Geocast Routing Protocols for VANETs: Survey and Geometry-Driven Scheme Proposal

Salim Allal*, Saadi Boudjit
Université Paris 13, Sorbonne Paris Cité,
Laboratoire de Traitement et Transport
de l'Information (L2TI), (EA 3043),
99, Avenue Jean-Baptiste Clément,
F-93430, Villetaneuse, France.
{salim.allal,boudjit}@univ-paris13.fr

Abstract

Vehicular Ad Hoc Networks (VANETs) are characterized by highly speed nodes, highly dynamic topology and frequent link disconnections. This raises a number of challenges especially in the field of data dissemination. Our study focuses on Geocast routing which consists of routing a message from a unique source vehicle to all vehicles located in a well geographically defined destination area called ZOR (Zone Of Relevance). In this work, we introduce some existing Geocast routing protocols for VANETs as well as a classification of these protocols based on the relay selection technique they use. We then provide a comparison of these protocols according to different criteria. While in literature ZORs are often assumed to be of any form and still chosen according to the scenarios and motivation needs of the authors [1], we consider a ZOR as a set of sub-ZORs and we choose simple geometrical forms for each sub-ZOR so that they would be easy to implement and to represent mathematically. We provide a geometrical vision angles based technique to define if two sub-ZORs are in the same direction in order to send them a single message, and hence, reduce messages overhead. Finally, we introduce a new routing protocol in Sub-ZORs (GeoSUZ) for VANETs based on our geometrical vision angles and greedy forwarding techniques. We compare GeoSUZ to GPSR routing protocol [3] and some numerical results show a significant gain in term of number of messages sent over the network.

Keywords: Survey, Routing protocols, Geocast routing, Sub-ZORs, VANETs

1 Introduction

Vehicular Ad Hoc Networks (VANETs) provide one of the most important fields of research for the high interest that Intelligent Transportation Systems ITS can offer through them in different sectors in both saving lives, time, energy and the planet. They are considered as an application to Mobile Ad Hoc Networks (MANETs) and are widely based on MANET fundamentals.

To ensure autonomous communication between vehicles on the road for the purpose of traffic management, safety alerting or infotainment, VANETs provide a large range of routing protocols in the literature. However, most of them result from the long theoretical work done in the framework of MANETs and need to be classified and subjected to meticulous studies, simulations and experimentation. That is why we must mention the fact that VANETs are a very specific case of MANETs characterized by a high mobility, frequent changes in topology, high and frequently variable density, long lifetime of nodes and regular moving patterns. In this work, we give a classification of the existing geocast routing protocols

Journal of Internet Services and Information Security (JISIS), volume: 3, number: 1/2, pp. 20-36
*Corresponding author: Tel +33-149-402-824, Web: http://www-l2ti.univ-paris13.fr/~allal/

for VANETs into beacon-based and distance-based protocols according to the technique used to select the relay intended to retransmit the geocast message.

The rest of this paper is organized as follow: in section 2 we present a brief overview of routing protocols in VANETs. In section 3, we list and present some geocast routing protocols in VANETs. In section 4, we give our classification according to the relay selection criteria divided into beacon-based and beaconless-based protocols and we present a detailed comparison of these protocols taking into consideration different parameters. In section 5, we present a brief overview of geocast routing protocols in VANETs. We then highlight our motivation behind splitting the destination area (ZOR) into a set of sub-ZORs, and considering simple geometrical forms to cover these destination areas. Section 6, presents a geometrical vision angles technique to define whether two sub-ZORs are in the same direction in order to send them a single message and hence, reduce the messages overhead. In section 7, we present our geocast routing protocol for VANETs based on our proposed geometrical vision angles and greedy forwarding techniques. Some numerical results which illustrate our protocol performances are presented in section 8 and finally, section 9 concludes the paper.

2 Routing protocols in VANETs

Routing tasks in VANETs are very challenging due to the high speed of vehicles making topology of the network highly dynamic and causing frequent links disconnections [16]. Routing protocols in VANETs are classified into six categories [8] considering the routing technique aspects: Topology-based, Position-based, Cluster-based, Geocast-based, Broadcast-based and Infrastructure-based.

