Combining the Spray Technique with Routes to Improve the Routing Process in VANETS

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Abstract: Vehicular networks represent a special type of wireless network that has gained the attention of researchers over the past few years. Routing protocols for this type of network must face several challenges, such as high mobility, high speeds and frequent network disconnections. This paper proposes a vehicular routing algorithm called RouteSpray that in addition to using vehicular routes to help make routing decisions, uses controlled spraying to forward multiple copies of messages, thus ensuring better delivery rates without overloading the network. The results of experiments performed in this study indicate that the RouteSpray algorithm delivered 13.12% more messages than other algorithms reported in the literature. In addition, the RouteSpray algorithm kept the buffer occupation 73.11% lower.

1 INTRODUCTION

Vehicular ad hoc networks (VANETs) represent a special type of wireless network that has gained the attention of researchers over the past few years. This type of network offers, through Intelligent Transport Systems (ITS), such services such as driver assistance, entertainment and dissemination of information (Taysi and Yavuz, 2012).

In VANETs, the high mobility of vehicles causes frequent disconnections among network nodes, which partitions networks and prevents the use of routing protocols designed for ad hoc networks. However, some features of VANETs can be used to assist in routing, such as mobility patterns limited by roads, the tendency of vehicles to move in groups and the integration of sensors into vehicles (Toor et al., 2008) (Li and Wang, 2007). There are several routing algorithms that have been proposed for VANETs, but recent technological achievements and their popularization, such as GPS, have opened up the possibility of proposing even more efficient protocols.

This article introduces the RouteSpray algorithm. This algorithm combines four important concepts in making routing decisions: (i) use of the store-carry-and-forward technique (Zhao and Cao, 2008) to route messages; (ii) transmission of messages based on direct contact (Spyropoulos et al., 2008a); (iii) use of the routes of the vehicles to assist in routing, assuming that the vehicles are equipped with GPS; and (iv) use of the controlled spraying of messages technique (Spyropoulos et al., 2008b). Keeping in mind that all the techniques mentioned above are studied in the literature with the aim of improving the routing process, the main contributions of RouteSpray are:

- To combine the controlled spray technique using routes to improve the routing process;
- To explore the geographic routing for mobile destinations;
- To offer a comparative study and a performance analysis of the controlled spraying technique and the use of routing information for routing.

Several protocols that aim to perform routing in VANETs have been presented. The main difference among these protocols is the information they consider in routing (history of contacts among nodes, location information, etc.) and the strategy they use to forward messages (number of generated replicas for each message). Nevertheless, there is a consensus among the scientific community that there is no ideal routing protocol that can be applied in all scenarios.

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The RouteSpray protocol aims to address scenarios in which the routes of vehicles are previously known, which has become common due to the popularization of navigation devices, especially if we consider fleets with controlled mobility, such as buses, trucks and taxis. This protocol was designed to use the routes of vehicles to make routing decisions, which is the only premise it requires.

The RouteSpray protocol was validated through a simulation of an urban environment where vehicles run through routes that connect the points of interest of a city. To ensure a more realistic simulation, the OMNeT++ simulator (Varga, 1999) was used together with the VeNeM software (Silva, 2012). The results of the experiments show that the RouteSpray algorithm delivered 13.12% more messages than other proposals reported in the literature and kept the buffer occupancy 73.11% lower.

The remainder of the paper is organized as follows: in Section 2, related studies are presented. In Section 3, the operation of the RouteSpray algorithm is described. In Section 4, the simulation environment and the experimental results are presented. Finally, in Section 5, conclusions and future studies are discussed.

2 RELATED WORKS

Over the past few years, several algorithms such as the DSR (Dynamic Source Routing) (Johnson and Maltz, 1996) and the AODV (Ad-hoc On-demand Distance Vector) (Perkins and Royer, 1999) algorithms have been proposed to solve the routing problem associated with ad hoc networks. Both protocols initiate data transmission only after establishing a path between source and destination, a characteristic that is often not satisfied in VANETs because this type of network suffers frequent disconnections caused by the high speed and high mobility of vehicles. To avoid data loss, routing protocols for VANETs consider the use of the store-carry-and-forward technique (Lee and Gerla, 2010).

