An Intelligent Routing Protocol for VANETs in City Environments

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Abstract

Routing plays important role in VANET applications but due to rapidly changing topology and high speed mobility of vehicles, conventional routing protocols suffer heavily. Current MANET routing protocols fail to fulfill these needs. In this paper we propose a VANET routing protocol that is especially designed for city environments. It consists of two parts: (1) Selection of next junction dynamically (2) Intelligent greedy strategy used to forward packets between two junctions. This paper presents a detailed description about our protocol and also discusses the improvement that it brings as compared to current routing protocols.

Keywords

Greedy Routing, VANET, City Environment.

1. Introduction

Vehicular Ad hoc Networks (VANETs) are based on short-range wireless communications (e.g., IEEE 802.11) for the use in driver safety and many other commercial applications. The Federal Communications Commission (FCC) has allocated 75 MHz in 5.9 GHz band for licensed Dedicated Short Range Communication (DSRC) for vehicle-to-vehicle and vehicle to- infrastructure communications. The radio range for VANETs is several hundred meters, typically between 250 and 300 meters. It is expected that more vehicles would be equipped with processing capabilities and wireless communication devices in the near future. We assume that vehicles should be equipped with wireless communication devices, GPS, digital maps, and optional sensors for reporting vehicle conditions. Vehicles exchange information with other vehicles as well as road-side infrastructures within their radio ranges. Many projects like ”CarTALK 2000” [1] or other projects like ”FleetNet - Internet on the Road” [2] have been developed based on concepts of MANETs and VANETs. In practice, many applications in VANETs need the support of multi-hop communication. For example, a moving vehicle may want to download audio songs from a server located several miles away. For multihop communication we need routing algorithms. Routing in VANETs is different from MANETs due the characteristics of VANETs, e.g., high dynamics, mobility constraints, high speeds of vehicles. On the other hand in VANETs we do not have the limitation of less computation power, limited battery. Therefore these factors provide us with potential to make use of these characteristics to develop more improved routing protocols. High dynamics in a large scale network will lead to uneven network density, which varies by time and location. It means the network might be sparsely connected in one area but densely connected in other area. On the other hand, some characteristics of VANETs, like mobility constraints and predicable mobility, provide the opportunities to facilitate routing in VANETs. Thus, numerous research challenges need to be addressed for inter-vehicular communications to be widely deployed in many areas. For example, routing in conventional mobile ad hoc networks is a challenging task because of the network's dynamic topology, because topology changes due to high mobility of vehicles. Numerous studies and proposals of routing protocols have been conducted; however these solutions can not be applied to the vehicular environment.

In this paper, we present a novel geographical routing protocol for VANETs for a city environment called IRPCE: Intelligent Routing protocol for city environments. As our protocol is designed for city environment, so our system takes into account vehicles speed, their direction, their location and also the layout of the roads like one way, bi directional and double lane roads. Based on a localization system like the GPS (Global Positioning System), our solution aims to efficiently route data in the network considering the dynamic vehicular density and the characteristics of city environments. Our proposed solution can be used for a variety of applications like driver safety, file sharing, chatting, internet browsing, and games.

The rest of the paper is organized as follows. In section 2, we describe the properties and characteristics of vehicular ad hoc networks. In section 3 existing approaches for routing in both MANET and VANET are presented. Section 4 describes our proposed routing protocol in detail and finally in section 5 we give conclusion.

2. VEHICULAR AD HOC NETWORKS

Vehicular ad hoc networks have been envisioned to be useful in driver safety and many commercial applications [3], [4]. For example, a vehicular network can be used to alert drivers to traffic accidents, potential traffic jams, road condition and much more providing increased convenience and efficiency. It can also be used to propagate emergency warning to drivers of preceding vehicles in case of am accident to avoid multi-car collisions on highways. Considering all these applications FCC has allocated 75 MHz in 5.9 GHz band for dedicated short range communications (vehicle-vehicle or vehicle-roadside), and IEEE is working on standard specifications for inter vehicle communication.

VANETs are different than MANETs in many ways. For example Instead of random movement in MANETs, the movement of nodes in VANETs is constrained by the layout of roads. Normally radio range for VANETs is several hundred meters, typically between 250 and 300 meters. In a scenario when there are no radio obstacles, the nodes can communicate with others in the radio range. But in city environment, there would be radio obstacles because of buildings. Another difference is that in VANETs vehicles move with much greater speeds as compared to MANETs therefore the topology in VANETs changes much more frequently. But on the other hand the vehicles mobility can be predicted based on the speed and direction as well as the layout of roads. Therefore we consider all these factors while developing our protocol for VANETs.

