Project Title

Blockchain Powered Parking Solution for Smart Cities

CSE400B

Capstone Project

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Introduction:

The urban landscape is undergoing a profound transformation fueled by the relentless evolution of urban mobility and the dynamic integration of technology into the fabric of city living. One of the critical facets experiencing a paradigm shift is the management of parking spaces in urban areas. As cities grapple with escalating populations and burgeoning vehicular traffic, the demand for intelligent, technology-driven solutions to streamline and monetize parking management has surged.

The traditional approach to parking, characterized by manual processes and static infrastructure, has proven increasingly inadequate in meeting the demands of a rapidly urbanizing world. In response, a new era of automated parking management, underpinned by modern technologies, is emerging as a beacon of efficiency and innovation.This change is not just convenient—it's essential as cities work to maximize available space, lessen traffic, and give drivers a smooth, uninterrupted experience navigating the complex urban landscape.

Modern Technology-Based Automated Parking Management in Urban Areas: Modern technology can play a crucial role in improving parking management in urban areas. This likely involves the use of digital solutions to make parking more efficient and user-friendly.

Real-Time Availability Tracking:

Real-time availability tracking is a fundamental aspect of modern parking management. It allows drivers to check the availability of parking spaces in real time, reducing the time spent searching for a parking spot.

Peer-to-Peer (P2P) Parking Sharing:

Peer-to-peer parking sharing implies that individuals can share their parking spaces with others. This can be a collaborative approach to solving parking issues, where those with available spaces can rent them out to those in need.

Integration with Navigation Apps:

Integrating parking information with navigation apps can help drivers find parking options more easily. Navigation apps can provide directions to available parking spots.

Secure Decentralized Environment:

The use of secure decentralized environments, possibly based on blockchain technology, can enhance trust and security in parking management systems. Decentralization can help ensure transparency and prevent data manipulation.

Motivation:

Examining the specifics of this parking revenue stream makes it clear that the convergence of technology, innovative ideas, and urban mobility is going to completely change the urban parking market. The demand for more intelligent, responsive, and user-centric parking management systems that can adjust to the intricacies of contemporary urban living is the driving force behind this change.

Some of the difficulties in monetizing urban parking management are mentioned below:

Trust and Security Concerns:

Trust and security are essential in parking management. Users need to trust that their vehicles will be safe, and security measures are in place to protect against theft or damage. **Legal and Liability Issues:**

Parking management services need to address legal and liability concerns, such as who is responsible in case of accidents or damage in parking facilities.

Pricing and Visibility:

Determining fair pricing for parking and ensuring that parking facilities are visible and easily accessible to users are crucial for successful monetization.

Marketing and Promotion:

Effective marketing and promotion strategies are needed to attract users to the parking management system and encourage them to use the service.

Maintenance and Upkeep:

Regular maintenance and upkeep of parking facilities are essential to provide a positive user experience.

Payment Processing:

Implementing secure and convenient payment processing methods is vital for monetizing parking management services.

Overall,this section highlights the potential of modern technologies in urban parking management and the challenges that need to be addressed to make monetization successful in this field.

Related Works:

Literature review:

[1]The paper discusses the challenges of finding parking spaces in urban areas due to increased urbanization and the growing number of vehicles.The proposed solution aims to use blockchain technology to create a transparent and efficient platform for renting out unused land as smart parking spaces.A Blockchain-based solution for creating smart parking spaces, with key contributions and services such as a Blockchain ecosystem, non-fungible parking tokens (NFTs), smart contracts, real-time surveillance, and a user-friendly mobile application for parking-related activities. Some noted inefficiencies include privacy concerns and security deposits. The main stakeholders involved are the certified landowners, contractors, and government agencies. Rental packages are available on an hourly, daily, and monthly basis, targeting both individuals and companies. However, the paper lacks specific technical details on the implementation of the system's searching/recommendation functionality for available parking spaces, offering only a high-level overview of the system's features.

[2]The paper mentions the development of a parking management system that leverages blockchain technology to enhance privacy ,transaction security and transparency to improve the overall parking experience.The information describes an Ethereum-based consortium blockchain parking system with contributions and services including the use of a consortium blockchain, privacy-preserving parking management, smart contracts for rentals, and user anonymity. Some identified inefficiencies are related to the storage of all data in the blockchain and user adoption. The main stakeholders involved in this system are vehicle users (drivers), parking space owners, government departments, certification authorities, blockchain developers, and service providers. Rental packages include hourly, daily, monthly, flexible duration, and dynamic pricing options, targeting both individuals and companies.The paper, however, lacks specific technical details regarding the implementation of the searching and recommendation algorithms. The recommendation algorithm is presumed to match user preferences with available parking spaces while ensuring user privacy and security, but the precise workings are not detailed.

