Emergency Message Reduction Scheme Using Markov Prediction Model in VANET Environment

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Abstract. Today's vehicles technologies are getting better as well as the price of the vehicle is not too expensive so that almost every household has an own car. However, road space is limited so there is high opportunity to see the accidents on the high dense road. Current VANET technology has been able to inform rear vehicles do not go there so that the traffic congestion can be reduced. In this scenario, there are very large amount of emergency message will be generated. It will increase the burden of road side unit. In this paper, we propose a Markov-based model to predict behavior of vehicles so that we can identify which cars really need to receive this message. Simulation results show that this method can reduces the unnecessary message transmission indeed.

Keywords: VANET · Emergency service · Markov chain · Prediction model

1 Introduction

Currently, we always can see a lot of cars on the road due to the booming economy lets every families have their own car. Depending on this phenomenon, the traffic accidents often occur, since the cars density become larger [1]. The reason is that all the cars also want to compete the right to use the road, but the

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capacity of a road is limited which could not carry such a high traffic [2]. Accordingly, some people began to not abide by the traffic rules so that the accident will be incurred. Transportation closely related to eneryone's life, hence we must address this issue. Vehicular ad hoc network (VANET) has been proposed for transmission between cars so that there are some applications also be presented for various transportation services which including the emergency service [3].

Emergency service, as the name suggests, is a service which used to deal with various unexpected situations [4]. Emergency service is composed of prior service and posterior service. The mission of prior service is to create a scheme to avoid accident is happened. Posterior service is a protective measure when the accident has occurred, so that impacts will not continue to expand. No matter what kind of service, they have one thing in common that all of components in VANET need to exchange their information. Therefore, there are very many emergency messages can be generated so that this network often encounters bandwidth bottleneck [5]. Especially, some vehicles is use of mobile communication network [6] so that they can not load such a large message.

Generally, emergency messages will send to all of neighboring cars. However, we found that not all of the car will pass through the accident scene [7]. According to this observation, we think that we can reduce more unnecessary messages transmission as long as we are able to predict the behavior of the vehicle. In this paper, we design a prediction model that based on Markov chain. Simulation results show that our method can successfully decrease quantity of emergency messages so that the bandwidth bottleneck can be relieved.

The rest of the paper is organized as follows. Section 2 introduces background and related works. Section 3 will give the problem definition then we will introduce our proposed method. The simulation results present in Sect. 4. Finally, we will summarize research contributions and discussing the future works in last section.

2 Background and Related Works

2.1 Vehicular ad hoc Network (VANET)

Vehicular ad-hoc network (VANET) is a technology which extending from the Mobile ad-hoc Network (MANET) [8,9]. The difference between VANET and MANET is that VANET is an exclusive network for vehicles. It can be roughly divided into three types which include Roadside-to-Vehicle Communications (RVC) [10], Inter-Vehicle Communications (IVC) [11] and Hybrid Vehicular Communication (HVC) [12,14]. RVC is that all vehicles can communicate with server through wireless access point or base station. IVC represents that messages can be transmitted via vehicles so that the flexibility is higher than RVC. But it has lower ability for computing and management because it is a distribution structure. Both these two types have their advantages and disadvantages so that some scholars combine them to HVC that is shown in Fig. 1.

