# Routing Protocol for Urban Mobile Networks based on Geographical Location

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## Abstract

*Vehicular Ad-Hoc Networks (VANETs) are an important research area due to the potential benefits they could bring to traffic optimisation in urban environments. The communication protocols used within such networks, due to the intrinsic properties of such environments, reflect a series of characteristics which set them apart from common approaches. Routing messages, using a carry-and-forward strategy without relying on epidemic protocols, are particularly hard to achieve because cars are in motion. We present such a routing protocol which uses location data and trajectory of the cars. The protocol not only minimizes the number of messages needed to transmit the data to the destination, but it also reduces the time interval needed for the transmission of messages between vehicles using the resources available at present in such environments. The protocol is designed for highly partitioned environments, affected by the dynamics of node connections within such networks.*

Keywords: **routing protocol, VANETs, carry-and-forward strategy, geographical location**.

## 1. Introduction

Routing using multi-hop paths is an important building block in many mobile wireless networks. In Vehicular Ad-Hoc Networks (VANET), a particular case of such mobile wireless networks with properties which distinguish them from other mobile wireless networks, the mobility of a vehicle is restricted to roads, to the movement of other vehicles, and to traffic rules [2]. Such networks are also affected by factors such as weather conditions, time interval and vehicle positioning, as well as packages transmission time.

We present a routing protocol that uses a combination of the 'store-carry and forward' paradigm [3] together with trajectory and geographical positioning data to optimize the routing decision, as well as the number of messages needed to deliver data to destination. We present results showing that the protocol increases the percentage of messages successfully delivered within the network and it reduces the network traffic.

The paper is structured as follows. Section 2 presents related work in data routing protocols for VANETs. In Section 3 we present the routing protocol, together with details about its implementation. Section 4 presents evaluation results. Finally, in Section 5 we give conclusions and present future work.

## 2. Related Work

In VANETs traditional routing protocols use some form of broadcasting scheme [2]. Each vehicle tries to improve its chance of forwarding the message to an appropriate other route-hop by broadcasting the message to all its neighbours. However, this easily leads to a large number of messages, and an overflow in the VANET environment. A routing algorithm based on the arrival angle was proposed in [1]. The algorithm uses the positioning of each node to implement the routing and interrogation functions in VANETs environments. Based on the positioning information, using the node's capabilities to measure the time of arrival (TOA), the time of arrival difference (TDOA), the arrival angle and the level of the signal, the algorithm tries to localize other nodes of a reference frame.

Vehicles can obtain positioning information from local (LPS) or global positioning systems such as GPS and Galileo. There are also solutions [3][4] that use the routing within a specific geographical area based on heuristic algorithms, choosing as next hop a neighbour which has the greatest advance towards the destination. Other protocols similar to the one described in this paper try to improve the routing performance using digital maps [5][6][7]. Such solutions are based on information related to the street topology, as well as location of vehicles. The source generally creates a list of junction nodes that will be crossed in order for the message to reach destination. To reach each junction node, a geographical protocol is applied to each street. Such solutions assume the existence of a point (the destination) where the message should be sent. This is not true for VANETs, because vehicles are constantly moving on dynamic trajectories.

From the study of vehicle mobility it can be inferred that they have a tendency towards grouping and forming car clusters [9]. Thus, the network is partitioned and most of the times there is no single point-to-point communication path between a source and a destination. Such factors make existing solutions for wireless ad-hoc relations unviable for VANET environments. The routing protocol presented in this paper considers more realistic factors of mobility, making use of parameters such as geographical position or the inherent clustering of vehicles.

## 3. The routing protocol

The routing protocol is based on the 'store-carry and forward' paradigm [8]. The architecture of a generic VANET application which uses the routing protocol is represented in Figure 1. Each box is a module implementing a different communication function. The routing protocol uses the services provided by the network transport protocol and provides functionality to higher-level applications.