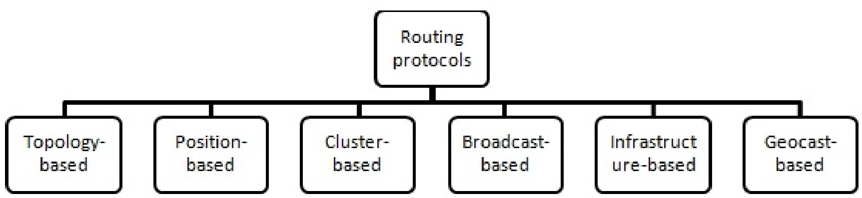


Figure 1: Categories of routing protocols in VANETs

2.1 Topology-based routing protocols

In this routing technique, the choice of a route from source to destination is based on links information previously collected by the vehicle (proactive/table-driven) or sought when needed (reactive/on-demand) [14, 10, 8]. Here, the step of searching or maintaining a route from source to destination is mandatory before sending data packets.

2.2 Position-based routing protocols

They are also called Geographic-basedprotocoles. This class uses vehicles' geographical information in the relay selection process assuming that each vehicle has the mean to know its geographical position (as GNSS - Global Navigation Satellite System) [10, 8, 14]. Here, the knowledge of the whole route is unnecessary to deliver the data packets.

2.3 Cluster-based routing protocols

In cluster-based routing protocols, the vehicles sharing similar characteristics, such as performing in the same direction with more or less the same velocity, can form a cluster and elect a cluster-head which manages the cluster and is in charge of inter-cluster communications [10, 8]. We note that intra-cluster communications are cluster-head free and perform using direct links.

2.4 Geocast-based routing protocols

Geocast routing protocols follow the principle of routing data packets from a single source vehicle to all vehicles belonging to the destination area called *zone of relevance ZOR* [10, 8]. However, to override the simple flooding of the geocast message from the source to the *ZOR*, a forwarding area called *zone of forwarding ZOF* is used to confine the message forwarding until it reaches the *ZOR*.

2.5 Broadcast-based routing protocols

This class of routing protocols uses the simple flooding on the network in order to reach all vehicles [10, 8]. Different relay selection techniques are used to reduce the message overhead.

2.6 Infrastructure-based routing protocols

This class of routing protocols uses infrastructure nodes as relays, such as the use of Roadside Units RSU in junctions and along the roads to route packets to reachable vehicles in the transmission range [10].

3 Geocast routing protocols in VANETs

Geocast is a routing protocol providing multi-hop wireless communication over an autonomous mobile environment (the use of an infrastructure is not mandatory). Initially proposed for MANETs [6], it quickly found adaptation for other networks such as Mesh networks, Wireless Sensor Networks (WSN) and VANETs.

Here are listed the existing Geocast routing protocols in VANETs: IVG, Cached Geocast, Abiding Geocast, DRG, ROVER, DG-CastoR, Mobicast, DTSG, Constrained Geocast, Geocache summarized below.

3.1 IVG

In [4], Bachir and al. proposed the Inter-Vehicular Geocast IVG protocol. The purpose of IVG is to inform vehicles located in a risk area called *multicast group* about any danger on the highway (e.g., when an accident occurs). To achieve this goal, the risk area is determined considering the precise obstacle location on the road and the driving directions which can be affected. The damaged vehicle broadcasts a message alert to the multicast group (Figure 2). The neighbors receiving the message test its relevance according to their location reporting to the risk area. All neighbors belonging to the risk area calculate a *differ time backoff* that promotes the furthest node in order to be a relay rebroadcasting the message (more distant is more favorable). This relay selection technique make the use of periodic beacons unnecessary.

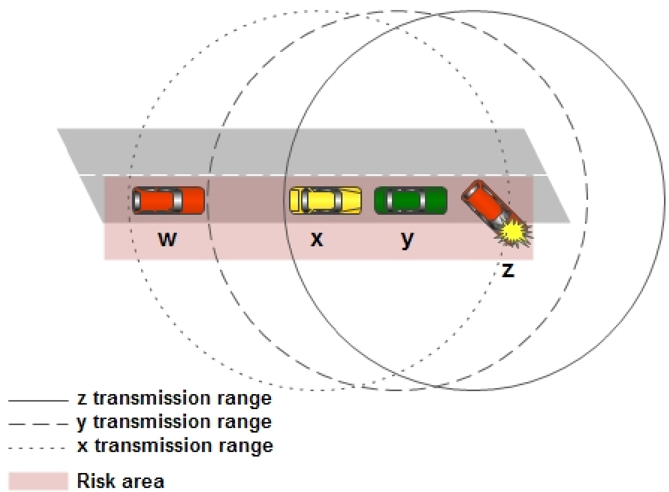


Figure 2: IVG Relay selection: **x** is more distant to **z** then **y**. **x** is a relay. **x** permits to reach **w** while **y** not.

