# Performance Analysis of CBRP, AODV and DSR Routing Protocols in VANETs Based on IDM-IM

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**Abstract.** Due to multi-lanes, speed limit, buildings around corners and traffic lights, Vehicular Ad Hoc Networks (VANETs) with urban areas especially in intersections have more complicated network topology, resulting in standard flat routing protocols inapplicable in VANETs. Theoretically hierarchy based routing protocol such as CBRP (Clustering Based Routing Protocol) can achieve better performance in VANETs. To the best of our knowledge, there is no literature reporting network performance tests on CBRP in VANETs. Existing Network Simulator (NS) does not contain CBRP, therefore this paper firstly implements CBRP into NS-2.35 and then aims to compare and analyze performance of CBRP against AODV (Ad Hoc On-demand Distance Vector) and DSR (Dynamic Source Routing) in VANETs based on IDM-IM (Intelligent Driver Model with Intersection Management) modeled by VanetMobiSim. Simulation results reveal that CBRP performs well compared to AODV and DSR in terms of delay, packet loss ratio and route costs.

**Keywords:** VANETs · CBRP · AODV · DSR · Network performance

## 1 Introduction

Over the past few years, advances and development of Intelligent Transport System (ITS) [1] have brought a new type of Mobile Ad Hoc Network (MANET) which is known as Vehicular Ad Hoc Network (VANET). VANETs can improve driver safety, reduce traffic accident and avoid road congestion by obtaining state of adjacent vehicles, road environment, traffic condition and entertainment information through communications between Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) [2]. So, unlike MANETs, due to the complex network environment characterized by features of vehicles, VANETs are far more difficult and challengeable. The specific details can be concluded as:

- Instability of wireless channel: Because of shared wireless channel in VANETs, communication quality can be easily affected by factors such as weather state, road condition, traffic lights and buildings around the corners at an intersection.
- Dynamic and rapid change of topology: High speed of vehicles frequently lead to rapid change of network topology and short life of wireless link in VANETs.


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- Limitation of network capacity: Given the fact that vehicles are constrained by predefined layout of streets, so the network capacity in VANETs is more restricted than traditional ad hoc networks.
- Unpredictability of traffic density: Network performance can be relatively poor when traffic density is either high or low. During the rush hours, number of vehicles sharply increase causing traffic jam and broadcast storm. On the contrary, sparse density may lead to high data packet loss ratio and sudden linkage interrupt of communication.

Such characteristics often make typical flat routing protocols, in which all nodes are equal and involved in routing process, such as AODV (Ad Hoc On-demand Distance Vector) and DSR (Dynamic Source Routing), unusable or inefficient in VANETs. One of the critical disadvantages of the flat routing protocols is that network scalability is limited and thus they do not perform well under dense networks. One way to solve this problem is hierarchical routing. With the cluster structure, the processing of data packet and routing information can only be restricted to a few nodes known as Cluster Heads (CHs). The rest mobile nodes are either Undecided or Cluster Members (CMs). In other words, the cluster routing can help reduce routing space and route costs. Hence, CBRP (Clustering Based Routing Protocol), as one of the typical hierarchy based routing protocol, can be able to provide better network scalability theoretically.

Although many clustering algorithms based on CBRP have been proposed, modified and testified, either network performance in VANETs has not been done or nodes' mobility model cannot reflect realistic vehicles' traveling traces. Therefore, in this paper, we firstly implement CBRP into NS2 and then combine with VanetMobiSim so as to analyze typical flat and clustering routing protocols in delay, packet loss ratio and route costs.

## 2 Related Work

In the perspective of network structure, routing protocols can be divided into flat and hierarchy-based routing. Typical flat routing protocols include AODV and DSR. But with expansion of network scalability, especially in the case of rapid mobility of nodes, flat routing protocols can achieve huge route costs and poor scalability which restrict the application scenarios. The basic idea of hierarchy based routing protocols, such as CBRP, is dividing mobile nodes into different clusters and each node is assigned either CM or CH. The work in [4] confirms that CBRP present better network performance in terms of packet delivery ratio, average delay and throughput than AODV, DSR and DSDV routing protocols in MANETs.