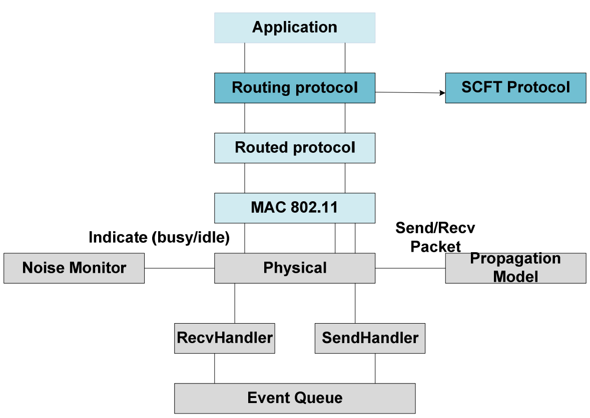


**Fig. 1. The architecture of a VANET system using the proposed routing protocol.**

The routing protocol uses the position of the vehicles, their trajectory and their state. Such information is obtained, for example, from GPS-enabled devices. First, a decision algorithm is used to choose the next hop to forward a message to. The forwarding hop can be another car or other communication device available within the road infrastructure. If such a hop exists, the message is forwarded to it. Otherwise, the message is stored until an appropriate hop is found.

The decision module of the routing solution uses locally-available digital maps and the trajectory of the vehicles. The routing protocol bases its decisions on the probability of the car's trajectory to come closer to the last known coordinate of the destination vehicle. For that we consider that each vehicle has GPS-enabled capabilities and is capable of transmission using wireless technologies. Also, each vehicle uses a trajectory planning application.

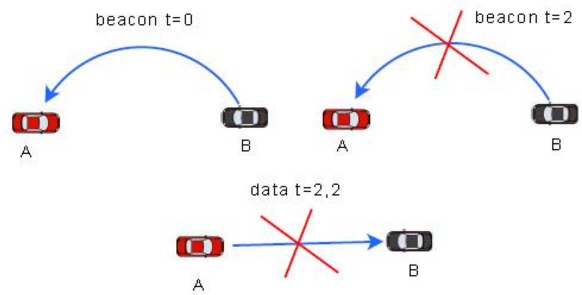


**Fig. 2. Example of beacon losses.**

Also, the decision is influenced by the distance between two vehicles. The wireless range of the equipments installed on the vehicles can create problems for message transmission. Cases of message loss [7] due to external factors are presented in Figure 2. It is desirable to have a range as wide as possible without influencing the protocol performance. Causes of message losses include the movement vectors of the two vehicles, the transmitter and the receiver.

The vehicle speed, wireless range and trajectory fitness are used to compute an area in which the messages transmitted have a high probability to reach their destination. The decision algorithm is:

*fitness(id) = fitness_distance(id) + fitness_speed(id)+ fitness_trajectory(id)*

*Message receiving*
***if** id_destination == id_vehicle **then***
*message successfully received*
***else***
*message stored in queue*

*Message sending*
***if** fitness(id_destination) > value **then***
*message forward*
***else***
*message stored -> use store-carry*

## 4. Implementation details

For evaluating the routing protocol we extended the VNSim simulator [9]. The simulator is designed to realistically model a wide range of VANET solutions, ranging from networking protocols to traffic applications. It includes two models (Figure 3): a vehicular mobility model, which uses realistic mobility maps and emulates various drivers' behaviours, and a wireless networking model, responsible for the simulation of networking components and communication protocols available within a VANET system. It uses a synthetic mobility model that integrates both microscopic and macroscopic motion. Its mobility model is in charge of importing the map topology and building the dynamic of all vehicles.

The extensions to the simulator include the components used by the routing protocols. According to this protocol, first the source sends the message to all its neighbours. All vehicles receiving the message take a decision to store or to forward the message. When a vehicle moves away from the destination of a message it forwards it to all its neighbours. If a neighbour vehicle does not come closer to the last known position of the destination of the message, it simply forwards the message further.