3. Related Work

In this section, we look at the existing routing proposals for both MANET and VANET and then discuss the problems in these protocols in the vehicular environment, especially in the city environments.

3.1. Routing in MANET

There are two approaches used for routing in MANETs known as Proactive and Reactive routing. They have been widely studied for MANET routing. Proactive routing (like OLSR [5] and TBRPF [5]) is a table-driven approach in which each node maintains one or more tables that contain routing information of all the nodes in the network. Existing proactive algorithms have two problems. Firstly they are not scalable, secondly they are not suitable in highly mobile environments, as the result they give very low communication throughput and poor route convergence. Reactive routing, like DSR [6] (Dynamic Source Routing) and AODV [7] (Ad hoc On-Demand Distance Vector routing), is an on-demand approach in which network routes are updated only when a source node wants to send data to a destination node. The drawback of existing reactive algorithms is their latency, as they require additional time to establish a route. To overcome the limitation of these algorithms, a new type of routing technique has been developed that is based on location information. Examples of this kind of routing are GPSR [8], LAR [8] and DREAM [9]. This geographical routing approach performs well to the dynamic nature of large scale ad hoc networks.

3.2. Routing in VANET

Recently, some routing protocols for VANETs have been proposed. In the following, we discuss the most important ones: GSR, A-STAR, GPCR and GyTAR.

'GSR' [10] (Geographic Source Routing) has been proposed for vehicular ad hoc networks in city environments. It combined position-based routing with topological information. The simulation results, with the use of realistic vehicular traffic in city environments showed that GSR outperforms topology-based approaches like DSR and AODV with respect to packet delivery rate and latency.

A-STAR [11] (Anchor-based Street and Traffic Aware Routing) guaranteed an end-to-end connection even if we have low traffic density. A-STAR used information on city bus routes to identify an anchor path with high connectivity for packet delivery. By using an anchor path, A-STAR guarantees to find an end-to-end connection even if the traffic density is low. This scheme also provided a route recovery strategy when the packets are routed to a local optimum by computing a new anchor path. The simulation results show A-STAR achieves obvious network performance improvement compared with GSR and GPSR. But one problem with this approach is that routing path may not be optimal because it is along the anchor path. Therefore it resulted in large delays.

GyTAR [12] (Improved Greedy Traffic Aware Routing protocol) is an intersection-based geographical routing protocol capable to find robust routes within city environments. It consists of two modules: (i) Selection of the junctions through which a packet must pass to reach its destination, and (ii) an improved greedy forwarding mechanism between two junctions. Hence, using GyTAR, a packet moved successively closer towards the destination along streets where there are enough vehicles to provide connectivity [12]. GyTAR out performed previous routing protocols in terms of packet delivery ratio, routing overhead and end-to-end delay.

3.3. Discussion

In the previous sections we took an overview of the VANET and discussed some of its important characteristics including frequently changing topology due to high speed movement of the vehicles and short connection lifetime when we have multihop communication. All these factors have a serious impact on the performance of topology based routing protocols.

A variety of routing protocols have been proposed in order to coup up with these factors. In GSR [10] the sender vehicle uses the street map in order to compute the shortest path and then the shortest path is selected by using Djikstra algorithm, then a sequence of junctions are calculated. But the problem with this approach is that it does not consider the traffic density on streets. Therefore there is a possibility that sequence of junctions and the shortest path calculated might not be appropriate due to low or no traffic density. ASTAR [11] tried to solve this problem but it also suffered because it took into account static vehicular traffic information of city bus routes. Another major issue with both GSR and ASTAR was that they used simple greedy forwarding to forward packets between two junctions without taking into account the velocity and direction of the next vehicle.

The latest protocol that we have studied is GyTAR. GyTAR out performed the previous routing protocols in terms of packet delivery ratio, end-to-end delay, and routing overhead. But we found a few issues in this protocol. First of all during junction selection the direction of the vehicles is not considered as a result this protocol suffers when there are vehicles on the road opposite in direction of destination like one way roads.

Consider Figure 1. In this figure the blue car wants to find the next junction. By using GyTAR protocol junction ‘J2’ will be selected, but in this case there is no vehicle in the direction of the destination (or this road can be one-way), therefore selection of J2 is not appropriate because we will face the local optimum problem while forwarding the packet by using this junction. So such situations will result in large end-to-end delays as well as decreased packet delivery ratio.

