CCN-Based Vehicle-to-Vehicle Communication in DSRC for Content Distribution in Urban Environments

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SUMMARY Dedicated Short Range Communication (DSRC) is currently standardized as a leading technology for the implementation of Vehicular Networks. Non-safety application in DSRC is emerging beyond the initial safety application. However, it suffers from a typical issue of low data delivery ratio in urban environments, where static and moving obstacles block or attenuate the radio propagation, as well as other technical issues such as temporal-spatial restriction, capital cost for infrastructure deployments and limited radio coverage range. On the other hand, Content-Centric Networking (CCN) advocates ubiquitous in-network caching to enhance content distribution. The major characteristics of CCN are compatible with the requirements of vehicular networks so that CCN could be available by vehicular networks. In this paper, we propose a CCN-based vehicle-to-vehicle (V2V) communication scheme on the top of DSRC standard for content dissemination, while demonstrate its feasibility by analyzing the frame format of Beacon and WAVE service advertisement (WSA) messages of DSRC specifications. The simulation-based validations derived from our software platform with OMNeT++, Veins and SUMO in realistic traffic environments are supplied to evaluate the proposed scheme. We expect our research could provide references for future more substantial revision of DSRC standardization for CCN-based V2V communication. 

key words: vehicular networks, non-safety application, dedicated short range communication (DSRC), content-centric network (CCN), in-network caching

1. Introduction
Dedicated Short Range Communication (DSRC) is a standard that initially aims to bring vehicular networks to North America, meanwhile also has been considering world widely in other regions and countries, i.e., Europe and Japan [1], [2]. DSRC is emerging as a leading technology for the implementation of Vehicular Ad-hoc Networks (VANETs). The second generation of DSRC technology in the 5.9 GHz band has the potential to support different types of application, e.g., active safety, public service, improved driving, business and entertainment [3]. Internet-related content downloading as one of non-safety application has been more concerned in delay-tolerant networks in the context of sufficiently exploiting vehicular resource for more convenience and comfortable life [4]–[6]. However, the Internet-based content distribution between vehicle and vehicle for non-safety application has not been sufficiently discussed in DSRC. And the key for developing localized vehicular non-safety application is information content itself, rather than addressable vehicle entity like traditional IP networking paradigm [7].

On the other hand, Information-Centric Networking (ICN) has motived the development of future Internet architectures based on named data objects (NDOs), instead of the current internet of host-to-host communication model [8]–[11]. The characteristics of Content-Centric Networking (CCN) as one of ICN oriented projects match this requirement of vehicular networks, which is only focused on content itself not content source location. Exploiting CCN in vehicular communications could become a prospective direction.

In this paper, we propose a CCN-based V2V communication scheme on the top of DSRC standard for content dissemination, while demonstrate its feasibility by analyzing the frame format of beacon and WSA (WAVE service advertisement) messages. According to the characteristic of vehicular networks, hierarchical structure of naming, on-path routing, Leave Copy Everywhere of cache strategy and least frequently used algorithm are assigned for vehicular CCN paradigm. Effective validations based on our software platform with simulations tools in realistic traffic environments are implemented. We expect CCN-based V2V communication for content distribution in urban environments could provide reference for future more substantial revision on DSRC standard. The background and our contributions will be described in the next section.

2. Background, Related Work and Our Contributions
The major DSRC standard includes the IEEE 802.11p amendment for Wireless Access in Vehicular Environments (WAVE), the IEEE 1609.2, 1609.3, and 1609.4 standards for security, network service, and multi-channel operation [12]–[14]. Vehicle-to-vehicle (V2V) based application supported by DSRC standard is restricted to basic safety message exchange for safety purpose [15], [16]. In order to modify DSRC standard for non-safety application, a brief description of DSRC protocol stack well documented and illustrated in some literatures [12]–[14] is briefly illustrated in Fig. 1 (a). TCP/UDP/IPv6 is used by only service channels.
and WAVE Short Message Protocol (WSMP) is used in both control and service channels.

WSMP is mostly used for safety applications and service, TCP/UDP/IPv6 stack is planned only for Internet-data service. One common control channel (CCH 178) on a fixed frequency is reserved for transporting control and safety messages; six service channels (SCH) are mainly used for exchanging non-safety data[14], as well as some safety-related information. Due to the channel-switch mechanism, content distribution becomes possible despite the safety application is always given priority over non-safety application.

