Journal of Network and Computer Applications 35 (2012) 1891–1900

Contents lists available at SciVerse ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

VEACON: A Vehicular Accident Ontology designed to improve safety on the roads

Javier Barrachina [a], Piedad Garrido [a], Manuel Fogue [a], Francisco J. Martinez [a,*], Juan-Carlos Cano [b], Carlos T. Calafate [b], Pietro Manzoni [b]

[a] University of Zaragoza, Spain
[b] Universitat Politècnica de València, Spain

ARTICLE INFO

Article history:
Received 28 November 2011
Received in revised form
9 May 2012
Accepted 3 July 2012
Available online 20 July 2012

Keywords:
Vehicular Networks
Ontologies
Intelligent Transportation Systems (ITS)
Vehicular accidents
VANETs

ABSTRACT

Vehicles are nowadays provided with a variety of new sensors capable of gathering information about themselves and from their surroundings. In a near future, these vehicles will also be capable of sharing all the harvested information, with the surrounding environment and among nearby vehicles over smart wireless links. They will also be able to connect with emergency services in case of accidents. Hence, distributed applications based on Vehicular Networks (VNs) will need to agree on a 'common understanding' of context for interoperability, and, therefore, it is necessary to create a standard structure which enables data interoperability among all the different entities involved in transportation systems. In this paper, we focus on traffic safety applications; specifically, we present the VEhicular ACcident ONtology (VEACON) designed to improve traffic safety. Our ontology combines the information collected when an accident occurs, and the data available in the General Estimates System (GES) accidents database. We assess the reliability of our proposal using both realistic crash tests, held in the facilities of Applus+ IDIADA in Tarragona, Spain, and Vehicular Network simulations, based on the ns-2 simulation tool. Experimental results highlight that both nearby vehicles and infrastructure elements (RSUs) are correctly notified about an accident in just a few seconds, increasing the emergency services notification effectiveness.

1. Introduction

Currently, one of the most important factors of globalization is transportation. Although the purpose of transport has not changed with globalization, the factors triggering the emergence of a global transportation system (e.g., volume, capacity, speed, and efficiency) have evolved. Moving goods and people as quickly as possible all around the world requires advanced integrated transportation systems (Di Lecce and Amato, 2009). Information Technology (IT) and transport infrastructure help to manage transportation systems in an accurate and effective manner. *Intelligent Transportation Systems* (ITS) will play a leading role in our society, especially in scenarios such as warning drivers about vehicle accidents in real time, efficiently managing vehicle information required by governments and authorities, or even being able to offer drivers a variety of added services.

The specific characteristics of Vehicular Networks favor the development of attractive and challenging services and applications. However, distributed applications based on Vehicular Networks need to agree on a 'common understanding' of context for interoperability on a contextual level. The Semantic Web (Berners-Lee et al., 2001) can be applied to modern transportation systems to build up such context. The Semantic Web is an extension of the traditional web which allows machines to interpret the meaning of data thanks to the use of ontologies. An ontology is a description of a small part of the real world, including the types of items that appear in this world, the relations among them, the leading elements, and their restrictions. Typically, an ontology is defined as a formal specification of conceptualization (Gruber, 1995).

In this paper we focus on safety applications. Specifically, our aim is to improve traffic safety by using an ontology-based approach in Vehicular Networks. To that end, we propose the *VEhicular ACcident ONtology* (VEACON), a novel lightweight ontology proposed to provide sharing and reusing knowledge about traffic accidents. VEACON allows to efficiently structure and encode the information collected by sensors in the vehicle, enabling the interoperability among all the agents involved in modern ITS (i.e., vehicles, RSUs, emergency services, and authorities).

* Corresponding author. Tel.: +34 696532959; fax: +34 978618104.
E-mail addresses: barrachina@unizar.es (J. Barrachina), piedad@unizar.es (P. Garrido), m.fogue@unizar.es (M. Fogue), f.martinez@unizar.es (F.J. Martinez), jucano@disca.upv.es (J.-C. Cano), calafate@disca.upv.es (C.T. Calafate), pmanzoni@disca.upv.es (P. Manzoni).

1084-8045/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jnca.2012.07.013

Nowadays, vehicular networking technologies allow a vehicle to alert emergency services in case of an accident. Although there are many solutions that relay on Vehicular Networks for that purpose, there are fewer solutions based on semantics to send accident information to the emergency services. In this paper, we explore the use of an ontology framework for sending critical information captured by vehicles involved in road accidents. This information will not only be sent to the emergency services, but also it will be shared among the nearby vehicles. Hence, this warning information will be used for different proposes such as: (a) preventing new accidents (avoiding that other vehicles collide with the vehicles already involved in the accident), (b) helping to allocate resources for a rescue, and (c) maintaining statistics on road accidents, which allows fast database searches and the creation of prediction models to estimate the severity of future accidents.