Another characteristic that can benefit routing algorithms for VANETs is the use of location information of network nodes, which has become possible due to the incorporation of Navigation Systems (NS) into vehicles. Routing protocols that use this technique are classified as position-based or geographic-based (Allal and Boudjit, 2012).

Opportunistic transmission and context information can both be used in VANETs to improve the routing process. One of the main algorithms for vehicle routing is the GeOpps (Leontiadis and Mascolo, 2007). The GeOpps is a single copy algorithm, which aims to route data messages to a specific geographic region. Its operation is based on calculating the estimated minimum time to the message delivery. To achieve this it explores the data provided by the navigation systems. The calculation of METD is done as follows: The algorithm traverses the route of the vehicle looking for the nearest point to the destination; after the NP is discovered, the algorithm queries the NS to get the estimated travel time from your current position to the NP; finally, the algorithm adds the time returned by the NS to the estimated time for the vehicle to travel in a straight line from the NP to the destination. In general, the METD can be calculated as follows:

$$METD = ETA\, to\, NP + ETA\, from\, NP\, to\, D$$

The GeOpps algorithm was designed for vehicular networks, and uses the vehicle routes to route messages toward the destination. However, the fact that it does not explore alternative paths using multiple copies of the message causes major delays in the delivery of the message, making it unviable for practical use.

Another scheme that explores opportunistic transmission combined with multiple copies of the message to ensure better delivery rates, is called Epidemic routing (Vahdat et al., 2000). The Epidemic algorithm uses the store-carry-and-forward technique to improve data delivery rates. It stores received messages in a buffer and takes advantage of opportunistic contact to replicate the stored messages to the other nodes of a network. This technique causes the network to flood with messages and ensures that one of the replicas of the message follows the shortest existing path to the destination. Hence, the Epidemic algorithm achieves a high message delivery rate and low delay for messages transmitted to the destination. Nevertheless, due to the excessive number of message replicas, this type of routing causes network degradation, abusive consumption of electricity and a large occupancy of buffers. Such characteristics make the Epidemic algorithm unusable in various scenarios.

To solve the problems associated with the Epidemic algorithm, an algorithm called Spray and Wait was proposed in (Spyropoulos et al., 2008b). The Spray and Wait algorithm uses the spray technique to decrease the number of replicas of messages sprayed over a network. Although the authors introduced the use of the algorithm in sparse networks, the spray technique was first used in cellular networks. This technique aimed to spray messages among the points that are most frequently visited by users (Tchakountio and Ramanathan, 2001). The Spray and Wait algorithm is divided into two phases. In the spray phase, the source node calculates the number of copies that must be sprayed. This calculation is based on the number of network nodes and on the desired delay time for the message to reach the destination. These copies are sprayed in an opportunistic manner among the nodes that enter the transmission area of the source node. If the message is not delivered to the destination in the spray phase, the nodes initiate the wait phase. In the wait phase, each node keeps the message in its buffer until it comes across the destination node, and only then does it deliver the message.

Although dense networks are beneficial to the operation of the Spray and Wait algorithm, in vehicular networks, density becomes a trap and compromises the performance of the algorithm. This negative effect occurs because the flow of vehicles becomes concentrated at intersections and traffic lights then spread along different directions that vehicles may follow. Such behavior causes some copies of the message to be taken away from the destination. As a solution, the Route Spray algorithm uses the routes of vehicles to determine the best route through which to send a message. The algorithm sprays messages only among the nodes that will encounter the destination node, thus preventing the messages from being sprayed among nodes that can never deliver them.

3 ROUTESPRAY ALGORITHM

To perform routing, the RouteSpray protocol assumes that vehicles are equipped with GPS and that in addiction to knowing their route, they also know the route of the message destination. Those are premises of all position-based algorithms (Mauve et al., 2001). The RouteSpray algorithm, however, differs from the others for predicting the mobility of the destination node. Furthermore, there is no need for a fixed network infrastructure; that is, it is possible to perform the routing among vehicles in a completely ad hoc manner.

The operation of the protocol is based on the use of two types of messages: control messages and data messages. Control messages are used to maintain the state of a network, which is achieved by sending context information to neighboring nodes. In order to avoid conflicts of messages created at the same time, each message generated in the network has a unique identifier, which consists of the address of the source node, the creation time of the message and a counter.

