IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

An Intersection Based Routing Protocol for Vehicular Ad Hoc Networks

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Abstract

Vehicular ad hoc networks (VANETs) allow vehicles to form a self-organized network without the need for permanent infrastructure .As a prerequisite to communication, an efficient route between network nodes must be established, and it must adapt to the rapidly changing topology of vehicles in motion. This is the aim of VANET routing protocols. In this paper we analyse an intersection based routing (GYTAR) approach that makes use of the navigational systems of vehicles. Intersection based routing can eliminate the problem of geographic source routing. By means of simulation we compare this approach with position-based ad hoc routing strategy (geographic Source Routing).Simulation results show significant performance improvement in terms of packet delivery ratio, end-to-end delay, and routing overhead.

Keywords: position based routing, GSR, GYTAR.

Introduction

Communication between vehicles by means of wireless. Technology has a large potential to improve traffic safety and travel comfort of drivers and passengers. Current advances in the field of wireless ad hoc networks show that inter-vehicle communication based on vehicular ad hoc networks is a feasible approach that has a competitive edge over cellular network-based telematics with respect to several aspects: low data transport times for emergency warnings, robustness due to the network's mesh structure, and low costs for usage due to the use of unlicensed frequency bands.

Several potential applications in the area of inter-vehicle communications require data routing algorithms for the Underlying ad hoc network: when communication endpoints are not within their respective radio transmission range, *unicast routing* is required to establish communication between two vehicles or between a vehicle and a fixed gateway. Communication

Partners are either selected based on their identity, e.g., IP address, or based on their geographic position. The latter case refers to applications where a person in a vehicle requests some information, e.g., on traffic flow or road conditions, from a specific geographic region. To support such application, *geocast routing* should also be provided by the underlying routing protocol.

Traditional ad hoc routing protocols have difficulties in dealing with the high mobility specific to vehicular ad hoc networks. In a recent paper we have shown for highway scenarios that routing approaches using position information, e.g., obtained from on-board GPS receivers, can very well deal with the mobility of the nodes. Vehicular ad hoc networks behave in different ways than conventional MANETs. Driver behaviour, mobility constraints, and high speeds create unique characteristics of VANETs.

In this work, we present a novel geographical routing protocol for vehicular networks in city environments called GyTAR: improved Greedy Traffic Aware Routing protocol. Based on a localization system like the GPS (Global Positioning System), our solution aims to efficiently relay data in the network considering the real time road traffic variation and the characteristics of city environments. It also takes into account information about vehicles speeds and directions since we suppose real city configuration with multi lanes and double direction roads. GyTAR aims to efficiently use the network resources (wireless bandwidth) by limiting the control message overhead, and to route data packets from sources to destinations in the vehicular network with a reduced end-to-end delay and low packet loss. Our solution is conceived but not limited to distributed infotainment applications and user services which require more than one hop communication, such as web browsing, chat, file sharing, games, delivering advertisements and announcements about sale information…

Vehicular AD HOC Networks

Inter-vehicle communication is an important component of the Intelligent Transportation System (ITS) architecture. The traditional ITS traffic monitoring systems are based on a centralized structure in which sensors and cameras along the roadside monitor traffic density and transmit the result to a central unit for further processing. Such systems are characterized by a long reaction time and a high cost for the deployment. An efficient alternative is the use of vehicle to vehicle communications. IVC represents a distributed and flexible system composed of vehicles, equipped with short range wireless communication capabilities that collaborate to form a temporary network between them. It enables a vehicle to communicate with other vehicles located out of the range of line of sight (or even out of the radio range if a multi hop network is built among several vehicles).

During these years, interest in applications for inter-vehicle communications increased in the EU, the US and Japan, resulting in many national vehicle safety projects such us CarTALK2000 and the Car2Car communication consortium in the EU and the VSCC (Vehicle Safety Communication Consortium) in the US. Moreover, the IEEE 802 committee started recently the development of a new standard, the IEEE 802.11p, targeting wireless communications in the vehicular environment. There are numerous emerging applications that are unique to the vehicular setting. For example, safety applications would make driving safer; driver information services could intelligently inform drivers about congestion, businesses and services in the vicinity of the vehicle. Mobile commerce could extend to the realm of vehicles. Existing forms of entertainment may penetrate the vehicular domain, and new forms of entertainment may emerge, all supported by the inter-vehicular communications capabilities. These emerging services are currently not supported.

