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Smart Parking System Application

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Abstract - Urbanization and increase in vehicles in metropolitan cities have exacerbated problems for parking space finding and management. Traditional parking systems are human-powered, ticketing-based, inefficient and unreliable, and do not meet the demands of modern smart city clear requirements. We have presented the specification and development of a Smart Parking System Application - an app developed with flutter and Node.js with express; it is a cross-platform mobile application that enables the ease of reservation and management of parking spaces for both the user and administrator.

The system consists of two modules, the User Module included secure login, parking search, booking, navigation with Google Maps, allow for notifications to users, and lets users log complaints, while the Admin Module allows the administrator to manage parking spaces, look up bookings and manage complaints. APIs make it scalable, and keep communication real-time, and these include Google Maps, Google Auth, and NodeMailer.

Keywords - Smart Parking, Mobile Application, Flutter, Express.js, Parking Management, Cloud Integration, IoT, Smart Cities.

1. INTRODUCTION

The increasing rates of urbanization and number of vehicles has made finding parking spaces a major issue in metropolitan cities. Traditional approaches such as a parking system that predominantly rely on traditional methods as ticketing, parking place occurrences, and human oversight are not efficient, presents limitations creating opportunity for error, and offers no real-time transparency for users. As a result, motorists often spend valuable time searching for a place to park their cars which leads to increased traffic congestion, fuel consumption and air pollution; issues related to the overall effectiveness of the transportation system with environmental and economic implications To remedy the deficiencies discussed, this project application of a Smart Parking System Application is mobile-based and supports

technology to better manage parking for users and administrators. Developed using Flutter for cross-platform access and Node.js with Express as the backend traction, this application incorporates state-of-the-art technology such as Google Authentication account login, Google Maps API is for routing purposes and NodeMailer for email server processing.

The Smart Parking Application is a clear merging of usability, automation, and real-time monitoring that addresses key limitations of traditional systems while contributing to the larger vision of smart city mobility solutions. This not only reduces waiting times and increases user satisfaction, but also provides accountability and transparency regarding limited urban parking resources.

2. LITERATURE SURVEY

In recent years, parking management has become an increasingly popular research issue, especially for smart cities and intelligent transport systems. In the early years, research primarily focused on the use of big data analytics for transportation purposes. For example, Elgendy & Elragal (2014) outlined how big data could be used to optimize urban mobility and analytics to facilitate and rationalize decision making processes. The authors concluded that through large scale data processing, it is possible to optimize vehicle motion and parking management. Tsai, Chiu, & Chen (2015) also explore the potential of big data analytics technologies, including MapReduce and Spark, and their capabilities in real-time traffic and parking data analysis, among numerous other applications. Subsequently, Vassakis et al. (2018) examined how predictive analytics can be applied within smart city infrastructures and revealed that the analysis of data driven models can add focus on parking issues and provide efficiencies on urban traffic flow.

Aside from data analytics, a number of authors studied Internet of Things (IoT)-based smart parking application. Idris et al. (2009) developed a car park management system for use with parking spaces and vehicles, leveraging sensors and GSM technology to inform users of the availability of car parking slots in real time. The work of Bagula et al. (2015), created a low-budget to

wireless sensor network application for smart parking to show how sensor-based monitoring system could lead to real-time vehicle detection. Polycarpou et al. (2013) designed a mobile parking guide system based on GPS and map integration to direct drivers to available slots, to reduce search time and congestion costs; although these were all examples of research in IoT, practicality proved to be an issue as they were all hardware-intensive and deployment costs were prohibitive to applications in large-scale ways.

Recent studies also examined cloud computing and edge computing in parking spaces. For example, Lin et al. (2017) explored an edge computing solution addressing latency in real-time systems focused specifically on parking. Another example is Al-Turjman (2017), who articulated the scalability of cloud platforms to meet demand for IoT devices in smart parking applications. All these studies emphasize the significance of scalable, distributed architectures necessary to address changing parking demand of growing cities.

