A Simple but Effective Congestion Control Scheme for Safety-Related Events in VANET

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SUMMARY   In this letter, a Simple but Effective Congestion Control scheme (SECC) in VANET has been proposed to guarantee the successful transmissions for safety-related nodes. The strategy derive a Maximum Beacon Load Activity Indicator (MBLAI) to restrain the neighboring general periodical beacon load for the investigated safety-related "observation nodes", i.e., the nodes associated with some emergent events. This mechanism actually reserves some bandwidth for the safety-related nodes to make them have higher priorities than periodical beacons to access channel. Different from the static congestion control scheme in IEEE802.11p, this strategy could provide dynamic control strength for congestion according to tolerant packets drop ratio for different applications.
key words: vehicular ad hoc networks, congestion control, safety-related, IEEE802.11p

1.   Introduction

VANET is being developed for applications including mainly safety-related scenarios, such as Cooperative forward Collision Warning (CCW), traffic signal violation warning, lane change warning and some information applications. The main way of information dissemination for safety-related applications in VANET relies on periodical beacon broadcasting. For safety-related applications, the correctness and up-to-datedness of the messages greatly depend on the successful emergent broadcast receive ratio and periodical beacons frequency. However, it has been observed that the performance of the broadcast based safety applications drops down seriously in dense scenarios, such as channel congestion due to heavy beacon load resulting in strong interferences at receivers. To our best knowledge, at present, the popular congestion control strategy proposed in VANET is to prevent any message, except from the highest priority, to be transmitted if the measured channel occupancy is larger than 50% [1]. This strategy, in fact, is a bandwidth reservation method for emergent events by restraining the periodic beacons load. Although this scheme sounds reasonable, there are no detailed implementation methods and related measurement ways published to make it practical.

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2.   Proposed Congestion Control Scheme

In our work, congestion control in VANET tends to avoid more severe jam before the performance of safety-related applications begins to degrade greatly. The objective is obtained by limiting the beacons' activity within a Maximum Beacon Load Activity Indicator (MBLAI). We will first introduce some assumptions and then describe our model in detail.

2.1   Assumptions and Model description

As we have indicated in Sect. 1, congestion control in VANET with dynamic network parameters is really a NP-Hard problem and need to be relaxed to evaluate the performance in different scenarios. Therefore, we convert the dynamically determined problem to a relatively static one with following assumptions:

Assumption 1: The SINR threshold for successfully decoding the received signal is fixed at $SINR_{th}$ for all vehicles;

Assumption 2: The transmitting power for each burst is fixed at P_t for all vehicles.

Assumption 3: The distances between sources and destinations can be readily obtained by the Receive Signal Strength Indicator (RSSI) under LOS (Line Of Sight) environment or hybrid TOA/AOA [2] algorithms under NLOS (Non Line Of Sight) circumstance.

With the above assumptions, we can formulate the relation of transmitting power at receiver and at transmitter as:

$$PT_i \cdot G_{i,j} = PR_j \tag{1}$$

where PT_i and PR_j are the transmitting power at transmitter i and received signal strength at receiver j respectively. $G_{i,j}$ denotes the experienced channel gain from i to j and is modeled as:

$$G_{i,j} = \frac{K}{d_{i,j}^n} \tag{2}$$

where K is a constant and $d_{i,j}$ is the distance between i and j with n as the path loss factor. For a given signal decoding threshold $SINR_{th}$, the allowed noise power at j is

$$PN_j = \frac{PR_j}{SINR_{th}} \tag{3}$$

Considering the thermal noise and interferences from other

ongoing links, the total noise power at j can also be expressed as:

$$PN_j = PTH_j + \sum_m \{G_{m,j} \cdot PT_m : j \in CS(P_m)\} \qquad (4)$$

where is the thermal noise around j and $CS(P_m)$ denotes the carrier-sense range of m under the transmitting power P_m. In the NS2 simulator, a default carrier sensing range of 2.2 times the transmission range is suggested for IEEE 802.11 series protocols. This static value is optimal in many network scenarios [3] and we also take this setting.

Now, with Eq. (1-4), for the transmitter i and receiver j, we have

$$PN_j^* = \frac{PT_i \cdot G_{i,j}}{SINR_{th}} = \frac{PT_i \cdot K}{SINR_{th} \cdot D_j^n} \qquad (5)$$

Where D_j denotes the maximum transmission range of node j, which is set the same to all nodes in overall network. The definition of PN_j^* intends to derive a lower bound for the allowable receiving power involving interferences at j, which could be later taken as the permitted Maximum Beacon Load Activity Indicator (MBLAI) around j. By *Assumption 1* and *2*, we can obtain the exact value of maximum allowed noise at j, i.e., PN_j. In other words, the congestion could be controlled if the total interferences at j satisfy the following inequality:

$$PN_j \leq PN_j^* \qquad (6)$$

The definition of PN_j^* in our proposed MBLAI, in fact, set the allowable beacon load around the intent receiver j.