Related Work

A.GEOGRAPHIC SOURCE ROUTING

The geographic source routing (GSR) algorithm tries to overcome the disadvantages of position-based routing approaches designed for MANETs when applied to VANETs in urban scenarios. For example, the position-based routing algorithm for MANETs, namely, GPSR , utilizes greedy forwarding strategy to forward messages towards a known destination. If, at any hop, there are no nodes in the direction of the destination, then GPSR has a recovery strategy called perimeter mode that routes around this void. The perimeter mode has two components. Geographic source routing uses a map of the urban area to avoid these problems. Using a static street map and location information about each node, GSR computes a route to a destination by forwarding messages along streets. The sender of a message computes a sequence of intersections that must be traversed in order to reach the destination. This sequence of intersections can be placed in the packet header or they can be decided by each forwarding node. The path between the source and destination is computed using Dijkstra's shortest path algorithm. Note that this approach does not take into account the vehicular traffic. That means the next street to be taken is determined without considering whether there is sufficient number of nodes on the street. In GSR, forwarding a packet between two successive junctions is done on the basis of simple greedy forwarding mechanism without considering vehicle direction, velocity. Thus, the selected vehicle chosen to forward data packet might not be the best choice. In order to overcome the packet loss and delay our proposed scheme will consider the traffic density, vehicular direction as well as speed to improve the performance of the vehicular networks.

Gytar – Improved Greedy Traffic Aware Routing Protocol

The proposed routing protocol in this paper is conceived to relay data in the vehicular network for distributed infotainment applications and user services which require more than one hop communication, such as web browsing, chat, file sharing, games, delivering advertisements and announcements about sale information, the available parking lot at a parking place.... In other words, this routing protocol ensures the user connectivity in specific environment, allows service continuity and possible extension of the wired network.

A. ***GyTAR Assumptions***

GyTAR considers that each vehicle in the network knows its own position thanks to the use of GPS2. Furthermore, a sending node needs to know the current geographical position of the destination in order to make the routing decision. This information is assumed to be provided by a location service like GLS (Grid Location Service). Moreover, we consider that each vehicle can determine the position of its neighbouring junctions3 through pre-loaded digital maps, which provides a street-level map. The presence of such kind of maps is a valid assumption when vehicles are equipped with on-board navigation system. We also assume that every vehicle is aware of the vehicular traffic (number of vehicles 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. On the basis of the above-mentioned assumptions, we give in the following a detailed description of the proposed inter-vehicle routing mechanism.

B. GyTAR Overview

GyTAR is a new 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 an (ii) improved greedy forwarding mechanism between two junctions. Hence, using GyTAR, a packet will move successively closer towards the destination along streets where there are enough vehicles to provide connectivity.

(1) ***Junction Selection***

Similar to position-based source routing, GyTAR adopts the anchor-based routing approach with street awareness. Thus, data packets will be routed between vehicles, following the street map topology. However, unlike GSR and A-STAR, where the sender computes statically a sequence of junctions the packet has to traverse in order to reach the destination, intermediate junctions in GyTAR are chosen dynamically and one by one, considering both vehicular traffic variation and distance to destination: when selecting the next destination junction, a node (the sending vehicle or an intermediate vehicle in a junction) looks for the position of the neighbouring junctions using the map. A score is given to each junction considering the traffic density and the curve metric distance to the destination. The best destination junction (the junction with the highest score) is the geographically closest junction to the destination vehicle having the highest vehicular traffic. To formally define this score, we need the following notations:

- J: the next candidate junction.
- I: the current junction
- D_j: the curve metric distance from the candidate Junction J to the destination.
- D_i: the curve metric distance from the current junction to the destination.
- $D_p = D_j/D_i$ (D_p determines the closeness of the Candidate junction to the destination point)
- Between junction I and junction J:

 N_v : total number of vehicles between I and J,

 N_c : number of cells5 between I and J,

 N_{avg}: average number of vehicles per cell ($N_{avg} = N_v/N_c$),

 N_{con}: constant which represents the ideal connectivity degree we can have within a cell.

- α, β: used as weighting factors for the distance and Vehicular traffic respectively (with $\alpha + \beta = 1$).

Hence, score $(J) = \alpha \times [\,1 - D_p] + \beta \times [\,\min (N_{avg}/N_{con}\,, 1)\,]$.

Figure 1 shows an example of how the next junction is selected on a street. Once vehicle A receives a packet, it computes the score of each neighbouring junction. Considering its curve metric distance to the destination and the traffic density, junction (2) will have the highest score. Then, it will be chosen as the next anchor.