3.2 Cached Geocast

The principle of adding a cache to the routing layer to store Geocasted messages in order to address the problem of local maximum in greedy forwarding technique was proposed by C. Maihöfer and al. in [12]. The cache is fed with the currently unroutable packets called *LocalMaxCache* and checked for favorable packets whenever new neighbors are discovered or one's neighbors move (periodic beaconing system is used).

The authors have almost proposed a ranged forwarding to overcome the problem of high nodes velocities. It consists of a dynamic transmission range *r* based on the real transmission range and the current nodes velocities. On relay selection, the most distant (nearest to destination) node within the range *r* is chosen.

3.3 Abiding Geocast

Maihöfer and al [13] proposed an approach of abiding Geocast that allows a periodical delivery of a Geocast message in Ad Hoc Networks. Three solutions are provided. Firstly, the use of a server that stores Geocast message (Unicasted from the source). Then the server uses a Geocast protocol to periodically deliver the Geocast message to the destination zone. Secondly, a node is elected in the relevant destination area in order to store the Geocast message and periodically or by notification retransmit it. Thirdly, the neighbor approch consists to allow all nodes to store the Geocast message. Hand over is done on entry and message delivery by notification.

For VANETs, the use of abiding Geocast is suitable for some applications as following: the use of server approach for information applications, advertising or informing drivers about the state of the road e.g., slippery surface, ice storm, etc. Elected node approach and neighbor approach are more adapted to safety applications to inform drivers about an accident on their direction. We note that periodic beaconing system is not mandatory since the Geocast message is periodically broadcasted.

3.4 DRG

Joshi and al. [7] defined in the context of DRG (Distributed Robust Geocast) protocol the *zone of relevance ZOR* as all nodes satisfying a set of geographical criteria for which the Geocast message is still pertinent, and *zone of forwarding ZOF* the set of nodes eligible to forward the Geocast message. The authors proposed a forwarding algorithm based on *more distant is more favourable* principle to select relays. DRG takes place in the manner that each vehicle when receiving a Geocast message tests its relevance according to its location. If the vehicle belongs to the *ZOR* then it reads the message. Otherwise, if the vehicle is in the *ZOF* then it forwards the message, else, the message is dropped. We notice that DRG does not need to exchange periodic beacons.

3.5 ROVER

Reliable Geographical Multicast Routing in Vehicular Adhoc Networks ROVER [9] proposed by M. Kihl and al. presents a technique similar to AODV which consists in broadcasting only control packets, while data packets are unicasted (a periodic beaconing system is used). ROVER assumptions are:

- each vehicle is identified by an Identification Number,
- each vehicle is equipped with a GPS receiver,
- vehicles have access to a digital map,
- *ZOR* is a rectangle area,
- *ZOF* includes the sender and the *ZOR*.

The goal of ROVER is to deliver an application generated message to all vehicles located into the specified *ZOR*. ROVER defines a message as a triplet [Application, Message, *ZOR*]. A vehicle considers a message if it belongs to the message's *ZOR*.

3.6 DG-CastoR

DG-CastoR [2] was proposed by Atechian and al. It is a Geocast routing protocol based on link availability estimation. The main idea of DG-CastoR is to estimate the neighbors that will have the same trajectory (ability to communicate) with the sender during a period of time, based on spatio-temporal similarity measures. In DG-CastoR, *Rendez-vous region* represents the Geocast routing area and the *Rendez-vous group* the trajectory of the source and the neighbors in which the link availability was estimed.