[3]The authors of this paper developed a model to provide smart parking solutions based on infrastructure integration mechanisms using blockchain technology. The integrated smart parking system described leverages blockchain technology to address trust and data integrity challenges in a smart city context. The contributions and services provided by the system include scalability through a layered architecture and a seamless user experience. However, there are identified inefficiencies related to high transaction costs, specifically gas fees associated with blockchain transactions.The key stakeholders involved in this system include individual clients, commercial users (enterprises), owners/operators of parking garages, developers of blockchain technology, local authorities, and data analytics and insights providers. The parking spaces can be lent for

various durations, including hourly rentals, daily rentals, monthly rentals, and custom durations, targeting both individuals and companies.The specific technical details of the implementation for searching and recommending parking spaces are not provided in the text. However, it is mentioned that the system involves the integration of various sensors, data processing, user interfaces, APIs, and real-time data analysis to offer accurate and up-to-date information to drivers.

[4]The authors proposed Blockchain-based Smart parking with Fairness, reliability and Privacy protection which is called BSFP. The paper discusses an integrated smart parking system that utilizes blockchain technology to address trust and data integrity challenges in smart cities. It focuses on privacy protection through cryptographic techniques, fairness with rewards for honest miners and penalties for dishonest ones, efficiency with constant time complexity for most operations, and the handling of parking operations. It identifies computation overhead and complex registration and payment procedures as inefficiencies. The system involves stakeholders like payment service providers, network operators, sensor providers, parking facility owners, local governments, and personal vehicle users. It offers parking spaces for various durations, targeting both individuals and companies. While it mentions the inclusion of fair allocation algorithms and a recommendation system, specific technical implementation details are not provided

[5]The authors proposed a privacy-preserving blockchain-based smart parking system which is an advanced solution that not only addresses the efficiency and transparency of traditional parking systems but also focuses on protecting user's privacy and ensuring trust through reputation management.The paper outlines an integrated smart parking system that uses blockchain technology to tackle trust and data integrity challenges in smart cities. It focuses on providing privacy-preserving smart parking with anonymity, reputation management, and fair parking rates. It highlights blockchain overheads, accuracy of reputations, and user learning curve as inefficiencies. The primary stakeholders are drivers, parking lots, and parking authorities, and the system offers parking packages on an hourly, daily, and monthly basis.Individuals and companies are targeted.Implementation of efficient searching/recommendation is not discussed.

Research Questions/Problem Statements:

Main Question: How to monetize and optimize the utilization of privately-owned empty parking spots to alleviate street parking congestion?

Sub-Questions:

a. **Facilitating Parking Spot Rentals:**What platforms or systems can be developed to facilitate the seamless renting of empty parking spots?How can technology be leveraged to connect parking spot owners with potential renters efficiently?

b. **Monetization Management**:What strategies can be employed to effectively monetize private parking spaces while ensuring affordability for users?How can dynamic pricing models be implemented to reflect varying demand and supply of parking spaces?

c. **Optimal Parking Spot Selection:**What criteria should be considered when evaluating the suitability of a parking spot, such as accessibility, amenities, and cost?How can a user-friendly interface be designed to help users find the most suitable parking spot for their needs?

d. **Security Measures:**What security measures can be implemented to safeguard both the parked vehicles and the parking spot itself?How can transactions be secured to protect the financial interests of both parking spot owners and renters?

e. **Cost Reduction Strategies**:How can operational costs associated with managing and maintaining parking spots be minimized?What technologies or methods can be employed to streamline transaction processes and reduce resource utilization?

The research aims to address the growing issue of street parking congestion by exploring the effective monetization and utilization of privately-owned empty parking spots. It involves investigating the development of platforms or systems that facilitate easy renting, implementing dynamic pricing for optimal monetization, and designing user-friendly interfaces to assist in spot selection. Additionally, the study explores security measures to protect both vehicles and transactions, as well as strategies to reduce overall operational costs. The goal is to provide a comprehensive solution that benefits both parking spot owners and users, ultimately contributing to improved urban parking management.

Objectives:

The outlined objectives align with the overarching goal of monetizing and optimizing the usage of private parking spots to alleviate street parking congestion.

