Performances of data packet protocols in VANETs

Roxana ZOICAN*, Ph. D.

**Cuvinte cheie.** Protocole de rutare, model de mobilitate, rețea ad-hoc fără fâr, rată de livrare a pachetelor, controlul suprasarcinii

**Rezumat.** Acest articol analizează performanțele unui protocol de rutare multi-hop utilizat în rețelele VANET (Vehicular Ad-Hoc Wireless Networks)-VANRP. Se realizează, de asemenea, o comparație între protocolul VANRP și alte două protocoale utilizate în rețelele ad-hoc urbane ((MURU și AODV). Rezultatele simulărilor demonstră că protocolul VANRP este mai performant din punct de vedere al ratei de livrare a pachetelor și al controlului overhead-ului.

**Key words.** routing protocols, mobility model, wireless ad-hoc network, packet delivery ratio, overhead control.

**Abstract.** There is a growing interest in deployment and evaluation of routing protocols for Vehicular Ad-Hoc Wireless Networks (VANETs) in urban contexts. The mobility model of nodes is one of the most important factors that impacts the evaluation of any wireless ad-hoc routing protocol using simulations. This paper analysis the performances of a multi-hop routing protocol, called VANRP (Routing Protocol for VANETs) and also it is realized a comprehensive comparison of the impact of this model against other two protocols for urban area ad hoc networks (MURU and AODV). Simulation results demonstrate that VANRP outperforms existing ad hoc routing protocols in terms of packet delivery ratio and control overhead.

1. **Introduction**

There is a growing commercial and research interest in the development and deployment of Vehicular Ad-Hoc Networks (VANETs). VANETs are special applications of the more general Mobile Ad-Hoc Networks (MANETs) and consist of a set of vehicles traveling on urban streets and capable of communicating with each other without a fixed communication infrastructure. VANETs are expected to be of great benefit for safety applications, gathering and disseminating real time traffic congestion and routing information, sharing of wireless channel for mobile applications etc.

With the rapid advance of information technology, it becomes easy to support low-cost inter-vehicle communication, and then to provide customized service to individual drivers. One example of service is to disseminate traffic information to drivers in a certain area, which helps drivers to choose the fast route to their destinations by making a detour of jamming roads.

There are several candidate network architectures for intelligent transport systems. One is that vehicles use cellular network infrastructure for communication. This architecture may have two drawbacks, which are high operation cost and limited bandwidth. Another architecture is a hybrid one that combines the vehicle-to-vehicle communication and vehicle-to-base station communication to alleviate the tight bandwidth budget of cellular networks. This architecture still requires that each vehicle subscribes data service in cellular networks, whose cost may be still quite high. Moreover, when vehicles reside in the area where cellular networks are not available or damaged, it would be difficult to keep smooth inter-vehicle communication. As a result, people have paid a lot of attention to vehicle ad hoc communication architecture, which greatly increases the flexibility of deployment and reduces the cost as well.
In VANETs, each vehicle or node moves on the road with high speed and the trajectory of the vehicle can usually be predicted by itself since the mobility pattern of the vehicle can be approximately inferred by the roadway geometry. Because nodes move with high velocity in VANETs, and the channel condition of each link is highly error-prone due to the reflection of tall buildings and obstacles along the road and interference from other source, the network topology of VANETs could be highly dynamic, which means frequent link disconnection may happen. This makes it challenging to set up a robust path between the source and the destination in VANETs.

Because of the high cost of deploying and testing any new VANET architecture in real world, simulations provide a vital alternative for conducting cheap and repeatable evaluations prior to actual deployment.

This paper proposed an efficient multi-hop routing protocol for urban area vehicular ad hoc networks, called VANRP (Routing Protocol for VANETs), based on MURU and Stop Sign Model. Its performances are compared with those of other two protocols: the classic AODV and the most recent MURU (MUlti-hop Routing protocol for Urban vehicular ad hoc networks). The performances of VANRP were evaluated with extensive simulations. Comparing to existing routing protocols, VANRP has better performance in terms of packet delivery ratio and control overhead.

2. Factors Affecting Mobility in VANETS

Mobility pattern of nodes in a VANET directly stresses the route discovery, maintenance, reconstruction, consistency and caching mechanisms. At any point in time, a VANET can have of a combination of both static and dynamic nodes. The static nodes tend to have a stabilizing influence on topology and routing by relaying the packets to/from the neighboring nodes. On the other hand, dynamic nodes add entropy to the system by causing frequent route setups, teardowns, and packet losses. In this section, there will be identified first the factors that influence the mobility in VANETS. Next it will be described the Stop Sign Model.

