RSU Deployment Scheme with Power Control for Highway Message Propagation in VANETs

Jun Tao, Limin Zhu, Xiaoxiao Wang, Jian He, and Ying Liu
Key Lab of CNII, MOE, Southeast University, Nanjing, China

***Abstract*—Nowadays, message propagation has been one of the major tasks of Vehicular Ad-Hoc Networks (VANETs).The main obstacle of message propagation, which relies on the data forwarding among vehicles, is the frequent change in network topology, as the intermittent link between the vehicles will degrade the performance of message propagation. Hence, RSUs are deployed to extend vehicle coverage and improve network performance in VANETs. However, non-optimal RSU deployment may result in greater power consumption and lower quality of network performance. In this paper, we study the vehicle mobility characteristics along the highway and propose a Cluster-based RSU Deployment (CRD) scheme with the Traffic-Aware Power Control (TAPC) method to maximize the network performance, as well as minimizing the energy consumption of RSUs. Moreover, we develop a data propagation algorithm, Data-Driven Message Propagation (DDMP), to improve the performance of message propagation in RSU-assisted VANETs. The performance of the proposed scheme is analytically evaluated by comparing performance in with and without our scheme scenarios. Through extensive simulations, with the aid of our scheme, the performance of message propagation is improved significantly, in terms of the propagation latency and the power consumption.**

***Index Terms*—VANETs, RSU deployment, power control, message propagation**

I. Introduction

As a type of ad hoc networks, Vehicular Ad Hoc Networks (VANETs) [1] are proposed to serve message propagation for vehicles, equipped with the wireless interfaces through multi-hop transmission among vehicles in the extreme networking environments, where most of the time there does not exist a stable end-to-end path between any two vehicles. Therefore, Road Side Units (RSUs) are deployed to improve the network performance, e.g., network connectivity, through communications between vehicles and RSUs. VANETs are able to accommodate a variety of applications including traffic safety [2], [3], traffic control [4], entertainment [5], commercial and daily information [6].

In many existing routing schemes of VANETs, data propagation depends on vehicle to vehicle (V2V) communications. However, due to the frequent change in network topology caused by unpredictable mobility of vehicles [8], the intermittent link between the vehicles will degrade the performance of message propagation. Moreover, limited transmission range and maldistribution of vehicles also narrow the coverage of VANETs [9], which may result in high data latency and low delivery ratio of message propagation. Therefore, RSUs, which can extend coverage of VANETs and offer a more stable network topology, are exploited to improve the performance of the message propagation in VANETs.

With the help of RSUs in VANETs, the performance of message propagation can be improved obviously. However, non-optimal RSU deployment may also introduce the problems, e.g., the redundant RSUs contributing little to the performance improvement and leading to the high cost of the deployment. On the other side, the interference generated by the densely deployed RSUs may also decrease the performance of message propagation. Besides, the power consumption of the RSUs is extremely high because they continuously working and providing service all the time. Therefore, how to properly deploy the RSUs to improve the performance of message propagation and conduct power control for RSUs to achieve the trade-off between the performance improvement and the energy saving is of great importance. Then the message propagation algorithm is expected to achieve higher performance in RSU-assisted VANETs.

In this paper, we investigate the cluster characteristics of the vehicles along the highway and propose a cluster-based RSU deployment scheme with power control to achieve the trade-off between network performance and power consumption. Then we design a message propagation algorithm to improve the performance of data dissemination in VANETs. The contributions of this paper are as follows.

1) We mathematically derive the characteristics of the traffic cluster with the vehicle mobility along the highway. Then an efficient cluster-based RSU deployment scheme is proposed to improve the network connectivity.
2) Considering the energy consumption, we exploit the power control method to reduce the energy consumption of RSUs without degrading the network connectivity. In the power control method, the RSUs are aware of the traffic change and conduct distributed power control to set their proper transmission ranges individually.
3) A corresponding data-driven message propagation algorithm, which takes the message size into account, is proposed to reduce the transmission latency with the aid of the RSUs. Finally, we evaluate our scheme in terms of the propagation latency and the power consumption.

The rest of this paper is organized as follows. In Section II, we explore the existing work and the achievements on RSU deployment and power control in VANETs. We investigate the characteristics of the vehicle cluster and present the RSU deployment scheme with detailed explanation on the power control process for the highway message propagation in Section III. The performance of our scheme is shown in terms of the propagation latency and the power consumption

978-1-4799-3512-3/14/$31.00 ©2014 IEEE

in Section IV. In Section V, we conclude this paper.

