Multicast routing protocol for advanced vehicular ad hoc networks

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Abstract

Transport sector has great impact on our daily life. Despite the huge number of vehicular models, driving process still faces many challenges due to the lack information about the roads and the surrounding sudden events, which can result in high number of accidents globally and especially in Saudi Arabia. A new technology, vehicular ad hoc networks (VANETs), has emerged to support Intelligent Transport System (ITS) and to offer advanced solutions for drivers to avoid different hazard events that occur on the road. In this paper, we discuss the multicast and broadcast communications in VANETs, Quality of Sevice (QoS) awaregroup addressing/managing solutions to VANETs which help inclassifying different application that explore and design a new cross-layer framework, aware of high mobility and efficiency.

Keywords: intelligent transport systems, paper information technology, smart systems for road safety, vehicular ad hoc networks

1. Introduction

VANETs is considered as a type of mobile ad hoc networks (MANETs), and it is a key component of the ITS architecture. The main aim of using VANETs-applications is to increase road safety, and provide more entertainment facilities on the road [1-13]. It has been reported in [14-18] that about 60% of rear-end collisions can be prevented if car drivers have a 0.5 second additional warning time. Therefore, designing new protocols, by utilizing VANETs to disseminate warning messages to a large number of vehicles spread across sparse geographical areas is vital and challenging. As mobile wireless devices and networks become increasingly important, the demand for Vehicle-to-Vehicle (V2V) as shown in Figure 1 and Vehicle-to-Roadside (VRC) or Vehicle-to-Infrastructure (V2I) communication will continue to grow as shown in Figure 2.

VANETs can be utilized for a broad range of safety or non-safety applications, allowing for value added services such as vehicle safety, automated toll payment, traffic management, smart logistics, navigation, location-based services such as finding the closest fuel station, restaurant or travel lodge and infotainment applications such as providing access to the Internet.
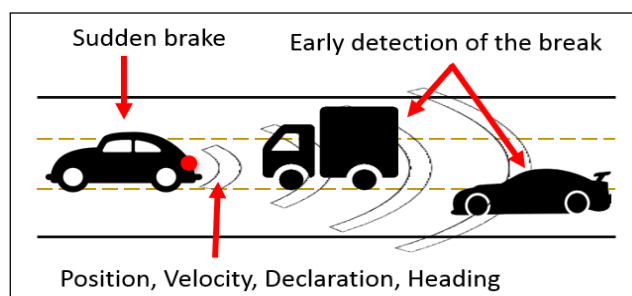

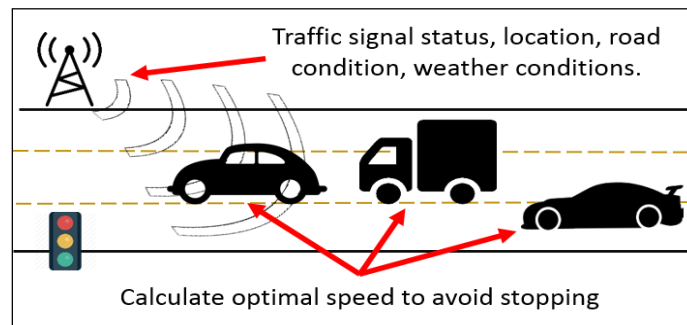Figure 1. Illustration of V2V communications

Figure 2. Illustration of V2I communications

Existing studies on VANETs have focused on specific areas including routing and communication algorithms, Quality of Service (QoS), and security. Having surveyed in-depth the state-of-the-art on these areas, we came to the conclusion that QoS aware group communications, such as multicast and broadcast in VANETs, is still in its infancy and an active research area due to several reasons [19, 20]. Firstly, most existing group communication algorithms and routing protocols used in VANETs have been originally devised for other types of wired and wireless networks, omitting the specific challenges of VANETs such as: high mobility, dynamic group management and variable density. Secondly, the relay node selection algorithms and routing metrics used in these protocols have only partially considered the QoS through limited metrics such as hop count, latency and packet loss ratio [21].