Researchers have been working on CH selection algorithm based on CBRP with the Lowest-ID (LD) algorithm [5–7]. Efficient Cluster Based Routing Protocol (ECBRP) implementing Efficient Clustering Scheme (ECS) [5] has been proposed and verified that ECBRP can provide better performance than CBRP in MANETs, however, whether CBRP or ECBRP can achieve better performance in VANETs is not clear.

Different from LD algorithm, mobility based clustering scheme MOBIC [6] selects the node with smallest variance of relative mobility as CH. Simulation results show MOBIC algorithm can achieve more stable cluster structure in MANETs. Compared to MOBIC, Affinity Propagation for Vehicular Networks (APROVE) [7] utilizing the affinity propagation algorithm in a distributed manner display obviously higher stability in cluster maintenance than MOBIC in VANETs under highway scenarios. But the performance tests under urban VANETs is not considered. Also some clustering algorithms have been proposed in [8–10], and they put emphasis on cluster stability as in [6, 7], however, none of those was imposed on a reasonable VANTEs model and performance analysis of the proposed algorithms has not be done.

Traffic accidents usually happen near an intersection in urban areas causing V2V communication a severe problem. A Multi-vehicle Select Broadcast (MSB) protocol in [11] is brought forward to broadcast safety messages to vehicles at an intersection with all directions. But the simulation work is based on a USC mobility generator [12] which cannot reflect real behavior of vehicular mobility. Because of those features in VANETs described in Sect. 1, setdest, a tool of NS2, being used to generate randomly wireless network mobile scenes based on Random Way Point (RWP) for general MANETs, cannot present specific vehicular movement patterns. Therefore in this paper VanetMobiSim [13], release 1.1, is selected for producing vehicles mobility in urban intersections as much close as possible in realistic scenarios and generating corresponding mobility traces for NS2 based on IDM-IM (Intelligent Driver Model with Intersection Management). As an advanced version of Car Following Model (CFM), IDM characterizes drivers' behavior based on action of front vehicles by smoothly changing the instantaneous acceleration.

The rest of this paper is organized as follows. Section 2 introduces related research on hierarchy-based routing protocols. Section 3 describes simulation model and network performance metrics. In Sect. 4, simulation results and analysis are presented. Finally, we come to a brief conclusion in Sect. 5.

## 3 Simulation Model and Performance Metrics

### 3.1 Simulation Model

Simulation scenario in $2000 \times 1000\ m^2$ with intersections, multi-lanes and traffic lights is modeled in VanetMobiSim. Random Initial Position Generator, Random Trip Generator and IDM_IM mobility model is adopted in our simulation. Specific parameters setting in VANETs is showed in Table 1. Figure 1 shows mobile scenario with 30 vehicles. Mobility topology file can be obtained in the xml script by adding

```
<extension
class="de.uni_stuttgart.informatik.canu.mobisim.extension
s.NSOutput" output="filename"/>
```

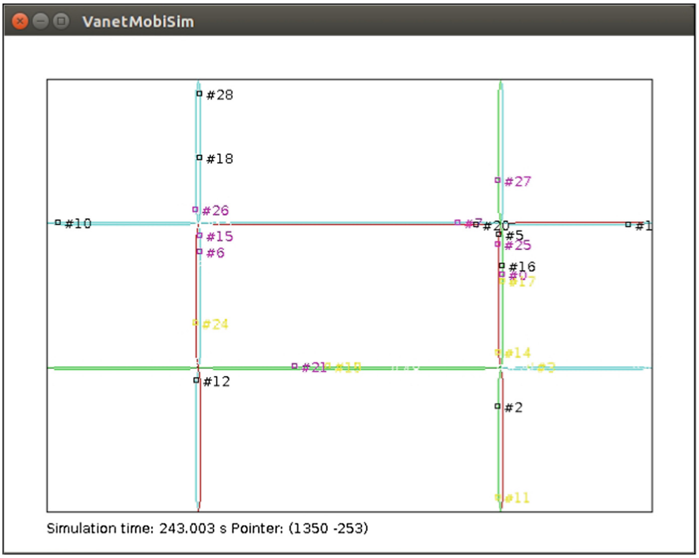


**Fig. 1.** Simulation topology scenario with 30 vehicles and four different colors of vehicles is used to distinguish vehicles traveling in four different lanes.

