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An Ontology based Approach for Messages Dissemination in Vehicular Ad Hoc Networks

Asma Bibi[1], Osama Rehman[2], Sohaib Ahmed[2]

[1] Bahria University Karachi Campus, Department of Computer Science, Karachi, Pakistan [2] Bahria University Karachi Campus, Department of Computer & Software Engineering, Karachi, Pakistan
{asma.bibi02@gmail.com, osamahussain.bukc@bahria.edu.pk, sohaib.bukc@bahria.edu.pk}

Abstract

Vehicular Ad-hoc NETworks (VANETs) is a special form of Mobile Ad-hoc NETworks (MANETs). The continuous developments in wireless networks have paved the way for the adoption of wireless data exchange for onroad vehicles. The application of VANETs is considered as a key component within the envisioned Intelligent Transportation Systems (ITS). One of the primary applications of VANETs is to enhance the safety measures for the vehicles on-road. Information about vehicles, such as vehicle speed and location coordinates are passed among vehicles to improve their awareness of each other. In VANETs, vehicles are referred to as nodes within a network where each node can act as both; end devise and router. The current design of VANETs has been identified with several drawbacks, while obtaining high performance in multi-hop message dissemination being as one of the most prominent issues. This problem need a solution to improve VANET's performance, especially over networks with high node densities. In this paper, we propose an ontologybased approach for multi-hop message dissemination over VANETs as a solution that would address the above highlighted issue.

Keywords: VANETs, Broadcast Storm, Multi-hop Messages Dissemination, Ontology.

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1. Introduction

In the near future, it is envisioned that vehicles would be able to communicate with one another [1]. A future where drivers would be warned of a potential crash in nearby or far away distances with the assistance of communication technologies. [2]. The technology to make this happen exist today and future possibilities are just around the corner. Continuing to build on the positive results of previous vehicular and communication systems-initiated Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication techniques [1]. Significant amount of research interests is focused towards V2V communication due to the absence of the need for major infrastructures deployment [1]. Another concern is to determine if a diverse group of drivers would accept V2V technology, especially for safety related services and to see how they respond to the new system [2]. What makes (V2V) communication work is a wireless technology called Dedicated Short Range Communication (DSRC) [3], which is similar to the IEEE 802.11 standard, and commonly known as Wi-Fi. DSRC based VANETs communication has been identified as a potential technology to adopt for the envisioned ITS framework. When DSRC is combined with GPS technology, the result is a low cost V2V communication system that provides a 360-degree view of similarly equipped vehicles within the communication range of each other. While adopting DSRC in VANETs, drivers can receive warning messages that can help drivers to respond quickly for avoiding potential crashes or traffic jams [3, 4]. In VANETs, usually different vehicles broadcast data over a network link and the other network nodes rebroadcast the same data back to the network link in response. This eventually leads to the well-known broadcast storm problem that may cause the whole network to melt down, further leading to the failure of network communication. The impact of broadcast storms in VANETs can be quantified in terms of message delay and packet loss rate measured by packet delivery ratio. The use of ontologies for representing knowledge has emerged as one of the promising approaches in many domains including learning [5], health-care [6] and specifically in ITS [7-9]. An ontology based approach can enhance the ITS in numerous ways such as urban management system [7], traffic safety [8] and autonomous vehicle assistance [9]. However, there are limited work found in the literature that discusses ontology-based approach with multi-hop message dissemination schemes for VANETs. Thus, in this paper, we propose an ontology-based approach for message dissemination, named Messaging Ontology for VAnets (MOVA) that aims to enhance performance of VANETs in order to disseminate messages between vehicles, especially for traffic safety related services. The rest of this paper is organized as follows. In section 2, related work with respect to broadcast storm problem in VANETs has discussed. Section 3 gives an overview of ontology and several ontologies based solutions in VANETs. In section 4, our proposed ontology, MOVA is discussed in details. Finally, we sum up our work with a conclusion in section 5.

