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Road Rescue: Decentralized Cross-Platform Service Orchestration Based on Blockchain for Roadside Assistance Application

Vinayak Somvanshi, Gandharvi Walavekar, Kevin Thakkar, Yogesh Kumbhar, Neha Deshmukh, and Kiran Deshpande

[1] Department of Information Technology, A. P. Shah Institute of Technology, Thane MH 400615, India; 20104003@apsit.edu.in (V.S.); 20104045@apsit.edu.in (G.W.); 20104023@apsit.edu.in (K.T.); 20104139@apsit.edu.in (Y.K.); npdeshmukh@apsit.edu.in (N.D.); kbdeshpande@apsit.edu.in (K.D.)

Abstract: Amid the rapid expansion of the vehicular network, the autonomous design of numerous roadside assistance systems, often involving third-party intermediaries, has raised significant concerns about security and reliability. In response, blockchain technology has emerged as a groundbreaking solution, effectively decentralizing these systems and enhancing their dependability and security. The initiative is singularly dedicated to crafting a cross-platform application for roadside assistance, aiming not only to streamline the assistance process but also to empower mechanics to broaden their service horizons. It bifurcates the system into distinct components tailored for mechanics and customers. Programmed in Dart on the Flutter framework, the application seamlessly connects with Firebase as the database, ensuring efficient data management and retrieval. Within this comprehensive application, we have integrated user-centric features, robust data security measures, and real-time service tracking capabilities, all contributing to heightened transparency and user control. Users can request assistance by identifying their precise locations and service requirements, and mechanics can verify their availability, promptly providing clients with well-informed alternatives. The blockchain is intricately connected through endpoints on the cloud, contributing to the overall efficiency of the application. The integration of smart contracts and thorough mechanic verification collectively fortify the reliability and security of the assistance process, establishing a robust foundation for the successful execution of requested services; this not only ensures data integrity and security but also optimizes the performance of the blockchain in facilitating seamless transactions.

Keywords: blockchain, roadside assistance, smart contract, peer-to-peer (P2P) network, cross-platform

1 Introduction

When it comes to present-day transportation, unplanned side events can quickly turn a typical drive into a traumatic experience. Whether it's a punctured tire, engine failure, or any other mechanical mishap, the need for prompt and reliable assistance is paramount. However, ineffectiveness, opacity, and trust issues plague traditional models of roadside assistance, leaving drivers exposed and irritated during emergencies [1] [2]. The provision of roadside assistance services is undergoing a paradigm shift with the introduction of blockchain technology [3] [4]. Originally developed as the foundational technology for cryptocurrencies, blockchain is expanding beyond its original use to a variety of domains, providing decentralized, unalterable, and transparent answers to persistent problems [5] [6] [7]. By utilizing blockchain's built-in features, a comprehensive cross-platform roadside assistance application can be developed, completely altering the way emergency services are delivered and administered.

Roadside assistance providers, intermediaries, and insurers are frequently involved in a fragmented network under the traditional model, which makes coordination, verification, and communication challenging [1] [2]. To make matters more dire for drivers, there can often be a lack of transparency in the payment settlement and service delivery processes, which leads to disagreements and delays [2]. A blockchain-based solution, on the other hand, provides a decentralized and transparent ecosystem where drivers, service providers, insurers, and regulatory bodies can all interact in real time, securely, and with ease [8]. Road-Rescue aims to explore the potential of blockchain technology in the context of roadside assistance and proposes a novel solution – a comprehensive blockchain-based cross-platform application tailored to meet the needs of drivers in distress. At its core, this application is envisioned as a dual-faceted solution, comprising distinct interfaces for both customers and mechanics, thereby furnishing a user-centric and efficient platform for emergency road assistance [9]. By making the most of blockchain's decentralization, immutability, and transparency, this application seeks to improve emergency response services by providing drivers with an easy and secure means to get assistance when they need it.

At the heart of the proposed application lies a distributed ledger, or blockchain, which serves as a tamper-proof record of all transactions and interactions within the ecosystem. The mobile application is bifurcated into two parts: Customer and Mechanic, providing a user-friendly and efficient platform for emergency road assistance. By integrating geolocation services, the design emphasizes instantaneous accessibility, empowering users to swiftly locate nearby service providers, reducing response times, and accelerating the dispatch process. Additionally, the application expands its utility by using geolocation to help users find and navigate essential roadside services like nearby restrooms, food malls, and hospitals for maximum accessibility and convenience [10]. Users will be able to use both conventional and blockchain-based payment methods to facilitate smooth transactions and pay for services. In addition to bridging the gap between traditional financial systems and blockchain technology, this hybrid approach improves accessibility and inclusivity by fulfilling the needs and preferences of a wide range of users, the convergence of blockchain technology and roadside assistance services offers a compelling opportunity to re-imagine and redefine the way emergency services are delivered and managed. By leveraging the decentralized, transparent, and secure nature of blockchain, a comprehensive cross-platform application can not only streamline the process of requesting assistance but also enhance trust, efficiency, and accountability throughout the ecosystem.

2 Motivation

The motivation for this project stems from the pressing need to modernize and enhance the existing roadside assistance services through the integration of blockchain technology into cross-platform mobile applications. Roadside assistance is a critical service for drivers, providing a safety net during vehicular emergencies [11]. However, the current approach is marred by inefficiencies, lack of transparency, and data privacy concerns. The integration of blockchain technology addresses these issues by introducing decentralization, trust, and security into the equation. Blockchain's decentralized ledger system ensures that assistance requests and responses are securely recorded and distributed across a network of nodes. This mitigates the risk of a single point of failure and enhances system reliability, reducing the waiting time for stranded drivers and improving their overall experience. The importance of roadside assistance services in ensuring the safety and well-being of drivers cannot be overstated, making their modernization and enhancement a matter of utmost significance [12].

Moreover, the transparency and immutability of blockchain records empower drivers to verify the legitimacy of service providers and the accuracy of their responses, fostering trust in the system. Cryptographic security measures within the blockchain protect sensitive user information, addressing critical data privacy concerns in today's digital landscape. This innovative approach not only streamlines and accelerates the process of requesting and receiving assistance but also enhances data security and privacy, making it a win-win solution for both drivers and service providers. The importance of integrating blockchain in this application cannot be overstated. By doing so, the system not only gains transparency and trust but also reinforces the security of sensitive user data. This integration promises to revolutionize the way drivers access roadside assistance [13], ensuring quick, efficient, and trustworthy service, ultimately enhancing the overall driving experience and road safety.

