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Research Article

Efficient Message Dissemination on Curve Road in Vehicular Networks

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Effective emergency message dissemination is a great importance on a specific road in vehicular networks (VN). The existing methods are not most efficient solutions for message dissemination on the curve road, which primarily focus on highway and urban road. In order to improve the efficiency of message dissemination on the curved road, the paper proposed a message dissemination method based on bidirectional relay nodes. The message can be disseminated in two directions simultaneously. The paper designed a relay node selection method based on the neighbor nodes' coverage length of the road. Different waiting delays are assigned to the neighbor nodes according to the cover capability of the road in which the message has not arrived. Simulation results demonstrated that the efficiency of the proposed method is superior to the common solutions in terms of the contention delay and the propagation velocity.

1. Introduction

Effective message dissemination is widely used in vehicular networks (VN). Transport commuting has become a ubiquitous part of daily life; vehicular networks play a positive role and improve the living standards of the people. VN can access the location where a traffic accident occurs and timely inform the relevant vehicles to adopt safety measurements. Traffic flow coordination can also benefit from the VN [1, 2]. People can get the current traffic information timely on the related road of the vehicle and then choose the optimal path. Traveling will become more convenient; an accurate match between user demand and vehicle dispatch can be achieved by related technologies of VN [3]. VN will make the intelligent transportation system a reality and can provide information regarding petrol stations, restaurants, services areas, weather information, navigation [4–6], and all desired information about the surrounding environment. The application of VN will raise efficiency and enhance the user experience. People in different vehicles can cooperate on different roads within the same team. Mobile devices and vehicles can also work together to finish the file upload and download [7, 8]. The large computational task can be divided into multiple subtasks according to [9–11], and vehicles can collaborate with each other or other heterogeneous devices to complete the computing task using the edge computing. Network security is important for the various applications in VN, while its own implementation process benefits much from VN [12, 13]. Efficient message dissemination plays a critical role in all the above application scenarios of VN.

Due to the rapid movement of vehicles, there are still some challenges in term of efficient emergency message dissemination in VN. In order to solve this problem, researchers propose a variety of different routing protocols. The current data transmission routing protocols in VN mainly include the protocol based on the geographical location, broadcast protocol based on the infrastructure,

and clustering-based protocol. In order to improve the efficiency of message dissemination, there are also some hybrid emergency message dissemination methods. The existing message dissemination schemes mainly focus on urban roads and high way, but there is little work to cope with the curve road scene.

Rural roads sometimes are tortuous compared with the urban roads and high way. When a landslide, debris flow, bridge collapse, and other accidents suddenly appear in a certain position on the curve road during tourism, broadcasting these messages to nearby vehicles can make them avoid danger and choose other available paths to reach the destination. Timely and effective message dissemination in a specific area of the road can ensure the safety of life and property and avoid unnecessary detours. The existing emergency message dissemination mechanisms may not be the optimal solution for message dissemination of the curve road scene. This paper designs an emergency message dissemination method for the curve road scenario; the key contributions of this paper are summarized as follows:

(i) The paper proposed a robust relay selection method based on the coverage capability of the road in which the message has not arrived, and the method can reduce the collision probability of the response messages from the neighbor nodes and improve the efficiency of relay selection

(ii) The paper designed a message broadcast scheme based on the bidirectional relay selection as to the curve road, which can improve the forwarding efficiency of the emergency messages

(iii) Simulation results showed that the proposed method improves the efficiency of the relay selection and the message broadcast on the curve road

The rest of the paper is organized as follows. Section 2 introduces the related work. Section 3 proposes the relay selection method based on the coverage capability of the neighbor nodes. Section 4 presents the message broadcast method for curve road. Simulation and result discussion are presented in Section 5. Section 6 concludes this paper.

2. Related Work

Due to the high mobility of the vehicles, there are some challenges for efficient message dissemination in VN. In order to solve the problem, researchers proposed a variety of message dissemination methods based on vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication. Common data dissemination is implemented by vehicle broadcasting in V2V communication; it can also be achieved by infrastructure broadcasting or the cooperation between the two ways.

Broadcast in the vehicular ad hoc network is very important to complete the data dissemination when the infrastructure is not available or has a heavy workload. To improve the multihop broadcast efficiently in the urban vehicular ad hoc network, link quality was considered to select the suitable relay node in [14]. For multihop message broadcast in urban vehicular ad hoc networks, the authors proposed a relay selection method by asynchronous contention based on iterative partition in [15] and then designed the directional broadcast, bidirectional broadcast, and multidirectional broadcast scheme to complete the message dissemination in target area. To solve the broadcast storm problem, effective candidate number, maximum forwarding distance, and global traffic density are all taken into account in relay node selection; the authors proposed a local topology-aware broadcast protocol in [16]. Taking into consideration the vehicle mobility and link quality in vehicular ad hoc network, the authors proposed the relay selection method and designed the corresponding broadcast protocols for broadcast delay and efficiency, respectively, in [17]. More broadcast methods in VN were surveyed in [18–20].

Geocast is the common solution for data dissemination in VN. Geographical location information of the candidate nodes is the major consideration in the position-based routing protocols. Tian et al. proposed the solution for the directional broadcasting in the VN; the neighbor node determines whether it needs to forward the message again according to the direction of the message propagation and its current location [21]. Karimi and Shokrollahi improved the existing greedy perimeter stateless routing (GPSR) based on the location prediction of the nodes. Whether the node was selected as the relay, the future location of the node should be considered [22]. With vehicles' location and mobile information, Ryu and Cha proposed the relay selection method based on the predicted link lifetime. The candidate node with the longest lifetime was selected as the relay node to forward messages [23]. Jiang et al. proposed the UAV-assisted geographic routing in VANETs based on the Q-Learning, the aerial component calculates the global routing path for the ground component, and then, the vehicle on the ground forwards the routing request to the optimal node [24]. Residual bandwidth and packet loss rate are considered to calculate the link utility of the two-hop neighbors; Alzamzami and Mahguob designed the geographic routing for urban VANETs based on the link utility [25].

With regard to the clustering-based message dissemination scheme, Alkhalifa and Almogren proposed a method based on the link stability for the construction of the clusters. In order to avoid the collision of broadcast messages among cluster members, the CSMA/CA method was designed based on cache size and vehicle density [26]. To improve the reliability of emergency message distribution in VN, the authors proposed a dynamic clustering scheme of vehicles and designed two MAC layer broadcast protocols in [27]. For the sake of improving the stability and maintenance time of clusters, Seo et al. proposed a cluster data distribution protocol PCDB based on the path similarity of nodes [28]. Abbas and Fan proposed a clustering-based multipath routing protocol with the ant colony optimization technique to achieve high efficiency of the data transmission [29]. Information can be delivered by the base station or RSU to the transportation management system. Dua et al. designed the routing protocol based on the cluster for the information delivery from the source to the nearest RSU.