2 Related Work

Mostly the broadcast storm problem arises in VANETs when the traffic density on the road increases [10]. In recent years, several research papers have been published for reducing the broadcast storm problem in VANETs [10 - 13]. In [10], authors elaborate the broadcast storm problem in their paper and gave three techniques: weighted ppersistence, slotted 1 persistence, and slotted p-persistence schemes, to resolve that problem. The techniques are tested over a single lane and multi-lane topographies, and results show that these techniques reduce broadcast redundancy and packet loss. In [11] the author proposed a novel technique to reduce the broadcast storm in wireless ad-hoc network and avoid unnecessary loss of packets during the broadcasting the messages. In [12], the author proposed the Street Broadcast Reduction (SBR) technique, and further discussed in [13] as enhanced Street Broadcast Reduction (eSBR) for reducing the broadcast storm problem in urban scenarios that aims to improve the performance of the safety related alert messages dissemination. In [14] authors present a distributed multi-hop broadcast algorithm for vehicular safety and for the reduction in end-to-end delays. Similarly, in [15] the authors propose a Bi-Directional Stable Communication (BDSC) relay node selection scheme for multi-hop broadcast in Vehicular Ad hoc NETwork (VANET) for improving reachability of messages dissemination in VANETs. In [16] the author proposes a broadcasting protocol, namely DV-CAST, for safety application in VANETs.

3 Ontologies in VANETs

In recent years, ontologies were identified as a potential technique for representing knowledge in diversified domains. Gruber [17] defined the term ontology as "a formal, explicit specification of a shared conceptualization". Thoughtfully, ontology is the investigation of the sorts of things that exist. It is normally trust that ontologies "carve the world at its joints” [18]. The use of ontologies in any application domains can exhibit features including information usability, extendibility of domain model, common understanding of shared knowledge among humans and machines, logic reasoning support in an application [19]. In the literature related to VANETs, few articles have been published on ontologies as answers for the issues and the challenges faced in VANETs. In [8], a Car Accident Ontology for VANETs (CAOVA) was proposed, and further discussed in [20] as a Vehicular Accident Ontology designed to improve safety on the roads (VEACON), which focused on road safety application. This ontology consolidates the data gathered when an accident happens, and the information accessible in the General Estimates System (GES) accident database. CAOVA [8] and VEACON [20] provide ontology based solutions to enhance traffic safety, and for empowering interoperability between vehicles, road side units (RSUs), road management specialists and crisis support vehicles. A dynamic vehicle ontology based routing for VANETs was proposed in [21], in which a new method based on ontologies and traffic information was presented for the proper routing of packets from source to their destinations. In [22], authors introduced an ontology for a reliable traffic information system in which the OWL language was used to develop the ontology while depending on road traffic situations. In [7], the authors highlighted the critical issues of traffic management in urban areas and proposed a technique using ontology and VANET to facilitate the interpretation of the information collected by the driver and to enable more efficient and optimal use of road infrastructure. In a similar vein, authors suggested a technique to improve the situation awareness during emergency transportation of patients [23]. Their technique consolidates semantic reasoning with the Car-2-X technology. The created framework persistently coordinates information recovered from intervehicular communication with organized knowledge from vehicular ontologies and the digital maps obtained from the OpenStreetMap.

In literature, the ontology-based approaches have been used for different purposes in VANETs. However, sparse work has been found in the literature that disseminates multi-hop messaging through ontology-based approach. Thus, it provides an opportunity for us to explore such an approach to reduce the broadcast storm problem between vehicle communications and improve the multi-hop message dissemination over the vehicular networks.

4 MOVA: A Multi-Hop Messaging Ontology for VANETs

In VANETs, several vehicles resend the received warning messages to other vehicles within a specific transmission range for increasing the coverage distance as shown in Fig 1. This phenomenon increases the packet collision rate, hence leading towards a decrease in packet delivery ratio and increases in the end-to-end communication delay. In our approach, we propose an ontology, namely MOVA for reducing the broadcast storm problem during V2V communication, hence improving the multi-hop message dissemination outcome.

