Implementing and testing a driving safety application for smartphones based on the eMDR protocol

Sergio Martínez Tornell, Carlos T. Calafate, Juan-Carlos Cano and Pietro Manzoni
Universitat Politècnica de València
Camino de Vera, s/n, 46022 Valencia, Spain
sermarto@upv.es, {calafate, jucano, pmanzoni}@disca.upv.es
Manuel Fogue, Francisco J. Martinez
University of Zaragoza, Spain
{m.fogue, f.martinez}@unizar.es

***Abstract*—Vehicular Ad-Hoc Networks (VANETs) offer opportunities for improvements in driving security and comfort. Vehicles can take advantage of collaboration schemes to disseminate important information. In this article we present a a driving safety application based on warnings dissemination for smartphones based on our eMDR protocol. The use of smartphones allows a quick development and deployment, avoiding the cost of specific hardware. Additionally, since most users are familiar with the use of smartphones, this alleviates the adoption barrier. Our application is integrated into a Navigation System which allows accessing road maps, current location and route information through an interface that we have created. We have analyzed the behavior of the wireless channel and the GPS location service under different conditions to assess the feasibility of our proposal.**

Result showed that, in C2C communications, smartphones provide a reasonable connectivity and enough precision even for certain type of driving safety applications.

***Index Terms*—smartphones, VANET, broadcast, warning message dissemination, real maps**

I. Introduction

Wireless networks have evolved at an incredibly fast rate, being applicable to several contexts and different communication solutions. Using them, vehicles can benefit from a collaborative distribution approach, harvesting this information through the Vehicular Ad-Hoc Network. This collaboration may result profitable when a local event, such as an accident, the detection of a problem on the road, or an incoming ambulance, occurs and must be notified to near vehicles. The information treatment and management is closely related to the idea of SmartCities [1] [2], a set of initiatives proposed by the European Commission to increase the efficiency of our cities by the use of technology.

In this article we describe a solution that exploits the direct communication between smartphones through an ad-hoc network to provide a better driving experience when using a navigation software. As a first approximation, we have built an application that implements our protocol "enhanced Message Dissemination based on Roadmaps" (eMDR) [3] to inform its users of the presence of an ambulance close to their route; this allows the drivers to act in consequence, anticipating its actions.

The rest of the paper is organized as follows: section II reviews applications that attempt to improve the user experience through collaboration. We then describe our proposed architecture in section III. In section IV we present our experiments, which evidence the feasibility of our solution. Finally, we remark our conclusions and future work in section V.

II. Related Work

In the last years, Vehicular Ad-Hoc Networks (VANETs) are receiving attention from academia, industry, and governments. Due to the high cost of deployment, VANET protocols and applications are usually tested through simulation. In [4] authors presented an example of a broadcasting protocol for VANETs that allows to disseminate information efficiently. Another example of a simulation based study is [5], where the authors presented a Car-to-Car (C2C) communication protocol. On the other hand, there have been also several projects that developed their own testbed platform based on dedicated hardware. CarTel [6] uses nodes deployed in vehicles and sporadic connections to open access points for the purpose of monitoring and classifying road surface conditions. However, vehicles do not communicate between them. In [7] researchers from UCLA presented CVet, a VANET testbed deployed over vehicles belonging to the UCLA car fleet. As far as we know, these and other solutions presented for fast prototyping and testing in VANETs are built over dedicated hardware, which increases the cost of deployment and impede their adoption.

As we have seen, none of the solutions currently available solutions in the market takes advantage of ad-hoc communication techniques. To the best of our knowledge, this is the first time that smartphones are proposed as a suitable platform for the quick development and prototyping of VANET applications.

