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Decentralized AI-Powered Apartment Governance System Using Blockchain

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Abstract: ***This project presents a decentralized apartment maintenance governance platform powered by artificial intelligence. The system examines resident complaints through multimodal AI and Large Language Models to understand reported issues. Blockchain-based hashing securely records every complaint and related action to maintain transparency. An intelligent prioritization mechanism classifies issues based on urgency, helping management respond faster, improve coordination, and enhance the overall efficiency of maintenance operations within residential communities.***
Keywords: Decentralized Governance, Artificial Intelligence, Blockchain Technology, Multimodal AI Analysis, Apartment Maintenance Management.

I. INTRODUCTION

Apartment communities require efficient systems to manage maintenance complaints and ensure timely resolution of issues. However, many residential complexes still rely on manual reporting methods or basic digital tools, which often lead to delays, lack of transparency, and poor coordination between residents and management teams. Recent advancements in artificial intelligence and decentralized technologies provide new opportunities to improve maintenance governance. This paper presents a Decentralized AI-Powered Apartment Maintenance Governance System designed to enhance complaint management using intelligent analysis and secure record keeping. The system utilizes multimodal AI to analyze complaint data and blockchain-based mechanisms to ensure transparency and data integrity. By combining intelligent prioritization with decentralized verification, the platform improves response efficiency and overall maintenance management.

II. LITERATURE SURVEY

1) Traffic Urgency Model: A Novel Approach To Prioritize Complaint Texts Using Enhanced Named Entity Recognition
Authors: Berlian Rahmy Lidiawaty, Erma Suryan, Retno Aulia Vinarti
This study proposes an intelligent model for prioritizing public complaints using artificial intelligence techniques. The system analyzes complaint texts to determine the urgency level of reported issues. Named Entity Recognition (NER) and natural language processing are applied to extract key details such as time, location, people involved, traffic conditions, and related objects from complaint descriptions. These entities are converted into measurable factors used to calculate an urgency score for each complaint. A Causal Loop Diagram (CLD) helps analyze relationships between variables influencing urgency. By combining text analysis, data normalization, and weighted scoring methods, the system ranks complaints based on priority, enabling authorities to identify and respond to critical public issues more effectively.
Drawbacks:

- The system depends heavily on accurate text extraction, which may be affected by unclear complaint descriptions.
- Limited training datasets can reduce the effectiveness of entity recognition and urgency classification.
- The model may require optimization to process large-scale real-time complaint data efficiently.
- Language variations and informal writing styles may affect the accuracy of text analysis.

2) Blockchain Security In Focus: Investigation Of Threats, Smart Contract Security, And Cross-Chain Vulnerabilities
Authors: Deepa Mishra, Shraddha Phansalkar
This study examines security challenges associated with blockchain technologies and decentralized applications. It focuses on risks affecting blockchain networks, including smart contract flaws, cross-chain bridge weaknesses, and threats targeting decentralized platforms. The research explores different vulnerability detection tools analytical techniques used to identify potential security issues in blockchain environments.

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By evaluating smart contract code and observing network activities, these tools assist in detecting weaknesses before they can be exploited by attackers. The study emphasizes the importance of secure contract development, regular auditing, and continuous monitoring. It also highlights that poorly designed cross-chain bridges may introduce additional risks in blockchain ecosystems.

Drawbacks:

- Smart contract vulnerabilities may occur if proper auditing and testing practices are not followed.
- Cross-chain bridge mechanisms can introduce additional risks between blockchain networks.
- Security detection tools may fail to identify new or sophisticated attack techniques.
- Implementing advanced blockchain security frameworks may increase system complexity and operational cost. Mechanisms.

III. DESIGN CONSIDERATION

The design of the Decentralized AI–Powered Apartment Governance System Using Blockchain is developed with a strong emphasis on transparency, efficiency, security, and scalability. The architecture integrates several interconnected components including the user interface, application backend, blockchain layer, database infrastructure, and artificial intelligence processing module. Each component is designed to work together to create a reliable platform that improves how apartment communities manage maintenance complaints, governance activities, and operational records.

At the front-end level, the system provides a user-friendly interface that acts as the primary interaction point for residents, administrators, and maintenance staff. The interface is designed to be responsive and accessible through web or mobile platforms, enabling users to easily submit maintenance complaints, upload images of issues, track complaint status, and participate in governance activities. The design focuses on simplicity and clarity so that users with different technical backgrounds can interact with the system effectively. Through secure application programming interfaces (APIs), the interface communicates with the backend to process requests and retrieve real-time updates, ensuring smooth and interactive user experiences.