3 Literature Review

In the realm of roadside assistance applications, technical challenges abound. Vehicle owners often face issues with interoperability among various mobile platforms, leading to inconvenience when accessing assistance services. Furthermore, the lack of standardized data exchange protocols and communication standards can hinder the efficient dispatching of service providers. In addition, ensuring the security of user data and payment transactions is a paramount concern, especially given the rise of cyber threats and data breaches. The problem at hand involves the development of a roadside assistance application that addresses these technical challenges by offering cross-platform compatibility, implementing robust data exchange protocols, and fortifying cybersecurity measures to create seamless, secure, and efficient experience for users in need of immediate assistance.

The rapid proliferation of roadside assistance mobile applications has revolutionized the way drivers seek help during unexpected road emergencies. However, despite the convenience they offer, existing solutions often fall short in delivering a seamless and secure experience.

Traditional methods of contacting tow truck companies or local garages can lead to frustratingly long wait times, jeopardizing driver safety and well-being. Furthermore, the current process lacks transparency, making it challenging for drivers to ascertain the authenticity of service providers and to ensure their data remains confidential [14]. To address these challenges and enhance the user experience, we propose the development of a blockchain-integrated, cross-platform roadside assistance application. This application aims to connect drivers with professional assistance swiftly, reducing response times during roadside emergencies, and fostering trust and transparency through blockchain technology. By enabling users to instantly share their location and issue details, the application streamlines the connection with nearby qualified mechanics, eliminating the arduous task of searching for help. In essence, this blockchain-based solution seeks to provide a stress-free and reliable means of receiving roadside assistance, ensuring the safety and peace of mind of drivers and transforming the landscape of roadside services.

In [15], the authors discuss the potential of blockchain technology in addressing compliance challenges posed by the General Data Protection Regulation (GDPR). The GDPR is a comprehensive European Union (EU) regulation designed to protect the privacy and data rights of individuals. It imposes strict rules on the processing of personal data and requires organizations to ensure that personal data is handled securely, transparently, and with explicit consent from the individuals involved. To ensure GDPR compliance, a pivotal element is the Customer Smart Contract. It manages customers' personal data, optimizing storage using Solidity's bytes32 data type. This personal data can include information like names, birthdates, and addresses, all of which must be handled in accordance with GDPR principles. To safeguard privacy and adhere to GDPR regulations, personal data is encrypted off-chain, preserving pseudonymity and ensuring that only encrypted data is visible on the blockchain. The Customer Smart Contract also tracks data operations and user consent, with defaults set to align with GDPR's "privacy by default" principle. GDPR-relevant data actions are encoded into the Customer Smart Contract, ensuring that users have control over their data and that these operations are carried out in compliance with the GDPR. Access to these operations is limited to the authorized Smart Contract, preventing unauthorized access and ensuring GDPR adherence. Additionally, customers retain the ability to revoke permissions, which is in line with the GDPR's "right to restrict processing," providing individuals with greater control over their personal data.

Blockchain technology has emerged as a transformative and disruptive force across a multitude of industries, including the domain of roadside assistance. Recent research has illuminated its potential to address several longstanding industry challenges, with a particular focus on enhancing payment security, transparency, and preventing fraudulent activities [5]. The appeal of blockchain lies in its capacity to fundamentally redefine transaction conduct and recording. Foremost among the concerns addressed in the literature is the enhancement of payment security and transparency through blockchain technology. Numerous studies have underscored the inherent advantages of blockchain, such as its immutability and decentralization, in significantly mitigating the risks associated with payment fraud, thereby fostering heightened user trust [16]. Smart contracts, a core feature of blockchain technology, have been widely recognized for their pivotal role. These self-executing contracts have found extensive application in automating payment processes, ensuring users receive the services they have contracted for while recording verification on the immutable blockchain ledger. Research has also delved into the application of blockchain in securing payment processing, highlighting the cryptographic principles that ensure the confidentiality and integrity of sensitive payment information [17].

Mechanic verification, an essential component of roadside assistance applications, has garnered significant attention in the literature. Blockchain-based solutions have risen to prominence as a promising avenue for addressing this challenge. Demonstrations have showcased blockchain's ability to systematically evaluate mechanics against predefined criteria, including certifications and expertise, thereby ensuring that only qualified mechanics become integral parts of the service network [18]. This application of blockchain not only enhances service quality but also fosters user trust.

The cross-platform accessibility aspect is explored, given its pivotal role in providing roadside assistance services to a wide range of users. The examination has accentuated the significance of cross-platform frameworks like Flutter in achieving this objective. Flutter's capability to create natively compiled applications that run seamlessly on both Android and iOS devices has played a pivotal role in its widespread adoption within the industry. This cross-platform adaptability enhances user accessibility during emergencies and ensures a consistent user experience across different platforms. The transparency of payment processes has also been the subject of extensive investigation. Research findings underscore the ability of blockchain to create immutable and transparent transaction records, significantly contributing to maintaining transparency and minimizing payment disputes. Additionally, the integration of multiple payment gateways within blockchain-based roadside assistance applications has further augmented payment flexibility, catering to a variety of user preferences [19].

However, despite the promising potential of blockchain-based cross-platform applications for roadside assistance, the literature highlights several challenges requiring further attention. Among these, scalability and latency issues associated with the Ethereum blockchain have emerged as critical areas of concern. This has led to calls for research into alternative blockchain platforms capable of delivering improved scalability while retaining essential security and transparency features.

