DSR-V: A Direction-based Stable Routing Protocol for VANETs

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Vehicular Ad hoc Networks (VANET) are a special pattern of mobile ad hoc networks formed by moving vehicles. Recently, VANETs gained lots of the researchers' attention because of their ability to provide many services ranging from road safety to road comfort. However, due to their special node movement characteristics, routing in VANETs is a challenging and complex task. In this paper, a direction-based stable routing protocol is proposed. In this protocol, route selection process considers not only the minimum number of available hops, but also the link stability between nodes along the route. A route with stable links is more likely to reduce the overall routing overhead as the probability of route breakage and route rediscovery is minimized. The performance of the proposed protocol has been evaluated through simulation and the obtained results show that our protocol minimizes the overall overhead compared to other traditional VANETs routing protocols.

يعتبر VANET نمطا خاصا من الشبكات اللاسلكية النقالة فيها السيارات المتنقلة هي التي تشكل الشبكة. ومؤخرا، اكتسبت VANETs الكثير من الاهتمام نظرا لقدرتها على توفير العديد من الخدمات التي تتراوح بين السلامة. الراحة على الطريق. ومع ذلك، نظرا لسمات خاصة مثل قدرة عالية على التحرك والطوبولوجيا الديناميكية، فإن مهمة العثور على مسار VANETs هو أكثر صعوبة وتعقيدا مقارنة بالبروتوكولات التقليدية. في هذا البحث، نقدم بروتوكول قائم على استخدام الاتجاه للعثور على مسار مستقر. البروتوكول المقترح. لا يعتمد فقط على الحد الأدنى لعدد القفزات المتاحة في عملية الاختيار ، وإنما أيضا الاستقرار على طول الطريق. أداء البروتوكول المقترح تم تقييمه عن طريق المحاكاة وتظهر النتائج أن البروتوكول يقلل من مجمل النفقات بالمقارنة مع غيرها من البروتوكولات التقليدية.

Keywords: Ad-hoc networks, Link stability, Routing, Vehicular networks

1. Introduction

Vehicular Ad-hoc NETwork (VANET) is a special pattern of the conventional Mobile Ad Hoc NETwork (MANET), where mobile nodes consist of vehicles equipped with wireless units for inter-vehicle communication. VANETs emerged as a result of the rapid technological advances in short-range wireless communication technologies as well as the support of governmental organizations and the automotive industry. Modern vehicles are now equipped with GPS receivers, digitized maps and on-board sensors. Adding to this the inter-vehicle wireless communication capabilities enabled a large range of VANET applications and services to come up, ranging from road safety to road comfort. However, in order to be largely deployed, many challenging problems need to be addressed, such as routing, security, efficient data dissemination and others.

Although MANETs and VANETs share many common characteristics, the special node movement characteristics of VANETs make MANETs protocols, especially topology-based routing, inapplicable in such highly dynamic environment. A good analysis of the performance of MANETs routing protocols in the VANETs environment can be found in [1] and [2]. Therefore, several routing protocols, specifically for vehicular ad-hoc networks, have been suggested recently. The main objective of most of the proposed solutions were to find the shortest route between a source and a destination, while minimizing the overhead incurred to save the scarce wireless bandwidth. A good survey of VANETs routing protocols can be found in [3]. However, it has been noticed in [4] and [5], that a shortest path is not always the best choice. In a highly dynamic environment, as in VANET, it is highly probable that the shortest path might be a path that is about to break because one of the nodes is approaching an intersection, thus getting out of transmission range. Moreover, the session duration between a source/destination pair is very short. Thus, it would be much better to select a longer, but more stable path that would last longer, hence decrease the overhead of re-establishing a new route. Therefore, link stability, in addition to the shortest path criterion, should be taken into consideration when selecting a route from a source to a destination.

Measuring link stability in VANETs is a challenging task. Several techniques have been proposed that mostly rely on the existence of a localization system, such as GPS, as in [5 and 6]. Although this is a valid assumption as GPS is now part of the vehicle's onboard navigation system, GPS signal is not always reliable as it requires the existence of line of sight, which is not the case in many situations like tunnels or urban cities with tall buildings.

In this paper, we propose a GPS-free routing protocol that favours the routes with stable links without relying on the vehicle's location information. A link between two nodes, A and B, is considered stable if the two nodes are moving along the same direction for a certain period of time. Our proposed protocol is evaluated through simulation and its performance is compared to the classical Ad-hoc On Demand Distant Vector routing protocol (AODV) [7] that showed acceptable results in VANETs and does not rely on car positioning. Results obtained showed that this approach decreases the overhead caused by control messages generated for route discovery and route repair as well as increases the overall packet delivery ratio.

