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Performance Optimisation for DSDV in VANETs

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***Abstract* — In recent years, Mobile Ad hoc NETworks (MANETs) have been great interest all over the world for its advantage of high mobility and flexibility. It is also among the greatest challenges in wireless communications. As a special type of MANET, Vehicular Ad hoc NETworks (VANETs) are considerably important in Next-Generation Networking (NGN). Unlike typical MANETs, VANETs are much more challenging due to high velocity, which makes classic MANET routing protocols cannot fit in such scenarios efficiently. This paper is intended to evaluate performance of two different routing protocols, namely DSDV and AODV, in various realistic scenarios. Thus, a DSDV optimization approach is therefore proposed to improve DSDV's performance in VANETs.**

Keywords - MANET, VANET, NS-2, DSDV.

I. INTRODUCTION

As first defined in January 1999 [1], Mobile Ad hoc NETwork (MANET) is a kind of self-configuring wireless network without a centralized administration approach. Such practice could lead to frequent and dramatic changes in the topology and structure of the network. This characteristic also makes MANET suitable for Vehicle-to-Vehicle (V2V) communication scenarios, or namely, Vehicular Ad hoc NETworks (VANETs).

After a decade of development, a few MANET routing protocols have been proposed for better connection maintenance. Generally, the protocols can be classified into four types:

- Proactive (Table-Driven). Routing tables at each node are updated periodically by distributing routing tables throughout the network. Examples are Destination Sequence Distance Vector (DSDV), Optimized Link State Routing Protocols (OSLR).
- Reactive (On-Demand). The entire network stays silent unless any connection is needed. Examples include Ad hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR).
- Hybrid (Proactive and Reactive). The routing is established initially and proactively, and it also serves additionally activated nodes on demand by flooding the whole network. One of the examples is Zone Routing Protocol (ZRP).
- Hierarchical Routing Protocols. They involve the concept of hierarchic levels and select proactive or reactive practice according to the hierarchic level of the node.

Since VANETs are special cases of MANETs, these mainly aim for the wireless communication among vehicles that normally have relatively high velocity. Besides high velocity, unlike the ones in MANET that usually move randomly in an open area, the nodes in VANETs could mostly only travel following certain pattern in few directions due to the road topology. Thus, certain improvements based on typical MANET routing protocols are essential and necessary.

Network Simulator 2 (NS-2) is used for our studies. It is cross platform open source software that supports simulation for most typical protocols of wired and wireless communication networks. The protocols used in this research, namely DSDV and AODV, are natively built in NS-2. Alternatively, users could also create their own protocols for NS-2.

The contributions in this paper are as follows:

- Comparing DSDV and AODV's performance in various realistic scenarios using NS-2;
- Proposing a DSDV optimization approach to make the classic DSDV routing protocol suitable for VANETs.

The rest of this paper is organized as follows. In Section II some related work by other researchers is described. Simulation process, *i.e.* the performance comparison work between DSDV and AODV, is illustrated in details in Section III. Section IV presents our DSDV optimization approach for VANETs. Section V is the conclusion section based on our study along with future research directions.

II. RELATED WORK

Many researchers have compared MANET routing protocols' performance differences in different scenarios, and few have done evaluation work to optimize typical MANET routing protocols' performance for VANET scenarios.

In [2], AODV, DSR, and ZRP routing protocols are examined under the scenario that 50 nodes move within a 1500m × 1500m area at the maximum speed of 20m/s. Their performances are measured according to 1) average end-to-end delay, 2) Time-To-Live (TTL) based hop count, and 3) Packet Delivery Ratio (PDR). In comparisons, DSR needs the fewest hops for communication, and meanwhile AODV could achieve the highest delivery ratio. Hence, it could be

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more meaningful to research on pure proactive and reactive routing protocols than to do on hybrid ones.

Two different types of MANET routing protocol, OSLR and AODV, are examined under VANET scenario [3]. Since OSLR and DSDV are both instances of proactive routing protocols, their work is valuable to us to some extent. After simulating in realistic downtown scenario, residential scenario, and suburban environment respectively, it can be seen that OSLR usually has the lower delay, whereas AODV often achieves higher PDR.

In [4], the authors involve the use of GPS and on-board sensors to enhance the process of route discovery and route selection. By which practice, typical AODV routing protocol can be improved to get a higher PDR in VANETs.