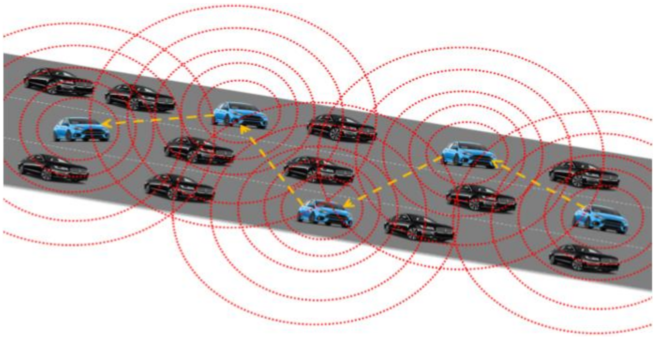

Fig. 1. Multi-hop Messages Dissemination in VANETs

We design a multi-hop message dissemination scheme for VANETs while using an ontology-based technique for improving performance especially for safety related messaging. The designed ontology can be directly integrated into each vehicle to obtain traffic information in real time. We attempt to quantify the impact of broadcast storms in VANETs in terms of message delay and packet loss rates. For this, we propose an ontology using VANETs that ensure a suitable presentation of collecting information from neighboring nodes. The information extracted out of the developed ontology serves as an input to optimize the selection of the next-hop relay nodes that plays a key role in multi-hop messaging schemes. A key characteristic of ontology is its completeness: an ontology should completely cover an area, i.e. not leaving concepts behind. It may also be defined as a complete semantic network, emphasizing that it is composed of a hierarchy of concepts. In this study, we explore the use of a formal ontology framework for sending critical information taken by vehicles. This information will be shared among the nearby vehicles by using multi-hop messages dissemination scheme.

4.1 Ontology Language

For our proposed ontology, we pick the web ontology language (OWL) to design and organize the information as shown in Fig 2. OWL is a semantic web language, intended for use by applications that need to handle the substance of information rather than simply displaying information to people. OWL enables greater machine interpretability of the content that supported by XML, RDF, and SRDF. Fig 2 shows the main classes of our proposed ontology and the Fig 3 describes the OWL based ontology for the class and subclasses. Ontology has the main class as a thing and all the other classes are subclasses, which brings the concepts of inheritance. In our Ontology there are four subclasses namely Vehicle, Road, Occupant and Message. For vehicle dataset shows the different fields such as speed, position, distance, vehicle-id etc. for the message dataset shows the different types of message such as request message, advisory message, alert message, safety and notification message. Road field shows the detail of the road like road scenario, road lane and road condition. Finally, occupant dataset shows the different field related to the person such his/her gender, age, weight and the seat position in the vehicle. We combine these fields as a single message and broadcast among the vehicles. These messages are built according to our ontology.

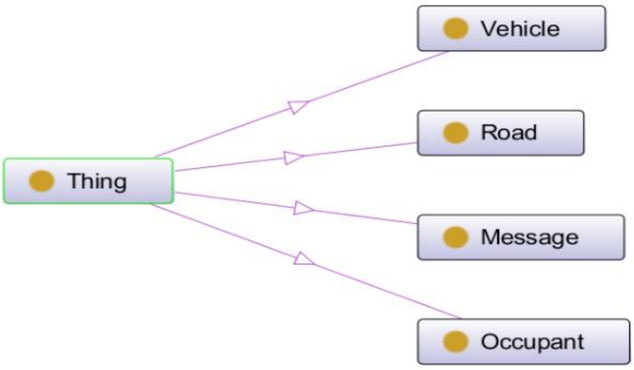

Fig. 2. Classes of the proposed Ontology

```
////////////////////////////////////////////////////////////////////

    // Classes

////////////////////////////////////////////////////////////////////
     -->

   <!--

    <owl:Class
rdf:about="http://www.semanticweb.org/asmabibi/ontologies/2017/5/
MultiHopMessagesDisseminationUsingOntology#Vehicle"/>

    <owl:Class
rdf:about="http://www.semanticweb.org/asmabibi/ontologies/2017/5/
MultiHopMessagesDisseminationUsingOntology#Message"/>


    <owl:Class
rdf:about="http://www.semanticweb.org/asmabibi/ontologies/2017/5/
MultiHopMessagesDisseminationUsingOntology#Occupant"/>


    <owl:Class
rdf:about="http://www.semanticweb.org/asmabibi/ontologies/2017/5/
MultiHopMessagesDisseminationUsingOntology#Road"/>

</rdf:RDF>
```