1.User Authentication and Authorization: Ensuring secure access to parking services is crucial. user authentication verifies the identity of individuals accessing the parking system, typically through credentials like usernames and passwords. Authorization then determines and restricts the actions those authenticated users can take, ensuring they only interact with specific features based on their permissions. This combined approach safeguards the integrity of the parking platform by controlling and verifying user identities, preventing unauthorized access, and protecting against potential misuse or tampering.

2.Digital Payment Systems for Monetization:The implementation of digital payment systems is crucial for streamlining transactions and improving user convenience in the context of monetizing parking spots. These systems enable efficient and secure processing of payments, reducing dependence on traditional payment methods. By embracing digital payments, the parking service enhances user experience, making transactions more seamless and contributing to a more modern and convenient payment ecosystem for parking services.

3.Parking Spot Recommendation System: The system aims to assist users in finding the most suitable parking spot by implementing a recommendation system. Factors such as accessibility, facilities, and cost efficiency are considered to enhance the overall user experience.Essentially, it guides users to the most suitable parking spots based on their preferences and requirements.

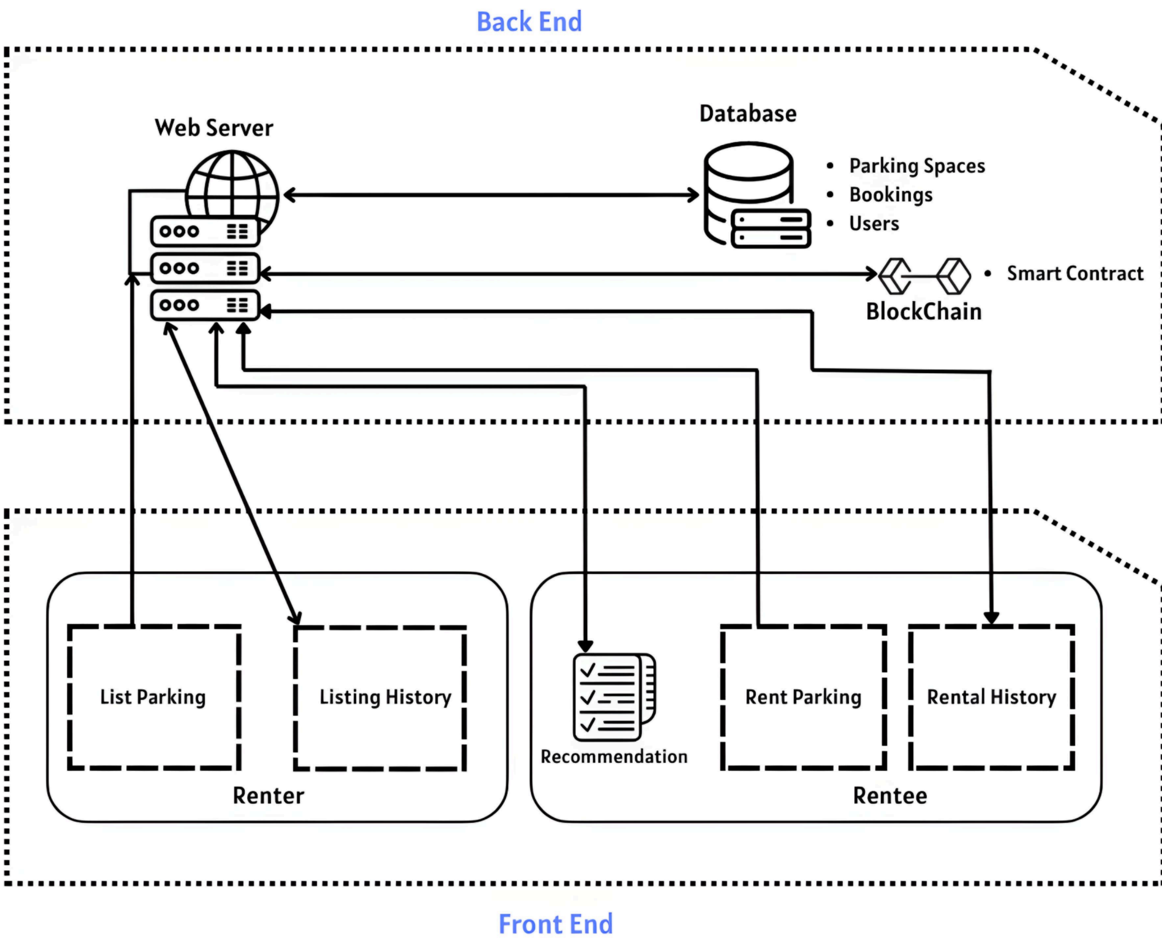
4.Monetizing Empty Parking Spots: The primary goal is to generate revenue and enhance the utilization of privately-owned parking spots, ultimately reducing street parking congestion. This involves developing strategies to effectively market and make these spaces available for rent.