The turning probability of the cluster was considered in the routing decision [30]. For the efficiency of data upload from vehicles to BS, Garbiso et al. designed the adaptive clustering method of vehicles according to the density of vehicles; the proposed method can ensure the effectiveness and fairness of data upload [31]. In addition, more clustering schemes in vehicular networks are introduced in [32–34].

As to the emergency message dissemination based on the road side unit (RSU), Tiennoy and Saivichit modified the structure of the named data networking (NDN) to improve the efficiency of data collection and distribution [35]. Li et al. used a quadtree model that represents a hierarchical decomposition of the global area and then proposed the selection approach of the RSU to forward the message to the destination area [36]. Fan et al. proposed a stochastic multihop broadcast scheme to solve the collision of the message rebroadcast by the vehicles which was firstly broadcast by RSU [37]. Sometimes vehicles do not get the full data requested when it run out the range of RSU; then, the base station is responsible for the data dissemination to complete the data requested. Liu et al. proposed the data dissemination solution for base station based on network coding technology [38]. To improve the efficiency of the content distribution from RSU, Dai et al. designed a schema based on the coding-decoding technology. The coded files are cached on multiple RSUs, the vehicle can offload the encoded packets from RSU, and then, it can decode the original file if it got enough coded packets [39].

Because of the good maneuverability of UAV, it is often used to the data distribution in the VN. We proposed the data distribution scheme based on the network coding [40] to improve the data dissemination efficiency in vehicular networks assisted by UAV with an active directional antenna. For the multimedia data offloaded from RSU, Nam et al. proposed the adaptive content precaching scheme for RSU based on the mobility of the vehicles, and RSU cached appropriate amounts of data according to the predictive speed of the vehicles [41]. As to the coverage problem of the multiple dynamic vehicles with the limited number of UAVs, Samir et al. proposed a control method for UAV's trajectories based on the reinforcement learning technology. The framework can achieve maximum vehicular coverage with the minimum number of UAVs and the minimum energy consumption [42]. Zhou et al. designed aerial-ground cooperative vehicular networking architecture to improve the availability of the network. UAV can be used for auxiliary communication when there is an interruption of VN, and data can be transferred by the way of UAV-to-UAV (U2U), UAV-to-vehicle (U2V), and vehicle-to-vehicle (V2V) [43].

The related research work focused on the scene of highway or urban scene. When selecting the relay node, few solutions take into account the length of the road that the candidate node can cover. In this paper, relay selection based on cover capability and a curved road broadcast mechanism based on the bidirectional relay is proposed, which can improve the efficiency of message dissemination in the curve road scene. Vehicles on the curve road can receive the message disseminated in time.

3. Relay Selection Based on Cover Capability

3.1. System Model and Assumption. Assume that multiple vehicles are traveling on the curve road, it is necessary to inform all vehicles within a specific segment due to an emergency, such as the road segment between point S and point D, as thown in Figure 1. There is no available infrastructure-assisted communication and message transmission between vehicles via broadcasting. Each vehicle is equipped with an OBU device which can accomplish the message receiving and sending. The communication radius of the vehicle is r. GPS is installed on each vehicle to access its own position information in real time. Map information of the current road is cached on every vehicle.

3.2. Optimal Relay Selection Based on Road Coverage Capability. Traditional solutions select the furthest neighbor node as the relay node. As to the highway scene shown in Figure 2, S is the current node, and v_{R1} and v_{R2} are in the communication range of the node S. S selects the node v_{R1} as the relay node to broadcast the message. As to curve road scene shown as the Figure 1, v_{R2} is selected as the relay node because it is closer to the reference point A. These relay selection methods are carried out without consideration for the road coverage capability of the candidate nodes. If we take the road coverage capability into account, v_{R1} is most suitable candidate of the scene shown in Figure 1. Thus, the relay selection method is proposed based on the road coverage capability of the candidates in the paper.

$$\mathrm{Width}_{\mathrm{seg}}(m,k)=\frac{1}{\omega}\left[(1+\omega)^{(((k-1)\bmod N)+1)/N}-(1+\omega)^{((k-1)\bmod N)/N}\right]\cdot\mathrm{Width}_{\mathrm{seg}}\left(m-1,\left\lceil\frac{k}{N}\right\rceil\right). \tag{1}$$

After receiving the message, collision may occur when the neighbor nodes try to response simultaneously. The RTB/CTB is employed to deal with the hidden terminal problem and the broadcast storm problem. Some contention approaches are proposed based on the distance partition [44, 45]. Waiting delay of neighbor node is determined according to the distance between the neighbor node and the reference point. The neighbor node whose waiting delay expired firstly obtains the opportunity of forwarding. We propose the optimal relay selection method based on the maximum length of uncovered roads (PBOL) to improve the broadcast efficiency for the curve road scene. The method is also suitable for the urban road scene, as shown in Figure 2. v_{R1} can cover the road segment between the point A and C, and the length of the road segment between the point A and C is d_{R1}; v_{R2} can cover the road segment between the point A and B, and the length of the road segment between the point A and B is d_{R2}; v_{R1} selected as the relay node is more suitable because the value of d_{R1} is greater than the value of d_{R2}.

When sending node wants to send message, it broadcasts RTB message at first. The message consists of the location information of the sending node and the maximum

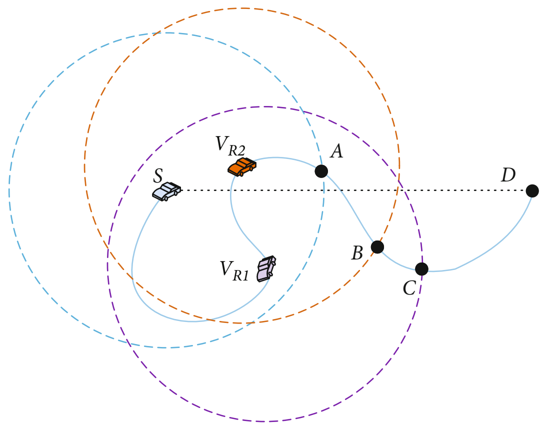

Figure 1: Curve road scene.