This paper is organized as follows: Section 2 reviews the related work regarding the use of ontologies applied on ITS. Section 3 presents VEACON, our proposed ontology. In Section 4, we assess the feasibility of our proposal by doing some real experiments as well as carrying out some simulation tests. Finally, Section 5 concludes this paper.

2. Related work

For the proper operation of traffic safety systems, we must consider two different factors: (i) vehicles must be able to communicate among them in order to share information and (ii) the shared information should be understood by all the entities involved in transportation systems. The first factor has been widely studied by the wireless networking research community (Martinez et al., 2010b; Bakhouya et al., 2011; Antolino Rivas et al., 2011; Daeinabi et al., 2011). However, the second factor has not yet been studied to the same extent.

Regarding the use of semantics in vehicular environments, some authors have worked on the integration of transportation systems information and semantics. Zhai et al. (2008b) presented an ontology for structuring data traffic. Zhai et al. (2008a) introduced a knowledge navigation system with urban traffic information based on the XML Topic Maps technology, enabling intelligent information retrieval through association between topics. These different works highlight the importance of using ontologies in ITS, however they do not provide any ontology specially designed for ITS safety.

Regarding ITS safety, Eigner and Lutz (2008) showed the need for ontological context models for VNs safety environments, and how all the components of the system would be able to understand one another through these models. They considered that vehicles should incorporate a variety of sensors to get data from the vehicles themselves, as well as from their surroundings. In addition, information obtained by these sensors could be shared with other vehicles using VNs. The authors showed that vehicular applications can benefit from the inherent characteristics of ontological models such as distributed composition, partial validation, richness and quality of information, as well as a certain level of formality. Additionally, authors proved that calculations on the model are still fast enough to fulfill real-time requirements imposed by the active safety systems of vehicles. However, they did not build a specific ontology. More recently, Kannan et al. (2010) proposed an ontology modeling approach for assisting vehicle drivers through warning messages during time critical situation. Authors focused on generating the alert messages based on the context aware parameters such as driving situations, vehicle dynamics, driver activity, and the environment.

Although the above presented works proposed ontological models for warning messages using Vehicular Networks, none of them enriched their proposal with historical information to estimate the severity of accidents using real crash tests.

3. VEACON: our ontology for Vehicular Networks

From the point of view of Communications and Information Technologies for Vehicular Networks, ITS applications will rely on efficient vehicular communications and smart exchange of information among all the entities involved, i.e., vehicles, RSUs, emergency services, management authorities, and police. When a traffic accident occurs, a crucial issue is to collect as much information as possible, since vehicles should rapidly warn nearby vehicles and the emergency services to obtain a quick and efficient response from them. However, the information usually collected in accidents is neither structured nor does it present relationships between their basic elements. We propose to organize this information using an approach based on the Semantic Web, where the information can be obtained through various techniques such as ontologies, classifications, taxonomies, thesauri, or topic maps (Garshol, 2004).

Our system gets the information from warning messages exchanged among vehicles and emergency services. This information should be, on the one hand, concise enough to avoid irrelevant information, but, on the other hand, it should not ignore any information that might be useful for the emergency services to determine the most suitable set of resources. Thus, the delivered information should include: data about the conditions under which the accident occurred, data about the occupants of the vehicle, as well as a description of the security systems included within the vehicle. When an accident occurs, all these data will be sent to the emergency services, providing a more detailed view of the conditions of the accident before their arrival.

In this work, we use an ontology based technique to group all these information sources, while allowing to make inferences over the collected data. An ontology formally represents knowledge about the entities within a domain, so we can elaborate estimations about the entities involved. In our case, we can estimate the different factors of the accident (impact severity, passenger injuries, and so on). Basically, an ontology consists of three parts: classes and instances of real-world items, relations among these items, and rules for modeling knowledge and complex behaviors (creation, restraint, and response).

Specifically, we propose the Vehicle Accident Ontology (VEACON), a novel lightweight ontology proposed with the aim of sharing and reusing knowledge about the vehicles involved in road accidents. VEACON meets our requirements since it: (i) promotes interoperability between different knowledge sources, (ii) provides an infrastructure or cooperative system, (iii) facilitates the information sharing, and (iv) enables domain knowledge reuse. These features cannot be provided by a simple rule based system. VEACON consists of a set of classes representing the categories of the entities of interest in the ITS domain, the attributes which define properties of those classes, and the relationships between those entities.

Figure 1 shows the basic VEACON ontology structure, which groups the available information into four different areas: vehicle, accident, occupant and environment. As for the languages, we decided to use the Ontology Web Language (OWL) (The World Wide Web Consortium (W3C), 2004) to create XML-based messages, since it is a flexible and expressive language which provides a basic syntax to describe the relationships between entities. Listing 1 shows an example of a VEACON-compliant warning message.