The paper is organized as follows. Section 2 surveys the related work. The proposed routing protocol is presented in section 3. Section 4 presents the experiments and analysis of the results. Finally section 5 concludes the paper with direction for future work.

2. Related work

Numerous routing protocols have been proposed recently in the literature for vehicular ad hoc networks. The earliest efforts were based mainly on one of the two basic ad-hoc routing algorithms classes: proactive or reactive. Traditional proactive routing protocols, as in [8 and 9], are based on maintaining constantly updated routing tables for routes between all nodes in a given network at all times. Consequently, routes are always available and routing process is fast. However, the large overhead of continuously updating the routing tables render this class of protocols inefficient in a highly dynamic environment. On the other hand, reactive algorithms, such as AODV [7] and DSR [10], rely on creating routes on demand. A route discovery is invoked whenever a route is needed to send data from a source to a destination. A Route Request message (RREQ) is flooded in the network until either reaching the destination, or reaching an intermediate node with valid routing information, or reaching the maximum packet time to live. In the first two cases, a Route Reply message (RREP) is sent back to the source and the route is established. In case of link breakage, an error is reported back to the source and the route discovery phase is re-invoked. Several experimental studies have been conducted to compare the performance of both classes in VANETs and results showed that reactive protocols are more preferred over proactive one. A detailed comparative study can be found in [1-3]. However, it is worth mentioning that route discovery phase in reactive protocols, which is flooding-based, causes a significant overhead in terms of the scarce bandwidth consumption, in addition to the delay and bandwidth consumption caused by frequent route breakage.

Reducing this overhead can be done by several ways. In position-based routing, as in [11-13], the location of the moving vehicles that are assumed to be known, are used to restrict flooding. The node closest to the destination is the one used for packet forwarding. This approach proved to be better suited for VANETs, however it suffers from several drawbacks. The main drawback appears in city scenario where a shortest path is not always the best path. Moreover, nodes location is assumed to be known, either through location servers, which is not scalable, or using GPS which is not always available.

Another approach is the cluster-based approach that relies on grouping the moving vehicles into clusters, where a cluster head in each cluster is responsible for all inter-cluster communication. The main objective achieved by clustering is scalability, which heavily depends on the cluster formation. Forming stable cluster is difficult to achieve because of the high mobility and dynamicity of the vehicular network. Examples of such protocols can be found in [14].

The protocol proposed in this paper aims at minimizing the routing overhead caused by frequent link breakage by considering the link stability in routing decision. Link stability, however, is not a new concept. A stable protocol for VANETs was proposed in [5] where routes are formed by vehicles moving along the same direction. Grouping vehicles according to their moving direction is performed assuming that each vehicle knows its geographical location and direction heading using an existing GPS receiver. In [15], the lifetime of a link is estimated by the number of messages generated periodically and received by this link's nodes. The higher the messages are, the stronger the link is as it reflects how long those two nodes were within range of each other. The network considered is an ad-hoc network with low nodes mobility. The associativity counter is reset whenever a node goes out of transmission range. As a result, variation in relative speed is not considered which affects the selection of a stable link. In [16], link breakage is decreased by estimating the future positions of the vehicles and the duration needed for data transmission to decide which route to choose. However, the performance is highly dependent on the prediction scheme used.

The proposed protocol in this paper is a GPS-free protocol that measures links stability using the one-hop beacon messages periodically generated by each vehicle to identify its presence. Stability is considered over a long period of time, allowing for relative speed variations. The details of the protocol are presented in the following section.

3. Direction-based stable routing protocol

The Direction-based Stable Routing protocol (DSR-V) is a reactive routing protocol for VANETs that aims at reducing the overhead incurred by the route discovery process as a result of link breakages. The route selection process, during the discovery phase, not only does it rely on the shortest path, but also links stability is taken into consideration. The intuition behind this is that a route with stable links, although longer, would be less likely to break, thus decreases the overhead associated with links repairs and route discovery. Such a feature is highly needed in an environment where vehicles are moving along pre-determined routes, thus the chance to find vehicles moving along the same direction is high. The main aspects of our proposed protocol are as follows.

