An IOT Embedded Pollution Monitoring Mobile App for Smart Cities

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Abstract: Over the past fifty years, there has been a significant migration of people from rural areas to urban centers due to a lack of facilities, educational institutions, healthcare services, and employment opportunities in remote regions. This mass movement has led to increased pressure on large cities, which now face challenges in maintaining a livable and healthy environment as their populations grow rapidly. The demand for civic amenities has surged, particularly impacting road traffic, which has become a major contributor to air pollution and has negatively affected urban environmental health. In today's world, it is crucial to continuously monitor environmental pollution in cities to ensure they remain healthy and livable. One effective solution is the use of the Internet of Things (IoT) combined with smart sensor systems. These technologies can be deployed for various monitoring purposes, including tracking pollution levels in large urban areas. By integrating IoT with a network of sensors, a centralized city office can efficiently manage and oversee the system. This research proposes a framework for air quality monitoring in smart cities utilizing IoT and advanced sensor technology. The system is designed to measure parameters such as humidity, carbon emissions, temperature, smoke, noise, and other hazardous particles present in the atmosphere. The collected data is then transmitted to a central office for analysis, enabling timely actions to improve the city's environmental conditions. Additionally, the gathered information is stored in a database for future reference and can be shared with research institutions and environmental agencies for further studies.

1. INTRODUCTION:

Noise pollution from sound, industrial waste and traffic noise is a major contributor to environmental degradation. Among the various forms of pollution, air pollution is one of the most significant, having a severe impact on human health. Climate scientists and environmental experts are deeply concerned about the effects of air pollution and its role in driving climate changeon aglobal scale. Therelease of numeroustoxic gases from road traffic and industrial waste poses a seriousthreatnotonlytourbanenvironmentsbutalsoto marine life. Over the past fifty years, there has been a significant migration of the global population from rural areas to major cities in search of better facilities and job opportunities.

2. ENVIRONMENT AND RELATED STUDIES

In smart cities, air quality is deteriorating due to rising traffic, industrial emissions, and construction activities. Pollutants such as particulate matter (PM2.5, PM10), nitrogen dioxide (NO□), sulfur dioxide (SO□), and carbon monoxide (CO) contribute to respiratoryproblemsandchronichealthconditionsamongurban residents. Monitoring air quality is essential for evaluatinghealth impacts and developing effective mitigation strategies.

Design of the System:

2.1Structure

The design of a mobile app for monitoring air pollution incorporates real-time data collection, analysis, and user engagement, utilizing Internet of Things (IoT) technology and advanced smart sensors.

2.1.1. System Architecture

This layer employs IoT-enabled sensors deployed at variouslocations across the city, including roadside areas, industrial zones, and residential neighbor hoods. These sensors monitor pollutants such as PM2.5, PM10, NO□, SO□, CO, and ozone (O□), along with environmental parameters like temperature and humidity. The mobile app presents real-time air quality data to users in an intuitive format. Key features include a dashboard, interactive heat maps, notifications, and tailored health recommendations. The cloud server gathers data from multiple sensors, filters out noise, and utilizes machine learning algorithms to identify anomalies and forecast air quality trends. It also calculates the Air Quality Index (AQI) using standardized formulas to assess pollution levels.

2.1.2. Cloud Infrastructure

Real-time pollution data storage and processing. Predictive analysis and anomaly detection using AI/ML models

2.1.3. IOT Sensor

Sensor types (e.g., PM2.5, NO2, CO2, VOCs). City-wide deployment strategy

2.1.4. DataTransmission

Utilization of wireless protocols such as LoRaWAN, Zigbee, or 5G.

2.1.5. App Feature and User Interface

Notifies users when air quality levels surpass safe limits, along with health advisory recommendations. It also offerspersonalizedalertsbasedonuserpreferences,such as high pollution levels in their current location or locations they frequently visit.

2.1.6. Technical Specification

Guarantees secure data transmission through encrypted channels (e.g., HTTPS, TLS). Safeguards user privacy by complying with data protection regulations and minimizing the collection of personal data

2.1.7. The User Flow

This design framework is intended to offer a complete and intuitive solution for real-time air quality monitoring, equipping users with essential information to make informed choices and foster healthier living in smart cities.

2.1.8. Health Recommendation

Provides personalized health recommendations based on the current AQI level. For instance, users might be advised to reduce outdoor activities during periods of high pollution. Also includes safety guidelines for vulnerable groups, such as children, the elderly, and individuals with respiratory conditions.