5.Cost Reduction and Optimization with Blockchain and DB: The integration of blockchain and efficient database management is targeted at reducing maintenance costs and optimizing transactions and resources. This strategic combination aims to enhance operational efficiency and minimize associated expenses.

6.Blockchain for Security and Transaction Tracking: Blockchain technology is leveraged to ensure the security of parking spots and cars. It provides a transparent and traceable framework for transactions, enhancing overall security measures within the parking management system.

These objectives collectively ensure that the parking management system is not only technologically sound but also socially responsible, environmentally conscious, and adaptable to various user needs and regulatory contexts.

Planned Methodology:



Data Collection:

In our project, we utilized Google Maps to identify potential parking spaces. We randomly selected some locations, aiming to create a diverse and comprehensive dataset. For each selected location, we collected the geographical coordinates - latitude and longitude - which provide precise information about the location of these potential parking spaces.

Along with the geographical coordinates, we also gathered the address information for each location as provided by Google Maps. This includes details such as the street name, city which offer additional context about the location.

However, it's important to note that while the geographical coordinates and address information are accurate as per Google Maps, other details associated with these locations are not real data.

These include the owner details, parking capacity, facilities available at the parking space, and other related information.

These additional details are hypothetical and have been created for the purpose of this project. They do not reflect the actual characteristics of the parking spaces. Therefore, while the dataset provides a realistic representation of potential parking spaces in terms of their geographical locations and addresses, it does not offer accurate information about the actual capacity, facilities, or ownership of these spaces.

Expected Outcome:

1.Parking Recommendations: The system will generate personalized parking recommendations based on analyzed data, considering factors such as distance, cost, rating, availability, security as well as ease of return.

2.Enhanced User Experience: Data analysis will contribute to an improved user experience by providing accurate and timely information about parking options, empowering users to make informed decisions.

Expected Result:

Final Product:

The final product is a user-friendly blockchain-powered parking system designed to revolutionize the way parking is managed and experienced. This innovative solution harnesses the power of technology to address various challenges associated with traditional parking systems, offering a seamless and secure experience for both parking providers and users.

Outcomes:

1. Improved Efficiency and Reduced Waiting Times:

The implementation of real-time availability tracking and seamless integration with navigation apps significantly improves the efficiency of the parking system. Users can quickly identify and navigate to available parking spaces, reducing the time spent searching for parking. This streamlined process contributes to a more efficient overall urban mobility system, minimizing congestion and waiting times.

2. Enhanced Security in Parking Transactions:

The use of blockchain technology ensures a secure and tamper-resistant environment for parking transactions. Each transaction is recorded on the decentralized ledger, providing an immutable record of all activities. This enhanced security reduces the risk of unauthorized access, fraud, and manipulation, instilling confidence in both parking providers and users.

3. Reduction in Fraudulent Activities Related to Parking:

By leveraging the transparency and security features of blockchain, the system mitigates fraudulent activities associated with parking. Smart contracts, governing the entire process, execute predefined rules and conditions, preventing unauthorized activities such as double bookings or false claims. This reduction in fraudulent behavior contributes to a fair and trustworthy parking ecosystem.

4. Streamlined Payment Processes with the Use of Smart Contracts:

Smart contracts automate the payment processes within the parking system. Users are charged based on the predefined conditions set in the smart contract, eliminating the need for manual payment processing. This automation not only reduces administrative overhead but also ensures transparent and accurate billing, fostering a seamless and convenient payment experience.

5. Enhanced User Experiences, Leading to Higher Satisfaction:

The user-centric design, coupled with real-time availability information and flexible rental packages, contributes to an overall enhanced user experience. Drivers can easily find, reserve, and pay for parking spaces, creating a hassle-free and satisfying parking journey. The user-friendly interface, coupled with the system's efficiency, promotes positive interactions and fosters higher satisfaction among both individual and corporate users.

In conclusion, the outcomes of the blockchain-based parking system extend beyond mere technological advancements. They directly impact the efficiency, security, and user satisfaction within the urban parking landscape, aligning with the broader goals of creating a smarter, more secure, and user-friendly city infrastructure.

Implementation :

Frontend Design :

- **User-Friendly Forms :** The signup and signin pages boast intuitive forms that are easy to navigate and understand. Clear labels, appropriate input fields and well-placed buttons guide users through the process effortlessly.

