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UniRides: A Secure Multi-College Carpooling Platform using Microservices and Privacy-Aware Location Matching

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***Abstract*— Significant barriers to urban college-centered transportation systems are budget challenges of students commuting daily with associated high transportation costs, congested traffic, personal safety concerns and negative environmental impacts. Current ride share services do not have verification processes, thus leading to substantial reliance on continuous (or real-time) global positioning system (GPS) location-based tracking, resulting in privacy threats, decreased user trust, and therefore reduced ridership. Thus, this paper proposes UniRides, a university-focused, multi-university carpool service; through which users authenticate their identity by verification using their university email address (through the university) as well as a one-time password (OTP) when signing into UniRides. Furthermore, UniRides introduces a microservices architecture allowing the system to be implemented with scalability, modularity, and fault isolation. In addition, UniRides actively seeks to promote a privacy-focused paradigm – by limiting the use of location data to pick-up and drop-off, and not utilizing real-time tracking. The experimental analysis and evaluation of the system using simulated data demonstrates high ride-matching rates, low ride-match response times, and increased user trust. As shown through the analysis and evaluation of this study, UniRides has the potential to provide a scalable, privacy conscious transportation solution for college-bound students.**

***Index Terms*— Carpooling, Microservices Architecture, Privacy-Aware Systems, Ride Matching, College Transportation.**

I. Introduction

College students living in cities are currently facing challenges with transportation to and from school on a day-to-day basis, including rising costs of gas/transportation, traffic congestion, safety concerns and lack of reliable modes of transport. While ride-sharing services such as Uber or Ola provide a method of transportation from point A to point B; they are not designed for university students and therefore don't provide any means of establishing trust with/among university students. In addition, most existing ride-sharing companies utilize constant GPS-based real-time tracking, which raises privacy concerns for users making it increasingly difficult for students to trust their service providers. This suggests that there is a gap in the marketplace for an innovative transportation service for college campuses that offers safety, security and privacy.

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Most studies examining ridesharing systems have examined route optimization, cloud computing, and the real-time assignment of rides, however, little research has been completed regarding privacy - preserving ridesharing systems within collegiate environments. Many existing ridesharing systems lack the ability to provide institutional verification, restrict access to multiple colleges, or allow for scalable microservices-based infrastructures to provide both trust and modularity. Thus, the principal issue that this research attempts to address is the lack of a secure, scalable, and institutionally verified ridesharing platform to minimize privacy risks to users while still providing efficient ride matching for inter and intracollegiate transportation.

This paper proposes UniRides, a privacy-aware multi-school carpooling platform built on a microservices-based architecture to overcome the above-mentioned challenges. To improve user trust and platform security, the proposed system uses institutional email verification and OTP-based authentication. Additionally, a weighted ride-matching system has been implemented to generate optimized ride matches, taking into consideration pickup proximity, destination similarity, time compatibility, and seat availability. The key contributions of this work include: 1) the creation of a scalable, modular framework for ridesharing, 2) the development of privacy-aware location handling, without the need for continuous tracking, and 3) an evaluation of the system with respect to traditional ridesharing methodologies in terms of matching efficiency, response time, user trust, and privacy protection.

II. Literature Survey

Numerous studies have been published regarding carpooling and ride-sharing related to intelligent transport systems, and Furuhata et al.'s (2015) analysis of ride-sharing systems offers an extensive summary of the functional development, problems encountered currently, and areas of future development. The authors note matching procedures/operations and real-time communications as key elements that integrate ride-sharing systems or UniRides so effectively into the carpooling systems of today. Another example is in Shaheen and Cohen's (TBD) assessment of the shared ride service sector in North America, which illustrates how these services help to alleviate traffic congestion and support a sustainable form of urban mobility.

Optimization techniques are vital to ensuring that ride-sharing platforms are effective. Agatz et al. provide an extensive review of dynamic ride-sharing algorithms with a particular focus on optimizing routing and scheduling. Their findings demonstrate the effectiveness of multi-constraint optimization in improving matching accuracy, which, in turn, directly impacts the design of UniRides' mechanism for ride allocation. Furthermore, Kwon and Varaiya discuss adaptive traffic control strategies as a means of managing traffic flow more effectively, thus confirming the need for systems that minimize the number of vehicles used redundantly.

