Mobile Agents in Vehicular Networks: Taking a First Ride

Oscar Urra, Sergio Ilarri, Thierry Delot and Eduardo Mena

Abstract A vehicular ad hoc network (VANET) is a type of mobile network whose nodes are traveling cars which communicate with one another using short-range wireless communications. These cars can exchange and share different information among them, which can lead to the development of interesting applications that require the cooperation of vehicles or using the vehicular network as a distributed computing platform. Along with the opportunities offered by vehicular networks, a number of challenges also arise. To ease the development of applications for vehicular networks, mobile agent technology may be of help.

However, even though previous works have proved the usefulness of mobile agents in wireless environments, the special features of VANETs call for new research efforts. Could mobile agent technology be useful in a VANET? In this paper, we study these issues and illustrate how mobile agents could drive the development of new applications for vehicular networks.

1 Introduction

In the last decade, a number of wireless and small-sized devices (e.g., PDAs or laptops) with increasing computing capabilities have appeared in the market at very affordable costs. These devices have started to be embedded into modern cars in the form of on-board computers, GPS navigators, or even multimedia centers.

This has led to the emergence of vehicular ad hoc networks (VANETs). In this kind of networks, cars traveling along a road can exchange information with other

Oscar Urra, Sergio Ilarri, Eduardo Mena
Department of Computer Science and Systems Engineering, University of Zaragoza, María de Luna 1, 50018, Zaragoza, Spain. e-mail: ourra@ita.es, {silarri, emena}@unizar.es

Thierry Delot
University Lille North of France, LAMIH UMR CNRS/UVHC, Le Mont Houy, 59313 Valenciennes Cedex 9, France. e-mail: Thierry.Delot@univ-valenciennes.fr

nearby cars. The lack of a fixed communication infrastructure, characteristic of ad hoc networks, implies that vehicles usually can communicate with one another only using short-range wireless communications. Nevertheless, a piece of information can be disseminated and reach a far distance by using many moving cars as intermediates, following multi-hop routing protocols [3].

On the other hand, mobile agents [5] could be defined as computer programs that have the ability to move from one execution place to another, i.e., they can transfer themselves between devices using a communication link. They have a number of features, such as mobility, autonomy, communication capabilities, and flexibility, that make them a good choice for the development of distributed applications.

The question is: Can mobile agents and vehicular networks work together? Apparently, mobile agents may have interesting features that could make of them an interesting approach to build applications for vehicular networks. However, it is not clear how much they can help or whether existing mobile agent technology is ready for this challenge. In this paper, we study these issues and how mobile agents could drive the development of new applications for VANETs. The rest of the paper is structured as follows. In Section 2, we present the technological context of this work. In Section 3, we study the combination of VANETs and mobile agents to identify benefits and challenges. In Section 4 we present a use case scenario, and finally, in Section 5 we draw some conclusions.

2 Technological Context

In this section, we present the technological context of this work. Two central elements are identified: the vehicular ad hoc networks and the mobile agents.

2.1 Vehicular Ad Hoc Networks

A *vehicular ad hoc network* (VANET) [6] is a highly mobile network whose nodes are the vehicles traveling along a road or a highway. The vehicles are equipped with short-range wireless communication devices (e.g. using Wi-fi or UWB [4] technologies) and can establish direct connections with other nearby vehicles. This has a number of advantages over a traditional direct-connection client-server approach, such as: 1) there is no need of a dedicated support infrastructure (expensive to deploy and maintain), 2) the users do not need to pay for the use of these networks, and 3) it allows a very quick and direct exchange of information between vehicles that are within range of each other.

VANETs open up a wide range of opportunities to develop interesting systems for drivers. For example, when a number of vehicles detect that their average speeds are very low for a long time, it probably means that they are in a traffic jam and an information message can be delivered to other vehicles driving towards that area.

However, a number of difficulties also arise: Two vehicles can communicate directly only if their wireless devices are within range of each other (about 100 meters with 802.11 technologies) and, given that the vehicles are constantly moving, the duration of the communication link can be very short (a few seconds). So, to allow the information to reach remote sites, the use of some multi-hop communication protocol is necessary (e.g., see [3]).

The development of applications for vehicular networks requires taking these and other constraints into account.

2.2 Mobile Agents in a Mobile Environment

Mobile agents are software entities that run on an execution environment (traditionally called *place*), and can autonomously travel from place to place and resume their execution at the target node [5]. Thus, they are not bound to the computer where they are initially created and they can move freely among computers. To use mobile agents it is necessary to execute a middleware known as a *mobile agent platform* [8], which provides agents the environment where they can execute.