Some other MANET routing protocol improvements for VANETs include deploying the concept of 'clustering' [5] and utilizing geographical information [6].

III. Performance Comparison of DSDV and AODV

As the most typical proactive routing protocol, DSDV, and one of the most commonly used reactive routing protocol, AODV, they share the same concepts of distance vector and routing table, but use a different mechanism for route discovery and connection establishment. Thus, their performance in the same scenario could reflect the different pros and cons of proactive and reactive routing protocols.

A. Simulation Enverionment

The Comparison work is taken on Network Simulator 2 (NS-2) software. Five realistic scenarios are used:

- Party scenario. It is a Person-to-Person (P2P) communication scenario that based on the reality condition of Hillside Restaurant in University of Surrey. There are 50 nodes moving within a 50m × 25m area at the maximum speed of 0.2m/s. Ideally this scenario can explain a common situation that a few people attend a common party, and some of them move around while others stay at certain places.
- Football Match scenario. This is another instance of P2P communications. As a result of rapid development of wearable devices, some of them, which are designed specifically for athletics to analyse their physical condition and performance during practices and matches, have even been approved to be used in formal matches such as FIFA World Cup [7]. Currently such devices usually work offline, but it could be forecasted that they would communicate with each other in an ad hoc manner to provide an overall statistical report to the coaching staff. The players in a football team, i.e. 11 nodes, moving within an official size football court at the maximum speed of 3.0m/s. Nodes' formation and movement pattern are designed according to reality.
- Malaga Urban scenario. Malaga is a city in Andaluzia, Spain, and it is often used for simulating and testing VANETs [8]. This scenario is based on a section of road in Malaga urban area, while 30 nodes moving within road structure at the maximum speed of 25m/s. Road physical topology is in a '8' shape that roughly covered 25,000 m^2 area.
- Malaga Highway scenario. A-357 highway in Malaga city is chosen as the reality support. This highway consists of two lanes in each direction, and the simulation select a 3.5-km part of such highway. 30 nodes move at the maximum speed of 30.55m/s (110km/h), which is the legal speed limit in Spain.
- A3 Highway scenario. A 3-kilometre part of A3 highway near Guildford in the UK is selected for this model. There are 3 lanes in each direction. Node number on the road is statistically analyzed according to the satellite image from Google Earth. 118 nodes travel at the highest speed of 31.55m/s (70mph), i.e. the national speed limit in the UK.

B. Criteria

Routing protocols' performance will be judged according to three metrics:

- Packet Delivery Ratio. PDR represents the percentage of successfully delivered packet number out of total. Generally speaking, the higher delivery ratio, the better performance. Its mathematical expression is (1).

$$PDR = \frac{\#\,packets_{received}}{\#\,packets_{sent}} \tag{1}$$

- Average throughput. It is the data rate of both information packet traffic and control traffic. It is defined as (2).

$$Throughput = \frac{\#\,packets_{sent} \times PacketSize}{time} \tag{2}$$

- Average end-to-end delay. This metric indicates the total time used for delivering a packet from the source node to the destination. The mathematical expression is shown as (3), assuming *n* packets are sent.

$$AverageE2EDelay = \frac{\sum_{1}^{n}(time_{received} - time_{sent})}{n} \tag{3}$$

C. Simulation Results

From described simulation method, the results are as follows.