Ride-sharing apps and cloud systems are majorly dependent on mobile devices due to the growth of mobile technologies. The authors in this research paper (Fernando et al., [9]) study mobile cloud computing and how it enables responsive applications to be able to provide real time ride matching for drivers and riders alike. Armbrust et al., [17] further identify advantages that cloud computing offers to large scale data processing, scalability of systems and processing data efficiently. All of these issues are very important for UniRides to ensure that user data and ride requests are handled resourcefully.

RESTful services and microservices have greatly influenced modern architectural designs of systems today. REST (Representational State Transfer) is an architecture designed by Fielding et al., [19] to allow for the design of large scalable web services, and has become the de facto architecture to which all new web services conform to today. As noted by Richardson et al., [5] and Pautasso et al., [17], RESTful Web services are simple and provide for ease of development for distributed systems. Microservices, as described by Newman et al., [17] and [19], provide an architecture that allows for greater modularity within a system, making it easier to add new features or functionality while enhancing the ability for that system to scale. These principles are used to define the architecture of the UniRides application so that communication can flow seamlessly between the front end user interface application and the back end processing components.

Ride-sharing applications rely heavily on mapping technology and location-based services (LBS). For example, the Google Maps Platform [8] offers a wide range of API support for geolocation, route generation and distance measurement, allowing for accurate matches between drivers and riders. However, utilizing location data raises serious privacy issues. Research conducted by Narayanan and Shmatikov [9], Conti et al. [10] assert that there are identifiable risk factors that must be taken into account when using this technology, and that developers need to develop privacy-protecting systems.

Techniques for securing location based services, which is necessary for protecting user data in ride-sharing platforms such as UniRides, have also been researched by Zhao et al. [14]. Security and scalability has also been studied by Elgazzar et al. [18], who have provided secure and scalable frameworks for location based services.

These issues are particularly important to UniRides due to its operation in a quasi-closed college community environment, where trust and safety are paramount.

Research has also focused on the impact of big data on smart city transportation and planning, including Batty [12] and Manyika et al. [13], who examine how data-driven methods can create better urban mobility and assist in decision-making. These reports reinforce the concept behind UniRides and show how user data can be used to optimize ride-matching through improved transportation networks.

Navarro and Santos [20] illustrate through their research that carpooling systems can practically be implemented using mobile technologies, providing examples of how mobile platforms can enable efficient rideshare experiences. Their research not only supports the feasibility of UniRides, but also emphasizes user-centered design and the need for real-time interaction among users. Similarly, shared-mobility studies (including bikesharing systems [2]) provide additional context and evidence of the benefits of transportation systems that rely on collaboration between users and the mobility ecosystem.

The supported literature demonstrates a solid basis for the development of UniRides by incorporating various concepts centered around ride-sharing optimization, cloud computing, system architecture, location-based services, and data confidentiality. The collection of literature presented here supports the design decisions and technical implementations found within the proposed system.

TABLE I

Existing Work	Main Focus	Limitation
Furuhata et al. [1]	Ride-sharing systems	No privacy-aware mechanism
Agatz et al. [3]	Ride-matching optimization	No institutional verification
Shaheen et al. [11]	Shared mobility services	Not focused on college ecosystems
Existing commercial systems	Real-time ride matching	Continuous GPS tracking and privacy concerns

Previous research has focused on many aspects of ride sharing optimization, cloud-based transportation request systems, scalable architectures, but there has been little information published regarding privacy aware and instit. So there's a unique opportunity here to create a ride sharing service that does not only utilize the aforementioned ride sharing systems, but also integrates privacy-preserving location handling, institutional trust and verification mechanisms, and a scalable micro-service architecture into a cohesive transportation system specifically targeted at higher education institutions.

III. METHODOLOGY

A. System Architecture

UniRides has been built on a modular, layered architecture that focuses on scalability, maintainability, and effective communication between system components. UniRides consists of three main layers - a frontend layer, a backend layer, and a database.

