VESPA: Let your vehicles speak together!

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***Abstract*— Aujourd'hui, la voiture est indiscutablement le mode de transport le plus utilisé. Ce succès a toutefois été accompagné de nombreux problèmes dans des domaines comme la sécurité ou encore l'environnement. Malgré de nombreux efforts pour tenter de le réduire, le nombre de personnes tuées sur les routes reste encore très élevé aujourd'hui, principalement à cause du facteur humain (comportement accidentogène, temps de réponse trop long, etc.). Pour tenter de réduire le nombre d'accidents, de nombreux programmes reposant sur l'utilisation des communications sans fil ont été initiés en Europe, au Japon ou aux Etats-Unis pour étudier les "Systèmes de Transport Intelligents (ITS)". De tels systèmes exploitent les technologies de l'information et de la communication, et plus particulièrement les réseaux sans fil, pour permettre aux véhicules de s'échanger des informations et ainsi avertir les conducteurs d'un danger (accident, freinage d'urgence, etc.).**

VESPA (Vehicular Event Sharing with a mobile P2P Architecture)[1] s'inscrit dans cette famille de systèmes. VESPA est conçu pour le partage d'informations dans les réseaux ad hoc inter-véhicules. L'originalité de VESPA réside dans le support de différents types d'événements pertinents pour les conducteurs (e.g. places de stationnement disponibles, freinages d'urgence, embouteillages, obstacles sur la chaussée, véhicule prioritaire demandant aux autres de lui céder le passage, etc.) A notre connaissance, VESPA est le premier système qui adopte une approche globale alors que les solutions existantes se focalisent sur un type d'événement particulier.

Dans cet article, nous présentons notre prototype de VESPA dont la version actuelle est implémentée sur des smartphones HTC équipés de récepteurs GPS. Nous détaillons principalement dans la suite l'évaluation de la pertinence des événements pour les véhicules ainsi que le protocole de dissémination utilisé. Ces éléments ont été conçus pour supporter les différents types d'événements mentionnés précédemment. Dans VESPA, la dissémination des événements est ainsi adaptée au type d'événement manipulé (e.g. une place de stationnement disponible doit être communiquée à tous les véhicules à proximité alors qu'un événement relatant un embouteillage doit être relayé exclusivement aux véhicules suivant celui qui relaie).

***Keywords*— VESPA, Vehicular Ad Hoc Networks, Information Sharing**

[1]Pour plus d'informations, consulter la page : http://www.univ-valenciennes.fr/ROI/SID/tdelot/vespa/

I. INTRODUCTION

Those last years, many works have focused on information exchange in vehicular ad hoc networks (VANETs). These wireless networks 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 [5] and provide bandwidth in the range of Mbps. Using such communication networks, the driver of a car can receive information – for example, about accidents, traffic congestion or available parking spaces – from its neighbours.

In that context, different systems have already been designed ([9], [6], [7], [4], [8]). They aim at assisting the drivers by providing them information about accidents, emergency braking or available parking spaces. VESPA follows a quite different approach. Contrary to the other systems, dedicated to the dissemination of one particular type of information, the originality of VESPA is to support any type of event occurring on the roads, even mobile events. Indeed, numerous types of events –both mobile and stationary– are possible, since there is a lot of information that drivers may find relevant, about: accidents, traffic congestion, emergency braking situations, fuel prices, available parking spaces, emergency vehicles such as ambulances, obstacles in the road, or the behaviour of drivers (e.g., strange manoeuvres due to intoxication or lack of vigilance), to name but a few possibilities. Therefore, VESPA relies on the concept of encounter probability to estimate the relevance of an event for a vehicle [3]. VESPA also includes a dissemination protocol [1]. This protocol ensures an adaptive broadcast of the events in the vehicular network according to their type.

The rest of this paper is organized as follows. Section II presents the main features of our VESPA system. Section III presents our prototype and describes the scenario of the demonstration. Finally, Section IV offers our conclusions.

II. VESPA

Many pieces of information may be exchanged in the context of inter-vehicle communications, for instance to warn drivers when a potentially dangerous event arises (accident, emergency braking, obstacle in the road, etc.) or to try to assist them (available parking spaces, traffic congestions, real-time traffic conditions on one road, etc.). Those different events may be detected by a car and lead to the generation of a message transmitted to the other potentially interested vehicles, either directly or using multi-hop relaying techniques. Once received by a vehicle, the relevance of a message has to be evaluated, according to spatial and temporal criteria to determine whether the driver should be warned or the message should be further broadcast.

A. Relevance estimation

To estimate the relevance of an event (i.e. determine whether a vehicle will encounter an event or not), it is necessary to have an estimation of the vehicle's trajectory. Therefore, VESPA does not rely on the use of digital maps since they are not always available or accessible on users' devices. It rather exploits mobility and direction vectors to characterize the vehicle's displacement and so estimate a future position of the vehicle. These vectors are computed thanks to GPS position statements (including 3-dimensional coordinates as well as a statement of the GPS time) obtained regularly.