**Table 1.** Simulation parameters in VANETs modeled by VanetMobiSim

| Parameters | Values |
|---|---|
| Simulation dimension | $2000 \times 1000$ m$^2$ |
| Simulation time | 1000 s |
| Number of intersections | 4 |
| Number of lanes | 4 |
| Traffic lights/intersection | 4 |
| Traffic lights switching time | 30 s |
| Number of vehicles | 20–100 |
| Maximum speed | 30 km/h |
| Initial position model | Random |
| Trip model | Random |
| Mobility model | IDM-IM |

NS2, release 2.35, is used to evaluate network performances with trace file generated by VanetMobiSim. Although CBRP is proposed long before, CBRP is not taken in NS2, thus the very first step is to implement CBRP into NS-2.35. CBRP implement has been done in early version with NS2, but the implement in update version NS-2.35 is more complicated. The implement work mainly include building 'CBRP' and adding it into ns-2.35 directory. Files needed to be built in 'CBRP' include cbrpagent.h/cbrpagent.cc, ntable.h/ntable.cc, hdr_cbrp.h/hdr_cbrp.cc and cbrp_packet.h. And then 'CBRP' has to be created parallel with 'AODV' and 'DSR' under the ns-2.35 directory. After that there are some files in NS-2.35 needed to be changed accordingly:

(1) Define a new type of packet in common/packet.h by adding

```
#define HDR_CBRP(p) (hdr_cbrp::access(p))
......
static const packet t PT_CBRP = 73;
......
name [PT_CBRP]="CBRP";
```

(2) Add a function declaration ‘ `void format cbrp(Packet *p, int offset);`’ in trace/cmu-trace.h and its definition in trace/cmu-trace.cc.

```
void format cbrp(Packet *p, int offset)
{
Hdr_cbrp *cbrph = HDR_CBRP(p);
Hdr_ip _*ph = HDR_IP(p);
sprintf(pt ->buffer() + offset,
"[%d #%d %d->%d] [%d #%d %d %d %d->%d]
[%d %d] [%d %d %d %d->%d]",
......
}
```

(3) To unite CBRP and Otcl, in tcl/lib/ns-packet.tcl, add

```
Set protolist{
......
HDLC
CBRP
}
```

(4) Change Makefile and Makefile.in by adding (Table 2).

```
'cbrp/hdr cbrp.o cbrp/ntable.o cbrp/cbrpagent.o n'
```

**Table 2.** Simulation parameters in network simulator

| Parameters | Values |
|---|---|
| Simulation time | 100 s |
| Transmission range | 300 m |
| MAC protocol | IEEE 802.11p |
| Routing protocol | CBRP/AODV/DSR |
| Propagation model | TwoWayGround |
| Packet type | CBR |
| Packet size | 512 bytes |

### 3.2 Performance Metrics

The network performance of CBRP is compared against AODV and DSR by the following metrics:

(1) Average End-to-End Delay: it defines the whole sum of possible average time such as taken by discovering path, retransmitting time in MAC layer and delivering efficient data packets from source nodes to destination nodes.
(2) Packet Loss Ratio: it is ratio of total number of packets dropped from source nodes to the number of packets sent from source nodes.
(3) Route Costs: it is ratio of routing control packets to data packets of CBR.

## 4 Simulation Results

In this section, the network performance of CBRP compared to AODV and DSR is presented and discussed. To obtain a proper evaluation on the performance differences, ten groups of experiment were conducted. Simulation results is showed in Figs. 2, 3 and 4.

