advanced cybersecurity protocols to protect data and system integrity.
- **Citizen Engagement**: Integrating feedback systems via mobile apps to involve citizens in real-time issue reporting and updates.

8. *Conclusion*

This IoT-based Smart City project demonstrates a cost-effective and scalable model for urban infrastructure management using various sensors and microcontrollers. By leveraging devices such as NodeMCU, ESP32, and Arduino Uno, the system efficiently monitors environmental parameters like gas, temperature, moisture, and light. Additionally, it supports automation and control of devices like motors and relays, which are vital for real-world smart city applications. The integration with platforms like

Blynk ensures real-time monitoring and user interaction, making the system both practical and innovative. This project is a step toward the vision of sustainable, safe, and technology-driven urban living.

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