The process of information exchange and the routing decision making can be divided into three distinct stages. In the first stage, communication is initiated by a handshake, when nodes exchange information about the packages that have already been delivered over the network, allowing for the control of messages stored in the buffer, which is achieved by deleting those that have already been delivered. In the second and third stages, the nodes exchange information about the state of the buffer. The source node sends its neighbor a list containing an identifier and the destination of each message in its buffer. With this information, the neighbor calculates, using the pre-established routes, the time in seconds that it will take to deliver each message. After the source node receives a response from the neighboring node, it is able to determine which is the best carrier for the message. More details about the routing stages are presented below.

Whereas node X entered the broadcast area of the node Y, the three stages would be as follows:

In the first stage, X sends Y a handshake message that carries the list of messages that had already been delivered in the network. Upon receiving this information, Y is able to go through its buffer deleting the messages listed as delivered. At the end of this process, with a consistent buffer, Y delivers the messages addressed to X and sends X a list of the messages it has in its buffer.

In the second stage, when X receives the list of messages in the buffer of Y, X calculates the time it needs to deliver each of these messages. Then, it sends Y a list containing the identifier and the time required to deliver each message. To calculate the delivery time of the message, X travels the destination route of the message looking for a intersection point with its route. At the end of this process, if X finds a point of intersection, it returns the time in seconds it takes to go from its current position to that point. If such intersection point does not exist, the algorithm returns a negative value, indicating that X is not able to deliver the message.

Finally, in the third stage, when Y receives information about the estimated time that X takes to deliver each message, it is able to decide which is the best carrier for the message. To make this decision, Y needs to estimate the time it takes to deliver the message itself and compare it to the estimated time returned by X. If Y has more than one copy of the message, it will use the binary spray technique to spray those copies to X. If the estimated delivery time returned by X is shorter than the estimated delivery time returned by Y, Y forwards the messages to X, making it responsible for delivering the message to its destination.

The entire routing process described above is presented in greater detail in pseudo-code:

```
input: message
```

```
if( received control message ) then
{
   if( handshake message ) then
   {
      Clean Buffer;
      Update Delivered Messages List;
      Delivers Messages Addressed To Source;
      Responds Messages List In Buffer;
   }
   else
   {
      if( response to handshake message ) then
      {
         Receives List Of Messages From Neighbour;
         Sends Message Contact Time;
      }
      else
      {
         Processes Response Contact Time;
         Decides For Better Transmitter;
      }
   }
}
else
{
  if( received data message ) then
  {
     if( message addressed to me ) then
     {
        Process Message;
     }
     else
     {
        Store In Buffer;
     }
   }
}
```

The improvement in performance afforded by the RouteSpray algorithm is due to the combination of two important concepts: (i) use of routes to obtain prior knowledge of contacts among nodes and (ii) use of the Binary Spray technique. This combination ensures better delivery rates without overloading networks. Both concepts are explained in greater detail below.

3.1 Use of Routes

Geolocation information in a network makes it possible to have prior knowledge about the position of the network's nodes. This feature enables package forwarding in the direction of the destination and improves data delivery rates. The use of the routes of vehicles ensures that the algorithm can predict the contacts among the network nodes. Thus, the algorithm can make the best forwarding decision.

Consider three vehicles that follow pre-established routes (Figure 1), where vehicle B has a package addressed to vehicle C. Although the route of vehicles B and C intersect, vehicle B will choose vehicle A as the best carrier of the message to the destination because vehicle A will meet vehicle C before vehicle B does. This process ensures that the message will be delivered in the shortest time possible.

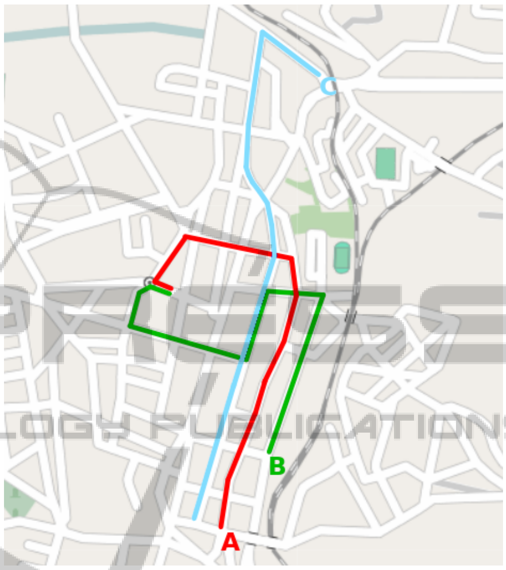

Figure 1: Pre-established routes for three vehicles.