3.7 Mobicast Routing

Chen and al. proposed in [5] a spatiotemporary multicast/Geocast protocol. Mobicast considers in addition to the space the time factor in the Geocast routing. Its goal is to transmit mobicast messages from a source to all nodes belonging to the *ZOR* (Zone Of Relevance) at time *t* called ZOR_t. To achieve this goal, the authors proposed a method to estimate the accurate ZOF (Zone Of Forwarding). Its scope is to overcome the problem of temporal network fragmentation, using adaptable *zone of approaching* ZOA to dynamically form flexible ZOF in order to disseminate the Mobicast message to the *ZOR* at the appropriate time (Figure-3).

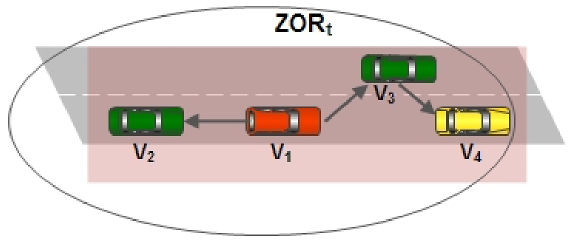


Figure 3: Mobicast Game application. Invitations initiated from V_1

3.8 DTSG

Rahbar and al. proposed in [15] DTSG protocol: Dynamic Time-Stable Geocast Routing in Vehicular Ad Hoc Networks. Its goal is to inform vehicles belonging to a specific region on the highway for a certain period of time about an event (e.g., accident), assuming that vehicles have the same speed on the highway, and that they rarely pass each other and advance in platoons. Then, DTSG protocol takes advantage of vehicles moving in the opposite direction (called: *Helping vehicles*) to disseminate the Geocast message to the different groups of vehicles. It works in two phases, the first called *pre-stable period* beginning when the source broadcasts his message until it reaches the end region thanks to helping vehicles. The second, called *stable period,* allows the protocol stabilization within the region.

3.9 Constrained Geocast

In [17], Wolterink and al. presented the paradigm of *Constrained Geocast* consisting on determination of the destination set of nodes basing on the future position of the nodes involved. [17].

3.10 Geocache

In [11], Lakas and al. presented the Geocache protocol consisting on a peer-to-peer application which allows to detect and avoid congestions. It is designed as a pull-based Geocast protocol integrated with a caching mechanism to reduce the amount of broadcasted messages during data dissemination.

4 Comparison

In this section, we present a classification of the Geocast routing protocols presented in the last section according to different parameters:

Periodic beacons

The relay selection technique in routing protocols consists in selecting one or a set of nodes which are the best characterized (e.g., best bandwidth, most near from the destination, most SNR...). Some protocols needs to exchange periodic short messages between nodes in order to share neighborhood's knowledge (list of neighbors, geographic positions...) known as beacon-based protocols. Other protocols don't need to use periodic beacons and take advantage of the distance in order to calculate a *differ time backoff* allowing to select a relay. SNR (Signal-to-Noise Ratio) can also be used to define the best relay according to radiofrequency characteristics (obstacles, fading ...), called beaconless protocols.

Forwarding strategy

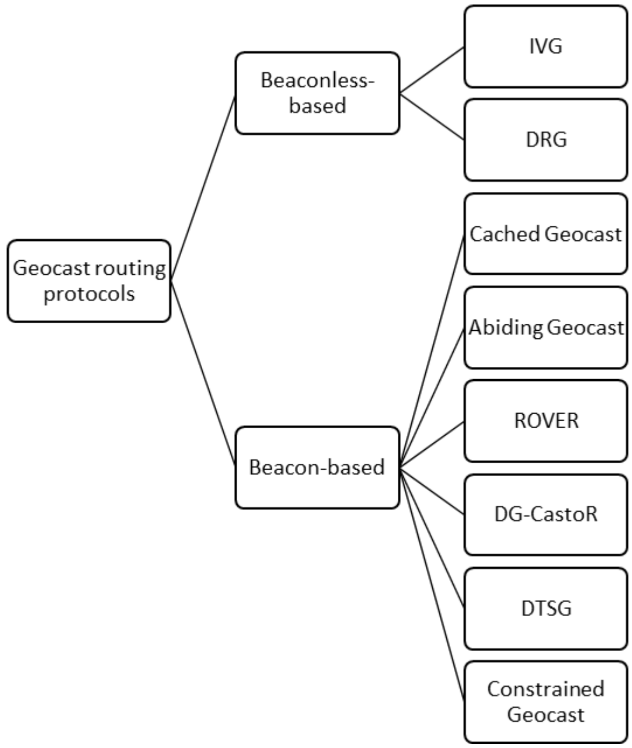


Figure 4: Relay Selection technique based classification of Geocast routing protocols

Forwarding strategy is the technique which allows the geocast message to reach the destination area. *Distance-based backoff time*, *store and forward* or *greedy forwarding* are some other used techniques.

