An Improved Vehicular Ad Hoc Routing Protocol for City Environments

Moez Jerbi*, Sidi-Mohammed Senouci*, Rabah Meraihi* and Yacine Ghamri-Doudane**
*France Telecom R&D, Core Network Laboratories, Lannion, France
{moez.jerbi, rabah.meraihi, sidimohammed.senouci}@orange-ft.com

** Networks and Multimedia Systems Research Group, 18 Allée Jean Rostand, 91025 Evry, Cedex, France
ghamri@ ensiie.fr

Abstract—**The fundamental component for the success of VANET (Vehicular Ad hoc NETworks) applications is routing since it must efficiently handle rapid topology changes and a fragmented network. Current MANET (Mobile Ad hoc NETworks) routing protocols fail to fully address these specific needs especially in a city environments (nodes distribution, constrained but high mobility patterns, signal transmissions blocked by obstacles, etc.). In our current work, we propose an inter-vehicle ad-hoc routing protocol called GyTAR (improved Greedy Traffic Aware Routing protocol) suitable for city environments. GyTAR consists of two modules: (i) dynamic selection of the junctions through which a packet must pass to reach its destination, and (ii) an improved greedy strategy used to forward packets between two junctions. In this paper, we give detailed description of our approach and present its added value compared to other existing vehicular routing protocols. Simulation results show significant performance improvement in terms of packet delivery ratio, end-to-end delay, and routing overhead.**

Index Terms— **City Environments, Greedy Routing, Vehicular Ad hoc Network**.

I. INTRODUCTION

Wireless communication technologies have enabled many of the conveniences in our lives, and also increased our day by day productivity. Another area where there is much potential for wireless technologies to make a tremendous impact is the area of inter-vehicular communications (IVC). The field of IVC is also known as vehicle-to-vehicle communications (V2V) and vehicular ad hoc networks (VANET).

VANETs are an instantiation of mobile ad hoc networks (MANETs). MANETs have no fixed infrastructure and instead rely on ordinary nodes to perform routing of messages and network management functions. However, vehicular ad hoc networks behave in different ways than conventional MANETs. Driver behavior, mobility constraints, and high speeds create unique characteristics of VANETs. These characteristics have important implications for designing decisions in these networks. Thus, numerous research challenges need to be addressed for inter-vehicular communications to be widely deployed. For example, routing in conventional mobile ad hoc networks is a challenging task because of the network's dynamic topology changes. Numerous studies and proposals of routing protocols have been conducted to relay data in such a context; however these solutions can not be applied to the vehicular environment due to the specific constraints and 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…

The rest of the paper is organized as follows. In section 2, we describe the properties and specific characteristics of vehicular ad hoc networks. Existing approaches on routing algorithms in both MANET and VANET are presented in section 3. Section 4 details the principles and components of GyTAR giving the added value of such proposition compared to existing vehicular routing protocols. Section 5 presents simulation setting and results. Finally, conclusion and future works are summarized in section 6.

II. 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 multihop 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 [17] in the EU and the VSCC (Vehicle Safety Communication Consortium) in the US.

Moreover, the IEEE 802 committee [12] 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.

Challenges of VANET vs MANET

VANET represents a direct application of mobile ad hoc network and shares numerous MANET properties, where communications are possible between vehicles within each other's radio range without need of a central infrastructure. However, there are significant differences related to the specific vehicular context. Thus, existing solutions designed for MANET (routing, security and QoS for example) can not be directly applied and must be adapted. VANET properties that derive this difference are:

- Communication, energy and processing capacity: power efficiency, for example, is not as important for inter-vehicular communications as it is for traditional ad hoc networking, since vehicles have a powerful and rechargeable source of energy. Vehicles are also characterized by a great processing capacity;
- Displacement environment and mobility model: vehicles in general are constrained to move within road infrastructures (highways, city roads). Furthermore, constraints imposed by this type of environment, namely the radio obstacles (ex: buildings) affect considerably the quality of radio transmissions. Finally, vehicle's mobility is directly related to the driver behavior;
- Network topology and connectivity: unlike ad hoc networks, VANET are characterized by a potentially large number of nodes that are highly mobile (i.e. according to cars' speed). This high mobility can be more or less important depending on road nature (small streets vs. highways). Consequently, a node can quickly join or leave the network in a very short time leading to frequent network partitioning and topology changes. These characteristics imply a weak connectivity reducing the lifetime of the routes.

