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A decentralized approach for information dissemination in Vehicular Ad hoc Networks

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ABSTRACT

Substantial research efforts on Ad hoc networks have been devoted recently to Vehicular Ad hoc NETworks (VANETs) to target Vehicle to Vehicle (V2V) and Vehicle to Roadside unit (V2R) communications in order to increase driver/vehicle safety, transport efficiency and driver comfort. VANETs are special subclass of Mobile Ad hoc NETworks (MANETs) for inter-vehicle communication and have relatively more dynamic nature compared to MANETs due to the rapid network topology changes. The development and implementation of efficient and scalable algorithms for information dissemination in VANETs is a major issue which has taken enormous attention in the last years. In this paper, an efficient distributed information dissemination approach is proposed, inspired by Ant-colony communication principles, such as scalability and adaptability that are useful for developing a decentralized architecture in highly dynamic networks. The main objective is to provide each vehicle with relevant information about its surrounding to allow drivers to be aware of undesirable events and road conditions. A "relevance" value into emergency messages is defined as an analog to pheromone throwing in Ant colony, to take an appropriate action. Simulations are conducted using NS2 network simulator and relevant metrics are evaluated under different node speeds and densities to show the effectiveness of the proposed approach.

1. Introduction

VANETs appeared as a subclass of MANETs for inter-vehicle communication. However, VANETs have relatively more dynamic nature as compared to MANETs with respect to network topology. The design and implementation of an efficient and scalable architecture for information dissemination in VANETs constitutes a major issue that should be tackled. Indeed, in this dynamic environment, increasing number of redundant broadcast messages will increase resource utilization, which would indirectly affect the network performance (Bakhouya et al., 2011). By relying on the participation of vehicles' community and wireless communication, information coming from one vehicle may not be credible and reliable to take right action or trigger an alert. Therefore, vehicles within a particular geographical area should be involved in communicating their context to confirm or reject an emergency situation. Involving multiple vehicles in exchanging context information will increase the confidence about a global current context. In addition, vehicles equipped with advanced sensors (e.g., ABS, ESP) and capable to become aware of specific abnormal conditions can share this information with other vehicles lacking this technology (Hartenstein and Laberteaux, 2010). For example, once the Automatic Braking System (ABS) within a vehicle is activated to indicate an icy road, strong rainfall or snow, the driver will be notified (Dar et al., 2010a). This information could be disseminated to other surrounding vehicles in order to be informed and eventually take preventive actions before getting into same dangerous situation. Another important scenario concerns exchanging information between vehicles to prevent traffic jams from growing too fast. For example, a vehicle having embedded traffic detection sensors can send traffic information to its following vehicles that can take preventive actions to avoid the congested areas (Dar et al., 2010a; Fuchs et al., 2007).

This paper proposes a decentralized Context Aware Information Dissemination (CAID) approach using two strategies (G1 and G2) that takes inspiration from the Ants' pheromones spreading

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principles for information dissemination in VANETs. The main focus is on critical emergency information dissemination in safety related applications. Ants' communication principles are used to develop new approaches of problem solving in different areas of research and development (Mullen et al., 2009; Rizzoli et al., 2007). In Ant colony, when Ants observe a food source they create pheromone to inform other Ants about route information to that food source (Chu et al., 2004); Detrain and Deneubourg, 2006). In some Ant species, the amount of pheromone deposited is proportional to the quality of the food source found, i.e., paths that lead to better food sources receive higher amount of pheromone (Dorigo et al., 2000). In the proposed Ant inspired information dissemination method, when an abnormal environmental event is noticed on the road surface, a safety message is created to inform other vehicles and roadside units (RSUs) along its way. Similar to the pheromone values, we defined the relevance value of safety messages, which depend upon the severity and event types. Furthermore, as pheromones are evaporated with the passage of time, the lesser used Ant paths are gradually vanished (Dorigo et al., 2000, 2006). Similarly, the relevance value decreases over time, with distance, till the corresponding safety message is vanished and dropped from the system.

The remainder of this paper is organized as follows. Section 2 presents the related work. The proposed dissemination strategy is described in Section 3 with an overview of Ant system. Simulation results are presented in Section 4. Conclusions and future work are given in Section 5.

2. Related work

VANET is a type of wireless network where nodes that communicate with each other are vehicles and RSUs. Unlike MANETs where nodes can freely move in a certain area, the movements of vehicles in VANETs could be predicted, because it is dependent on streets, traffic and specific rules. Communication between nodes in VANETs is less reliable due to the high mobility and different traffic patterns compared to MANETs. In addition, in VANETs, the safety information should be disseminated to other surrounding vehicles in order to be informed and eventually take preventive actions. For example, a vehicle having an embedded traffic detection sensor can disseminate current traffic state to its following vehicles that can take preventive actions to avoid the congested areas (Hartenstein and Laberteaux, 2010).