III. Demo Application

We have built our VANET application system upon standard smartphones based on Android [8]. With this election we avoid the requirement of a special approval for installation in vehicles, and we also take advantage of the relatively low price of these devices and its high penetration rate. The Intelligent Transport Systems (ITS) application that we have implemented broadcasts the location and the route of an approaching ambulance using the enhanced Message Dissemination based on Roadmaps (eMDR) protocol [3], informing nearby drivers which will be able to act accordingly to favor the progress of the ambulance toward its destination. In this section we briefly describe our platform as well as the behavior of eMDR.

A. *Wireless Radio*

Smartphones are usually equipped with an 802.11b/g interface that, in this case, has been configured to work in ad-hoc mode. The typical transmission power of these devices is 16 dBm (40mW), which is far from the maximum allowed transmission power for IEEE802.11g in Europe: 20 dBm (100 mW).

B. *Navigation Software*

We decided to integrate our VANET application architecture inside an existing opensource navigation software: OsmAnd [9]. The map rendering process in OsmAnd is composed of different layers that are rendered sequentially. We therefore programmed our application as a special layer that not only draws new data on the map, but also uses the socket API to communicate with other vehicles.

Our application is implemented as a new layer that adds information obtained from the VANET to the map view in OsmAnd. Figure 2b shows our "Warning Ambulance Application" running. We can see two idle neighbors represented by green circles, and a neighbor in alarm mode, represented by an ambulance icon; the orange line is the ambulance's route, and the blue one represents the vehicle programmed route. Both the right red button and the left route-shaped button, are used for testing purposes. The red button activates the alarm mode and broadcasts the programed route; it is supposed to be available only to authorized devices, such as ambulances, police-cars, etc. The other one is used to select between three forwarding modes: (i) normal forwarding, *i.e.* following eMDR rules, (ii) unconditional forwarding, *i.e.* every alarm message is rebroadcasted, and (iii) forwarding disabled, *i.e.* no alarm message is rebroadcasted.

C. *GeoHelper Interface*

To simplify the management of geographical data we have developed a class called "GeoHelper". This class collects and processes data from files and different interfaces provided by both OsmAnd and the Android operating system.

This class provides an estimated current location and speed based on the last two updates provided by the Global Positioning System (GPS) interface and the direction of the current road. Figure 1 provides an example of how this *position estimation system* works. In T1 and T2, GPS updates arrive; in T3, a *getLocation()* call occurs and a guessed location is returned. Finally, in T4, a new GPS update arrives and the location and the movement vector is consequently updated. Moreover, location is restricted to the closest road.

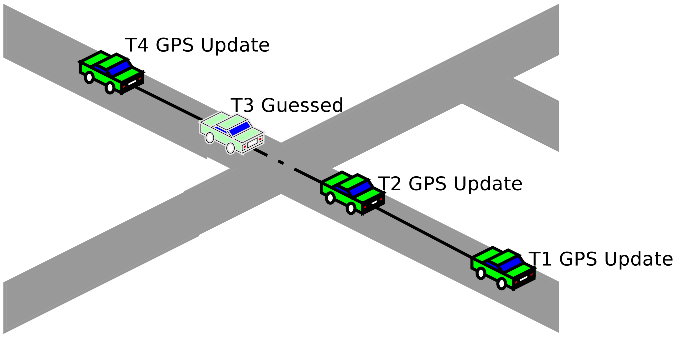
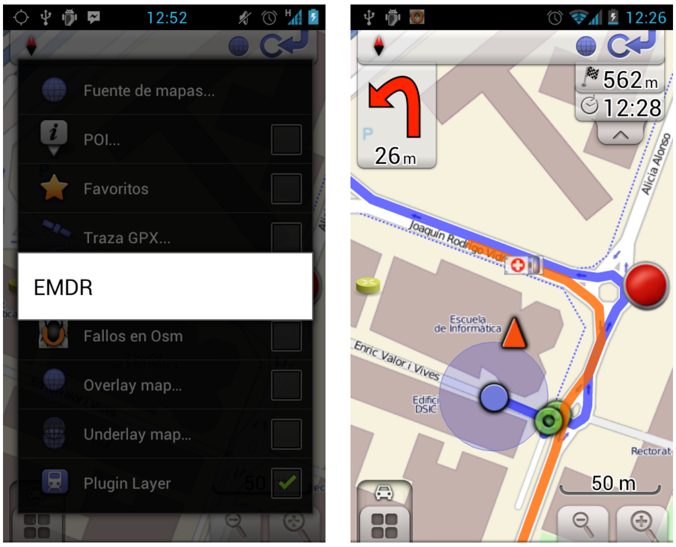


Fig. 1: Estimated position system example.