In our current work, we focus on the design of a routing protocol that is suitable for handling the characteristics of such environment.

III. RELATED WORK

In this section, we look at the existing routing proposals in both MANET and VANET and then discuss the inconvenience of using such protocols in the vehicular environment, especially in the city environments.

A. Routing in MANET

Proactive and reactive routing approaches have been widely studied for MANET routing. Proactive routing (like OLSR [10] and TBRPF [10]) is a table-driven approach in which each node maintains one or more tables that contain routing information to every other node in the network. Existing proactive algorithms are not suitable in highly mobile environments, as they result in poor route convergence and very low communication throughput. Reactive routing, like DSR [2](Dynamic Source Routing) and AODV [6](Ad hoc On-Demand Distance Vector routing), is an on-demand approach in which network routes are not updated with changing topology and a route discovery is initiated 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 the existing algorithms, a new type of routing technique, based on location information, has been developed. Examples of this kind of routing include: GPSR [1] (Greedy Perimeter Stateless Routing), LAR [1] (Location Aided Routing) and DREAM [11] (Distance Routing Effect Algorithm for Mobility). This geographical routing approach adapt well to the dynamic nature of large scale ad hoc networks. For example, GPSR [1] uses nodes positions and packet's destination to make packet forwarding decisions. GPSR makes greedy forwarding decisions using only information about the node's immediate neighbors in the network topology. When a packet reaches a region where greedy forwarding is impossible, the algorithm recovers by routing around the perimeter of the region. By keeping information about the local topology only, GPSR performs better in per-node state compared to shortest-path algorithms as the number of network destinations increases.

B. Routing in VANET

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

'GSR' [7] (Geographic Source Routing) has been recently proposed as a promising routing strategy for vehicular ad hoc networks in city environments. It combines position-based routing with topological knowledge. The simulation results, with the use of realistic vehicular traffic in a city environments, show that GSR outperforms topology-based approaches (DSR and AODV) with respect to delivery rate and latency. In another study [5], the same authors 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 vehicles.

'A-STAR'[3] (Anchor-based Street and Traffic Aware Routing) is a position-based routing scheme designed specifically for IVC in a city environments. It features the novel use of city bus route information to identify anchor paths of higher connectivity so that more packets can be delivered to their destinations successfully. A new recovery strategy for packets routed to a local optimum[1] was also proposed, consisting of the computation of a new anchor path from the local maximum to which the packet is routed.

The Greedy Perimeter Coordinator Routing (GPCR) protocol [8] has been designed to deal with the challenges of city scenarios. It does not require any global or external information such as a static street map. The main idea of GPCR is to forward data packets using a restricted greedy forwarding procedure. That means when choosing the next hop, a coordinator node (a node on a junction) is preferred to a non-coordinator node, even if it is not the closest node to destination.

C. Discussion

In the previous sections, we discussed VANET characteristics including high-speed node movement, frequent topology change, and short connection lifetime especially with multi-hop paths. These three characteristics degrade significantly the performance of conventional topology based routing protocols designed for MANETs. This is due to packet control overhead (route discovery, route maintenance, etc.) caused by frequent update of routing information of the whole network, route failures and transient nature of links. The frequently changed topology suggests that a local routing scheme without the need to keep track of global routing information scales better in VANET and consume a low wireless bandwidth. In addition, the popularity of the Global Positioning System (GPS) also makes position-based routing, which maintains only local information about the node's position, a popular routing strategy. But at the same time, the direct application of geographic routing protocols to VANET is not suitable. Indeed, we note that existing geographic routing improvements are often based on a simple greedy forwarding concept (closest vehicle to the destination) without taking into account urban environment characteristics. This leads to difficult signal reception due to radio obstacles such as high-rise buildings.