- **Interactive Home Page :**

List Parking Spots **:** This section provides users with a clear and organized list of available parking spots. Information might include location details, parking type and pricing.

Find Parking Spaces with Google Maps Integration **:** Leverage the power of Google Maps to allow users to visually locate available parking spots in their vicinity. This integration enhances user experience by providing a familiar and user-friendly map interface.

Manage Bookings **:** A dedicated section allows users to view, park or cancel their existing parking reservations. This empowers users to manage their parking needs efficiently.

User Profile Management **:** A comprehensive user profile section enables users to view their personal information, listing or rental history.

- **Technologies Used :**

HTML : The foundation of our web app's structure and content is built with HTML. This ensures the proper layout and organization of all elements on the page.

CSS : Cascading Style Sheets (CSS) is used to style our web app's visual appearance. CSS allows for customization of fonts, colors, backgrounds, and overall layout. This creates a visually appealing and user-friendly interface.

JavaScript (JS) : JavaScript adds interactivity and dynamic behavior to our web app. It enables features like form validation, real-time updates on parking availability, interactive elements on the map, and potentially user account management functionalities.

- **Additional Considerations :**

Responsive Design **:** Our web app is designed to adapt seamlessly to different screen sizes, ensuring optimal viewing experience on desktops, tablets, and smartphones.

Backend :

The backend of this web application utilizes a powerful combination of MySQL and PHP to ensure efficient data storage, retrieval, and manipulation.

Relational Database with MySQL :

Data Storage **:** MySQL serves as the central repository for all application data. It creates a structured and organized environment for storing information like:

- bookings (booking_id, user_id, space_id, start_time, end_time, total_cost, license_plate, drivers_license, status)
- parking_spaces(space_id, lat, lon, user_id, owner_name, owner_mobile, capacity, available_capacity, start_time, end_time, price_per_hour, facilities)
- users (user_id, username, dob, gender, residential_address, city, zip, contact, email, nid, password, eth_address)

Relational Structure **:** Tables are created within the database to store related data. These tables are linked through unique identifiers, enabling efficient data retrieval and manipulation. For example, a "bookings" table is linked to a "users" table using unique user_id and booking_id references.

Data Security **:** MySQL offers various security features to protect sensitive user data. User passwords are stored using secure hashing algorithms, and access to the database is restricted using appropriate credentials.

Dynamic Processing with PHP :

Server-Side Scripting **:** PHP acts as the bridge between the user interface (frontend) and the database (backend). It processes user requests submitted through our web app.

Data Interaction **:** PHP scripts handles tasks like,

- User authentication (login/signup)
- Retrieving parking availability information
- Processing booking requests (adding, modifying, canceling)
- Managing user profiles and settings
- Interacting with the Google Maps API
- Potentially integrating with payment gateways

Dynamic Content Generation **:** PHP scripts can dynamically generate web page content based on user input or retrieved data.So this allows in our web app for features like displaying personalized user information, updating parking availability in real-time, and presenting dynamic search results.

Secure and Traceable Transactions with Smart Contracts :

This web application takes a leap forward in security and transparency by incorporating Solidity smart contracts for managing parking transactions.

Decentralized Code : One Smart contract is deployed on our private blockchain network to eliminate the need for a central authority to control transactions, promoting decentralization and trust.

Immutable Code : Once deployed, the code of a smart contract cannot be altered. This ensures all transactions operate according to the predetermined rules established within the contract, fostering immutability and tamper-proof records.

Traceable Transaction History : All transactions involving our smart contract will permanently record on our private blockchain, providing a transparent trail. This allows for easy verification of transaction details and dispute resolution if necessary.

Blockchain Structure :

This web application leverages a powerful combination of technologies to seamlessly integrate with a local blockchain network for development and testing purposes.

Technologies used **:** TRUFFLE , GANACHE , WEB3.JS

Truffle : Truffle acts as a development framework specifically designed for building and testing Ethereum applications. It offers features like:

- Smart contract compilation and deployment to the local blockchain.
- Automated testing of smart contracts with a built-in testing suite.

Ganache : Ganache is a popular personal blockchain simulator. It provides a user-friendly interface for managing the local blockchain network, including **:**

- Creating and managing accounts for testing purposes.
- Exporting and importing blockchain data for testing scenarios.

Web3.js : This JavaScript library serves as the bridge between the web application and the local blockchain. It allows the web app to interact with smart contracts deployed on the local chain, enabling features like **:**

- Reading data from the blockchain.
- Executing transactions on deployed smart contracts.
- Managing user accounts and signing transactions.