3.1. Link stability

Link stability is a measure of the quality of the link between two vehicles, as defined in [19-21]. This measure reflects the cost of re-establishing a new route if a route, with this link being part of, breaks. Accordingly, it is considered as an important aspect that should be taken into consideration by the routing algorithm. In our proposed protocol, we consider a link between two vehicles, A and B, to be stable if A and B are within communication range of each other for a period of time greater than a certain threshold. The value of this threshold is a configurable parameter that depends on many factors among which are the transmission range and vehicle velocity. Two cars moving along the same direction can hear their periodically generated beacons often. Unlike the work in [15], the number of beacon messages is considered over a longer period of time, thus tolerating vehicles getting in and out of their common transmission range because of change in speed or network traffic conditions. For example, the beacon counter maintained by vehicle A for vehicle B that is moving along its direction is not reset if B gets out of transmission range unless being out of range lasts for more than a predefined time. In addition, two vehicles, A and B, are not considered moving along the same direction unless the number of received beacons exceeds a certain threshold to excludes the cases when they are crossing each other while moving in opposite directions.

3.2. Protocol overview

The proposed protocol is an AODV-based reactive routing algorithm. AODV protocol is table-driven and is composed of two phases: route discovery phase, and route maintenance phase. In the discovery phase, a route request message (RREQ) is initiated and sent to all neighbour nodes by a source node wishing to send data to a specific destination node, as shown in fig. 1-a. Each intermediate node, upon receiving the RREQ message, creates and saves a route back to the source then, either replies back with a RREP unicast message if it knows a route to that destination, or rebroadcasts it if it is seen for the first time. As the RREP travels back to the source, each intermediate node creates a route to the destination. When the source receives the RREP message, it creates a route to the destination, saves it in its routing table and the data sending process starts, as shown in fig. 1-b. Upon receiving multiple RREPs, the source node selects the shortest path to the destination, which is path 1-3-6-8 in fig. 1-b.

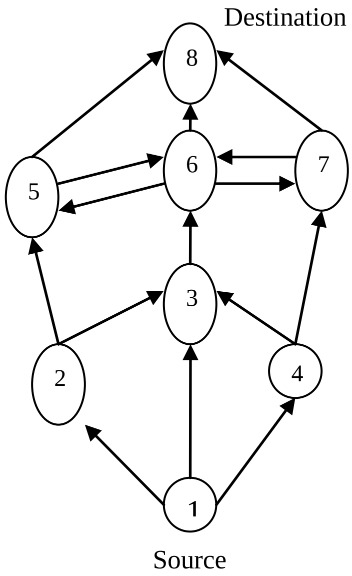

Fig. 1-a. RREQ broadcasted.

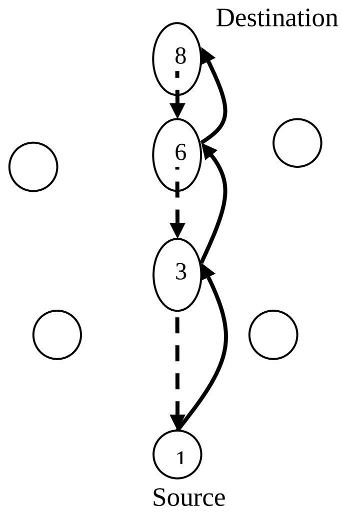

Fig. 1-b. -- RREP, — DATA unicasted.

In DSR-V protocol proposed, each node keeps track of the number of beacon messages, periodically emitted by all nodes, received from each of its neighbours. These values represent how stable each of the links is. Upon initiating or receiving a RREQ message, it is only sent through stable links, until reaching the destination. The path selected by the source node is then the shortest one amongst stable paths. This is shown in fig. 2 where the path selected by the DSR-V protocol is 1-2-3-6-7-8 which is a longer path but a stable one. The selection process is a local decision that does not impose any extra overhead.

4. Experimental analysis

To further prove our concept, we simulated the behavior of the proposed protocol using Vsim, a VANET simulator created in the University of Ulm, Germany [17]. The simulator used combines both a validated road traffic simulation with a communication simulation as discussed below. In the following subsections, we present the simulation methodology, then the analysis of the results obtained.