D. *eMDR overview*

EMDR uses location and street map information to facilitate an efficient dissemination of warning messages in VANETs, avoiding the well known broadcast storm problem and taking into account the effects of buildings to avoid wasting transmissions.

In eMDR, vehicles operate in either *warning* or *normal* mode. EMDR works as follows: When $vehicle_i$ starts the broadcast of a warning message, it sends m to all of its neighbors. When a new message m is received, the vehicle tests whether m has already been received. If m is received for the first time, it is rebroadcasted to the surrounding vehicles only when the distance d between sender and receiver is higher than a distance threshold D, or the receiver is in a different street than the sender. Two vehicles are in a different street when: (i) both are indeed in different roads (this information is obtained using the GPS and the offline maps stored in the device), (ii) the receiver, in spite of being in the same street, is near to an intersection, or (iii) the receiver detects that it has neighbors in different streets. Hence, warnings can be rebroadcasted to vehicles which are traveling on other streets, overcoming the radio signal interference due to the presence of buildings. If the message is a *beacon*, it is simply discarded.



(a) Layer selection screen. (b) Application screenshot

Fig. 2: Different application screenshots.

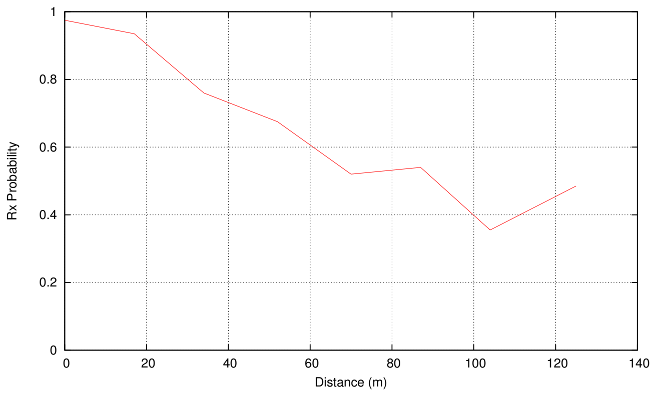


Fig. 3: LOS Rx Probability vs Distance.

IV. Evaluation

We have designed a set of experiments to evaluate different parameters: (i) message reception probability when in Line Of Sight (LOS), (ii) message reception probability when nodes are in different streets, and (iii) GPS updates inter-arrival time. All the experiments were performed in a real environment: vehicles were parked in streets with a typical traffic flow. Since all mobiles were inside vehicles, the transmissions were also affected by different issues related to adverse signal effects caused by the structure of the vehicle.

1) Message reception probability when in LOS: In this experiment we placed two of the handsets in different cars; then, using our application, sent a burst of 200 warning messages and counted the number of messages successfully received. Figure 3 shows the reception probability when varying the distance. It can be observed that the reception probability, decreases when the distance increases, as expected. Our experiments have shown that the threshold distance is optimal when the reception probability at such a distance is of 40%. Therefore, we have chosen 100m as the threshold distance for our eMDR protocol.

2) Message reception probability when in N-LOS: In this experiment the cars where located in perpendicular streets. One of them was located 25 meters away from the intersection, and the second vehicle was moving away from the intersection. The not so surprising result was that the moving node stopped receiving messages as soon as it moved a few meters away from the intersection. With these results in mind, we decided that the threshold distance under eMDR to consider that a vehicle is “near to an intersection” would be configured to 10 meters. Experiments have shown that the best parameter to detect if a vehicle is close to an intersection is the detection of neighbors from different streets. This method avoids problems related to the street layout representation format of OsmAnd.