Solidity Code:

```
/// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract ParkingBooking {
   struct Booking {
      uint256 bookingId;
      uint256 userId;
      uint256 spaceId;
      uint256 startTime;
      uint256 endTime;
   }

   Booking[] public bookings;

   function addBooking(uint256 _bookingId, uint256 _userId, uint256 _spaceId, uint256
_startTime, uint256 _endTime) external {
      bookings.push(Booking(_bookingId, _userId, _spaceId, _startTime, _endTime));
   }

   function getBooking(uint256 index) external view returns (uint256, uint256, uint256, uint256,
uint256) {
            Booking memory booking = bookings[index];
      return (booking.bookingId, booking.userId, booking.spaceId, booking.startTime,
booking.endTime);
   }
}
```

Recommendation Algorithm:

Sorting, filtering, and weighted scoring are all incorporated into the recommendation system to give consumers customized recommendations. During the suggestion process, factors including price, security, ease of return, rating, distance, and availability are taken into account. The relative weights assigned to each criterion in the recommendation process are determined by these parameters.

The system uses the Min-Max normalization scale, which scales each parameter to a range between 0 and 1, to guarantee a fair comparison across many criteria. Values can be standardized by this method, which also guarantees that parameters with various scales or units can be compared successfully.

The normalized value for each parameter is calculated using the Min-Max normalization formula:

Normalized value = (Cost – Min Cost) / (Max Cost – Min Cost)

The final score for each recommendation is determined by calculating the weighted sum of these parameters after they have been normalized. User preferences are recorded on a scale from 1 to 6, and these preferences are used to decide the weight allocated to each parameter. A larger weight denotes a higher priority the user has given to the parameter.

The total score for each recommendation is calculated using the formula:

totalScore = (distanceWeight × DistanceNorm) + (costWeight × costNorm) + (RatingWeight × ratingNorm) + (availabilityWeight × availabilityNorm) + (eorWeight× eorNorm)

The algorithm may produce recommendations that are in line with user priorities and preferences thanks to this total score, which represents the combined effect of all the parameters on the recommendation.

Algorithm Complexity:

Complexity of Time:

O(N x M) [For N parking places to be normalized with M features]: This complexity results from the normalization process of each parking spot's features. The algorithm's temporal complexity is O(N x M) since it must normalize M characteristics for each of the N parking spaces.

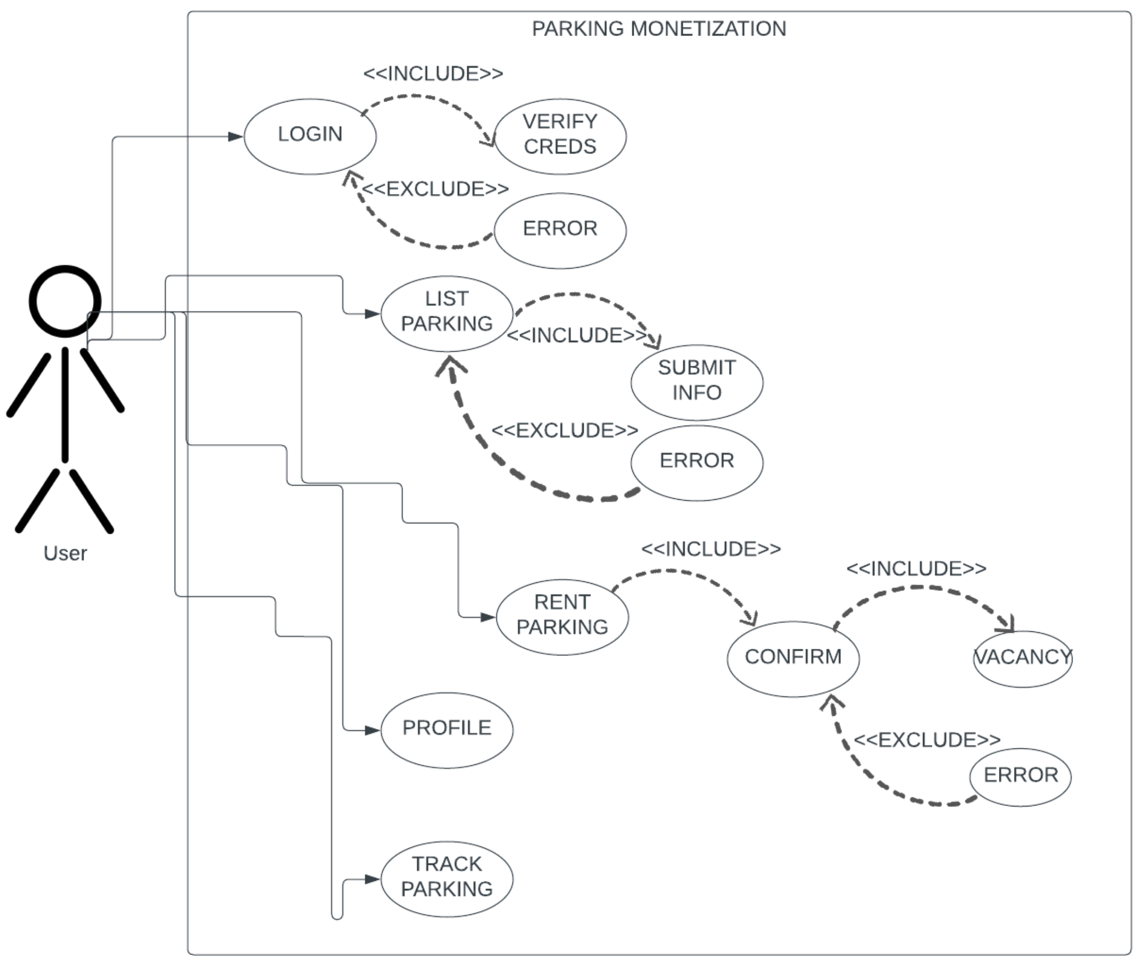
O(N Log N) [For List Sorting Using finalScore]: The list must be ordered in accordance with these scores once each parking spot's final score has been determined. Most sorting algorithms, such as quicksort or mergesort, have an O(N Log N) time complexity when sorting N elements.

