An Effective Data Processing and Data Dissemination in Vehicular Networks

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ABSTRACT

We consider the effectiveness of data processing and data dissemination in vehicular networks. The advantage of proper data dissemination and processing is to avoid further accidents and traffic congestion at the time of an accident. Mainly there are three positions where data can be processed in vehicular ad hoc networks (VANETs), such as cluster head, Road-Side Unit (RSU) and cloud. In this paper we propose a cost-effective scheme for selecting the best position for data processing. The results show that our proposed scheme selects the most effective data processing position in terms of cost and time.

CCS CONCEPTS

• **VANET → communication** ; *data processing*; *data dissemination*;

KEYWORDS

VANET, autonomous vehicles, data processing, data dissemination

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1 INTRODUCTION

Vehicular Ad Hoc Networks (VANET) have been an emerging technology for connecting cars and providing communication between cars. VANET supports a variety of applications, such as safety applications, infotainment and so on. Communication in VANET has been standardized by Institute of Electrical and Electronics Engineers (IEEE) as Dedicated Short-Range Communication (DSRC) and by European Telecommunication Standards Institute as Intelligent Transportation Systems (ITS).

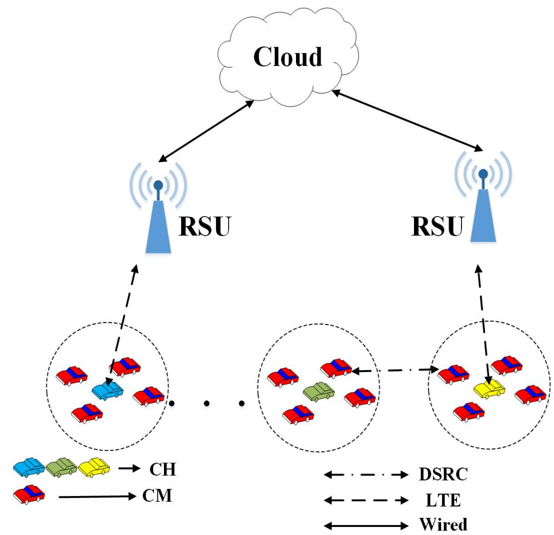

Figure 1: Cluster-based basic system model.

VANET has mainly three types of communication, such as vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle (I2V). The increasing vehicular communication has compelled the authorities to look into the support of vehicular communication in LTE, and for this purpose the 3rd Generation Partnership Project (3GPP) has already started to consider the VANET communication in LTE [1]. This LTE technology provides a reliable connectivity for vehicles in VANET.

VANET today is going to the next level i.e., autonomous vehicles (AVs). These AVs can move without any human intervention. National highway safety administration (NHTSA) [2] has classified the autonomy of vehicles in 5 levels. A level '0' indicates the manual driving vehicles i.e., without automation. The levels '1' and '2' have limited automations. Level '3' vehicles are fully automated but with some limited safety environment. Level '4' vehicles are the one that are fully automated and run without human intervention. The

