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Network coding with crowdsourcing-based trajectory estimation for vehicular networks

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ABSTRACT

It is a great challenge to transmit data in vehicular networks, where the link among nodes is very shaky because of the rapid movement of vehicles. In this paper, we propose a Network Coding with Crowdsourcing-based Trajectory Estimation (NC/CTE) method to transmit data in vehicular networks. Key points are designated beforehand in movement area. Every node estimates which of Key points the other nodes in the discovered area close to at the different times. The estimation is completed by every node in crowdsourcing method based on the pre-trajectory of GPS navigation. Network coding, recoding and reverse forwarding are used for data transmission according to the result of trajectory estimation. Simulation results show that NC/CTE is able to cut down 1/2 overhead messages of TBNC when mobile nodes have shared their GPS trajectories. It improves the reliability and scalability of vehicular networks.

1. Introduction

Vehicular networks are emerging as a special Ad-hoc Network, which connects thousands of vehicles for exchanging information. Vehicle can access Vehicular Ad-hoc NETworks (VANETs) when it enters the communication range of any other vehicle in the networks. VANETs is applied as a low-cost solution for Intelligent Transport Systems (ITS) Martinez et al., 2011), and diverse applications associating with traffic safety (Sharef et al., 2014), traffic efficiency, entertainment, file sharing and so on (Karagiannis et al., 2011). In VANETs, vehicles move at different speeds, so the topology of networks changes rapidly over time. It will be difficult to find the path between a pair of vehicles using ordinary Ad-Hoc routing protocol. Vehicles often get disconnected to VANETs when they are driven quickly in the area with sparse traffic. In this scenario, Vehicular networks are also regarded as a class of Delay Tolerant Networks (DTNs) (Benamar et al., 2014). Data are disseminated in Vehicular DTNs (VDTNs) focusing on the longer disrupting vehicles.

However, the network scenario is usually dynamic when vehicles move quickly. If vehicular networks are regarded as VANETs, the loss ratio of packets is very high when vehicles move into VDTNs scenario (Zhu et al., 2013). If VDTNs routing protocols are used, overhead messages will be increased when vehicles move into VANETs scenario (Khabbaz et al., 2012). If vehicular networks are separated into VANETs and VDTNs, vehicles need constantly switching between two different routing protocols according to the change of network scenarios (Villas et al., 2014). It will result in more delays in data dissemination. How to simultaneously improve the reliability, scalability and delay has turned into a paramount problem in vehicular networks (Ferreira et al., 2014). It is necessary to research the method which can be used in both scenarios and balance the three parameters.

Positioning technology has been introduced to vehicular networks as a means to enhance their performance. Many research works focus on applying GPS data to vehicular networks (Wu et al., 2013; Bilal et al., 2013; Perez-Gonzalez et al., 2015). But they only require the coordinates where data were collected, and their aim of using GPS is to find precisely the position of the event. The node transmits its coordinates to the others for localizing themselves (Koutsonikolas et al., 2007). GPS technology is popular now to mobile devices because they have been upgraded from the location to the navigation. Vehicles plan the trajectory previously in navigators such as GPS, BDS or smart phones, and will move along them. The trajectories of vehicles can be stored and shared in vehicular networks. So the change of networks topology can be predicted based on the estimated trajectory of every node (Soares et al., 2014). The source need not broadcast packets to the destination, and only sends packets to the intermediate nodes moving to the transmission path (Jiang et al., 2014). Overhead packets will be quenched in this method.

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In our former work (Li et al., 2013), we try to use the GPS navigation data of nodes to forward packets. However, there are still two unsolved problems in former researches: (1) There are too heavy loads on the central sever to estimate the dynamic topology of networks. (2) The velocities of mobile nodes are variable. When the node is estimated to arrive the path, but does not appear, the packet may be lost, and the reliability and delay of vehicular networks are even worse.

In this paper, we present a Network Coding with Crowdsourcing-based Trajectory Estimation (NC/CTE) method to transmit data in vehicular networks. It imports network coding to improve the reliability and crowdsourcing to balance the load. Every vehicle shares its trajectory estimation with others in the discovered area, and computes the change of network topology at different time in crowdsourcing-based method. Packets are divided into short fixed-size blocks. After network coding implemented, encoded blocks are sent out in the source. The experiments show that NC/CTE can reduce the delay and overhead packets, and improve the reliability and scalability of vehicular networks in any scenario.

The remainder of this paper is organized as follows: In the next section, we discuss the related work. NC/CTE is proposed and implemented on vehicular networks in Section 3. The evaluation and analysis of the NC/CTE are showed in Section 4. The paper is concluded in Section 5.