Layout of Streets: Streets force nodes to confine their movements to well defined paths irrespective of their final destination. This constrained movement pattern largely determines the distribution of nodes and connectivity of the network. Streets can be single or multiple lanes and can allow either one-way or two-way traffic.

Traffic Control Mechanisms: The most common traffic control mechanisms at intersections are the stop signs and traffic lights. These mechanisms result in formation of clusters and queues of vehicles at the intersections, and reduce their average speed of movement. Reduced mobility implies more static nodes and slower rate of route changes in the network. Besides reducing mobility, cluster formation also affects network performance by increasing contention for the wireless channel.

Interdependent Vehicular Motion: Movement of every vehicle is guided to a large extent by the movement of other vehicles surrounding it. For example, a vehicle would maintain a minimum distance from the one in front of it, increase or decrease its speed, and may change to another lane to avoid congestion.

Speed Limit: The speed of the vehicle decides how quickly or how slowly the vehicle’s position changes, which in turn determines how quickly the network topology changes. Thus speed limit on a road directly affects how often the existing routes are broken or new routes are established.

Block Size: A city block can be considered as the smallest area surrounded by streets, usually
containing several buildings. Over an area comprising many blocks, the size of block plays an important role in vehicular communication pattern. The block size determines the number of intersections in the area which in turn determines the frequency with which a vehicle stops. It also determines whether nodes at neighboring intersections can hear each other’s radio transmission.

Stop Sign Model (SSM)

In the Stop Sign Model (SSM), every intersection has a stop sign, such that any vehicle approaching the intersection must stop at the signal for a fixed waiting period. Each vehicle’s motion is governed by the vehicle in front of it. This is quite intuitive – a vehicle moving on a road can never move further than the vehicle that is moving in front of it, unless it is a multi-lane road and the vehicles are allowed to overtake each other. Throughout this paper, it is assumed that all roads have a single lane and that no vehicles are allowed to pass each other.

3. The VANRP protocol

It was considered a VANET in an urban area (e.g. the city of Bucharest). It was modeled a north-east area with 2 fixed block size (World Trade Center and the Exposition Building) across the area. All streets are assumed to be two-way. The mobility information of each vehicle can be characterized by the average speed and the movement trajectory, which is determined by the destination and the road geometry. Vehicles communicate with each other through short range wireless channels (100m-150m) with WiFi network interfaces.

Each vehicle is assumed to be equipped with global position system (GPS) and digital maps, and then a vehicle knows its location and street-level road geometry at any instance. With advanced location registration and lookup services, it was assumed that a source node is able to get the location of any destination nodes without incurring much traffic overhead.

Even though VANETs have unique characteristics such as the unstable channel condition and high mobility of each vehicle, it can still find some spaces to improve the performance of routing in VANETs.

1) Route Request: If a source node wants to send data packets to a destination node, the shortest trajectory from the source to the destination can be calculated with the roadway geometry plus source and destination’s location as well as mobility information. VANRP tries to find a routing path using the shortest trajectory as the guidance. Due to the restriction of roadway geometry, the relative position of destination to source resides in a finite set. The information of the shortest trajectory can be used to reduce control overhead of routing.

Once receiving the route request packet in which the trajectory information is piggybacked, the receiving node will process the packet if itself locates in the broadcast area. Otherwise, the node simply drops the packet.

2) Path Determination: Traditional routing protocols (i.e. AODV) that tries to find the shortest path is not suitable in VANETs because of the highly dynamic network topology and channel condition. On the other extreme, it can be selected the path with the smallest bit error rate of each link. However, it may significantly increase the number of hops, which incurs a long end-to-end delay. Furthermore, due to the rapid change of network topology, the path breakage probability increases as the number of hops becomes large.

Considering the direct reflection path and ground reflection path between the two mobile nodes, two-ray ground reflection model is used to calculate the received power at distance $d_{\text{link}}$. 
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\[ Pr = PtGtGrHt^2Hr^2/d\text{link}^4l \]  \hspace{1cm} (1)

where \( l (l \geq 1) \) is the system loss, \( Hr \) and \( Ht \) are the heights of the transmit and receive antennas respectively.