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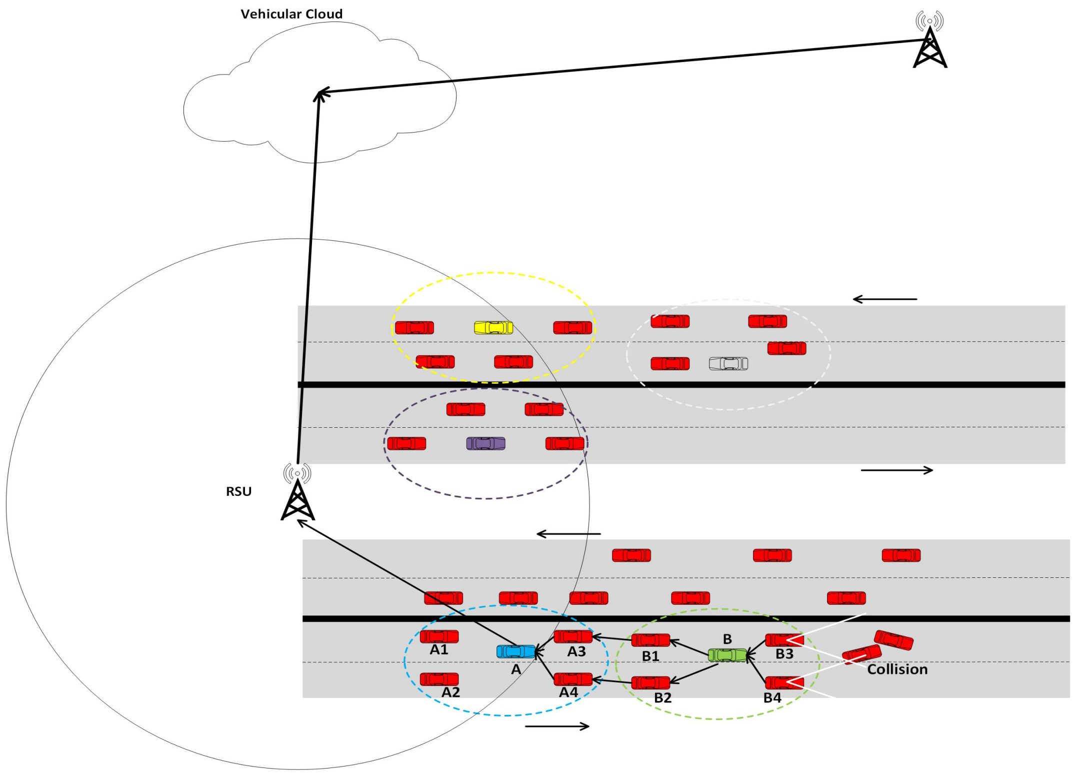

Figure 2: An urban area collision scenario for our proposed scheme.

level '4' vehicles are equipped with a number of sensors, cameras, a Global positioning system (GPS), etc.

Automation of vehicles is important to prevent accidents caused by human error such as, perceptual error, distraction error, response error [3], etc. Autonomous vehicles may move independently or in the form of clusters. In this paper, we focus on the effective data processing and data dissemination in cluster-based autonomous vehicles. Our scheme has three processing positions, such as cluster head (CH), Road-Side Unit (RSU), and vehicular cloud. The most effective one is selected to process the data and then disseminates it to the destination. Figure. 1 shows the basic scheme for cluster-based VANET communication. Clustering in VANET has been considered as an efficient means for communication. Some of the widely used clustering algorithms in VANET are mentioned in [4], such as position based, destination based, lane based, MAC based, and hybrid scheme. Stability of clustering is an issue in VANET, because of high mobility. Many research has been done on the stability of clustering in VANET. Authors in [5] consider the speed difference as a parameter to create stable clusters. Authors in [6] propose a trajectory-based clustering algorithm for VANET using affinity propagation technique. Other works, such as using traffic flow [7], using road identities [8], are also done to make clustering stable in VANET.

The rest of the paper is organized as follows. We explain the system model of our scheme in VANET in Section 2. We propose the optimization problem of our scheme in Section 3. We evaluate the performance of our proposed scheme in Section 4. Finally, we conclude our paper along with future work in Section 5.

2 SYSTEM MODEL

2.1 System Architecture

The system architecture contains three components such as vehicular cloud, RSU, and vehicles. The basic system architecture is shown in Figure. 1, where we can see the vehicles moving in clusters. Vehicles communicate with each other (V2V) as well as with RSU (V2I). RSU is a central entity that monitors traffic and prevents collision cause by traffic congestion. Vehicular cloud is a group of vehicles cooperating with each other to make a cloud and to facilitate other vehicles in processing and communicating the data.

2.2 Assumptions

The assumptions for our proposed idea are as follows:

- Vehicles are in fully automated mode.
- Vehicles are moving in the form of clusters.
- RSUs are connected via wired network.
- RSUs are deployed in such a way that they can cover all side of traffic in their range.
- vehicles are using two modes (DSRC, LTE).
- Traffic statistics are sent to the group head via last encountered RSU.

2.3 Concept of Effective Data Processing and Dissemination

The aim of this paper is to effectively select a processing position for data and send it to a destination to avoid traffic congestion in case of an accident. From CH, RSU and cloud, being the three processing positions, only one is selected to process the data and forward it to the destination. The selection is based on a cost-effective scheme. The procedure of our scheme is shown in Figure. 2,where an accident happens in an urban road environment.