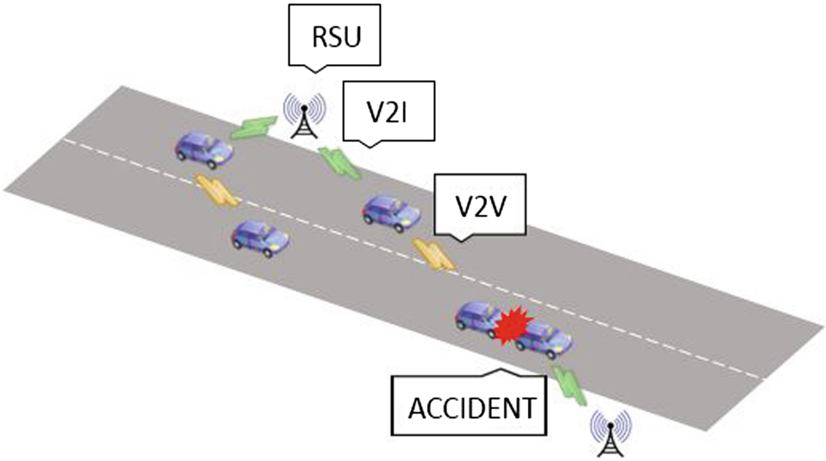

Fig. 1. Types of vehicular ad-hoc network

2.2 Markov Chain

Markov chain is an expression of transition of status [13]. These status are independent with each other, but any two successive events have causal relationship. It means that the previous event will affects the next event that is shown in Eq. (1):

$$P_{(i,j))} = P(E_{n+1} = i|E_n = j) \tag{1}$$

where $P_{(i,j)}$ represents a probability that a transition from event I to event j. This also means that we are able to predict future events as long as this probability can be calculated. In this study, we will define vehicles behavior as status of Markov chain then design a predition model for various operations in RSU.

3 Proposed Mechanism

Our method is composed to V2V and V2I so that this method not only provides more computing power, but also has higher flexibility. The key to this approach is crossroad, because crossroad can be regarded as a phased destination so that we are able to judge whether cars will pass through the accident sence. Hence we set RSU in every crossroads in order to predict direction of cars successfully that is shown in Fig. 2. All of common symbols are listed in Table 1. Main goal of proposed method is to minimize the quantity of emergency messages so we can define our problem via linear programming that is shown in Table 2.

Generally, emergency message is sent by broadcasting. It means that any cars can received this message as long as they have layer 2 network interface. If we want to reduce more unnecessary transmissions, we must focus on layer 3 technique so that RSU can know the IP address of cars which need to receive the

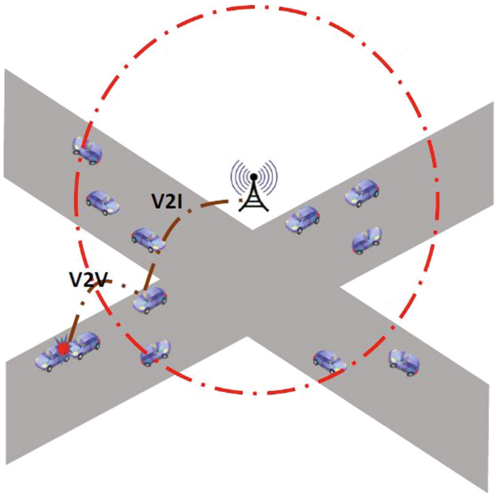

Fig. 2. Use of HVC as VANET type

Table 1. Important symbol list

Values	Definition
T	Transition matrix
$S = \{S_1, ..., S_n\}$	Information of video i
$C = \{C_1, ..., C_m\}$	Number of cars
P_{ij}	Probability that a car move from i-lane to j-lane
$\theta_{(nearest)}$	Difference of angle with nearest car
$v_{(nearest)}$	Difference of speed with nearest car
$d_{(nearest)}$	Difference of distance with nearest car

Table 2. Linear programming model

Minimize $\sum_{i=1}^{n} \sum_{j=1}^{m} Q_{i,j}$

s.t.

$$m > n$$
$$0 < P_{ij} \leq 1$$
$$P_{i1} + P_{i2} + P_{i3} = 1$$
$$0 < \theta < 90$$
$$60(km/hr) \leq v \leq 120(km/hr)$$

emergency message. Many important roads have been planned to three-lane, It means that a car has two choices of direction as long as it is driving in the middle lane. We use these three lanes as three states which represent right-lane, middle-lane and left-lane that is noted as 1, 2 and 3 respectively. Then a transition matrix can be generated:

$$T = \begin{pmatrix} P_{11} & P_{12} & P_{13} \\ P_{21} & P_{22} & P_{23} \\ P_{31} & P_{32} & P_{33} \end{pmatrix}$$

