Vehicular Communications 1 (2014) 197–207

Contents lists available at ScienceDirect

Vehicular Communications

www.elsevier.com/locate/vehcom

Cluster-based traffic information generalization in Vehicular Ad-hoc Networks

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A R T I C L E I N F O

Article history:
Received 16 May 2014
Received in revised form 24 August 2014
Accepted 25 August 2014
Available online 17 September 2014

Keywords:
Traffic information systems
CTIS
VANET
Clustering

A B S T R A C T

Vehicular Ad-hoc Network (VANET) is an emerging field of wireless networks providing different applications such as traffic information for participant vehicles and related authorities. However, deploying of such applications is mainly depending on the market penetration rate of this technology. In this paper, we propose a new 3-steps approach for estimation of traffic volume in a road segment based on actual volume of wireless-equipped vehicles. For this propose, we first collect the traffic information for different groups of vehicles using a new clustering algorithm. Then, a chaining technique between the clusters transmits this information to a roadside cloud. Finally, we employ a generalization method to extension of the total traffic volume from the collected data. Performance of the proposed approach is evaluated using extensive simulation for different traffic densities, and the stability of the clustering technique and also estimation accuracy of the proposed approach is shown in comparison with state-of-the-art existing schemes.

1. Introduction

Efficient traffic management is becoming of great interest today as traffic congestion becomes a more and more severe problem. Throughout the world millions of hours and gallons of fuel are wasted everyday by vehicles stuck in traffic. Therefore, congested flow conditions have a negative impact on the economy, health, and environment. The improvement of traffic flow and congestion reduction can be achieved by means of Traffic Information Systems (TISs) [1]. In general, the aim of TIS is to capture, evaluate and disseminate traffic-related information. Conventional technologies (e.g. Traffic Management Center (TMC) and Road Data Services (RDS)) in TIS offer very restricted bandwidth; therefore, traffic information has to be limited in details. These drawbacks can be overcome by Cooperative Traffic Information Systems (CTISs), where traffic-related information is collected individually by vehicles and exchanged between themselves using wireless networks [1,2].

With emerging Vehicular Ad-hoc Networks, plenty of applications have been created for vehicles on the roads. Two main communication types are presented in ad-hoc domain of VANETs [3]: communication among nearby vehicles called Vehicle-to-Vehicle (V2V) and communication between vehicles and roadside infrastructure that called Vehicle-to-Infrastructure (V2I). These communication types provide requirements of CTIS, efficiently [1]. In general, CTIS can be classified as either infrastructure-less or infrastructure-based [2]. The infrastructure-less CTIS typically apply data aggregation techniques to limit bandwidth use and maintain scalability. As the traffic information is a subject of interest to many vehicles in a given geographical area, the broadcast nature of V2V communication fits very well the objectives of infrastructure-less CTIS. However, the problem is that several overlapping aggregates for the same area may exist, making it difficult to compare them. Therefore, the quality of V2V communication-based approaches greatly depends on the quality of the aggregation techniques [2]. Infrastructure-based CTIS can rely on V2I communications technology [4]. The drawback of such systems is that service charges will most probably apply. However, they can be deployed in the near future as in contrast to VANET technology, low-cost wireless Internet access will soon be very common [3].

Several articles have discussed CTIS using VANET, but the most of them implicitly assumed that all the vehicles on the road participate in VANETs. However, the important factor that affects major applications in VANETs is the market penetration of wireless-equipped vehicles. It is predicted that it will take a relatively long time before all vehicles on roads are equipped with wireless transceivers like DSRC-enabled systems (i.e. in USA alone it will take more than 10 years to acquire 100% penetration rate if a new technology will start to be deployed on vehicles now [5]). Thus,

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http://dx.doi.org/10.1016/j.vehcom.2014.08.003
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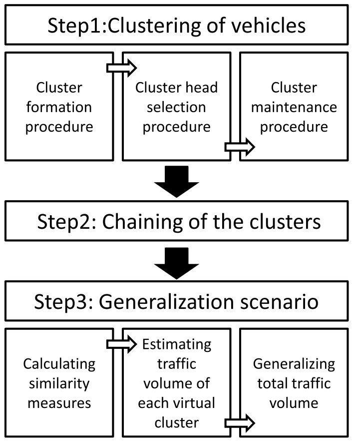

Fig. 1. All steps of the proposed approach.

studying the effects of market penetration is interesting, because it influences the density of participant vehicles.

