electronics

MDPI

Article

Mitigating Broadcasting Storm Using Multihead Nomination Clustering in Vehicular Content Centric Networks

Ayesha Siddiqa, Muhammad Diyan, Muhammad Toaha Raza Khan, Malik Muhammad Saad and Dongkyun Kim *

School of Computer Science & Engineering, Kyungpook National University, Daegu 41566, Korea; asiddiqa@knu.ac.kr (A.S.); m.diyan@knu.ac.kr (M.D.); toaha@knu.ac.kr (M.T.R.K.); maliksaad@knu.ac.kr (M.M.S.)
* Correspondence: dongkyun@knu.ac.kr

Abstract: Vehicles are highly mobile nodes; therefore, they frequently change their topology. To maintain a stable connection with the server in high-speed vehicular networks, the handover process is restarted again to satisfy the content requests. To satisfy the requested content, a vehicular-content-centric network (VCCN) is proposed. The proposed scheme adopts in-network caching instead of destination-based routing to satisfy the requests. In this regard, various routing protocols have been proposed to increase the communication efficiency of VCCN. Despite disruptive communication links due to head vehicle mobility, the vehicles create a broadcasting storm that increases communication delay and packet drop fraction. To address the issues mentioned above in the VCCN, we proposed a multihead nomination clustering scheme. It extends the hello packet header to get the vehicle information from the cluster vehicles. The novel cluster information table (CIT) has been proposed to maintain several nominated head vehicles of a cluster on roadside units (RSUs). In disruptive communication links due to the head vehicle's mobility, the RSU nominates the new head vehicle using CIT entries, resulting in the elimination of the broadcasting storm effect on disruptive communication links. Finally, the proposed scheme increases the successful communication rate, decreases the communication delay, and ensures a high cache success ratio on an increasing number of vehicles.

Keywords: vehicular content centric network (VCCN); pending interest table (PIT); cluster information table (CIT); roadside units (RSU); hello packet (HP)

check for updates

Citation: Siddiqa, A.; Diyan, M.; Khan, M.T.R.; Saad, M.M.; Kim, D. Mitigating Broadcasting Storm Using Multihead Nomination Clustering in Vehicular Content Centric Networks. *Electronics* **2021**, *10*, 2270. https://doi.org/10.3390/electronics10182270

Academic Editor: Martin Reisslein

Received: 15 July 2021
Accepted: 14 September 2021
Published: 15 September 2021

1. Introduction

The internet of things (IoT) interconnects the complex network of devices and enables them to exchange information. It uses that information in various applications such as smart health, smart city, smart vehicles, smart homes, business automation, and social connection. For example, smart health monitors patients in remote locations and provides timely medical service in case of emergency. However, social IoT enables members of society to communicate with one another and share ideas. In smart cities, the responsive smart infrastructure creates an automated environment. IoT also changes the business environment and increases competition in the market. Moreover, smart vehicles automate the traveling experience and provide the most efficient communication and reliable path in abnormal situations. These next-generation vehicles (smart vehicles) have changed travel experience and communication process. These smart vehicles are talkative nodes and continuously exchange beacon messages with other vehicles [1,2]. In a beacon message, they share vehicle ID, direction, and speed information with the neighbor vehicle. The neighbor vehicles receives the packet and generates the beacon packet in response [3–6]. Due to the high speed of mobile nodes, they change the topology frequently and create communication delay, disruptive communication links, and network load.

However, these vehicles also communicate with infrastructure for a quick response [7,8]. In vehicle-to-infrastructure (V2I) communication, vehicles forward information to road side units (RSUs). When an RSU receives the message from the vehicle, it adds the required information. However, an RSU is an uncompromised entity in V2I communication [9]. Therefore, an RSU sends a quick response to vehicles, provides efficient data delivery, ensures efficient caching, and provides reliable communication. However, if the vehicle changes its location, then the handover process with the new RSU starts again, which increases the network load and packet drop ratio.

To solve the above-mentioned problem, an information-centric network (ICN) is proposed. It is a content-based communication network instead of IP-based communication. When the requester vehicle propagates the request packet, each intermediate vehicle receives the request, uses the prefix match, and searches the requested content in the local cache of the vehicle. If the content is not found, then it updates entries in the table and forwards them to other vehicles in its vicinity till it is found the provider vehicle [4,5]. The producer vehicle sends the response in a response packet and uses the reserve path of the request packet. However, the content-centric network (CCN) is a project of ICN. It uses an interest packet for request generation and a data packet for interest satisfaction. It updates pending interest table (PIT) and forward information base (FIB) entries according to the communication process. Due to the high mobility of vehicles and unpredictable location in VANETs, the content centric network (CCN) is a decent alternative to overcome the previously specified problems, as each vehicle has a built-in cache to satisfy the requests at any location. For this purpose, it proposes unique PIT and FIB headers to maintain entries during communication to reserve paths. In addition, there are various VANET protocols that have been proposed recently to overcome mobility issues, minimize communication delay, and ensure efficient communication [4,7,10,11].

Various cluster-based routing protocols have been proposed to group vehicles based on common interests [12]. In every cluster, the head vehicle is selected to satisfy the maximum interests of the network. However, in the case of disruptive communication links due to cluster head vehicle mobility, the vehicles create an interest-broadcasting storm, and, the nomination process to select the new cluster head vehicle starts again. This increases the network load and communication delay and decreases the packet delivery ratio.

We propose a method for mitigating broadcasting storms using multihead nomination clustering in vehicular content centric networks. The novel contributions of this method are given below:

- It extends the hello packet header to extract the information from neighboring vehicles. This information is used to select the most appropriate head vehicles (HV) in the clustered network.
- If there is more than one head vehicle HV in the network, then its information is shared with the RSU. The RSU receives that information and maintains it in the cluster information table (CIT).
- Depending on information, the RSU selects the most appropriate HV to satisfy the maximum number of interests in the network.
- If the interesting content is not available in the network, then interest is forwarded from HV to RSU. If there is a disruptive communication link, the RSU utilizes the CIT entries to select the new HV to eliminate the broadcasting storm in the network.