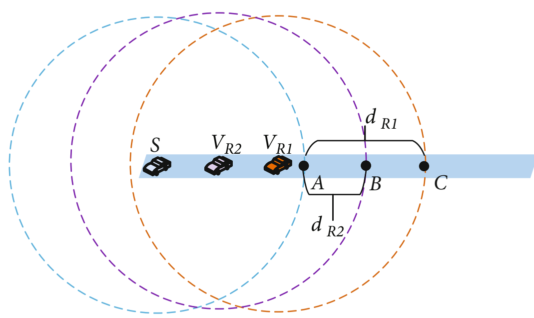

Figure 2: Highway scene.

uncoverage road length of the message that the node can cover at any location in the communication range of the sending node. After receiving RTB from sending node, all neighbor nodes in the communication range can calculate the length of the road that it can cover and the message have not arrived at according to the location information of the sending node, its own location information, and the local cached map information. Every neighbor node maps the length of the road that it can cover to the new location of the maximum uncovered road length of the message that the node can cover being at any location in the communication range of the sending node. Then we partition the maximum uncovered road length d_{max} into multisegments with the formula (1), $\mathrm{Width}_{seg}(m, k)$ represents the length of the kth segment in the mth partition, $\mathrm{Width}_{seg}(0, 0) = \mathrm{d}_{max}$. ω is a constant used to adjust the width of partitioned segment. Which segment the neighbor node belongs to determines its waiting delay, the nodes belong to the same segment with the same waiting delay. When the waiting delay expires firstly, nodes belong to the same segment broadcast a black-burst message. Nodes belonging to other segments receive the black-burst message, and they will give up the contention. Then, the segment that the nodes' waiting delay expires firstly will be partitioned recursively until the partition times reached the predefined threshold. After the final round of the partitioning, the neighbor nodes in the selected partition will randomly choose their back-off periods from the available contention windows, the one with the minimum delay is selected as the forwarder. The procedure of the relay selection is shown as Algorithm 1.

We take an example to illustrate the details of the procedure. As shown in Figure 1, node S wants to broadcast a message; then, it first broadcast RTB, and neighbor nodes receive it. The intersection of node S' communication range, and the road is A. The neighbor node of node S may appear anywhere along the road between the point S and the point A. Suppose that the intersection of a neighbor node v_{R1}'s communication range and the road is C, then, the length d_{R1} of the uncovered road that v_{R1} can cover is the length of the road between A and C. The length of the road between any two poins can be calculated by the math method, which has been widely used in Google Map and Baidu Map. Given the coordinates of the source and the destination, the map can output the distance between the source and the destination. Neighbor node may appear at any location of the road that belongs to the node S' communication range; then, S can get the length of uncovered road that the neighbor node can cover being at any location of the road and the message have not arrived at and then take the maximum value d_{max} as the maximum coverage length that the neighbor nodes can cover.

Then, S node puts its own location information and the the maximum coverage length d_{max} that the neighbor nodes can cover into RTB message when it sends RTB. After receiving RTB from node S, any neighbor node v_{Ri} can calculate the length of the uncovered road it can cover according to the sending node's location information, communication radius, cached map information, and its own location information, which is denoted by d_{Ri}. The neighbor node can map its location to the d_{max} according to the length of the uncovered road it can cover. Mapped locations of the neighbor node v_{R1} and v_{R2} are shown as Figure 3.

Then, d_{max} is divided into different N segments with the formula (1). v_{R1} is mapped in the hth segment. After $(h-1)$ th time slot, v_{R1} broadcasts a burst message. Other neighbor nodes receive the burst message from the node v_{R1}, and they will give up the contention. There may be multiple neighbor nodes locating at the hth segment, so the hth segment is divided iteratively until the maximum number of recursive partition M is reached with the same method. Lastly, nodes belonging to the kth segment of the Mth iteration select a waiting delay randomly; the node with the minimum waiting delay is selected as the relay.

4. Message Broadcast Method for Curve Road

4.1. Relay Selection Based on PBOL. The relay selection strategy has an important influence on the speed of message dissemination. The common way is to select the node farthest from the sending node or the reference point as the relay node. Relay selection by this method may not be the optimal solution for the curve road. As to the scenario of the Figure 1, there are two available neighbor nodes in the communication range of the node S. With the common way, the node v_{R2} will be selected as the relay node, which can cover the section of the road between A and B. If v_{R1} is selected as the relay node with the proposed method PBOL, the section

Input: location of the sending node and its neighbors;
Map information; communication radius;
Output: relay selected;
while partitionNum ≤ M **do**
  segment$_k$=formula (1);
  if (d_{Ri} ∈ segment$_k$ and partitionNum < M) **then**
    delay$_{\mathrm{Ri}}$ = delay$_{\mathrm{Ri}}$ + k^*time slot;
  else
    if (d_{Ri} ∈ segment$_k$ and partitionNum = M) **then**
      delay$_{\mathrm{Ri}}$ = delay$_{\mathrm{Ri}}$ + k^*time slot + randomValue;
    end if
  end if
  while delay$_{\mathrm{Ri}}$ epired **do**
    node$_{\mathrm{Ri}}$ broadcast Burst message;
    break;
  end while
  Relay = node$_{\mathrm{Ri}}$;
  if (node$_x$ receive the burst message before delay$_x$ expired) **then**
    node$_x$ give up contention;
  end if
  partitionSegment = Segment$_k$ which the node$_{\mathrm{Ri}}$ locate in;
  partitionNum++;
end while
return: Relay;

Algorithm 1: Relay selection based on PBOL.

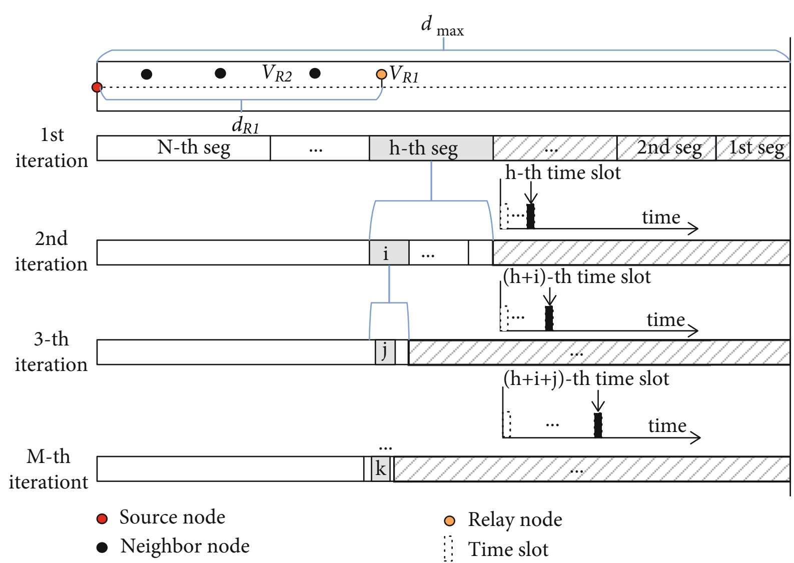

Figure 3: Relay selection on the curve road.

of the road between A and C can be covered. In this case, v_{R1} acting as the relay will be more efficient than the node v_{R2}. The proposed method PBOL is used to select the relay when the emergency message is broadcasting on the curve road.