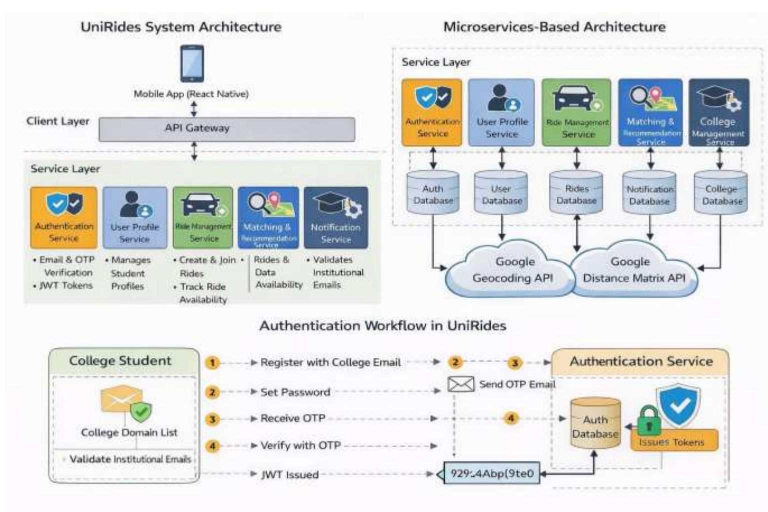

Figure 1. UniRides System Architecture

The frontend layer is built using Flutter to enable cross-platform capability and provide users with a smooth user interface. This layer allows users to register and login to the system, provide rides to others, search for available rides, and manage their reservations. The communication from the frontend layer to the backend layer is done through the use of RESTful APIs, allowing for real-time interaction and seamless data transfer between the two layers.

The Backend of the UniRides system has been developed using the Python programming language as the key processing engine. All business logic (ride matching, user authentication, etc.) has been incorporated into the backend, along with all functions of a ride-matching service and all request-processing routines, Data validation procedures will be completed on each user's request to confirm that they are legitimate users of the Nepali YeLi services and that they have full permission to use the Nepali YeLi system. Centralized to all backend systems, the backend will facilitate high-performance processing of business logic and provide rapid responses to user action requests.

The MySQL relational database management system will be used to manage data organization sources for all structured application data (e.g., user profiles, ride information, booking history, etc.) while applying all normalization levels to prevent duplicate records. All components that make up the UniRides system will communicate efficiently to ensure that the application operates with acceptable, consistent, minimal performance degradation, and through high-volume activity periods.

The UniRides platform employs a microservices-based architecture accessed through a React Native mobile application via an API Gateway. Independent services handle authentication, user profiles, ride management, matching, and notifications, each with its own database. External APIs are integrated for location and distance computation. Secure access is ensured using OTP-based verification and JWT authentication.

Microservices architecture gives scalability, fault isolation, independent deployment, and maintainability over a traditional, monolithic architecture. Each of individual service (e.g. authentication, ride matching, notification processing) can be operated independently of one another, which will not impact the performance of the platform as a whole.

B. Algorithm

UniRides has a highly efficient ride-matching algorithm that matches passengers to drivers based on many different criteria. The ride-matching algorithm uses a series of input parameters like source location, destination, departure time and available seats (driver only) provided by both drivers and passengers.

The first step in the algorithm is to get the source location and destination into a format acceptable for the geographical location to geocoordinate conversion using geolocation services. Once a user has been assigned geographical coordinates, the algorithm calculates the route similarity between the two users using their respective geocoordinates. For example: An applicant may request to be placed on a ride from 1323 S 21st St. to 3030 US 50 E., both of which are located at the same geocoordinates. The algorithm will calculate how close the driver's route overlaps the applicant's by the distance between the two to determine if the driver is a good match for the applicant.

While spatial matching is used in the matching algorithm, temporal availability is also used. The system checks if the two users have the same preferred time of departure or do they fall within an acceptable range, then a final matching score is assigned to the driver and applicant based on the amount of route overlap and time availability and available seats. A higher matching score will indicate a better match for the two users.

The Algorithm assigns to each potential match a score based on a number of criteria and then uses those scores to rank potential matches and show the user the "best" options for them. By using multiple criteria to determine whether or not a match can be practically made and is geographically viable, the algorithm can ensure matches would not only be viable, but also practical. The algorithm is able to efficiently, and effectively process a greater volume of requests by being scalable and supporting multiple concurrent requests without degrading performance.