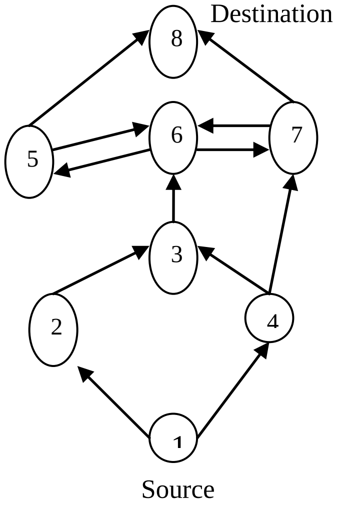

Fig. 2-a. RREQ broadcasted.

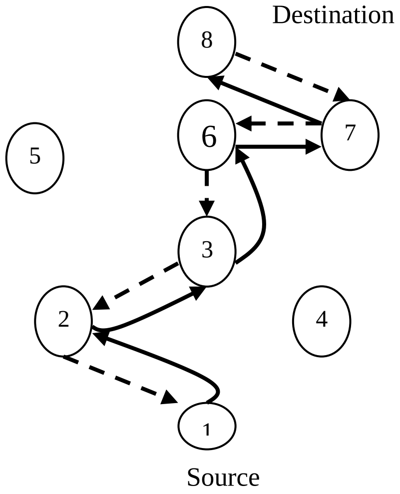

Fig. 2-b. -- RREP, — DATA unicasted

4.1. Traffic model

Traffic simulation is based on the traffic model of Nagel and Schreckenberg [18] where vehicles are generated randomly from the roads endpoints, heading to randomly chosen destinations. Their velocity and position are updated every 100 msec taking into consideration the rules for changing lanes. In our experiments, two models were used: a single bidirectional road model that represents a highway scenario, and the city of Ulm model that represents a medium size city. In the highway scenario, vehicles are generated from both ends and move in opposite directions. In the city scenario, generation points were chosen randomly from intersection points along the map. The maximum vehicle velocity in both scenarios was chosen to be 80 Km/h.

4.2. Communication model

In this model, vehicles are communicating using the IEEE 802.11b standard, where every 100 ms each vehicle broadcasts a beacon message to exchange its state with the surrounding neighborhood. A beacon message (HELLO message) is used by each node to build its own neighbor table. Each HELLO message is of length 105 bytes. The transmission range is set to 250m as defined in the 802.11b standard.

4.3. Experimental results and analysis

Simulation experiments were conducted and the protocol performance was compared to the performance of the classical AODV routing algorithm. The key performance metrics of interests in evaluating routing protocols are as listed below.

- Packet delivery ratio: defined as the ratio between number of packets received at the destination and total number of packets sent to that destination
- Routing overhead: defined as the ratio between the number of control packets used by the routing algorithm to the total number of data packets generated.

A Constant Bit Rate (CBR) data packets were generated between randomly selected source/destination pairs at an average varying between 5 Kbps up to 50 Kbps and a participation ratio of 25%. Participation ratio represents the percentage of vehicles engaged in generating data for randomly selected destinations. Simulation time was set to 30 minutes to allow for stabilization and every point in the graph is the average of 10 runs with a 90% confidence interval.

Two different sets of experiments were conducted. The first set represents the highway scenario, while the second set represents the city scenario. The results obtained for a highway scenario are shown in figs. 3 and 4. It can be noticed that the average packet delivery ratio of the proposed

DSR-V protocol outperforms AODV for different data rates as well as the total routing overhead. The improvement is expected as relying on stable links decreases the probability of link breakage, thus resulting in higher values for delivery ratio. However, the small value of improvement is due to the fact that a route breakage occurs only when vehicles go out of transmission range due to variations in speed or direction at exit points.

Figs. 5 and 6 represent results obtained in a city scenario where intersections exist. As can be seen, the improvement is better in both delivery ratio and routing overhead. However, it can be noticed that the overall packet delivery ratio of AODV in the city scenario was lower than in the highway scenario. This is because of the effect of the higher number of intersections, thus higher number of changes in vehicles directions. Also, the effect of tall buildings that would affect the links as well as block transmissions. In DSR-V, this effect can also be seen but the improvement over AODV is higher that in the highway case. This is because DSR-V decreases the impact of the intersections. However, the effect of the tall buildings remains the same.

