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A Multi-Agent Approach For Routing On Vehicular Ad-Hoc Networks

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Abstract

Vehicular Ad-Hoc Network is a special form of mobile ad-hoc networks (MANETs) which is a vehicle to vehicle and vehicle roadside wireless communication network. VANET is a new standard that integrates Wi-Fi, Bluetooth and other mobile connectivity protocols. The essential requirement of VANET is that it should be able to communicate in any environment irrespective of traffic densities and vehicle locations. Vehicular communications are made in fluctuating environment and should work both in urban and rural areas. Considering the large number of nodes participating in these networks and their high mobility, debates still exist about the feasibility of routing protocols. Analyzes of traditional routing protocols for MANETs demonstrated that their performance is poor in VANETs. The main problem with these protocols in VANETs environments is their route instability. Consequently, many packets are dropped and the overhead due to route repairs or failure notifications increases significantly, leading to low delivery ratios and high transmission delays. This paper introduces a multi-agent system approach to solve the problems mentioned above and improve Vehicular ad-hoc network routing.

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1. Introduction

A VANET is one of the most promising applications of mobile ad-hoc networks [2]. It consists of nodes, which are vehicles moving freely with high speed and communicate with other nodes via wireless

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links. VANETs allow vehicles to avoid problems, either by taking any desired action or by alerting the driver i.e. when an accident occurs in a road or highway, alarm messages must be disseminated to inform all other vehicles. To achieve communication and dissemination of information, VANETs do not depend on fixed infrastructure or access point. The architecture of VANET consists of three categories: vehicle to vehicle ad hoc networks [5], vehicle to infrastructure (e.g., fixed gateways around the road sides) and hybrid architecture.

Figure 1: Vehicular Ad-Hoc Networks [6]

The main applications of VANET provide safety and comfort for passengers helping drivers on the roads by anticipating hazardous control of Traffic flows, blind crossing and collision prevention, allow them to communicate with other vehicles and with internet hosts so the passenger can download music, send emails, watch online movies and can chat online etc [3].

In VANETs, routing management system requires network operations distribution because every node also acts as a router. It requires also cooperation between nodes to transmit information. It must continue to operate normally in case of failure of one or more nodes, it must be intelligent to choose the best routes and react quickly to events that may occur like changing communication environments etc.

In addition, because of the frequent movement of mobile nodes, the topology of vehicular ad-hoc networks is generally dynamic. Moreover, limited memory, changing environments, rapid change in topology, frequent disconnection and bandwidth make the routing protocols designed for ad-hoc networks [4] inappropriate for this type of highly dynamic networks. Accordingly it is necessary to develop new routing protocol for vehicular ad-hoc networks distinct from the traditional routing protocols [7].

Multi-agent systems take into account the aspects of cooperation, autonomy, distribution and intelligence; they are particularly interesting in distributed and dynamic environments. Consequently, a routing protocol based on this technology seems appropriate to solve the afore-mentioned problems.

Our contributions in this paper are as follows: 1) use of agent technology to collect context information (vehicle’s direction, interests, communication environments etc.) 2) Agents are used to optimize communication and reduce network traffic 3) use of agent to find the best routes.

The remainder of this paper is organized as follows. Section 2 deals with the motivations that underlie this study. Section 3 discusses related works on routing protocols for VANETs. Section 4 presents the proposed approach. Finally, section 5 concludes the paper with a summary of the presented approach and discusses our future work.
2. Motivations

A multi-agent approach is presented in this study to deal with routing in VANETs. An agent technology solution is proposed to perceive the environment and collect context information that will be used to optimize communication, reduce network traffic and find the best routes.

Concerning the choice of agent technology to come up with new routing protocol approach for VANET, it is simply motivated by the characteristics of agents such as intelligence, autonomy, interactivity and mobility. Indeed, it can be used to significantly reduce the cost of communication, particularly the elimination of redundancies, by moving the data collected by an agent introduced in each cluster.