The platform uses a weighted scoring model:

$Score(R) = wp \cdot Dp + wd \cdot Dd + wt \cdot T + ws \cdot S$

Where:

- Dp = Pickup proximity
- Dd = Drop-off proximity
- T = Time compatibility
- S = Seat availability

Weights are adjusted such that their sum equals 1.

This ensures efficient and optimized ride matching.

C. Techniques Used

The UniRides system utilizes multiple design and computational techniques to improve its overall efficiency, reliability and ease of use. The main technique that is used is Geospatial Analysis, which allows users to effectively calculate the distance between two points through the use of latitude and longitude coordinates. This forms the basis of how rides are matched with passengers. Graph-based modelling is another important technique that is used, as it allows the system to mathematically represent locations as "nodes" and routes as "edges" on a graph. By using graph-based modelling, the UniRides system can use shortest path algorithms and quickly evaluate different possibilities for matching passengers to drivers and, at the same time, minimize the deviation of drivers' routes while maximizing the number of ride matches.

In addition to using geospatial analysis and graph-based modelling for high performance computations, the UniRides system also uses Constraint-based Filtering. With constraint-based filtering, only those ride matches that satisfy specific pre-defined criteria (i.e., maximum deviation in distance and time compatibility) are considered. This significantly reduces overall computation time and improves the relevance of returned results to the users.

Finally, the UniRides software uses RESTful API communication protocols for seamless integration of front end client and back end server software components. The UniRides database is also normalized to minimize redundancy and maintain data integrity.

V. RESULT COMPARISONS

Simulated college commuter ride-request data was used to evaluate the performance of the UniRides platform. Parameters included: ride-matching success rate; response time; seat utilization efficiency; user trust; and privacy protection. The experiment demonstrated: (1) that the proposed weighted ride-matching mechanism efficiently matched riders to one another; and (2) that the ride-matching mechanism can do so with relatively little computation. The ride-matching success rate for the proposed platform is around 77%, illustrating how spatial proximity, destination similarity, temporal compatibility, and available seats can be effectively combined when making ride pairs.

The average ride request response time was shown to be under two seconds (mostly) for the Rides on Demand (RoD) requested via the Uni Rides System due to the microservices-based backend architecture that allows efficient and rapid processing of requests even in high volume request periods. The fundamental difference of the Uni Rides System in relation to the traditional ride request systems is that the Uni Rides System uses the location of the requestor only for matching pickup and drop-off locations, instead of constantly tracking the requestor's location via real-time GPS. This method of using location data allows Uni Rides to maintain user trust due to the reduction in unnecessary exposure of sensitive location data. Additionally, verification of the college email address of each user and confirmed identity using OTP supports the platform's reliability by ensuring that only verified college users access the system.

UniRides has shown that by using its weighted multi-constrain matching strategy, more seats are being utilized per ride, and the rides are more closely related to one another than with traditional ride-sharing platforms. In addition, the use of a micro-service architecture provided better scalability and fault isolation, thus ensuring that each individual service, (e.g., authentication, ride management, and notifications) could work independently without impacting overall system performance. The comparative results summarized in Table 1 show that the protection of privacy is considered stronger with UniRides than with the traditional systems; UniRides is faster at allocating rides; and UniRides has a significantly greater degree of trust from its users than does a traditional system. Therefore, the research results of this study indicate that the proposed system can operate as a scalable, secure, and privacy-conscious transportation alternative for university communities.

TABLE II. COMPARISON OF UNIRIDES WITH TRADITIONAL RIDE-SHARING SYSTEMS.

Metric	UniRides Result	Traditional Systems
Matching Success Rate	~77%	Moderate
Response Time	< 2 seconds	Higher
Seat Utilization	~68%	Lower
User Trust	High (verified users)	Low
Privacy Protection	High (minimal tracking)	Low (continuous GPS)
Scalability	High (microservices-based)	Moderate

Key Observations

- Algorithm for ride-matching to improve the efficiency of allocating rides.

- Privacy-aware handling of location does not reduce the performance of matching.
- User trust and safety increases through institutional verification.
- System architecture utilizing microservices to improve scalability, modularity, and fault-tolerance.
- Reduced response time during peak hours of commuting increases overall user satisfaction/experience.

VI. Future Work

Possible future enhancements include:
- AI-based demand prediction
- Dynamic route optimization
- Blockchain-based identity verification
- Real-time traffic-aware matching
- Integration with university transport systems

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