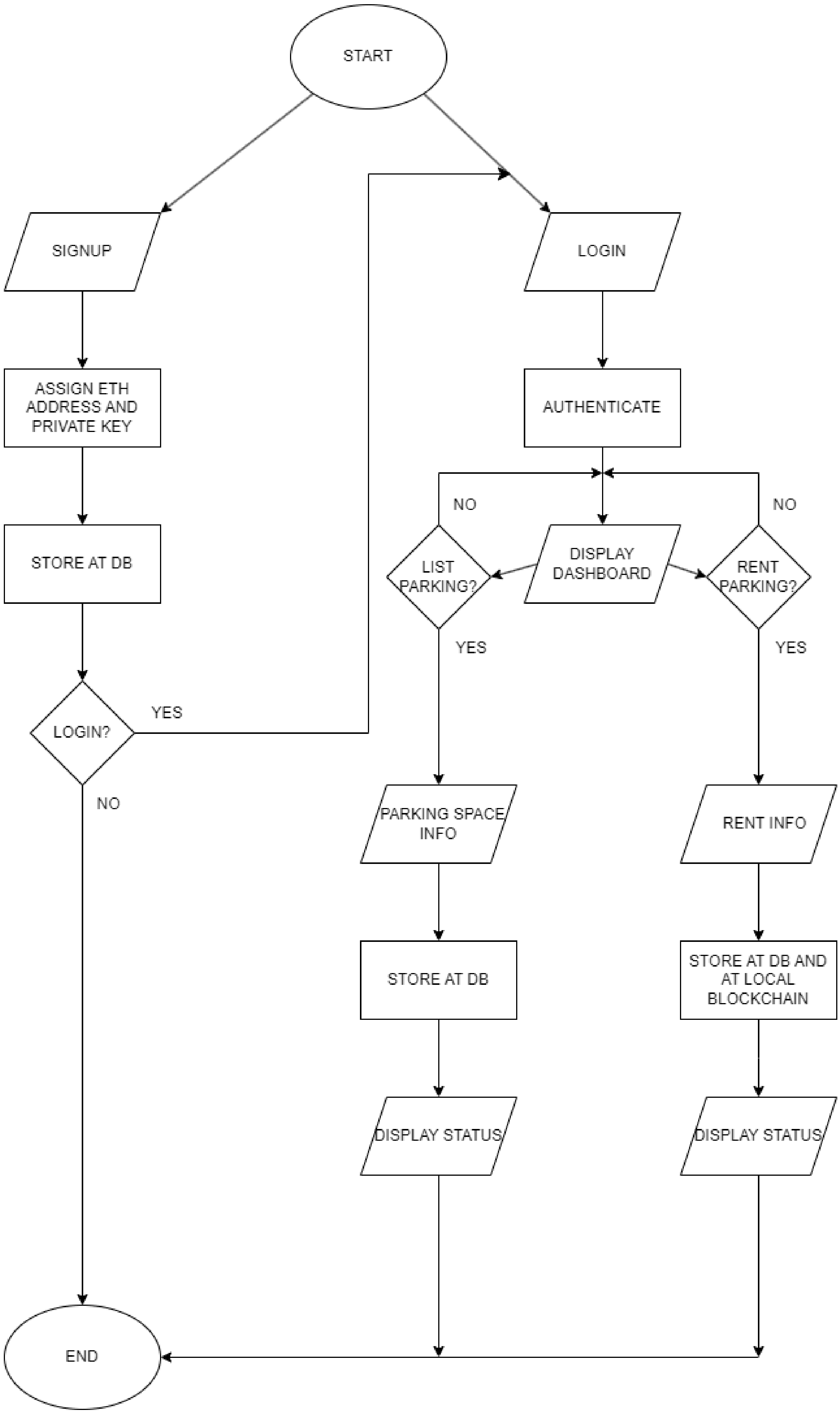
As a result, for the recommendation algorithm, the dominating factor, which is O(N x M), determines the overall time complexity.