4 Methodology

4.1 System Development

The roadside assistance application implements a blockchain-based system to connect customers with service providers for on-demand roadside assistance. When a customer opens the app and logs in, they can request a service by specifying their location and needs. The request triggers a smart contract that queries the blockchain network and returns a list of available service providers in the vicinity. The customer selects a provider, confirms the request, and the contract notifies the provider. Upon receiving the request, the provider can accept or reject it. If accepted, the provider confirms their availability and ETA. The service provider then travels to the customer's location to render the service. Once complete, the provider collects payment from the customer, encoded in the smart contract [20]. The contract records the service transaction on the blockchain while the application generates an invoice. Figure. 1 illustrates the activity diagram for the roadside assistance application, depicting the sequence of interactions between customers, service providers, and the blockchain-based smart contract system. The customer can also track the provider's location in real time. Overall, the blockchain-powered platform delivers an efficient, trusted means to access on-demand roadside assistance [21].

A pivotal decision in the development process was the choice of the Flutter framework, a renowned cross-platform development framework. This decision was predicated on the necessity of ensuring accessibility during emergencies, regardless of the user's device operating system (Android or iOS). The application enables the process of a customer requesting vehicle services through two individual mobile applications, and a mechanic fulfilling those requests. With two distinct swimlanes for the customer and the mechanic, the diagram delineates their respective roles [10]. The mechanic begins by registering on the application, providing shop details, and listing available services. Customers log in using a one-time password and access a map displaying nearby facilities and services. Customers can choose between requesting a specific service for their vehicle or selecting a facility such as a gas station. If opting for a service, customers view available services, and nearby mechanics, and make a selection. Alternatively, choosing a facility allows customers to explore nearby options and navigate to their chosen facility. After initiating a service request, it is sent to the mechanic's application, where the mechanic can accept or reject it. Rejected requests trigger the allocation of another mechanic. If accepted, the mechanic proceeds to provide the service, receive payment, and receive a rating from the customer. Users initiate assistance requests through the customer application by providing essential information, including their location and the nature of the vehicular issue they are facing. Upon request submission, the system swiftly notifies nearby registered mechanics through real-time communication protocols [22]. Mechanics can view and respond to assistance requests in real time, ensuring a prompt response during emergencies. Once a mechanic accepts a service request, they gain access to critical details, including the user's location and specific service requirements.

In cases where a mechanic decides to decline a service request, the system promptly notifies the user of this decision through real-time communication channels. To maintain user satisfaction, the application offers swift solutions when initial requests are declined. Users are presented with alternative mechanics in their nearby area who are available to assist. The handling of declined requests and the presentation of alternative solutions are facilitated through robust real-time communication protocols integrated into the application. These protocols ensure that mechanics and users can exchange vital information efficiently and in real time. When a user initiates an assistance request, the system

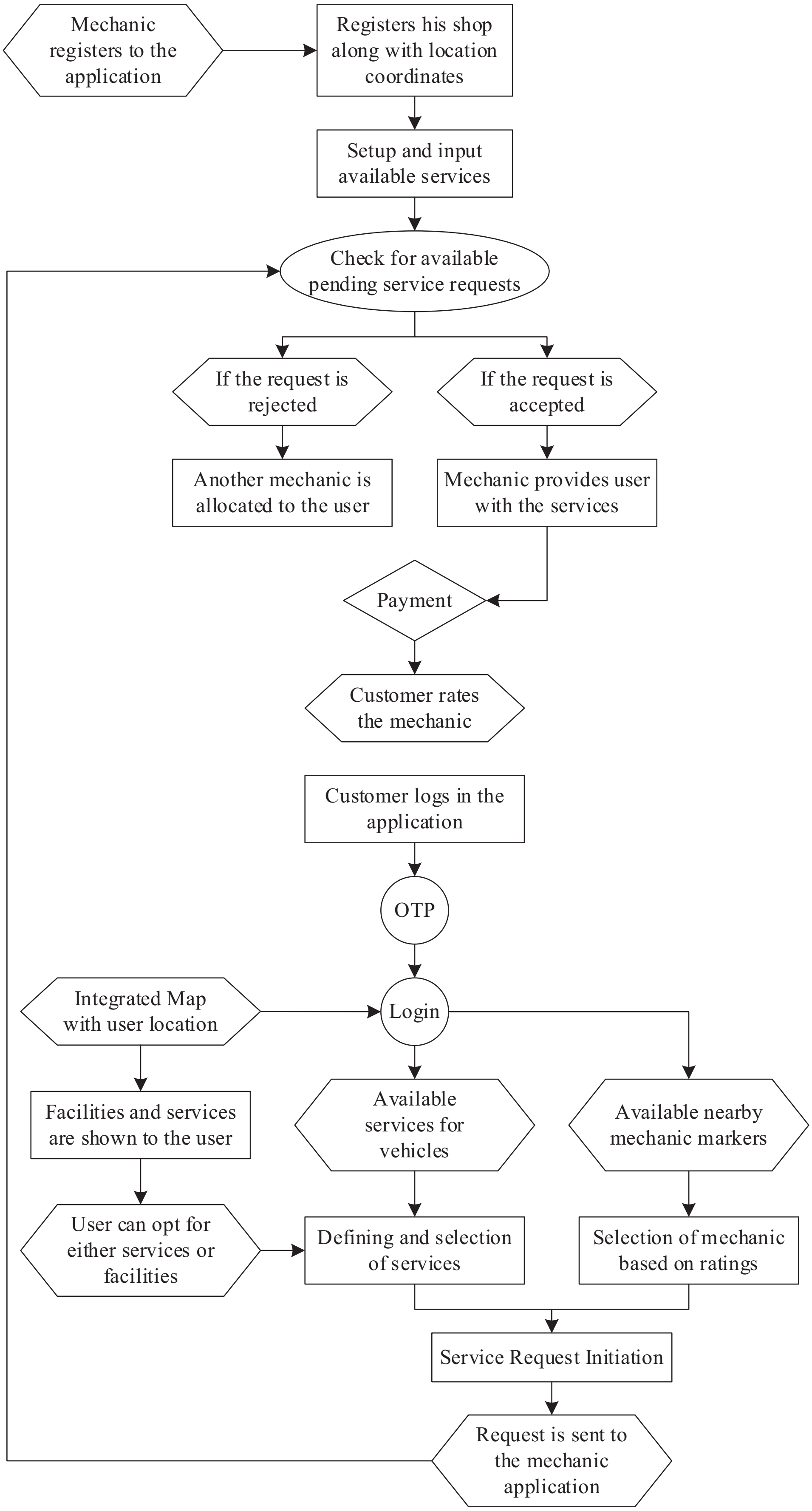

Figure. 1. Roadside Assistance Application Activity Diagram evaluates the availability of registered mechanics in the vicinity. Mechanics are assessed based on their proximity to the user's location, ensuring that the nearest available mechanic is considered as the primary option. The customer application displays available mechanics on a map interface, with real-time updates on their locations. This visual representation empowers customers to make informed selections. The system enables mechanics to access the user's specific service requirements in real time. This ensures that mechanics arrive prepared to address the issue promptly.

