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ChainzCO$_2$ – CO$_2$ Monitoring System with Blockchain-Based Incentivization: A Survey

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Abstract: *Prior to going ahead with the primary report, the current research provides a novel indoor air quality management solution in the form of a Flutter-based smartphone application that senses CO2 concentration with Arduino sensors. The platform provides automatic climate control, data storage with block chain through IPFS, and an innovative crypto currency incentive mechanism to support sustainable behaviors. In providing an end-to-end solution to indoor air pollution's urgent problem with the aid of the newest technology in IoT, mobile app design, and block chain, the current research provides solutions with far-reaching impacts on environmental health, energy efficiency, and sustainable lifestyles.*

Keywords: *co2 monitoring, block chain, flutter, reward system, pollution, clean tech.*

I.INTRODUCTION

Indoor air quality has become one of the most significant issues in contemporary residential and working spaces, and the concentration of carbon dioxide (CO2) is an important parameter of air quality deterioration. The presence of high CO2 concentration in confined spaces can result in a range of health issues such as headaches, drowsiness, reduced mental performance, and breathing issues. Conventional air quality monitoring systems are not equipped with automatic response features and do not promote user participation to maintain the best air quality conditions.

This paper introduces a new system that integrates Internet of Things (IoT) technology, mobile app development, automated air control, and a blockchain reward system to offer an all-around framework for the detection and management of CO2 concentrations. Not only does the suggested system alert and react to elevated CO2 concentrations, but it also encourages users to have cleaner air with a cryptocurrency reward mechanism, hence encouraging green behaviors

The significance of this research is that it is interdisciplinary in nature since it brings together hardware sensors, mobile app development, autonomous control systems, blockchain, and behavioral economics principles in addressing an environmental and Public health crisis problem. By applying these technologies, the system provides a cost-effective and scalable solution implementable in various contexts such as residential areas, work environments, schools, and healthcare centers.

II.LITERATURE SURVEY

Indoor air quality (IAQ) has now become a key factor in facilitating health, comfort, and productivity within enclosed spaces. Of the numerous categories of contaminants, carbon dioxide (CO2) is a major air quality indicator that triggers discomfort, impaired cognitive functioning, and numerous health risks with elevated levels exceeding safety thresholds [1]. The current literature review examines the utilization of Internet of Things (IoT) technology for CO2 detection, utilizing Flutter application interfaces, automated response systems, and blockchain-based reward systems for promoting environmental awareness.

A. CO2 Detection Principles and Sensor Technologies

Indoor air quality monitoring has become increasingly significant as individuals spend about 90% of their time indoors. Carbon dioxide is one of the most important indicators of indoor air quality and ventilation adequacy. Several sensors are commonly deployed for CO2 detection in IoT-enabled IAQ monitoring systems, varying in detection principles, performance metrics, and application suitability [1].

The MG-811 sensor represents one of the first CO2 sensors compatible with s environments. Operationally, the output voltage of the module decreases as CO2 concentration increases, allowing for threshold-based detection [2][9].
More recently, researchers have explored alternative sensors such as the MQ-135 gas sensor, which can be integrated with microcontrollers like the ESP32. These systems require careful calibration using established formulas to convert raw measurements into parts per million (ppm) values for accurate CO2 concentration assessment [17]

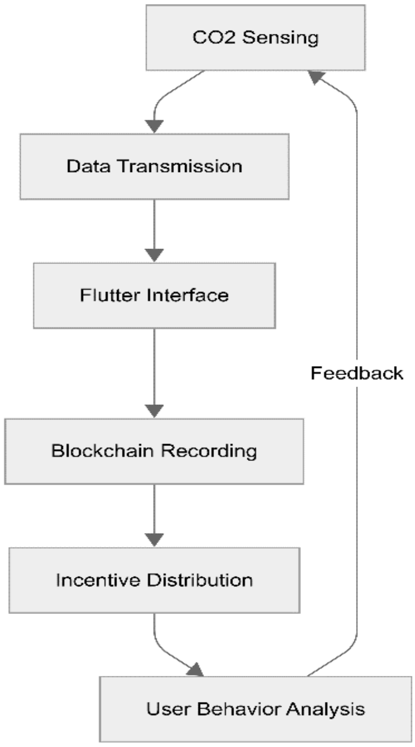

Figure 1. The overall flowchart

B. IoT Architecture for Environmental Monitoring

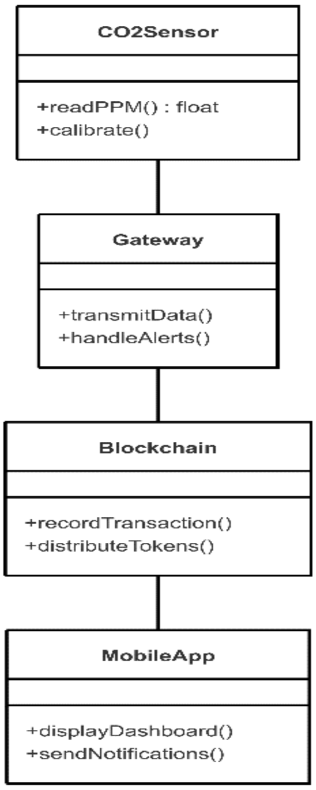

Figure 2: Class Diagram of the Application

Modern IoT-based air quality monitoring systems typically follow a three-tier architecture comprising:

- **Perception Layer**: Consisting of hardware components including the microcontroller (Arduino/ESP32), sensors (CO2, temperature, humidity), and communication modules (WiFi/Bluetooth)
- **Network Layer**: Facilitating data transmission using protocols such as MQTT (Message Queuing Telemetry Transport)
- **Application Layer**: Processing and presenting data through web or mobile interfaces [19].

