Performance Assessment of Routing Protocols in Cognitive Radio Vehicular Ad Hoc Networks

Jyoti Grover and Sunita Singhal

Abstract Cognitive radio technology is an inventive method to solve spectrum scarcity problems in wireless networks. Growing interest of cognitive radio (CR) technology in vehicular communication systems has led CR-enabled vehicular ad hoc network (CR-VANET). It allows the efficient use of radio frequency spectrum. In vehicular ad hoc networks (VANETs), mobility of nodes leads to frequent changes of network topology making routing a challenging task. It is important to balance different parameters such as impact of spectrum availability, dynamic nature of VANET, varying interference and security while designing solutions for CR-VANETs. In this paper, we have compared AODV and DSR routing protocols in CR-VANET scenario and have found that AODV protocol is more suitable. It is observed that on-demand routing protocols outperform reactive protocols. All the experimental work is conducted through OPNET network simulator.

Keywords Cognitive radio · VANET · CR-VANET · AODV · DSR · Routing

1 Introduction

As the number of vehicles on the road is increasing, it is bringing many challenges such as improving road safety and in-vehicle entertainment. At present, the main objective of vehicle industry is to upgrade the traveling experience of users by strengthening vehicular communication effectiveness with improved safety and performance, as well as Internet connection and commercial applications. Therefore, vehicular ad hoc network (VANET) has developed as an refined technology that can reinforce applications such as safety and traffic monitoring, collision avoidance,

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multimedia streaming and data collection for smart cities in alliance with wireless sensor networks and vehicle-to-vehicle (V2V) communication.

Government and international companies allocate operation licenses in different frequency bands. The electromagnetic spectrum is overburdened in some bands, while it is under utilized in others. It becomes problematic to assign new licenses as most part of the spectrum is already allocated. On the other hand, some frequency bands are observed with minimum spectrum usage in certain regions of the world. Wireless communication is becoming popular and there is an increased requirement for more bandwidth and electromagnetic spectrum. Additionally, applications like video streaming consume high bandwidth and can cause congestion on particular channel. Spectrum is a scanty resource and it should be used precisely. One of the prominent solutions is to access the spectrum opportunistically. There are more prospects of finding a blank spectrum on highways that can be accessed opportunistically. Thus, it is very useful to embed cognitive radio technology in VANET as spectrum availability can be exploited using opportunistic spectrum access. The main concept of CR network is to share the same bandwidth with unlicensed (secondary) users that was permitted to licensed (primary) users without causing any interference. A CR equipment detects the vacancy of the spectrum and assigns the secondary users to avail the unoccupied radio spectrum.

VANET is egressing technology that allows one hop and multi-hop communications among vehicles in order to build safety applications. Apart from these safety applications, VANET is also used to implement non-safety applications such as multimedia data sharing and Internet access. With the enlarging demand of VANET, cognitive radio is the most promising solution to deal with spectrum scarcity. It is required to provide efficient use of spectrum and proper VANET deployment in order to successfully implement CR-VANET [1]. It acquires geographical environment information to control distribution of spectrum in primary and secondary users so that emergency information can be conveyed timely to nearby vehicles on the road.

Performance of VANET is effected if same communication protocols which were designed for fixed frequency bands are applied in scenario of dynamic use of spectrum bands [2]. Therefore, it is required to develop routing protocols suitable for cognitive radio environment. This paper focuses on the assessment of ad hoc on-demand distance vector (AODV) and dynamic source routing (DSR) in cognitive radio environment. However, there are some papers in literature [3, 4], where different routing protocols are compared in VANET scenario. But we have presented comparative investigation of AODV and DSR routing protocols in CR-VANET. The major contribution of our paper can be summarized as follows:

1. Elaborative description of CR-enabled vehicular ad hoc networks.
2. Assessment of DSR and AODV protocols in cognitive radio environment.
3. Evaluation of applicability of AODV routing protocol in CR-enabled VANET. The organization of the paper is as follows. Section 2 presents background of this technology. In Sect. 3, CR-VANET is revisited. Section 4 presents routing

protocols in CR-enabled VANET. Experimental setup and comparative results are presented in Sect. 5. Finally, concluding remarks with future work are covered in Sect. 6.

