An Adaptive and Hotspot Aware Taxi Zone Queuing System on Internet of Vehicles

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ABSTRACT

Taxis have a vital role in the transportation system and Internet of Vehicles (IoV) techniques can be used to improve the fuel and time efficiencies of taxis. However, the existing work does not address the traffic congestion that may occur when a large amount of taxis gathers in certain queuing areas. This paper proposes an adaptive and hotspot-aware taxi zone queuing system to deal with the problem while still guarantees the fuel and time efficiencies. The adaptive scheme features data collection, hotspot extraction, an adaptive zone queuing protocol, and navigation services for taxi drivers. Real data were collected from Taiwan Taxi Inc., the largest taxi company in Taiwan. Queuing zone hotspots were identified through the analysis of the collected data. The hotspots represented. A navigation service was based on the proposed protocol. To verify the feasibility of the proposed system, a prototype was implemented. The experimental results demonstrated that the proposed scheme outperformed other schemes in reducing waiting time and the average number of taxis.

KEYWORDS

Hotspot Aware, Internet of Vehicles, Queuing Model, Real Data Analysis, Route Planning, Zone Queuing

1. INTRODUCTION

Taxi services are useful and convenient, and have become one of the principal means of city transportation. According to a survey conducted by the Taiwanese Ministry of Transportation and Communications (Ministry of Transportation and Communications Taiwan, 2016), more than 87,000 taxis are in operation in Taiwan. Taipei City alone has 30,000, and the greater Taipei area (Taipei City and New Taipei City) accounts for 60.6% of the taxis in Taiwan. According to the aforementioned survey, the average taxi operates for 9.5 hours per day, 3.5 hours (37%) of which the taxi is unoccupied. The empty cruising distance of an average taxi daily is 47.9 km, which wastes fuel and causes traffic problems. Currently, 73.4% of taxi drivers find passengers by hunting, 38.1% by receiving dispatch calls, and 25.2% by waiting. Each of these methods has its particular disadvantages. Drivers who adopt the hunting method, in which they look for passengers along the side of the road, may endure unpredictable lengths of time between customers, resulting in an unstable income. Drivers who find passengers by dispatch, the allocation of which is based on the free taxi nearest to the passenger, must pay a fixed operation fee to the company which dispatches them, plus a commission for each dispatch accepted, regardless of whether it results in a successful transaction. Therefore, the costs associated with being dispatched are large. Drivers who wait, for example at a taxi stand, consume less gasoline.

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than those who hunt, but must wait longer than those who adopt hunting or dispatching. The more taxis wait in the queuing line, the longer each taxi must wait for a passenger, and if the number of taxis in the queue is larger than the rank’s capacity, it can lead to congestion.

Several studies have proposed solutions to improve taxi service efficiency and income. On-air queuing (Hou, Fan, & Lian, 2012) is an effective model that has been adopted by Taiwan Taxi Inc. Many areas have a high, stable demand for taxis, however passengers are usually scattered and tend to request a taxi using the Internet or cell phones instead of attempting to hail one beside the road. Consequently, drivers who adopt the hunting or waiting models got poor business efficiency. Using an on-air queuing model, taxi companies establish an on-air queuing system in areas that have high demands. When a taxi enters the queuing zone, the system allocates a queuing number to the taxi driver. Taxi drivers can take a break or hunt for passengers in the queuing zone before they reach the head of the queue. Dow et al. proposed an efficient geo-aware taxi queuing model using location-based service and zone queuing techniques, which effectively improved the carrying probability and average profit for taxi drivers, but it had the potential to cause difficulties when drivers were unfamiliar with the traffic in the queuing zone. To deal with this problem, the authors proposed a route planning mechanism for the taxi drivers; that mechanism calculated various routes to increase each driver’s chance of finding a passenger. When a taxi entered a queuing zone and requested route planning, the system planned a route that included the places where passengers had historically tended to request taxis. This solved the problem of taxi drivers who were unfamiliar with the queuing zone traffic. However, above mentioned on-air based queuing methods were not able to prevent traffic congestion as the disadvantage, which tends to happen when large amount of taxis gather in certain queuing areas.

To solve the aforementioned problems, the authors developed an adaptive and hotspot-aware taxi zone queuing system on Internet of Vehicles. First, the authors considered real GPS data from three queuing areas used by Taiwan Taxi Inc. and real-time data from roadside units (RSUs). Next, the queuing zone is divided into grids, and the hotspot grids were identified where the historic demand for taxi service was high. The expected waiting time of each zone-based queue was calculated using an M/M/1 queuing model. The workflow of queuing zone can be described as follows. When the first taxi enters the queuing zone, the system adds it into the zone-based queue and guides it to the first available hotspot. When the waiting time is long or when the hotspot grid has been occupied, the system will add the next taxis entering the queuing area into a new zone-based queue and directs these taxis to the next available hotspot. Real-time data is used to estimate the expected waiting time. If a taxi enters the zone while multiple zone-based queuing lines are operating, the system will compare the expected waiting time of all queues and guides the taxi to the queue with the shortest wait.

The rest of this paper is organized as follows. Section 2 discusses studies closely linked with this research. Section 3 describes the adaptive zone queuing protocol. Section 4 details the system implementation and prototype. Section 5 demonstrates the experimental results. Section 6 presents the conclusions and discusses future research directions.

2. RELATED WORK

To ensure the success of this research, some related work is described in this section. The authors will introduce GPS-based services, taxi carrying studies and queuing studies in this section.

Generally, taxi companies equip their vehicles with ITS devices, for example, GPS devices, Global System for Mobile Communications (GSM) real-time positioning device, and Mobile Communication device (MCD) for more convenient management and dispatching. Various studies focus on applications and trajectory for taxi and take advantage of GPS devices’ feature that periodically uploading location data such as (Ma, Zheng, & Wolfson, 2015) and (Rohani, Gingeras, Vigneron, & Gruyer, 2015). Location data plays a crucial role in trajectory planning, especially trajectory planning in urban traffic environment. (Pan, Qi, Wu, Zhang, & Li, 2013) obtained the GPS data from Hangzhou city and proposed the IDBSCAN clustering algorithm improving from DBSCAN (Ester, Kriegel, Sander,
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Representing Knowledge