II. Related Work

Due to the advancement in technology, VANETs have attracted many research attentions, especially in RSU deployment and power control.

A. Traditional RSU deployment

Deploying RSUs to improve the performance of message propagation in VANETs, using graph theory [11], game theory [12] and math algorithms [13]–[15], has been investigated by many researchers in the past few years. To address the issue of distributing contents to vehicles, [12] proposed a strategic game to model the case in which the operators perform their deployment decisions concurrently. Also an extensive game was used to study the dynamics, where one operator is the deployment leader and moves first. In [11], the Voronoi-based RSU Placement was proposed by using Voronoi diagrams for the VANETs and the vehicle mobility to achieve the minimal delay. The CMP scheme was proposed in [16], where the placement problem was formulated with an integer linear programming model to maximize the aggregate throughput in the network. The impact of the wireless interference, the population distribution and the speeds of the vehicles were also considered in the model.

B. Power control scheme in VANETs

Power control in VANETs guarantees the efficient usage of power, which makes great contribution to the Green Communication. Recently, many efforts have been made to improve the power utilization. A fully distributed and proactive approach, DB-DIPC, was proposed in [17]. In DB-DIPC, the neighboring nodes periodically and interactively contact with each other through power adjustment to maintain the network connectivity. In [18], EAR (Efficient Angular Routing) algorithm was designed through finding the minimal possible length of the path between a source and a destination involving the minimal number of the nodes to achieve the optimal power consumption. However, most of the existing power control schemes only consider the amount of the power consumed by vehicles and ignore the power consumption of RSUs, which contributes a large percentage of the total power cost in VANETs.

In this paper, we tackle the deployment problems by utilizing the geometrical characteristics of the vehicles. We propose a Cluster-based RSU Deployment scheme (CRD) with power control method. Then we design a message propagation algorithm with the aid of the deployed RSUs to improve the performance of data propagation in VANETs.

III. RSU Deployment with Power Control for Data Propagation

In this section, we investigate the characteristics of the vehicle mobility along the highway. Then the Cluster-based RSU Deployment (CRD) scheme with the Traffic-Aware Power Control (TAPC) method is proposed. Finally, the Data-Driven Message Propagation (DDMP) algorithm is designed to support the CRD scheme.

A. Problem Formulation

We consider the scenario where the vehicles move in the same direction on the highway. Due to the speed limit in each segment of the highway, the vehicle speed is usually kept around the speed limit. Therefore, we suppose all vehicles move with the same speed. Compared with the transmission range of vehicles, the width of the road can be ignored. Assuming that the process of the vehicles' arrival is a *Poisson* point process [20], [23]. We study the cluster characteristics of vehicles, which are exploited to deploy the RSUs and conduct power control among RSUs. A cluster, which is disconnected from others, is a set of vehicles which can communicate with each other. Denote r_v and r_{RSU} as the transmission range of the vehicles and the RSUs, respectively. I_{RSU} is the interval between any two adjacent RSUs.

As the arrival of vehicles is a *Poisson* point process and the exponential inter-arrival distribution is with mean $1/\lambda$, the interval x between neighboring vehicles follows the exponential distribution, $f(x) = \lambda e^{-\lambda x}$. Thus the probability that x is smaller than r_v can be computed as

$$Pr\{x < r_v\} = \int_0^{r_v} f(x)dx = 1 - e^{-\lambda r_v}.$$

Then the cluster size can be calculated by figuring out the number of intervals between the two neighboring vehicles which is less than r_v. Thus the probability of there existing a cluster and n intervals in one cluster, which means the start and the end node of the cluster are the vehicles with the distance more than r_v from their neighbor vehicles outside the cluster, is computed as

$$g(n) = (e^{-\lambda r_v})^2(1 - e^{-\lambda r_v})^n,$$

The expectation of cluster size C is

$$E[C] = \lim_{n\to\infty} \frac{\sum_{i=1}^{n}(g(i)\sum_{j=1}^{i} d_j)}{\sum_{i=1}^{n} g(i)},$$

where $g(i) = (e^{-\lambda r_v})^2(1 - e^{-\lambda r_v})^i$ and d_j is the distance of the interval between any two neighboring vehicles.