Fig. 3. Description of the classes used in proposed ontology

4.2 Design

For our ontology design, we used Protégé; which is a free open-source tool for building an intelligent system. It is supported by a strong community of educational, management and commercial users, who use to build knowledge-based solutions in various areas such as biomedicine, e-commerce and organizational modeling. Protégé's plug-in architecture can be adapted to construct both simple and complex ontologybased applications. Developers can integrate the output of Protégé with rule systems or other problem solvers to construct a wide range of intelligent systems. Protégé have several types of Reasoner like pallet, FaCT++, HerMiT, ELK and many more. These reasoned play a vital role in creating ontology written in web ontology language (OWL). For our ontology we use FaCT++ as a Reasoner, it plays a vigorous role in developing and using an ontology written in OWL and it is a tableaux-based Reasoner. Basically, the proposed ontology contains three parts: as shown in Fig 4, classes and instances of real-world entity, relations among these entities and the rules for modelling knowledge and complex behaviours (creation, restraint and response). Fig 5 shows an example of our proposed ontology in which we show the properties of our ontology i.e. object property and data property. Object properties shows the relation between the classes, while the data property contain the information of our classes that will be transfer between vehicles. This information is about vehicle, road, message and the occupant, that are the main four classes used by the ontology. The example also shows the detail of a road, that include the Road-Scenario, Road-Lane and about Road-Condition. As we use highway scenario for our ontology and a three-lane road structure. The Road-Condition tells the state of the road, either in a good condition, bad or worst condition.

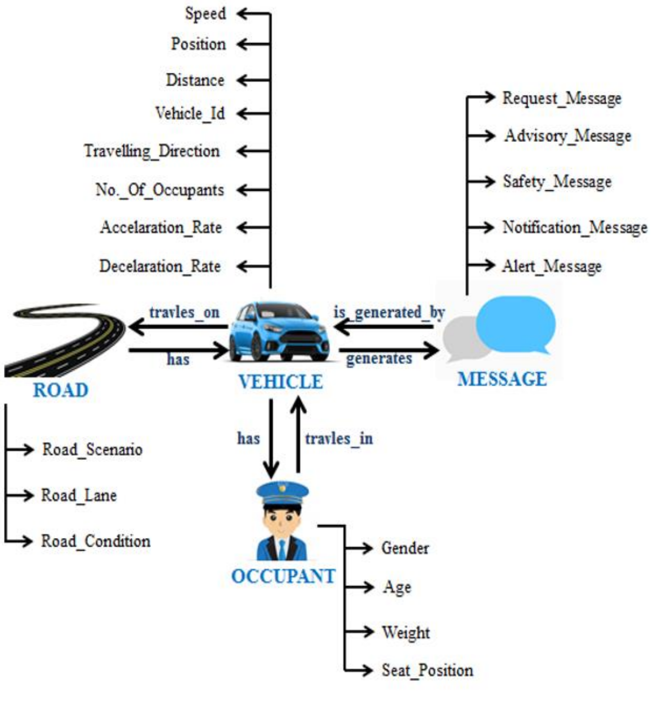

Fig. 4. Elements of the proposed ontology for VANETs

```
    <owl:ObjectProperty
rdf:about="http://www.semanticweb.org/asmabibi/ontologies/2017/5/
MultiHopMessagesDisseminationUsingOntology#generates">
        <rdfs:range
rdf:resource="http://www.semanticweb.org/asmabibi/ontologies/2017
/5/MultiHopMessagesDisseminationUsingOntology#Message"/>
        <rdfs:domain
rdf:resource="http://www.semanticweb.org/asmabibi/ontologies/2017
/5/MultiHopMessagesDisseminationUsingOntology#Vehicle"/>
    </owl:ObjectProperty>

<Road_Lane rdf:datatype="&xsd;integer">3</Road_Lane>
        <Road_Condition rdf:datatype="&xsd;string">
Good</Road_Condition>
        <Road_Scenario rdf:datatype="&xsd;string">
Highway</Road_Scenario>
```

Fig. 5. An example of the proposed ontology

5 Conclusion

In this paper, we presented an ontology based approach for the message dissemination in VANETs. The aim of designing this technique is to reduce the broadcast storm problem in VANETs, hence improving multi-hop messages dissemination that can be measured in terms of packet delivery ratio and the end-to-end communication delay. In our approach, the ontology encodes the information regarding the vehicle and the surrounding environment and transfers this information among vehicles. The work aims to improve the multi-hop messages dissemination in VANETs over large coverage areas and over high nodes density networks. Currently, our approach does not have detailed concepts for the complex scenarios in VANETs. Hence, future work of this paper would attempt to create a comprehensive ontology-based model for VANETs and to develop a platform for validating the proposed solution.

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