KHAT: Unified Toll Gate System Application

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Abstract

Toll gates are mainly used on main roads and highways to collect toll fares from passing vehicles. The collected fees provide sustainable road maintenance, development, and improved revenue. However, the implementation of toll gates across different emirates and cities causes inconvenience to motorists as they must adhere to the different platforms of tolling systems from one city to another. The main goal of this project is to develop the Khat platform, which is a automatic payment system that facilitates all traffic payments in the UAE using a unification strategy, i.e., bringing all traffic applications and corresponding databases into a common platform. Implementing this application will lead the UAE to futurize the driver's experience by ensuring an easy and direct form of payment. In addition, business owners and investors may take advantage of the high number of users per application to advertise their products or service. Hence improving the marketing and advertising industry will contribute directly to the nation's economic growth.

1. Introduction

A toll gate [1] is a road pricing mechanism used to recoup road construction and maintenance costs. Dubai [2] and Abu Dhabi [3] have several toll roads, with varying rates depending on traffic and usage frequency. Toll gates, often used for business, have car-friendly structures, minimizing vehicle damage. They offer less congested routes, saving time and reducing fuel consumption. Toll gates enhance economic productivity and attract investors. According to ITC and RTA [4], toll-gated routes are alternatives to congested roads, with tolls used to repay loans and generate non-tax revenue.

Toll gates operate manually or electronically, with the electronic approach being more efficient [5]. Laser sensors or cameras detect vehicles, activating a reader to search for the pass radio frequency. The system checks license plate validity, deducts toll fares, and notifies account issues.

Difficulty in paying tolls on multiple platforms in the UAE poses an ongoing dilemma for individuals and authorities [1]. Individuals struggle to manage payments on different websites, complicating tracking for authorities as numbers increase [1].

The project aims to establish the Khat (خط) platform, unifying various databases related to toll payments and traffic fees into a single database. Khat simplifies the payment process across traffic applications, integrating fare-sensing technology on all gates for a unified account across the UAE. This automatic payment system covers toll-gate payments, traffic fines, parking fees, etc., with a focus on unification. In contrast to well-known unified payment gateways like Google Pay [6] and Apple Pay [7], Khat stands out with its target-specific, local, secure, and private features. It specifically addresses traffic-related payments, provides an efficient solution, securely stores information in local government databases, and prioritizes user data privacy.

2. Background and Related work

Introducing our latest innovation in transportation convenience - a wallet application that seamlessly integrates both Darb and Salik's smart toll gate systems into one user-friendly platform. With this app, you can easily manage and pay for all your toll fees, whether you are driving through Darb's highways or using Salik's toll gates in Dubai. Say goodbye to the hassle of carrying multiple cards or downloading separate apps and enjoy a more efficient and streamlined toll payment experience [1].

Highway maintenance is traditionally funded through national budgets or fuel taxes [8]. Toll gates, a direct method, collect fees from drivers passing the road [8]. The selection of toll systems considers economic feasibility, traffic flow, and profit maximization [9]. Toll

collection has transformed from human-operated booths to RFID and license-plate imaging systems [10] [11].

Manual toll booths involve cash or credit card payments, with a capacity of 120 cars per hour per lane [9]. Automated toll systems accept tokens, smart cards, and magnetic cards, processing 350 to 600 vehicles per hour per lane [9]. Wireless systems, using RFID, handle 1800 to 2300 vehicles per hour per lane [9].

RFID technology features a read range of 3-5 meters, fast read rates, and secure encryption [12]. Tags on vehicles, linked to RFID readers, store unique identification numbers, and can update data from central databases [13].

License-Plate Imaging recognizes vehicles by their registration plates, automating toll tax collection [14]. The system compares the number plate to an authorized database and deducts toll fees [15].

Digital wallets, trending globally, offer convenient, secure, and speedy payment options [16]. NFC-enabled smartphones emulate credit/debit cards for physical payments [17]. In the UAE, online transactions reached $16 billion in 2019, with e-wallets used for various purposes, including toll payments [18].

Both Salik and Darb have mobile apps accepting e-wallet payments [18]. Salik offers payment options through cards or the local noqodi e-wallet [18]. Darb allows payments through credit/debit cards, and Apple Pay.

In summary, our wallet application integrates Darb and Salik toll gate systems, providing a convenient, secure, and efficient toll payment experience [1]. The report explores traditional toll collection methods, RFID technology, license-plate imaging, and the rise of digital wallets, emphasizing their relevance in the UAE's cashless economy [8] [12] [14] [16].