Mobile agents have been found particularly useful for the development of applications in mobile environments. Such an environment has a number of advantages (e.g., the processing is not tied to a fixed location) but also some drawbacks, such as the limited computational power of mobile devices and the communication constraints imposed by the use of wireless communications (that usually offer a low bandwidth, a high latency, and intermittent/unreliable connectivity). In this scenario, mobile agents can be very useful because they could help to reduce the negative effects of such limitations (e.g., see [7, 10]).

3 Mobile Agents and VANETs

In a VANET there are many vehicles, distributed on a wide geographic area, that exchange data based on certain conditions. The similarity with a situation where software agents move from one computer/device to another makes mobile agents a very suitable option to implement applications for VANETs. In this section, we describe potential benefits and difficulties for the adoption of mobile agents in VANETs.

3.1 Benefits of Using Mobile Agents in VANETs

In VANET applications, data may need to be transported from vehicle to vehicle in order to reach locations that are not directly accessible due to the short range of the wireless communications used. Then, two major problems arise. First, as the

propagation of the data can be slow, the information can be outdated when it reaches its destination. Second, it can be difficult to determine the destination itself and how to reach it: It could be a specific car, every vehicle in an area, the vehicles matching a certain condition, etc. To deal with these drawbacks, mobile agents can be very useful because of their adaptability and mobility features. Thus, they can bring a processing task wherever it is needed, and the algorithm or agent's logic can be changed at any time by deploying new versions of the agent code.

Another important advantage of mobile agents in VANETs is that they can move to wherever the data are located, to process and collect only the relevant data (filtering out data which are unnecessary). In other words, they can perform a local data aggregation and filtering and thus reduce the network load.

Finally, we believe that mobile agents can be very useful for data dissemination in vehicular networks. Thus, they can adapt easily to changing environmental conditions in order to improve the dissemination. For example, a basic flooding dissemination protocol such as [2] will fail if the traffic density of the vehicles is low and there are not enough vehicles to re-diffuse the data towards the target. Other dissemination protocols, such as carry-and-forward [12], where the vehicles may hold the data to be transmitted until these data can be relayed to other vehicles, can be used in that case. However, considering the variety of existing dissemination protocols mobile agents seem an ideal technology since the routing decisions lie with the data (encapsulated in the mobile agents) and different dissemination protocols (dynamic and adaptive to the current conditions) can be implemented.

Summing up, we believe that mobile agents could be very useful in vehicular networks and that the applicability of this technology in a VANET calls for new research in the field. As far as we know, [1] is the only work that uses this technology in a vehicular field (besides our initial proposal in [9]). However, it focuses on the case of traffic management with a fixed support infrastructure and does not consider the general case of agents hopping from car to car in a vehicular ad hoc network.

3.2 Difficulties for the Adoption of Mobile Agents in VANETs

While the use of mobile agents in vehicular networks can bring interesting benefits, there are also some difficulties that could hinder their adoption in this context. In particular, it is not clear that current mobile agent platforms are completely ready to be used in an effective way in a vehicular network.

The most important challenges arise from the fact that a VANET is a highly dynamic environment where nodes can come and leave at any time and where it is not easy or convenient to assume the existence of any kind of centralized node that can be relied upon. Therefore, the design of the different services provided by a mobile agent platform should not be based on this assumption.

As an example, existing agent tracking services have been developed with a fixed network in mind and are not appropriate (or even useful) in a mobile environment. This service is used by the platform to track the location of all agents and execution

places at every moment, and is also used by agents to communicate with others. In existing mobile agent platforms [8] (e.g., JADE or SPRINGS) this service is usually provided by a centralized component, whose tracking data are updated every time an agent moves to a new place. This approach would be challenging in a VANET, where centralized nodes do not exist and direct communications are not always possible. Instead, the platform could not even need to be aware of every single agent present in the vehicular network, and agents could be able to establish communication only with other nearby agents that are in range of their communication devices.

Other difficulties to use existing mobile agent platforms in a vehicular ad hoc network are related to communication and security issues. Thus, in a traditional distributed fixed network direct communications between nodes is the usual. However, in a vehicular network, when an agent wants to hop to another car it will be broadcasted and any vehicle within communication range could receive it. The agent must be re-started only in one receiving vehicle. Moreover, the agent should be conveniently encrypted and a security mechanism should be applied to allow its execution only if both the agent and the receiving vehicle trust each other. Similarly, other security issues could arise, most of them also existing in fixed networks but heightened by the open character of vehicular networks (e.g., see [11, 10]).