Complexity of Space:

O(N) [The total space complexity varies according to the quantity of parking spaces]: The recommendation algorithm's amount of parking spots taken into account largely determines the space complexity. O(N) space complexity results from the algorithm's need to store information on each parking spot, which makes the space complexity linearly dependent on the number of parking spots.

Diagrams :




START
SIGNUP
LOGIN
ASSIGN ETH ADDRESS AND PRIVATE KEY
AUTHENTICATE
STORE AT DB
NO
NO
LIST PARKING?
DISPLAY DASHBOARD
RENT PARKING?
YES
YES
LOGIN?
YES
NO
PARKING SPACE INFO
RENT INFO
STORE AT DB
STORE AT DB AND AT LOCAL BLOCKCHAIN
DISPLAY STATUS
DISPLAY STATUS
END

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Appendix:

CO	Knowledge Profile(K)	Complex Engineering Problem (EP)
CO1) Creating user-friendly Interfaces for drivers to find and pay for parking spots and blockchain guarantees secure and transparent transactions, aided by smart contracts for automated payments and enhanced user trust.	(i) Background [K1, K2, K3] : (K1) : Monetizing a blockchain-based parking system combines technology, economics, and data analysis for success. The system relies on blockchain's decentralization and immutability, using cryptography and consensus for security and transparency. (K2) : Algebra and Discrete Math for smart contracts, Statistics for data insights, and Formal Software Engineering for reliability.	(i) Background [EP1] : Deep blockchain understanding is crucial, encompassing data structure, consensus, cryptography, and decentralized ledgers.[K3] , Specialized engineering knowledge includes blockchain, cybersecurity, IoT, data analytics, Smart Contract Development, UX Design [K4,K5] Ensuring data security, transparency, trustworthiness, and economic impact analysis [K7]. Engagement with research

	(K3) : Engineering basics, blockchain knowledge, cybersecurity, IoT integration, economics, and user-centric design are fundamental for monetizing a blockchain-based parking system.	literature involves learning from existing knowledge, sharing findings, and staying updated with the latest research[K8]. (ii) Research Questions/Problem Statements [EP6] : Maximizing revenue from privately owned parking spots to alleviate street parking congestion.

CO2) Examined updated blockchain based literatures to define the problems and formulate the objectives for this project.	(i) Related Works [K8] : Papers on blockchain based car parking management systems and smart contracts. (i) Related Works [EP1] : Evaluate research papers for adherence to engineering fundamentals, including sound theory, methodology, data analysis, ethics, and practical applicability.[K3,K4,K6,K7, K8]. (ii) Objectives [EP2, EP6, EP7] : EP2 : Involves balancing privacy and transparency, scalability and decentralization, regulatory compliance, and user adoption with security, among other technical and engineering challenges. EP6 : Diverse stakeholders, from drivers , Parking Lot Owners and Operators, governments to technology providers and environmental advocates, have varying needs in blockchain-based parking management. EP7 : Blockchain Infrastructure is a high level problem and smart contracts with data privacy and security are the sub problems

CO2) Examined updated blockchain based literatures to define the problems and formulate the objectives for this project.	(i) Related Works [K8] : Papers on blockchain based car parking management systems and smart contracts.	(ii) Planned Methodology [EP2, EP6] : EP2 : Assessment, interdisciplinary collaboration, ethical considerations, user-centered design, scalability, data security, and continuous improvement.
		EP6 : Stakeholder engagement, assessment, ethical framework, user-centered design, and adaptability.

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