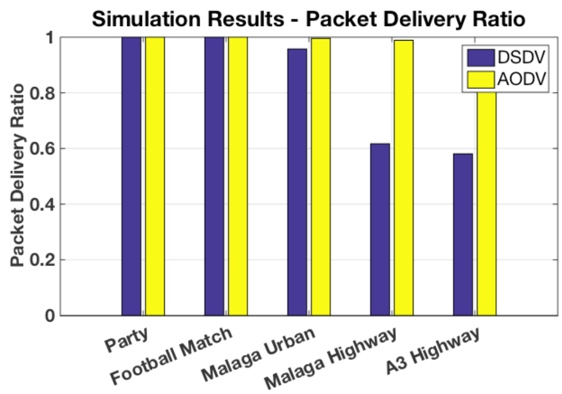

Figure 1. Performance Comparison – Packet Delivery Ratio

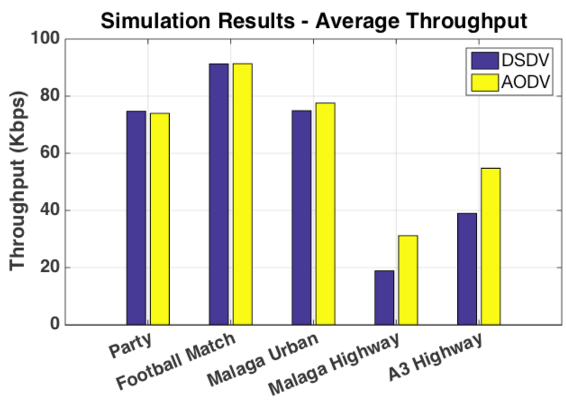

Figure 2. Performance Comparison – Packet Delivery Ratio

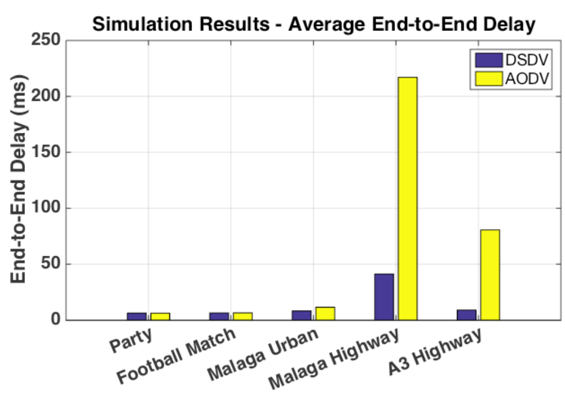

Figure 3. Performance Comparison – Packet Delivery Ratio

In the two P2P scenarios, DSDV and AODV have similar performance, which is high PDR with low delay. The main differences appear in the V2V scenarios, specifically, in highway scenarios. In Figure 1. , the PDR of using AODV could be about 1.5 times of the one of using DSDV, and so does the average throughput. However, when comparing average end-to-end delay, DSDV has a significant advantage. In the two highway scenarios, the delays for DSDV are approximately 1/4 and 1/9 of the ones for AODV respectively.

Due to the high velocity, wireless communication environment are much more challenging in VANETs than in normal MANETs. From all the three V2V scenarios it can be seen that in VANETs, AODV could have a much high PDR, whereas DSDV has significant lower delay.

IV. DSDV Optimization for VANETs

In the specific scenarios such as VANETs, average end-to-end delay should be the primary requirement, since for VANET applications, for instance, accident alarming, they are driving assistant while the driver still needs to keep concentrating on the road condition and take appropriate actions. Take Malaga highway scenario simulation results for example, when a node is travelling at the speed of 30.55m/s, the average end-to-end delay (134.375ms) could lead to 4.24m travel distance, which is unacceptable in an urgent situation. Actually, for safety services in VANETs, the maximum allowable latency is 100 ms [9]. From related works and previous simulation work demonstrated above, proactive routing protocols have the superiority of the lower delay. Considerably, DSDV is more suitable for VANETs than AODV.

The most significant shortage of DSDV in VANETs is low PDR. In Malaga highway scenario and A3 highway scenario, DSDV could only achieve PDR of 0.7120 and 0.5806 respectively. One of the main targets of this paper is to find a proper approach to increase PDR while keep the low delay in typical DSDV routing protocol.

A. *Principles*

There are three main parameters in DSDV:

- Update period. It is the time interval between two updates.
- Minimum update periods. This represents the missing update periods before link break. In other words, if a node has not heard from a neighbor for a certain update period, the neighbor node will be declared as unreachable.
- Settling time. It is used for avoiding fluctuations in routing selection process.

The main concept of improving DSDV in this paper is shortening update period and minimum update periods to make routing table refresh more frequently; and shorten or even cancel settling time, as in high mobility scenarios such as highway, connection routes among mobile nodes can change frequently and dramatically. Even if a node may receive route information that does not contain the best metric, it is still worth advertising since the route can ensure a valid connection. The concept of settling time is then not so important.

B. *Different Parameters' Influence on Performance*

The default parameters of DSDV in NS-2 are:

- Update period: *perup_* = 15s;
- Minimum update periods: *min_update_periods* = 3; and
- Settling time: *wst0_* = 6s.

The traffic scenario used for this section is A3 highway scenario. It detailed configuration is illustrated as TABLE I.