The motivation of the proposed scheme is to mitigate the broadcasting storm on disruptive communication links in the network. Moreover, the proposed scheme is intended to avoid the re-selection process of head vehicles by maintaining a unique cluster information table (CIT). It mitigates the excessive packet flow in the network. However, if the requested content is not available in the network, then the proposed scheme also enables the only head vehicle to send a request to RSU. This process minimizes the bottleneck effect on RSU. The objective for proposed scheme to minimize the communication delay, increase the communication efficiency and mitigates the broadcasting storm on disruptive communication links.For The remaining paper is structured as follows. Section 2 briefly explains the previous contributions of the related literature. Section 3 gives the overview of the system model in detail. Section 4 discusses the simulation setup and its results in detail. The conclusion and future work are explained in Section 5.

2. Related Work

Vehicles are continuously exchanging information with one another and propagating interest in the network. Vehicles with common interests are clustered together for efficient request satisfaction. In each cluster, the head vehicle is selected to satisfy most requests. However, in case of disruptive communication links due to head vehicle mobility, a broadcasting storm is created in the network. Moreover, the head vehicle selection process restarts again and creates excessive packet flooding in the network. It also increases the communication delay between vehicles. The most relevant literature regarding the above-mentioned problems is summarized in the following sub-sections.

2.1. Clustering Schemes in CCN

For the dissemination of content, a deep-learning-based approach is used in [13]. It consists of three phases. In the first phase, the probability of a stable vehicle connection is determined to identify vehicle pairs using the Wiener process. In the second phase, a convolutional neural network is used to find the social relationship, e.g., between pairs of vehicles. The social relationship between vehicles is estimated for optimal network performance; for example, data held by vehicle V_j requested by Vehicle V_i should not be broadcasted. A convolutional neural network learns automatically from the values of its filter to identify vehicle community/social relationships. In the last phase, once a V2V pair is confirmed, the content is disseminated. Based on social similarity in [14], cooperative caching is studied considering vehicle mobility. Furthermore, the content replacement policy is investigated considering the popularity of the content, i.e., the time between requesting the same content.

The scheme proposed in [15] uses the Markov model to predict the mobility direction of vehicles. The clusters are made based on distance, the number of hops, link expiration time, and the probability that neighbors maintain their status. In the case of head vehicle changing its location, the head vehicle selection process starts again. The author in [16] proposed a cluster-based device mobility management scheme. The complete cluster information is maintained in the cluster head vehicle. Before leaving the cluster, the provider vehicle forwards the current location information to the cluster head to satisfy the pending interests.

The research paper [17] discusses the various approaches of cluster vehicular networks. In [18], two techniques, fuzzy C mean and Q-LEACH, are combined to cluster the vehicles in the network. The optimal cluster head vehicle is selected based on the distance and degree of the neighbor vehicle. This information is collected through sensor nodes. It achieves a lower latency rate and higher throughput. In the research paper [19], the vehicles with the same trajectory made a cluster to ensure successful communication. The cluster head (CH) was selected based on direction and speed information. In the case of a request, the RSU forwards required data to CH to cache the data and forward them on request to the provider. The authentication of the cluster and data reliability is not provided.

2.2. Routing Schemes in CCN

The author of [20] proposed updated content forwarding on the network to increase the cache hit ratio with minimum communication delay. According to the routing scheme proposed in [21], the most popular content has been cached in the network to satisfy the interest packets. It achieves a high packet delivery ratio. In their research paper [5], Maryam et al. used trajectory information sharing between highly mobile vehicles to ensure successful request satisfaction. The complete trajectory match for interest satisfaction leads the content provider vehicle away from the consumer vehicle. It increases the communication delay in the network.

In [22], the Markov decision model is used to predict the movement direction of vehicles to cache the most popular content on RSU and vehicles to achieve a high packet delivery ratio. In [10], the content-centric network properties are utilized in smart vehicles. It ensures a successful packet delivery rate by sharing the route information to neighbor vehicles. The vehicles with the same direction respond to each other. It ensures successful communication within the minimum delay.The scheme proposed in [23] tracks the movement of the vehicle on the specific lanes and ensures successful communication. The resource allocation problem is modeled as a Markov decision model process and using approximation function in [24]. The authors proposed a resource-allocation method based on an actor–critic (A3C) learning algorithm to achieve successful communication within high dimensions and have better convergence properties [24]. CCN is proposed for the collection of vehicular traffic information [25]. A unique name is assigned to traffic events, and location-based routing is adopted. For the efficient collection of information cache hit and cache miss is studied. The proposed caching is based on the vehicle movement and probability of the channel usage ratio. Caching and forwarding of content in NDN induces the redundancy of the content due to multiple copies of the same content, which leads to increase overhead in the network. In [26], optimal caching policy is studied based on the popularity of the content considering constraints such as available storage and bandwidth.

A probabilistic interest forwarding mechanism is presented in [27]. It considers the probability of forwarding the interest to be high in a low dense vehicular environment and vice versa. The Yaqub et al. [28] proposed a push-based data forwarding scheme. The relay vehicles receive the segmented data packets.

According to previous research findings, V2V provides efficient communication and various traffic-aware messages broadcasting to neighbor vehicles. It increases network load and compromises the delay. In V2I, vehicles request data from RSU to satisfy the requests. However, data authentication and privacy policy are not defined. Vehicles have a built-in cache to save data and satisfy requests. However, they did do provide the validity of data in the cache and RSU.

There are several research contributions that solve the problem of frequent communication link disruption between vehicles and decrease broadcasting storms in the network. In cluster-based vehicular routing protocols, head vehicles satisfy the interests of the network. However, if the head vehicle is not available in the network, it creates an interest broadcasting storm. This increases network load and packet collision probability, and re-polling for head vehicle selection increases the communication delay.

3. System Model Overview

In this section, the proposed scheme of mitigating broadcasting storm using multihead nomination clustering in a vehicular content-centric network is discussed. Later on, the working of the proposed scheme is discussed in detail along with a unique feature description and its implementation in two different scenarios. As shown in Figure 1, the proposed scheme includes several clusters on the road. Each cluster has a unique id $C = \{C1, C2, C3, \ldots, Cn\}$ and a cluster head vehicle id $HV = \{HV1, HV2, HV3, \ldots, HVn\}$. It is represented in separate sub-part of Figure 1. Each HV shares its information with the nearest RSU. This information is maintained in cluster information table (CIT). If HV changes its location, then RSU utilizes its CIT information to select a new HV. The RSU maintains the CIT of clusters and content in its database to satisfy the interests of clustered vehicles. The HV cache maintains the most similar content previously requested from the network and neighbor information table (NIT). The other vehicles in the cluster save the requested content and identity of HV to forward the requests. The proposed scheme extends the naïve hello packet header to obtain the information of the clustered vehicles. The novel head vehicle selection parameters include the speed of a vehicle, its location information to calculate the distance, the maximum similar cached content value, and the connection information in the cluster. If the vehicle has minimum distance from a neighbor, maximum similar cached content, maximum neighbor vehicles, and comparable speed, then it is selected as a head vehicle. This information is shared with RSU and maintained in cluster information table (CIT). If there are several head vehicles nominated by clusters, then CIT entries are used to compare the information and select the most appropriate vehicle as HV. The head vehicle satisfies the interest of vehicles not only in V2V communication but also in V2I communication.