In DSRC, data service could occur from a content server (or a remote host) to moving vehicles using access point such as road side unit (RSU), which rely on a stable and reliable wireless link between vehicles with RSUs[17], which communication scenario is shown in Fig. 1 (b). The vehicles could be offered content files through WSA service happened in RSU-to-vehicle (R2V) communication.

For content distribution, the current working mechanism of DSRC meets some issues. IP-based data service in DSRC is restricted with its temporal-spatial property. On one hand, in a harsh vehicular environment, the link for every vehicle could not be guaranteed: vehicles stay within the wireless range of a road side unit (RSU) only for a short duration within which it needs to complete a given service transaction[18]. Besides, obstructions of high buildings in urban environments block or attenuate radio propagation so that packet delivery ratio is seriously impacted[16], [18]–[20]. On the other hand, in an early stage of RSU deployment for DSRC, radio coverage of RSUs is technological limited as well as considerable capital expenditure and maintenance overhead[3], [21]. Moreover, in the situation that currently internet band-width almost reaches limitation[8], it is difficult to complete downloading a file within the radio coverage scope[3], [18].

The ICN approach fundamentally decouples information content from its source address, which is fit the requirement of vehicular networks and mitigates the temporal-spatial limitation that is shortness in existing DSRC service. Thereby we consider CCN should be added into DSRC for content distribution in V2V communication that currently only enables WAVE short message (WSM) for safety application in DSRC standard.

So far, a few opened literatures evaluate ICN applied to VANET with a modification of current communication standard DSRC and with effective validations in a real traffic environment with massive cars, some examples being[16], [22]–[24] indicate a direction forward CCN. In [17], slight modifications to the DSRC standard is proposed to improve RSU-awareness for WSA-based non-safety application.

In [23], L. Wang et al. proposed named data and designed the data structure in vehicular communication. Literature[22] proposes content-centric vehicular networking paradigm completely instead of TCP/UDP/IP in the network layer of DSRC.

In [25], parked cars are used for content downloading instead of relying on RSUs only, which extends the RSU service coverage. The work in [15] tackled content downloading in vehicular networks by optimizing APs (access points) deployment to increase data penetration rate.

In [16] a CCN paradigm is applied in a vehicular network performs more efficient and robust for content distribution in obstruction environments by simulation-based validation.

Increasing RSU deployment served as an alternating solution in some literatures can well improve data transaction[15], [26], even though multi-RSU synchronization and capital costs are still difficult to be tackled.

F. Bai et al. in [21] took a top-down framework called Information-Centric Network on Wheel to develop generic network architecture for supporting spatially-temporally localized and data-intensive vehicular application. Authors suggest the developed protocols for information management should allow for in-network data aggregation, storage, replication, and both push-based dissemination (TCP/IP) and on-demand pull-based querying (CCN). These instructive opinions enlighten the new scheme design in our work.

In [27], authors proposed a novel vehicular information network architecture to support location-based forwarding, content aggregation and distributed mobility management.

In [28], a cluster-based organization of vehicles is designed based on named data networking. Reference vehicles named barycenter plays router role to improve the chance of
In view of aforementioned, a solution scheme named CCN-based V2V communication for content distribution in metropolitan areas is proposed to run on top of DSRC shown in Fig. 2. This design derives from the enlightenment of in-network caching technique of CCN. In-network caching is employed to facilitate data propagation through V2V communication. The main contribution of this paper is summarized as follows:

1. Propose a coexistence of TCP/UDP/IPv6 and CCN paradigm in DSRC standard stack for more efficient content dissemination. IPv6 is used for content offering to vehicular networks by server-RSU-vehicle communications; CCN paradigm is used for content propagation in vehicular networks by vehicle-to-vehicle communication;
2. Analyze the feasibility with respect to availability of CCN for vehicular networks and possibility of adding CCN protocol (CCNP) on DSRC standard. Through piggybacking content name on a beacon frame, an Interest of CCN could be achieved. A modified WSA (WAVE service advertisement) message is recommended for announcing CCN service and channel availability when operating CCN framework on DSRC;
3. Propose hierarchical structure like a web URL for naming, broadcast of on-path routing, and Leave Copy Everywhere for cache strategy in vehicular CCN;
4. Simulation-based validation is carried out by our software platform with simulation tools of OMNeT++ 4.4.1, Veins 3.0 framework and SUMO 0.21.0. We made program for CCN protocol used in simulation. The traffic routes for every vehicle are generated by self-developed system. The real-world traffic system with massive cars enables the simulation results more reliable for evaluation.