Multiple researchers on their part have reported the necessity of mobile-first applications to better serve the user. Khanna and Anand (2016) developed a prototype smart parking system for Indian cities based on mobile applications for booking and

cancellation penalties or provisions for complaints for the limited parking spots, both of which are crucial in ensuring accountability for the proper use of the finite resource of parking spots. Geng and Cassandras (2013) also presented a study on a reservation-based parking system and expanded upon the concept of dynamic pricing within a reservation-based parking system, and demonstrated how economic incentives could be used to manage demand for parking, and maximize slot utilization.

The review of work in smart parking has demonstrated that even though a lot of work has been done in smart parking, most work is either completely sensor-based IoT of simplistic mobile navigation. Also, only a small number of solutions have addressed a complete set of criteria by allowing booking management, secure authentication, cancellation penalties, and complaint handling all within a single integrated solution. Therefore, the proposed Smart Parking Application aims to offer a holistic, scalable, and simple system that balances user convenience and complete administrative oversight.

3. EXISTING SYSTEM

Conventional parking systems remain largely reliant on unautomated methods, including paper tickets, human management, and cash processes

These systems are, in the main, very inefficient, opaque, and do not meet the needs of many urban environments. Drivers, on the whole, expend large amounts of time looking for available parking spaces, which are contributing factors to congestion, fuel consumption, and air pollution. Because conventional systems do not offer real-time data on parking availability, users make an educated guess or physically explore the parking in question. That leads to unnecessary frustration and urban mobility inefficiencies.

Some of the earliest prior smart-parking prototypes addressed urban mobility constraints using hardware-based solutions, for example, RFID tags, GSM modules, and sensor-based slot detection. Smart-parking models, for instance, were based on an IoT framework based on sensor technology that could automatically determine, once a slot was occupied, and then reported that on real-time basis to a centralized management system. While an improvement in accuracy, sensor-based models - had high installation/maintenance costs and scalability problems that make them impractical for large-scale implementation in large urban areas. Additionally, GSM- and RFID-based smart-parking frameworks had a limited scope of functionality too (e.g., simply reporting, showing availability), and could not allow users to book or navigate to the space (or lock user complaints).

Moreover, other mobile parking apps are usually proprietary and standalone and often do not provide any built-in administrative tools. Many mobile parking apps include basic mobile features such as slot search or directions but do not permit enforcement actions that penalize cancellations and no-shows so the efficiency of the utilization of available slots is impaired. Additionally, these apps rarely include complaint registration or feedback systems; therefore, they do not allow users to take recourse when they are unhappy with the service. Most administrative tools do not provide real-time dashboards, analytics, or reporting so parking operations cannot enable real-time improvements in utilisation or customer satisfaction.

Therefore, traditional parking management systems have three primary challenges: (1) no real-time transparency for the user, (2) no accountability or enforcement mechanisms, and (3) limited scalability because they are reliant on hardware-based or mobile-light solutions. The shortcomings of existing parking systems present an opportunity for a more holistic, scalable, and economical smart parking solution .

4. PROPOSED SYSTEM

The Smart Parking System Application is intended to address both unmet needs in traditional and existing

smart parking solutions, by blending modern mobile technologies and cloud services and administrative capabilities into a single app. The system will provide real-time transparency and accountability, as well as ease of use for end users and administrators alike to maximize limited parking spaces available in urban settings. An important design consideration is that unlike other sensor-heavy IoT prototypes, which are expensive and hard to scale, this system is aimed to be a cost-effective and scalable mobile first solution, utilizing cloud-hosted backend services.

Proposed system architecture follows a client–server architecture. The client side features a mobile application written in Flutter, serving both users and administrators for the system. Our use of Flutter for the mobile framework provides cross-platform support for both Android and iOS; hence, we are able to maintain our development efforts without duplicate development efforts on these platforms. The server side features a Node.js backend with Express.js, which manages all business logic (e.g., booking validation, cancellations penalties, complaints completion of complaints), and other external APIs. Data storage will leverage a combination of unstructured data with MongoDB where user and complaints are stored, plus structured data with MySQL for bookings and transactional data.

The User Module allows users to log in via Google Auth or OTP securely; book a parking slot and cancel bookings (with penalties in place to limit such actions and abuses); collaborate with Google Maps API to assist the user to navigate from their location to the booked parking slot to promote a smooth parking experience; and offer a mechanism to lodge complaints via the app, including uploading a picture to improve accountability towards existing communication. In terms of upcoming educative features, we can inform the user and share reminders automatically via emails (using NodeMailer and Gmail API for sending emails), driving reliability and trust towards our system.