4.2. Emergency Message Broadcast Mechanism on Curve Road. To improve the efficiency of the message dissemination, we adopt a bidirectional relay broadcast mechanism when necessary. After the current relay node is determined, if there is an uncovered road segment between the current relay node and the sending node, then the current relay node starts to select the bidirectional relay nodes with the proposed method PBOL, as shown in Figure 4. Assuming that the road before v_s have been covered by the message, v_s starts to select the unidirectional relay node with the proposed method PBOL. There are neighbor nodes v_1 and v_{22} available in its communication range. Based on the method PBOL, the source node v_s selects v_1 as the relay node and

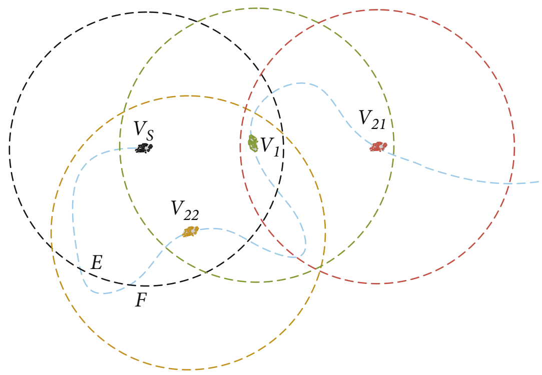

FIGURE 4: Bidirectional relay selection on the curve road.

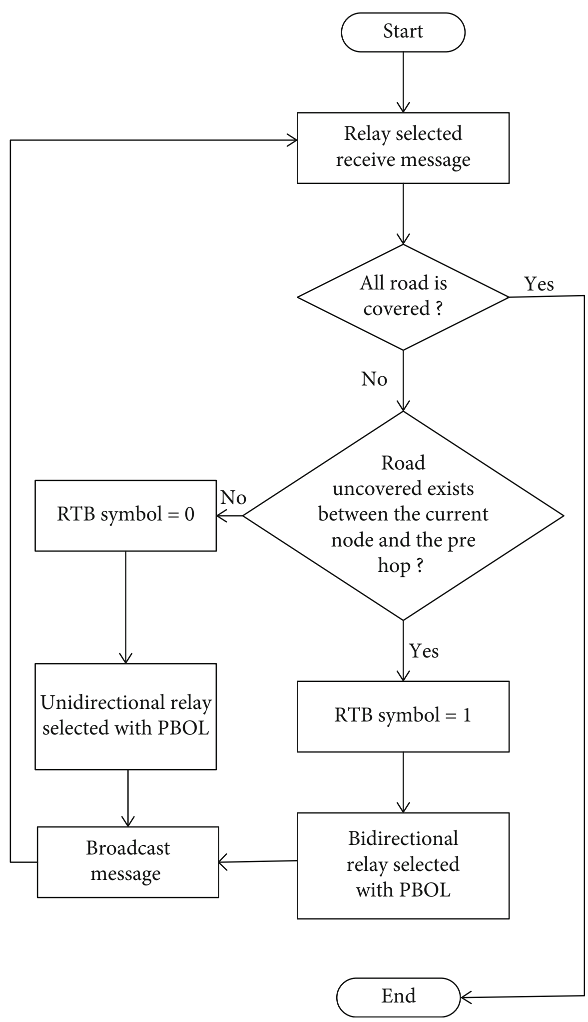

FIGURE 5: Flow diagram of relay selection on the curve road.

```
Input:   message broadcast;
Output: ∅;
function voidBroadcast( )
    while (not all road is covered by the message) do
        Current node sets RTB symbol and sends RTB;
        Neighbor nodes receive RTB;
        if (RTB symbol==0) then
            Unidirectional relay = Select unidirectional
          relay with method PBOL;
            Current node broadcast the message;
            Current node = Unidirectional relay;
            Current node updates the road coverage
          of the message;
             Broadcast( )
          end if
          if (RTB symbol==1) then
             Bidirectional relays = Select the bidirectional
          relays with method PBOL;
             Current node broadcast the message;
             Current nodes = Bidirectional relays;
             Current nodes update the road coverage
          of the message;
             Broadcast( );
        end if
     end while
end function
```

ALGORITHM 2: Message broadcast on curve road.

then broadcasts the message. After the node v_1 receives the message, it can be concluded that there is a road section between v_s node and v_1 node (road section between E and F) being not covered according to the coordinates of v_s node, communication radius r, its own location information, and map information. v_1 now needs to start the bidirectional relay node selection by the PBOL method. If there is no uncovered road section between the node v_1 and the previous hop v_s, v_1 only need to select the unidirectional relay node for message forwarding by the PBOL method.

For bidirectional relay node selection method, when the current relay node v_1 broadcasts the RTB messages, the symbol of RTB is set to 1 which indicates that bidirectional relay node selection is requested. If there is no neighbor node in the communication range of the current relay node, the current relay node adopts storage-carry-forward strategy. The uncover road is partitioned into two parts by the current relay node v_1: one part is before the current relay node and the other part is behind the current relay node. The current relay node selects one from its neighbor nodes who can cover the maximum length of the front uncovered road as the front relay node and selects one from its neighbor nodes who can cover the maximum length of the back uncovered road as the back relay node. v_1 selects the v_{21} as the front relay and v_{22} as the back relay in Figure 4. The selected relay node decides to select the unidirectional relay or bidirectional relay based on whether there is uncovered road segment between itself and the prehop, the flow diagram of the relay selection is shown as Figure 5. The procedure is repeated until all the road is covered by the message, which is shown as the Algorithm 2.