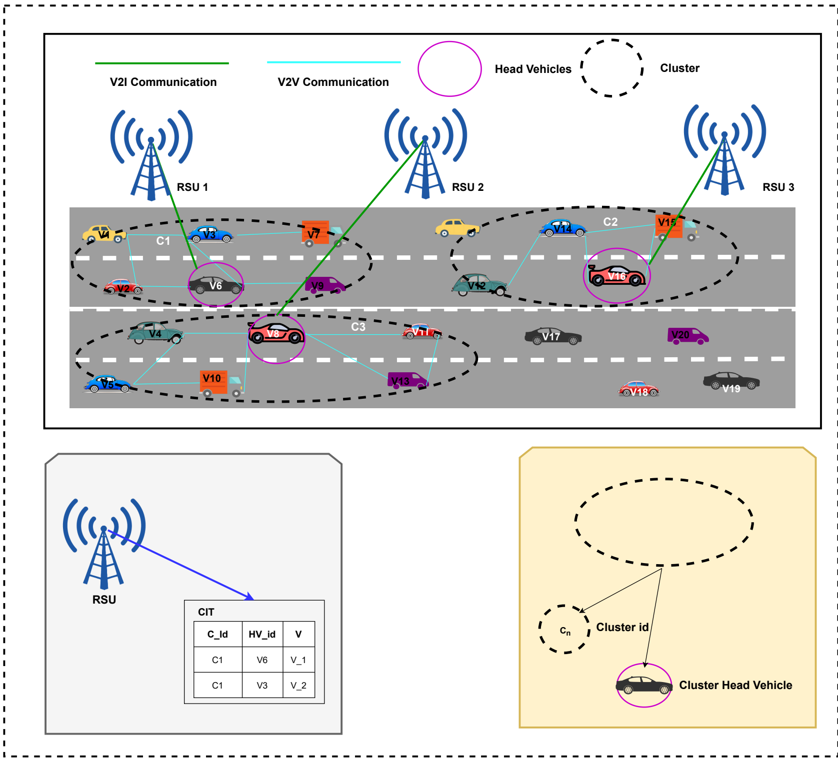


Figure 1. System Model of Proposed Scheme.

Initially, the distance between sender and receiver vehicles has been calculated. Equation (1) is used to calculate the Euclidean distance d_i between two vehicles. The i shows any number of vehicles $i = \{i_1, i_2, i_3, \ldots, i_n\}$. d_{x1} is the x-coordinate and d_{y1} is the y-coordinate of the sender vehicle. d_{x2} is the x-coordinate and d_{y2} is the y-coordinate of the receiver vehicle. After receiving the location information from the one-hop neighbor vehicles, each vehicle calculates its distance from its neighbor vehicle.

$$d_i = \sqrt{(d_{x2} - d_{x1})^2 + (d_{y2} - d_{y1})^2} \tag{1}$$

Speed s information is used to compare the mobility information of the vehicle. Each neighbor vehicle, which receives the speed information, calculates its speed difference to estimate the stability of the vehicle in the network using Equation (2). The disruptive communication links might be created if the speed difference between two vehicles is higher than the threshold. The s_{vn} is the speed of the receiver vehicle and s_{vi} is the speed of the sender vehicle.

$$s = \sqrt{(s_{vn} - s_{vi})^2} \tag{2}$$

Each vehicle shares its location, similar cached content, speed, and one-hop neighbor information in the network. h represents the number of hop counts to estimate the neighbor vehicles in the vicinity of the sender vehicle v_i. h is an integer number (1, 2, 3...n) to presents its connectivity in the network. The c represents the similarity of content between sender and receiver vehicle. Both are estimated using hello packet exchange. d is calculated using Equation (1). s is a speed evaluated through Equation (2). To calculate the V parameter to select the head vehicle given by Equation (3), some parameters are needed;

s, h, c, and d. This value is evaluated by each vehicle in the cluster. Based on Equation (3), the head vehicle is selected, whereas the total sum of $\alpha + \beta + \gamma = 1$.

$$V = (\alpha s + \beta h + \gamma c) \diagup d \tag{3}$$

The working of proposed routing protocol has been discussed in detail in the following subsection.

Working of Proposed Scheme

In this section, firstly, the working of the proposed scheme is explained in detail. Secondly, the algorithms have been discussed. Lastly, the implementation of the proposed scheme in various scenarios has been explained. Algorithm 1 explains the head vehicle selection in the cluster, and Algorithm 2 elaborates the working of the proposed routing protocol on disruptive communication links. The working of proposed scheme is discussed below.

Algorithm 1: Head Vehicle Selection Algorithm

Input: Speed s, Hop-count h, Similar cached content c and Distance d
Output: Head vehicle HV selection
v$_n$ exchange HP
v_i maintain HP entries in NIT
Calculate V=$(\alpha * s + \beta * h + \gamma * c)/d$
Compare V on v_i
Send V, HV_id and C_id $\longrightarrow$ RSU
RSU Save information $\longrightarrow$ CIT
if V_i<V_{i+1} **then**
    Select v$_{i+1}$ as HV
else
    Select v$_i$ as HV

Algorithm 2: Mobility Management Algorithm

Input: V in CIT
Output: new HV Selection
FIND HV in C$_i$
if HV = $FALSE$ **then**
    Search V_i in CIT
    if $CIT \longrightarrow V$ **then**
        Select new HV
    else
        HP exchange Starts again

Step 1: Each vehicle in the cluster broadcasts a hello packet in the network. The extended hello packet header is defined in Figure 2. The hello packet maintains the Vehicle ID and its Speed, and Location information along with cached Content IDs. The size of the extended hello packet fields is 22 bytes. This information is used to select the most appropriate head vehicle (HV) in the cluster.