The proposed vehicular routing protocols solved this problem by forwarding packets through streets. However, applying intersection-based routing to IVC may not be without any problems. An example is GSR [7], where the sender calculates the shortest path to the destination using the Djikstra algorithm and according to the street map. Then it computes a sequence of junctions through which the packet has to pass in order to reach the destination. 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. A-STAR [3] also suffers from problem of connectivity on some sections of streets since it uses static vehicular traffic information based on city bus routes to find a path from source to destination. Moreover, in A-STAR and 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 the following section, we give detailed description of our approach and present its added value compared to other existing vehicular routing protocols.

IV. 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.

---

[1] Situation where there is no neighbor of the forwarding node s, which is closer to destination than s itself.

A. *GyTAR Assumptions*

GyTAR considers that each vehicle in the network knows its own position thanks to the use of GPS[2]. 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)[15]. Moreover, we consider that each vehicle can determine the position of its neighboring junctions[3] 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 neighboring junctions using the map. A score is given to each junction considering the traffic density and the curvemetric[4] 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 curvemetric distance from the candidate junction J to the destination.
- D_i: the curvemetric 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 cells[5] 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 neighboring junction. Considering its curvemetric distance to the destination and the traffic density, junction (2) will have the highest score. Then, it will be chosen as the next anchor.

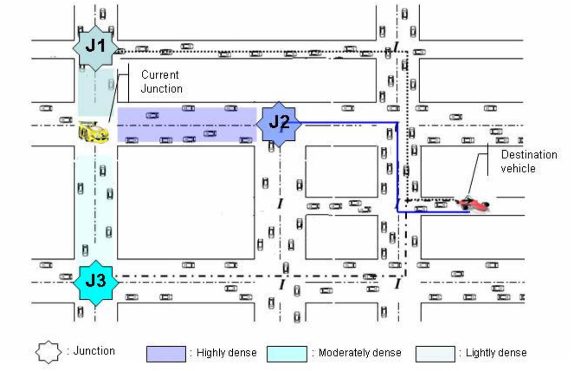


Figure 1. Selecting junctions in GyTAR.

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

2) Forwarding Data between two junction:

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 neighbor table in which position, velocity and direction of each neighbor

---

[2] The popularity of GPS on vehicles in today's world makes this assumption acceptable.

[3] A place where two or more roads join or meet.

[4] This term describes the distance measured when following the geometric shape of a road.

[5] The cell is determined based on the wireless transmission range of vehicles.

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 neighbor using the recorded information (velocity, direction and the latest known position), and then selects the next hop neighbor (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 neighbors table was updated).

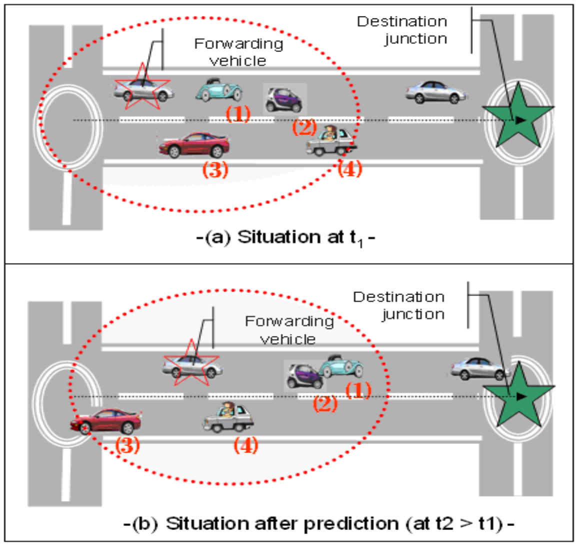


Figure 2. Forwarding data between two junctions using improved greedy strategy.

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"[15]: the forwarding vehicle of the packet in a recovery mode will carry the packet until the next junction (cf. Figure 3 (a)) or until another vehicle, closer to the destination junction, enters/reaches its transmission range (cf. Figure 3 (b)).