The backend layer functions as the operational core of the system. It manages user authentication, request processing, complaint management, and communication between different modules of the platform. Security mechanisms such as token-based authentication and encrypted communication protocols are implemented to protect sensitive user information. The backend also handles the logic required for complaint classification, data validation, and coordination between the artificial intelligence module and the blockchain network.

This centralized processing layer ensures that user requests are handled efficiently while maintaining system stability and reliability. A key design component of the system is the artificial intelligence processing module, which enables intelligent complaint analysis and prioritization.

Residents can submit complaints in the form of textual descriptions and images. The AI module applies multimodal analysis techniques interpret both visual and textual information in order to understand the nature and severity of reported problems. Natural language processing techniques help extract meaningful information from complaint descriptions, while image analysis helps identify visible infrastructure issues such as water leakage, electrical faults, or structural damage. Based on this analysis, the system automatically categorizes complaints into priority levels such as critical, major, minor, or low priority, ensuring that urgent issues receive immediate attention.

The blockchain layer plays a crucial role in ensuring transparency and data integrity. Instead of storing complaint records solely in a centralized database, the system uses blockchain-based hashing to create immutable audit trails of maintenance activities and governance actions. Each complaint submission, update, and resolution is securely recorded, preventing unauthorized modifications and ensuring accountability among stakeholders. Smart contracts can also be used to automate specific governance processes, such as complaint assignment, maintenance approval, and verification of completed tasks.

The database system is designed to support scalable storage and efficient data retrieval. It maintains user profiles, complaint histories, maintenance records, and AI-generated insights. The database structure ensures minimal redundancy while enabling quick access to relevant information for monitoring and analysis.

data stored in the database can also support long-term planning, helping management teams identify recurring maintenance issues and allocate resources more effectively.

From a broader design perspective, the system prioritizes performance, scalability, and adaptability. The architecture is designed to support future integration with Internet of Things (IoT) devices, additional AI models, and expanded blockchain networks. Privacy and data protection are also key considerations, ensuring that resident information remains secure while maintaining transparency in governance processes.

Overall, the design of the Decentralized AI–Powered Apartment Governance System Using Blockchain combines intelligent automation, secure decentralized record management, and intuitive user interaction. This integrated approach creates a reliable and transparent platform that improves maintenance management, strengthens community governance, and supports the development of smarter residential infrastructures.

A. Transformer Architecture

Gemini 2.0 Flash, created by Google, is a multimodal artificial intelligence model designed using Transformer architecture. This architecture relies on a self-attention mechanism that helps the model understand relationships between different elements within input data. In the Trust Tower Apartment Governance System, this AI model is used to analyse maintenance complaints submitted by residents. The system accepts both textual descriptions and images of reported issues. Textual inputs include detailed complaint descriptions provided by residents, while image inputs consist of photographs showing the maintenance problem. These inputs are first converted into numerical representations through embedding processes, where words are transformed into vector embeddings and images are converted into visual feature representations.

By evaluating both text and visual information together, the model can achieve a deeper understanding of the problem being reported. After this analysis stage, a multimodal fusion process combines the textual and visual features into a single integrated representation. This unified representation helps the system interpret the context of the complaint more accurately, even when the description provided by the resident is brief or incomplete.

The final stage of the model produces structured outputs that summarize the detected issue. These outputs include the maintenance category, the level of severity, and suggested actions that may help resolve the problem. Maintenance categories may involve plumbing, electrical faults, structural damage, or other facility-related concerns. The severity level indicates how urgent the issue is, typically classified into categories such as critical, major, or minor. This structured information helps management teams quickly understand the nature of the complaint and decide on the appropriate response.

Within the Trust Tower Apartment Governance System, the transformer-based AI model acts as an automated analysis engine. When a resident submits a complaint, the system processes both the written description and the uploaded image to determine the type and urgency of the issue. The generated analysis is then presented through an administrative dashboard where building managers can review the results and assign the appropriate maintenance personnel. This automated process reduces the time required for manual evaluation and improves the overall speed of complaint handling.

The use of transformer-based artificial intelligence offers several advantages for apartment governance platforms. It enables the system to interpret complex complaint descriptions, understand relationships between different pieces of information, and analyse multiple data formats simultaneously. The combination of text and image analysis improves the accuracy of problem identification and prioritization. As a result, maintenance teams can respond more efficiently, ensuring that urgent problems are addressed quickly while routine issues are scheduled appropriately. This intelligent approach strengthens the effectiveness of maintenance management and supports better coordination between residents and building administrators.