3) GPS updates inter-arrival time: Another important issue when checking the feasibility of our solution is the freshness of the GPS data in smartphones. During our experiments we collected 11856 measurements for this metric. We found that the mean inter-arrival time for GPS updates was 1.07s, while the maximum value was of 15s, and only in 102 times was its value different from 1.0s. Although we have configured the GPS interface to notify our application about location changes as soon as possible, the minimum time between updates that the system was able to provide was of 1.0s. If we consider that, a vehicle with a speed of 25 m/s, a max acceleration of 0.8 m/s^2 and a max deceleration of 4.5 m/s^2 can typically travel between 21.40 m and 25.40 m in a second, our position estimation system, assuming a constant direction, will introduce a maximum error of 3.6m. We believe that this value is small enough to be used in VANETs.

V. Conclusions and Future Work

In this paper we showed that the use of smartphones opens a new horizon for VANET applications. We presented an implementation of an ITS warning service based on VANETs and implemented on Android smartphones. This application offers a smart interface to geographic information through the integration in a Navigation Software, thus taking advantage of more than the mere geografic position. We have demonstrated, through measurements, that in C2C communications smartphones provide a reasonable connectivity and enough precision even for critical-mission collision avoidance applications.

In the near future we will explore the possibilities that emerge when evolving from a pure ad-hoc network to a heterogeneous and more versatile network, especially by taking advantage of others network interfaces. Moreover we will explore the fusion of other sources of data, like the integration with the OBD-II system of the vehicles.

Acknowledgments

This work was partially supported by the *Ministerio de Ciencia e Innovación*, Spain, under Grant TIN2011-27543-C03-01.

References

[1] “European commission’s website for smartcities,” http://eu-smartcities.eu/mobility_transport, last visit Jul 2012.

[2] “Esafety website,” http://ec.europa.eu/information_society/activities/esafety/index_en.htm, last visit Jul 2012.

[3] M. Fogue, P. Garrido, F. J. Martinez, J.-C. Cano, C. T. Calafate, and P. Manzoni, “Evaluating the impact of a novel message dissemination scheme for vehicular networks using real maps,” *Transportation Research Part C: Emerging Technologies*, vol. 25, no. 0, pp. 61 – 80, 2012. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0968090X12000678

[4] L.-C. Tung and M. Gerla, “An efficient road-based directional broadcast protocol for urban vanets,” in *Vehicular Networking Conference (VNC), 2010 IEEE*, dec. 2010, pp. 9 –16.

[5] R. Frank, E. Giordano, P. Cataldi, and M. Gerla, “TrafRoute: A different approach to routing in vehicular networks,” in *Wireless and Mobile Computing, Networking and Communications (WiMob), 2010 IEEE 6th International Conference on*. IEEE, Oct. 2010, pp. 521–528.

[6] J. Eriksson, H. Balakrishnan, and S. Madden, “Cabernet: vehicular content delivery using wifi,” in *Proceedings of the 14th ACM international conference on Mobile computing and networking*, ser. MobiCom ’08. New York, NY, USA: ACM, 2008, pp. 199–210. [Online]. Available: http://doi.acm.org/10.1145/1409944.1409968

[7] M. Gerla, J.-T. Weng, E. Giordano, and G. Pau, “Vehicular testbeds; validating models and protocols before large scale deployment,” in *Computing, Networking and Communications (ICNC), 2012 International Conference on*, 30 2012-feb. 2 2012, pp. 665 –669.

[8] J. Gozalvez, “First google’s android phone launched [mobile radio],” *Vehicular Technology Magazine, IEEE*, vol. 3, no. 4, pp. 3 –69, december 2008.

[9] “Osmand website,” http://www.osmand.net, last visit Jul 2012.