TABLE I. SIMULATION CONFIGURATION

Parameter	Value
Number of Nodes	118
Number of Lanes	6
Area Size	3000m × 22m
Max Speed (m/s)	31.55
Simulation Time Length	110s

1) Update Period

The update period variable, i.e. *perup_*, is changed from default 15s up to 17s and 19s, down to 13s, 11s, and 9s respectively. Other parameters are set as default and are left unchanged. Its influences on performance are indicated in from Fig.4 to Fig.6.

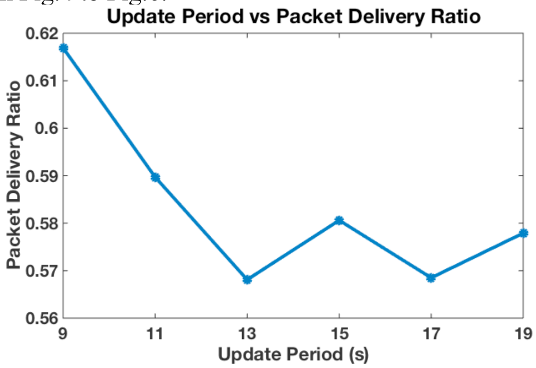

Figure 4. Update Period vs. Packet Delivery Ratio

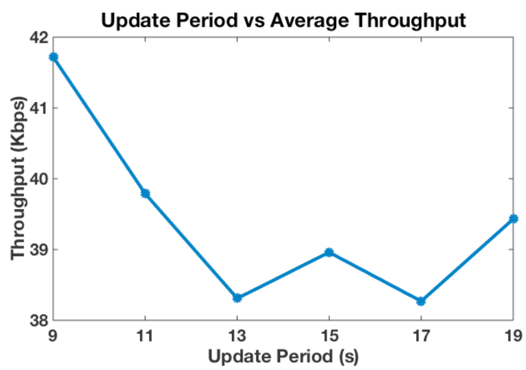

Figure 5. Update Period vs. Packet Delivery Ratio

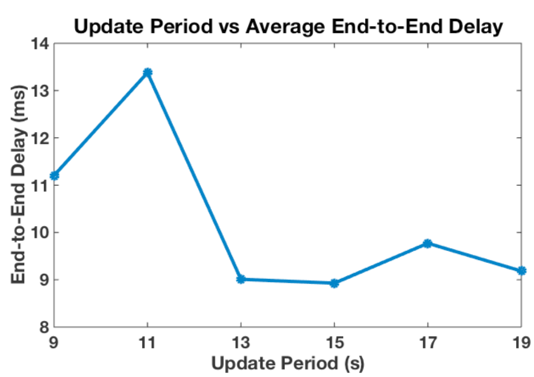

Figure 6. Update Period vs. Average End-to-End Delay

Shortening update period could lead to a limited increase in PDR, which keeping delay metric sufficient enough, but peaks in delay metric appear at both ends. The overall effect is yet unclear.

2) Minimum Update Periods

The minimum update periods variable, i.e. *min_update_periods*, is defined as 1, 2, 3 (default), 4, and 5, to examine its impact. Results are shown as from Fig.7 to Fig.9.

