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RESEARCH PAPER

Transportation Routing in Urban Environments Using Updated Traffic Information Provided through Vehicular Communications

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Abstract: Finding optimal routes for vehicles to reach their destinations is deemed to be a significant challenge and that is an objective in Intelligent Transportation Systems (ITS). In this paper, we propose a mechanism for vehicle routing based on the availability of updated traffic information. The proposed mechanism includes two phases. In the first phase, we propose a TIS (Traffic Information System) which collects the updated traffic status and stores it in the traffic information center. The proposed TIS approach consists of wired or wireless infrastructure and ad hoc inter-vehicle communications. This information will be used for vehicle navigation when a vehicle intends to run some errands. In the second phase, through exercising the available updated traffic information; we propose two different Dijkstra-based vehicle route suggestion algorithms named one-step vehicle path suggestion and step-by-step vehicle path suggestion. In the former, the algorithm is invoked only once at the beginning of the trip in order to obtain the best route towards the destination. The obtained route is then used by the vehicle throughout the journey. Nevertheless, in step-by-step path suggestion algorithm the suggested route toward the destination is being updated and refreshed at each intersection. The proposed step-by-step algorithm is further enhanced by two novel methods for avoiding loop creation. Results of the extensive simulation study using NCTUns 6.0 network simulator shows that both of the routing algorithms use the updated traffic information while the step-by-step algorithm outperforms the one-step path suggestion algorithm.

Key words: intelligent transportation systems (ITS), VANETs; WiMAX networks; road-side unit (RSU); directional antenna; dynamic vehicle routing; vehicles navigation; traffic information system

1 Introduction

The soaring trend in producing vehicles and the necessity for utilizing the personal cars as well as public vehicles in modern life, have made people reluctantly spend significant amount of time while commuting. Needless to say, heavy traffic congestion aggravates this problem. Traffic congestion has various negative effects on travellers, businessmen, agencies and cities. According to TTI's 2011 urban mobility report, collected from 439 U.S. urban areas; Schrank et al.[1] discussed that one major factor is the amount of time and fuel wastage. According to this report, the top 15 urban areas comprise approximately 58% of the delay estimated for 2010, and the top 20 areas account for over 65% of annual delay. Furthermore, the urban districts with the populations of more than 3 million; accounts for 1.6 billion gallons (about 70% of the national estimation) of fuel wastage. As the congestion increases each year, the imposed cost will increase accordingly.

As shown in Table 1; the overall cost of congestion in urban areas is \$100.9 billion in 2010 or an average of \$713 per auto commuter. Therefore decreasing congestion level may lead to travel time and fuel consumption reduction and more importantly huge cost reduction. For decades, Intelligent Transportation Systems aim at improving the quality of urban transportation systems through employing various advanced technologies. Clearly, finding the efficient routes is an important objective in ITS which can be achieved through these two mechanisms: (1) Traffic information systems, (2) Vehicle routing protocols. Through the former mechanism real-time traffic information can be acquired, e.g. the density and speed of the vehicles; and the latter one makes use of the

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acquired traffic information in order to obtain the routes that the drivers should take.

Table 1 Congestion effect on the average commuter (for 439 U.S. urban areas)[1]

Congestion statistic per auto commuter			
Population Group	Average Cost ($)	Average Delay (hours)	Average Fuel (gallons)
Very large areas	1083	52	25
Large areas	642	31	11
Medium areas	429	21	5
Small areas	363	18	4
Other urban areas	327	16	3
439 area average	713	34	14
439 area total	100.9 billion	4.8 billion	1.9 billion

Most of the current vehicle route suggestion systems use pre-set and offline city map along with the navigation data obtained from the GPS. Nadi and Delavar[2] enhanced the capabilities of these systems by utilizing offline and estimated traffic status which is mostly based on the previous historical data. However, these systems suffer from not employing the real-time traffic information in their routing process. As a result, their suggestions might not always be the optimal option due to the rapid change of traffic status. Recent progress in vehicular communications based on DSRC (Dedicated Short Range Communications) systems makes it possible to obtain traffic information in a real-time manner. With the information employed in vehicle route suggestion algorithms, more efficient routes will be attained.

The proposed approach includes two major phases. (1) Updated traffic information collection; (2) Vehicle route suggestion. In the first phase, we make use of the capabilities of inter-vehicle communications in order to design and implement the traffic Information system. In the second phase, through applying the collected traffic information, each RSU (Road-side unit) can find the best route towards the destination. For this purpose, we have proposed two algorithms called one-step vehicle path suggestion and step-by-step vehicle path suggestion algorithm.

The rest of this paper is organized as follows: Section 2 is aimed to give an overview of the related work. In section 3, the proposed mechanisms for both phases are explained. In section 4 the complexity analysis for both algorithms is precisely explained. In section 5 the simulation framework is described and the obtained results are evaluated. Eventually, section 6 sums up the study and summarizes our findings.

2 Related works

Since our work consists of two major phases, namely traffic information collection and optimal path suggestion process, some of the previous studies regarding both issues have been surveyed in the following.

2.1 Traffic information systems

In the field of ITS there are several ways to acquire the traffic information. Some of the most common methods include video and image processing, infrared sensors, magnetic sensors, inductive loop detector and piezoelectric Sensors. Mimbela and Klein[3] discussed the pros and cons of each these methods in details. Since those methods are not suitable enough in large scales and also cannot be applied in all weather and traffic conditions, some newer and more applicable methods have been proposed. Some of those novel methods are as follows.

In more advanced methods GPS (Global Positioning System) is used as a supplementary tool for traffic information collection. Dhingral and Gull[4] discussed the relationship between car speed, road capacity and road density. In this study a traffic model has also been proposed by observing and formulating historical traffic information and the developed model can be exercised to evaluate and estimate the number of vehicles in an urban environment. Skordyli and Trigoni[5] used stationary Aps (Access Points) in order to detect the vehicles' speed and the road density to help their protocol to plan navigation paths. However, the road density is hard to be detected using stationary access points. Therefore, the average vehicle speed detected by sensors has been considered and the number of the vehicles on a road is calculated according to the traffic flow theory Dhingral and Gull [4].

Vehicle to vehicle communications is also taken advantage in some recent methods. Kitani et al.[6] proposed a method which efficiently collects, retains and propagates traffic information via inter-vehicle communication with "message ferrying" method. In the proposed method, buses have been used as message ferries which travel along regular routes. For improving information propagation performance in low density districts, buses collect as much traffic information as possible from the vehicles in their proximity and disseminate this information periodically to the adjacent vehicles.