3. Proposed Scheme

Based on aforementioned, we propose a coexistence of IPv6 and CCN paradigm in DSRC protocol stack shown in Fig. 2 (a) for more efficient content dissemination. Considering avoid radical changes in DSRC standard, the TCP/UDP/IP protocols for IP packets delivery is remained, which is working only in RSU-to-vehicle communication for content downloading from a server to vehicles via a RSU. A CCN protocol is designed into transmission and network layers to participate in the V2V communication for content propagation in the vehicular network. In MAC layer, specific service channels for IP packets and CCN packets are designated respectively. In WSMP, the piggybacked beacon is proposed as an Interest message for requesting a content file. A modified WSA message is exploited to announce content name and its service channel on which the CCN packets could be transmitted.

Corresponding to Fig. 2 (a), CCN-based data delivery scenario is shown in Fig. 2 (b). For a fraction of vehicles, content offering is relied on RSU-to-vehicle (R2V) communication, which is supported by TCP/UDP/IPv6 protocol in network layer. Content distribution among vehicles is relied on vehicle-to-vehicle (V2V) communication, which is supported by CCN framework. In-network caching can facilitate data propagation through V2V communication.

4. Feasibility Analysis for Proposed Scheme

4.1 CCN Could Be Available by Vehicular Networks

The various ICN initiatives aim to address different Internet’s problems and limitations by designing new Internet architectures. CCN is characterized by the basic exchange of content request messages (called “Interests”) and content return messages (called “Content Objects”) [29]. CCN could utilize in-network caching technique that holds copies of desired information to assist information spread between vehicles in urban environments.

The essence of CCN lies in decoupling contents from host not at the application level, but at the network level, which is well introduced in some literatures [8], [9]. In CCN, the location of a content file is independent of its name. Publish/subscribe is the main communication model: a content source announces (or publishes) a content file,
while a user requests (or subscribes) to the content file. With publish/subscribe paradigm by in-network caching, the content generation and consumption are decoupled in time and space, so contents are delivered efficiently and scalable.

4.1.1 Naming

CCN introduce a hierarchical structure to name a content file like a web URL (e.g. /www.kobe.com/morii-lab/shiraishi/v1), where / is the delimiter between components of a name. This naming mechanism is compatible with current URL-based applications, which also may imply a lower deployment hurdle when merge CCN protocol and TCP/UDP/IP into a vehicular network. Its hierarchical nature can help mitigate the routing scalability issue since routing entries for contents might be aggregated [9].

4.1.2 Routing

CCN just replace network prefixes (in IP routing) with content identifier (like IP address), so the modification of IP routing protocols and systems may not be difficult [8]. CCN suggests inheriting IP routing, thus has compatibility to a certain degree. Therefore, CCN might be deployed incrementally with current IP network [8]. In vehicular networks, IP paradigm is still remained for data offering by RSU-to-vehicle communication, thus CCN might be the best candidate in our work due to its compatibility to IP routing.

4.1.3 Caching

CCN natively supports on-path caching [30], [31], since each content router first consults its content storage whenever it receives an Interest message and caches all content objects [8]. The integration of router and storage makes routing simplified, which is fit the dynamic and complicated vehicular network.

4.1.4 Proposed CNN Vehicular Networks

Because the topology of vehicular network is dynamic, it is difficult to maintain routing tables; hence, the routing advertisement (for contents) is mainly performed by broadcast model. Figure 3 shows a procedure of a file distribution. The WSA service offers a file to vehicle-A from RSU via content server, and caches it. This file will be distributed using CCN paradigm by vehicle-to-vehicle communication. The vehicle A advertises the file name and service channel by WSA message. The vehicle B sends an Interest for requesting this file. The requested content name is piggybacked in a beacon as Interest message. The prefix matching rule is working for a decision in vehicle-A. If a matched file is found, vehicle-A immediately sends this file to vehicle-B, otherwise vehicle-A broadcast Interest beacon to other vehicles.

How to achieve Advertisement and Interest messages of CCN in DSRC specification will be illustrated in the upcoming subsection.