2 Background

The main objective of cognitive radio standard is to alleviate the exiguity of spectral resources for wireless communication through smart sensing and rapid resource allocation methods. It is well known that most of the available spectrum is dedicatedly allocated to licensed users (primary users). Generally, it is under utilized depending on the time and the location where communication is taking place. Three approaches have been mentioned below for CR-based communication on the basis of how secondary user accesses the licensed spectrum:

1. Opportunistic spectrum access [5]: In this approach, the secondary users can participate in the communication when a frequency band (mainly used by primary users) is found as idle.
2. Sharing of spectrum [6]: Here, the secondary users synchronize with the primary users and mutually follow a protocol called interference constraint protocol so that quality of service of the primary network can be ensured.
3. Spectrum sharing using sensors [7]: Secondary users sense the status of the channel, i.e., active or idle. Based on the decision made by spectrum sensing, they adapt their transmit power.

A coordinated spectrum sensing framework for cognitive radio VANET is introduced by Xiao et al. [8]. The forwarding node having significant available spectrum bands switches between channels which are common with the receiver and transmitter in order to transmit more data through this forwarding link.

There are some negative effects of cognitive radio technology in vehicular networks. For example, secondary users not detecting a primary (licensed) user and thus causing interference to the primary user. Kakkasageri et al. [9] proposed a model to improve the performance of cognitive radio technology in vehicular networks. It uses cognitive agent model for perceiving intelligent information dissemination. Connectivity-based routing protocols [10] provide spectrum awareness for route selection. It observes the SU network connectivity that is determined by the PU channel usage based upon graph theory and mathematical analysis.

3 Cognitive Radio Vehicular Ad Hoc Network (CR-VANET)

A VANET is a subclass of mobile ad hoc network (MANET) constructed over moving vehicles on the road. There are two types of links formed in VANET:-(a) vehicle-to-vehicle (V2V) and (b) vehicle-to-infrastructure (V2I). It incorporates information and

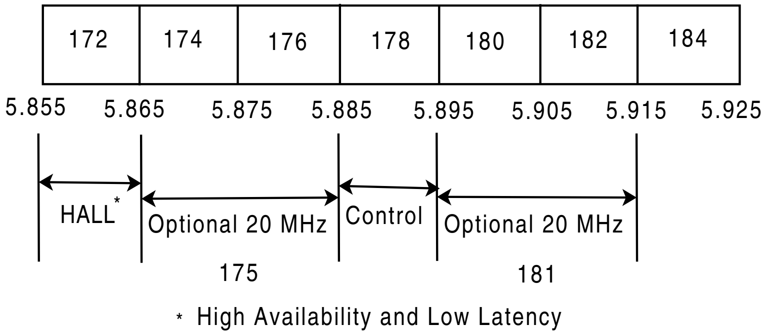


Fig. 1 Dedicated short range communication (DSRC)

communication technology to vehicles and roadside infrastructure. VANET uses 5.9 GHz dedicated short range communication (DSRC) [11, 12] for establishing connection between vehicles and their environment. Currently, IEEE 802.11p standard [13] is working on PHY and MAC layers of DSRC. This standard is an alteration of the popular IEEE 802.11a standard. It deals with the issues such as highly dynamic environment and short span established links. It is a challenge in VANET to complete communication between vehicles in very short time duration due to the high speed of the vehicles. DSRC has been allocated 75 MHz of the radio spectrum by Federal Communications Commission (FCC) to implement vehicular communications. Similar bands are allocated by governments in Japan and Europe. There are 6 service channels and one control channel in 5.9 GHz DSRC spectrum. Bandwidth of each channel is 10 MHz. Different channels of DSRC band are illustrated in Fig. 1.