5. Performance Evaluation

5.1. Simulation Settings. In order to evaluate the performance of the relay selection method, we choose a 4 km long mountain road as the simulation scene which is in Ziquejie Park, China [45] and shown as the Figure 6. The message

Figure 6: Simulation scene of the road.

is expected to cover all parts of the road from the Start to the end. The position distribution of vehicles on the road obeys Poisson distribution, and vehicles drive at a fixed speed on the road without lane change and overtaking. The speed of vehicles obeys the uniform distribution in $[(1/2)v_{max}, v_{max}]$. Due to the mountain road condition, the maximum speed v_{max} is 40 km/h. In order to verify the performance of the scheme in different vehicle densities, the vehicle density varies from 0.025 to 0.305. The arrival rate of the message is set to 2 EMs/s. PBOL is compared with binary-partition-assisted MAC-layer broadcast method (BPAB) [46], trinary partitioned black-burst-based broadcast mechanism (3P3B) [44], and relay selection based on the distance to reference point (PBOP) [45] in the view of contention delay, one-hop delay, and message propagation speed. $(M, N, \omega) = (2, 4, 2)$ in PBOP and PBOL. Simulation is conducted in MATLAB, and the main parameters are shown in Table 1.

In the following we will give a brief overview of metrics. Partition delay is the time consumed during the partitioning phase. $N_{m,k}$ means the number of time slots consumed if k-segment is selected in mth iteration. $P_{sel}^{m,k}$ denotes the possibility of k-segment being selected in mth iteration. T_{slot} is the value of every slot. The average partition time consumed T_{part} is shown as

$$T_{part} = \left(\sum_{m=1}^{M} \sum_{k=1}^{N} \left(N_{m,k} P_{sel}^{m,k} \right) + 1 \right) T_{slot}. \tag{2}$$

Contention latency is the time consumed in the contention phase, and the equation for the average contention delay is shown as the formula (3). P_{sel}^{k} means the possibility of k-segment being selected as the final segment in the last iteration. $T_{cont\_seg}^{k}$ means the contention latency of k-segment.

$$T_{cont} = \sum_{k=1}^{N^M} T_{cont\_seg}^{k} P_{sel}^{k}. \tag{3}$$

One-hop delay is the average time consumed of one-hop message delivery; the equation for it is shown as the formula (4). T_{init} means the initializing time (i.e., sender accesses the channel), $T_{partion}$ is the partition delay, and $T_{contention}$ is the contention delay which are explained as before. T_{data} means the time consumed of the data transmission.

Table 1: Major simulation parameters.

Parameters	Default values
Bit rate	18 Mbps
Message packet size	500 bytes
RTB packet size	20 bytes
CTB packet size	14 bytes
Slot time	13 μs
DIFS	58 μs
SIFS	32 μs
Transceiver's switching time	1 μs
Communication range	500 m

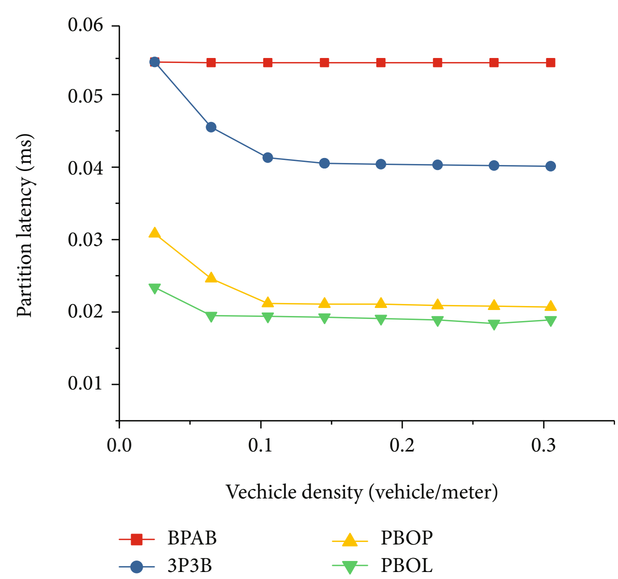

Figure 7: .Partition delay under different vehicle densities.

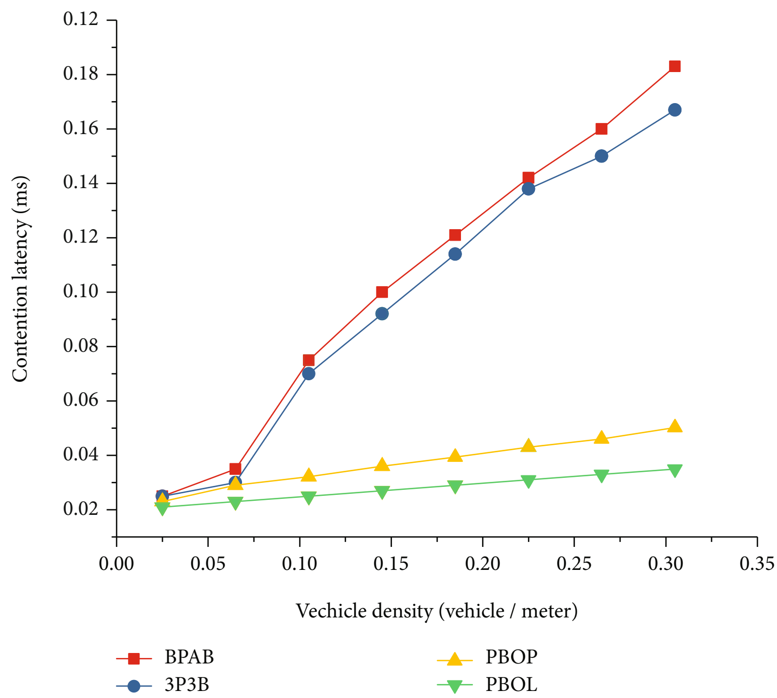

Figure 8: Delay of contention under different vehicle densities.

$$T_d = T_{\text{init}} + T_{\text{partion}} + T_{\text{contention}} + T_{\text{data}}. \quad (4)$$

One-hop message progress is the ratio of the road length that the selected relay can cover and $\text{Length}_{\text{optimal}}$, the equation for it is shown as the formula (5). $\text{Length}_{\text{relay}}$ represents the length of road that the selected relay can cover, and the disseminated message has not arrived. Assuming the node can be at any road location in the current sender's communication range, $\text{Length}_{\text{optimal}}$ means the maximum length of the node can cover and the disseminated message has not arrived.

$$\beta = \frac{\text{Length}_{\text{relay}}}{\text{Length}_{\text{optimal}}}. \quad (5)$$

Message dissemination speed is the propagation velocity of the message disseminated, and the equation for it is shown as the formula (6). $\text{Length}_{\text{road}}$ represents the length of road that the message has been arrived. T_{consu} means the time consumed to cover the road segment with the length being $\text{Length}_{\text{road}}$.

$$V_{\text{speed}} = \frac{\text{Length}_{\text{road}}}{T_{\text{consu}}}. \quad (6)$$

5.2. Simulation Results. The partition latency of the proposed solution is checked with the road segment between S_1 and E_1 of Figure 5. The partition latency under the different vehicle densities is shown as Figure 7. The partition latency of BPAB keeps stable, and the partition latency of the other three methods decrease with the increment of the vehicle density. The number time slots spent for the partition procedure of BPAB is fixed as $M - 1$. If there are more available vehicles locate on the road segment, then there will be no need to waiting too long to select the segment with vehicles. The partition latency of PBOL is lower than PBOP, because the distance between vehicles and the reference point maybe similar but the road coverage capability of the vehicles maybe different. The advantage of PBOL is not obvious anymore with increase of vehicle density, because there will be more vehicles close to each other and these vehicles have the similar capacity of road coverage. As to these vehicles in PBOP, the distance from the reference point is also similar.