The Admin Module offers Admins a strong management contingent. Admins are allowed to add/delete/update slots, view active bookings and upcoming bookings, view summary analytics dashboards on who is using the parking slots, including all complaints that where submitted, as complaint management is planned into the system prompting admins to respond to user complaints,

allowing them to report complaint integrity by responding to the complaint (which provides and the imestamped accountability). This would increase transparency, and set up trust between users

and providers. The analytics dashboards offer us something even more valuable - Utilisation Trend Path; Reporting dashboards will further allow Administrators to optimise their resource allocations during the life of the booking, because the timeline of complaints and resolutions will be physically logged on the dashboard as records.

The proposed system as a Smart Parking System integrates all these features to assure the solution has: real time slot availability, fairness in booking management, accountability with penalties and complaints, and administration quickly with dashboards and analytics. In addition to this, the solution is designed with the future in mind, including possibilities for integrating IoT-based sensors for automatic slot detection, machine learning to drive demand forecasting, and multiple payment gateways to facilitate cashless transactions. With all these aspects into consideration, the proposed solution provides an accountable, feasible and sustainable parking solution for modern smart cities

5. IMPLEMENTATION

The proposed Smart Parking System Application was developed using a modular development process, ensuring that the User Module and Admin Module were developed, tested, and integrated systematically. The development stack was selected with the intention of enabling compatibility across platforms, scalability, and direct integration with third parties.

For the front-end mobile application, the Flutter framework was a natural choice because it created a cross-platform mobile application and would run on Android and iOS devices seamlessly. Built on top of the Dart programming language, Flutter offered a single code base to test and run on multiple platforms, reducing the development time to market and offering consistent performance on all devices. Furthermore, the user interface was designed to be usable and responsive to enable functional navigation including login and booking, slot cancellation, complaints development, and user profile management. A different dashboard interface was created, still using the Flutter framework, on which administrators could visualize real-time data, manage slots, and manage complaints.

On the backend, the system made use of the Node.js environment with the Express.js framework, which was ideal for processing concurrent requests. The backend provided core processing, including the booking logic

implementation, handling cancellation penalties, sending notifications, and authenticating to the users.through RESTful APIs, allowing the system to be scalable with the possibility to integrate additional modules.

Data was managed using a hybrid approach to storage. MySQL was then used for structured data, such as booking details, a log of penalties imposed, and user transaction data. MongoDB was used for unstructured data, such as complaints text descriptions and uploaded images. The entire system utilized a dual database approach to improve flexibility of data but still provide performance and reliability.

To maximize functionality, several APIs and third-party services were integrated. After researching a variety of APIs, we decided to use the Google Authentication API for secure login, and Google Maps API for navigation support and location services. We implemented NodeMailer using the Gmail API - this service was used to send booking confirmation emails, cancellation emails and reminder notifications to users. By doing this, we knew they were aware of their booking, and it allowed transparency and user trust in us because we were able to contact them consistently.

We deployed the system on cloud-based hosting services, such as Firebase and AWS, that provided us with scalability; therefore, we could be sure the application could meet growing demands from users without sacrificing performance. We followed security measures through HTTPS protocols, token-based authentication and ensured database connections were encrypted to protect sensitive user information.

Testing was a key element that helped confirm the system's veracity. Unit testing was performed to confirm correctness of each individual function like, login validation, booking, and email notifications. Integration testing was performed to confirm that the modules (user, admin, database, API) were properly interacting. System testing was performed to validate the complete end-to-end workflow including booking, receive confirmation, go to parking area, and handling of complaints. User acceptance testing was later completed as well with a few users being asked for input regarding their usability, speed, and overall experience. Finally, performance testing under concurrent load has also demonstrated that the backend system can handle multiple simultaneous requests (booking) with great latency.

6. RESULTS

The Smart Parking System Application underwent extensive testing under various scenarios to assess functional, performance and usability aspects.