2. Related works

Earlier studies focus on applying Ad-Hoc routing protocol to vehicular networks. They use position-based (Naumov and Gross, 2007) or road-based (Nzouonta et al., 2009) routing scheme to transfer messages. These routing protocols can leverage real-time vehicular traffic information to create paths to the destination vehicles. Location-based routing (Wu et al., 2013; Bilal et al., 2013; Perez-Gonzalez et al., 2015; Koutsonikolas et al., 2007; Naumov and Gross, 2007; Nzouonta et al., 2009; Lochert et al., 2003; Yang et al., 2010) are used to forward packets to vehicles geographically close to the destinations. Other studies (Burgess et al., 2006; Benamar et al., 2014) transfer messages ammong vehicles in "carry-and-forward" paradigm like DTNs. The positions of vehicles or roadside equipments are used for improving the reliability of VDTNs. The deficiency of above studies is not to estimate the future positions of the vehicles. However, the relative movement among the vehicles is so fast that the destination may deviate from the relay vehicles when the packets arrive. They will be inefficient on the rapidly changing VANETs.

GPS is utilized to estimate the trajectories of mobile nodes in a few studies (Miles et al., 2013). With increasing usage of smart phones, navigation systems based on smart phones are popular. More and more vehicles are navigated by GPS systems or smart phones. Vehicles trajectory have become the valuably estimated input for data forwarding (Zhang et al., 2014). In Leontiadis et al. (2010), a protocol is proposed to enable efficient multi-hop routing capabilities. It supports two-way communications between vehicles and Wi-Fi APs. Vehicular mobility is predicted on the navigation system in terms of its destination and path. TSF (Jeong et al., 2012) considers a reliable, efficient APs-to-vehicles data delivery by minimizing the packet delivery delay. Data delivery is performed through the computation of a target point based on destination's trajectory. Roadside APs can be selected as relays where destination vehicle is expected to pass by. TBD (Jeong et al., 2011) utilizes vehicle trajectory information to improve communication delay and delivery probability for vehicles-to-APs destination communications. A delay model of packets routing along roads is set up. The path with minimum delay can be found with the help of the real-time traffic condition information. TMA (Jeong et al., 2013) and TMC (Jiang et al., 2015) are two methods that exploit vehicle trajectories for efficient multicast in vehicular networks. TMA tailors and optimizes for multicast data delivery in terms of transmission cost. TMA central server figures out how data are delivered to the moving vehicles in the multicast group. TMC is designed to be a distributed approach. Vehicles make message forwarding decisions based on vehicle trajectories shared through inter-vehicle exchanges. These studies (Miles et al., 2013; Zhang et al., 2014; Leontiadis et al., 2010; Jeong et al., 2012, 2011, 2013; Jiang et al., 2015) show that trajectory estimation is able to improve the reliability of vehicular networks more than location-based routing protocols.

Network coding has been proven to be a promising approach that can improve the reliability of mobile networks and reduce overhead packets by combining them (Li et al., 2014). In Peng et al. (2014), an adaptive network coding is proposed to enhance reliability in mobile WSN by considering redundancy. However, the algorithm is not suitable for the broadcast scenario. AdapCode (Hou et al., 2008) is proposed to reduce broadcast traffic in the process of code updates for the reliable data dissemination. In Egbogah et al. (2010), the viability of adopting network coding is researched as a means of improving reliable data delivery in large scale MANETs. These studies (Li et al., 2014; Peng et al., 2014; Hou et al., 2008; Egbogah et al., 2010), show that network coding is suited for mobile networks due to the broadcast nature of their communications.

In recent years, researchers pay attention to utilize network coding for the improvement of reliability in vehicular networks. In Egbogah et al. (2010), a theoretical model is proposed to compute the achievable throughput of cooperative mobile content distribution in VANETs using symbol-level network coding. It captures the effects of multiple practical factors, and optimizes design choices for network coding-based cooperative mobile content distribution. In the scheme of Wu et al. (2015), network coding is combined to a fuzzy logic algorithm to get a low overhead message and a high packet dissemination ratio in VANETs. Network coding is used to improve the packet reception ratio by utilizing the broadcast nature of wireless channels. INPAC (Chen and Zhong, 2014) is proposed as packet opportunistic forwarding for network-coding wireless networks, a solution using a combination of game-theoretic and cryptographic techniques. If INPAC is used, being cooperative in packet forwarding is a sub-game perfect equilibrium. Network coding can also be used in the lower layers of wireless network for enhancing efficiency. In Kerusauskas Rayel et al. (2013), nonbinary network coding is applied to the multiple access cooperative VANETs, a Nakagami-m fading model is used to evaluate the reliability of the proposed scheme. According to the numberical results, the combination of network coding and multiple antennas leads to a much more reliable VANETs. Above researches (Egbogah et al., 2010; Wu et al., 2015; Chen and Zhong, 2014; Kerusauskas Rayel et al., 2013) show that network coding is also an effective method to enhance the reliability of vehicular networks.

In the following works, we will combine network coding with the pre-trajectory of mobile nodes for the improvement of the scalability and reliability of vehicular networks.

3. Network coding with crowdsourcing-based trajectory estimation

In this section, we present the method of Network Coding with Crowdsourcing-based Trajectory Estimation (NC/CTE). It estimates the trajectory of mobile nodes as the basis for network coding.