Besides, clustering as a technique to form groups of nodes, can greatly improves vehicular networks performance. The cluster dynamically moves on the road and vehicles join or leave the cluster according to their speed and proximity to identified Cluster Head (CH); also, vehicles can communicate with other Cluster Members (CMs) based on V2V communication. The V2V communication is flexible and independent of the roadside conditions, which is particularly attractive for the areas where the roadside infrastructures are not necessarily available [6]. In addition, other main challenges in vehicular networks such as network stability and scalability which is issues by high mobility and frequently changes of topology can be addressed by clustering technique [7].

1.1. Our contribution

We are motivated to propose a new cooperative traffic information system by observing inherent drawbacks of existing approaches such as less robust and unstable structure, and lack of consideration to the market penetration rate of equipped vehicles. Hence, the main objective of this paper is to introduce a hybrid approach for the estimation of traffic density of roads and preparing traffic information for vehicles in optimum way. Our other contributions include the following:

- We obtain the advantages of both V2V and V2I communication for CTIS with proposing a new clustering algorithm and chaining scenario for linking to the RSUs, respectively.
- A new technique to control number of formed clusters in the road segment is introduced which discards small groups of members before converting to a cluster.
- Also, we provide a new technique for generalization of traffic information in low penetration terms of equipped vehicles.

1.2. Organization

The rest of this paper is organized as follows: In Section 2, we briefly review the literature of traffic information management and clustering techniques. Section 3 introduces the system design and different steps of the proposed approach which is depicted in Fig. 1. Then, we evaluate the performance of the proposed approach through simulation in Section 4. Finally, Section 5 concludes the work and simulation results.

2. Related works

A variety of information technologies have been developed for intelligent vehicles. The applications and the requirements for vehicular networks are illustrated in [8]. Also, several techniques have been proposed in the literature, dealing with traffic information management. Some of these proposed schemes are summarized below.

2.1. Traffic information management protocols

A Self-Organizing Traffic Information System (SOTIS) is proposed in [9]. It works within an approximate radius of 50 to 100 km of an individual user. As a vehicle receives the information, it is compared with a 'knowledge base' to establish whether the information is more accurate/updated than the existing information and only results of the analysis are transmitted. The authors of [10] proposed a system called TrafficView. Its main objective is to gather and disseminate information about the position and speed of vehicles. The basic idea behind the information dissemination in TrafficView system is data aggregation. The information is restricted only to the vehicles positioned ahead of the current vehicle. A new system called Infrastructure-Free Traffic Information System (IFTIS) to tackle the urban environment is presented in [11]. Based on the motivation that vehicles in geographical proximity often share similar traffic information, the authors introduce a location-based group concept, in which only a group leader is responsible for information broadcast.

A client–server system called CoCar is proposed in [12]. The system is used to investigate the application of UMTS technology to CTIS. Vehicles equipped with the CoCar system send traffic reports to the center using Internet access via UMTS. The reports are aggregated and integrated with information obtained from other sources. The center sends processed traffic information to all vehicles that belong to the cell from which the reports were originated.

Furthermore, the idea of involving Mobile Ad-hoc Networks (MANETs) for street and highways communications was inspired. The new type of network, is known as Vehicular Ad-hoc Network [3]. VANET provides a wireless communication between moving vehicles, using a Dedicated Short Range Communication (DSRC). It is essentially IEEE 802.11a amended for low overhead operation to IEEE 802.11p called Wireless Access in Vehicular Environments (WAVE). DSRC is specifically designed for Vehicle-to-Vehicle and Vehicle-to-Infrastructure communications [13]. In order to using VANET in traffic estimation, in [14] a solution was presented to estimate the traffic density in urban environments at any given time by using Vehicle-to-Infrastructure communication. Proposed scheme allows ITS to continuously estimate the vehicular density in a certain area by accounting for the number of beacons received per RSU and the topology of the map where the vehicles are located.

Another significant parameter which is considered in traffic estimation is learning capability. In this case, a Classification And Regression Trees (CART) model was proposed in [15] which predicts the short-term traffic volume at single locations in three steps: using the decision trees to classify the historical traffic states; founding the linear regression models and storing the weights in the leaf nodes of the trees model; and prediction the future traffic state through assigning the current state vector to the most congenial historical pattern and regression model. Also, the authors of [16] have proposed the OLWSVR approach for the short-term prediction of freeway traffic flow. The proposed scheme is an online weighted support-vector machine for regression, which combines an online support-vector machine for regression with a weighed learning method.