We believe that these are the most important issues to consider for the application of mobile agent technology in vehicular networks. Other potential difficulties, considered for the general case of mobile environments, are cited in [10].

4 Use Case Scenario: Monitoring the Environment

An example application scenario is that of using mobile agents in a VANET to monitor environmental parameters (such as CO_2, temperature, etc.) within a certain geographic area [9]. The vehicles involved in the monitoring tasks can carry one or more environmental sensors so that the interesting parameters can be read from the environment. The agents hop from car to car to reach the area that must be monitored and then try to remain within it boundaries (moving to other vehicles if necessary). So, moving cars are used as both physical carriers of the agents and intermediate points to reach the target area. Using existing vehicles and mobile agents for monitoring greatly increases the flexibility compared to an approach based on the use of static sensors. Thus, it becomes possible to monitor virtually any area that we want.

However, the initial solution proposed in [9] has an important limitation: the monitoring process always ends in a fixed and well-known site, where the monitoring results (carried by mobile agents) are gathered. Thanks to the adaptability and mobility features mentioned in Section 3.1, we are currently improving our approach so that it is also possible to start and end the process on any vehicle in the VANET (i.e., to issue monitoring tasks from a moving vehicle). The main difficulties encountered are: estimating the position of the destination car when the monitoring process ends, and then reaching that position using a multi-hop route.

5 Conclusions

Mobile agent technology can provide interesting benefits thanks to the mobility, autonomy and flexibility of mobile agents. However, while mobile agents have been largely studied in the literature in a variety of application scenarios, including mobile and wireless environments, the use of mobile agents in vehicular networks is a completely unexplored area. This paper represents a first step to cover this gap in the research of mobile agents and vehicular networks. Thus, we have presented the benefits that mobile agents can provide to develop applications for vehicular networks and the difficulties involved.

Acknowledgements The authors thank the support of the CICYT project TIN2007-68091-C02-02, the ITA Institute of Aragón, and the OPTIMACS project supported by the French ANR agency.

References

1. B. Chen, H. Cheng, and J. Palen. Integrating mobile agent technology with multi-agent systems for distributed traffic detection and management systems. *Transportation Research Part C*, 17(1):1–10, 2009.
2. W. R. Heinzelman, J. Kulik, and H. Balakrishnan. Adaptive protocols for information dissemination in wireless sensor networks. In *5th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom'99)*, pages 174–185, 1999.
3. C. Lochert, H. Hartenstein, J. Tian, H. Fler, D. Hermann, and M. Mauve. A routing strategy for vehicular ad hoc networks in city environments. In *Intelligent Vehicles Symposium (IV'03)*, pages 156–161. IEEE Computer Society, 2003.
4. J. Luo and J.-P. Hubaux. A survey of research in inter-vehicle communications. In *Embedded Security in Cars - Securing Current and Future Automotive IT Applications*, pages 111–122. Springer, 2005.
5. D. Milojicic, F. Douglis, and R. Wheeler. *Mobility: processes, computers, and agents*. ACM, 1999.
6. S. Olariu and M. C. Weigle, editors. *Vehicular Networks: From Theory to Practice*. Chapman & Hall/CRC, 2009.
7. C. Spyrou, G. Samaras, E. Pitoura, and P. Evripidou. Mobile agents for wireless computing: the convergence of wireless computational models with mobile-agent technologies. *Mobile Networks and Applications*, 9(5):517–528, 2004.
8. R. Trillo, S. Ilarri, and E. Mena. Comparison and performance evaluation of mobile agent platforms. In *3rd Intl. Conf. on Autonomic and Autonomous Systems (ICAS'07)*. IEEE Computer Society, 2007.
9. O. Urra, S. Ilarri, T. Delot, and E. Mena. Using hitchhiker mobile agents for environment monitoring. In *7th International Conference on Practical Applications of Agents and Multi-Agent Systems (PAAMS'09)*, pages 557–566. Springer, 2009.
10. O. Urra, S. Ilarri, R. Trillo, and E. Mena. Mobile agents and mobile devices: Friendship or difficult relationship? *Journal of Physical Agents. Special Issue: Special Session on Practical Applications of Agents and Multiagent Systems*, 3(2):27–37, 2009.
11. G. Vigna, editor. *Mobile Agents and Security*, volume 1419 of *Lecture Notes in Computer Science*. Springer, 1999.
12. J. Zhao and G. Cao. VADD: Vehicle-assisted data delivery in vehicular ad hoc networks. In *25th IEEE International Conference on Computer Communications (INFOCOM'06)*. IEEE Computer Society, 2006.