To calculate the expectation of the cluster size, we have

$$\begin{aligned} E[x|x < r_v] &= \frac{\int_0^{r_v} x\lambda e^{-\lambda x}dx}{1 - e^{-\lambda r_v}} \\ &= \frac{1 - e^{-\lambda r_v}(\lambda r_v + 1)}{\lambda(1 - e^{-\lambda r_v})}, \end{aligned}$$

which shows the mean length of the interval between the two neighboring vehicles is less than r_v.

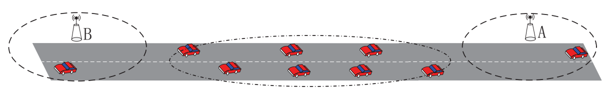
Finally, the expectation of cluster size is

$$\begin{aligned} E[C] &= \frac{\lim_{n\to\infty}\sum_{i=1}^{n}(g(i)\sum_{j=1}^{i} E[x|x < r_v])}{(e^{-\lambda r_v})^2(1 - e^{-\lambda r_v})} \\ &= \frac{1 - e^{-\lambda r_v}(\lambda r_v + 1)}{\lambda e^{-\lambda r_v}(1 - e^{-\lambda r_v})}. \end{aligned}$$

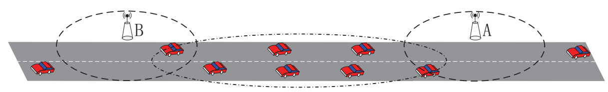
B. The Cluster-based RSU Deployment Scheme

Aiming at enhancing the performance of RSU-assisted VANETs, we propose the *Cluster-based RSU Deployment*

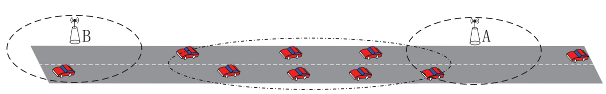
(CRD) scheme. The CRD scheme can provide direct or multi-hop communication service for every vehicle to achieve full-connected network topology through deploying RSUs in the optimal location. The vehicles in a cluster, which locate between two neighbor RSUs, can obtain the service from the RSUs, only when there at least exists one vehicle of this cluster within the transmission range of the two RSUs. Therefore, there are three scenarios shown in Fig. 1, which can describe the relationship among the cluster size, $E_{clu}(\lambda, r_v)$, the interval of RSUs, I_{RSU}, and the transmission range of the RSU, r_{RSU}.



(a) $I_{RSU} > E_{clu}(\lambda, r_v) + 2 * r_{RSU}$



(b) $I_{RSU} < E_{clu}(\lambda, r_v) + 2 * r_{RSU}$



(c) $I_{RSU} = E_{clu}(\lambda, r_v) + 2 * r_{RSU}$

Fig. 1: The relationship among I_{RSU}, $E_{clu}(\lambda, r_v)$ and r_{RSU}.

In Fig. 1, a vehicle cluster moves between two RSUs, i.e., from RSU A to B. If the cluster is out of the communication range of neither A nor B, which is described in Fig. 1(a), the communication service is not available until the cluster moves into the transmission rang of RSU B, resulting in the higher latency. On the other hand, Fig. 1(b) illustrates the case where the two RSUs get too closer and the cluster can communicate with both RSU A and B. In this way, the high latency problem could be addressed because the vehicles in the cluster can keep contact with the RSUs all the time. However, the number of deployed RSUs in this solution is relatively higher, which means huge cost of the deployment scheme. Hence, the CRD scheme, shown in Fig. 1(c), is proposed to get trade-off between the cost and the network performance according to

$$I_{RSU} = E_{clu}(\lambda, r_v) + 2 * r_{RSU}.$$

The λ can be analyzed by the toll station at the entrance of the highway. Through deploying the RSUs in this way, each vehicle cluster, which at least locates within the transmission range of one RSU, can constantly receive the communication service from the RSUs. Thus the CRD scheme achieves the higher performance with the less deployment cost.