Each channel is reserved for different types of applications. Safety applications are implemented using channel 172. Channel 174 and 176 are reserved for non-safety applications. Channel 175 is a conjunction of channels 174 and 176. High priority safety messages are sent through channel 178. It supports vehicle-to-vehicle broadcast messages, high priority safety messages and service announcements. Low priority applications are implemented using channel 180 and 182. High priority services are implemented using channel 184.

Wireless technology used for VANET allows nodes to listen to one channel at a time. There is single transceiver equipped in each vehicle according to DSRC deployment. This approach can monitor one channel at a time. Other approach can be used where nodes can be equipped with multiple transceivers. It allows the access of multiple channels simultaneously. This can be understood by taking a simple example. If a vehicle is equipped with two transceivers, one transceiver can monitor the control channel and at the same time send/receive the safety message on a service channel. It becomes expensive and complex by employing multiple transceivers.

Control channel 178 is the most important channel of DSRC. Proper scheduling algorithm is required by the channel for its efficient usage. The control channel is monitored by all the nodes to broadcast safety messages or brief service channel

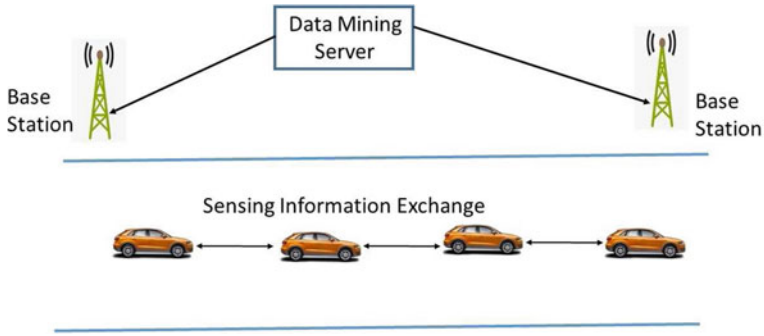
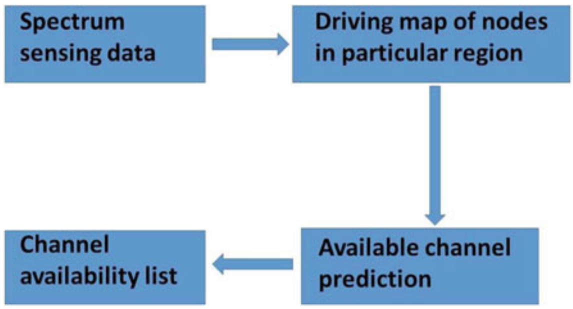


Fig. 2 Spectrum information exchange in cognitive VANET

Fig. 3 Phases of a typical cognitive radio VANET



announcements. Communication on the control channel is for a brief duration of time due to availability of limited bandwidth. So, it is required that all the nodes periodically switch to the control channel to receive safety messages. Time synchronization plays a significant role in order to guarantee that safety messages are received by all nodes.

Cognitive radio technology in VANET [14, 15] enables efficient usage of radio spectrum and improves efficiency of vehicular communications. Figure 2 shows a typical spectrum exchange mechanism in cognitive VANET. Vehicles on the road cooperate and exchange spectrum information with each other and nearby base stations. These base stations, further, send the information to data mining servers.

Figure 3 illustrates different phases of a typical cognitive radio VANET. Format of the information maintained by data mining servers is shown in Fig. 4. It stores the list of free channels at each location on highways where free spectrum can be used opportunistically. Cognitive radio VANET improves the performance of current and egressing applications of VANET, e.g., V2V and V2I communication, public safety and non-safety (entertainment, information related) applications.