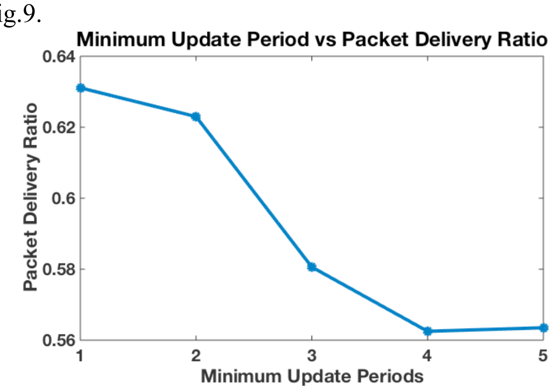

Figure 7. Minimum Update Periods vs. Packet Delivery Ratio

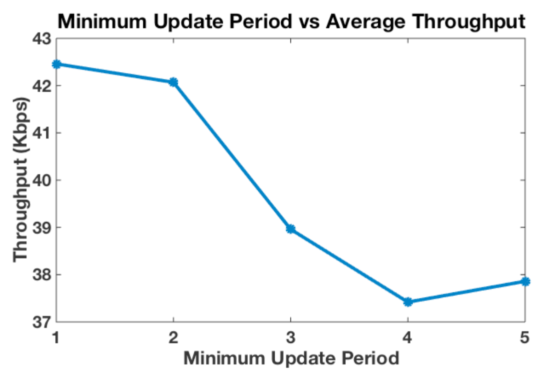

Figure 8. Minimum Update Periods vs. Average Throughput

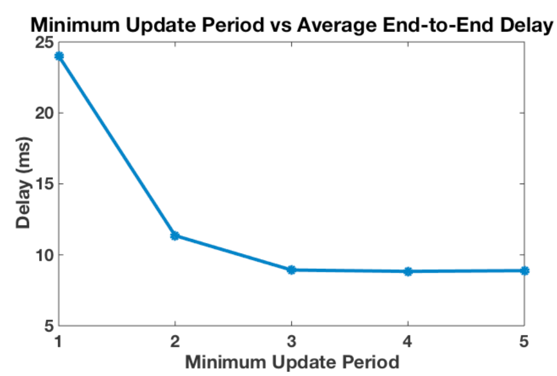

Figure 9. Minimum Update Periods vs. Average End-to-End Delay

When *min_update_periods* increases, the drop of packet delivery ratio has a limit to around 0.56. If *min_update_periods* is changed from 3 to 2, a 0.4 gain in PDR can be observed while average end-to-end delay only increases by less than 3ms. When *min_update_periods* is modified further to 1, an unobvious increase in PDR accompanied by a significant increase in average end-to-end delay.

3) Settling Time

Settling time is used to prevent advertising routes with worse metrics. As discussed before, the guarantee of a successful connection is more important than any single metric. In this section, *wst0_* is tested at 10s, 8s, 6s (default), 4s, 2s, and 0 respectively. Results are displayed as follows.

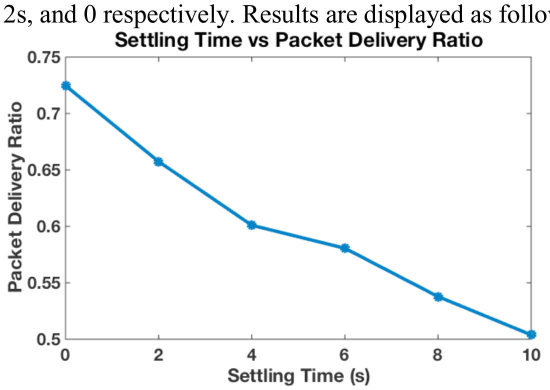

Figure 10. Settling Time vs. Packet Delivery Ratio

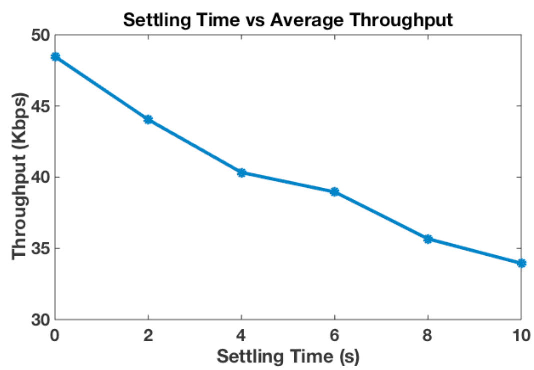

Figure 11. Settling Time vs. Average Throughput

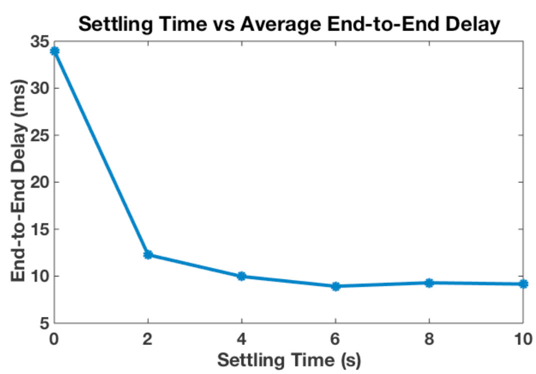

Figure 12. Settling Time vs. Average Throughput

By far, settling time has the most significant influence on DSDV's performance. As settling time decreases, PDR increases significantly. The best result of PDR in this experiment could be as high as 0.7247, which could be considered as the similar level of AODV's PDR. Meanwhile, the average end-to-end delay of DSDV in this case is still far less than the one of AODV.

C. Final Optimization

According to previous experiments, the final DSDV optimization is:

- Update period: 9s,
- Minimum update periods: 2, and
- Settling time: 0.