C. Power Control among RSUs

Through investigating the relationship among I_{RSU}, r_{RSU} and $E_{clu}(\lambda, r_v)$, we found that the larger the RSU communication range is, the less RSUs are required along the highway. However, larger r_{RSU} leads to more power consumption of the RSUs, which means the greater operation cost simultaneously. Define $E_{power} = Q(i) * (E_{elec} + \epsilon R^{\alpha})$ as the amount of the transmission power cost, where R is the transmission range of the RSU and $Q(i)$ represents the amount of the data transmitted. According to [19], E_{power} can be computed as

$$E_{power} = \begin{cases} Q(i) * (E_{elec} + \epsilon_{Friis} r_{RSU}^2) & r_{RSU} \leq d_0 \\ Q(i) * (E_{elec} + \epsilon_{two\_ray} r_{RSU}^4) & r_{RSU} \geq d_0 \end{cases},$$

where the energy consumed per bit in the transceiver electronics, $E_{elec} = 50nj/bit$, the coefficients $\epsilon_{Friis} = 10pJ/bit/m^2$, $\epsilon_{two\_ray} = 0.0013pJ/bit/m^4$, the threshold distance $d_0 = 75m$. The power consumption will increase rapidly as r_{RSU} grows, especially when $r_{RSU} \geq d_0$.

To reduce the power consumption on RSUs, we propose the *Traffic-Aware Power Control* (TAPC) method, which exploits the change of traffic flow to calculate λ and switches the transmission range of the RSUs to the proper value. When the traffic flow becomes spare, due to the decrease in the cluster size, the r_{RSU} should be enlarged to keep the network connectivity. Once the traffic flow gets dense, resulting in the increment of cluster size, r_{RSU} should be reduced to avoid the excessive power consumption of the RSUs. Aiming at achieving the trade-off between the network connectivity and the power consumption, the TAPC scheme consists of two steps: 1) The mean intervals of the vehicles passing each RSU are calculated independently; 2) Each RSU adjusts its transmission range to achieve the full-connected network according to the mean interval.

1) Traffic Flow Awareness Process: As the arrival of vehicles may vary in different time, the original r_{RSU} may be non-optimal. When r_{RSU} is larger than the expected value, the excessive r_{RSU} value leads to the unnecessary waste of power of the RSUs. Whereas, the smaller r_{RSU}, which is less than the calculated value, results in the decrement of the network connectivity. Therefore, the vehicle mobility information will be collected, e.g., counting the number and the speed of the passing vehicles, to support the transmission range switch decision. In this way, each RSU collects the arriving time of the vehicle j, t_j, the vehicle number n and the speed v of the vehicle passing by in each time interval independently. The average interval of the vehicles passing RSU_i, namely λ_i, can be computed as

$$\lambda_i = \frac{n}{v \sum_{j=1}^{n} (t_j - t_{i-j})}.$$

2) Transmission Range Switch Decision: After λ_i is computed, the RSUs will calculate the transmission range and switch its transmission range to the right value according to

$$r_i + r_{i+1} + E_{clu}(\lambda_i, r_v) = I_{RSU}, \tag{1}$$

where r_i denotes the transmission range of RSU_i. Firstly, the RSUs, which have the same λ as their neighbors, $\lambda_i = \lambda_{i+1}$, are selected to conduct power control. Then the transmission range of the RSUs can be computed according to $r_i = (I_{RSU} - E_{clu}(\lambda_i, r_v))/2$. When there are no neighbor RSUs with similar λ, we also choose the two neighbor RSUs with the least difference in λ, i.e., $min(|\lambda_i - \lambda_{i+1}|)$, to perform the transmission range switch according to $r_i = (I_{RSU} -$

$E_{clu}(\lambda_i, r_v))/2$. After power control is completed among the RSUs, the neighbor RSUs will conduct transmission range switch according to formula 1 until all RSUs finish the range switch.

D. RSU-assisted Data Propagation in VANETs

After the RSUs are properly deployed, the *Data-Driven Message Propagation* (DDMP) algorithm in the RSU-assisted VANETs is proposed to improve the performance of message propagation along the highway. The design of DDMP algorithm is inspired by the size of data, which includes two kinds of cases. One is the small size of the data, which can be transmitted quickly. Here the proper path is important to minimize the transmission latency. The other is the large data size, to improve the performance of the data propagation, multi-paths are chosen for packet routing and the message is divided into several independent parts and transmitted simultaneously through the chosen multi-paths.