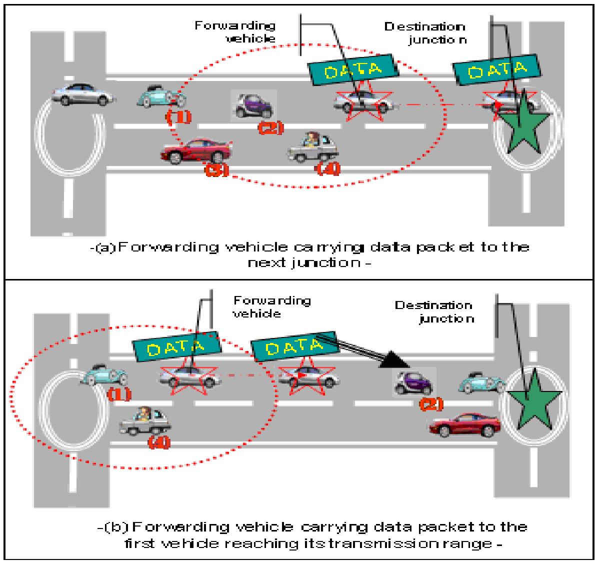


Figure 3. Recovery strategy used in a local optimum.

V. SIMULATIONS AND RESULTS

A. Simulation Setting

To evaluate the performance of our proposed approach, we used the Qualnet simulator [13]. We implemented two versions: B-GyTAR (Basic GyTAR without local recovery: a packet is simply dropped when it encounters a local maximum situation), and 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. B-GYTAR and GyTAR are then compared to GSR and LAR.

1) Mobility Model:

The mobility model used in the simulation has a great impact on protocols behavior and the obtained simulation results. For this purpose we extended and adapted the mobility model proposed in [16] to our needs and routing context. Our tool generates realistic random vehicles' displacements according to the city (or map) constraints and structure (roads are bidirectional with multi lanes). It is also based on existing real world maps such as publicly available TIGER (Topologically Integrated GEographic Encoding and Referencing) database from U.S.

While vehicles start moving, we can have access to the real time vehicular traffic condition and variation of each street in the chosen map. Moreover, the vehicle speed depends on the vehicle type (bus, car or other) and also on the road type (highway, normal street...), while in [16], vehicle speed limit depends only on type of road.

2) *Simulation Setup:*

The vehicular movement pattern generation is based on a 2500×2000 m² rectangle street area, which consists of 16 intersections and 26 two way roads (Fig.1. shows a snapshot of this simulation area). In each road, a certain number of vehicles are deployed randomly. For the displacement behavior, each vehicle chooses one of the intersections as its destination, and moves along the road to this destination with an average speed of 30 or 50km/h depending on vehicle type; and so on.

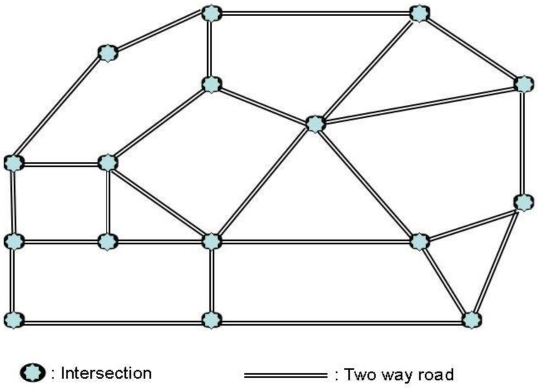


Figure 4. City simulation area.

We vary the number of vehicles from 100 to 300. Each vehicle has a radio propagation range of 266 meters with a channel capacity of 2 Mb/s. The simulation results are averaged over five runs. Each simulation takes 200 seconds of simulation time. 15 random connections were established using CBR traffic at 0.1-1 second (1-10 packet(s)/second) with a packet size of 128 bytes. The weighting factors (α; β) are set to (0.5;0.5). A sensitivity analysis for these key parameters of the algorithm will be done as future work in order to determine the good balance between distance and density for the delivery success. All the key parameters of our simulation are summarized in the following table:

Table 1: Simulation setup.

