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Transportation Research Procedia 25 (2017) 1380–1396

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2016 Shanghai. 10-15 July 2016

Roadside Infrastructure Planning Scheme for the Urban Vehicular Networks

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Abstract

Vehicular ad hoc network (VANET) is an emerging technology for future on-the-road applications. However, because of the vehicle mobility uncertainty, the temporal network fragmentation influences the communication connectivity. The roadside unit (RSU) has been considered to support the Vehicle-to-Infrastructure (V2I) communication and to increase the vehicle-to-vehicle (V2V) communication connectivity. Currently, it is impossible to deploy a large number of RSUs at the initial stage of VAENT due to the expensive installation cost, and the authority limitation. This paper proposes a Connectivity-oriented Maximum Coverage RSU deployment Scheme (CMCS), aiming at the maximum V2I communication performance in urban areas. The paper simulates the V2V&V2I network in a real urban area of Chengdu city in China via NS2 and VanetMobisim simulators. Results show that our RSU deployment scheme is able to cover the majority of vehicles on the road and guarantee the communication performance with a reduced number of RSUs.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: Vehicular ad hoc network; V2I communication; RSU deployment scheme; RSU connectivity

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2352-1465
Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.
10.1016/j.trpro.2017.05.163

1. Introduction

Nowadays, more than one mill human are injured or died because of traffic accidents every year around the world (1). Studies show that most traffic accidents happen due to the inattention of drivers to the front view (2) and the absence of the immediate warning message for drivers (3). Vehicular ad hoc networks (VANETs) have become a emerging technology supporting a wide range of applications, including traffic safety warning (4), transport efficiency, and information or entertainment (5). According to the report (6), identified V2I safety applications could potentially target approximately 2.3 million crashes and $202 billion in costs; and V2I systems targeted 25 percent and 14 percent of all light-vehicle crashes and all heavy-vehicle crashes. With the advent of RSUs, drivers are not only informed of the surrounding real-time traffic conditions, but also get access to the Internet or infotainment services in the vehicle (7,8).

According to the study in U.S. Department of Transportation in 2011 (9), a simplistic RSU requires $13,000–$15,000 per unit capital cost and up to $2400 per unit per year for operation and maintenance. With the RSU's participation into the VANET, the message can be disseminated in a more reliable manner with smaller transmission delay (10). Intuitively, it is desirable to install RSUs at the place with high traffic flow. However, the RSU deployment scheme becomes complicated if we take into account, the transmission range of RSU, the installation cost, and ITS Equipment Capability and Compatibility (11).

In this paper, we develop a RSU deployment scheme (CMCS) based on the 2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products (11). Our CMCS model is established by considering the RSU inter-connectivity, the RSU installation cost, the number of links and vehicles covered by each RSU. We formulate the scheme as the multi-objective optimization problem, with the objective to maximize the RSU inter-connectivity and the total number of vehicles covered by all installed RSUs. Simulation results show that the proposed RSU deployment scheme can identify the optimal RSU locations with the high communication connectivity performance.

2. Related works

For VANET applications, many researchers focus on the V2V communications (12-15), and only a few concentrate on V2I communications. Based on studies of the American Association of State Highway and Transportation Officials (AASHTO), the reaction time of drivers is less than 2.5 s in 90% of cases (16). In (17), Pan Li et al. shows that the optimal RSU deployment can minimize the end-to-end transmission delay. The instant warning message delivery is very important for drivers to take immediate action and to avoid potential danger.

2.1 RSU location type on the road

Many scholars have conducted analysis on where on the road is the most appropriate place to deploy a RSU. The discussion focuses on whether a RSU should be deployed in the midway or closer to the intersection of the road.

In 2008, Kafsi et al. (18) indicate that vehicles are more likely to appear in the midway or the entering area of the road segments, although most vehicles are crowded in the congested intersections. They propose the RSU should be deployed in the midway of the road segment. However, in 2010, Trullols et al. (19) propose that the intersections are the proper location to deploy the RSUs after simulating the potential for the information dissemination of one RSU deployed in the midway and at the intersection. In this paper, the RSU location type is set according to '2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products'(11), which reads that "Early deployment of connected vehicle field infrastructure are likely to be installed alongside (or as part of) existing ITS equipment and existing traffic signal controllers." Therefore, traffic signal controllers are selected as the RSU location type in this paper.

2.2 Overview of RSU deployment schemes

In this section, RSU Development Schemes are grouped into 3 classifications based on the deployment objective, including 'network connectivity objective', 'traffic coverage objective', and 'information dissemination objective'.