Algorithm 1 Data-Driven Message Propagation

Require: pkt
if $size(pkt) < S$ **then**
  if v_{dest} within RSU **then**
    RSU send pkt to v_{dest}
  else if v_{dest} out of cluster **then**
    while v_{dest} without RSU **do**
      wait
    end while
    RSU send pkt to v_{dest}
  else
    while cluster without RSU **do**
      wait
    end while
    send pkt follow $Dijkstra$ path
  end if
else if $size(pkt) \geq S$ **then**
  if v_{dest} out of cluster **then**
    RSU send pkt to v_{dest} within itself
  else
    $fl_{dest} \leftarrow 0$
    $i \leftarrow 0$
    while $\exists fl_k = null, k \in V$ **do**
      for v_j within v_b with $flag_b = i$ **do**
        if $fl_j = null$ **then**
          $fl_j \leftarrow i + 1$;
        end if
      end for
      $i \leftarrow i + 1$;
    end while
    while cluster without RSU **do**
      wait
    end while
    while RSU not finished sending pkt **do**
      $hop \leftarrow min(fl_i)$ within RSU
      RSU send pkt to v_i with $fl_i = hop$
      while $hop \neq 0$ **do**
        v_i send pkt to v_j with $fl_i = fl_j + 1 = hop$
        $hop \leftarrow hop - 1$
      end while
    end while
  end if
end if

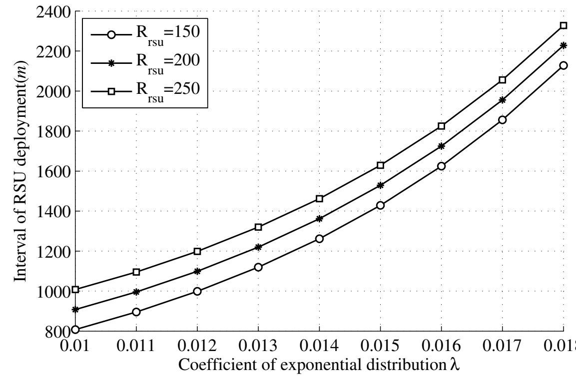


Fig. 2: I_{RSU} $vs.$ r_{RSU}.

Algorithm 1 describes the detailed implement of DDMP algorithm, where $size(pkt)$ is the size of message to be propagated and S represents the threshold of packet size for choosing the different sub-algorithms. v_i denotes vehicle i and v_{dest} indicates the destination vehicle of the message to be propagated. Further *within* and *without* mean the case of within and out of the RSU communication range. V denotes the set of all vehicles in the same cluster, where v_{dest} locates. Then fl_i is the mark of v_i, which stands for the hops from v_i to v_{dest}. For the propagation of small size messages, an optimal path is decided by $Dijkstra$ algorithm to reduce the transmission latency. When the data size is relatively large, the vehicles are labeled with the different fls according to the transmission range of the vehicle, r_v. Then the RSU divides and transmits the packet to the vehicles, which have the minimal fl value, within its transmission range. The vehicles with fl simultaneously deliver the messages to the vehicles with $fl - 1$ until reach the destination vehicle. Once the minimal fl of the RSU changed, the algorithm for large data size propagation will be re-conducted until the RSU finishes data propagation.

IV. Performance Evaluation

A. Simulation Setup

In order to evaluate the performance of the proposed RSU deployment scheme with power control method for highway message propagation in VANETs, we consider a scenario where the arrival of vehicles is a *Poisson* point process and the mean of exponential inter-arrival distribution is $1/\lambda$. Assume that the vehicles are heading towards the same direction with the same speed. The r_v is set to $200m$ and the speed of the vehicles is $100km/h$.

B. The Analysis of CRD Scheme

We first analyze the relationship among I_{RSU}, λ, r_{RSU} and network connectivity in the CRD scheme. Seen from Fig. 2, the interval of RSU increases with the coefficient of exponential distribution λ, as well as r_{RSU}. The network connectivity of the proposed CRD scheme is demonstrated in Fig. 3, where the communication range of RSU is 200m. The network connectivity decreases as the interval of the

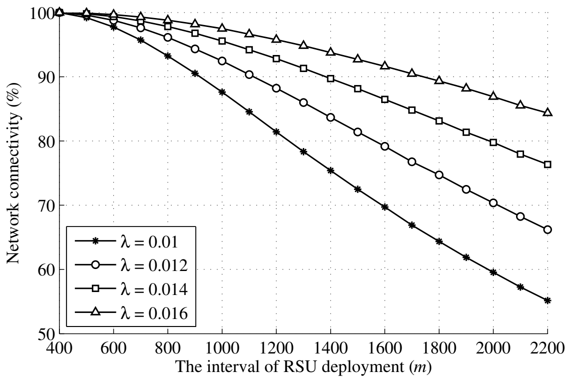


Fig. 3: The network connectivity $vs.$ I_{RSU}.

