



HyBR: A Hybrid Bio-inspired Bee swarm Routing protocol for safety applications in Vehicular Ad hoc NETWORKS (VANETs)

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ABSTRACT

Increasing interests in Vehicular Ad hoc NETWORKS (VANETs) over the last decade have led to huge investments in technologies and research to improve road safety by providing timely and accurate information to drivers and authorities. To achieve the timely dissemination of messages, various routing protocols for VANETs have been recently proposed. We present a Hybrid Bee swarm Routing (HyBR) protocol for VANETs. HyBR is based on the continuous learning paradigm in order to take into account the dynamic environmental changes in real-time which constitute a key property of VANETs. The protocol combines the features of topology routing with those of geographic routing. HyBR is a unicast and a multipath routing protocol (aimed at both urban and rural scenarios) which guarantees road safety services by transmitting packets with minimum delays and high packet delivery. To demonstrate the effectiveness and the performance of HyBR, we conducted a performance evaluation based on several metrics such as end-to-end delay, packet delivery ratio, and normalized overhead load. We obtained better performance results with HyBR in contrast to results obtained from traditional routing algorithms such as Ad hoc On-Demand Distance Vector (AODV) topology-based routing protocol and Greedy Perimeter Stateless Routing (GPSR) geography-based protocol.

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1. Introduction

The design of new Intelligent Transportation Systems (ITSs) is playing a major role in improving road safety, traffic monitoring and comfort for passengers in order to avoid accidents and traffic congestion [34]. To achieve these goals, ITSs need to support the delivery of timely and accurate information to drivers and authorities through a reliable Vehicular Ad hoc NETWORK (VANET).

VANET is considered to be a special kind of Mobile Ad hoc NETWORK (MANET) with specific characteristics [44]. In VANETs, nodes are vehicles which move according to a restricted mobility pattern based on many factors such as road course, encompassing traffic and traffic regulations [37]. VANET supports communications among vehicles via Inter-Vehicle Communication (IVC) and between vehicles and fixed Road Side Unit (RSU) equipment through Roadside-to-Vehicle Communication (RVC). RSUs can be deployed at critical locations such as slippery roads, service stations, dangerous intersections or places well-known for hazardous weather conditions [8]. Nevertheless, unpredictable and inconsistent relative

node velocity may cause intermittent link breakages. Moreover, a node in VANETs can be equipped with a Global Positioning System (GPS) device to easily determine its own location.

One of the most important aspects that determines the success of VANET is the reliable message routing from a source node to a destination node. Routing in VANET relies on the presence of a sufficient number of VANET nodes that constitute strong paths to allow the forwarding of messages in the network. These paths can be affected by the vehicles' mobility and traffic density, frequent network topology changes making them unsustainable and unreliable [20]. Therefore, the design of an efficient routing protocol for VANET is considered to be a critical issue. Moreover, one of the most important requirements in the routing process is to share integrated data with road safety service in real time in order to provide the information passengers need to help them make safe decisions. Service guarantees are important in delivering messages with a maximum packet delivery ratio on one hand, and on the other hand with a minimum routing overhead and end-to-end delay which have become a challenge for most routing protocols for VANETs. Route discovery and maintenance can affect the requirements of safety applications [14]. In this work we focus on the following issue: when communication end-points are not within their respective radio transmission range, how is it possible to

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establish communication between two vehicles or between a vehicle and a roadside base station which satisfies the constraints imposed by road safety applications? To address this challenge, we propose a new bio-inspired routing protocol called the Hybrid Bee swarm Routing protocol for VANET (HyBR). It is a hybrid protocol that combines geographic routing based on Global Positioning System (GPS) to establish routes, with topology-based routing which discovers paths using network topology data. HyBR is based on the continuous learning paradigm.

1.1. Contributions of this paper

To decrease the routing overheads frequently incurred by traditional routing protocols, HyBR disseminates the transmitted packets in a stochastic manner [10]. In addition, HyBR uses multiple paths simultaneously between the source and the destination to send packets in order to reduce the transmission time (end-to-end delay), to decrease routing overhead and to increase packet delivery ratio. Consequently, HyBR guarantees data transmissions in real time to help drivers make safe decisions and to improve road safety. To validate the effectiveness and performance of HyBR, we have implemented HyBR using the network simulator ns-2 [33]. We conducted our performance evaluation by using realistic scenarios of VANETs through ns-2. We compare the performance of our proposed HyBR approach with well-known past routing approaches such as Ad hoc On-Demand Distance Vector routing protocol (AODV) [36] and Greedy Perimeter Stateless Routing (GPSR) [23] considered as standard topology-based and geography-based routing protocols respectively. Our performance evaluation experiments are based on performance metrics such as the average end-to-end delay, the packet delivery ratio, and the normalized routing overhead.