2.1.9. Community Feedback

Enables users to report issues related to air quality (e.g., burning garbage or construction dust) to local authorities through the app.

3. LITERATURE SURVEY:

The integration of mobile technology with air pollution monitoringhasbecomecrucialintacklingenvironmental issues, especially in urban areas. Various research studies, projects, and technological advancements emphasize the role of mobile apps in tracking air quality and providing real-time feedback to users. Below is a summary of key literature on mobile air pollution monitoring applications?

3.1Applications in Pollution Monitoring App

Air pollution mobile monitoring apps have become increasingly important as concerns about air quality and itseffects on public health, particularly in urban areas, grow. These apps leverage real-time data from IoT-enabled sensors and advanced analytics to deliver timely information about pollution levels to users. Air quality monitoring is a crucial tool for enhancing air quality, safeguarding public health, and ensuring adherence to regulations. It can also help identify sources of pollution, track climate change, and support research and development efforts.

3.2 Performance Metrics and Optimization

A number of factors affect how well WebRTC-based platforms work:

Latency: For the best user experience, real-time systems need to have negligible latency.

Network Resource Consumption: Effective titrate control guarantees quality without using up too much band width.

Service quality or QoS: Measures such as resolution, packet loss, and jitter are essential for preserving high-quality communication. Banerjee et al. (2020) conducted research that emphasizes how WebRTC's congestion control algorithms, including Google's Congestion Control (GCC), optimize resource utilization while providing consistent performance under a range of network situations.

3.3Challenges and Limitations

A mobile app for monitoring pollution can deliver real time insights into air quality and environmental conditions but encounters various challenges and limitations

Scalability: As more people join, peer-to-peer networks close their effectiveness.

Security: Mobile by default allows for encryption, but signaling server flaws can make systems vulnerable to monitoring sensor. Despite being extensively supported, cross-browser compatibility might cause discrepancies due to variations through mobile implementations.

3.4 Directions for the future

New developments in pollution monitoring mobile app for smart cities:

AI and ML Integration: Integration with additional smart city services, such as traffic management. Extension to monitor other environmental parameters, including noise and water pollution. Enhanced AI/ML models for tailored health recommendations.

Edge computing: processing data closer to users to improve scalability and reduce latency.
Web Assembly (WASM): Enabling smart monitoring app applications to encode and decode more quickly and effectively.

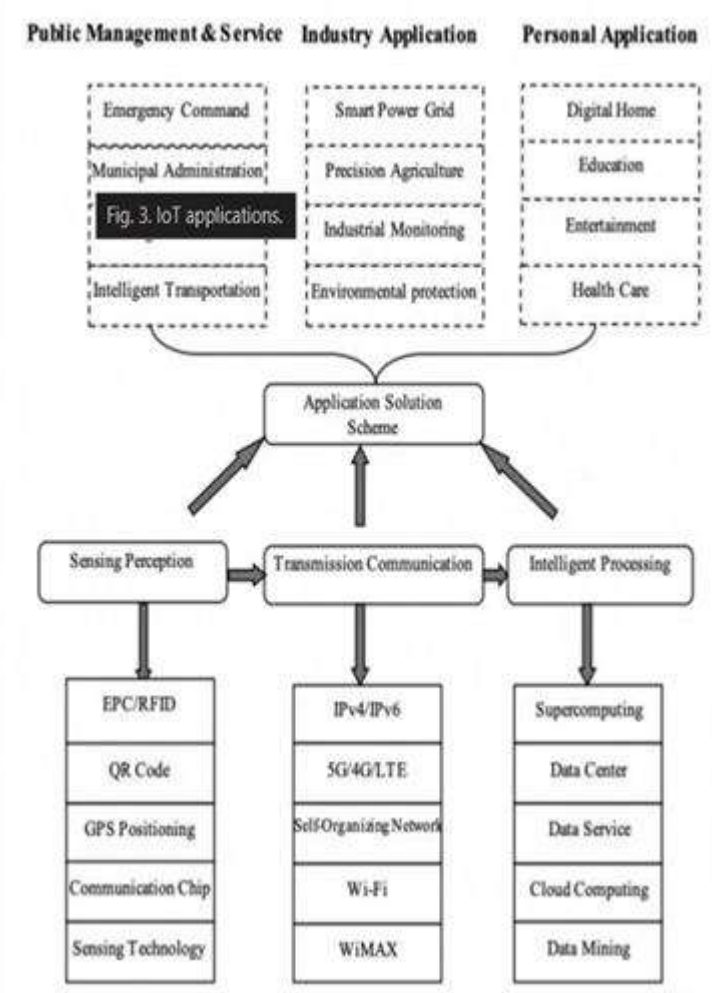

Fig. 3. IoT applications.