Vehicles at the front capture the incident (video/image) and send to their CH. The CH then decides whether to send the data to the RSU or process it, depending on the following equations.

$$X = min\{CLD, RSU, CH\}, \quad (1)$$

$$CLD = [PT_{cld} + (CT \times L_{CLD})] \times PC_{CLD}, \quad (2)$$

$$RSU = [PT_{rsu} + (CT \times L_{RSU})] \times PC_{RSU}, \quad (3)$$

$$CH = [PT_{ch} + (CT \times L_{CH})] \times PC_{CH}, \quad (4)$$

where PT_{cld}, PT_{rsu}, and PT_{ch} are the processing time for cloud, RSU, and CH, respectively. CT is the communication time, L is the number of links and PC is the processing cost (incentive). From the above equations and the value of X data processing position is selected as follows:

$$X_{ch_i} + X_{rsu_i} + X_{cld_i} = 1, \quad i = 1, ..., N. \quad (5)$$

where $X_{ch_i}, X_{rsu_i}, X_{cld_i} \in \{0, 1\}$, this shows that the data can be processed by CH, RSU or cloud and only one of $X_{ch_i}, X_{rsu_i}, X_{cld_i}$ can be 1.

From Equation 5, it is decided to select CH as the processing position then we calculate the total packet delivery time as follows:

$$T_{CH_i} = PT_{ch_i} + (CT \times L_{CH}) + \sum_{j=1}^{M}(\sum_{i=1}^{N} PD_i)_j, \quad i = 1, ..., N \;\&\; j = 1, ..., M, \quad (6)$$

where N is the total number of vehicles, M is the total number of transmission links, and PD is the propagation delay. If from Equation 5, RSU is selected as the processing position, then we have to check the proximity of the cluster with RSU, and also the up-link and down-link data rates.

$$CH_i \notin RSU_R, \quad (7)$$

where Equation 7 shows that CHi is not in the range of RSU. The data is not sent to RSU, but processed by CH. Up-link and down-link data rates R_{u_i} and R_{d_i} allocated to the vehicle are greater than those of the up-link and down-link total capacity C_u and C_d, then it is not sent to RSU where the following conditions are given

$$\sum_{i=1}^{N} R_{u_i} \geq C_u, \quad (8)$$

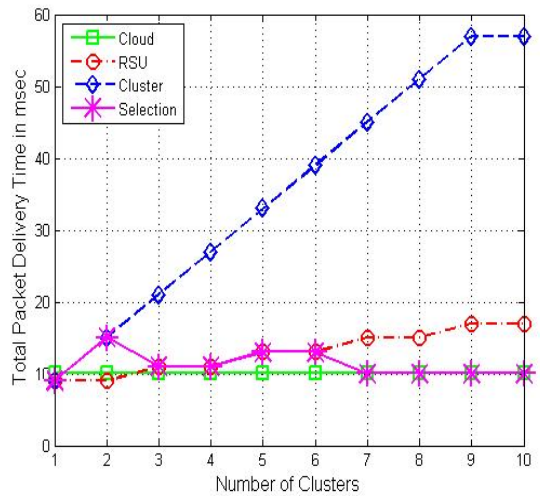

Figure 3: First scenario: Total packet delivery time with respect to number of cluster, where the number of cluster is increasing.

$$\sum_{i=1}^{N} R_{d_i} \geq C_d, \quad (9)$$

If the Equations 7, 8 and 9 are not true then the data can be processed by RSU. The total packet delivery time for RSU is:

$$T_{RSU_i} = PT_{rsu_i} + (CT \times L_{RSU}) + \sum_{j=1}^{M}(\sum_{i=1}^{N} PD_i)_j, \quad i = 1, ..., N \;\&\; j = 1, ..., M, \quad (10)$$

At the last, if data cannot be processed by RSU due to the following reasons shown in Equations 11 and 12, it is sent to the vehicular cloud for processing.