In order to verify the relay selection effectiveness of the method proposed, PBOL is compared with BPAB, 3P3B, and PBOP in the view of contention delay. The result is shown in Figure 8, we can see that the contention delay of PBOL is lower than another three methods. Because the relay node is selected based on the length of the road, it can cover instead of the distance from the sending node or the reference point. Some neighbor nodes may have the similar distance from the sending node or the reference point, but they have the different road cover capability and then they are mapped into different waiting slots. This can reduce the probability of collision and shorten the contention delay.

For the purpose of verifying the effectiveness of the proposed relay selection scheme, the proposed scheme PBOL is compared with BPAB, 3P3B, and PBOP in the term of one-hop average delay under different vehicle densities. The result is shown in Figure 9, and we can see that the delay of our method PBOL is lower than another three methods in term of one-hop average delay. Because the waiting delay of the neighbor nodes in our method is determined according to the length of the road it can cover, and nonequal

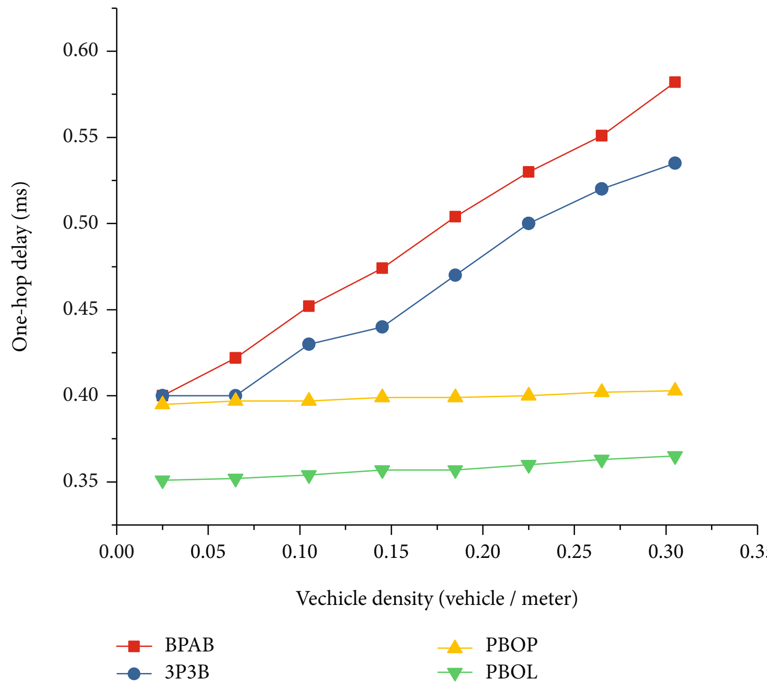

FIGURE 9: One-hop average delay under different vehicle densities.

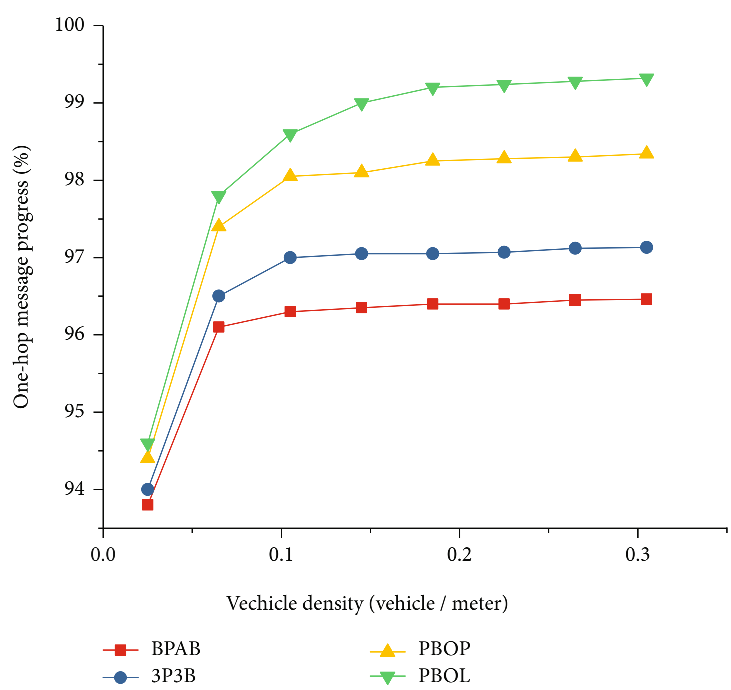

FIGURE 10: One-hop average message progress under different vehicle densities.

length partition of the coverage length is adopted. Collision probability of the neighbor nodes' response will be lower which results in the lower competition delay and one-hop delay.

The proposed method PBOL is compared with other three methods BPAB, 3P3B, and PBOP in terms of the average one-hop message progress. As the vehicle density increases, the average one-hop message progress of several schemes also increases to some extent and finally is maintained at a stable state, which is shown as Figure 10. That is because there are more available candidate nodes with the increment of the vehicle density. Once the vehicle density reaches a certain level, the improvement of average one-hop message progress is limited. PBOL has a better average one-hop message progress compared with the other three methods because PBOL selects the relay based on the

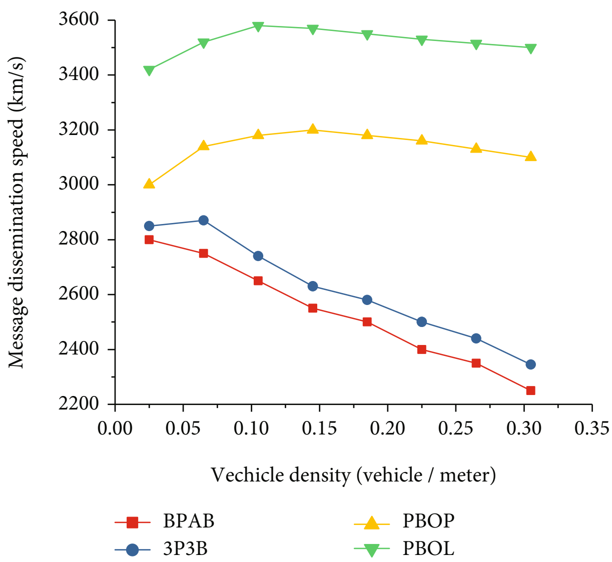

FIGURE 11: Message dissemination speed under different vehicle densities.

road coverage capability of the candidate node and the other three methods select the relay based on the distance between the candidate node and the reference point.