3. Phase I: Requirement & Analysis

Our project, a wallet application named "KHAT," integrates both Darb and Salik smart toll gate systems into a unified platform, providing a user-friendly and efficient solution for managing toll gate payments in the UAE. Users can link their Salik and Darb accounts to the app, make direct payments, view transaction history, check balances, and set up automatic top-ups. The application aims to streamline toll gate payments, enhancing the overall user experience.

3.1 Functional Requirements

The functional requirements outline key aspects of the system's behavior and performance. Firstly, to use the application, a mandatory internet connection is required. Users have the flexibility to create accounts through various means, including email, UAE Pass. Once an account is established, users can log in using their chosen credentials.

Financial management features include the application's ability to notify users when their wallet is empty. Users can register credit/debit cards, check account balances, and deposit money, with the flexibility to specify deposit amounts. Additionally, the application allows users to link Salik and Darb accounts, verifying the linkage.

In the context of traffic-related functionalities, the application queries Darb and Salik accounts to monitor toll gate passages. Moreover, the application facilitates the withdrawal of money from the user's wallet for toll gate passages. These functional requirements collectively define the core capabilities and interactions within the system.

3.2 Non-Functional Requirements

Non-functional requirements are instrumental in defining the inherent characteristics and limitations of the system. In terms of performance, the application is expected to deliver a prompt response time, specifically ranging from 2 to 3 seconds for user inputs. For portability, the application should be accessible on major platforms, including Apple's App Store and Android's Google Play, and should seamlessly install on devices running Microsoft or macOS systems. Security measures require users to complete 2-factor authentication using a password and OTP, with user data encryption during all communications.

Usability is prioritized, with the app's user interface designed to be easily learnable within a maximum of 20 minutes for an average user. Reliability demands consistent performance, emphasizing optimal functionality 24/7 and maintaining a failure rate not exceeding 5%. Space requirements involve the integration of scalable storage solutions through connection to a cloud database.

Implementation specifications dictate the use of the Dart programming language for app development. Lastly, resource usage requirements underscore efficiency, directing the application to minimize resource consumption while running on devices.

Collectively, these non-functional requirements provide a comprehensive framework for the system, encompassing its performance, accessibility, security, usability, reliability, space utilization, implementation, and resource efficiency.

3.3 Technical Requirements

Hardware and software specifications are essential for technical operation.

Hardware Requirements:

- Devices: PCs/Laptops/Smartphones
- Hard Disk: Minimum 1 TB
- Input Devices: Keyboard, Mouse
- RAM: Minimum 8 GB
- Processor: Quad Core 1.2 GHz

Design Software Requirements:

- Programming Language: Dart
- Operating System: Windows and macOS
- DBMS: Cloud Firestore – Firebase
- Back-end Logic: Firebase
- IDEs: Visual Studio Code

4. Phase II: Design and Architecture

As figure 1 illustrates, the Khat platform encompasses various components, including the Khat Mobile Application (KMA), Khat Database (KDB), Khat Connector (KC).

Khat Mobile Application (KMA):
The KMA serves as the user-interface software facilitating the interconnection of platform components. It empowers users to execute location-based traffic-specific payments, offering functionalities such as registration, login, personal details management, payment method updates, and configuration of traffic applications. Users can receive payment notifications, understand payment procedures, generate receipts, and access their payment history through the KMA.

Khat Database (KDB):
KDB is specifically designed to store user information and account details in a secure manner that is aimed to be accessible to traffic authorities through existing databases. KDB will store user details.

Khat Connector (KC):
Operating as middleware, the KC bridges the front-end and back-end components of the platform. It executes API between our database and other toll-gate mobile applications, determining whether a user has unpaid toll fees on different toll gate services. Upon detection, it automatically activates the corresponding traffic application from the registered list within Khat. Users are proactively notified about impending payments through the KMA once the application is activated.

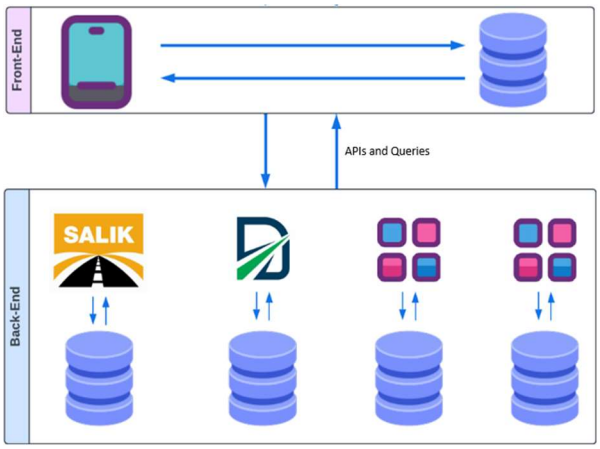


Figure 1: KHAT Provisional Architecture

Figure 2 illustrates how the project is connected in a logical manner. It shows how the user interacts with the application and what kind of functions the user or application can do. Furthermore, it shows how other toll gate systems interact with our application.