P_{ij} represents the probability that a car move from i-lane to j-lane. Via this matrix, we can calculate out the probability that whether cars will pass through the accident sence, hence the results can help us to decide which car really requires this emergency message. The value of T depends on the real three-lane environment that is shown in following:

$$T = \begin{pmatrix} \alpha_{11} \times \frac{1}{2} & \alpha_{12} \times \frac{1}{2} & 0 \\ \alpha_{21} \times \frac{1}{3} & \alpha_{22} \times \frac{1}{3} & \alpha_{23} \times \frac{1}{3} \\ 0 & \alpha_{32} \times \frac{1}{2} & \alpha_{33} \times \frac{1}{2} \end{pmatrix}$$

Assuming that all drivers will obey the traffic rules so they can not cross the middle-lane to reach next lane directly. Basing on this priciple, P_{13} and P_{31} are set as 0. α is an effect parameter which used to illustrate the physical meaning, e.g. angle, speed and distance. We simply normalize these three metrics to derive α as Eq. (2) that shown in following:

$$\alpha_{ij} = \frac{\frac{\theta_{(nearest)}}{\theta_{max}} + \frac{v_{(nearest)}}{v_{max}} + \frac{d_{(nearest)}}{d_{max}}}{3} \tag{2}$$

where $\theta_{(nearest)}$, $v_{(nearest)}$ and $d_{(nearest)}$ are difference with nearest car. Use of these three metrics because the nearest car will affects current car whether overtaking. In the initial process, the broken vehicle will sent a emergency message to RSU that telling it where is accident happened. So in the beginning of algorithm, we will define two cases which represents that accident sence is located in right side, front or left side. The proposed algorithm will compare the probability of in T_i. For instance, an accident occur in the right side so that Case1 is chosen. Then we must compare whether the probability that i vehicle enter to 1^{st}-lane is maximum. If $T_i(P_{j1}) = Max(T_i)$ is true that represents i vehicle will probably turn right, hence the emergency message will sent to i vehicle. The main body of proposed algorithm is shown in the following:

```
Emergency Message Reduction Algorithm (Output)
   const
     Ti;
   Case
     Case1: Event happened in the right side
```

```
     Case2: Event happened in the front
     Case3: Event happened in the left side
Repeat
   switch  Case1
     if Ti(Pj1)=Max(Ti)
         sent message to vehicle i;
     end
   switch  Case2
     if Ti(Pj2)=Max(Ti)
         sent message to vehicle i;
     end
   switch  Case3
     if Ti(Pj3)=Max(Ti)
         sent message to vehicle i;
     end
     until Year = MaxYears
end.
```

4 Simulation

4.1 Simulation Setting

The simulation is performed by utilizing MATLAB (Version 7.11, R2010b). The detail parameters setting are listed in Table 3. In our simulation, size of scenario is set as $1200 \times 1200\,(m^2)$. There are four crossroads in this range so number of RSU is also four. Radius of RSU is set as 300 (m). And speed of any vehicles are ramdoly set within a range which is 30 (km/hr)–60 (km/hr). And all of vehicles are in a normal distribution. Any roads have six lanes which are the two-way street. A simulation scenario is shown in Fig. 3.

Table 3. Simulation parameters

Parameters	Values
Size of field of interest	$1200 \times 1200\,(m^2)$
Number of cars	10–100
Number or RSU	4
Radius length of RSU	300 (m)
Vehicle speed	30 (km/hr)–60 (km/hr)

4.2 Simulation Results

In Fig. 4, we can see that proposed mechanism can reduce about 70% messages than broadcasting method in 10 vehicles case. It is slightly higher than other number of vehicles, because of that the neighboring vehicles are few so that