Fig. 4 Spectrum information maintained by data mining servers

Location Server	Available Channels
(X_i Y_i Z_i)	(ch_1 ch_2 ch_3) for user i

4 Routing in Cognitive Radio VANET

In this paper, we have considered two well-developed on-demand routing protocols in VANET: AODV [16] and DSR [17]. In reactive protocols, a source node finds a route to the destination whenever data communication is needed. In this **Route Discovery Phase**, origin (source) node broadcasts a route request (**RREQ**) packet. Nodes receiving this packet, further, forward it. Destination node or any node who knows the path to destination node unicast route reply **RREP** to origin node. Now, source node can start sending the data packets using unicasting. Apart from **RREQ** and **RREP** packets, AODV and DSR protocols send **RERR** packets for route maintenance. A survey of on-demand routing for CR-based networks is presented by Salim et al. in [18]. However, they have not considered cognitive radio in VANET.

5 Experimental Setup and Simulation Results

In our present work, we have assessed AODV and DSR routing protocols in cognitive radio VANET under dynamic traffic scenarios. The simulation model is built in the OPNET simulator [19] with multi-radio multi-channel extensions as it facilitates the simulations of complex networks. The simulation model includes 100 nodes in an area of 3000 m $\times$ 3000 m. We have used two-ray ground propagation model. User Datagram Protocol (UDP) is used at transport layer. Table 1 presents list of parameters for our simulation framework.

Performance of routing protocols in CR-VANET scenario is measured using following parameters:

- **Packet Delivery Ratio (PDR)**: It is the proportion of the number of sent packets by source end and the number of packets collected by the destinations end at application layer.
- **End-to-End Delay**: It is the time difference between sending and receiving a packet from source to destination in a network. It is also called propagation time. This delay is measured in seconds.
- **Throughput**: It is defined as number of packets passing through the network per unit of time. Throughput is measured in Kb/seconds.

Figure5 shows effect of simulation time on end-to-end delay. AODV and DSR routing protocols are considered for evaluation. It is observed that end-to-end delay is more when compared with AODV protocol. This may be due to high speed of

Table 1 Simulation parameters

Parameter	Description
Packet size	1024 bytes
Simulation start time	10 s
Data traffic	Constant bit rate (CBR)
Data rate	2 Mb/s
Simulation area	3000 m × 3000 m
Transmission range	250 m
Simulation time	1000 s
Wireless standard	802.11p
Node speeds	50–100 Km/h
Average speed	1–15 m/s

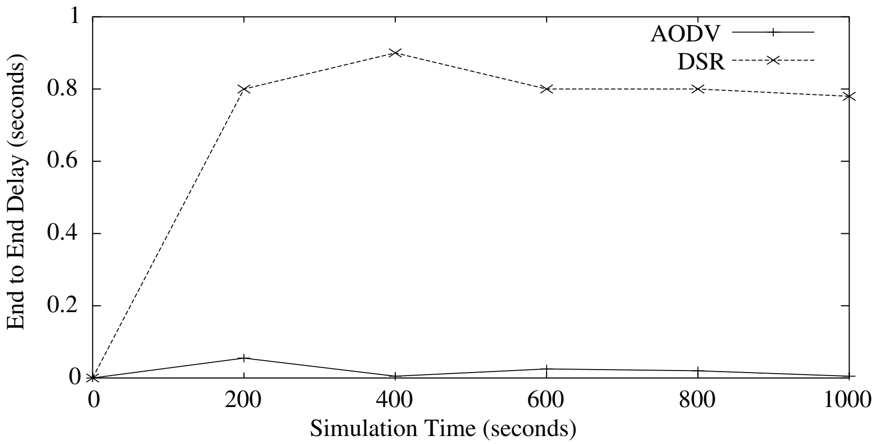


Fig. 5 Comparison of AODV and DSR in terms of end-to-end delay

nodes in VANET. In DSR, **RREQ** and **RREP** packets contain the complete address of all the intermediate nodes. It maintains route cache to store existing routing entries until they become invalid. There are more link failures in VANET, and DSR takes more time to maintain its cache. That is why AODV is having low end-to-end delay as compared to DSR.