PBOL is compared with BPAB, 3P3B, and PBOP in terms of message propagation speed so as to verify the effectiveness of the relay node selection scheme proposed in this paper. The message propagation speed of several schemes under different vehicle densities is compared. The result is shown as Figure 11, and we can see that PBOL has obvious superiority compared with another three methods in term of the propagation speed. Because PBOL considers the road cover capability of the neighbor node, not the distance between the neighbor node and the sending node or the reference point. Meanwhile, we use bidirectional relay to broadcast the message when necessary. The method can make the message cover more parts of the road with less hops and improve the speed of message dissemination.

6. Conclusion

The paper proposed a relay selection method based on the maximum road coverage capacity to improve the message dissemination efficiency on curve road in VN. The method can reduce the waiting delay of neighbor nodes and improve the access efficiency. When there is an uncovered road segment between the current relay and the prehop sending node, this paper proposed a bidirectional message dissemination method based on the bidirectional relay selection, and the method can speed up the message dissemination in an emergency. The simulation results indicate that our proposed data dissemination solution is best when the speed of message dissemination is a real concern in VN. In the future, the data dissemination method based on the network coding will be explored in vehicular networks.

Data Availability

Requests for data, 12 months after publication of this article, will be considered by the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] D. L. Guidoni, G. Maia, F. S. H. Souza, L. A. Villas, and A. A. F. Loureiro, "Vehicular traffic management based on traffic engineering for vehicular ad hoc networks," *IEEE Access*, vol. 8, pp. 45167–45183, 2020.

[2] T. Liu, A. A. Abouzeid, and A. A. Julius, "Traffic flow control in vehicular multi-hop networks with data caching," *IEEE Transactions on Mobile Computing*, vol. 19, no. 1, pp. 231–244, 2020.

[3] D. Cao, K. Zeng, J. Wang et al., *Bert-based deep spatial-temporal network for taxi demand prediction*, IEEE Transactions on Intelligent Transportation Systems, 2021.

[4] A. Benmir, A. Korichi, A. Bourouis, M. Alreshoodi, and L. Al-Jobouri, "GeoQoE-Vanet: QoE-aware geographic routing protocol for video streaming over vehicular ad-hoc networks," *Computers*, vol. 9, no. 2, p. 45, 2020.

[5] Y. Sun, L. Xu, Y. Tang, and W. Zhuang, "Traffic offloading for online video service in vehicular networks: a cooperative approach," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 8, pp. 7630–7642, 2018.

[6] Q. Jian, Y. He, and X. Shen, "Improving video streaming quality in 5G enabled vehicular networks," *IEEE Wireless Communications*, vol. 25, no. 2, pp. 133–139, 2018.

[7] M. A. Yaqub, S. H. Ahmed, and D. Kim, "Asking neighbors a favor: cooperative video retrieval using cellular networks in VANETs," *Vehicular Communications*, vol. 12, pp. 39–49, 2018.

[8] G. Luo, Q. Yuan, H. Zhou et al., "Cooperative vehicular content distribution in edge computing assisted 5G-VANET," *China Communications*, vol. 15, no. 7, pp. 1–17, 2018.

[9] J. Chen, G. Mao, C. Li, W. Liang, and D.-g. Zhang, "Capacity of cooperative vehicular networks with infrastructure support: multiuser case," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 2, pp. 1546–1560, 2018.

[10] Y. Liu, S. Wang, Q. Zhao et al., "Dependency-aware task scheduling in vehicular edge computing," *IEEE Internet of Things Journal*, vol. 7, no. 6, pp. 4961–4971, 2020.

[11] J. Wang, C. Jin, Q. Tang, N. Xiong, and G. Srivastava, *Intelligent ubiquitous network accessibility for wireless-powered MEC in UAV-assisted B5G*, IEEE Transactions on Network Science and Engineering, 2021.

[12] M. Waqas, S. Tu, S. U. Rehman et al., "Authentication of vehicles and road side units in intelligent transportation system," *CMC-COMPUTERS MATERIALS & CONTINUA*, vol. 64, no. 1, pp. 359–371, 2020.

[13] J. Wang, H. Han, H. Li, S. He, P. K. Sharma, and L. Chen, "Multiple strategies differential privacy on sparse tensor factorization for network traffic analysis in 5G," *IEEE Transactions on Industrial Informatics*, vol. 18, no. 3, pp. 1939–1948, 2021.

[14] X. Zhang, Q. Miao, and Y. Li, "An adaptive link quality-based safety message dissemination scheme for urban VANETs," *IEEE Communications Letters*, vol. 22, no. 10, pp. 2104–2107, 2018.

[15] Y. Bi, H. Shan, X. S. Shen, N. Wang, and H. Zhao, "Multi-hop broadcast protocol for emergency message dissemination in urban vehicular ad hoc networks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 17, no. 3, pp. 736–750, 2016.

[16] W. Wang, T. Luo, and H. Kang, "A local information sensing-based broadcast scheme for disseminating emergency safety messages in IoV," *Mobile Information Systems*, vol. 2019, 11 pages, 2019.

[17] X. M. Zhang, L. Yan, K. H. Chen, and D. K. Sung, "Fast, efficient broadcast schemes based on the prediction of dynamics in vehicular ad hoc networks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 21, no. 2, pp. 531–542, 2020.

[18] H. S. Basheer and C. Bassil, "A review of broadcasting safety data in V2V: weaknesses and requirements," *Ad Hoc Networks*, vol. 65, pp. 13–25, 2017.

[19] M. Chaqfeh, A. Lakas, and I. Jawhar, "A survey on data dissemination in vehicular ad hoc networks," *Vehicular Communications*, vol. 1, no. 4, pp. 214–225, 2014.