Moreover, optimizing group-communication performance under heterogeneous constraints is still an unexplored issue in VANETs. In other words, existing routing schemes are not enough to capture all constraints and performance parameters in VANETs. There is a growing need to devise novel QoS based cross-layer routing protocols that consider the real-time aspect of VANETs applications to address the specific challenges such as dynamic group management and fast handover whih have been lightly considered in current existing works. Indeed, there is an urgent need to refocus the research agenda on group communications, away from narrower concerns and move towards a more innovative and QoS aware multicast for the next VANETs generation. We place a strong emphasis on group communication due to the key role played by this communication pattern in VANETs. VANETs applications range broadly, from road safety applications to the vehicle or to the driver, to entertainment and commercial applications for passengers. Delivering QoS aware applications in VANETs usually centers around two fundamental themes, namely, cross layer design, and efficient group communication protocols. These will be discussed, in turn, in what follows.

2. Increasing Road Safety with Optimal Cross Layer Design

The cross-layer design and protocols are the cornerstone for handling efficient group communications in wireless and ad hoc networks VANETs where unpredictable variables such as node mobility, node density, etc., are challenging the network performance. Most existing studies [21] consider cross layer within limited aspects and only elastic traffics. In addition, it is worth stating that the optimal interactions between physical MAC and routing layers have not been fully exploited yet in IEEE 802.11p, especially within QoS aware multicast communication and this is the issue that will be tackled in this paper.

In addition, VANETs are expected to support a mixture of traffic types with heterogeneous QoS requirements. To achieve this goal in VANETs, transport layer, routing and MAC protocols need to cooperate and integrate properly. By exploiting the interactions between various layers of the network stack, the cross-layer design is the key element in overcoming current communication limits. Thus, this research emphasizes the design and analysis of innovative cross-layer multicast algorithms for VANETs.

This paper proposes and discusses the ability of developing new cross-layer routing metrics that can optimally deal with QoS-aware applications. Currently, most existing routing

protocols, e.g., [19, 20] only consider the following aspects: path length, packet delay, packet loss, bandwidth and packet size, MAC level measurement. None of these take the sensitivity of the applications to QoS into account in the route calculation.

As we introduced, VANETs has two transmission schemes, namely, the vehicle-to-vehicle (V2V) and the infrastructure-to-vehicle (I2V) or vehicle-to-infrastructure (V2I). In practice, point-to-point of unicast routing is the fundamental and basic routing for sending information from source to destination. The main problem however of unicast is the high rate of contentions when different sources are requesting channel access. While the broadcasting technique aims at transmitting messages and data for all receivers in the access range, the multicast has shown its efficiency when only a group of end-users vehicles are requesting the same kind of information. In literature, different routing protocols have been proposed for VANETs growing from simple protocols to the complex ones and aiming at the three "Cast" techniques. Up to now, most of these protocols are proposed for network layer (L3) independently of the layer 1 (L1) and layer 2 (L2). Assuming PHY and MAC are already established in VANETs while working on L3 only could be logical for safety applications, however, the capability of VANETs to carry-on multimedia and entertainments data demands a review of layers 1 and 2 techniques.

The key challenge of multicast is to control the channel load to avoid channel congestion where only a group, formed based on several metrics, of vehicles is addressed. Finally the optimization problem of multicast in VANETs becomes more and more complex when multimedia applications is targeted in vehicular environments.

In the light of this, it is important to have a certain level of Quality of Service (QoS) control in VANETs, no matter what type of data (alerts, audio, video, IP messages) is transmitted, so that the requested information are delivered to the vehicles on time and with satisfying quality. Surely, to support QoS in VANETs at layers 1 and 2 for multicast transmission is a very challenging topic. This includes, but not limited to, developing new metrics of QoS, new scheduling algorithms, new power allocation and new metrics for group composition.

3. Multicast Routing State Maintenance

The routing paths of multicast packets intended for mobile vehicles could change frequently. Based on the multi-hop nature of vehicular networks, data dissemination relies on two key components: the knowledge of node locations and a method for forwarding data to their destination. One of the simplest techniques to disseminate data to a large number of vehicles is to use the broadcasting method. The primary objective of broadcasting is to distribute information from a source to many unknown or unspecified destinations. Thus, flooding approach is the fundamental mechanism used in broadcasting. Consequently, when flooding is used in dense vehicular environment, it introduces significant overhead due to redundant re-broadcasting which in return can lead to the broadcast storm problem. To avoid blind flooding and minimize the signalling overhead, multicast aims at sending data to selected receivers. These receivers are interconnected by a multicast delivery tree that should be dynamically refreshed and built according to the dynamic nature of VANETs. The cost associated with the reconstruction of a multicast tree is important because this incurs significant routing overhead. To maintain a multicast delivery tree, two approaches may be used: the "soft state" approach in which branches are deleted if not refreshed within a timeout and the "hard state" that requires explicit leave requests when members leave or relocate.