Routing Maintenance

The routing maintenance describes the way the path to the destination area is found and can either be *proactive*, *reactive* or *Hybrid*. Figure 4 shows our relay selection technique classification and Table 1 shows a comparison of the presented Geocast Routing Protocols for VANETs.

5 Background

Geocast routing in VANETs consists of routing a message generated from a single source vehicle to all vehicles belonging to a well geographically defined destination area ZOR (Zone of Relevance). Literature provides a large range of papers dealing with geocast routing in VANETs. We can cite IVG [4], cached Geocast [12], Abiding Geocast [13], DRG [7], ROVER [9], DG-CastoR [2], Mobicast [5], DTSG [15], constrained Geocast [17], Geocache [11], etc. These protocols could be classified according to different parameters as the used relay selection technique (beacon-based or beaconless-based), the used recovery mode strategy or the used forwarding strategy.

In most geocast routing protocols mentioned above, the forms of ZORs are assumed to be of circular or rectangular shape and confined in a unique geographical zone. This makes the representation of forms of ZORs, their origin and positioning arbitrary and are choosen according to the scenarios and motivational needs of authors. In our current work, we delegate affectation of geographic destination areas (ZORs) to a competent authority (as road safety services) which will provide the coordinates or designations of stretches of roads where vehicles will be likely affected by an event (accident, for in-

	IVG	**Cached Geocast**	**Abiding Geocast**	**DRG**	**ROVER**	**DG-CastoR**	**Mobicast**	**DTSG**	**Constrained Geocast**	**Geocache**
Periodic Beacons	No	Yes	Yes/No	No						
Forwarding Strategy	Greedy Forwarding	Store and Forward	Greedy Forwarding	Greedy Forwarding	Multi hop			Multi hop		
Routing Maintenance	Reactive	Reactive		Reactive	Reactive			Reactive		
Scenario	Highway	Highway & Ubran	Highway & Ubran	Highway	Ubran	Ubran	Highway & Ubran	Highway (sparse)	Highway	Urban
Recovery strategy	Flooding	Ranged Forwarding	Store and Forward	Flooding	Flooding			Flooding		
Infrastructure Requirement	No	No	Yes/No	No	No	No	No	No	Yes	No
Mobility of destination zone	No	No	No	No			Yes			
Digital map	No	No	No	No	No		No	No		
Control Packet overhead	Low	Low			High			Moderate		
Spatial relevance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time constraint	No	No		No			Yes			
Year	2003	2004	2005	2007	2007	2008	2009	2010	2010	2011

Table 1: Geocast Routing Protocols Comparison

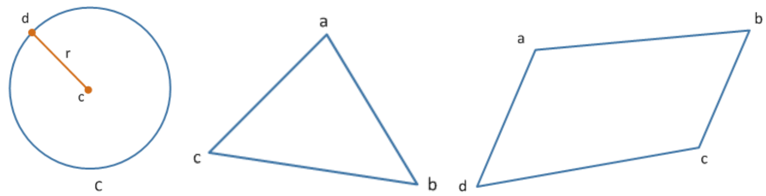
stance). It will also provide its nature, location, duration and why not periodic pictures or even videos. An appropriate algorithm on on-board unit inside vehicles can be implemented for the road accidents case. It will consider the position of the concerned vehicle, the rules of circulation traffic and a digital map of the city, in order to process designations of relevant destination areas.

5.1 Zone of Relevance shapes

Knowing that roads' forms are either geometrically simple taking the form of straight lines and turning in elliptical or circular arc, or can be in some places of any forms. In order to cover all forms of roads, we consider that the road network is represented by a two dimensional Euclidean plane geometry. Moreover, we choose simple geometrical forms of *ZOR*s, so that they will be easy to implement and represent mathematically.