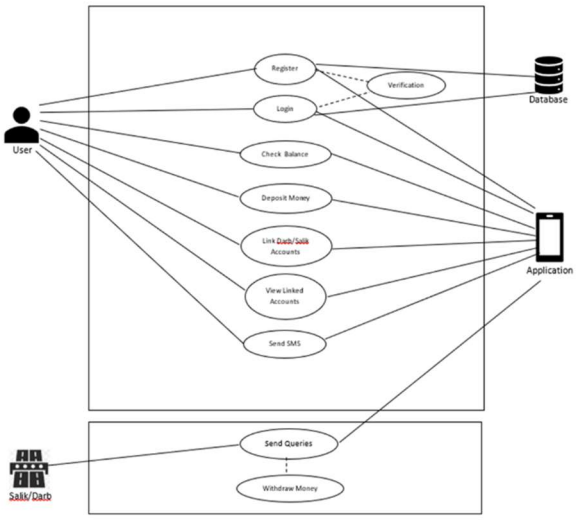


Figure 2: KHAT Use-Case Diagram

5. Phase III: Implementation and Testing

Stage 1 involves an in-depth analysis of existing platforms, such as [6] and [7], akin to the Khat Platform, to glean valuable insights for development. Careful architectural design (refer to Figure 1) ensures that each component incorporates necessary features, guaranteeing correct and efficient functioning.

In Stage 2, we concentrate on designing and developing the Khat Mobile Application (KMA) using Google Flutter [28]. Emphasis is placed on scalability, reliability, security, efficiency, and user-friendliness. The KMA integrates seamlessly with the Connector (KC) and Database (KDB). The tentative application outlook (see Figure 3) incorporates all previously discussed components and functionalities, offering a comprehensive user interface. The KMA provides a direct interface for both the KDB, hosted on Firebase for robust and scalable data storage, and the KC.

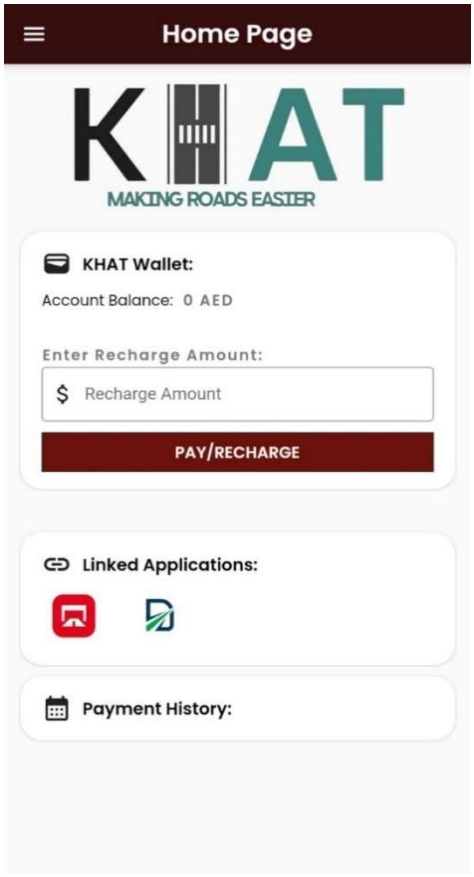


Figure 3: KHAT Mobile App

Moving to Stage 3, we define the conceptual and logical architecture of the Khat Database, with the physical design implemented using Firebase as the database solution.

In Stage 4, the focus shifts to the design and implementation of the middleware application, KC. Leveraging Flutter Fire APIs ensures seamless integration with the KMA, facilitating the selection of the appropriate traffic application for payment.

The final stage, Stage 5, involves comprehensive testing of all functionalities within the developed prototype of the Khat platform. This multi-stage approach ensures a systematic and thorough development process, culminating in a robust and well-tested platform.

