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Extended Abstract Submission

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Development of an Algorithm for Ridesharing in an Autonomous Mobility-on-Demand System

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This work addresses the following topic(s) from the Call for Contributions:
(Please check at least one box)

☐ Placemaking to integrate urban spaces and mobility
☒ Promoting sustainable mobility choices in metropolitan regions
☐ Governing responsible mobility innovations
☐ Shaping the transition towards mobility justice
☐ System analysis, design, and evaluation
☐ other: ________________________

Extended Abstract

From here 700-1000 words, grouped by the following sections:

Problem statement

The growing urban population worldwide has put tremendous pressure on urban transport systems, leading to problems like traffic congestion, environmental pollution, and accidents. Several innovative mobility solutions have emerged to address these problems and handle the rising demand sustainably; autonomous vehicles (AVs) are among the most significant. AVs can sense their environment and guide themselves without human intervention, demonstrating significant potential for crash prevention, travel time reduction, and fuel efficiency improvement. However, several challenges remain to be overcome before AVs can be commercially deployed. Besides digital security and ensuring their safety in a mixed-traffic environment, a key challenge lies in determining ownership models for AVs. However, there is wide agreement among experts that the full potential of AVs can be realized only when they are deployed as part of public transit rather than as a private mode. It is expected that such deployment can address sustainability, equity, and accessibility goals (Jiang, 2022).

This research focuses on such a system that envisions using AVs to offer *Mobility-on-Demand (MoD)* public transport services within a geographical boundary. MoD is a derivative of the *Mobility-as-a-service (MaaS)* concept, that allows users to book a service of their choice through a mobile application, as and when the demand arises. This concept offers various advantages, like the convenience of customized and subsidized services without owning a vehicle, and fuel savings. With the wide acceptance of the MoD concept, a further specialization was introduced: the possibility to share transport resources. Sharing of MoD services is referred to as *ridesharing*, which is essentially an arrangement in which people with similar itineraries and time schedules utilize spare seats

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in a vehicle and share the travel cost (Furuhata et al., 2013). Ridesharing enables better capacity utilization of cars, which leads to larger benefits like congestion reduction. The objective of this research is to develop an algorithm for ridesharing in this autonomous MoD system (A-MoD) under study. While the MoD and ridesharing concepts are widespread in conventional vehicle systems, they are still largely theoretical for autonomous systems. This work is therefore expected to make a distinctive contribution to the growing literature on AVs.

Research objectives

The key objective of this research is to develop an optimization algorithm for ridesharing in an A-MoD public transport system. It is expected that the inclusion of optimization techniques like ridesharing and dynamic routing in the design facilitates accurate assessment of parameters like the required fleet size and vehicle size.

There are two types of ridesharing: *static and dynamic*. While a static rideshare requires pre-arranged trips, a dynamic rideshare allows real-time matching of riders with vehicles already in the network (Shen, Huang & Zhao, 2016). Since a MoD system is studied here, the algorithm will focus on dynamic ridesharing. Common optimization objectives for dynamic ridesharing systems include reducing the distance travelled and travel times while maximizing the number of participants (Agatz et al., 2012).

Methodological approach

Dynamic ridesharing is described in the literature as an automated process of ride-matching (routing, scheduling, and pricing) between drivers and passengers on very short notice or even en route (Furuhata et al., 2013). An extensive review of the existing literature on dynamic ridesharing algorithms was undertaken as part of this work. This review offered insights into aspects like the key participants of a dynamic ridesharing system, their goals, and the relevant constraints. Further, three main steps were identified as being part of a typical ride-matching process:

1) **Request generation:** The commuter generates a ride request by providing details like pick-up and drop-off locations, and origin and drop-off time windows.
2) **Searching and Matching:** The system searches for a suitable vehicle to fulfill the ride request and then looks for a second request to match with the first for sharing, while considering constraints.
3) **Execution:** This step ensures that the time windows promised for both matched trips are met, by deciding the order of execution of the requests and by planning the route accordingly.

Beyond the above three steps, a *framework* needs to be defined, which is the mechanism by which changes get updated in the system, e.g., when a new request enters the system or when trips are assigned to vehicles.

This research further reviewed existing methodologies for each of the above steps, for example, *Rolling Horizon Strategy* (Agatz et al., 2011) and *Network Partitioning Algorithm* (Pelzer et al., 2015) are some approaches for defining the framework. Similarly, *Greedy Matching, Hungarian Algorithm*, etc. (Hanna et al., 2016) are common matching algorithms. These various methods available for the above steps were then compared with the requirements of the envisioned system. An algorithm was then proposed, that merged the strengths of these methods, improved upon their shortcomings, and accounted for the system-specific requirements. E.g., battery capacity is a constraint specific to an A-MoD system.

Results

The outcome of this research was the framework for an algorithm for ridesharing in an A-MoD system, that proposed methodologies for each of the above-mentioned steps while considering service-level and autonomous system-specific requirements. The service-level requirements were in the form of limiting values for the journey and waiting times envisioned for this system by the administrative stakeholder. The framework also included additional constraints to consider the system's goal of prioritizing this service for those with accessibility and mobility issues. A model pseudo-code was created based on this framework. The next step envisioned for this work is the testing of this algorithm on a simulated road network of the planned deployment site, within a plug-in for the MoD service. This step is expected to validate the algorithm and refine it where necessary. Additionally, this research has identified certain KPIs to measure the performance of the algorithm, such as its potential to reduce the number of cars on the road and improve accessibility. The work envisions testing these KPIs after the validation step. This work is unique in the sense that it is developed at the intersection of multiple cutting-edge transport innovations; with further improvements, it can be expected to find valuable applications during real-time deployment.

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