Step 2: Each neighbor vehicle receives the hello packet and maintains the received information in the neighbor information table (NIT). It also shares its information in response. When the vehicle needs some content from the network, it broadcasts an interest packet in the network. There are several clusters are available on the road. Each cluster has a unique cluster_id (C_id).

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Version #   |       1       |         Packet length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Vehicle Id           |          Speed*4Bytes         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Area ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |             AuType            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Location (X)                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Location (Y)                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Content Ids                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Network Mask                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         HelloInterval         |    Options    |    Rtr Pri    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     RouterDeadInterval                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Designated Router                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Backup Designated Router                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Neighbor                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              ...                              |
```

Figure 2. Multihead selection-scheme-extended hello packet.

Step 3: Each cluster shares its C_id, head vehicle ID (HV_id), and value V with the nearest RSU. The information is maintained in CIT. The table header of CIT is shown in Figure 3. If there are several nominated head vehicles in the cluster, then the RSU uses that information in CIT to select the most appropriate HV in the network. The RSU also informs the other vehicles in the cluster.

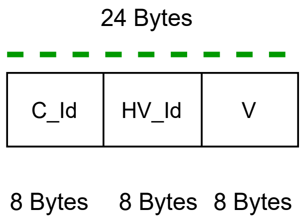


Figure 3. RSU Cluster Information Table (CIT).

Step 4: If the requested content is not available in the relay vehicle content store, then it forwards it to the HV. Now, the head vehicle satisfies the interest of the vehicle using a data packet. If the content is not available in the network, then HV forwards the interest packet to the nearest RSU.

Step 5: Now, RSU sends the requested content to the HV. Then, head vehicle forwards the data packet to the requesting vehicle.

Algorithm 1 explains the process of head vehicle selection in the cluster. Firstly, all vehicles (v_n) in the cluster share their information in the cluster using an extended hello packet (HP). Each vehicle v_i that receives the HP maintains the information in the neighbor information table (NIT) and sends the response. Every vehicle calculates the values of V by using that information (s, h, c and d) and compares the values of V on v_i. If there are several head vehicles (HV) that are nominated in the cluster, then values of V, along with HV_id and cluster number C_id, are sent to RSU. Each RSU maintains that information in

CIT. After that, the RSU compares values of V_i and V_{i+1}. Furthermore, it selects the HV that has the highest value V. The V is calculated using Equation (3).

Algorithm 2 describes the proposed scheme HV selection on disruptive communication links. Before leaving the cluster C_i, HV sends the leave packet to RSU. Now, if the RSU does not find the HV in the cluster, then RSU searches the new V_i entry in its CIT. If the value of V is available in CIT, then the new head vehicle HV is selected. Otherwise, if there is no entry in CIT regarding that particular cluster, then the hello packet (HP) will be exchanged again.

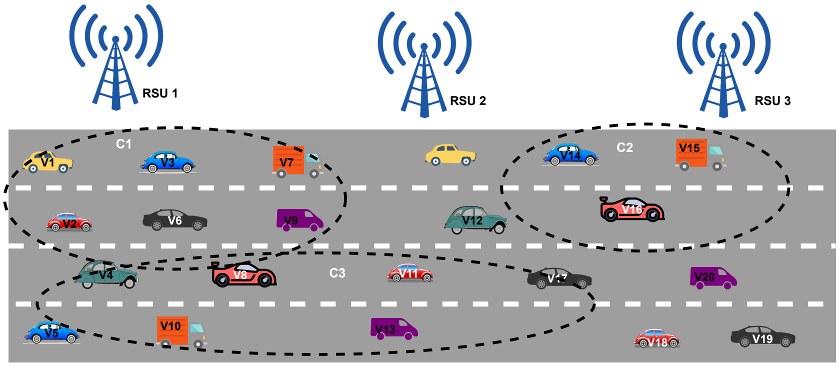
The proposed scheme is tested in two different scenarios. Scenario 1 explains the working of the proposed scheme in stable network topology, and scenario 2 describes the working of the proposed solution in dynamic network topology. A detailed description is given below.

Scenario 1: Stable Network Topology

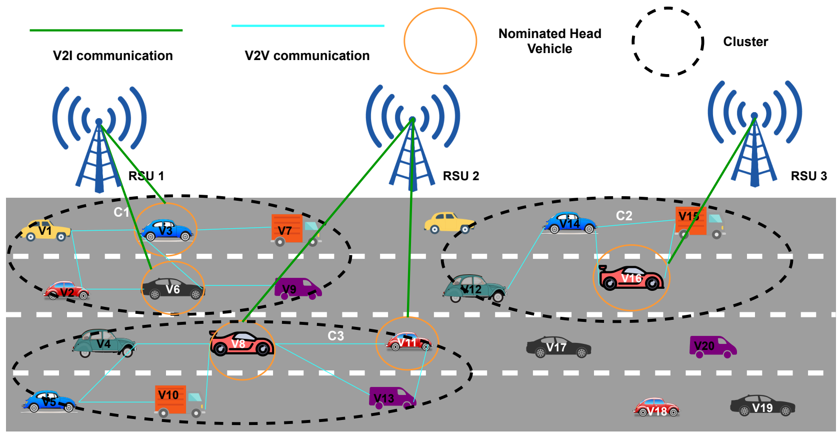