4.2 Possibility of DSRC Standard Used for CCN

To leverage CCN in vehicular networks will result in sophisticated amendment on DSRC standard. Quantity of specifications and frame format might be involved in. In this paper, only limited efforts defining Advertisement and Interest messages, are done.

4.2.1 Modify WSA Message Acting as Advertisement Message to Announce Content Name and Service Channel

Figure 1 (a) illustrates the protocol stack for DSRC [12], [13]. At the PHY and MAC layers, DSRC utilizes IEEE 802.11p for wireless access for vehicular environments, a modified version of the familiar IEEE 802.11p (WiFi) standard. In the middle of the stack, IEEE 1609 framework specifies the networking services (1609.3) and multi-channel operation (1609.4). DSRC supports Internet protocols for the network and transport layers, i.e., Internet Protocol version 6 (IPv6), User Datagram Protocol (UDP) and Transmission Control Protocol (TCP). In Fig. 2 (a), added CCN protocol is used to content service for V2V communication.
Safety and non-safety application are separated on different channel, which is controlled by multi-channel operations (1609.4). In PHY layer, there are one control channel (CH) and 6 service channels (SCH) are available shown in Fig. 4 (a).

A consensus in the industry is to send all collision avoidance safety messages on control channel 178 [2], [12]. Other six service channels have not been sufficiently used and not been exclusive for specified applications, while channel 174 and 176 are reserved for medium power application, which is responding to IP packets transmission [1], [12]. In order to avoid channel interference, in this paper we suggest Channel 174 is allocated to IP packets for R2V communication, Channel 176 is allocated to CCN packets for V2V communication.

The WSA is a management message. The WSA includes information offered in an area, for example, traffic alert, tolling, navigation, entertainment, and internet access. WSAs are sent on the CCH during the CCH interval, the services that a WSA advertises is offered on SCHs. Service type, service offering channel and other connection parameters are carried in WSA message [12]. Although most of service is provided by RSUs, a vehicle could also send a WSA [12], thus this provides a possibility for advertising its content from a vehicle for V2V communication. This means both RSUs and vehicles can broadcast WSAs for announcing service offerings including content name and corresponding service channels.

If SCH 174 is designated for IP packets and SCH 176 is designated for CCN packets, the channel information can be carried in a WSA message. Figure 4 (b) shows the format of WSA [12], in the optional field, Service Info and Channel Info can be modified for suiting the proposed scheme. In Service Info field, a service type and corresponding service channel are indicated: IP service (IP address) or CCN service (content name). Service Info field is linked to Channel Info field by the Channel Index [12]. If the service is IP service, the Channel Number is set to 174; if the service is CCN, the Channel Number is set to 176. Thereby service advertisement including content name and channel number could be achieved.

4.2.2 Piggyback Content Name on a Beacon Acting as an Interest Message

An Interest occurs in vehicle-to-vehicle communication for requesting content files. We need to choose a suitable Interest’s substitute in DSRC specifications.

WSMP is specifically designed for the short message exchange in vehicular networks. On one hand, WSMP packets can carry high-priority safety message, traffic and road message, or beacon frame. WSMP packets can be directly exchanged by WAVE devices without IP overhead both on CCH and SCH [12]. Beacons are one-hop broadcasted short message whereby all vehicles send status information about the vehicle type, position, speed, and direction.

On the other hand, broadcast is one of options for Interest routing in dynamic vehicular network. Beacon enables to satisfy either the V2V communication requirement or the broadcast characteristic so that beacon can be a substitute of Interest in vehicular CCN. Thereby we design the Interest message by modifying the beacon frame. The format of beacon frame is shown in Fig. 5 [32]. In the frame body the last field is Vendor-Specific element, the content name of an
Interest could be piggybacked onto the last field of frame body, while being fully compliant with the 802.11p/WAVE specification. A beacon piggybacked by a content name acts as an Interest of CCNP service. Piggybacked beacon as an Interest is sent to vehicles, which is supported by WSMP. If Interest receiver fortunately cache this content, the content file is sent to the subscriber, which is supported by CCNP service.

4.2.3 Cache Strategy in Vehicular CCN

Although there are sufficient cache strategies proposed for CCN in previous works, e.g., LCD (leave copy down), MCD (move copy down), Prob (copy with probability), ProbCache (a weighted probability cache) and so on [33]–[37], due to VANETs characteristic of mobility, short-lived and intermittent connectivity, caching strategy has to be uncoordinated, distributed and enhanced. A cache strategy called leave copy everywhere (LCE) for every vehicle is borrowed for V2V communication in our work. LCE can expand coverage range of transmission and decrease relay times. The operation of LCE in vehicular network will be described in Sect. 5.