SIMULATION / SCENARIO		**MAC / ROUTING**	
Simulation Time	200s	MAC protocol	802.11 DCF
Map Size	2500 x 2000 m2	Channel Capacity	2 Mbps
Mobility Model	Our own realistic mobility model	Trans. Range	~266 m
Number of intersections	16	Traffic Model	15 CBR connections
Number of roads	26	Packet sending rate	0.1 – 1 second
Number of vehicles	100-300	Weighting factors (α; β)	(0.5;0.5)
Vehicle velocity (city)	30-50±5 Km/h	Data packet size	128 bytes

B. *Simulation Results and Analysis*

The performance metrics used to evaluate the simulation results are:

- *Packet delivery ratio*: the fraction of originated data packets that are successfully delivered to their destination vehicles.
- *End-to-end delay*: the average time it takes for a packet to traverse the network from its source to destination.
- *Routing overhead*: the ratio of number of bytes of total control packets to those of total data packets delivered to the destinations during the entire simulation.

The algorithms are compared under various data transmission rates and various vehicle densities. Detailed analysis of the simulation results are given in the following.

1) *Packet Delivery Ratio:*

In Figure 5, we present the obtained packet delivery ratio of the four studied protocols. Figure 5 (a) shows that GyTAR achieves the highest packet delivery ratio for the different CBR rates (a relative improvement of over 9% than GSR).

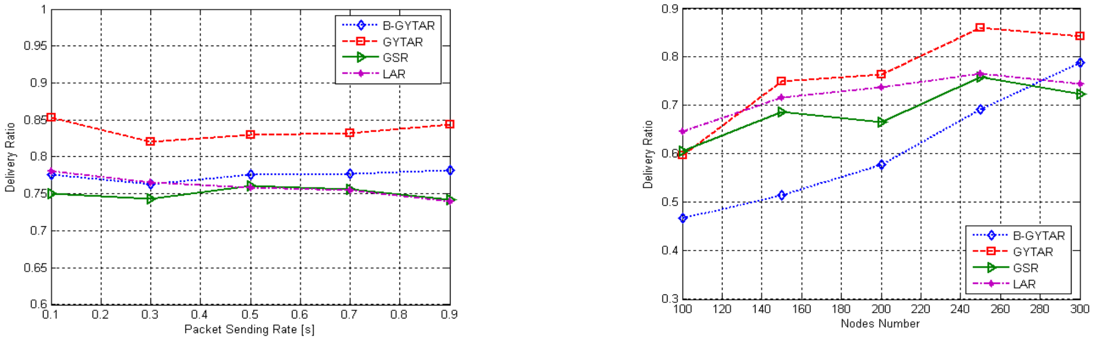
This is mainly because in GyTAR, the path is determined progressively following road traffic density and urban environment characteristics. Hence, a packet will move successively closer towards the destination along streets where there are enough vehicles to provide connectivity. While in GSR, a complete sequence of waypoints is computed before the packet is originally transmitted by the source and without considering the vehicular traffic. Consequently, some data packets can not reach their destination due to a problem of connectivity on some sections of streets.

LAR achieves a lower delivery ratio than GyTAR because it uses a route discovery mechanism. Consequently, some data packets can not reach their destination because it is very difficult to maintain an end-to-end connection in the vehicular environment (frequent topology change and network fragmentation).

In Figure 5(b), it is observed that more packets are delivered as node number increases. This is expected, especially for B-GyTAR, GyTAR and GSR, since more nodes increases 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.

In general, GyTAR has a much higher delivery ratio than B-GyTAR (Up to 20% relative improvement). This is because with local recovery, packets that encounter local optimum can be rerouted and delivered instead of being dropped. The increase in packets delivery ratio is more significant at lower node number where local optimum is encountered frequently. For example, with local recovery, GyTAR delivers 25 % more packets than B-GyTAR at 150 nodes, while only 7% more at 300 nodes.