The estimated future position is highly dependent on the t_n and t_{n-i} time interval selected between the position statements used to compute the vectors. Thus, if t_n and t_{n-i} are far away, the estimation of the future position is not precise but provides an overall impression of the object's direction. If the time interval is shorter, then the estimation is much more precise on the short term but no global view of the displacement can be observed. As an example, see arrows A and B in Figure 1.

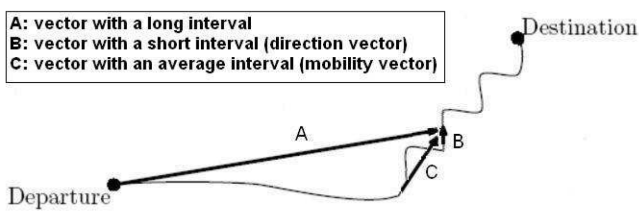

Fig. 1. Mobility and direction vectors

Depending on the way we select the time interval $[t_{n-i}, t_n]$, we distinguish:

- The *direction vector*, which is computed with a short interval. It provides a quite precise estimated future position but only in the very short term (see arrow B in Figure 1).
- The *mobility vector*, whose role is to provide an overall impression of the object's movement in addition to a good estimated future position. To achieve a good compromise between the previous two cases (arrows A and B in Figure 1), an "average" interval must be used to compute it (see arrow C in Figure 1).

Using the mobility and direction vectors, the positions of the vehicle and the event, we can deduce four elements which have an influence on the encounter probability:

- The minimal geographical distance between the vehicle and the event over time (Δd).
- The difference between the current time and the time when the vehicle will be closest to the event (Δt).
- The difference between the event's generation time (stored in *CurrentPosition*) and the moment when the vehicle will be closest to it (Δg, *expected age of the event*).
- The angle between the direction vectors of the vehicle and the event (denoted by a colinearity coefficient c).

As an example, Figure 2 shows the geometrical representation of Δd and Δt. In the figure, B represents the vehicle position, C the position of a stationary event, and $\overrightarrow{AB}$ is the mobility vector of the vehicle. Point D can then be determined, which allows a right-angled triangle to be constructed in D with $[BC]$ as hypotenuse. D is the closest point to C on the straight line between A and B. $|\overrightarrow{DC}|$ (= Δd) represents the minimal geographical distance between the vehicle and the event over time. $|\overrightarrow{BD}|$ is the distance between the vehicle and the point D. Since the mobility vector $\overrightarrow{AB}$ has a temporal dimension, $|\overrightarrow{BD}|$ can be converted into time to obtain Δt.

As explained previously, the vehicle estimates its direction vector and the event's direction vector. From these two direction vectors, a *colinearity coefficient* (c) is obtained, which is a measure of the angle formed by the vectors. For direction-dependent events that are not relevant for all nearby vehicles, but only for the vehicles travelling in a particular direction (e.g. emergency braking, accident, etc.), this allows us to determine whether the directions of the vehicle and the event match. For non-direction-dependent events, c is set to 0.

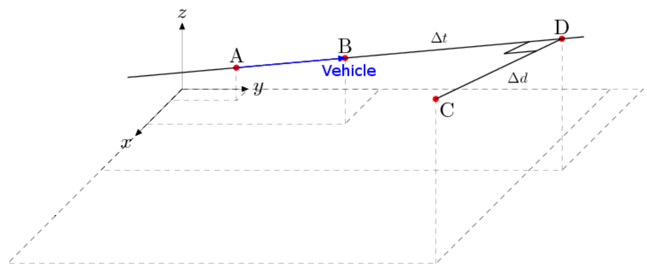

Fig. 2. Representation of Δd and Δt

Once these Δd, Δt, Δg, and c values have been calculated, they are used to estimate an "encounter probability" between a vehicle and an event. The encounter probability (EP) is a value between 0% and 100%. It is computed, based on the previous values, using the following function:

$$\mathbf{EP} = \frac{\mathbf{100}}{\alpha \times \mathbf{\Delta d} + \beta \times \mathbf{\Delta t} + \gamma \times \mathbf{\Delta g} + \zeta \times \mathbf{c} + \mathbf{1}}$$

where α, β, γ and ζ are penalty coefficients with values ≥ 0. They are used to balance the relative importance of the Δd, Δt, Δg, and c values. The bigger the coefficient is, the more penalized the associated valued is when computing the EP. For example, the greater the α value, the shorter the spatial range where the event is relevant. β and γ are used so that only the information about events that will be encountered very rapidly and the most recent information is considered. Finally, ζ is used to weigh the importance of the colinearity coefficient. Notice that if the vehicle is moving away from the event, then Δt is 0 and Δd is the current distance to the event. Therefore, the computation of the EP makes sense even in cases where an interesting event (e.g., a parking space) is behind us. The EP is used to determine the relevance of an event. The greater its value, the more likely the vehicle is going to meet the event.