Besides, Least Frequently Used (LFU) replacement algorithm is suggested to run in all caches. In metropolitan areas, LFU algorithm in caches is reasonable according to link popularity [35]. In our simulation, since only one file is assumed to be distribution, LFU algorithm is not included in simulations.

5. Application Descriptions of Proposed and Existing Schemes

Application cases corresponding to the proposed CCN-based scheme and existing DSRC-based scheme respectively for comparison are depicted in Fig. 6 and Fig. 7. The target is all of cars capture a file that is initially placed in a content server.

5.1 Case-A: Proposed CCN-Based Scheme

In the case of CCN-based scheme shown in Fig. 6, cars are sorted into two groups according to the derivation of the file from R2V or V2V. First, WSA service offers a file to a fraction of cars from RSU. These cars belong to Group 1. Secondly, other cars acquire this file from cars in Group 1, these cars belong to Group 2. The cache policy of Group 1 shown in (a): after node 1 downloads a file from RSU, caches this file. The cache policy of Group 2 is shown in (b) and (c). The nodes in Group 2 capture the file by two ways. One is shown in (b): node 1 catches the file from node 2 of Group1, caches this file. Another shown in (c) is, node 1 requests the file via relay node 2 of Group2 to node 3 of Group1. On the back way, this file is cached in every node. Above operations called leave copy every-where are repeated for every node.

5.2 Case-B: Legacy DSRC-Based Scheme

In the case of DSRC-based scheme shown in Fig. 7, WSA service offers a file to cars by broadcast from RSU via content-server. Cars obtain the file only from RSU. All of vehicles capture files through R2V communication. Single-RSU and five-RSU deployments are shown in Fig. 7 (a) and (b) respectively, which is used to estimate the multi-RSU
deployment. The maximum number of a reasonable RSU deployment is 5 in the experimental area, which is decided by the radio coverage range defined in DSRC specifications. The furthermore explanation will be followed in the Sect. 6.1.

In the next section, the applications of case-A and case-B will be simulated in various scenarios.

6. Simulation-Based Validation

Proposed CCN-based scheme is compared to existing DSRC-based scheme in the different scenarios for evaluating the performance of content distribution. Cars are going into a metropolitan area called Sannomiya of Kobe in Japan showed in Fig. 8 (a), which is a realistic traffic map downloaded from OpenStreetMap [38]. If zooming in the central location, the vehicle movements can be observed in Fig. 8 (b). The simulation is implemented by OMNeT++ 4.4.1 (network simulator) [39], combining Veins 3.0 framework (vehicular network simulator) [40] and SUMO 0.21.0 (urban mobility simulator) [41], in which IEEE 802.11p protocol stack and signal attenuation caused by obstacles are included [40]. Besides, we designed software to generate the traffic routes for every car, so the reasonable and realistic traffics could be able to be provided. This traffic system enables the simulation results more reliable for validation.

One file of 2.92 MB will be distributed to cars from RSU. The simulation traffic area is scoped within $1.06 \times 1.2$ km$^2$.

A file of 2.92 MB is divided into 2000 packets to distribute to cars. All of cars are assumed to be DSRC-CCN-equipped in case-A and DSRC-equipped in case-B. With different traffic loads (200 and 800 cars) and different RSU deployment (1 or 5), cars will receive the file within 900 seconds simulation time. The packet delivery ratio as a main metric is evaluated.

6.1 Simulation Scenarios

6.1.1 Traffic Load

The low traffic load and the high traffic load are respectively provided for two schemes for evaluating the effectiveness and robustness of proposed scheme. For the high traffic density, in the same lane, the distance between two adjacent vehicles is around 10 meters [5]. According to this estimation, 200 cars and 800 cars are assumed to be a low and a high traffic loads respectively. The simulation scenarios are as follows:

1. 200 cars of low traffic load are going into a metropolitan area in both schemes.
2. 800 cars of high traffic load are going into a metropolitan area in both of schemes.