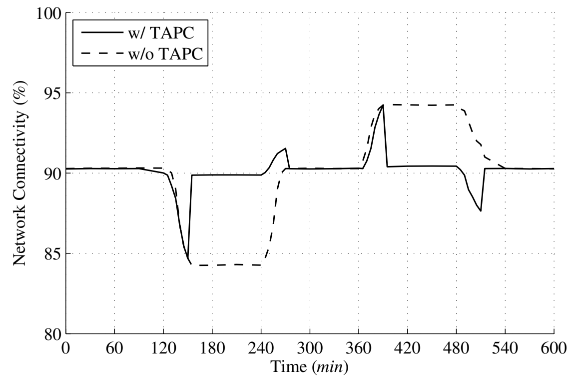


Fig. 4: The network connectivity

RSUs increases. From the scenario with $\lambda = 0.01$ and $r_{RSU} = 200m$, we can find that the proposed I_{RSU} is $907m$ and the network connectivity is about 90%. This is suitable for other scenarios with the different λ and the proposed I_{RSU} as well. Our CRD scheme can achieve at least 90% of the network connectivity. Because there still exist some vehicles not in any clusters and the size of some clusters are less than expectation, the network does not reach full-connected.

C. The Performance of TAPC

Next, we evaluate the performance of the TAPC method,where `w/` and `w/o` denote the cases with and without TAPC, respectively. The arrival of vehicles at the entrance of the highway is reflected by the λ, which is 0.01 when time changes from 0 to $120min$. The λ drops to 0.008 when time is in $[120, 240]min$. Then it keeps 0.01 when time changes from 240 to $360min$ and reaches 0.012 in $[360, 480]min$. Finally, the λ returns to 0.01 in $[480, 600]min$. The RSUs are deployed with $\lambda = 0.01$ and $r_{RSU} = 200m$. Moreover, each RSU conducts the TAPC method every 30 minutes. Figure 4 shows the effect of the changed λ value on the network connectivity in both `w/` and `w/o` TAPC scenarios. Obviously, the network connectivity in the `w/o` TAPC scenario changes as λ, which has an effect on the length of the cluster size. However, in the `w/` TAPC scenario, the network connectivity remains stable and fluctuates with the change of the λ when the RSUs switch to the corresponding r_{RSU}. In Fig. 5, the power consumption from 120 to $240min$ in the `w/` TAPC scenario is higher than that of the `w/o` TAPC scenario. The reason is that the λ drops at $120min$, which results in the increment of r_{RSU}. When the λ increases at $360min$, the r_{RSU} decreases, which results in the lower power consumption in the `w/` TAPC scenario. The power consumption in the `w/` and `w/o` TAPC scenarios are nearly the same at the time interval $[0, 120]$, $[240, 360]$ and $[480, 600]min$. This is because the r_{RSU} returns to $200m$ when $\lambda = 0.01$. The network connectivity and the total power consumption demonstrate that the TAPC method can improve the network performance and reduce the power consumption in the different traffic flow scenarios.

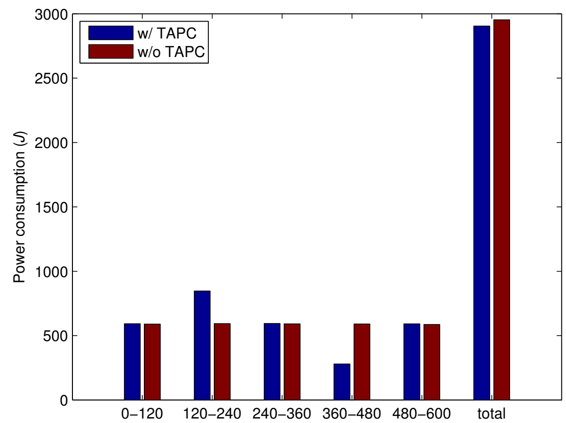


Fig. 5: The power consumption

D. The Network Latency of the DDMP Algorithm

Finally, we evaluate the proposed DDMP algorithm in terms of the network latency in the highway scenario, where $\lambda = 0.01$ and $r_{RSU} = 200m$. Considering the size of the message, we also evaluate the influence on the message propagation performance with the different size of the message, respectively.