$$P_{r_i} \geq P_{RSU}, \quad i = 1, ..., N, \quad (11)$$

$$D_T \geq T_H, \quad (12)$$

where P_{r_i} and P_{RSU} are the processing rate assigned to the data and processing rate of RSU, and D_T is the density of traffic it is greater than some threshold value T_H. The total packet delivery time for cloud is:

$$T_{CLD_i} = PT_{cld_i} + (CT \times L_{CLD}) + \sum_{j=1}^{M}(\sum_{i=1}^{N} PD_i)_j, \quad i = 1, ..., N \;\&\; j = 1, ..., M, \quad (13)$$

3 OPTIMIZATION PROBLEM

Our optimization problem is defined as how effectively to select the processing position considering time and cost. The selection of one

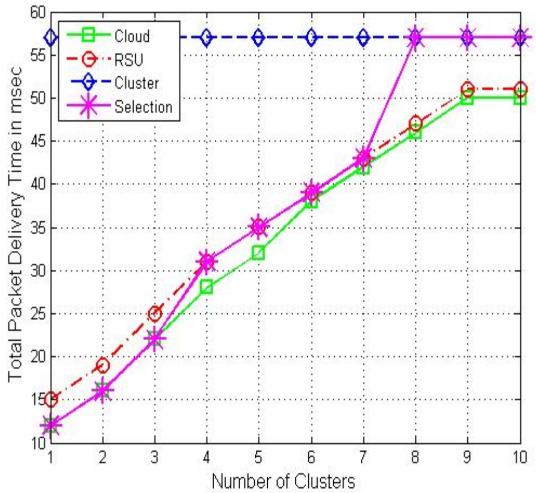

Figure 4: Second scenario: Total packet delivery time with respect to number of cluster, where the first cluster is in RSU range then 2nd then 3rd and so on.

among CH, RSU and cloud is our task. The optimization problem is formulated as:

$$min \sum_{i=1}^{N} T_{CH_i}.X_{ch_i} \quad + \quad T_{RSU_i}.X_{rsu_i} \quad + \quad T_{CLD_i}.X_{cld_i}. \qquad (14)$$

The optimization here depends on Equations 1 through 5 and Equations 6, 10 and 13. For the ease of simulation, we use the values of processing cost (PC) of CH, RSU, and cloud in the ratio of 0.4, 0.7, and 1, respectively. For the values of processing time (PT) of CH, RSU and cloud in the ratio of 1, 0.6 and 0.4, respectively.

4 PERFORMANCE EVALUATION

Our goal is to effectively process the data and send it to the destination, so that further traffic congestion can be avoided. We investigate the performance evaluation of our scheme in this section. We consider an urban road traffic environment, where an accident happens as shown in Figure. 2. The length of the road segment is $2.5km$, per cluster range is $200m$, per RSU range is $600m$ and there are 10 number of clusters in road segment. The goal is how effectively data is sent to avoid further collisions. We use two scenarios, the first as shown in Figure. 3, according to the number of clusters for performance in terms of Processing cost and delivery time. For 1 or 2 clusters, in the first scenario CH is selected to process the data and disseminate it, because it costs less for the data processing and dissemination than RSU or cloud for less number of clusters. For clusters 3 to 6, RSU is selected as a processing position. For more than 6 clusters, cloud is selected as the most effective data processing position.

We elaborate the second scenario in which we have 10 clusters, 4 RSUs (3 clusters/RSU) and suppose initially the 1st cluster that encounters the accident is within the range of RSU, and then 2nd and the 3rd and so on. As shown in Figure. 4, we can see that the total delivery time when data is sent by cluster to cluster is much higher than that of RSU. However the total delivery time of cloud remains almost similar to the RSU. The effective selection of CH, RSU or cloud is marked by asterisk in the graph.

5 CONCLUSIONS

This paper proposed an idea of selecting the effective data processing position among CH, RSU, and cloud, and then disseminate the data to the destination to avoid further accident and traffic congestion. We have done a mathematical analysis to check the cost effective selection of data processing position. The result showed that the selection according to our scheme is better rather to select RSU or cloud directly. For future work, we will implement the same scheme in a real-time scenario using a realistic network simulator (e.g., OMNET++) and a realistic road-mobility simulator (e.g., SUMO).

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