6.1.2 Road Side Unit (RSU) Deployment

The RSU deployment is shown in Fig. 8 (c):

1. The RSU named RSU-0 is deployed in simulation scenario for both schemes. When the RSU-0 shown in Fig. 8 (c) is deployed in two schemes, it is located in the center of the traffic area of ABCD.
2. Five RSUs named RSU-0∼4 are deployed only in existing DSRC-based scheme to observe how much improvement that multi-RSU deployment works.

One RSU typically can reach with a single hop distance [42]. DSRC messages reach their destinations in a single hop [12]. The single-hop distance is decided by DSRC-equipped devices. DSRC defines four classes of device, labeled A-D, each class is associated with a maximum allowed transmit power at the antenna and a desired transmission range [12]. Device participating in safety is normally in class C associated with a theoretical transmission range of 400 meters with no fading or interference [13], [14]. Considering harsh environmental factors and bigger TCP/UDP packet size for content delivery, the practical coverage range

Fig. 8 Simulation scenario: (a) city scenario (Sannomiya of Kobe, Japan), (b) cars movements, and (c) RSU deployments.
is reduced to 75%, approximately 300 meters [14]. Considering the higher vehicle density in the traffic center than in the edge of the downtown, five RSUs in the experimental zone of $1.06 \times 1.20 \text{km}^2$ are radially deployed from the center shown in Fig. 8 (c).

6.1.3 File Size and Packet Number

A file of size 2.92 MB is setup to be distributed from a server to cars. This file is broken into segments to be transmitted. We setup MSS (maximum segment size) of 1460 bytes for TCP packet, which is in the range of typical MTU (maximum transmission unit) between 576 bytes in the Internet and 1500 bytes in Ethernet [5], [43], [44]. The typical size proposed by CCN is also 1500 bytes in packet-level [45], [46]. Thus, in the simulation the consistent packet size could be able to be used for both TCP/UDP/IP packets and CCN packets, as well as compatibility with wireless network like Ethernet. Whereby 1500 bytes MTU is adopted, which leads to 1460 bytes (subtracting TCP/IP header) maximum segment size (MSS), so the packet number is 2000. 2000 packets are distributed from RSU to cars.

Table 1 shows the major simulation parameters.

### Table 1 Simulation parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Latitude: 34.6862–34.6878; Longitude: 135.1864–135.1877</td>
</tr>
<tr>
<td>Vehicle number</td>
<td>200 (low traffic load) &amp; 800 (high traffic load)</td>
</tr>
<tr>
<td>RSU number</td>
<td>1 &amp; 5</td>
</tr>
<tr>
<td>File size</td>
<td>2.92 MB</td>
</tr>
<tr>
<td>Packet number</td>
<td>2000</td>
</tr>
<tr>
<td>MSS of TCP/IP/UDP packet</td>
<td>1460 bytes</td>
</tr>
<tr>
<td>MTU</td>
<td>1500 bytes</td>
</tr>
<tr>
<td>On-path routing</td>
<td>Broadcast</td>
</tr>
<tr>
<td>Beacon interval as Interest</td>
<td>1 sec.</td>
</tr>
<tr>
<td>Broadcast interval for RSU</td>
<td>0.01 sec.</td>
</tr>
<tr>
<td>Broadcast interval for vehicles</td>
<td>0.05 sec.</td>
</tr>
<tr>
<td>Simulation time</td>
<td>900 sec.</td>
</tr>
<tr>
<td>Max. Transmission power</td>
<td>20 mW</td>
</tr>
<tr>
<td>MAC Bit Rate</td>
<td>18 Mbit/s</td>
</tr>
<tr>
<td>Transmission range</td>
<td>300 meters</td>
</tr>
<tr>
<td>Vehicle speed</td>
<td>0–60 km/h</td>
</tr>
</tbody>
</table>

6.2 Simulation Results

When there are 200 cars in a scenario, the ideal total number of received packets by all of cars is $200 \times 2000$; it is $800 \times 2000$ for 800 cars. Packet delivery ratio is a metric to evaluate how many packets are received by cars. 

$$\text{Packet delivery ratio} = \frac{\text{Received packets}}{\text{Total packets}}$$

6.2.1 Comparison in Different Traffic Load

Figure 9 (a) and (b) show the packet delivery ratios in 200 and 800 cars scenarios respectively, which is corresponding to Case-A in Fig. 6 and Case-B in Fig. 7 (a). In both of scenarios, proposed CCN-based scheme performs outstandingly than DSRC-based scheme.