(a) 300 nodes (b) 0.2 [s] (5 packets / second)

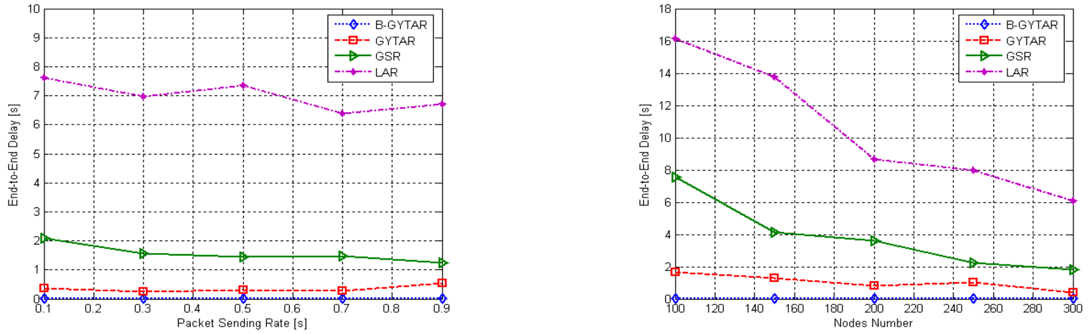
Figure 5. Delivery ratio vs. (a) Packet sending rate and (b) nodes number

2) End-to-End Delay:

In this section, we compare the performance of GyTAR and B-GyTAR with GSR and LAR in terms of end-to-end delay experienced by data paquets. As shown in Figure 6, GyTAR and B-GyTAR achieve a much lower end–to-end delay than LAR and 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. In contrast, the geographical routing protocol LAR uses a route discovery mechanism which causes longer delays.

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.

B-GyTAR achieves a lower delivery delay than GyTAR, since in GyTAR with local recovery, packets that encounter local maximum will be stored in a buffer and carried by the vehicle, which may cause longer delays. This is confirmed in Figure 6 (b), where GyTAR and B-GyTAR have almost the same delivery delay at higher node number where local maximum is encountered rarely.



(a) 300 nodes (b) 0.2 [s] (5 packets / second)

Figure 6. End-to-end delay vs. (a) Packet sending rate and (b) nodes number

3) Routing Overhead:

In Figure 7, we evaluate the routing overhead of the four protocols as function of data sending rate and vehicle density.

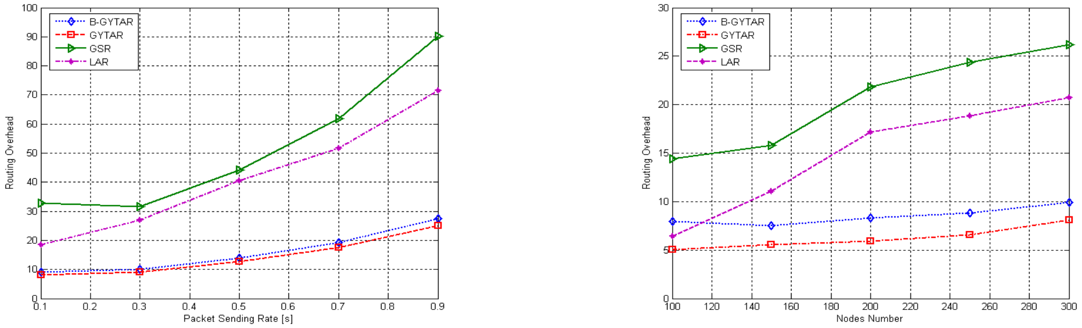
Figure 7(a) shows that the routing overhead increases for all the protocols with increase in packet sending rate. This is expected since the number of control messages is constant (number of nodes is set to 300) whereas the total data packets received decreases with the increase in packet sending rate.

In Figure 7(b), 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, B-GyTAR and GyTAR outperforms the two other studied protocols 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. While in LAR, we have three types of control messages (Route Request, Route Reply, and Route Error) used for route discovery and route maintenance (Remind that this latter is triggered frequently in VANETs).

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 neighbor's position inference used in GyTAR. Hence, the frequency of hello messages recommended for GSR [8] is three times greater than the one needed by GyTAR.