5.1.1 Circle shape

Simple geometrical form represented by the knowledge of two information: coordinates of the center and its radius. For the sake of implementation, we represent all the *ZOR*s' forms by their coordinates. We represent the circle shape by the coordinates of its center and those of one point of its contour. In



(a) Circle shape (b) Triangle shape (c) Quadrilateral shape

Figure 5: Zone of Relevance shapes

Figure 5a, the circle C is represented by the coordinates of its center c and the point d where the distance between them is the radius r: $\{(x_c, y_c), (x_d, y_d)\}$.

5.1.2 Triangle shape

As illustrated in Figure 5b, a triangle T is represented by the coordinates of its three corners: $\{(x_a, y_a), (x_b, y_b), (x_c, y_c)\}$.

5.1.3 Quadrilateral shape

A quadrilateral Q is a polygon with four sides (or edges) and four vertices (or corners) represented by the coordinates of its corners: $\{(x_a, y_a), (x_b, y_b), (x_c, y_c), (x_d, y_d)\}$. Figure 5c illustrates this shape.

We note here the use of only convex and concave forms, because the complex quadrilateral in our case can be represented by two triangles.

Some remarks:

- The naming of the corners of forms follows arbitrarily the clockwise.
- The choice of these three shapes is motivated by their simplicity of representation and by their identification through the number of their coordinates.
- It is possible to enlarge our set of shapes to infinite by confining the space occupied by the *ZOR* to represent it as it is in reality. However, in implementation, more a form is represented by several coordinates, more the time spent in processing this form is longer. For this reason, we reduce the set of forms in our model to 3 simple geometrical ones.

The three considered shapes can cover several places and can be used in case of curved routes as illustrated in figure 6.

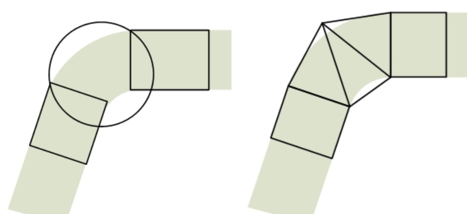


Figure 6: Curved routes covered by the considered shapes.

5.2 *ZOR* is a set of sub-*ZOR*s

We consider the scenario illustrated by Figure 7. If the red star represents an accident that happens in lane B_l (the left lane of the road B after the junction), vehicles belonging to sections $A_l(Z_1)$, $A_r(Z_3)$ and $B_l(Z_2)$ at the entrance of the junction need to be informed about the accident. Thus, vehicles that want to take this road affected by the event can act to find an other path. This facilitates the flow at the level of the intersection.

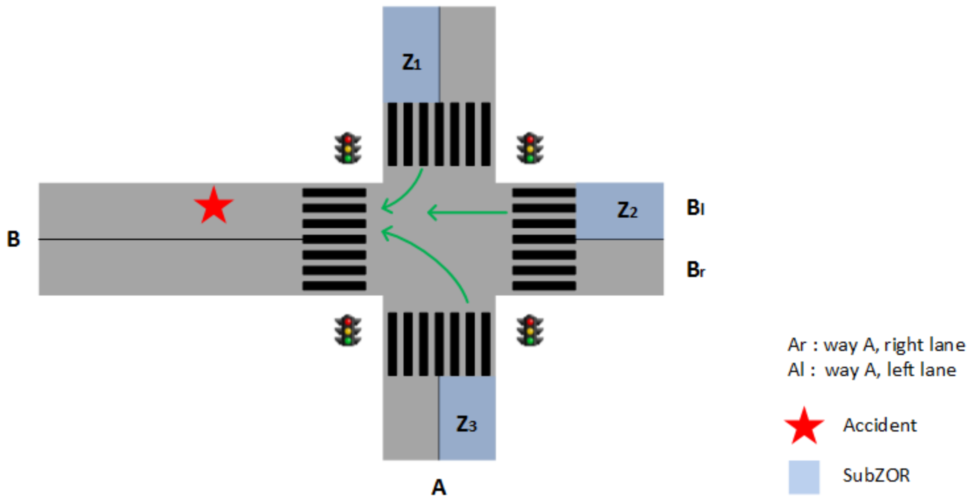


Figure 7: Example of relevant Sub-*ZOR*s.

We can also consider the scenario of an emergency vehicle that announces its arrival at a crowded place as it advances on the road.
We note that the intersection of some parts of the Sub-*ZOR*s is probable and acceptable. In this case, vehicles belonging to these few locations receive the same message twice; thus, they ignore the second.