When traffic load is increased from 200 cars to 800 cars, for the proposed scheme, the packet delivery ratio can still keep 97%; the legacy scheme takes more long time to reach 67%. The proposed scheme represents stronger robustness than legacy scheme in high traffic load scenario.
6.2.2 Comparison in Different RSU Deployment

The existing DSRC scheme is deployed with 1 and 5 RSUs respectively shown in Fig. 10(a) and (b). In order to observe easily, the data curve shown in Fig. 9 is also attached in the Fig. 10.

When one RSU is deployed in DSRC scheme, the performance is fade than proposed scheme in Fig. 10(a). If RSU deployment is increased to 5 shown in Fig. 10(b), the performance is still fade comparing with the proposed scheme despite the proposed scheme is deployed only one RSU. Besides, even though RSU deployment is increased to 5, the data delivery ratio is not so much improved because of the impact of obstacle shadow.

Above observation presents the fact that in current DSRC, although multi-RSU deployment could improve data transmission to a certain degree, its efficiency is not limitless increasing. In-network caching technique perhaps could realize more effective improvement for data transmission.

6.2.3 Evaluation on Cache Function

Furthermore, we analyse the detailed component of packet delivery ratio, which is composed of two parts. One is contributed by cache nodes (V2V communication); another is contributed by RSU infrastructure (R2V communication). In the low traffic load (200 cars) shown in Fig. 11, 87% packets are delivered by V2V communication, which is relying on cache function; 13% packets are delivered by R2V communication. Similarly, in the high traffic load (800 cars), 89% packets are delivered in V2V communication, only 11% packets are delivered from RSU. These results mean vehicle-to-vehicle communication supported by cache nodes is much active than RSU-to-vehicle communication supported by RSU. The cache nodes dominate the packet delivery.

Thereby we conclude the proposed CCN-based scheme performs stronger robustness and stability even in both of the low and high traffic loads scenarios. Besides, though its RSU deployment can be reduced to the minimum (only one), it enables to achieve high packet delivery ratio because
in-network caching participates in most of packet delivery process.

7. Conclusion

A rich set of vehicular applications can be envisioned such as safety and non-safety applications. Though the primary motivation for deploying DSRC is to enable collision prevention, it can also be used for more general entertainment, commercial, and social purposes of non-safety application beyond the initial collision avoidance. In this paper, we concentrate on a particular application of content distribution. We reviewed the related reference literatures, which enlightens our inspiration. We analyze DSRC protocol stack and Content-Centric Networking, whereby proposed a CCN-based scheme that adds CCN framework into DSRC standard for facilitating content propagation in vehicular networks. CCN framework is used for vehicle-to-vehicle communication; current DSRC standard is still served to RSU-to-vehicle communication.

Besides, we demonstrate the feasibility that a CCN framework might be working on the top of DSRC standard relying on modifying beacon and WSA message acting as Interest and Advertisement message of CCN. Certainly, to leverage CCN paradigm in vehicular networks could result in sophisticated amendment on DSRC standard, that means quantity of specifications and frame format might be involved in, however, in this paper just limited and basic efforts are done. In addition, according to the characteristic of vehicular networks, hierarchical structure of naming, on-path routing, Leave Copy Everywhere of cache strategy, and Least Frequently Used algorithm are borrowed for vehicular CCN paradigm.

Proposed CCN-based scheme is compared to current DSRC-based scheme in various scenarios with massive cars traffic for evaluating its performance. The simulation tools of OMNeT++ & Veins & SUMO, associating with CCN protocol and realistic traffic routes generated by our software platform, enable a reliable validation. Simulation results demonstrate the proposed CCN-based scheme performs stronger robustness and stability in both of low and high traffic loads scenarios. Additionally, the RSU deployment can reduced to the minimum, simultaneously which enable to achieve high packet delivery ratio because CCN framework participates in most of packet delivery process so as to effectively facilitate data delivery for DSRC IP service.

Vehicular Content-Centric Networking opens a prospective direction for disseminating contents in metropolitan areas. The efforts to develop DSRC standards are still underway in different regions and countries, so we expect our research work could provide references for DSRC standardization that will be implemented in the future fascinating vehicular networks.

References


[29] https://en.wikipedia.org/wiki/Content_centric_networking


[38] https://www.openstreetmap.org/


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