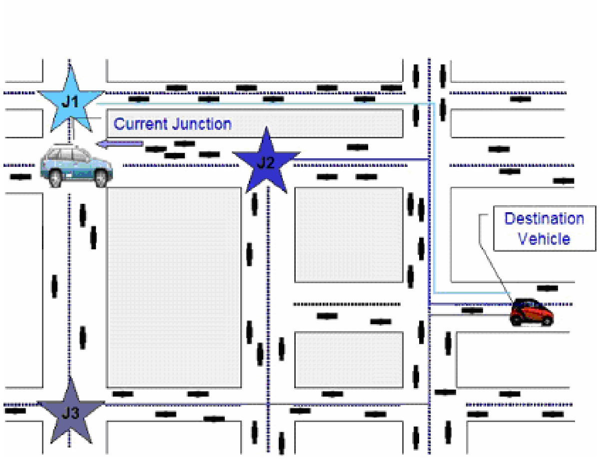

Figure 1. Limitation of GYTAR

4. An Intelligent ROUTING PROTOCOL for City Environments- IRPCE

The routing protocol proposed in this paper is for routing of data in the vehicular network which require more than one hop communication. Most of distributed infotainment applications and user services like games, web browsing, chat, file sharing, delivering advertisements and finding available parking positions at a parking place.... In other words, this routing protocol ensures the user connectivity in city environment.

4.1. Protocol Assumptions

Our protocol assumes that each vehicle in the network knows its own position. Therefore it is assumed that each vehicle has GPS installed. Furthermore, a sending node needs to know the current geographical position of destination in order to make the routing decision. This information is assumed to be provided by a location service like HLS (Hierarchical Location Service) [13]. Moreover, it is also assumed that each vehicle can determine the position of its neighboring junctions through use of pre-loaded digital maps. When vehicles are equipped with on-board navigation system then presence of such kind of maps is a valid assumption. It is also assumed that each vehicle has knowledge about its velocity and direction. Another assumption is that every vehicle is aware about the density and direction of vehicular traffic between two junctions. This information can be provided either through a simple distributed mechanism for on-road traffic estimation realized by all vehicles or by traffic sensors installed beside the junctions [12]. On the basis of the above-mentioned assumptions, we give in a detailed description of the proposed inter-vehicle routing mechanism.

4.2. Protocol Overview

It is a new junction based routing protocol capable of finding routes with high density of vehicles in direction of the destination. It consists of two modules: (i) Selection of the next junction through which a packet must pass to reach its destination (ii) Intelligent greedy forwarding mechanism between two junctions.

4.2.1. Junction Selection. Similar to GyTAR [12] our protocol also adopts the anchor-based routing approach with street awareness. Thus, data packets will be routed between vehicles, following the street map topology. Intermediate junctions are also chosen dynamically and one by one, but junction selection mechanism is different from GyTAR. When selecting the next junction, a sending or intermediate vehicle looks for the position of neighboring junction by using digital maps and a weight is calculated and assigned to all the candidate junctions based on the number of vehicles in the direction of the destination and distance of candidate junction to the destination. To formally assign weights to junction we use the following algorithm.

For all the candidate junctions ‘i’

- Ni: the next candidate junction.
- C: the current junction
- *Dn*: the curvemetric distance from the candidate junction ‘Ni’ to the destination.
- *Dc*: the curvemetric distance from the current junction ‘C’ to the destination.
- $Dp = Dn/Dc$ (*Dp* determines the closeness of the candidate junction to the destination point)

Between junction *C* and junction Ni:

- *T:* total number of vehicles between ‘C’ and ‘Ni’ moving in the direction of destination,
- α, β: used as weighting factors for the distance and vehicular traffic respectively (with $\alpha + \beta = 1$)