3. Related Work

In VANET, the routing protocols are classified into various categories: topology based routing protocols, position based routing protocols, cluster based routing protocols, geo cast routing protocols and broadcast routing protocols.

The topology based routing protocols use links information that exists in the network to perform packet forwarding. They are further divided into reactive, proactive and hybrid protocols.
- Proactive protocols: In proactive routing scheme, a mobile node maintains routes to other node and updates its routing table all the time. E.g., Fisheye state routing (FSR)[18].
- Reactive protocols: A mobile node in reactive routing protocols does not need to record and update timely its routing table, but it only maintains the currently route. E.g., Ad-hoc On demand Distance Vector (AODV) [19].
- Hybrid protocols: The hybrid protocols try to find the best compromise between proactive and reactive routing protocols. E.g., Zone Routing protocol (ZRP) [20].

Position based routing protocols consists of class of routing algorithm. They share the property of using geographic positioning information in order to select the next forwarding hops [9]. E.g., Geographic Source Routing (GSR) [10].

Broadcast routing protocols is frequently used in VANET for sharing, traffic, weather and emergency, road conditions among vehicles and delivering advertisements and announcements. Broadcasting is used when message needs to be disseminated to the vehicle beyond the transmission range i.e. multi hops are used. E.g., Distributed vehicular broadcast protocol (DVCAST) [13,14].

Geo cast routing protocols are used in VANET to deliver the packet from source node to all other nodes within a specified geographical region. It is basically a location based multicast routing. It main aims are to build a virtual community based on future locations prediction of the mobile nodes in the network. E.g., Robust Vehicular Routing (ROVER)[11].

In cluster based routing protocols, the network is divided into small partitions called clusters. The main goal of clustering is to find an interconnected set of clusters. E.g., Hierarchical Cluster Based routing (HCB)[12].

VANETs possess exceptional network features that distinguish them from other kinds of ad hoc networks, such as highly dynamic topology. From the above mentioned characteristics, it is evident that conventional MANET routing protocols have difficulties from finding stable routing paths in VANET environments. In fact, topology based routing protocols suffer from the initial route discovery process and consumes a lot of bandwidth for periodic updates of topology. Furthermore, one pitfall of geo cast is network partitioning and also unfavorable neighbors which may hinder the proper forwarding of messages which makes them unsuitable for safety applications in VANET.
In the literature, it has been demonstrated that clustering improves the performance of the VANETs and can be utilized in numerous applications [16, 22, 23]. Some clustering algorithms are as follows. Daeinabi et al. [24] proposed an efficient clustering algorithm for clustering in VANETs. The authors get different factors such as entropy, direction of vehicle and number of neighbors to perform the clustering of vehicles in an exacting area. In [25] an open inter-vehicle communication network algorithm for clustering was proposed by Blum et al. by taking into account vehicle dynamics. In [26] Fan et al. suggested a clustering algorithm based upon the direction of vehicle. In [27] an adaptive connectivity aware routing in VANETs was proposed by Yang et al. The authors demonstrated the choice of the optimal path based on collecting data from diverse regions. In [28] Wu et al proposed mobility-sensitive data dissemination protocol for VANETs by decreasing the total of the weight between source and destination.

However, those clustering approaches do not address the case of vehicular interests (e.g., looking for a free parking space, chatting, traffic congestion etc.) and direction sense. Moreover, the choice of the best path is not only influenced by mobility of the vehicles, density and direction.

Due to the mobility of nodes in VANETs, the backbone must be continuously reconstructed in a timely fashion, so the research on more distributed, adaptive and intelligent protocol becomes critical. That is why, agent technology has become an exciting and promising research area for vehicular ad-hoc networks. In [29] Kumar et al proposed an agent learning–based clustering algorithm in vehicular ad hoc networks. The authors evaluated the performance by taking different metrics like node participation, percentage of connectivity, cluster head period, connectivity preservation ratio and message transmission ratio. Tyagi et al [30] proposed an architecture of VANET based on clusters that’s designed by mobile agents. The authors create a new clustering concept with the help of mobile agents among the VANET nodes. However, in those studies one of the vehicle which is cluster head takes all the decisions on behalf of the other vehicles. And as the topology changes, these decisions may be not be valid.