As shown in Figure 4a, if vehicles are interested in similar content, then they are grouped in the same cluster. Each cluster has a unique identity. After the creation of the cluster, vehicles exchange the hello packet to calculate the V and nominate the HV in its vicinity, as shown in Figure 4b. If there are several HV nominated in the cluster, then this information is forwarded to the RSU along with the cluster ID and vehicle ID. When RSU receives the information, it maintains that information in CIT and selects the vehicle that has a maximum value of V as HV, as shown in Figure 4c. Figure 5 shows that the interest packets start forwarding to the HV. The HV receives the interest packet and satisfies them using the data packet. The HV satisfies the interest of the network. If the requested content is not available in the cluster, then the HV forwards the interest packet to RSU, and RSU sends the response using the data packet to HV.

Scenario 2: Dynamic Network topology

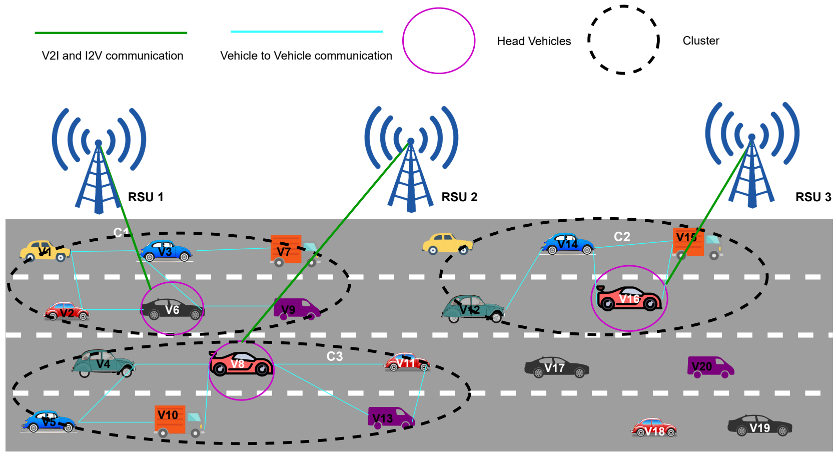
The vehicles are highly mobile nodes, and the topology changes frequently. The frequent communication link disruption creates a broadcasting storm and increases communication delay. The proposed scheme maintains several entries of nominated HV on RSU. Therefore, if a head vehicle moves out of the cluster, then, while leaving HV, it sends the leave packet to the RSU. The leave packet contains entries of vehicle id and cluster id. While leaving the cluster, the HV whose v_{id} is 5, send its information to RSU. Now the RSU has the information of other HVs of that cluster. It therefore selects the alternative vehicle as new HV and informs other vehicles about the updated HV ID, as shown in Figure 6. Now, all interest packets start forwarding to new HVs and HV stats forwarding data packets in response.



(**a**) Proposed Scheme clustered Vehicles.



(**b**) Multiple head vehicle selection and Information sharing with RSU (roadside units).



(**c**) Proposed Scheme Head Vehicle Selection.

Figure 4. Multihead Selection Scheme working.

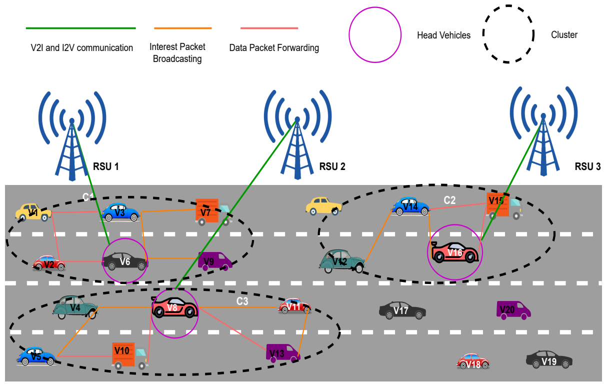


Figure 5. Interest Packet Broadcasting and Data Packet Forwarding in Proposed Scheme.

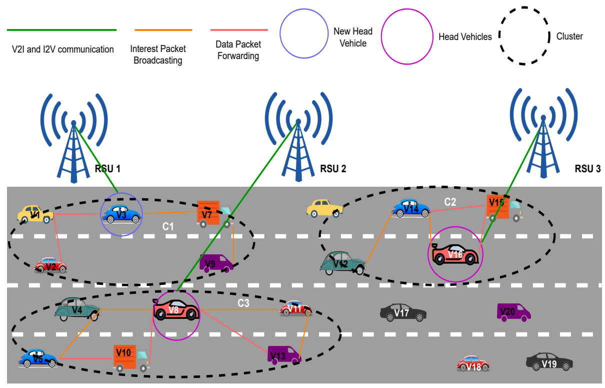


Figure 6. New Head Vehicle Selection in Proposed Scheme.

4. Simulation Setup

In this section, the performance of the proposed scheme is evaluated and compared with IBFS [10], COMP [15], and MCRP2 [29] routing protocols. The proposed scheme extended the hello packet header and uses novel CIT to eliminate the broadcasting on disruptive communication links. In the case of disruptive communication links, it uses CIT entries to select the alternative communication delay because there is no need to restart the HV. It also reduces the c head vehicle selection process. The elimination of broadcasting on broken edges and transferring the head vehicle selection process from vehicles to RSU minimizes the network load and excessive packet flooding.

The proposed scheme is simulated in ns2 tcl script, and its performance is measured using awk script. The parameters and specifications used during implementation are defined in Table 1. The simulation parameters are selected from the literature. The performance of the proposed scheme is evaluated using four parameters. There parameters and results are explained below:

1. Packet Delivery Ratio $(PDR\%)$
   PDR is a successful packet delivery between various vehicles. The core goal of the proposed scheme is to ensure successful communication. Equation (4) shows the percentage calculation of PDR. The total received message (M_r) is divided by total sent messages (M_s) in the cluster, by various consumer vehicles, and multiplied by 100 for the percentage.
   $$PDR(\%) = \frac{M_r \times 100}{M_s} \tag{4}$$
2. Communication Delay (sec)
   This is the average time (t) taken by the packet that was generated from the source and reached the destination. The communication delay is calculated in seconds. The fol-

lowing Equation (5) shows the summation of the average time taken by packets in communication.

$$\sum_{1}^{n} t_n sec \tag{5}$$

3. Interest Drop Fraction $(IDF\%)$
The proposed scheme eliminates the broadcasting of disruptive communication links. Therefore, the interest packet drop fraction is minimum on an increasing number of vehicles. Moreover, if the interested content is not available in the network, then HV forwards the interest packet to RSU. The equation to calculate IDF is given below.

$$IDF(\%) = 100 - PDR \tag{6}$$

4. Cache Success Ratio (CSR)
The CSR is the number of requests satisfied by the head vehicle. The cache miss ratio (CM) is the number of dropped requests or unsatisfied requests. CH is the number of requests satisfied by the vehicles. Equation (7) to calculate CSR is given below.

$$CSR = \frac{CH}{CH + CM} \tag{7}$$

Table 1. Simulation Parameters.

Parameters	Specifications