1) Short message propagation: Considering the real-time safety related driving messages propagation as the short message application with the aid of the RSUs, we assume the message transmission delay is $0.1s$ per hop. The latency for all vehicles to get the messages, shown in Fig. 6, is less than 1 second in the scenarios and becomes larger with the I_{RSU} increasing. when $\lambda = 0.01$, where the optimal interval of the RSU is about 907m, we observe that the average latency is about $0.2s$. Due to the higher connectivity of the VANETs, most vehicles can receive the safety related messages within 2 hops. Besides, the `w/` DDMP outperforms `w/o` DDMP scenario in terms of the latency, especially when $I_{RSU} \geq 1000m$.

2) Large message propagation: The performance of large message propagation is evaluated by measuring the time spent to transmit $100MB$ packets with the transmission rate $20MB/s$. In Fig. 7, the average transmission time of DDMP

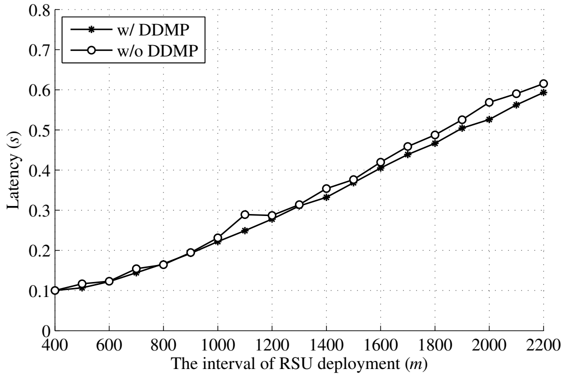


Fig. 6: The latency of short message

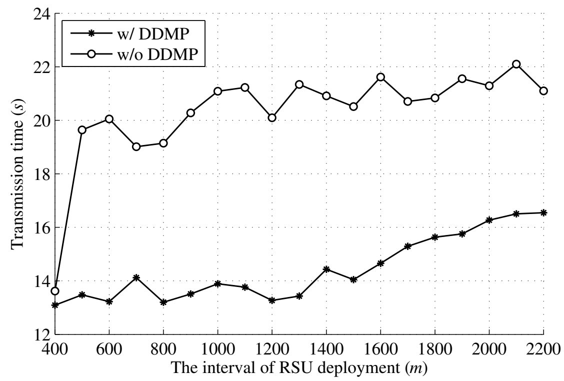


Fig. 7: The transmission time of large message

algorithm, which is from $14s$ to $15s$, is less than that of the `w/o` DDMP scenario, which ranges from $20s$ to $22s$. The reason is that in DDMP algorithm, there will be at least one vehicle transmitting the packet per hop and the large messages are transmitted through multi-paths, which reduce the transmission time of the propagation in the VANETs.

V. Conclusions

In this paper, exploring the characteristics of the vehicle mobility on a one-dimensional highway, we proposed the CRD scheme with TAPC method to achieve a trade-off between the network performance and the power consumption. Besides, the DDMP algorithm was presented to improve the performance of the highway message propagation in VANETs. Through the extensive simulation, we verify our proposed scheme, which achieves better performance in terms of the propagation latency and the power consumption. In addition, considering the two-dimensional scenario, our future work will focus on the RSU deployment using the reverse traffic.

VI. Acknowledgement

The work is supported in part by the National Natural Science Foundation of China (No. 61272532, 61300200, 61370206 and 61370209), Natural Science Foundation of Liaoning Province (No. 2013020019).

References

[1] Y. Li and W. Wang, “Horizon on the move: Geocast in intermittently connected vehicular ad hoc networks,” *INFOCOM, 2013 Proceedings IEEE*, pp. 2553-2561, 2013

[2] F. Farnoud and S. Valaee, “Reliable broadcast of safety messages in vehicular ad hoc networks,” *INFOCOM 2009, 2013 Proceedings IEEE*, pp. 226-234, 2009.

[3] R. Zheng, “Information dissemination in power-constrained wireless networks,” *INFOCOM, 2006 Proceedings IEEE*.