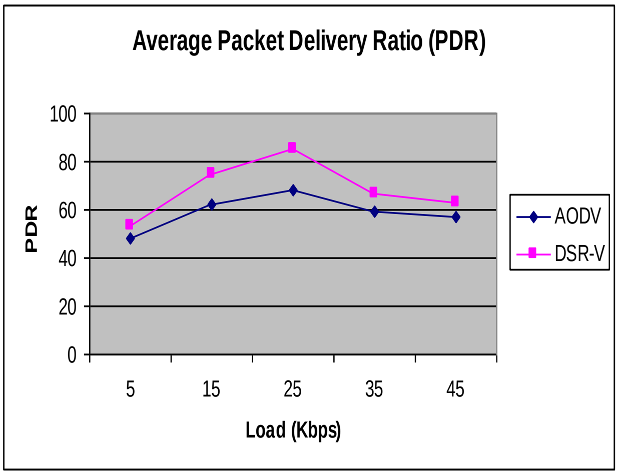

Fig. 3. Average packet delivery ratio.

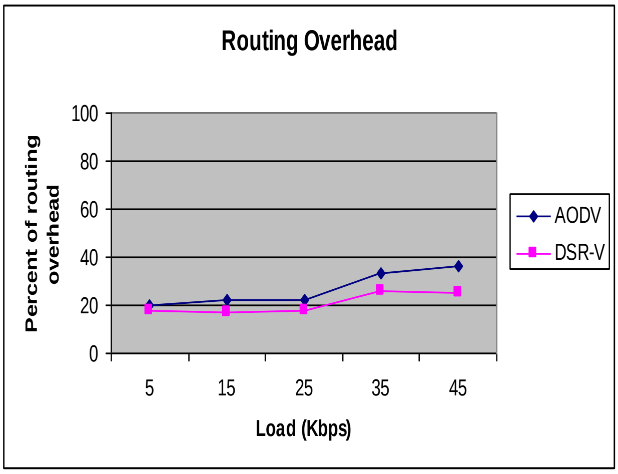

Fig. 4. Routing overhead.

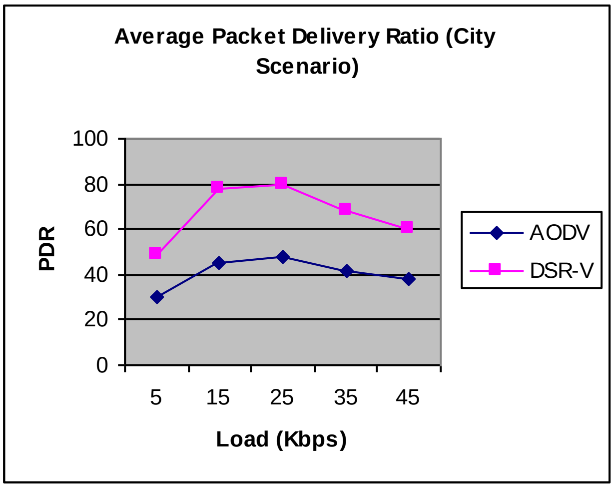

Fig. 5. Average packet delivery ratio.

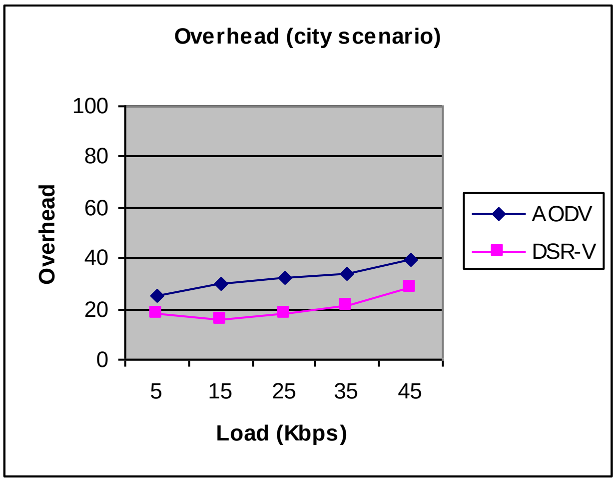

Fig. 6. Routing overhead.

5. Conclusions

The direction-based stable routing protocol proposed in this paper offers a robust solution to routing in VANETs, as it seamlessly combines the best in the reactive and stable approaches. In this paper, we present a reactive routing algorithm that favours routes with more stable links with the aim of decreasing the overhead caused by frequent route breakage in a highly mobile environment such as VANETs. The performance of the proposed protocol is compared against the classical AODV protocol in terms of packet delivery ratio as well as routing overhead in a highway scenario as well as a city scenario. Results showed that the proposed protocol outperforms AODV both in packet delivery ratio as well as in routing overhead.

Currently, the performance of the protocol is under investigation to study the effect of varying the vehicles' speed and transmission range on the overall performance.

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