Simulator	NS2
Area Of Simulation	10,000 m × 10,000 m
RSU Range	500 m–1000 m
Vehicle Range	300–600 m
No of Vehicles	50, 100, 150, 200, 250
No of RSUs	Varies
MAC Layer	802.11 p
Packet Size	1024 Bytes
Data Size	1 KB
Query Size	5 per s
Cache Update	13 s

Experimental Results Analysis

The proposed scheme is evaluated in two different scenarios. The first scenario is to evaluate the performance of the proposed scheme in a stable topology. In the second scenario, the performance is evaluated in dynamic topology. A detailed discussion is given in the section below.

1. Packet Delivery Ratio (PDR %)
According to Figure 7, the results show that with the increasing size of vehicles, the PDR of the proposed scheme increases compared to COMP. This enables satisfying the interest of vehicles through the head vehicle. If the content is not available in the cluster, then it forwards to the RSU. The RSU sends the data packet in response. Only HV can send interest packets and receive the data packets from RSU. In the case of disruptive communication links, it eliminates the broadcasting, and RSU uses CIT entries to select the new HV. This minimizes the packet collision probability. Moreover, if the content is not available in the network, then it is satisfied by the RSU. Therefore the interest satisfaction rate also increases with the increasing number of vehicles. However, in the case of COMP, the Markov model is used to predict the mobility of the vehicle. However, if the vehicle moves out of the communication range, then the communication process starts again. Therefore, the PDR of COMP

decreases with an increasing number of vehicles. IBFS and MCRP2 do not handle disruptive communication links.

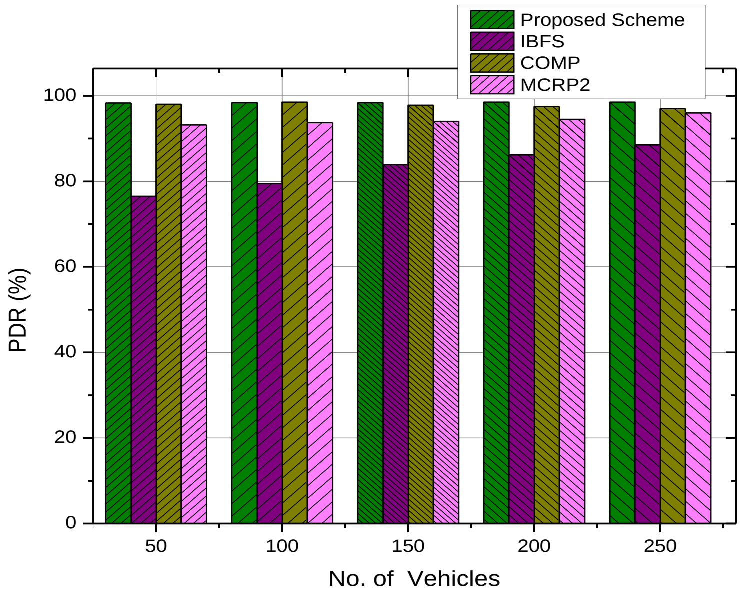


Figure 7. Packet Delivery Ratio of Multihead Selection Scheme.

2. Communication Delay (s)
   As shown in Figure 8, the communication delay in the proposed scheme decreases with the increasing number of vehicles because the interest is satisfied from the HV. Initially, the delay is high because the requested content is not available in the network. However, once the content is available in the CS of vehicles, then with an increasing number of vehicles, the communication delay decreases. Moreover, if the content is not available in the network, then the RSU satisfies the interest packet. On disruptive communication links, the nominates the new HV, so it eliminates the HV nomination process in V2V communication. It provides efficient communication within the minimum delay. In the case of COMP, with disruptive communication links in the cluster, the head vehicle selection process starts again in V2V communication. IBFS has the highest communication delay because it uses selective interest packet forwarding, which increases the communication delay. The communication delay of COMP decreases upon increasing number of vehicles, because the PDR is also low compared to the proposed scheme. In the case of disruptive communication links, the link establishment process starts again.
3. Interest Drop Fraction (IDF %)
   As shown in Figure 9, the IDF of the proposed scheme decreases with an increasing number of vehicles because it uses CIT entries to handle the disruptive communication links. In the case of COMP, the IDF is high because with disruptive communication links, the link establishment process starts again. IBFS starts broadcasting on disruptive communication links so its IDF is high with an increasing number of vehicles. So, using CIT entries and V2I communication in the proposed scheme ensures less IDF compared to IBFS, COMP, and MCRP2.

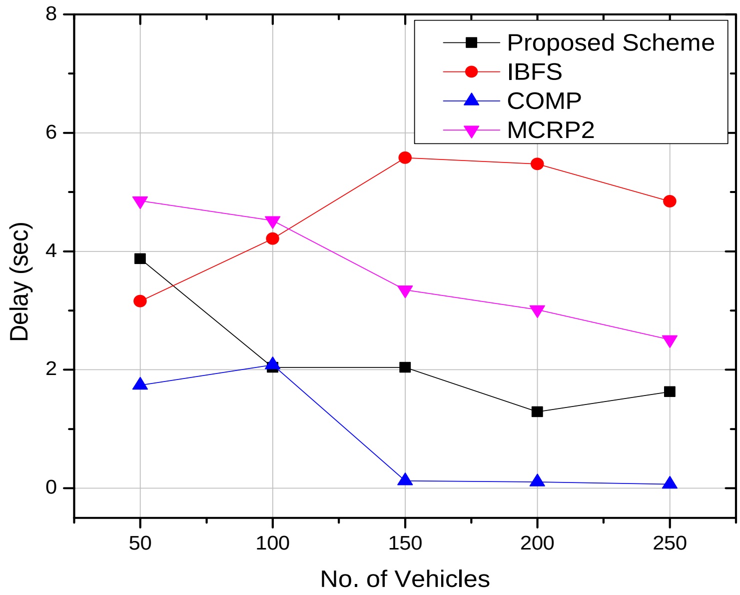


Figure 8. Average Communication Delay of Multihead Selection Scheme.

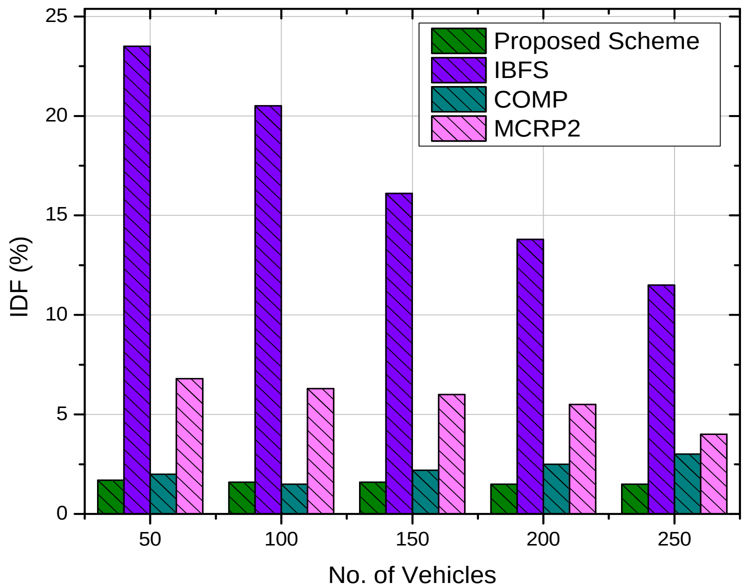


Figure 9. Interest packet Drop Fraction of Multihead Selection Scheme.

4. Cache Success Ratio (CSR)
CSR is the number of successful packets satisfied in the cluster. As shown in Figure 10, the CSR of the proposed scheme is higher than COMP because it grouped the vehicles with the same interest. The maximum interests are satisfied by the HV. If the content is not available, then HV forwards the interest to RSU. In the context of disruptive communication links, the RSU has a list of other nominated HV. Therefore, instead of re-selection of HV, the new HV is nominated by RSU to satisfy the interest packets. In the case of COMP, to satisfy the interest packet on disruptive communication links, the cluster HV selection starts again. It decreases the CSR in COMP. IBFS and MCRP2 also show increments in CSR but lower than the proposed scheme.