[20] A. Mchergui, T. Moulahi, B. Alaya, and S. Nasri, "A survey and comparative study of QoS aware broadcasting techniques in VANET," *Telecommunication Systems*, vol. 66, no. 2, pp. 253–281, 2017.

[21] D. Tian, C. Liu, X. Duan et al., "A distributed position-based protocol for emergency messages broadcasting in vehicular ad hoc networks," *IEEE Internet of Things Journal*, vol. 5, no. 2, pp. 1218–1227, 2018.

[22] R. Karimi and S. Shokrollahi, "PGRP: predictive geographic routing protocol for VANETs," *Computer Networks*, vol. 141, pp. 67–81, 2018.

[23] M. Ryu and S.-H. Cha, "Mobility prediction based multi-directional broadcasting for both highway and urban vehicular sensor networks," *IEEE Access*, vol. 8, pp. 148595–148605, 2020.

[24] S. Jiang, Z. Huang, and Y. Ji, "Adaptive UAV-assisted geographic routing with Q-learning in VANET," *IEEE Communications Letters*, vol. 25, no. 4, pp. 1358–1362, 2021.

[25] O. Alzamzami and I. Mahgoub, "Link utility aware geographic routing for urban VANETs using two-hop neighbor information," *Ad Hoc Networks*, vol. 106, p. 102213, 2020.

[26] I. S. Alkhalifa and A. S. Almogren, "NSSC: novel segment based safety message broadcasting in cluster-based vehicular sensor network," *IEEE Access*, vol. 8, pp. 34299–34312, 2020.

[27] B. Ramakrishnan, R. Bhagavath Nishanth, M. Milton Joe, and M. Selvi, "Cluster based emergency message broadcasting technique for vehicular ad hoc network," *Wireless Networks*, vol. 23, no. 1, pp. 233–248, 2017.

[28] M. Seo, S. Lee, and S. Lee, "Clustering-based data dissemination protocol using the path similarity for autonomous vehicles," *Symmetry*, vol. 11, no. 2, p. 260, 2019.

[29] F. Abbas and P. Fan, "Clustering-based reliable low-latency routing scheme using ACO method for vehicular networks," *Vehicular Communications*, vol. 12, pp. 66–74, 2018.

[30] A. Dua, P. Sharma, S. Ganju et al., "RoVAN: a rough set-based scheme for cluster head selection in vehicular ad-hoc networks," in *IEEE Global communications conference (GLOBECOM).*, pp. 206–212, Abu Dhabi, United Arab Emirates, December 2018.

[31] J. Garbiso, A. Diaconescu, M. Coupechoux, and B. Leroy, "Fair self-adaptive clustering for hybrid cellular-vehicular networks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 2, pp. 1225–1236, 2021.

[32] M. Ayyub, A. Oracevic, R. Hussain, A. A. Khan, and Z. Zhang, "A comprehensive survey on clustering in vehicular networks: current solutions and future challenges," *Ad Hoc Networks*, vol. 124, article 102729, 2022.

[33] C. Cooper, D. Franklin, M. Ros, F. Safaei, and M. Abolhasan, "A comparative survey of vanet clustering techniques," *IEEE Communications Surveys & Tutorials*, vol. 19, no. 1, pp. 657–681, 2017.

[34] B. T. Sharef, R. A. Alsaqour, and M. Ismail, "Vehicular communication ad hoc routing protocols: a survey," *Journal of Network and Computer Applications*, vol. 40, pp. 363–396, 2014.

[35] S. Tiennoy and C. Saivichit, "Using a distributed roadside unit for the data dissemination protocol in VANET with the named data architecture," *IEEE Access*, vol. 6, pp. 32612–32623, 2018.

[36] P. Li, T. Zhang, C. Huang, X. Chen, and B. Fu, "RSU-assisted geocast in vehicular ad hoc networks," *IEEE Wireless Communications*, vol. 24, no. 1, pp. 53–59, 2017.

[37] X. Fan, B. Yang, R. Yamamoto, and Y. Tanaka, "Road side unit assisted stochastic multi-hop broadcast scheme for instant emergency message propagation," in *17th International Conference on Advanced Communication Technology (ICACT).*, pp. 450–457, PyeongChang, Korea (South), July 2015.

[38] K. Liu, L. Feng, P. Dai, V. C. Lee, S. H. Son, and J. Cao, "Coding-assisted broadcast scheduling via memetic computing in SDN-based vehicular networks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 19, no. 8, pp. 2420–2431, 2017.

[39] M. Dai, S. Lu, N. Zhang, X. Li, and H. Wang, "Error correction CP-BZD storage codes for content delivery in drive-thru internet," *IEEE Transactions on Intelligent Transportation Systems*, vol. 21, no. 11, pp. 4869–4882, 2020.

[40] S. Huang, C. Huang, Y. Yin, D. Wu, M. W. A. Ashraf, and B. Fu, "UAV-assisted data dissemination based on network coding in vehicular networks," *IET Intelligent Transport Systems*, vol. 16, no. 4, pp. 421–433, 2022.

[41] Y. Nam, H. Choi, Y. Shin, E. Lee, and E.-K. Lee, "Adaptive content precaching scheme based on the predictive speed of vehicles in content-centric vehicular networks," *Sensors*, vol. 21, no. 16, 2021.

[42] M. Samir, D. Ebrahimi, C. Assi, S. Sharafeddine, and A. Ghrayeb, "Leveraging UAVs for coverage in cell-free vehicular networks: a deep reinforcement learning approach," *IEEE Transactions on Mobile Computing*, vol. 20, no. 9, pp. 2835–2847, 2021.

[43] Y. Zhou, N. Cheng, N. Lu, and X. S. Shen, "Multi-UAV-aided networks: aerial-ground cooperative vehicular networking architecture," *IEEE Vehicular Technology Magazine*, vol. 10, no. 4, pp. 36–44, 2015.

[44] C. Suthaputchakun, M. Dianati, and Z. Sun, "Trinary partitioned blackburst-based broadcast protocol for time-critical emergency message dissemination in VANETs," *IEEE Transactions on Vehicular Technology*, vol. 63, no. 6, pp. 2926–2940, 2013.

[45] D. Cao, Y. Liu, X. Ma et al., "A relay-node selection on curve road in vehicular networks," *IEEE Access*, vol. 7, pp. 12714–12728, 2019.

[46] J. Sahoo, E. H.-K. Wu, P. K. Sahu, and M. Gerla, "Binary-partition-assisted MAC-layer broadcast for emergency message dissemination in VANETs," *IEEE Transactions on Intelligent Transportation Systems*, vol. 12, no. 3, pp. 757–770, 2011.