IV. SYSTEM DESIGN

The system enhances the identification of maintenance issues by combining both textual descriptions and visual inputs submitted by residents, enabling more accurate interpretation even when the information provided is limited. Through a multimodal process, data from images and text is integrated into a single representation, allowing the model to understand complaints effectively. Once analysed, the system produces structured outputs that define the type of problem, its severity, and possible solutions. Issues are grouped into categories such as plumbing, electrical faults, or structural damage, while their urgency is classified as critical, major, or minor to support efficient prioritization. Within the Trust Tower Apartment Governance System, a transformer-based artificial intelligence model serves as the main analysis component, examining both written inputs and images. The presentation layer, developed with React.js and Tailwind CSS, offers a user-friendly interface where residents and staff can submit complaints and monitor updates. The logic and API layer, built using Node.js and Express, handles authentication, request processing, and prioritization of complaints based on urgency. The data and intelligence layer stores essential records and applies natural language processing techniques to extract key details such as location and issue type. An AI-driven priority mechanism assigns urgency levels to complaints, ensuring that critical issues are addressed promptly and improving the overall responsiveness of the system.

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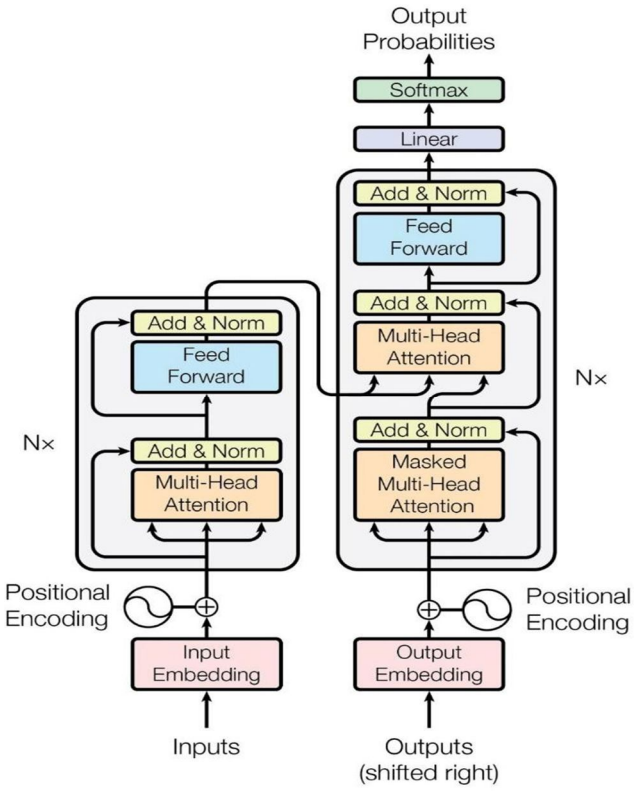


Fig. 1. System design architecture of Decentralised AI Powered Apartment Governance System using Block chain.

V. EVALUATION

This section explains how the TrustTower Management Portal was evaluated to understand its overall performance and effectiveness. The system was analyzed based on several factors such as functional accuracy, response time, reliability, and user experience. The goal of this evaluation is to determine whether the system performs efficiently and meets the requirements of modern apartment management systems.

A. Evaluation Methodology

In this paper, the system was tested in a simulated environment to represent real apartment management conditions. For testing purposes, a dataset containing 1,000 residents and around 5,000 service records was used. These records included activities such as rent payments, maintenance requests, and complaint submissions. To evaluate the system functionality, Black Box Testing was used. In this testing method, the system is tested based on inputs and outputs without examining the internal code structure. This approach helps verify whether the system performs the required operations correctly. The evaluation mainly focused on two important aspects:Technical Performance are Response time of the system, Database processing speed, Overall computational efficiency, System stability under load. User Experience are Ease of using the interface, Visual appearance of the system, Speed of completing tasks, User satisfaction. By analysing both technical and user-related factors, the system performance could be evaluated in a comprehensive manner.