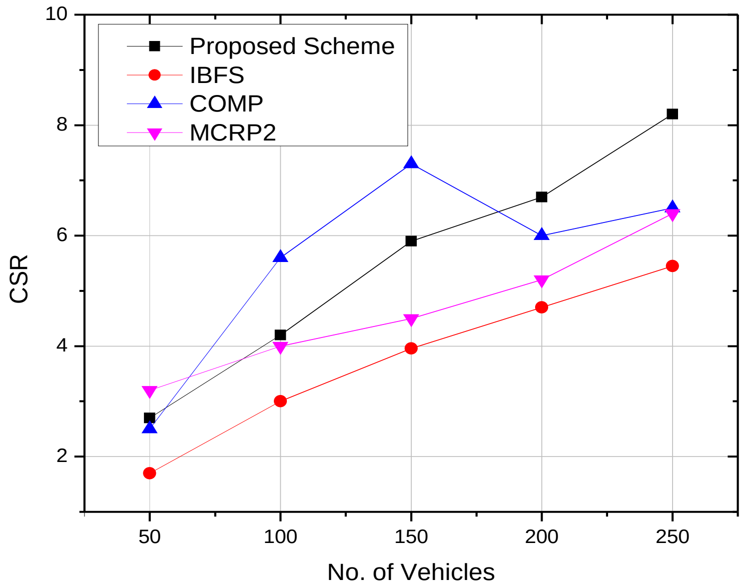


Figure 10. Cache Success ratio of Multihead Selection Scheme.

5. Conclusions and Future Work

Similar-interest vehicles are clustered together to satisfy requests through head vehicles. However, vehicles are highly mobile nodes and change topology frequently. If the vehicles create disruptive communication links, then it creates a broadcasting storm. Moreover, if the head vehicle moves out of the cluster, then the head vehicle selection process starts again. Therefore, the proposed scheme, namely mitigating the broadcasting storm using multihead nomination clustering in a vehicular-content-centric network, provides efficient communication within the minimum delay. It clusters the vehicles that have the same interest in the network. It extends the hello packet header to fetch the information from the vehicles. This information is used to select the HV of the cluster to satisfy the maximum interest of the network. Moreover, if the interesting content is not available in the network, instead of forwarding individual interest packets by vehicles to the RSU, the proposed scheme only allows HV to forward the interest packet to RSU and receive the response. There could be a number of vehicles nominated as the HV. In this case, the proposed scheme maintains the nominations in the CIT on the RSU. In the case of disruptive communication links due to HV mobility, the RSU uses those CIT entries to select the new HV. It eliminates the broadcasting storm and excessive packet flooding in the network. Moreover, it minimizes the communication delay and the network load. If the content is not available in the network, then RSU satisfies the interest of the network. It increases the packet delivery ratio. The results show that the proposed scheme achieves high PDR within minimum delay and less IDF compared to other routing protocols. The proposed scheme increases the communication efficiency of clustered vehicular networks. The proposed scheme provides an efficient methodology for selection of head vehicles and broadcasting storm mitigation in a highly dynamic network. However, vehicles have limited caching capacity, and the proposed scheme did not provide any content caching mechanism. In the future, we will work on the content update and caching scheme based on a multi-criteria content selection technique. We also aim to implement the proposed scheme in the real world.

Author Contributions: Conceptualization, A.S. and M.D.; Investigation, D.K.; Methodology, A.S. and D.K.; Supervision, D.K.; Visualization, M.D. and M.T.R.K.; Writing—original draft, A.S.; Writing—review and editing, M.D., M.T.R.K., and M.M.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2016R1D1A3B01015510).

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Not Applicable.

Acknowledgments: This research was collectively supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2016R1D1A3B01015510) and by the BK21 FOUR project (AI-driven Convergence Software Education Research Program) funded by the Ministry of Education, School of Computer Science and Engineering, Kyungpook National University, Korea (4199990214394).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Chen, C.; Wang, C.; Qiu, T.; Atiquzzaman, M.; Wu, D.O. Caching in vehicular named data networking: Architecture, schemes and future directions. *IEEE Commun. Surv. Tutor.* **2020**, *22*, 2378–2407.
2. Li, L.; Wang, W.; Gao, Z. Driver's Social Relationship Based Clustering and Transmission in Vehicle Ad Hoc Networks (VANETs). *Electronics* **2020**, *9*, 298.
3. Chiluveru, R.; Gupta, N.; Teles, A.S. Distribution of Safety Messages Using Mobility-Aware Multi-Hop Clustering in Vehicular Ad Hoc Network. *Future Internet* **2021**, *13*, 169.
4. Maryam, H.; Wahid, A.; Shah, M.A. Mitigating broadcast storm in interest/data packet forwarding in vehicular content centric networking. In Proceedings of the 2017 International Conference on Communication Technologies (ComTech), Rawalpindi, Pakistan, 19–21 April 2017; pp. 162–167.
5. Maryam, H.; Shah, M.A.; Arshad, S.; Siddiqa, A.; Wahid, A. TFS: A reliable routing protocol for Vehicular Content Centric Networks. In Proceedings of the 2017 13th International Conference on Emerging Technologies (ICET), Islamabad, Pakistan, 27–28 December 2017; pp. 1–6.
6. Siddiqa, A.; Shah, M.A.; Khattak, H.A.; Akhunzada, A.; Ali, I.; Razak, Z.B.; Gani, A. Social internet of vehicles: Complexity, adaptivity, issues and beyond. *IEEE Access* **2018**, *6*, 62089–62106.