4. POLLUTION MONITORING TECHNICAL ASPECTS:

Fixed stations equipped with advanced sensors monitor air pollution levels in real time, offering a continuous flow of data that tracks pollutant fluctuations over short intervals. Sensors monitor air quality and transmit data to a microcontroller. If any value falls outside the normal range, the relevant authorities are promptly notified.

Fundamental Elements

A Number of underlying technologies and three fundamental APIs that manage media capture, processing, and transmission form the foundation of mobile monitoring app.

Air Quality Sensor

Embedded sensors gather real-time data on key pollutants, which are then sent to a microcontroller for analysis.

Microcontroller/Processor Unit

The central processing unit receives and processes data from the sensors, and may transmit this data to the cloud or directly to the mobile app.

Wireless Communication Network

A dependable communication protocol (such as Wi-Fi, LoRa, Bluetooth, or cellular) that guarantees the seamless transfer of sensor data to the cloud or directly to the mobile app.

Architecture

For connection establishment and maintenance, WebRTC's architecture uses a combination of signaling techniques and browser capabilities

Sensor Layer (Data Collection)

Environmental sensors, including those for air quality (PM2.5, PM10), gases (CO, NO2, CO2), and weather conditions (temperature, humidity, wind speed), are deployed at key locations across the city.

Gateway Layer

These devices serve as intermediaries between the sensor nodes and the cloud, managing data aggregation, preliminary filtering, and real- time data transmission. Gateways transmit data via wireless communication technologies like Wi-Fi, LoRaWAN, Zigbee, or cellular networks, based on the distance and specific network needs.

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Cloud Platform

A cloud database (such as AWS, Google Cloud, or Microsoft Azure) stores raw sensor data, historical pollution records, and user-related information. Cloud-based analytics systems analyze the pollution data to compute air quality indices (AQI), identify trends, and make predictions. Machine learning or statistical models may be employed to forecast pollution patterns using historical data.

Mobile Application Layer

The app retrieves real-time data from the cloud platform and presents it through user-friendly interfaces, such as AQI levels, graphs, or maps. The app leverages the mobile device's GPS to deliver location-based pollution data, enabling users to view the air quality in their current area or at selected locations.

Essential Monitoring Protocols

Protocol uses several protocols to provide safe and effective real-time communication.

Data Collection Protocol

Specifies how environmental sensors (such as air quality sensors and weather sensors) interact with data aggregation devices or gateways for communication.

Data Transmission Protocol

A low-power, wide-area network protocol designed to transmit data over long distances while consuming minimal energy, making it ideal for IoT applications in smart cities.

Data Security Protocol

A low power, wide-area network protocol optimized for transmitting data over long distances with minimal energy usage, making it perfect for IoT applications in smart cities.

Data Aggregation Protocol

MQTT (Message Queuing Telemetry Transport) is a lightweightmessagingprotocoldesignedfortransmitting small amounts of data with minimal bandwidth usage, often used in IoT and sensor networks.

User Interface & Reporting Protocol

Encrypts information sent via signaling channels.

Real-Time Control Protocol

Gives feedback for congestion control and keeps an eye on the quality of the transmission.

Techniques for Optimization

Mobile app uses a number of techniques to maximize efficiency in a range of network scenarios:

Efficient Data Transmission

Apply data compression algorithms to minimize the size ofdata transmitted between sensors, gateways, and the cloud platform. Methods such as gzip or binary encoding can help reduce bandwidth usage and shorten transmission times.

Energy Efficiency and Power Management

Utilize energy-efficient sensors and embedded devices that consume minimal power to extend the operation all life of battery- powered sensors deployed in the field.

Edge Computer for Data Processing

Conduct data processing locally at the edge (e.g., on the sensor node or gateway) to minimize the amount of raw data sent to the cloud. Basic processing tasks like filtering, averaging, or a normal detection can be done at the sensor level, reducing bandwidth consumption and cloud processing time.