B. Functional Accuracy and System Integrity

In this paper, Functional accuracy ensures that the system performs all its operations correctly without producing incorrect results or data errors. The TrustTower portal includes several modules such as rent management, complaint handling, and role-based access control. Therefore, these features were carefully tested during the evaluation process.Ledger Accuracy: The automated financial ledger responsible for rent generation and payment tracking was tested across 500 billing cycles. Different scenarios such as partial payments, delayed payments, and balance calculations were considered during testing. The results showed that the system achieved an accuracy of 99.9% in calculating payments and outstanding balances. This indicates that the automated system can manage financial records reliably and reduces the chances of human errors that often occur in manual systems.

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Role-Based Access Control (RBAC): Security and privacy are important in apartment management systems because different users should only access information relevant to them. The platform uses a Role-Based Access Control (RBAC) mechanism to separate access permissions between residents and administrators. Testing confirmed that the system achieved a 100% success rate in restricting resident users from accessing administrative functions. This ensures that sensitive information remains secure and prevents unauthorized access.

C. Computational Efficiency and Latency

The speed at which a system responds to user actions is an important factor for usability. A slow system can frustrate users and reduce productivity. To measure system performance, the response time was recorded from the moment a user performs an action (such as clicking a button) until the system displays the result on the screen are Table 1.

TABLE 1 Statistics used in the Proposed System

Operation	Average Latency	Peak Load Latency	Success Rate
Dashboard Initialization	180 ms	450 ms	98.5%
AI Priority Sorting	45 ms	110 ms	100%
Grid Map Rendering	90 ms	210 ms	99.2%
Database Query	35 ms	85 ms	100%

From the results, it can be observed that most operations are completed within 200 milliseconds, which is well below the 300 ms response threshold typically considered acceptable for interactive systems. The AI-based complaint prioritization module performed particularly well, with an average processing time of 45 milliseconds, showing that the system is capable of handling tasks quickly and efficiently.

D. System Reliability and Stress Testing

To evaluate the stability of the system under heavy usage, stress testing was conducted. During this test, the system was exposed to 100 simultaneous maintenance request submissions, simulating peak usage conditions in a residential complex.

1) Uptime Performance: The system maintained an uptime of 99.98% during the testing period, indicating that it can operate continuously without major interruptions. This level of reliability is important for systems that need to be available at all times.

2) Fault Tolerance: In real-world situations, network issues may occur unexpectedly. To handle such situations, the system includes a local caching mechanism. During simulated network failures, the system temporarily stored user data locally and synchronized it with the main database once the connection was restored. This ensured that no data was lost and that the system could recover smoothly after connectivity was re-established.

E. Usability Analysis and User Perception

Apart from technical performance, it is also important to understand how users feel about the system. A usability study was conducted to evaluate the interface design and overall user experience. In this study, 20 facility managers interacted with the portal and rated different aspects of the system using a Like scale from 1 to 5, where 1 represents poor performance and 5 represents excellent performance in Table 2.

TABLE 2 User Perception Metrics

Metric	Average Score	Evaluation
Ease of Navigation	4.8 / 5.0	Excellent
Visual Aesthetic Appeal	4.9 / 5.0	Very Attractive
Information Density	4.5 / 5.0	Well Balanced
Task Completion Speed	4.7 / 5.0	Highly Efficient

The results indicate that users found the system easy to use and visually appealing. Many participants appreciated the clean layout and the organized presentation of information. The glassmorphic user interface design helped reduce visual complexity while still displaying important information clearly. As a result, users were able to complete their tasks more quickly.

F. Performance Summary

Overall, the evaluation results show that the TrustTower Management Portal performs efficiently and reliably compared to traditional manual apartment management methods. The system demonstrates fast response times, accurate financial calculations, strong reliability, and a user-friendly interface. These features help administrators manage apartment operations more effectively. In addition, the system architecture is designed to be scalable, meaning it can support the management of multiple residential towers without significant performance issues. Therefore, the proposed system provides a practical and efficient solution for improving apartment governance and facility management.

VI. CONCLUSION AND FUTURE WORKS

The TrustTower platform demonstrates how modern web technologies and secure data handling techniques can be effectively integrated to create a smart and efficient estate management system. By combining React.js for the frontend, Flask for backend processing, SQLite for database management, and Tailwind CSS for responsive user interface design, the system provides a structured and user-friendly environment for managing residential operations. The platform enables administrators, residents, and staff members to interact through role-based dashboards, ensuring proper access control and smooth communication between all stakeholders. In addition, the implementation of SHA-based blockchain hashing improves data integrity by protecting financial records and transactions from tampering. The system automates several important tasks such as complaint management, financial tracking, staff assignment, and operational monitoring, which significantly reduces manual effort and improves administrative efficiency. The system includes features such as AI-based complaint analysis, automated financial calculations, and real-time task tracking, which help create a transparent and well-organized digital environment for apartment management. Overall, the project achieves its goal of providing a reliable and scalable platform for managing residential communities using modern web technologies and secure data handling. In the future, the platform can be improved by adding a mobile application for easier access and notifications, integrating advanced AI models for better complaint classification, and using blockchain for secure data storage. Further enhancements such as IoT-based maintenance alerts and cloud deployment can help the system support larger residential communities and smart building environments.