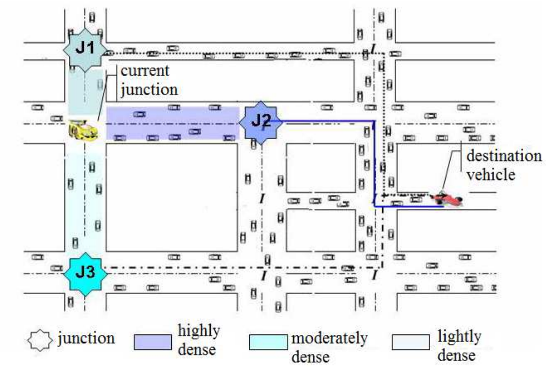
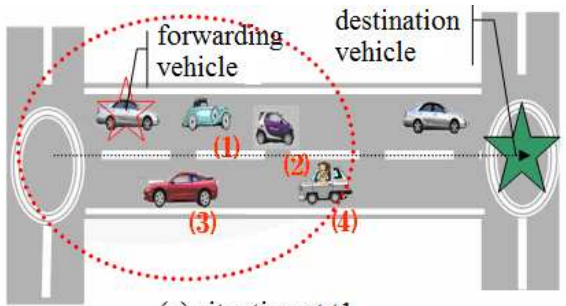


Figure 1. Selecting junctions in GyTAR

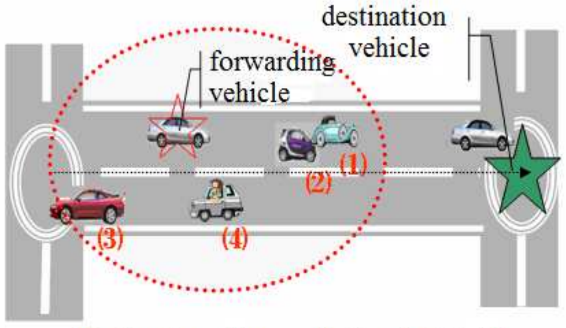
Using this real time traffic aware approach, the determined route will be the one with higher connectivity.

(2) ***Forwarding Data between two junctions:***

Once the destination junction is determined, the improved greedy strategy is used to forward packets between the two involved junctions. For that, all data packets are marked by the location of the next junction. Each vehicle maintains a neighbour table in which position, velocity and direction of each neighbour Vehicle are recorded. This table is updated through hello messages exchanged periodically by all vehicles. Thus, when a packet is received, the forwarding vehicle computes the new predicted position of each neighbour using the recorded information (velocity, direction and the latest known position), and then selects the next hop neighbour (the closest to the destination junction). This approach is illustrated in Figure 2, where vehicle (1), Which is moving in the same direction as the forwarding vehicle with a speed greater than vehicle (2), will receive the forwarded packet since at time (t2), it is the closest to the next junction. However, without using prediction, the forwarding vehicle would choose vehicle (4) as the next hop instead of vehicle (1) since it was the closest to the destination junction at time t1 (last time the neighbours table was updated).



(a) situation at t1



(b) situation after prediction (at t2>t1)

Figure 2. Forwarding data between two junctions using Improved greedy strategy.

Recovery Strategy

Despite the improved greedy routing strategy, the risk remains that a packet gets stuck in a local optimum (the forwarding vehicle might be the closest to the next junction). Hence, a recovery strategy is required. The repair strategy of GyTAR is based on the idea of "carry and forward": the forwarding vehicle of the packet in a recovery mode will carry the packet until the next junction or until another vehicle, closer to the destination junction, enters/reaches its transmission range .

Simulations and Results

A. Simulation Setting

To evaluate the performance of our proposed approach, we used the network simulator2. I have implemented greedy traffic aware (GyTAR) with the recovery method. We also implemented a version of the position-based vehicular routing protocol GSR [7] since there is not any publicly available implementation of the protocol. Then GyTAR were compared to GSR.

1) Packet Delivery Ratio:

In Figure 5, we present the obtained packet delivery ratio of the two studied protocols. Figure 5 show that GyTAR achieves the highest packet delivery ratio for the different CBR rates (a relative improvement of over 11% than GSR). This is mainly because in GyTAR, the path is determined progressively following road traffic density and urban environment characteristics. Hence, a packet will move successively closer towards the destination along streets where there are enough vehicles to provide connectivity. While in GSR, a complete sequence of waypoints is computed before the packet is originally transmitted by the source and without considering the vehicular traffic. Consequently, some data packets cannot reach their destination due to a problem of connectivity on some sections of streets.

In Figure 5, it is observed that more packets are delivered as node number increases. This is expected, especially for, GyTAR and GSR, since more nodes increase the probability of connectivity, which in turn reduces the number of packets dropped due to the local maximum. When the network density increases so much (>250) there is an increase of radio interferences and collisions between nodes due to hidden/exposed terminals. That's why the delivery ratio decreases for all protocols. The increase in packets delivery ratio is more significant at lower node number where local optimum is encountered frequently.