In reality, the received signal quality is determined not only by the received power \( Pr \), but also on the thermal noise and inter-node interference. The average link SNR (signal-to-noise ratio) is used to evaluate the link quality with Rayleigh fading. The link SNR can be calculated as follows:

\[ \text{SNR}_{\text{link}} = \alpha^2 Pr/(P_{\text{thermal}} + \alpha^2 P_{\text{ini}}) \]  \hspace{1cm} (2)

where \( Pr \) is the received power at the end of a link, \( P_{\text{thermal}} \) is the thermal noise power, \( P_{\text{ini}} \) is the sum of received power from all the interferers and \( \alpha \) is the amplitude values of the fading channel with Rayleigh distribution.

If the binary phase shift keying (BPSK) modulation is used, the bit error rate (BER) of the link with Rayleigh fading can be calculated as follows:

\[ \text{BER}_{\text{link}} = \frac{1}{2} \left[ 1 - \left( \frac{\text{SNR}_{\text{link}}}{1 + \text{SNR}_{\text{link}}} \right)^{1/2} \right] \]  \hspace{1cm} (3)

In VANETs, the link quality between a pair of nodes may significantly decrease when either node turns at a corner, since the line-of-sight transmission will not be available. The packet error rate (PER) over a link can be calculated as follows:

\[ \text{PER}_{\text{link}} = 1 - (1 - \text{BER}_{\text{link}}) L + f(mo) \]  \hspace{1cm} (4)

where \( L \) is the packet length and \( f(mo) \) is the function of node mobility.

Considering the link-layer retransmission, the calculation of PER is adjusted as follows:

\[ \text{PER}_{\text{link}}^N = 1 - \Sigma (1 - \text{PER}_{\text{link}}) \text{PER}_{\text{link}}^i \]

\[ \text{PER}_{\text{link}}^N = 1 - \Sigma (1 - \text{PER}_{\text{link}}) \text{PER}_{\text{link}}^i \]  \hspace{1cm} (5)

where \( N \) is the expected number of retransmission required per link.

Suppose that each hop has the same PER given in Equation (5) and that path has \( n \) hops, the PER of the path is calculated as follows:

\[ \text{PER}_{\text{path}}^N = 1 - (1 - \text{PER}_{\text{link}}^N)^n \]  \hspace{1cm} (6)

From Equations (1), (3), (4), and (5), it can be seen that \( \text{PER}_{\text{path}}^N \) is a function of the hop distance \( d_{\text{link}} \).

4. Numerical Results

The area considered in simulations was assumed to be on a 1500m x 1500m square area, where the street layout is in grids with block length of 150m. A number of vehicles are deployed to the streets and the initial location of each vehicle is randomly chosen to reflect the even distribution on the map. It was compared VANRP with the original MURU and AODV. The performance metrics are: packet delivery ratio and total control overhead. It was used our VANSIM simulator.

The packet size is 256 bytes. The simulation time is 350 seconds and each case is repeated 70 times to achieve a high confidence of the results.

The performances of the routing protocols were analyzed for two models:

1) MODEL 1: A fixed source and a fixed destination: In this model, a fixed source sends packets to a fixed destination located 2 blocks away from source.

Figure 1 shows the data delivery ratio as the function of the total number of nodes.

![Fig. 1. The data delivery ratio.](image-url)
not suitable for urban vehicular ad hoc networks. In contrast, the data delivery ratio of VANRP and MURU is much greater than 60% as the network density increases.

Figure 2 shows the overhead of routing protocols measured in the total number of routing packets sent. Since VANRP and MURU have a larger data delivery ratio, the average overhead needed per packet is much lower than that of AODV.

![Fig. 2. The control overhead.](image)

2) MODEL 2: Mobile source and mobile destinations: Five mobile source-destination pairs were selected.

Figure 3 shows the data delivery ratio. As can be seen, VANRP and MURU outperforms other two protocols significantly.

![Fig. 3. The data delivery ratio.](image)

Figure 4 shows the average routing overhead. The overhead of AODV increases slightly as the increase of network density by the fact that more nodes participates in the finding of routing paths as the network density increases. The increases of data delivered introduce the increases of the total overhead needed in VANRP and MURU. However, the use of trajectory constrained and self-tuning route request greatly reduce the overhead of the latest two.

![Fig. 4. The control overhead.](image)

5. Conclusion

In this paper it was analyzed a routing protocol, called VANRP, for vehicular ad hoc networks. Comparing to the traditional AODV routing protocol, the simulation results demonstrate that the VANRP has much better performance in terms of packet delivery ratio and algorithm overhead.

References