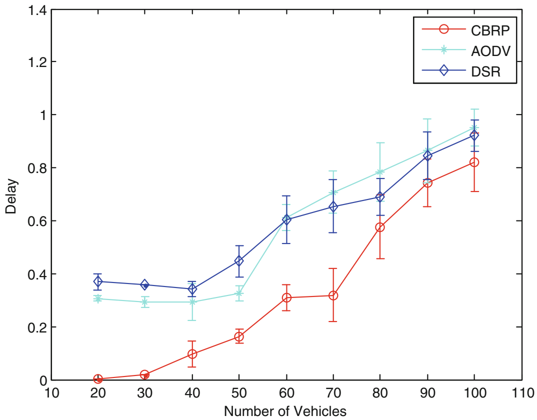


**Fig. 2.** Average end-to-end delay vs. number of vehicles

As number of vehicles increase from 20 to 100, traffic density changes from low to high, packets delivering time from source vehicles to destination vehicles increase resulting delay time in Fig. 2 increase accordingly. Packet loss ratio in Fig. 3 increases as a result of packet congestion caused by vehicles growth. In Fig. 2, CBRP present lowest delay. The experimental data shows that, in sparse vehicle density, delay of AODV and DSR is higher 5–20 times that of CBRP. In Fig. 3, in low density CBRP, AODV and DSR can achieve pretty close performance, while in high density, CBRP present better packet loss ratio. In Fig. 4, both AODV and DSR increase slowly in low density, while increase sharply in high density. However, in either sparse or dense

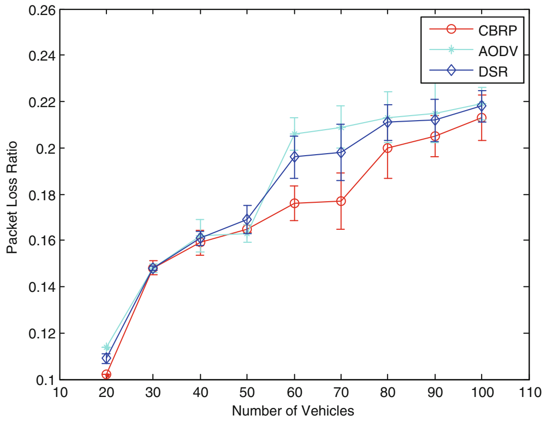


**Fig. 3.** Average packet loss ratio vs. number of vehicles

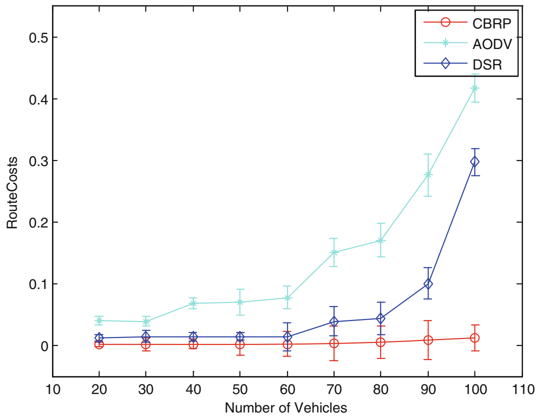


**Fig. 4.** Average route costs vs. number of vehicles

network, CBRP displays smallest, stable and robust route costs. Especially in high density, route costs of AODV and DSR is 10–40 times that of CBRP. In conclusion, simulation results and analysis of experimental data prove the advantage of CBRP in terms of delay, packet loss ratio and route costs.

## 5 Conclusions

In this paper, we present difficulties and challenges in VANETs, discuss flat and hierarchy-based routing protocols and analyze existing models being used. Our simulation scenario is modeled by VanetMobiSim and network performance of CBRP, AODV and DSR is analyzed in NS2. Simulation results indicate that, delay, packet loss ratio and route costs of the former is much better than that of the latter two, which evidences, not only in theory but also in practice, the stronger robust performance of CBRP especially under high density of VANETs.

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