Security and Privacy Optimization

Encrypt all data exchanged between sensors, gateways, cloud platforms, and mobile apps using secure protocols (such as TLS or HTTPS) to safeguard against data breaches and unauthorized access.

Security in mobile app for smart cities

Security in a pollution monitoring mobile app for smart cities is essential to safe guard sensitive environmental data, protect user privacy, and maintain the integrity of the system.

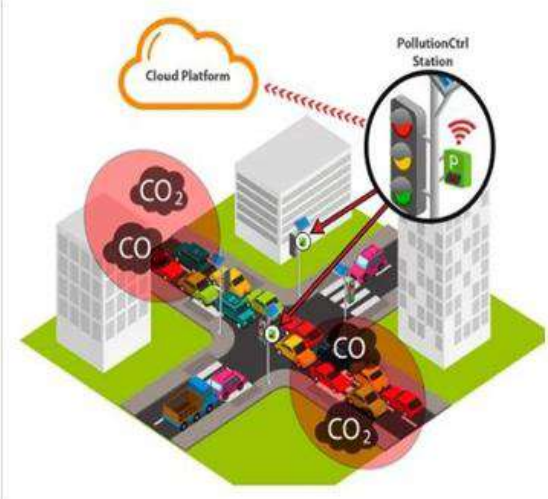

Fig.1. Monitoring Solution for Pollution

Data Encryption

Store sensitive data, such as user information or pollution readings, in an encrypted format on cloud servers or databases. This ensures that even if unauthorized access occurs, the data remains secure. Store sensitive data, including user information and pollution readings, in an encrypted format on cloud servers or databases to ensure that the data remains secure, even in the event of unauthorized access.

User Authentication and Authorization: Implement secure user authentication methods like O Auth 2 or multi-factor authentication (MFA) to ensure that only authorized users can access the app and its data. Apply role-based access control to assign specific permissions to users according to their roles (e.g.,city officials, researchers, or the general public), limiting access to sensitive features or data based on the user's role.

Data Integrity and Validation: Real-time monitoring and anomaly detection are critical components of any IoT- based system, especially for pollution monitoring in smart cities. These techniques help identify unusual behaviors or potential security breaches, such as sensor tampering or the introduction of false data

Real Time Monitoring: Browsers need the user's express consent to access screens, cameras, and microphones. Unauthorized access is prevented by granting permissions just for a single session.

Anomaly Detection: Anomaly detection aims to identify data that significantly deviates from established patterns, which may suggest sensor malfunctions, tampering, or data manipulation.

False Data Injection Detection: Performing consistency checks across sensor can help detect when a specific sensor provides incorrect data that dos not match nearby sensor reading. If one sensor reports unusually high pollution level while other in the same area show normal level, it could signal false data input or a malfunction.

Integration with Incident Response Systems: When an anomaly or breach is detected, automated response systems can be activated. For instance, a sensor suspected of tampering can be temporarily disabled, or the user can receive an immediate notification. Logs of detected anomalies, including details such as sensor ID, location, and time, can be stored for further analysis by administrators or relevant authorities. This helps identify patterns of malicious activity or recurring technical problems.

5. CONCLUSION:

The architecture of a pollution monitoring mobile app for smart cities is centered around an IoT ecosystem comprising environmental sensors, data transmission through gateways, cloud-based storage and analysis, and a mobile app interface. These components collaborate to deliver real-time data, insights, and alerts regarding pollutionlevels. The system prioritizes data security and privacy while providing decision-making support for both users and city authorities. This architecture facilitates proactive air quality management, contributing to better public health and enhanced urban living conditions. In recent decades, migration from rural areas to big cities in search of better living conditions and opportunities has significantly increased. This migration has rapidly raised the city's population, outpacing the available civic facilities. The growing population has placed immense pressure on the city's environment, challenging its ability to remain livable and healthy. A major contributor to this issue is road traffic, which has become a significant source of air pollution, making the environment increasingly unhealthy. This research proposes a framework for monitoring air pollution in urban environments, with actions based on data collected from a sensor system. The proposed frame work can measure various environmental factors, including humidity, carbon emissions, temperature, smoke, sound, and other hazardous particulates in the air. In future work, the framework will be tested through simulations and by installing multiple sensor nodes in different areas of the city to collect real-time data. The results and findings from these real-time measurements will be shared in an upcoming article.

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