3.2 Binary Spray

Routing schemes based on a single copy of a message cause major delays in delivery. On the other hand, routing schemes based on flooding cause network degradation. To obtain the lowest delay in delivery without degrading a network, in (Spyropoulos et al., 2008b), the authors proposed the "spray" technique, which consists in generating a number of controlled copies of messages and spraying them among the nodes of a network. When a vehicle wants to transmit a message, it generates a controlled number of copies (L). To calculate the value of L, the existing number of nodes in the network and the desired delay time for the message to reach its destination are taken into account. Spraying can occur in two different ways, which are referred to the authors as Source Spray and Binary Spray.

In spraying based on Source Spray, the source node forwards L copies of the message to the first distinct L nodes it finds. In Binary Spray, the source node starts with L copies; while node A has $n > 1$ copies (is the source or the carrier) and meets another node B (that does not have any copies), it will deliver to node B $\lfloor (n/2) \rfloor$ copies and keep $\lceil (n/2) \rceil$ copies for itself;

when the node has only one copy, it will choose direct contact to perform the delivery.

Another feature of the Source Spray technique is that a message requires only two hops to reach the destination; that is, the source forwards the message to the carrier, which becomes responsible for delivering it to the destination. This feature causes delays in the delivery of messages in networks with controlled mobility, which makes such a technique unusable in VANETs. In Binary Spray, on the other hand, the fact that the carrier node receives more than one copy of the message and forwards them in future contacts indicates that this technique performs routing based on multiple hops, reducing the delivery time of the message. Therefore, Binary Spray was chosen as the message routing method for the RouteSpray algorithm.

4 PERFORMANCE ANALYSIS

Although the evaluation of routing protocols in real environments is desirable, the high cost of implementation and the difficulty of mobilizing enough staff to perform the experiments make such implementation unfeasible. Consequently, the scientific community evaluates routing protocols through simulations. RouteSpray performance was evaluated through simulations, comparing it with the Epidemic, Spray and Wait and GeOpps protocols, which are the main routing protocols used for sparse and vehicular networks.

The performance of the RouteSpray protocol was evaluated according to the following metrics: (i) message delivery rate; (ii) occupancy of buffers; (iii) number of messages sent over a network; and (iv) average delay of message delivery. The message delivery rate refers to the number of messages delivered to the destination and is important in determining the effectiveness of a protocol. The occupancy of buffers is defined as the sum of all messages stored in the nodes of a network. Occupancy must be considered because devices that are used in mobile networks have restrictions regarding storage. The number of messages sent over a network is the sum of all messages sent, including the control messages, and indicates the numbers of transmissions needed to ensure the delivery of the messages. The average delay for message delivery is useful to indicate the efficiency of the algorithm to perform routing.

For the simulation scenario, 16 routes were generated between the points of interest of Barbacena city, in Brazil. Because its a city that emerged and developed without proper planning, its streets and avenues arose haphazardly. Thus the graph that represents such scenario has no standard, unlike the graph of Manhattan (Bai et al., 2003). For the simulation, the number of vehicles in the network varied between 5 and 100, generating networks with different densities. For simulations in which the number of vehicles is greater than the number of routes, more than one vehicle travels the same route. In this case, in addition to the vehicles being distributed evenly among the routes, the vehicles leave at different times. The transmission speed was also considered to be higher than the locomotion speed.

The MiXiM framework (Köpke et al., 2008), an extension to the OMNeT++ Network Simulator (Varga, 1999), was used for the simulation. Vehicular mobility simulations based on random mobility models do not correspond to reality because the movement of vehicles is limited to the restrictions of streets and avenues (Gamess et al., 2012). Furthermore, parameters such as speed and direction suffer variations. For this reason, vehicular mobility was generated using the VeNeM software (Silva, 2012).

The parameters used in the simulation are presented in Table 1.