Motivated by some inherent drawbacks of existing approaches, and based on the study on agent technology, our objective is to develop a relatively simple, low overhead and adaptive routing protocol for VANETs.

4. Proposed Approach

Our approach is based on the use of agents for routing in an attempt to solve the afore-mentioned problems. The Agents are responsible for collecting routing information and discovering the best route to send data packets. To this end, a routing algorithm is based on cluster routing protocols and context-information group to find and optimized paths. Each group defined by these characteristics specifies which context information can be distributed inside the cluster between agents. In VANETs, we consider context or context information as any relevant information that can be used to distinguish the situation of a node such as movement direction, state and interests [21].

4.1. Architecture

By local context-information, we mean the fact that every node on the network only knows about its neighbors to start with. Each agent performs its task in collaboration with other agents. In other words, the agent explores the communication environment and collects context-information for routing. This agent called context-agent. In addition, with a variety of routes available for forwarding message, we need an agent to quantify various aspects of these routing schemes in order to compare them and select the most appropriate one to choose the best cluster. This agent called optimization-agent. The main goal of this
agent is, not only, to link between clusters represented by an agent called agent cluster-head, but also to optimize communication between them using context-information collected.

Furthermore, to send data packets, we need an agent to discover the best routes, this agent called router-agent which stores all the distance between neighbours in the same cluster and gives a local topology which is represented by a tree in which the root is the cluster-head agent. The multi-agent architecture is illustrated by figure 2.

![Figure 2: A MAS's architecture](image)

In order to achieve this overall goal, we first want to define a way to select these four agents.

### 4.2. Agents election procedure

The clustering concept offers tremendous benefits for VANETs. However when designing for a particular application, designers must carefully examine the formation of clusters in the network. Depending on the application, certain requirements for the number of nodes in a cluster or its physical size may play an important role in its operation.

#### 4.2.1. Context-agent election procedure

The node is elected as context-agent which has the most neighbor (Nb) nodes sharing the same context-information. In order to collect context-information and support the cluster formation process, each node uses a neighbor table, where it stores context information about its neighbor nodes, such as their ID’s, their context information (the movement Mvt). The neighbor table is maintained by periodically broadcasting HELLO messages. A HELLO message contains Identifier (ID), Movement Mvt( direction, sense, interest) and the number Nb (initialized to 0).

#### 4.2.2. Cluster-head – Agent election procedure

To select the cluster-head, called here agent-cluster-head, we must take into consideration the number of nodes a cluster head can handle ideally (designed by M), transmission power, mobility, and battery power of the nodes. Thus, due to the mobility of nodes, the agent-cluster head election procedure is delayed as long as possible to reduce the computation cost.

A node is chosen, by context-agent, to be a cluster head if its weight is higher than any of its neighbour weight. In [15] Chatterjee and al., calculate the weight as:
\[ W(u) = \alpha \times D(u) + \beta \times P(u) + \gamma \times M(u) + \delta \times T(u). \]  

(1)

Where \( \alpha, \beta, \gamma, \) and \( \delta \) are the weighing factors for the corresponding system parameters and their sum is 1.

Thus:

- \( D(u) \) : the degree -deferece for every node and the number of nodes that cluster-head can handle ideally. In [15] the author did not specify the method to determine this number \( M \) but according to our approach \( M \) is the sum of all nodes \( N \) that:

\[ N \in E = \left\{ M'/CM' \leq CR \right\} \]  

(2)

Where \( C \) is the center node of a cluster and \( R \) is the radius. We represent here the group as a circle.