The integration of technologies was central to the development process. Two key integrations that warrant elaboration are Firebase for data storage and retrieval and Google Maps for location-based services. Firebase was opted for as the database solution owing to its proficiency in real-time data synchronization. Mechanic locations, expressed in latitude and longitude coordinates, find storage in Firebase, ensuring expeditious retrieval and presentation on the customer's map interface. The integration of Google Maps serves to augment the user experience, enabling real-time visualization of nearby mechanics' locations and expediting decision-making in exigent scenarios [10]. Efficient data management and the seamless incorporation of geolocation services are imperative for optimal functionality. This section expounds upon the methodologies employed for data storage and integration, underscoring the utilization of Firebase for storing mechanic locations and Google Maps for the provision of real-time location-based services.

The system comprises several interconnected use cases to facilitate registered users in obtaining services. The top-level "Service needed" use case represents the overarching goal, with two sub-use cases, "Roadside Assistance" and "Nearby Mechanics," serving as specific ways to achieve this goal. The "Login" use case is a prerequisite for both "Roadside Assistance" and "Nearby Mechanics", and it is extended by the "Help Alert" use case, providing an emergency option for users while Figure. 2 illustrates the use case diagram for customers and mechanics within the system.

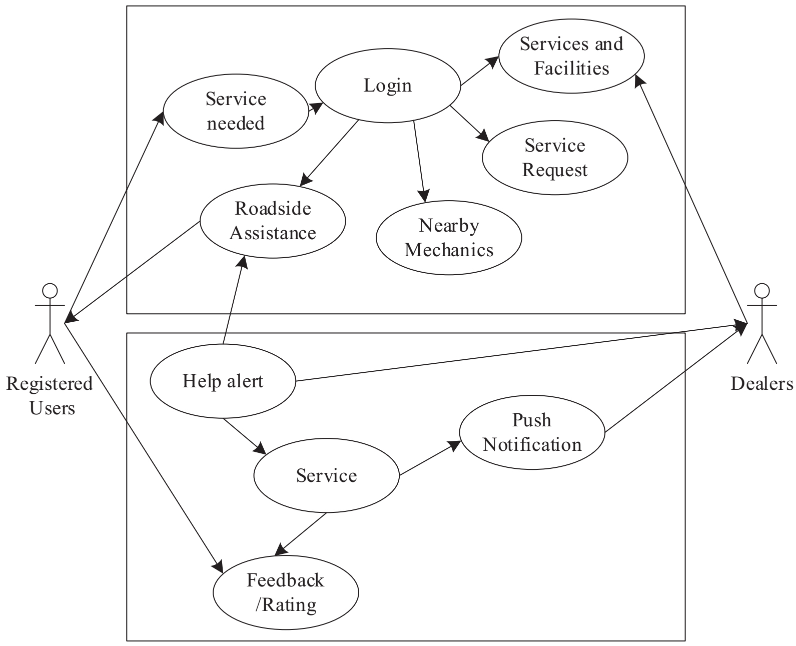

Fig. 2. Use Case Diagram for Customer and Mechanic

"Roadside Assistance" involves registered users requesting aid, while "Nearby Mechanics" focuses on finding nearby service providers. "Help Alert" allows users to send emergency alerts. The "Service" use case encompasses providing services to registered users and dealers, acting as a sub-use case for "Roadside Assistance" and "Nearby Mechanics". Additional use cases include "Feedback/Rating" for user evaluations, "Services and Facilities" for dealers offering various services, "Service Request" for dealers receiving requests, and "Push Notification" for dealers sending notifications to users. Each use case specifies its associated actors and relationships, creating a comprehensive framework for user-system interactions.

4.2 Blockchain Integration

The customer initiates the process by requesting service from a mechanic, who then creates a smart contract detailing the work, repair cost, and payment terms. After the customer signs the contract, funds are held in escrow until the repair is finished. The mechanic begins work, submits a photo and detailed report upon completion, and the customer approves payment if satisfied. This process provides advantages over traditional car repair methods. Firstly, it provides greater transparency, allowing the customer full visibility into the repair process and the ability to track the progress of the work in real time. Secondly, it enhances efficiency by automating the payment process through smart contracts, eliminating the need for manual intervention. Thirdly, it ensures enhanced security by holding funds in escrow until the customer is satisfied with the work.

The mechanic verification process leverages blockchain technology to ensure a robust and secure framework. When the mechanic applies for certification, their credentials, encompassing education and training records, are stored on a blockchain database. Blockchain technology is instrumental in this phase as it introduces a decentralized and tamper-proof ledger system. Each piece of information is securely recorded in a block, linked to the previous one, creating an immutable chain of data. This decentralized nature of blockchain ensures that the stored data is resistant to tampering or unauthorized access. Furthermore, the utilization of smart contracts, self-executing contracts stored on the blockchain, automates the verification process. These smart contracts are programmed with predefined criteria, including those related to mechanic pending requests, feedback, location, and other necessary assessments in the service request [23]. As the mechanic's credentials and relevant data are securely stored on the blockchain, the algorithmic assessment process accesses this information in a transparent and reliable manner. The decentralized structure of the blockchain guarantees that data integrity is maintained throughout the certification process. The criteria set in the smart contract, which includes various assessments such as mechanic pending requests and location details, are autonomously executed, ensuring an efficient and trustful verification process. The verification of mechanics within the roadside assistance application is facilitated through blockchain technology [24], ensuring the authenticity and suitability of mechanics for providing roadside assistance and car repairs.

Mechanics seeking registration within the application provide detailed information about their shop, including certifications, equipment, and expertise. The application securely encrypts and transfers mechanic registration data to the blockchain network for verification [25].