Various information dissemination approaches were proposed in the literature (Nadeem et al., 2004; Brickley et al., 2007). Flooding is the simplest technique for information dissemination in Ad hoc based networks, in which nodes disseminate a received message to all their neighbors. This algorithm can lead to the broadcast storm problem that severely affects the resources consumption due to redundant message rebroadcasts (Ni et al., 1999). Several techniques have been proposed to solve this problem by preventing certain nodes from rebroadcasting received messages or by differentiating the timing of rebroadcasts, e.g., using strategies based on a broadcasting probability, or according to the number of same received messages, the distance between receivers and senders, or the location (i.e., position) in an appropriate cluster of nodes (Bakhouya, 2013; Ye et al., 2012). However, it should be noted that these methods used various static threshold parameters which are not appropriate for dynamic networks, such as VANETs, wherein adaptability is an important issue to consider (Bakhouya and Gaber 2014). In Bakhouya et al. (2011), an adaptive approach for information dissemination is proposed where each node can dynamically adjust the values of its local parameters using information from neighboring nodes. It is worth noting that broadcasting and dissemination are two different issues: broadcasting protocols can be tackled at the routing layer, while dissemination algorithms deal with the application layer.

Applications in VANETs can be classified into two main categories, i.e., comfort and safety applications (Dar et al., 2010b; Nadeem et al., 2006). In general comfort related applications are aimed to improve passenger comfort and traffic efficiency, e.g., traffic-information, weather information, gas station or restaurant location, advertisements and other Internet services (Caliskan and Graupner, 2006). In safety-related applications, high reliability and short delays are required for information dissemination. In other words, safety messages are time-critical; vehicles are required to disseminate warnings immediately to avoid probable accidents and traffic congestions (Zhuang et al., 2011). However, safety and comfort applications are not completely separated from each other. For example, a message generated for accident can be seen as a safety urgent message from the perspective of nearby vehicles. The same message can be seen by farther vehicles as an informative message to choose an alternative optimal route with low traffic jams (Hartenstein and Laberteaux, 2010).

The role of RSU is important in urban areas where density of vehicles is commonly very high, since vehicles cannot always verify all received messages from neighbors in a timely manner, which can cause message loss. Several works are devoted to RSUs location, coverage area extension, and its effective use in information dissemination process. For example, two different optimization methods for placement of a limited number of RSUs in urban areas are proposed in Mullen et al. (2009), namely Binary integer programming and Balloon expansion heuristic methods. These methods were used to tackle the optimization problem of minimizing an average reporting time. Indeed, a RSU typically can reach with a single hop only a fraction of the interested vehicles. Three algorithms to extend RSU's coverage area using multi-hop inter-vehicle communications are proposed by Bakhouya and Gaber (2014). These algorithms apply a set of geometrical rules based on the position of sending nodes. In Nadeem et al. (2004), inter vehicle communication is integrated with vehicle to infrastructure communication as an extension of the IEEE 802.11p MAC standard to increase driver's awareness in safety-critical cases. In Dar et al. (2010b), a hybrid network architecture is proposed, that consists of multiple Ad hoc clusters, connected through proxy servers and cellular links to target the delivery of emergency messages to all intended vehicles in a short time interval. A RSU-aided message authentication scheme (RAISE), where RSUs are responsible for verifying the authenticity of the messages sent from vehicles and notifying the results back to all the associated vehicles, is proposed by Nadeem et al. (2006).

Since vehicles can receive safety messages, that can be more or less critical, from the infrastructure and other vehicles, selecting useful and reliable information is one of the most important issues in the context of VANET safety applications (Huang et al., 2010). In the absence of a central authority monitoring in VANETs, application of an accurate trust and reputation mechanism might be extremely helpful in that context. For example, a TRIP model, to decide whether to accept, disseminate or discard traffic warnings coming from other vehicles is proposed by Marmol and Perez (2012), by assessing the trustworthiness/reliability of the issuer of such message. The priorities are assigned to messages based on their urgency level (Suthaputchakun and Ganz, 2007). Higher priority messages are transmitted more times than lower priority messages to provide higher reliability for higher priority messages. Disseminating emergency messages to different distances according to their importance is proposed by Zhuang et al. (2011). In Moreno et al. (2009), a distributed power control method is proposed to control the load of periodic messages on a channel. It is based on a strict fairness criterion, i.e., a distributed fair power adjustment that copes with vehicular environments. A WAVE-enhanced safety