- \( P(u) \) : The sum of the distances with all its neighbors.
- \( M(u) \) : The mobility, which is the average speed for every node during current time \( T \).

4.2.3. Optimization – Agent election procedure

In order to minimize messages and congestion traffic, the messages must be communicated to the interest cluster. Optimization-agent is the vehicle that can listen to the different vehicles of the overlapping clusters that they lie.

The optimization-agent is selected by a pair \((C_i, C_j)\) of cluster-head-agents that lies using the distance separated to it:

\[ \text{Distance}_{opagent} = \max(d_i, d_j) \]  

(3)

Where

- \( d_i \) : The distance between cluster-head, and optimization-agent1.
- \( d_j \) : The distance between cluster-head, and optimization-agent2.

4.2.4. Router– Agent election procedure

Given that the nodes are uniformly distributed across the cluster and the average number of hops for the cluster head-agent increases. So to discover the best route and to maintain a local topology, the selection of a route must take into consideration the mobility of the nodes. In [17] Ramalingam et al., propose associativity factor as a metric. The main goal of our approach is to select router-agent in such a way that the routes are stable over a long period of time. The node elected, by cluster-head-agent, as the router-agent is that it has maximum associativity.

In [17], at each time \( T \), a node \( N \) considers what its current neighbors are already present in the previous period \((T-1)\) and adds 1 to the value associated with each. There are two possible cases:

- If a neighbor node appears, it takes the value 1.
- If a neighbor node has disappeared, its associated value is 0.

At each time period, the associativity of \( N \) is the sum of the values associated with each of its neighbors.

4.3. Proposed algorithm

Based on the preceding discussion, our algorithm proceeds in four steps: Discover neighbors, collect context-information, cluster formation and Routing.
Step1: Discovery neighbors
By using a neighbor table, where it stores information about the nodes, such as their ID’s and its state (initialized at ordinary node). The neighbor table is maintained by periodically broadcasting two messages: “Who is my neighbor? “ and “I am your neighbor”.

Step2: Collect context-Information
The neighbor table is maintained by periodically broadcasting HELLO messages (as explained in section 4.2.1).

Step3: Cluster formation
To form the cluster, we start by electing the context-agent (as explained in section 3.2.1). To inform its neighbors, the context agent must broadcast the message “Context-Agent Declaration” which contains neighbors list, state, and ID_Context-Agent. The second step is cluster-head-election (as explained in section 4.2.2). The node selected as cluster-head broadcast the message “Cluster-head-Agent_Declaration” contains neighbors list, ID_Context-Agent , state, and ID_Cluster-head-Agent. After optimization-agent election (as explained in section 4.2.3), the pair cluster-head-agents must broadcast the message”optimization-agent-Declaration” which contains ID_optimization-Agent, ID_cluster-head-Agenti, ID_cluster-head-Agentj.

Finally, electing the node as the router-agent (as explained in section 4.2.4) and broadcasting the message “Router_agent_Declaration” which contains its ID, neighbors list, and ID_cluster-head-agent.

Step4: Routing
The network formed by the nodes and the links can be represented by tree where the root is cluster-head_agent. To form and maintain the tree, the agents exchange periodically a message “Branch ” which contains ID_agent, ID_root, ID_parent and the distance separates it from the root. The message “Branch” is transmitted to a 1-hop and is stored by a router-agent to be sent to cluster-head -agent to find the best route.

5. Conclusion
The underlying routing protocols to VANETs must adapt themselves to a dynamically changing communication environment, frequent disconnection etc. Motivated by these facts, this study has sought to justify the possibility to apply agent technology as a promising solution to the development of the routing system.

In this paper, we have proposed a multi-agent approach for routing in VANETs. The new routing system is based on four agents that cooperate to find the best route and to reduce the traffic network.

Actually, the proposed work in this paper is part of a broader approach in which our algorithm’s steps need to be implemented. This is the direction in which we plan to guide our future work.

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