The smart contract introduces a sophisticated architecture designed to ensure secure and efficient verification processes for mechanics within the realm of blockchain. Within this framework, distinct components, such as the structures denoted by "MechanicRecord", "MechanicProfile", and "ServiceRequest", serve as integral organizational tools, playing pivotal roles in systematically capturing and managing crucial information related to a mechanic's performance, verification details, and service requests. Mappings within the contract serve as dynamic linkages between user addresses and pertinent data entities, encompassing service requests, mechanic records, user roles, and mechanic profiles. These mappings act as foundational elements, facilitating seamless data association and retrieval. Modifiers, functioning as sophisticated access controls, embody specific roles and conditions. They restrict certain functionalities to the contract owner while catering to exclusive functionalities for customers and mechanics, respectively. This further refines access, limiting functions solely to those mechanics who have undergone successful verification. Figure. 3 illustrates the request process through smart contracts. Upon contract instantiation, the constructor initializes the contract owner's address.

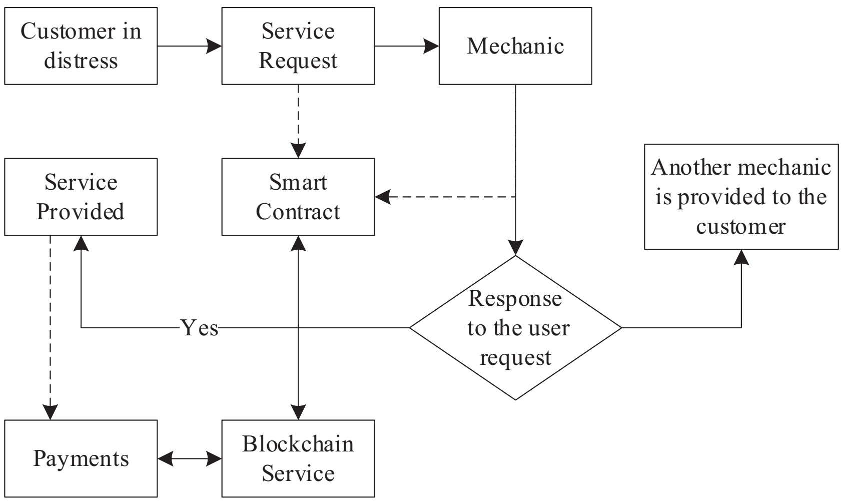

Figure. 3. Request Process through Smart Contract

A crucial aspect of the contract's functionality lies in the nuanced management of user roles, distinguishing between customers, mechanics, or unregistered entities. This dynamic role assignment is orchestrated by the contract owner, introducing a layer of flexibility and adaptability.

The mechanic registration process involves the storage of verification details within a "MechanicProfile". Subsequent verification carried out through the verification of the mechanic and service request function, represents a pivotal step in affirming the legitimacy of a mechanic's status. Service request orchestration, initiated by customers through the "createRequest" function, encompasses the detailed specification of a mechanic, geographical coordinates, and specific request conditions. The resulting data is systematically stored within the "mechanicRequests" mapping, forming the basis for subsequent interactions. The contract also provides verified mechanics with the autonomy to accept or reject pending service requests through the respective functions. This mechanic-centric approach underscores the decentralized decision-making capabilities within the system. Mechanic performance evaluation is facilitated through the feedback function, allowing customers to provide ratings. This rating mechanism serves as a vital feedback loop, shaping subsequent service dynamics and contributing to the continuous improvement of the mechanics' services. Complementing these functionalities are auxiliary functions focusing on geospatial calculations. Notably, the "withinRadius" and "calculateDistance" functions play critical roles in determining spatial proximity, introducing a spatial dimension to decision-making processes.

The mechanic verification process in our roadside assistance application is intricately interwoven with blockchain technology, offering a robust and secure framework. When a mechanic applies for certification, their credentials, including education and training records, are immutably stored on the blockchain database. This decentralized ledger system ensures data integrity, with each piece of information forming an unalterable chain of data. The smart contract, a self-executing contract on the blockchain, automates the verification process by incorporating predefined criteria, encompassing assessments like mechanic pending requests, feedback, and location details from service requests [26]. The resulting verification record, generated as an immutable blockchain transaction, serves as a tamper-proof and transparent representation of the mechanic's status, indicating whether they have been verified and accepted or declined based on the established criteria. This process not only fortifies the authenticity and suitability of mechanics for providing roadside assistance but also instills trust and transparency in the verification mechanism. The decentralized nature of blockchain contributes to the reliability and security of the overall verification process, affirming its pivotal role in the seamless execution of the roadside assistance application.

The payment system within the application incorporates a secure and efficient framework, utilizing MetaMask integration and smart contract-based transactions. Users and mechanics have the option to link their MetaMask wallets to the application, providing a secure means of managing digital assets during transactions. This integration allows users to maintain direct control over their wallet's private keys, ensuring the security and inaccessibility of funds to unauthorized parties [27] [28]. The generation of smart contracts governs transactions when users and mechanics reach an agreement on a service. These contracts encompass crucial payment details, including the service fee, estimated completion time, and any special agreements, establishing an immutable record on the blockchain. This immutability ensures that payment terms cannot be altered post-agreement, fostering trust and transparency. Upon the completion of a service and user satisfaction, the smart contract autonomously executes the payment, transferring funds from the user's wallet to the mechanic's wallet. The confirmation mechanism inherent in blockchain technology guarantees the immutability and security of transactions. Real-time notifications of confirmed blockchain transactions provide users and mechanics immediate confirmation of successful payment execution, enhancing the overall reliability and transparency of the payment process. The application also embraces various digital wallets, including but not limited to PayPal, Apple Pay, or Google Pay, providing users with a seamless experience and multiple choices for digital transactions. This comprehensive approach enhances user convenience and underscores a commitment to secure and adaptable payments. Figure. 4 illustrates mechanic verification through blockchain.