[4] A. Wegener, H. Hellbruck and C. Wewetzer, “VANET simulation environment with feedback loop and its application to traffic light assistance,”*GLOBECOM Workshops, 2008 IEEE*, pp. 1-7, 2008.

[5] B. Liu, B. Khorashadi and D. Ghosal, “Assessing the VANET’s local information storage capability under different traffic mobility,” *INFOCOM, 2010 Proceedings IEEE*, pp. 1-5, 2010.

[6] N. Liu, M. Liu and G. Chen, “The sharing at roadside: Vehicular content distribution using parked vehicles,” *INFOCOM, 2012 Proceedings*, pp. 2641-2645, 2012.

[7] I. Filippini and F. Malandrino, “Non-cooperative rsu deployment in vehicular networks,” *Wireless On-demand Network Systems and Services (WONS), 2012 9th Annual Conference on IEEE*, pp. 79-82, 2012.

[8] L. Villas and A. Leandro, “Network partition-aware geographical data dissemination,” *Communications (ICC), 2013 IEEE International Conference*, pp. 1439-1443, 2013.

[9] Y. Li and W. Wang, “Geo-dissemination in vehicular ad hoc networks,” *Communications (ICC), 2012 IEEE International Conference*, pp. 302-306, 2012.

[10] Z. Huang, S. Wang and B. Ding, “History based predictive routing in multi-lane delay tolerable VANETs,” *Communications (ICC), 2012 IEEE International Conference*, pp. 5440-5444, 2012.

[11] P. Patil and A. Gokhale, “Voronoi-based placement of road-side units to improve dynamic resource management in Vehicular Ad Hoc Networks,” *Collaboration Technologies and Systems (CTS), 2013 International Conference on IEEE*, pp. 389-396, 2013.

[12] I. Filippini and F. Malandrino, “Non-cooperative rsu deployment in vehicular networks,” *Wireless On-demand Network Systems and Services (WONS), 2012 9th Annual Conference on IEEE*, pp. 79-82, 2012.

[13] M. Rashidi, I. Batros and T. Madsen, “Placement of Road Side Units for floating car data collection in highway scenario,” *Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2012 4th International Congress on IEEE*, pp. 114-118, 2012.

[14] B. Aslam, A. Faisal and C. Zou, “Optimal roadside units placement in urban areas for vehicular networks,” *Computers and Communications (ISCC), 2012 IEEE Symposium on IEEE*, pp. 423-429, 2012.

[15] J. Chi, Y. Jo and H. Park, “Intersection-priority based optimal RSU allocation for VANET,” *Ubiquitous and Future Networks (ICUFN), 2013 Fifth International Conference on IEEE*, pp. 350-355, 2013.

[16] T.J. Wu, W. Liao and C. Chang, “A Cost-Effective Strategy for Road-Side Unit Placement in Vehicular Networks,” *Communications, IEEE Transactions on*, 60.8: 2295-2303, 2012.

[17] Chigan, X. Chun and J. Li, “A delay-bounded dynamic interactive power control algorithm for VANETs,” *IEEE International Conference on ICC 2007*, pp. 5849-5855, 2007.

[18] S. Misra, S. Dhurandher and M. Obaidat, “Optimizing power utilization in vehicular AD HOC networks through angular routing: a protocol and its performance evaluation,” *Global Telecommunications Conference, GLOBECOM 2009*, pp. 1-5, 2009.

[19] T. Rappaport, “Wireless communications: principles and practice,” *New Jersey: Prentice Hall PTR*, 1996.

[20] Y. Zhuang, J. Pan and Y. Luo, “Time and location-critical emergency message dissemination for vehicular ad-hoc networks,” *Selected Areas in Communications, IEEE Journal*, 29.1: 187-196, 2012.

[21] N. Panwar and M. Dave, “Stability Based Routing Scheme for Vehicular Networks,” *Computational Intelligence and Communication Networks (CICN), 2012 Fourth International Conference on IEEE*, pp. 191-196, 2012.

[22] MF. Jhang and W. Liao, “Cooperative and opportunistic channel access for vehicle to roadside (V2R) communications,” *Mobile Networks and Applications*, 15.1: 13-19, 2010.

[23] D. Miorandi and E. Altman, “Connectivity in one dimensional ad hoc networks: a queuing theoretic approach,” *ACM/Springer Wireless Networks*, pp. 573-587, 2006.