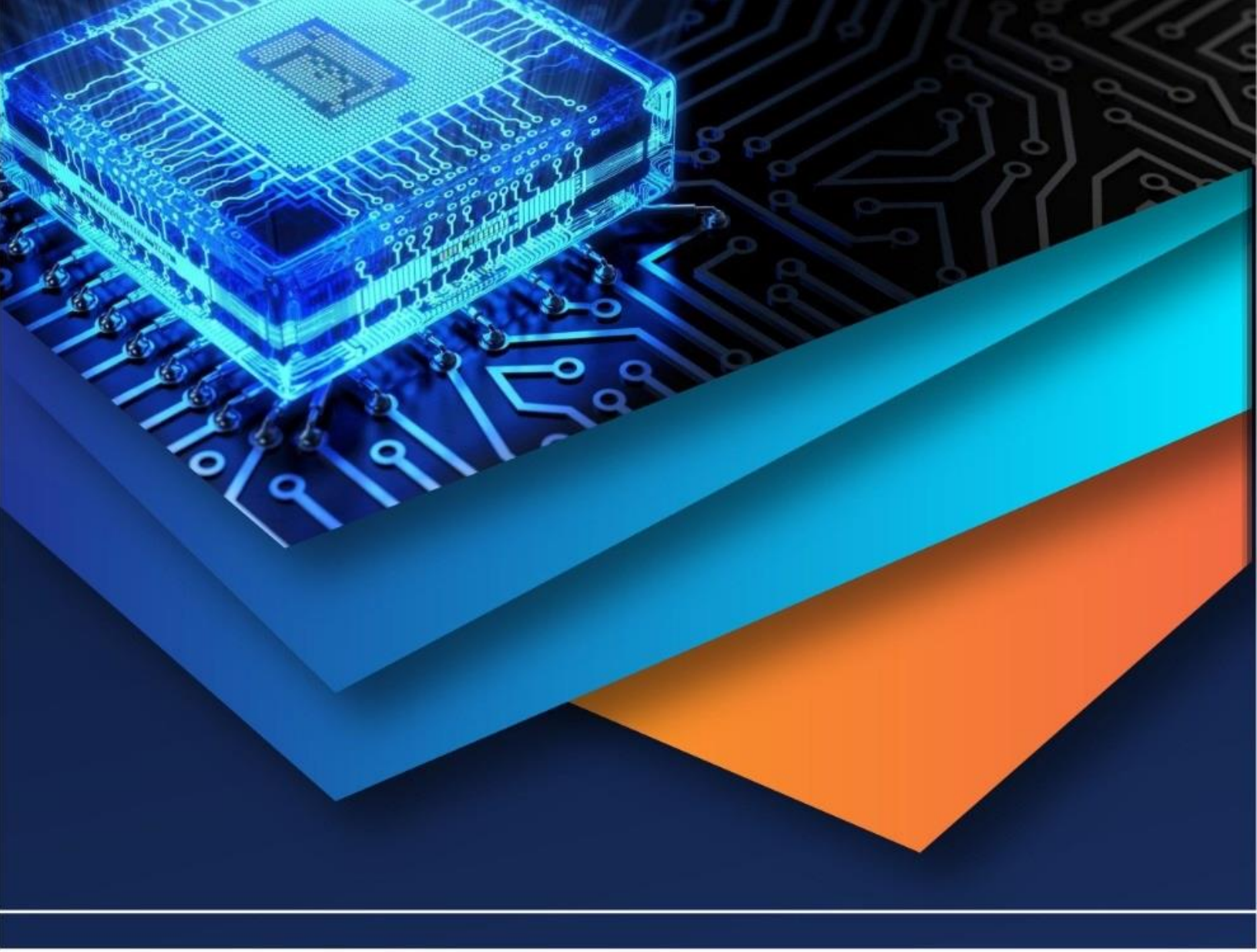
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