To provide secure and transparent payment processing, the application integrates with the Ethereum blockchain[29]. Ethereum-compatible wallets, such as MetaMask, are incorporated to allow users to manage their digital assets within the application. Users initiate payment requests within the application, specifying the required service and agreeing to associated fees. This action triggers the creation of a payment transaction. To enhance security, users are encouraged to link their MetaMask wallets to the application. The application emphasizes the secure management of private keys to prevent unauthorized access to digital assets. All payment transactions are securely recorded on the Ethereum blockchain [30], creating immutable and transparent records. Users and mechanics can independently verify these records, minimizing the potential for payment disputes.

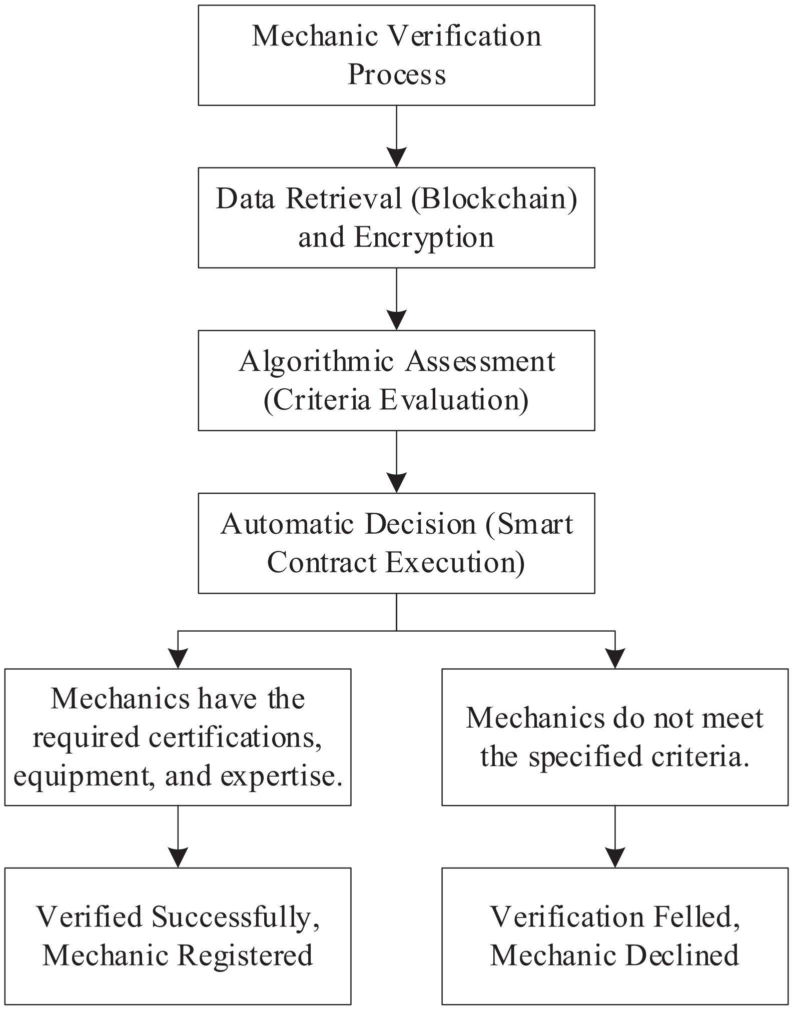

Figure. 4. Mechanic Verification through Blockchain

5 Testing and Validation

5.1 Software Testing

For the comprehensive blockchain-based cross-platform application designed for roadside assistance, a crucial aspect of the development process is software testing. Software testing involves systematically evaluating the application to identify and address any defects or issues that may compromise its functionality, security, or user experience. A thorough testing approach included unit testing, integration testing, system testing, and acceptance testing. Unit testing focuses on individual components to ensure they function as expected, while integration testing verifies the interactions between these components. System testing evaluates the application as a whole, and acceptance testing ensures that the application meets the specified requirements and user expectations. This testing methodology aims to enhance the reliability, security, and overall quality of the blockchain-based roadside assistance application.

This testing approach is particularly well-suited for the project due to the decentralized and cross-platform nature of the application. The integration of blockchain technology requires meticulous testing to ensure the integrity and security of the distributed ledger [10]. Comprehensive testing also addresses potential challenges related to the application's compatibility across various platforms and devices, ensuring a seamless experience for users. Given the critical nature of roadside assistance, rigorous testing is essential to identify and mitigate any potential risks or vulnerabilities. The systematic and multifaceted testing methodology aligns with the project's complexity and the need for robust performance, ultimately contributing to the development of a reliable and efficient cross-platform application for roadside assistance. This feature not only enhances accountability but also facilitates streamlined dispute resolution processes, contributing to a more trustworthy and reliable roadside assistance ecosystem. The application's design focuses on cross-platform compatibility, allowing users to access roadside assistance services seamlessly across various devices and operating systems. Through thorough testing on different platforms, the application can guarantee a consistent and user-friendly experience.

The software testing process comprises several crucial phases, each serving distinct purposes to ensure the robustness and efficacy of the cross-platform application for roadside assistance as mentioned in Table 1. Commencing with Unit Testing, this preliminary stage is dedicated to validating individual components and functionalities inherent to both the customer and mechanic modules [31]. The focus is on confirming the independent, correct operation of each building block within the service application. Subsequently, "Integration Testing" takes center stage, where the emphasis shifts to examining the collaborative performance of diverse application components. This encompasses the backend systems and mobile platforms, evaluating how they harmoniously interact to integrate customer requests and mechanic responses. Moving forward, "System Testing" extends the evaluation to encompass end-to-end scenarios, specifically scrutinizing the complete process of roadside assistance requests. This includes the systematic assessment of customer request processing, mechanic assignment, and status updates, ensuring seamless integration across the entire system. Ultimately, "Acceptance Testing" assumes the role of the final arbiter, verifying that the cross-platform application aligns with all user requirements. This phase adopts a user-centric perspective, meticulously assessing the application's functionality on various devices to ascertain a smooth and satisfactory experience for both customers and mechanics.

Table 1. Test Phases for Roadside Assistance Application

Test Phase	Description
Unit Testing	Validate individual components and functions of the service application, ensuring proper functionality of customer and mechanic modules.
Integration Testing	Verify interactions between application components, backend systems, and mobile platforms for seamless integration of customer requests and mechanic responses.
System Testing	Validate end-to-end scenarios of roadside assistance requests, including customer request processing, mechanic assignment, and status updates.
Acceptance Testing	Ensure the cross-platform application meets user requirements, including smooth interactions for customers and mechanics on various devices.