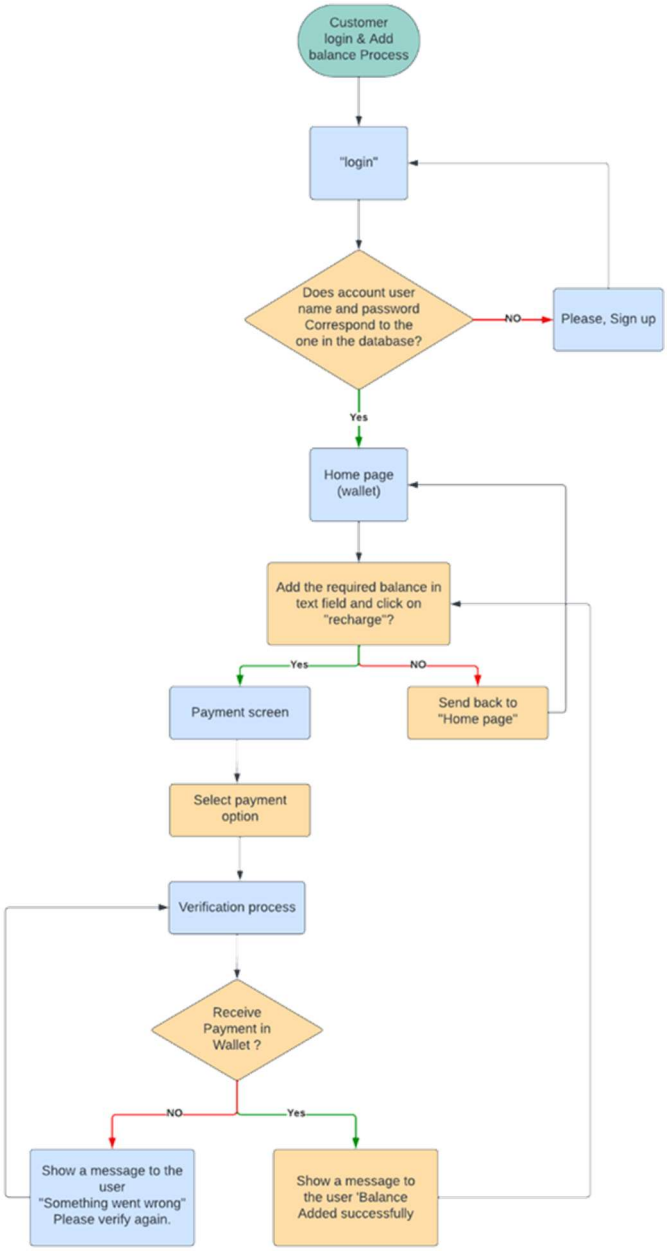
Flutter Framework (KMA):
The primary front-end development tool utilized for this project was the Flutter framework. Flutter, an open-source UI software development toolkit, was chosen for its ability to facilitate rapid and efficient cross-platform mobile application development. Its extensive widget library and hot-reload feature significantly expedited the iterative design and development process.

Firebase (KDB):
Firebase, a comprehensive mobile and web application development platform, served as the backbone of the project's back-end infrastructure. This decision was motivated by Firebase's real-time database capabilities, authentication services, and seamless integration with Flutter. Utilizing Firebase's cloud-hosted NoSQL database eliminated the need for server management and provided a scalable solution that perfectly complemented the chosen front-end technology.

Integration of Flutter and Firebase: FlutterFire APIs (KC):
Through FlutterFire APIs, our mobile application's integration with Firebase was seamless. FlutterFire is a set of plugins that provides Flutter support for various Firebase services, allowing for efficient data exchange, user authentication, and other key functionalities [19].

As figure 4 illustrates, the flow chart for Customer Login and Add Balance process includes inputting login credentials, selecting the payment method, verifying payment information, processing the transaction, and updating the account balance. It is designed to be simple and efficient for customers to use.

Figure 4: KHAT Flowchart



6. Conclusion

In conclusion, the Khat platform is an innovative solution to the inconvenience caused by the different tolling systems across various emirates and cities in the UAE. The platform's automatic payment system, which unifies all traffic applications and corresponding databases, aims to provide a smoother and more efficient driver's experience. It is worth mentioning that the Khat platform's unification strategy is not limited to the existing toll gate systems in the UAE, but it also has the potential to include toll gate systems of other emirates if they choose to implement it in the future. By doing so, the Khat platform will become a comprehensive and all-inclusive traffic payment system that covers the entire UAE, offering a seamless and convenient experience to all motorists. In addition, the platform could potentially expand its services beyond toll payments and include other road services such as paying Mawaqif parking fees, further enhancing the driver's experience and convenience. The Khat platform's expansion will not only improve the overall transportation infrastructure in the UAE but will also provide opportunities for business owners and investors to advertise their products or services, contributing to the nation's economic growth. Ultimately, the Khat platform has the potential to revolutionize the way the

UAE handles its traffic-related payments while promoting sustainable growth and development.

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