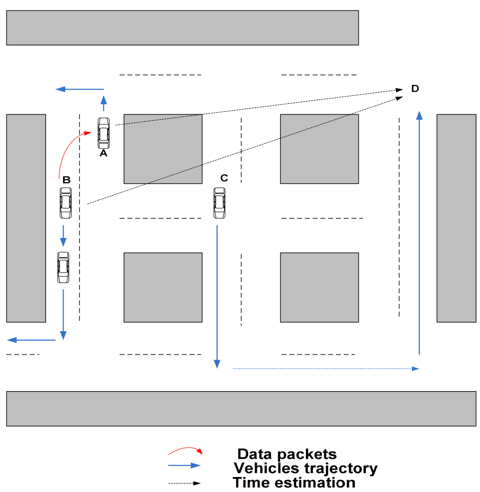


**Fig. 3. The routing strategy.**

Following traffic analysis in urban and extra urban environments and the analysis of the main factors which lead to message loss [2], we determined several factors having an influence on the performance of a routing protocol within VANET networks, namely speed, vehicle trajectory, the distance between vehicles, the distance between vehicles following the known trajectory, traffic density and partitioning of the cells. The fitness function considers all these parameters.

In case of the fitness function for speed a decision is made according to the difference between the speed vectors of the carrier vehicle and the destination vehicle. The fitness function of distance has the greatest weight in the decision because, if it is not in direct range or neither the destination vehicle approaches the vehicle sending the message, nor the vehicle sending the message has any neighbours in its action range, then it is preferable for the message to move to store-carry rather than be transmitted but not received by any other vehicle (Figure 3). The function appreciates if there are neighbours that might reach the destination or the forwarding vehicle is within the distance covered by the wireless range. If this is the case the message is transmitted. The fitness function of the trajectory looks for the road segments that are common to the vehicle carrying the message and the destination vehicle. If such common segments exist, then the protocol uses a fitness function to approximate the time when the vehicle will reach that segment. If there is a time difference in which the two vehicles reach the same point, the function determines that the two vehicles can meet, so the message is forwarded to neighbours that are capable to transmit the message to its destination. The message reception function allows the vehicle to listen to the environment and to receive messages if these emerge. If the vehicle receiving the message is the actual destination vehicle, then the message is considered delivered.

## 5. Results

To evaluate the proposed routing protocol we simulated an urban environment that resembles a real-world traffic situation in Bucharest. Using this scenario we executed a number of experiments. In each experiment we considered that the wireless range for each vehicle is 200m, the wireless range of the access points available within the road infrastructure is 1000 m, and there is a flow of 100 vehicles/hour/each lane of each road. We executed a series of experiments by varying the average speeds, distance between cars and various trajectories for the vehicles. We were particularly interested in the amount of messages being successfully delivered and the instant number of messages in transit. The second parameter was particularly important to evaluate if the protocol leads or not to epidemic situations.

The graph in Figure 4 presents the results obtained and emphasizes the percentage of delivered messages in relation to simulation interval. These results show the performance of the routing protocol to successfully deliver messages and the load of the network. As presented, the percentage of messages being delivered is above 90%.

The simulation experiments revealed that the number of received messages increases. Analyzing the obtained results we noticed an increase in the number of messages received. This is due primarily to the messages being temporarily stored and forwarded to the neighbours when possible.