5.2 Functional Testing

Functional testing for Roadside Assistance involved systematically verifying that each component and feature of the application performs its intended function correctly. This testing method ensures that the application's functionalities align with the specified requirements, covering aspects such as user interactions, data processing, and blockchain integrations. The theory behind functional testing lies in validating the application's behavior against expected outcomes and detecting any deviations or defects that may compromise its reliability. Functional testing is essential to ensure the seamless operation of features like location tracking, service requests, and payment processing, all interconnected through blockchain technology [32].

Functional testing is particularly well-suited for this project due to its ability to address the intricate interactions between various modules and functionalities in a comprehensive blockchain-based application. By meticulously examining each feature's functionality, the testing process can identify potential issues related to data integrity, smart contract execution, and cross-platform compatibility. Given the critical nature of roadside assistance, where timely and accurate responses are paramount, functional testing becomes a linchpin in delivering a robust and reliable application. This method aligns with the goals of the Global Coalition for the Improvement of Humanity (GCIH) by ensuring the deployment of a secure and efficient technology solution, ultimately contributing to the betterment of global transportation systems and emergency services. The justification for using functional testing in this project lies in its ability to address the specific challenges posed by blockchain technology. It allows for the verification of smart contract logic, ensuring that the execution of transactions is accurate and secure. Additionally, functional testing helps identify and rectify any issues related to the interoperability of the application across multiple platforms, a critical aspect of a roadside assistance service that needs to be accessible to users on diverse devices and operating systems.

According to Table 2, Test Case ID TC001 is dedicated to evaluating the foundational aspect of processing customer requests within the system, focusing on its ability to accurately register requests and provide detailed acknowledgments regarding the requested service. The successful outcome of this test, indicated by the “Pass” status, validates the system’s adherence to its intended design principles, ensuring the effective capture of customer requests and the initiation of subsequent service processes. Subsequently, Test Case ID TC002 expands this evaluation to encompass mechanic assignment and real-time status updates, pivotal components for the seamless functioning of a roadside assistance system. A positive outcome not only confirms the system’s capability to register requests but also affirms its proficiency in coordinating mechanic assignments and facilitating transparent communication throughout the entire process. Test Case ID TC003 shifts the focus to customer control and flexibility, examining the system’s handling of request cancellations prior to mechanic assignment, and emphasizing the importance of empowering customers to manage their requests effectively. This test ensures a successful cancellation process, potentially mitigating unnecessary service charges for customers. Test Case ID TC004 further explores the interaction between mechanics and the system, assessing the timely receipt and confirmation of service requests, a critical aspect for ensuring efficient service delivery. Addressing communication aspects, Test Case ID TC005 evaluates the effectiveness of the notification system for both customers and mechanics, emphasizing the significance of timely and accurate updates for maintaining transparency. Finally, Test Case ID TC006 concludes the testing regimen by scrutinizing the secure processing of financial transactions for completed services, underscoring the necessity of implementing secure mechanisms to instill user trust and ensure the financial integrity of the roadside assistance platform.

Table 2. Test Cases for Roadside Assistance Application

Test Case ID	Description	Expected Result	Actual Result	Status
TC001	Verify customer request processing.	Successful processing of the customer request with accurate details.	Acknowledgment received with correct service details.	Pass
TC002	Test mechanic assignment and status updates.	Proper assignment and timely status updates for the assigned mechanic.	Mechanic assigned successfully, real-time updates observed.	Pass
TC003	Test customer cancellation of a service request.	System cancels the request without assigning a mechanic.	Request canceled successfully before mechanic assignment.	Pass
TC004	Validate mechanic response to a service request.	Mechanic acknowledges and accepts the service request promptly.	Mechanic accepted the request successfully.	Pass
TC005	Verify notification system for both customers and mechanics.	Timely and accurate notifications for customers and mechanics.	Notifications received promptly on both ends.	Pass
TC006	Validate payment processing for completed service.	Secure and accurate processing of payment for the completed service.	Payment processed successfully, and the transaction reflects the correct amount.	Pass

6 Results and Discussion

In this in-depth analysis of the roadside assistance application, we have conducted an exhaustive examination of its potential to bring about a significant transformation in the delivery of roadside assistance services to customers. For instance, Figure. 5 illustrates the mechanic markers on the user application, demonstrating how these smart contracts facilitate real-time updates and communication between users and service providers. This intricately developed application is intentionally crafted to provide highly effective services to individuals encountering vehicular emergencies. It functions as a dynamic digital platform for mechanics, offering them opportunities to broaden their professional horizons. For instance, Figure. 6 shows mechanic information on the map, while Figure. 7 displays service requests on the mechanic application. Additionally, the application stands out through a comprehensive array of features centered around user needs, supported by a steadfast commitment to ensuring the security of user data. This security is demonstrated through a robust sign-in/sign-up process and the additional safeguard of password reset functionality. Users have seamless control over their profiles, allowing them to manage personal details, payment information, and individual preferences. Crucially, users maintain the ability to review their entire service history, fostering transparency and trust. The roadside assistance application incorporates a real-time tracking feature that enhances the overall customer experience by providing live updates on the approaching service provider. This not only minimizes waiting times but also adds an extra layer of safety and assurance for users during distressing situations.

Furthermore, we delved into the intricacies of contract deployment, a procedure that demands scrupulous attention to detail to ensure seamless integration into the application's blockchain ecosystem. Our results highlighted the indispensability of efficient deployment protocols to guarantee the flawless assimilation of contracts into the decentralized fabric of the blockchain. The application explored the pros and cons of deploying contracts on public, private, and consortium blockchains. Our research emphasized the need to choose blockchain options wisely, considering factors like scalability, cost-efficiency, and data confidentiality. These technical insights are crucial for refining our smart contract functionality, enhancing the robustness, security, and reliability of our blockchain-based roadside assistance application.