2.2 Description of SECC Control Procedure

To make our SECC scheme practical, we introduce a parameter AP (Approaching Percentage), which indicates the distance between current beacon load and MBLAI. Considering the high dynamic property of VANET due to mobility, a real time control scheme is computation consuming with a great number of overheads, which still could not catch the ongoing traffic and topology changing. Therefore, we execute SECC with interval T seconds, and make SECC active with AP reserved bandwidth in advance. When congestion detected by SECC will occur, we turn to the duration field in beacon header, which is plotted in Fig. 1, to restrain the neighboring traffics. With NAV (Network Allocation Vector) parameter in duration fields, the Onode, i.e. Observation node, could broadcast a larger NAV value to hinder part of the traffics generated on neighbors. The detailed working procedure of our proposed SECC is coded in Fig. 2. d and p indicates the duration for restraining neighbors and proportion of neighbors selected to be controlled, respectively. Function *order* sort the neighbors by their channel gains in ascending order. Function *select* choose front %p neighbors from ordered list to restrain. Function *setNAV* set the NAV fields of selected list to d period.
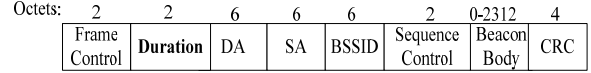

Octets:	2	2	6	6	6	2	0-2312	4
	Frame Control	**Duration**	DA	SA	BSSID	Sequence Control	Beacon Body	CRC

Fig. 1   Beacon header format.


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Input:  T, P_t, SINR_th, AP, d, p

Output: SECC scheme

Begin
    timer=0; list L=NULL;
    While high priority messages are generated on Onode
    do
        if  (timer% T ==0) {

            compute   PN*_Onode  by Equation (5);

            calculate  distance  with  neighbors  from  collected
             beacons;
            get  G  of neighbors to Onode by Equation (2);
            order( G );

            compute   PN_Onode  by Equation (4);

            if ( PN_Onode ≥ AP · PN*_Onode ) {

                L=select( G , p );
                setNAV(L,d);

            } // end of if ( PN_Onode ≥ AP · PN*_Onode )