Table 1: Parameters used in the simulation.

Parameters	Values
Simulation time	2700 seconds
Playground X	1.49 miles
Playground Y	2.51 miles
Amount of nodes	5, 10, 25, 50, 75, 100
L Values	2, 3, 6, 8, 12, 20
Band frequency	2.4 GHz
Transmission power	110.11 mW
Signal attenuation	-70 dBm
Package size	512 bits

In the simulation time parameter, the value 2700 seconds was used because it corresponds to the time required for the vehicle to undertake a circular route, passing through some points of interest in the city. For the Playground size parameters, it was used the values returned by the software VeNeM, that correspond to the size needed to cover all the rotes. The L Values parameter varies according to the number of network nodes and respects the minimum limits suggested by (Spyropoulos et al., 2008b). The parameters related to the physical environment which are: frequency band, transmission power, signal attenuation and size of the package, were configured with values used by the 802.11b standard. The 802.11b standard was chosen because the 802.11p, that was designed to be used in vehicular networks, was discontinued (IEEE, 2010).

4.1 Results

When a scenario imposes no storage constraints, the Epidemic algorithm delivers all messages that are sent, which makes it an important tool for comparing routing algorithms. Another algorithm that achieves delivery rates similar to those of the Epidemic algorithm and also causes less network degradation is the Spray and Wait algorithm. Although both algorithms are good sources of reference rather than referrals., they are designed for sparse networks, and do not benefit from the characteristics of vehicular networks. Therefore, in addition to being compared with these two algorithms, the RouteSpray is also compared with the GeOpss algorithm, which takes advantage of the routes of the vehicles to perform message routing. Assuming the Epidemic algorithm delivers 100% of messages sent over the network, the RouteSpray, Spray and Wait and GeOpps algorithms delivered 57.66%, 44.23% and 13.11% of messages, respectively. The values obtained are presented in greater detail in Figure 2.

The best message delivery rate is achieved by the RouteSpray algorithm, as a consequence of the use of the routes of the vehicles combined with the pulverization of multiple copies of messages. The GeOpps algorithm had the lowest performance on the number of messages delivered. This result shows that the algorithms that use multiple copies of messages outperforms the algorithms that use routing information. However, the combination of the two characteristics has proven more effective than using each one individually.

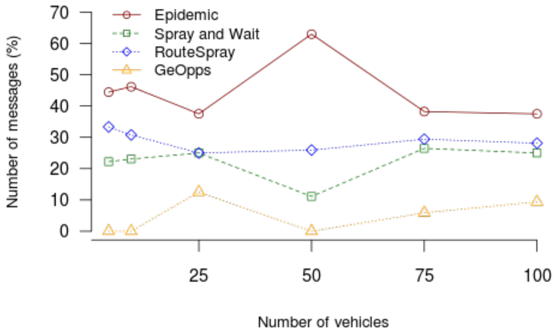

Figure 2: Delivered messages on the network.

As shown in Figure 3, the Epidemic algorithm requires that the nodes have large storage capacities because each network node stores a copy of each transmitted message. This feature can be perceived more clearly by observing the transmissions required in a network with 75 nodes in which, to deliver 15 messages, the Epidemic algorithm stored 1035 copies of the messages. The GeOpps algorithm does not make replicas of the message, therefore its use has no impact in the buffers of the nodes. This characteristic can be proven by looking at the figure 3. The Spray and Wait and the RouteSpray algorithms caused little buffer occupancy, demonstrating the efficiency of the spray technique, as shown in Figure 4. The RouteSpray algorithm achieved a buffer occupancy 73.38% lower than that achieved by the Spray and Wait algorithm because it controls the messages stored in the buffer, deleting those that have already been delivered. In the RouteSpray algorithm, the presence of messages in the buffers of the nodes indicates that the information that the message was delivered has not spread enough to reach all the nodes.

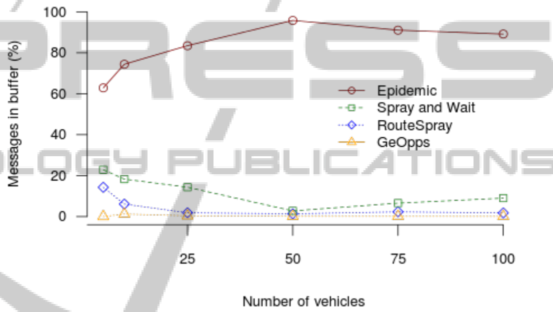

Figure 3: Comparison of the buffer occupancy of the three algorithms.