B. Dissemination of events

1) Representation of events: In the following, we explain how the events are represented as messages exchanged between the vehicles. Each event is characterized by:

- A unique *Key*.
- A *Version* number to distinguish between different updates of the same event. Once generated, an event is disseminated among a set of potentially interested vehicles. To update the information transmitted to other vehicles, for example because a mobile event has moved, the vehicle which created the event may produce a new version of the same event.
- The *Importance* attribute, to determine whether the information should be presented to the driver or not. Unless the event is a very important one (e.g., emergency braking), the driver is informed only if s/he is interested in that type of event.
- The *CurrentPosition* attribute indicating the generation time and place of the event.
- Two different preceding reference positions and their timestamps (*DirectionRefPosition* and *MobilityRefPosition*) for each vehicle to receive information to evaluate the mobility and direction of an event (see Section II-A), which is necessary to estimate the event's relevance.
- The *LastDiffuserPosition* used by the dissemination protocol and containing the position of the last vehicle which relayed the message.
- The *HopNumber* attribute indicating the number of broadcasts of the message.
- A *Description* field describing more precisely the represented event (e.g., accident, emergency braking, etc.). This field is used to transmit concrete information to drivers when they need to be warned.

2) Dissemination Protocol: Our objective as concerns the dissemination protocol is to disseminate different types of events (an accident, an emergency braking, an available parking slot, etc.) in the vehicular network. Therefore, we have to support different dissemination modes (e.g. an emergency braking has to be diffused to the vehicles driving in a particular direction whereas an available parking slot has to be transmitted to all close vehicles, whatever their direction, as it may interest them). VESPA uses a dissemination protocol[2] relying on the EP to determine the vehicles which have to broadcast an information they received. It also allows diffusing the messages in the right direction, that is, towards the vehicles for which these messages may be relevant according to the type of event considered. Thus, when a message about an event is received by a vehicle, the vehicle will relay the message if the value computed for the EP is greater than a predefined diffusion threshold. Anyway, since this may happen at the same time on different vehicles, the same event may potentially be diffused numerous times by different vehicles. So to avoid flooding and so network congestion, our solution aims at desynchronizing the diffusions performed by the different vehicles. Therefore, each vehicle waits for a period t before broadcasting the message. The size of that period depends on the distance between the receiving vehicle and the one which sent the message. The intuition behind this is to choose, among the neighbouring vehicles which received the message, the farthest neighbour from the sender to relay the message. Indeed, this farthest neighbour may have the greatest number of neighbouring vehicles not yet informed about the event being transmitted. It is so the best candidate to try to broadcast the message to all concerned vehicles as quickly as possible[3]. The value of t is determined by each vehicle as follows:

$$t = D \times (1 - \frac{d}{r})$$

where D is the maximum time to wait before broadcasting, r is the communication range of the wireless network used by the vehicles to communicate, and d corresponds to the distance between the receiving and the diffusing vehicle[4]. Since d may vary from 0 to r, t is between 0 and D.

III. Prototype & Demonstration

For obvious scalability reasons, our dissemination and relevance estimation techniques were evaluated on a simulator. Anyway, a prototype of VESPA has been implemented using Microsoft

[2]See [1] for more details.

[3]This removes the need of real-time monitoring the positions of the vehicles. Such a monitoring is indeed unrealistic in such dynamic environments.

[4]The value of d is computed using the position of the last vehicle that has relayed the event stored in the corresponding message.

.Net to observe its behaviour in “real conditions”[5]. Our VESPA prototype runs on smartphones equipped with embedded GPS receivers (see Figure 3). The dissemination protocol presented in Section II-B was implemented using Wifi communications.

In real conditions, the generation of many events could be initiated using the numerous sensors embedded in our cars (for example, by coupling the airbag system with the creation of an event representing an accident). Since the smartphone is not connected to these sensors, the generation of the events is managed by the device (using the GPS signal) in the current version of our prototype.

Fig. 3. Testing VESPA in a real environment

During our demonstration, we will show how an event, once created, is disseminated in the vehicular network according to its type. We will therefore consider different events such as a vehicle leaving a parking space (i.e., an event relevant for all the vehicles that are close to that space during a given period of time), and an emergency braking only relevant for the vehicles following the vehicles generating that event.

IV. Conclusion & Perspectives

In this paper, we have presented our VESPA prototype. VESPA is complementary to existing navigation systems. Indeed, whereas navigation systems can be used to guide drivers, VESPA may provide them information about the road hazards they may encounter along their displacement. It can also help them to find an available parking space once they have reached their destination.

Our prototype now supports the dissemination of different types of events in the vehicular network using an encounter probability. Our actual work is to evaluate VESPA in real conditions using our prototype. We are also studying how to improve it. Therefore, we are working on the aggregation of the events received by a vehicle. Our goal is to extract additional knowledge to be used by the drivers. For example, using the summaries generated with the available parking spaces [2], it becomes possible to determine the areas where the probability to find an available parking space is high.

[5]The number of vehicles used during our field tests remain limited for the moment.

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