Besides being tested in the original A3 highway scenario, the optimized DSDV is also examined in two more challenging scenarios. Based on previous research [10], the metric of packet size and packet sending rate could have critical impacts on MANETs' performance. In detail, the impacts are:

When packet size increases,

- Packet delivery ratio decreases;
- Average throughput increases;
- Average end-to-end delay increases.

When packet sending rate increases,

- Packet delivery ratio stays relatively stable;
- Average throughput increases;
- The trend of average end-to-end delay is unclear.

Thus, two tougher A3 highway scenario that are even more challenging than the original one are proposed according to the findings listed above. The configuration comparison of the three scenarios is indicated in TABLE II.

TABLE II. SCENARIO CONFIGURATION COMPARISON

Parameters	Scenario Name		
	A3 Original	*A3 Tougher 1*	*A3 Tougher 2*
Packet Size	512bytes	2048bytes	2048bytes
Packet Sending Rate	2	0.5	8

Optimization results are demonstrated as follows. Since average throughput metric has a stationary linear relationship with packet size and packet sending rate, it is pointless to list it in this part.

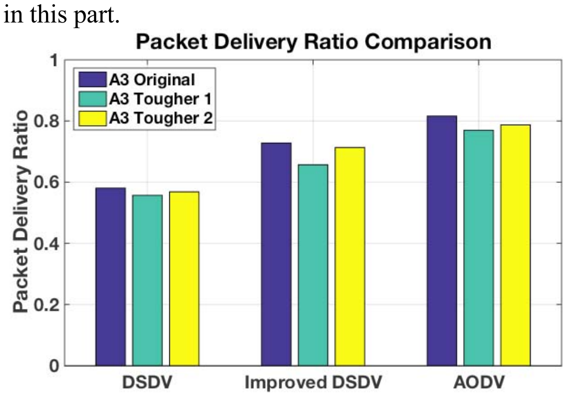

Figure 13. Packet Delivery Ratio Comparison

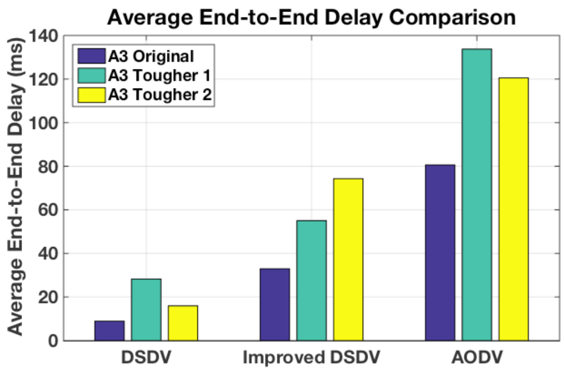

Figure 14. Average End-to-End Delay Comparison

V. CONCLUSION

A DSDV optimization approach has been proposed in this paper, which modifies the typical classic DSDV routing protocol to make it more suitable for VANETs. By shortening update period and minimum update periods and abolishing the concept of "settling time", DSDV can achieve sufficient PDR while keeping low average end-to-end delay. In addition, the relationships between DSDV parameters and vehicle's velocity can be described as follows:

$$perup\_ \propto \frac{1}{v} \tag{4}$$

$$min\_update\_periods = \begin{cases} 3, \text{when } v \text{ is low} \\ 2, \text{when } v \text{ is high} \end{cases} \tag{5}$$

$$wst\_ = 0 \tag{6}$$

where v is the velocity of mobile node. The detail of the proposed DSDV optimisation method is described in Algorithm 1. The velocity threshold is selected as 25 m/s according to the performance difference between urban scenario and highway scenarios.

Algorithm 1 Improved DSDV for VANETs

Input: Original *perup_*, *min_update_periods*, and node's velocity v

Output: Optimized *perup_* and *min_update_periods*

```
Initialize perup_ = 15 s, min_update_periods = 3,
  where
  perup_ represents update period, and
  min_update_periods stands for minimum update
  periods in DSDV. Let wst0_ = 0, where wst0_
  represents settling time;
while v > 25 m/s, do
    perup_hi_ = max { - v + 40, 1}, according to (4);
    min_update_periods_hi = 2, according to (5);
end while
Let perup_ = perup_hi_, min_update_periods =
min_update_periods_hi.
```

Since the mathematical expressions of the optimization approach are still not rigorous enough, future work will focus on summarizing the mechanism of this optimization to draw more accurate relationships between parameters and performance. Thus, this approach will be tested in more VANET scenarios to verify its performance.

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