Cooperative Parking Space Allocation in Vehicular Ad Hoc Networks

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Abstract—**By exchanging events in a vehicular ad hoc network, drivers can receive interesting information while driving. For example, they can be informed of available parking spaces in their vicinity. Obviously, a suitable protocol is needed to disseminate the events efficiently within the area where they are relevant. Moreover, in such a competitive context where each vehicle may be interested in the resource, it is crucial not to broadcast that resource to each driver in the vicinity. Otherwise, those drivers would waste time trying to reach a parking space and only one of them would be satisfied, which would lead to a poor satisfaction in the system.**

To solve this problem, we propose a reservation protocol to allocate parking spaces in vehicular ad hoc networks that avoids the competition among the vehicles. In this paper, we present the basic ideas of our proposal.

I. Introduction

Nowadays, there is a great interest in developing systems to assist drivers on the road, providing them with different types of relevant information. VANETs rely on the use of short-range networks (about a hundred meters), like IEEE 802.11 or Ultra Wide Band (UWB) standards for vehicles to communicate [1] and provide bandwidth in the range of Mbps. Using such communication networks, the driver of a car can receive information from its neighbors. Many pieces of information can be exchanged in the context of inter-vehicle communications, for instance to warn drivers when a potentially dangerous event arises (an accident, an emergency braking, an obstacle on the road, etc.) or to try to assist them (with information about traffic congestions, real-time traffic conditions, etc.). Particularly, different works have addressed the advertisement of available parking spaces [2], [3], [4], [5]. Finding an available parking space is indeed stressful, time-consuming and contributes to increasing traffic. Besides, it leads to fuel consumption and environment pollution due to the emission of gases. Some works, such as [3], emphasize the costs of searching for parking spaces. According to that work, nearly one out of two vehicles on the move are searching for a parking space.

The work presented in this paper is an extension of VESPA[1] (Vehicular Event Sharing with a mobile P2P Architecture), which is a system developed to share information about events in inter-vehicle ad hoc networks. In such environments, data is received from other vehicles and stored locally in a data cache. Then, query evaluation techniques are used to sift through the stored information to determine what is relevant for that time and location, and issue a warning or transmit information to the driver when necessary.

In this paper, we focus on the exchange of information about available parking spaces using VESPA. As opposed to other types of events, it is not enough to indicate the presence of the event to the driver. Indeed, if the same information (i.e., the same available parking space) is presented to several interested drivers, this will lead to a competition between the vehicles and only one of them will be able to take that parking space. It is so crucial to propose a solution for parking spaces to be "reserved" and so communicated to a single driver. The fully decentralized environment imposed by vehicular networks makes that reservation process particularly challenging since vehicles keep moving and no reliable link or central server can be used. Although other solutions have been proposed to disseminate information about available parking spaces using short range communications (e.g., [2]), to the best of our knowledge, no other work has tackled the problem of parking space reservation in vehicular ad hoc networks.

II. Reservation Protocol

Coordinating different vehicles in vehicular ad hoc networks for them to choose one vehicle to which the parking space will be allocated is not an easy task. Indeed, no centralized server is available in such environments where vehicles only communicate through short range communication networks. Moreover, all the vehicles have the same importance/role. So, we propose a protocol in which a *coordinator* vehicle is chosen for each parking space. The role of such a coordinator is to collect, from its neighbors interested in finding an available parking space, the necessary information to decide to which vehicle the resource will be allocated. In the following, we will call "reservation" the process consisting in allocating parking spaces to vehicles. Our goal is to ensure that the information about a parking space is shown only to the driver of the vehicle that is chosen to occupy it, in order to minimize competition. Anyway, even if we try to help the elected vehicle to reach the parking space while it is still available, we cannot ensure that no other driver will see and use the available parking space before. This is obviously unavoidable. What

[1] See http://www.univ-valenciennes.fr/ROI/SID/tdelot/vespa/ for more information.

our protocol eventually ensures is an effective dissemination of information about available parking spaces, without leading to a competition.

At first, the coordinator is the vehicle that leaves the parking space[2]. It sends a message to inform the vehicles in its communication range that a parking space is available. Then it waits for potential answers. Among the vehicles receiving the information, only those interested in the parking space answer to the coordinator. Each interested vehicle v_i provides to the coordinator its vehicle's identifier and the information necessary for the coordinator to choose the vehicle to which the resource has to be allocated, such as the time t_i, corresponding to the current duration of the search of a parking space for that vehicle.

After a period of time T (amount of time during which the coordinator waits for answers from interested vehicles), the coordinator chooses, among the vehicles that answered, the one for which the parking space is "reserved". Different policies may be applied to choose the vehicle to which the parking space should be allocated (e.g., select the furthest vehicle, the vehicle that has been searching for a parking space the longest, etc.). Finally, the vehicle sends a message to the coordinator to acknowledge the reception of the coordinator's message and to confirm that it will take the resource (i.e., the parking space). This acknowledgement avoids losing parking spaces. In case the chosen vehicle does not accept the parking space, another vehicle is chosen by the coordinator. This exchange will be performed in a short time. However, if the acknowledgement should get lost, the parking space would be allocated to a second vehicle, generating some competition; this unlikely inconvenience is preferable to the possibility that the advertisement of the parking space gets lost.

In case no interested vehicle answered, a new coordinator is elected. The new coordinator has to be farther from the resource to increase the probability to reach new potentially interested vehicles. In the case of parking spaces, the coordinator should however not be selected too far away from the available slot. Indeed this would increase the probability that another vehicle arrives to park in that parking space in the meanwhile. Instead, we choose the new coordinator according to the demand in terms of available parking spaces in its vicinity.

Our goal is to find an interested vehicle as quickly and as close to the parking space as possible. Therefore, each vehicle periodically broadcasts to its neighbors its "state" (i.e., whether it is searching for a parking space or not). This allows each vehicle to estimate the approximate number of nearby vehicles searching for a parking space. So, when a new coordinator has to be elected, the former one broadcasts a message to its neighbors. The neighboring vehicles receiving that message (and not already coordinators for another parking space) reply to the coordinator by indicating their estimations. The coordinator then sorts the candidates in increasing number of these estimations and contact the vehicles in that list following that order until one vehicle confirms the reception of the proposal and so becomes the new coordinator. In case no candidate coordinator answers, the former coordinator keeps its role and, after a while, broadcasts again the message about the available parking space. By then, new vehicles interested can now be in its neighborhood. If not, a process to switch the coordinator is initiated again.

Thus, vehicles interested in finding an available parking space can be located even if they are further from the available parking space than the communication range of the wireless network used. Each vehicle receiving a notification about an available parking space has to verify if that information is relevant, using the mechanism described in [6], to estimate if it can reach the spot while it is still estimated available. In that case, it declares its interest in the parking space.

[2]If the event is generated by a fixed sensor in the parking space, an initial coordinator is chosen between the vehicles receiving this event.

III. Prototype and Experimental Evaluation

We have implemented a prototype of VESPA (using the .NET/C# framework) that runs on any PDA with Windows Mobile, GPS and Wi-Fi connection. The dissemination protocol relies on Wi-Fi communications to support the exchanges of data between the vehicles. For the moment, the events are generated manually by the driver.

We have started the evaluation of our proposal in both a real and a simulated environment, obtaining interesting preliminary results. Our goal is to evaluate different strategies to advertise available parking spaces in different scenarios (a parking lot, a city, etc.).

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