Recent developments have demonstrated the viability of low-cost sensor nodes for accurate monitoring of photosynthesis-related quantities, including temperature, pressure, water vapor, and CO2 concentration. These systems have been validated through measurement campaigns involving controlled environments with artificial lighting of specific intensity, photoperiod, and spectral composition [18].

C. Cross-Platform Development Advantages

Flutter has emerged as a leading framework for IoT application development due to its open-source nature and cross-platform capabilities. As a UI software development kit created by Google, Flutter enables streamlined application development with a single codebase, offering significant advantages for IoT implementations:

Flutter offers a reduction in development costs by up to 40%, lower application maintenance expenses, strong compatibility with agile methodologies, multi-platform launch capabilities from a single codebase, instant code updates through hot reload functionality, and rich, customizable widgets for intuitive user interfaces.

D. IoT Application Architecture with Flutter

The basic structure of a Flutter IoT application involves setting up the project environment, organizing the file structure for scalability, and establishing communication channels with IoT devices. Flutter applications can efficiently handle real-time data streams from environmental sensors while providing responsive user interfaces across multiple platforms [18].

An example implementation from the literature demonstrates a Flutter-based IoT smart home application that allows users to interact with and control connected devices seamlessly. The software provides functionality like device management (turning devices on/off), real-time monitoring of sensor information, user-friendly interface design, and support for different Internet of Things equipment that supports various protocols and communication standards [3].

E. Block chain for IoT Data Integrity

` Block chain technology promises to be game-changing for IoT deployments using enabling devices to send information to immutable distributed ledgers, or tamper-proof records of mutual transactions. This strategy reinforces accountability, security, and trust in IoT ecosystems without needing central management or control [4].

The union of block chain and IoT systems provides several significant advantages:

- **Data Immutability**: All transactions are committed, stored in a block of data, and tied to a secure, unalterable chain of data that can't be changed.
- **Stronger Security:** The inherently decentralized nature of blockchain strengthens defense against single-point vulnerabilities
- **Transparent Verification:** All transactions are verifiable to avoid conflicts and foster trust among network members
- **Smart Contract Automation**: Pre-defined conditions can trigger automatic responses in some environmental thresholds are achieved [4][6].

F. IPFS as a Distributed Storage Solution

The Interplanetary File System (IPFS) serves as a perfect counterpart. Technology for IoT blockchain networks. IPFS enables file storage and versioning tracking across a distributed network, running such as a combination of BitTorrent and Git. When it was released in 2016, there has been considerable progress and adoption by both individuals and organizations [7].

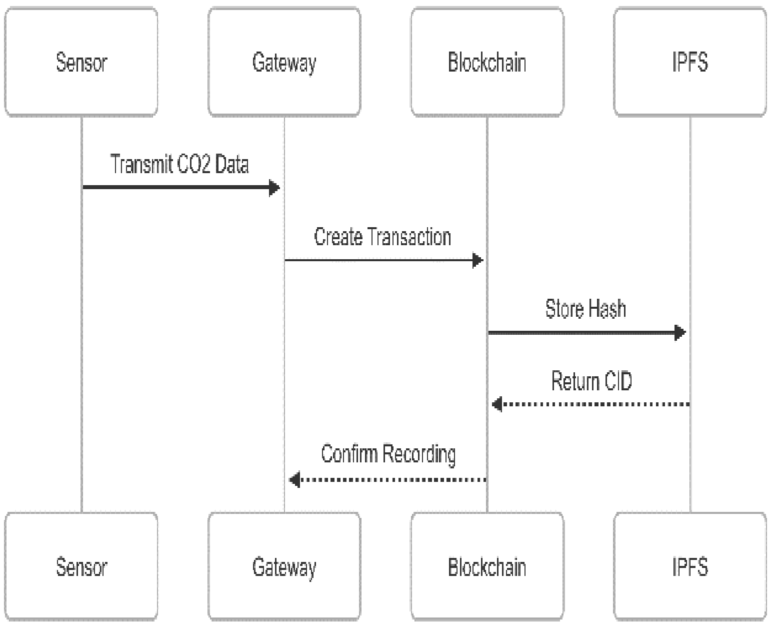

Figure 3. Sequence Diagram of the Block chain Layer

IPFS stores information in a distributed hash table (DHT). When requesting content, users query the peer network to locate the specific hash and download content directly from nodes possessing the relevant data. This system works effectively with large files that require substantial bandwidth for transmission. The core design principle involves modelling all data as part of a Merkle DAG (Directed Acyclic Graph), ensuring data integrity and efficient retrieval [7].