A few of studies in the literature have focused on the multicast issue in VANETs [16]. These studies have proposed different classification for the multicast routing protocols. According to [16], multicast protocols in VANETs can be classified into two main classes: multicast/geocast and spatiotemporary multicast/geocast routing protocols. An example of the first class is the DRG (Distributed Robust Geocast) which distributes multicast traffic to a set of vehicles within a specific static geographic location. If a receiving vehicle is outside the distribution scope (Zone of Relevance or ZOR), the vehicle should drop multicast packets. While in the ZOR, vehicles should be able to receive the geocast message. To increase the reliability of transmission, this protocol has defined also a new forwarding zone (Zone of Forwarding or ZoF) that should include the ZOR to insure that geocast messages can be surely delivered to vehicles inside the ZOR. However, a periodic retransmission mechanism is still needed to overcome the network fragmentation problem. Another similar routing protocol within the same

first class of protocols named IVG (Inter-Vehicle Geocast) is also discussed in [22]. This protocol forms temporarily and dynamically multicast groups based on the location, speed and driving directions of vehicles in case of an emergency event. To overcome the fragmentation problem, periodic broadcasts are used to deliver multicast messages to receiving vehicles.

Unlike ordinary multicast and geocast routing protocols, the second class of spatiotemporary protocols intend to multicast a message to all vehicles in a specific geographic zone at a specific time. An example of these protocols is the mobicast protocol. This protocol uses the same concepts of broadcasting and forwarding zones (ZOR and ZOF) as in IVG except it considers mobile multicast/geocast region. Other classifications of multicast routing protocols for V2V communications have been proposed by [23-26]. According to their findings, the authors proposed to classify multicast routing protocols into two main classes: topology-based and location-based. The topology-based protocols select forwarding vehicle nodes based on the network topology information, whereas location-based protocols select the nodes based on the location information such as the position of the source, the position of receivers and the coordinates of the multicast region. In general, topology-based protocols are proactive protocols that construct group-based multicast meshes through periodic membership report messages. While there are many topology-based protocols such as ODMRP, MOLSR and MAODV that were designed for MANETs, only the GHM (Group Header Multicast) was proposed for VANETs [17].

Besides, a wide range of location-based multicast routing protocols has been proposed in the literature for VANETs. According to [17], these types of protocols can be further divided into two schemes based on the dependency on multicast membership or not. A set of extensions of the PBM (Position-based Multicast) such as SPBM (Scalable Position-based Multicast) and RSGM (Robust and Scalable Geographic Multicast) are proposed as location-independent multicast protocols, whereas the LBM (Location-based Multicast), RBM (Role-based Multicast) and IVG are considered as location-dependent multicast membership protocols [10]. While all the above described protocols and classes have addressed the issue of single source multicast, future multicast routing protocols should take into consideration the scenario of multi-source multicast where a vehicle can be simultaneously a receiver and a source of multicast messages. In addition, most existing multicast solutions in VANETs are under the umbrella of tree-based approach. However, some recent studies proposed to support multicast communication using network coding, where all links in the network can be utilized, instead of a tree. Although network coding can achieve the best throughput theoretically, it requires the modification of existing packet forwarding mechanisms, which is hard to achieve. Nevertheless, network coding based multicasting is a promising avenue and is worthy of thorough investigation, especially within the context of QoS provisioning.

4. Conclusion

The majority of the multicast protocols that have been initially proposed for MANETs are still valid for VANETs. However, to choose one of these protocols for a certain vehicular services, a further study is needed and there is also a need to develop evaluation tools that define unified scenarios and incorporate vehicular traffic patterns and channel models so that the merits and the tradeoffs offered in the discussed protocols can be compared. In particular future consideration of road side static nodes in these protocols can help to provide more relevant network topology and geographical information that improves not only routing but also the construction of the multicast network topology. We concluded that future multicast routing protocols should be flexible and take into consideration the scenario of multi-source multicast where a vehicle can be simultaneously a receiver and a source of multicast messages.

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