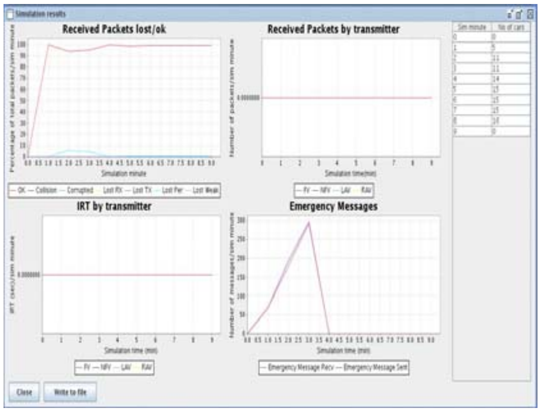


**Fig. 4. Results obtained during the protocol simulation.**

Although the experiments are based on varying various parameters namely speed, vehicle trajectory, the distance between vehicles, the distance between vehicles following the known trajectory, traffic density and partitioning of the cells, we noticed that the protocol is able to reach a very good level of performance. In case of an urban environment, the routing protocol reaches 95% message delivery. The routing protocol ensures good tolerance to delay and good message transmission even in case of partitioned vehicle networks. At the same time, the network is not overflowed with messages.

## 6. Conclusions and future work

VANETs bring benefits to traffic optimisation in urban environments, fuel saving or the reduction of pollution effects that most cities face. Within VANETs, the communication protocols are extremely important, because, due to the intrinsic properties of such environments, they reflect a series of characteristics which set them apart from traditional approaches.

We present a routing protocol designed for VANET environments. The protocol is able to reduce the time interval needed for the transmission of messages between vehicles using the resources currently available in such environments. It is also designed for highly partitioned environments, affected by the dynamics of node connections within networks. For this the solution adopts the ‘store-carry and forward’ paradigm for delay tolerant networks.

The evaluation of the protocol revealed that the solution functions properly and is able to increase the number of message correctly delivered, while minimizing the time for the transmission and optimizing the network throughput.

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## 7. References

[1] D. Niculescu, B. Nath, “Ad Hoc Positioning System (APS) Using AOA”, In Proc. of The 22nd Annual Joint Conf. of the IEEE Computer and Comm. Societies, San Francisco, 2003.

[2] V. Cabrera, F. J. Ros, P. M. Ruiz, “Simulation-based Study of Common Issues in VANET Routing Protocols”, VTC2009-Spring, Barcelona, Spania, 2008.

[3] V. Naumov, T. R. Gross, “Connectivity-Aware Routing (CAR) in Vehicular Ad-hoc Networks”, In Proc. of the 26th IEEE International Conference on Computer Communications (INFOCOM ’07), Anchorage, Alaska, USA, pp. 1919–1927, May 2007.

[4] C. Lochert, H. Hartenstein, J. Tian, H. Fußler, D. Hermann, M. Mauve, “A Routing Strategy for Vehicular Ad Hoc Networks in City Environments”, In Proc. of the IEEE Intelligent Vehicles Symposium 2003, Columbus, OH, USA, pp. 156–161, Jun. 2003.

[5] B. C. Seet, G. Liu, B.S. Lee, C. H. Foh, K. J. Wong, K. K. Lee, “A-STAR: A Mobile Ad Hoc Routing Strategy for Metropolis Vehicular Communications”, In Proc. of the 3rd International Networking Conference IFIP-TC6 (IFIP ’04), Athens, Greece, pp. 989–999, Dec. 2004.

[6] J. Tian, L. Han, K. Rothermel, C. Cseh, “Spatially Aware Packet Routing for Mobile Ad Hoc Inter-Vehicle Radio Networks”, In Proc. of IEEE Intelligent Transportation System Conference (ITSC ’03), Shanghai, China, pp. 1546–1551, Oct. 2003.

[7] D. Niculescu, B. Nath, “Trajectory Based Forwarding and Its Applications”, in Proc. of the 9th annual int. conference on Mobile computing and networking, San Diego, USA, 2003.

[8] I. Leontiadis, C. Mascolo, “GeOpps: Opportunistic Geographical Routing for Vehicular Networks”, In Proc. of the IEEE Workshop on Autonomic and Opportunistic Communications, Helsinki, Finland, 2007.

[9] A. Gainaru, C. Dobre, V. Cristea, "A Realistic Mobility Model based on Social Networks for the Simulation of VANETs", in Proc. of the 2009 IEEE 69th Vehicular Technology Conference (VTC2009-Spring), Barcelona, Spain, 2009.