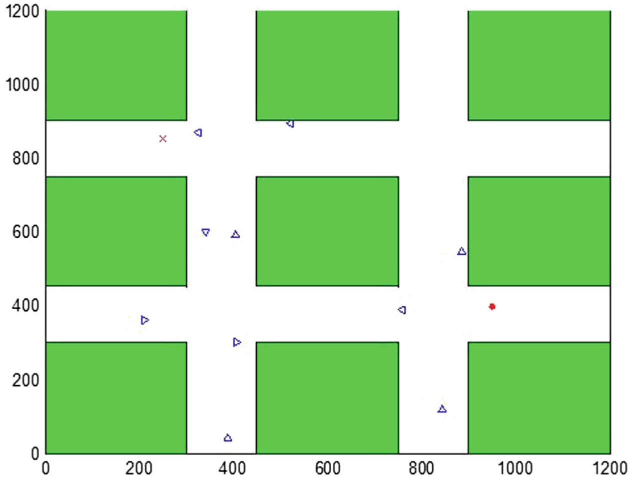

Fig. 3. Simulation scenario

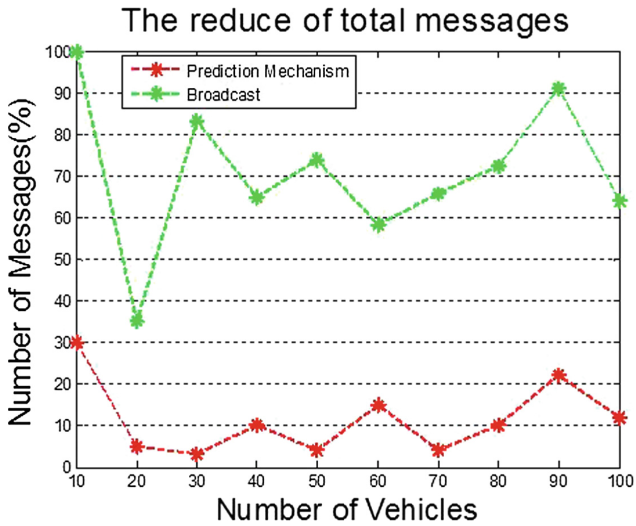

Fig. 4. Comparison of number of sent messages

RSU could not make an accurate prediction due to value of $d_{(nearest)}$ is too long. But it is still an acceptable result. Moreover, our proposed mechanism is very stable. It proof that our proposed mechanism false rate is not high.

In order to verify feasibility of the proposed method, we set an accident event in the left side. The vehicles distribution model of three lanes are same. We can see Fig. 5 that state 1 is fewer than others. It means that our method can successfully guides traffic to other ways. In other words, our method cannot too many misjudgment due to a large number of messages reduction.

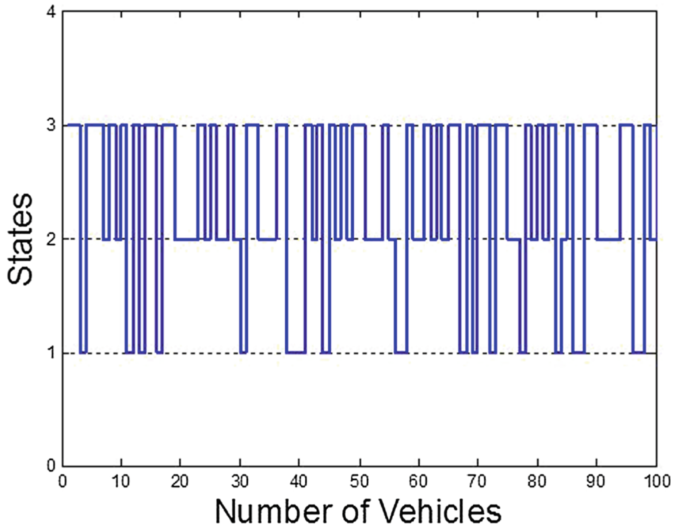

Fig. 5. Markov process of proposed method

5 Conclusion

Vehicle technologies continuously updated so that our life becomes more convenient. But it causes traffic accidents also continue to occur. Although current technique has ability to relieve traffic congestion, it makes RSU encounters huge bandwidth bottleneck. In this paper, we use Markov chain to design a prediction model so that we can accurately send the emergency messages to the vehicles which really need to pass through the accident scene. Simulation results show that our method can reduces more unnecessary messages transmission as well as provides a stable transportation environment. Since the real scenario is complex so there are more metrics need to be considered, e.g. destination of vehicles, real traffic sign even the various functions of the vehicle. For instance, there are police cars and ambulances will go to accident scene after an accident has happened. Therefore, the emergency messages should be include suggestion of alternative road. In order to improve contributions of this study, we will consider to above metrics in our future works.

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