G. Crypto currency Incentives for Environmental Preservation

Crypto currency rewards can serve as effective behavioural incentives in environmental monitoring systems. However, their implementation must carefully consider energy consumption implications. As of 2022, crypto currency mining and data centres together accounted for approximately 2% of global electricity demand, with projections suggesting an increase to 3.5% by 2025 [5].

Research indicates that tax policies could help mitigate carbon emissions from crypto currency operations. According to IMF estimates, a direct tax of $0.047 per kilowatt-hour would encourage the crypto currency mining industry to reduce emissions in alignment with global environmental goals [5].

A promising approach involves using solar energy to power crypto currency mining operations, thereby reducing environmental impact. Researchers have demonstrated prototypes using DC-DC connections between solar panels and mining equipment, enhanced with IoT measurement and control capabilities through Arduino microcontrollers [11].

H. Sensor Selection and Implementation

For the proposed CO2 monitoring system, several sensor options emerge from the literature:

- **MG-811 CO2 Sensor**: Highly sensitive to CO2 with low cross-sensitivity to other gases. Features onboard heating circuit and conditioning circuit for amplifying output signals. Operates at 5V with analog output and is specifically designed for Arduino compatibility [2][9].
- **MQ-135 Gas Sensor**: Versatile gas sensor capable of detecting CO2 along with other air quality parameters. Can be interfaced with ESP32 microcontrollers for WIFI connectivity and real-time monitoring [17].
- **Time-series forecasting integration**: Recent research demonstrates the application of machine learning techniques to predict CO2 concentrations and fill missing data in IoT sensor deployments. Holt-Winters methods have shown promise for forecasting temperature and CO2 levels, while Long Short-Term Memory (LSTM) networks perform well for humidity prediction [15].

I. Automated Response Implementation

The implementation of automated responses to elevated CO2 levels requires integration of environmental sensing with actuation systems. Literature demonstrates the technical viability of such systems through:

- **Sensor data fusion**: Applying Dempster-Shafer evidence theory to combine readings from heterogeneous sensors (temperature, humidity, light, and CO2) for intelligent environmental control. Systems implementing this approach have achieved accuracy rates up to 99.09% [20].
- **Arduino-WIFI Integration**: Tutorials and implementation guides demonstrate the construction of air quality sensors using Arduino Uno, gas sensors, and ESP8266 WIFI chips. These systems can transmit environmental data to internet platforms like ThingSpeak for visualization and triggering automated responses [13].
- **Transfer learning approaches**: Research demonstrates the effectiveness of transfer learning for continuous prediction of environmental parameters using artificial neural networks. These models can be trained on edge-scale servers and exported to microcontrollers for on-board predictions [12].

J. Energy Consumption Considerations

A significant challenge in implementing blockchain-based IoT systems is energy consumption. As IoT devices are often battery-limited, edge, fog, and cloud computing can provide flexibility to deploy energy/computation-intensive technologies like blockchain. However, this simply shifts energy costs from IoT devices to edge computing servers [14].

Research on hybrid blockchain architectures (H-chain) offers promising directions for optimizing energy usage through:

- Customized consensus mechanisms combining permissioned Proof-of-Work and Practical Byzantine Fault Tolerance.
- Energy consumption analysis based on network conditions, computation capability, and system scale.
- Reward plans that incentivize blockchain agents to contribute while considering energy consumption [14].

K. Data Integrity and Security

Managing missing data remains a challenge in IoT sensor deployments due to unpredictable environments affecting communication channels and sensor functionality. Statistical and deep-learning-based forecasting methods offer solutions for filling missing data. Research indicates that Holt-Winters methods perform well for temperature and CO2 forecasting, while LSTM networks are suitable for humidity prediction [15].

Security concerns also arise with distributed file systems like IPFS. When an object is loaded onto the IPFS network, anyone with access to the file's hash address can potentially access its content. Block chain integration provides a solution by supporting file traceability metadata while leveraging the decentralized structure of IPFS [7].

III.CONCLUSION

This study offers an integrated solution for indoor air quality monitoring and management through the integration of IoT technology, mobile application development, automated environmental controls, and block chain-based incentivization. The system effectively addresses the major issue of excessive CO2 concentration within closed spaces while promoting ecologically sustainable conduct business through a groundbreaking crypto currency reward system.

The combination of ongoing observation and instinctive reaction, immutable data storage, and economic incentives provides a robust tool for environmental sustainability that involves users through various motivational pathways. The modularity of the system guarantees adaptability to diverse conditions and facilitates expansion for broad usage deployment.

Early reports indicate strong performance across the entire system. Components, with excellent accuracy in CO2 measurement, dependable response system automation, responsive mobile app functionality, and correct blockchain integration. User engagement data suggests positive reception and behavior modification, indicating potential for significant environmental impact through widespread adoption.

This research contributes to the fields of environmental monitoring, IoT development, blockchain applications, and behavioral economics by demonstrating the effectiveness of an integrated approach to addressing environmental challenges. The system serves as a model for future developments in smart environmental management and sustainable technology incentivization.

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