(a) 300 nodes (b) 0.2 [s] (5 packets / second)

Figure 7. Routing Overhead vs. (a) Packet sending rate and (b) nodes number

VI. 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 LAR and 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.

REFERENCES

[1] B. Karp and H. T. Kung, "GPSR: Greedy perimeter stateless routing for wireless networks", *ACM/IEEE MOBICOM'00,* pp. 243-254, New York, NY, USA, August 2000.

[2] Y. Ko and N. Vaidya, "Locaton-aided routing (LAR) in mobile ad hoc networks", *ACM/IEEE MOBICOM'98*, pp. 66-75, Dallas, USA, August 1998.

[3] D. B. Johnson, D. A. Maltz, Y.-C. Hu, "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR)", *Internet Draft : <draft-ietf-manetdsr-10.txt>*, 19 July 2004.

[4] B.-C. Seet, G. Liu, B.-S. Lee, C. H. Foh, K. J. Wong, K.-K. Lee, "A-STAR: A Mobile Ad Hoc Routing Strategy for Metropolis Vehicular Communications". *IFIP NETWORKING'2004*, pp. 989-999, Athens, Greece, December 1-5, 2004.

[5] Z. Chen, H. Kung, and D. Vlah, "Ad Hoc Relay Wireless Networks over Moving Vehicles on Highways", Poster, *ACM Mobihoc'2001*, pp. 247-250, Long Beach, CA, October 2001.

[6] H. Füßler, M. Mauve, H. Hartenstein, M. Käsemann, and D. Vollmer, "Location-based routing for vehicular ad hoc networks", student poster, *ACM/IEEE MOBICOM'2002*, Atlanta, Georgia, USA, September 2002.

[7] C. E. Perkins, E. M. Belding-Royer, and S. Das, "Ad Hoc On Demand Distance Vector (AODV) Routing", *IETF Request For Comments 3561*, 2003.

[8] C. Lochert, H. Hartenstein, J. Tian, D. Herrmann, H. Füßler, M. Mauve, "A Routing Strategy for Vehicular Ad Hoc Networks in City Environments", *IEEE Intelligent Vehicles Symposium (IV2003)*, pp. 156-16, Columbus, OH, USA, 1, June 2003.

[9] C. Lochert, M. Mauve, H. Füßler, H. Hartenstein, "Geographic Routing in City Scenarios", *ACM/IEE MOBICOM'2004*, Philadelphia, PA, USA, September 26 - October 1, 2004.

[10] T. Clausen, P. Jacquet, "Optimized Link State Routing Protocol", Request for Comments (Experimental), *IETF Request For Comments 3626*, 2003.

[11] R. Ogier, F. Templin, and M. Lewis, "Topology dissemination based on reverse-path forwarding (TBRPF)", *IETF Request For Comments (Experimental)*, 2004.

[12] S. Basagni, I. Chlamtac, V.R. Syrotiuk, B.A. Woodward, "A distance routing effect algorithm for mobility (DREAM)", pp. 76-84, *ACM/IEEE MOBICOM'98*, 1998.

[13] IEEE 802.11 Wireless Local Area Networks, grouper.ieee.org/groups/802/11/

[14] Scalable Network Technologies Inc., Qualnet simulator, http://www.scalable-networks.com.

[15] J. Li, J. Jannotti, D. De Couto, D. Karger, and R. Morris, "A scalable location service for geographic ad hoc routing", *ACM/IEEE MOBICOM'2000*, pp. 120.130, 2000.

[16] J. Davis, A. Fagg, and B. Levine, "Wearable Computers as Packet Transport Mechanisms in Highly-Partitioned Ad-Hoc Networks", *in International Symposium on Wearable Computing*, October 2001.

[17] A. K. Saha and D. B. Johnson, "Modeling Mobility for Vehicular Ad Hoc Networks", Appeared as a poster in the First *ACM Workshop on Vehicular Ad Hoc Networks (VANET 2004)*, Philadelphia, Pennsylvania, October 2004.

[18] Car2Car Communication Consortium, www.car-to-car.org