        } // end of if  (timer% T ==0 )
    done; // end of while
End
```
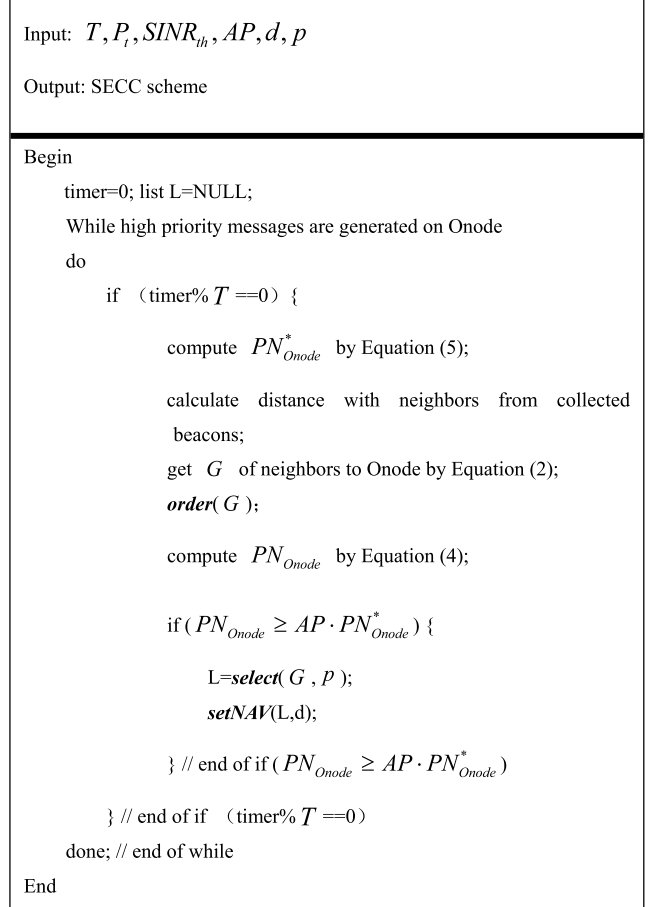
Fig. 2   Pseudocode of SECC.

## 3. Performance Evaluation and Numerical Results

In this section, we will evaluate the performance of our proposed scheme by Vanetmobisim and NS2. The general simulation parameters are listed in Table 1.

The Queue model used in our simulation is just DropTail strategy due to the simplified setting for routing scheme, i.e., DumbAgent, which implies that no routing is required.

The Simulation topology is plotted in Fig. 3 in a $1000 \, \text{m} \times 1000 \, \text{m}$ field where 50 vehicles are uniformly distributed and moving following the IDM-IM mobility model. The intersections are randomly generated by applying a Voronoi tessellation to a set of randomly distributed points. The Onode is designated as node 0. The other parameters for IDM-IM model are listed in Table 2. Based on the introduction and analysis in Sect. 2, we could launch the congestion control strategy according to Fig. 2 on a node, i.e.

Table 1   Simulation common parameters setting.

Parameters	values	Parameters	values
Propagation model	TwoRayGround	Mac	802.11extent
T/s	10	d/s	5
p	20%	Number of vehicles	50
Packet size/B	250	Simulation period/s	300
Simulation field/m×m	1000×1000	Path loss factor	2.2
$SINR_{th}$/dBm	-90	P_t/mW	0.3754
transmission range /m	300	Frequency/Hz	5.9e+9
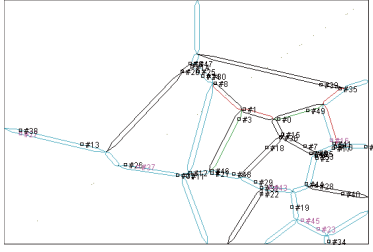
Fig. 3   Simulation topology.

Table 2   scenario setting.

Parameters	values	Parameters	values
Lane number	2	Traffic light	2
Min.Stay(s)	0.5	Max. Stay(s)	10
Mobility model	IDM-IM	Traffic rate(packets/s)	10
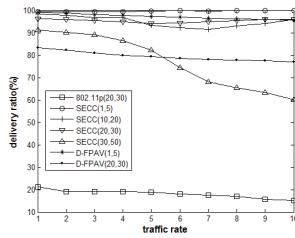
Fig. 4   delivery ratio vs. traffic rates.

the observation node Onode, by limiting or restraining the neighboring traffic flows before beacon load activity is approaching the MBLAI PN^*_{Onode}.

Figure 4 shows the delivery ratio performance comparison between IEEE802.11p broadcasting scheme, D-FPAV [4] (Distributed Fair Power Adjustment for Vehicular networks) and our proposed SECC model with $AP = 50\%$, which means our SECC model will work when current beacon load activity on Onode approaching 50% of the MBLAI PN^*_{Onode}. The symbol SECC (x,y) expresses that our SECC model runs with a minimum velocity x and a maximum velocity y respectively for all nodes. The traffic rate is represented by the number of packets sent per second, which in fact is taken as the beacon frequency in our simulations. As shown in Fig. 4, the delivery ratios of our SECC model are always higher than that of IEEE802.11p with different
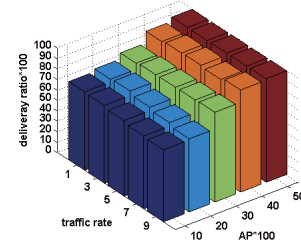
Fig. 5   delivery ratio vs. traffic rates and *AP*.

velocity settings. The delivery ratio of IEEE802.11p is still less than 20% during the overall simulation period when the minimum and maximum velocity are 20 and 30 respectively. Further, it has a lowest value of only 15.1% when traffic rate is 10 packets/s. However, with $AP = 50\%$, our SECC model could greatly improve the number of successfully delivered packets on Onode and restrain the unnecessary transmitting attempts that would result in large number of collisions and energy consuming when network is approaching congestion. The performance of SECC model is relatively steady with traffic rates change and the fluctuation begin to occur only when minimum velocity is larger than approximate 30 m/s. The reason is that the high velocity makes network more dynamic and cause our SECC model, which is based on the perception and measurement of the number of surrounding active nodes and the distances between Onode and its neighbors, not competent for such dramatic topology change. For D-FPAV, because it is a power control based distributed congestion control algorithm that introduces game theory based Max-Min strategy, it also has a better performance when velocity is low. However, when mobility level increase, D-FPAV shows worse delivery ratio than SECC due to its larger convergence time that make D-FPAV cannot catch the topology changing.

The delivery ratio performance on different values of *AP* has been evaluated as shown in Fig. 5. The velocity is set to uniform (10,20) meaning that the driving speed is uniformly chosen from minimum velocity 10 m/s to maximum velocity 20 m/s. The results show that the delivery ratio decreases with *AP* falling but there is still approximate 70% packets successfully received by Onode. The performance falling when *AP* is small is due to the underestimation of the current beacon load and not reserving enough delay and bandwidth for congestion control mechanism working. In our simulation, it is only taken 0.5 s to make *AP* from 10% to zero, which may not meet for the delay requirement for broadcasts dissemination to update active neighbors and congestion level estimation.

4.   Conclusions

We have proposed a congestion control strategy to alleviate the severe packets collisions and traffic jam in VANET. This strategy could provide flexible control dynamics to vehicles that are associated with safety-related events and eager for higher priorities than general periodical beacons to dissem-

inate emergent warnings.

Acknowledgements

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