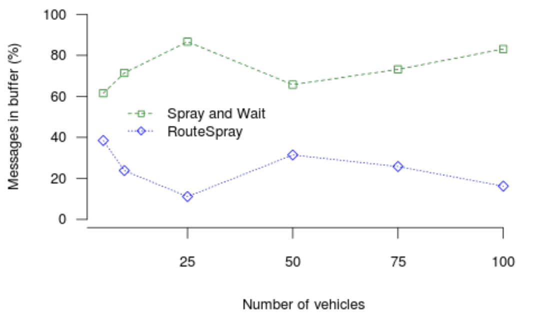

Figure 4: Improvement in the buffer occupancy by spray technique.

As previously discussed, the use of control messages by the RouteSpray algorithm improves data delivery rates and controls the buffer occupancy. However, an additional cost is introduced into the network, causing a greater number of message transmissions. This effect is demonstrated in Figure 5. Although the RouteSpray algorithm results in more message transmissions than the Epidemic algorithm, it causes less overhead in the network because the control messages have no payload data.

The moment of the message gets its destinantion is

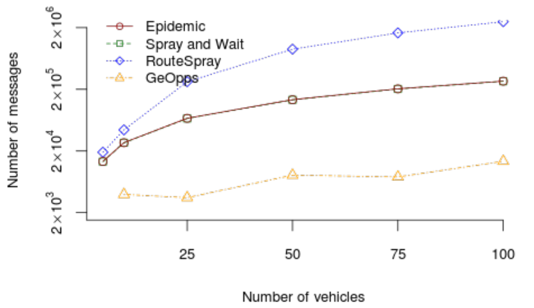

Figure 5: Messages sent over network.

another important feature to be analyzed. Such information enable evaluate the efficiency of the algorithm to perform routing. A shown in Figure 6, the algorithm GeOpps has the worst performance, which is expected because it is an single copy algorithm. The epidemic algorithm achieves the best result due to a message flooding algorithm. However, for the network of 10 nodes, caused a bigger delay than other algorithm due to the number of messages received. The RouteSpray ensures better results than Spray and Wait, losing only with sparses networks, of 5 and 10 vehicles. This causes a higher delivery rate and a major impact over the average delay time.

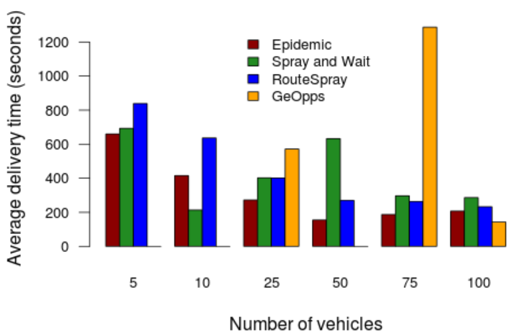

Figure 6: Messages sent over network.

5 CONCLUSIONS

Routing in vehicular networks remains an unresolved problem. Several algorithms continue to emerge for use under specific conditions and scenarios. Because VANETs have several features that are not found in other types of networks, and such features make it possible to obtain information that can be used in routing without incurring an additional cost in a network, the RouteSpray algorithm was proposed in this study. This algorithm proved to be more efficient than other algorithms designed for vehicular routing based on vehicular routes presented to date by the scientific community.

Despite the challenge of routing packets through highly dispersed networks, which is common in VANETs, the RouteSpray algorithm exhibited a good message delivery rate, surpassing the performance of algorithms with previously established efficiencies. In addition to a good message delivery rate, the RouteSpray algorithm also requires little storage space, which makes it applicable in devices with limited resources.

The RouteSpray algorithm is suitable for application in networks in which the routes of vehicles are known. One example of a good application of the algorithm is in transportation companies, such as bus, taxi or carrier companies. The RouteSpray algorithm offers the possibility of dynamic communication, even in non-routine situations in which programmed routing would fail, such as when delays occur because of changes in traffic or flat tires.

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