PDR is also evaluated by varying the simulation time in Fig. 6. Here, also AODV routing protocol outperforms DSR. This is due to the fact that DSR route discovery phase leads to uncertain length of control and data packets. So, DSR is not suitable because of sporadic connectivity behavior of CR-VANET.

Figure7 considers the effect of simulation time on throughput of both the protocols. Here, also AODV outperforms DSR. This is also due to the same reason as defined above.

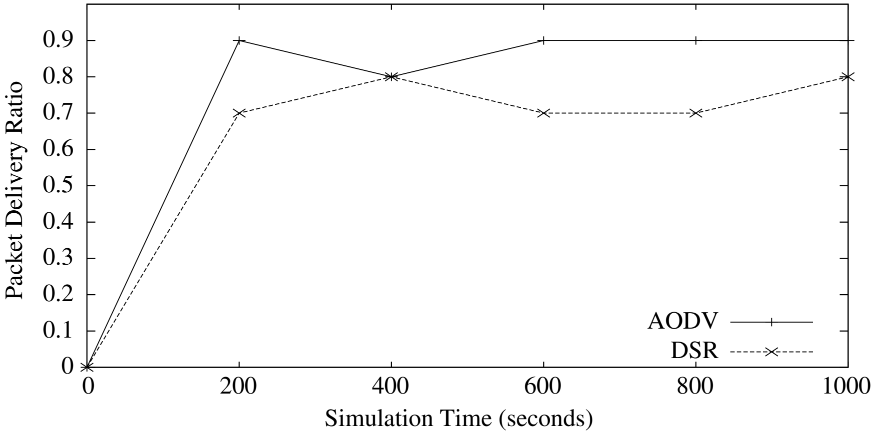


Fig. 6 Comparison of AODV and DSR in terms of packet delivery ratio

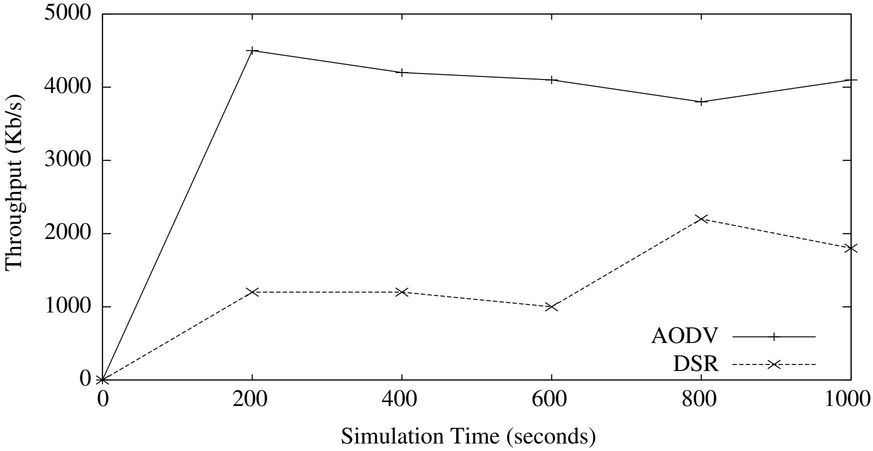


Fig. 7 Comparison of AODV and DSR in terms of throughput

In this paper, we have shown the impact of simulation time on PDR, throughput and end-to-end delay to assess the realization of AODV and DSR routing protocols in CR-VANET.

6 Conclusion and Future Work

This paper discusses the performance assessment of ADOV and DSR routing protocols in CR-VANET. We have not focussed proactive protocols because they have more energy requirements than reactive protocols. Proactive protocols transmit control packet periodically and cache all the paths in a table even if there is not data to be sent. On-demand or reactive protocols behave better in high dynamic scenario such as in VANET. The experimental results illustrate that AODV is more suitable in CR-VANET scenario as compared to DSR. The reason is that DSR route discovery phase causes arbitrary length of control and data packets. Therefore, AODV is found more suitable in CR-VANET. As a part of our future work, we would like to incorporate environmental effects on CR-VANET while assessing the performance of routing protocols.

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