The rest of this paper is organized as follows. Related work is presented in Section 2 followed by Section 3 which describes our proposed hybrid routing protocol HyBR for VANETs. In Section 4, the experimental evaluation of proposed HyBR approach is explained. Section 5 presents the performance results obtained. Finally, Section 6 concludes the paper and highlights areas of future work.

2. Related work

Recently proposed routing protocols for VANETs can be broadly classified into two categories. One category is topology-based and uses network topology data to connect vehicles, and the other category of protocols called Geography-based routing protocols extends Global Positioning System (GPS) services to route the packets in VANETs.

2.1. Topology-based routing

Traditionally, topology-based routing protocols were initially proposed for MANETs, and were applied to VANETs because they have many common properties such as node mobility, distributed and self-organizing topology, non-existence of central control, etc. [25]. However, VANETs can be distinguished from MANETs because of their specific characteristics such as very high node mobility, limited degrees of freedom in mobility patterns which can be somewhat predictable, since vehicles move in rural or urban areas consisting of roads, highways, buildings, etc.

In point of view routing, the MANET protocols are based on the IEEE 802.11 as a medium access control standard, and the transmission range is lower or equal to 250 m which is sufficient in such contexts where an important number of nodes tend to move with low speed. However, this transmission range is not enough for the

transmissions between vehicles because of their very high speed which made these transmissions instable. Consequently, topology-based routing protocols have been applied to VANETs but with the IEEE 802.11p standard which allows the transmission range to reach 300 m at least in order to make the network more stable [21]. Also, the routes used to disseminate data between vehicles have a short time of life compared with routes used by MANET nodes. This situation conducts to vehicular network partitioning [11]. All these differences have led to VANET researchers and designers adapting MANETs routing protocols to meet VANETs specificities [1,3]. Consequently, discovering routes in this case of topology-based routing, the setup of topological end-to-end paths between a source and a destination before sending the packets is the fundamental step. These topology-based routing protocols can be reactive or proactive.

The most common MANET routing protocol that has been applied to VANET is the Ad hoc On-demand Distance Vector (AODV) [36] protocol. The route discovery method of AODV is based on routing tables which store the routes toward multiple destinations. Each destination is indicated using only the next hop node to reach this destination. The source disseminates a Route REquest (RREQ) to its neighbors which in turn sends the same packet to their neighbors and so on, until the final destination is reached. Once the route request reaches the destination or an intermediate node which knows the path toward the destination, a Route REplay (RREP) is sent back to the source node through the reverse route. AODV uses a sequence number to discover fresh paths and to prevent routing loops. Abedi et al. [1] extended AODV to apply it to VANET using directions and positions of the source node and the destination node obtained from GPS to find routes. Basically, source and destination directions are used for the next hop selection. To do this, an intermediate node can be selected as the next hop in the requested route if it is located and moves in same direction as the source and/or destination. This modified AODV routing protocol for VANET uses the mobility model of vehicles to support the various characteristics of VANETs. This reactive protocol establishes updated routes only when required. However, the intermediate nodes could indicate inconsistent routes if the sequence number is not updated and, the idea to choose the next hop in same direction of source and destination does not guarantee the optimality of the route found. In addition, the network can be flooded by multiple RREQ and RREP in addition to unnecessary bandwidth consumption due to periodic beaconing.

Santa et al. [40] modified the well-known Optimized Link State Routing protocol (OLSR) proposed by Clausen and Jacquet [15] to apply it to VANET. Santa et al. proposed a unicast, link state, and proactive VANET routing protocol. With their routing protocol, each vehicle periodically sends HELLO messages in its transmission range to detect neighboring vehicles. Then, Topology Control messages (TC) are used to disseminate this information throughout the whole network. Moreover, TC messages are used to compute next hop destinations for all nodes in the network using the shortest hop forwarding paths. With the adapted OLSR algorithm, each vehicle selects MultiPoint Relays (MPRs) among all one-hop terminals, assuring that all neighboring vehicles which are two hops away can be reached through a minimum set of vehicles. Thus, only the MPRs vehicles forward messages leading to a decrease in VANET routing overheads when the network is highly dense. Since OLSR vehicles might have access to other networks such as the Internet or via an Ethernet link that are not running the OLSR protocol, a particular message called the Host and Network Association (HNA) message is periodically transmitted by this interconnected vehicle to inform other OLSR vehicles about this new interconnection and its parameters. In addition, this proactive protocol finds the different paths to all nodes, even if some paths are not requested, thereby reducing the route discovery delay. How-

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