Theresults confirmed that the system met the original design ideas and objectives by delivering real-time booking of slots, secure login, navigation, cancellation (with penalties), and complaint resolution. The functional testing validated true behavior of the application: both user and admin modules behaved as intended with all relevant use cases. Users could book slots, receive email confirmations, cancel bookings with penalties, and use the Google Maps API with turn by turn navigation to the parking locations. Admins could manage parking slots, view and monitor parking slot reservations, and administer complaints from the dashboard.

When it comes to operational performance, the backend system that was deployed on cloud infrastructure was validated on customer bookings with simulating multiple concurrent booking requests and additional cloud services. The application sustained some stability and processed requests with negligible latency while under stress. User acceptance testing (UAT) conducted with participants revealed they were very satisfied with the site, with users especially appreciating the booking confirmation emails, penalty enforcement mechanism, and the complaint resolution mechanism. Administrators found the analytics dashboard valuable for monitoring slot usage, providing accountability back to the venue, and ensuring accountability across multiple staff members.

7. CONCLUSION

The development and evaluation of the Smart Parking System Application have shown that it has the potential to improve both the effectiveness and transparency of urban parking management substantially. By combining up-to-date mobile technology with a cloud based backend, the system was able to overcome elements of traditional parking approaches and the weaknesses of previous prototypes to satisfy our goal of enriching man's experience with solid evidence of progress. The application provides users with a seamless parking experience consisting of secure authentication, real time booking, navigational support, cancellation (with penalty) and complaint handling. Further to the user's experience, administrators are provided with a centralized dashboard where management can manage parking slots in real time, view booking trends and respond to complaints in an efficient manner.

Performance test results and user acceptance trials confirmed that the Smart Parking System Application is a reliable and usable application. Not only did participants report back positively about their experiences with booking confirmations, navigation integration and the complaints handling approach, they also suggested that the penalty system was reasonable and fair. The penalty system evidently limited the potential misuse of parking spots as well as holding users accountable for reserving parking spots when they did not use them. With continually stability under high traffic loads and favorable response times reported by users, we conclude that the application is suitable scalable for future deployment in smart city contexts.

Overall, this study provides value towards the vision of intelligent transportation systems, as it represents a practical, scalable and sustainable approach to parking management. However, it should be noted that the current version of the system relies on the manual entry of slot availability to stay up to date, and real-time IoT-based detection has not yet been put into practice. Future enhancements, specifically IoT integration for automatic detection of parking slots, AI-based demand prediction, and multi-payment gateway flexibility, will further build on the application and expand the scope of work. With these enhancements and others that could be identified, the Smart Parking System Application will be positioned to become a key offering in the infrastructure of smart cities, contributing to reduce in congestion, time saving.

8. FUTURE ENHANCEMENT

Although the Smart Parking System Application presents a scalable and efficient framework for parking management, there remains potential for deeper functionality and enhanced efficiency. For instance, one of the main improvements is to introduce IoT based sensors to allow for real-time detection of slot occupancy. By placing ultrasonic or infrared sensors in the parking bays, the system could automatically update bay availability without the need for user input, ensuring enhanced accuracy.

Another opportunity for improvement is the addition of artificial intelligence (AI) and machine learning (ML) models for predictive analytics. By analyzing historical booking data, traffic flows and time-of-day trends, the system could predict parking demand and dynamically recommend the most optimal parking zones to users. Additionally, AI-powered dynamic pricing models, could be used to provide price incentives encouraging drivers to park in less congested areas, further balancing overall demand across the city.

The app could be extended to include multi-payment gateway integration so that users have payment options using credit card, UPI, digital wallets, or contactless payment methods. This would create a better user experience and link it to current global trends around cashless payments. Moreover, cloud scalability and multi-location features would allow the application to work seamlessly in more than one city making it a complete smart city service.

Accessibility and inclusivity can be further enhanced with multi-language options, voice-based assistance, and better options for differently-abled users. Lastly, future iterations could also include integration with municipal systems and traffic management authorities, to enable enforcement in no-parking zones, and automated fine generation and data sharing for urban planners.

If these modifications were executed this will not only bolster the current application, but also establish it as a robust, and sustainable component of smart city region's mobility asset structure, to help mitigate pressures caused by increasing urbanization, and vehicle population challenges.

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