7. Siddiqua, A.; Shah, M.A.; Khattak, H.A.; Din, I.U.; Guizani, M. ICAFE: Intelligent congestion avoidance and fast emergency services. *Future Gener. Comput. Syst.* **2019**, *99*, 365–375.
8. Korichi, A.; Kerrache, C.A.; Fekair, M.e.A.; others. RCVC: RSU-Aided Cluster-Based Vehicular Clouds Architecture for Urban Areas. *Electronics* **2021**, *10*, 193.
9. Wahid, A.; Yasmeen, H.; Shah, M.A.; Alam, M.; Shah, S.C. Holistic approach for coupling privacy with safety in VANETs. *Comput. Netw.* **2019**, *148*, 214–230.
10. Wahid, A.; Shah, M.A.; Qureshi, F.F.; Maryam, H.; Iqbal, R.; Chang, V. Big data analytics for mitigating broadcast storm in vehicular content centric networks. *Future Gener. Comput. Syst.* **2018**, *86*, 1301–1320.
11. Khan, U.A.; Lee, S.S. Multi-layer problems and solutions in VANETs: A review. *Electronics* **2019**, *8*, 204.
12. Ahsan, W.; Khan, M.F.; Aadil, F.; Maqsood, M.; Ashraf, S.; Nam, Y.; Rho, S. Optimized node clustering in VANETs by using meta-heuristic algorithms. *Electronics* **2020**, *9*, 394.
13. Gulati, A.; Aujla, G.S.; Chaudhary, R.; Kumar, N.; Obaidat, M.; Benslimane, A. Dilse: Lattice-based secure and dependable data dissemination scheme for social internet of vehicles. *IEEE Trans. Dependable Secur. Comput.* **2019**, doi:10.1109/TDSC.2019.2953841.
14. Yao, L.; Wang, Y.; Wang, X.; Wu, G. Cooperative caching in vehicular content centric network based on social attributes and mobility. *IEEE Trans. Mob. Comput.* **2019**, *20*, 391–402.
15. Huang, W.; Song, T.; Yang, Y.; Zhang, Y. Cluster-based cooperative caching with mobility prediction in vehicular named data networking. *IEEE Access* **2019**, *7*, 23442–23458.
16. Gohar, M.; Khan, N.; Ahmad, A.; Najam-Ul-Islam, M.; Sarwar, S.; Koh, S.J. Cluster-based device mobility management in named data networking for vehicular networks. *Mob. Inf. Syst.* **2018**, *2018*, 1710591 .
17. Satyajeet, D.; Deshmukh, A.; Dorle, S. Heterogeneous approaches for cluster based routing protocol in vehicular ad hoc network (vanet). *Int. J. Comput. Appl.* **2016**, *134*, 1–8.
18. Mamatha, T.; Aishwarya, P. An efficient cluster based routing protocol using hybrid FCM-Q LEACH for vehicular ad hoc networks. *Int. J. Appl. Eng. Res* **2019**, *14*, 1604–1612.
19. Sampath, V.; Karthik, S.; Sabitha, R. Position-Based Adaptive Clustering Model (PACM) for Efficient Data Caching in Vehicular Named Data Networks (VNDN). *Wirel. Pers. Commun.* **2020**, *117*, 2955–2971.
20. Amadeo, M.; Campolo, C.; Ruggeri, G.; Lia, G.; Molinaro, A. Caching Transient Contents in Vehicular Named Data Networking: A Performance Analysis. *Sensors* **2020**, *20*, 1985.
21. Kumar, S.; Tiwari, R. Optimized content centric networking for future internet: Dynamic popularity window based caching scheme. *Comput. Netw.* **2020**, *179*, 107434.

22. Park, S.; Oh, S.; Nam, Y.; Bang, J.; Lee, E. Mobility-aware distributed proactive caching in content-centric vehicular networks. In Proceedings of the 2019 12th IFIP Wireless and Mobile Networking Conference (WMNC), Paris, France, 11–13 September 2019; pp. 175–180.
23. Suder, J.; Podbucki, K.; Marciniak, T.; Dąbrowski, A. Low Complexity Lane Detection Methods for Light Photometry System. *Electronics* **2021**, *10*, 1665, doi:10.3390/electronics10141665.
24. Chen, M.; Wang, T.; Ota, K.; Dong, M.; Zhao, M.; Liu, A. Intelligent resource allocation management for vehicles network: An A3C learning approach. *Comput. Commun.* **2020**, *151*, 485–494.
25. Nakazawa, T.; Tang, S.; Obana, S. CCN-based inter-vehicle communication for efficient collection of road and traffic information. *Electronics* **2020**, *9*, 112.
26. Qazi, F.; Khalid, O.; Rais, R.N.B.; Khan, I.A. Optimal content caching in content-centric networks. *Wirel. Commun. Mob. Comput.* **2019**, *2019*, 6373960.
27. Tizvar, R.; Abbaspour, M. A density-aware probabilistic interest forwarding method for content-centric vehicular networks. *Veh. Commun.* **2020**, *23*, 100216.
28. Yaqub, M.A.; Ahmed, S.H.; Kim, D. A Detailed Simulation Study of the Push-Based Protocol for Critical Data Dissemination in Vehicular Named Data Networks. In Proceedings of the 2019 International Conference on Networking and Network Applications (NaNA), Daegu, Korea, 10–13 October 2019; pp. 191–195.
29. Ostrovskaya, S.; Surnin, O.; Hussain, R.; Bouk, S.H.; Lee, J.; Mehran, N.; Ahmed, S.H.; Benslimane, A. Towards multi-metric cache replacement policies in vehicular named data networks. In Proceedings of the 2018 IEEE 29th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), Bologna, Italy, 9–12 September 2018; pp. 1–7.