2) End-to-End Delay:

In this section, we compare the performance of GyTAR with GSR in terms of end-to-end delay Experienced by data parquets. As shown in Figure 6, GyTAR achieve a much lower end–to-end delay than GSR in all configurations. This is because in GyTAR, the number of hops involved to deliver packets is reduced due to the improved greedy strategy used to forward packets between two junctions, and also because GyTAR does not need to keep track of an end-to-end route before sending data packets: the route is Discovered progressively when relaying data packets from source to destination. Delay of GSR is higher than GyTAR because packets whose delivery was suspended are stored in the buffer for longer time than in GyTAR's suspension buffer.

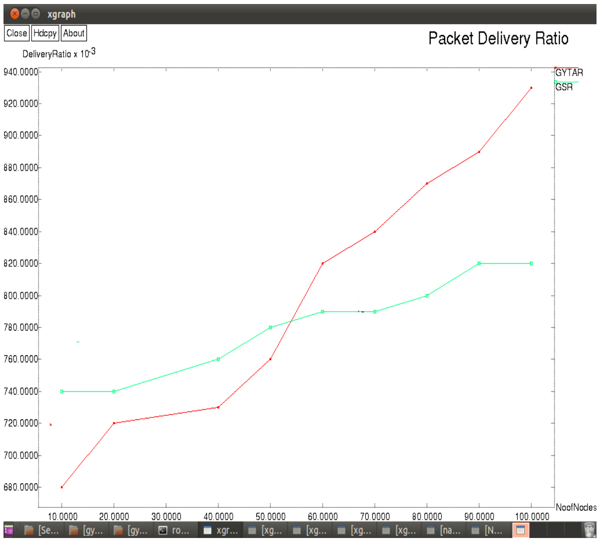


Figure 5. Delivery ratio V$_S$ number of nodes.

Figure 6. End-to-end delay V$_S$ number of nodes.

3) Routing Overhead:

In Figure 7, we evaluate the routing overhead of the two protocols as function of data sending rate and vehicle density. It shows that the routing overhead increases for all the protocols with increase in packet sending rate. This is expected since the number of control messages is constant (number of nodes is set to 100) whereas the total data packets received decreases with the increase in packet sending rate. In Figure 7, it is observed that the increase in the vehicle density leads to an increase in the routing overhead since the rate of control messages depends on the number of nodes. In general, GyTAR outperforms the other protocol in all cases (i.e. when varying data transmission rates and also with different vehicle densities). This is expected since in both GyTAR variants, we have only the hello messages as control messages and we have already seen that the fraction of data packets that are successfully delivered to their destination vehicles is high. Although GSR uses only hello messages as control messages, it shows higher routing overhead than GyTAR. This is because GyTAR does not need as many hello messages sent as GSR. This is due to the mechanism for neighbour's position inference used in GyTAR. Hence, the frequency of hello messages recommended for GSR is three times greater than the one needed by GyTAR.

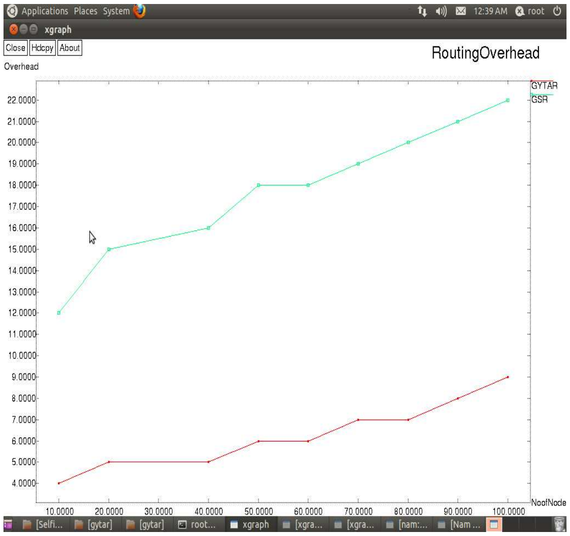


Figure 7. Routing Overhead V$_S$ number of nodes.

Conclusion and Future Work

In this work, we have presented an improved greedy routing protocol (GyTAR) which uses real time traffic density information and movement prediction (following direction and speed) to route data in vehicular ad hoc networks. Conceived for city environments, the proposed protocol is a geographic routing using the map topology and the vehicles density to efficiently select the adequate junctions that data packets cross to reach the destination. In addition, an improved greedy forwarding strategy was used to route data packets between two successive junctions. We demonstrated by a comparative simulation study that GyTAR outperforms GSR in terms of packet delivery ratio, data packet end-to-end delay and routing overhead.

We are currently extending this work into the following directions. First, we want to perform other extensive simulation study to analyze the impact of the weighting factors α and β, used for junction score calculation, on the GyTAR performances. Second, we want to study approaches where real-time road densities are inferred from observing hello transmitted packets and vehicle movement patterns.

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