Hence, $\text{Weight (Ni)} = \alpha \times [\,1 - Dp\,] + \beta \times [\,T\,]$

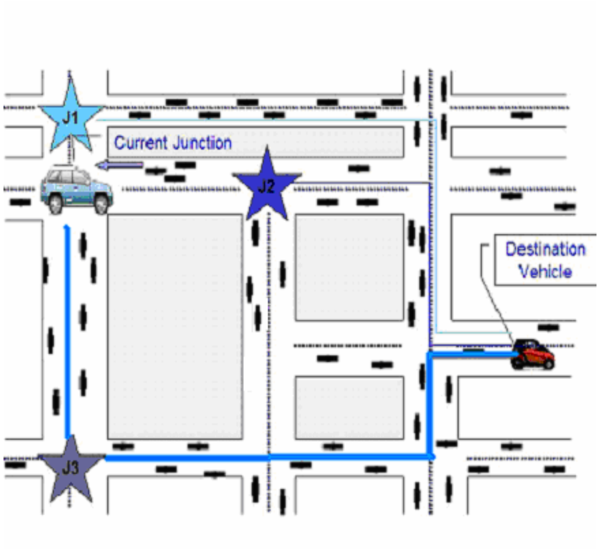

Figure 2. Junction Selection

Consider the figure 2 given above. In this case there are two candidate junctions J2 and J3 available. Our algorithm will assign weights according to the number of vehicles in the direction of the destination and curvemetric distance. Road towards J2 can be one way or the direction of all the vehicles can be opposite to the destination, therefore J3 will have more weight than J2 and it will be selected as the next junction. In this way our algorithm removes a limitation of GyTAR [12] because in case of GyTAR junction ‘J2’ would have been selected instead of J3, which is not the appropriate choice in this case. Similar technique will be followed for selecting all other junctions for forwarding the packets. In figure 2, blue line shows the possible path through which the packet reaches the destination. Hence, in our protocol, a packet will move successively closer towards the destination along streets where there are enough vehicles in the direction of destination to provide high connectivity.

4.2.2. Forwarding data between two junctions. The next junction is selected by using the algorithm given above. In order to forward the packet between two junctions, two things are considered (i) Direction of next vehicle (ii) Speed of the next vehicle. In order to keep information about both of these things each vehicle maintains a table in which speed and direction of neighboring vehicles are recorded. This table is updated by periodic hello messages by neighboring vehicles. When the vehicle need to forward the packet then it uses the information from the table to calculate the new predicted position of neighboring vehicles [12]. By doing this the vehicle that will be closest to destination after time t2 is selected as the next vehicle.

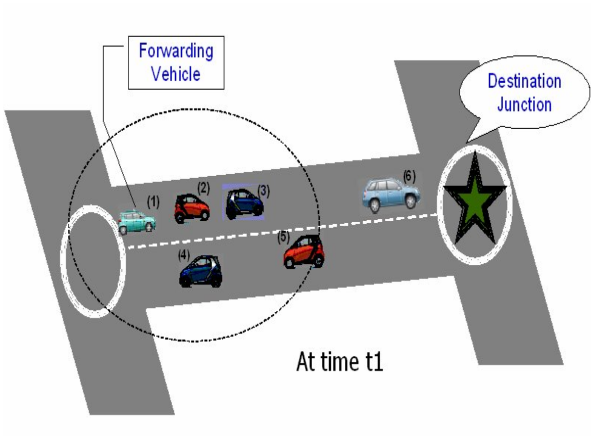

Figure 3. Forwarding data between two junctions at t1

In figure 3 suppose vehicle 1 at time t1 wants to forward packet. Suppose speed of vehicle 2 is greater than vehicle 3. Vehicle 1 will forward packet to vehicle 2 instead of vehicle 3 because as shown in figure 4 at time t2 vehicle 2 will overtake vehicle 3 due to its higher speed and it will be the closest node to the destination. Therefore it is selected as the next hop. It is different from traditional greedy routing approach, in which vehicle 1 will forward packet to vehicle 5 which is the closest node to the destination junction.

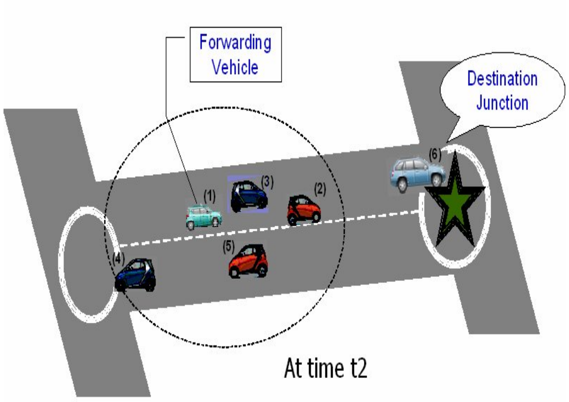

Figure 4. Situation at time t2

4.2.3. Recovery Strategy. We need a recovery strategy when we can not find a forwarding vehicle to forward the packet. If a vehicle can not find a forwarding vehicle then carry and forward strategy [14] will be used. Vehicle will carry the packet until next junction or until it finds a vehicle moving in its direction within its vicinity.

5. Conclusion

In this paper we proposed an intelligent routing protocol for VANET for city environments (IRPCE). Conceived from the idea presented in GyTAR [12], we identified and removed the issues that we faced in this protocol. Keeping city environment in mind our proposed protocol is geographical routing protocol using digital maps and vehicle density to select next junction. We provided a new junction selection algorithm, an intelligent greedy forwarding strategy to forward packets and a new recovery strategy which can better coup up with city environments.

6. References

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