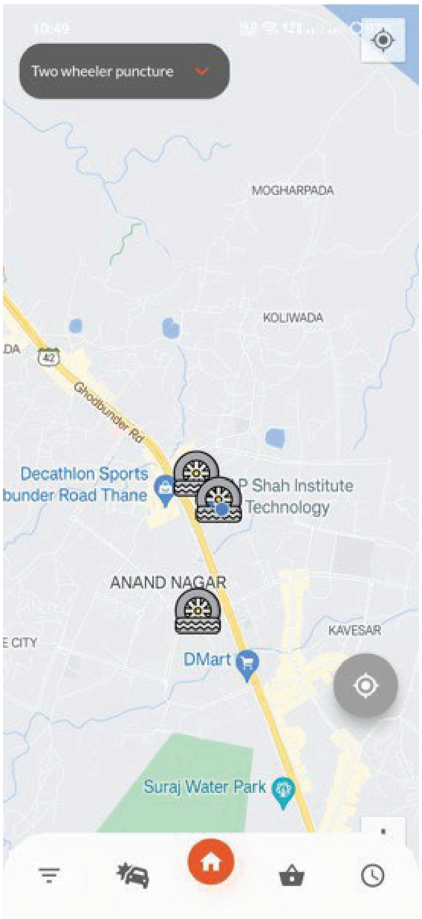

Figure. 5. Mechanic Markers on the User Application

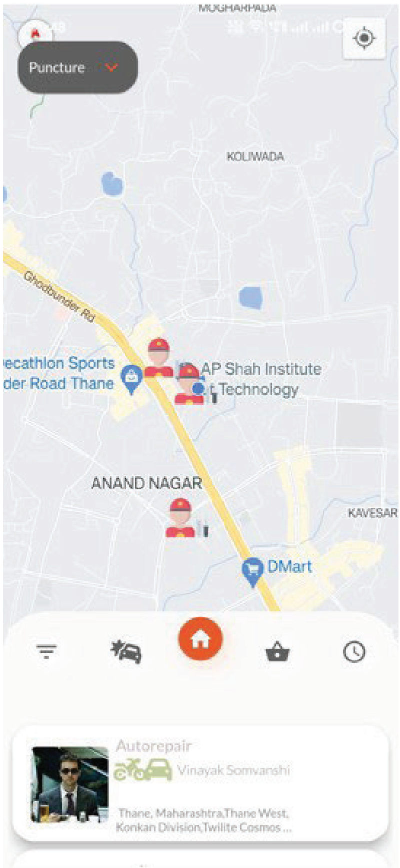

Figure. 6. Mechanic Information on the Map

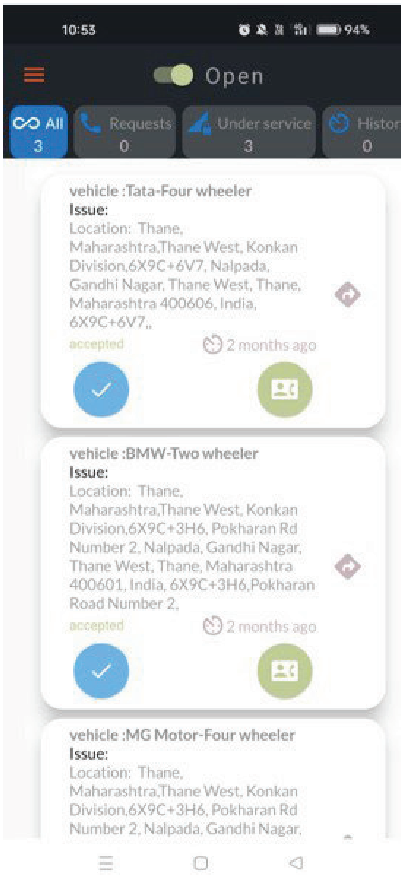

Figure. 7. Service Requests on the Mechanic Application

6.1 *Future Implications*

In terms of future enhancements, there are several promising directions. We foresee the integration of telemetry data from vehicles as a significant area for development. Modern vehicles are equipped with various sensors that monitor critical aspects of a vehicle's condition. Integrating this telemetry data with the application can enable automated service requests based on real-time vehicle diagnostics. This could lead to faster response times and more accurate problem diagnosis. Additionally, by analyzing historical data and usage patterns, the application could predict when specific vehicle parts or systems may require servicing.

Moreover, the implementation of Natural Language Processing (NLP) in the app's communication channels holds potential for enhancing the user experience. AI-driven chatbots [32] could provide users with interactive and personalized support, from answering queries to guiding them through emergency situations. AI can leverage historical data and user preferences to offer tailored recommendations for vehicle maintenance and roadside assistance. These prospective developments underline the application's ongoing potential for improvement, ensuring its ability to provide efficient, secure, and user-centric roadside assistance services while adapting to emerging technologies and user needs.

7 Conclusion

In the current landscape of the rapidly expanding vehicular network, the centralized structure of many roadside assistance systems, typically involving third-party intermediaries, has generated considerable apprehensions regarding the security and reliability of these systems. Blockchain technology, identified as a groundbreaking solution, has emerged to effectively decentralize such systems, thereby fortifying their dependability and security. Our dedicated initiative revolves around the development of a cross-platform application for roadside assistance, seeking not only to streamline the assistance process but also to empower mechanics in expanding their service offerings. The bifurcation of the system into tailored components for mechanics and customers is a distinctive feature of our approach. Programmed in Dart on the Flutter framework, the application seamlessly interfaces with Firebase as the database, ensuring the efficient management and retrieval of data. This comprehensive application integrates user-centric features, robust data security measures, and real-time service tracking capabilities, collectively heightening transparency and user control. Users can effortlessly request assistance, specifying their precise locations and service requirements, while mechanics can promptly confirm their availability, presenting clients with well-informed alternatives. The intricate connection of the blockchain through endpoints on the cloud significantly contributes to the overall efficiency of the application. The incorporation of smart contracts and meticulous mechanic verification processes serves to reinforce the reliability and security of the assistance process, establishing a resilient foundation for the seamless execution of requested services. This multifaceted approach not only ensures data integrity and security but also optimizes the performance of the blockchain in facilitating seamless transactions. Looking ahead, our research envisions further enhancements through the integration of telemetry data for proactive assistance and the utilization of AI-driven chatbots for personalized support, promising a paradigm shift in the landscape of roadside assistance and vehicular network security.

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