5.3 Challenges and Idea of resolution

After we presented our coverage technique of sub-*ZOR*s using simple geometric shapes, we face the challenge of proposing an optimal technique to transmit messages from a single source to all vehicles located in different sub-*ZOR*s in order to cover the total *ZOR*. We consider the scenario of road network illustrated in Figure 8, where S represents a unique source vehicle and A, B, C sub-*ZOR*s composing the same *ZOR*. In this scenario, the same message will take approximately the same path to reach A, B and C through vehicles p and q. In the case where S sends few messages to A, B and C, the problem of overloading the network does not arise. However, when S generates a considerable size of data (as video streaming), the use of greedy forwarding will generate three times the same stream (destined to A, B and C) at p-level and two times the same stream (destined to A and C) at q-level.

We previously mentioned that a geocast message is destined for all vehicules located in the same *ZOR* and in our illustration above, we proved that a *ZOR* is a set of sub-*ZOR*s. Thus, the content of the same geocast message is destined to reach all vehicles in different sub-*ZOR*s. Also, we have noted in our state of art the effectiveness of greedy forwarding technique through algorithms like IVG [4], DRG [7], etc. as well as the problem of local maximum and its solutions proposed in these papers. In order to obtain the best results in term of messages overhead and time processing, we provide in the next section a technique permitting us to determine whether some sub-*ZOR*s are in the same direction in order to

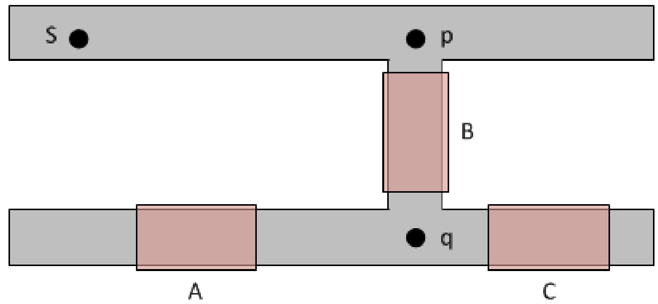


Figure 8: Message Transmission Scenario.

address them the same message stream.

6 Vision angle routing technique

Before a source S sends a geocast message, it calculates the distance between its own position and the nearest point of the ZOR (or the different sub-ZORs).

In two-dimentional plan, the distance between two points $A(x_A, y_A)$ and $B(x_B, y_B)$ is defined in (1).

$$d_{AB} = \sqrt{(x_B - x_A)^2 + (y_B - y_A)^2} \tag{1}$$

Depending on the form of the sub-ZOR destination, the distance between the source S and the sub-ZOR is calculated as following:

6.1 Circular sub-ZOR C

$$d_{SC} = \min(d_{Sd}, d_{Sc}) = d_{Sd} \tag{2}$$

Where c, r and d are the center of the circular sub-ZOR C, its radius and the nearest point on its contour respectively. The radius $r = d_{Sc} - d_{Sd}$.

6.2 Triangular sub-ZOR T

$$d_{ST} = \min(d_{Sa}, d_{Sb}, d_{Sc}) \tag{3}$$

Where a, b and c are the three corners of the triangular sub-ZOR T.

6.3 Quadrilateral sub-ZOR Q

$$d_{SQ} = \min(d_{Sa}, d_{Sb}, d_{Sc}, d_{Sd}) \tag{4}$$

Where a, b, c and d are the four corners of the quadrilateral sub-ZOR Q.

Figure 9 illustrates our vision angle technique itself based on the distance between the source and the different sub-ZORs. We consider S as the source of the geocast message M, and A and B two sub-ZORs constituting the total ZOR. When S needs to inform the sub-ZORs A and B about an event, it firstly calculates the distances d_{Sa} and d_{Sb}. In our case, sub-ZOR A is closer to S than sub-ZOR B ($d_{Sa} < d_{Sb}$). Thus, S needs to know if sub-ZOR B is in the same direction as sub-ZOR A. In other words, is sub-ZOR B accessible via sub-ZOR A or, does B belongs to the vision angle of S through A? The angle θ represents the angle $\hat{Sab}$ of the triangle Sab. The angle γ, is an arbitrary vision angle fixed according

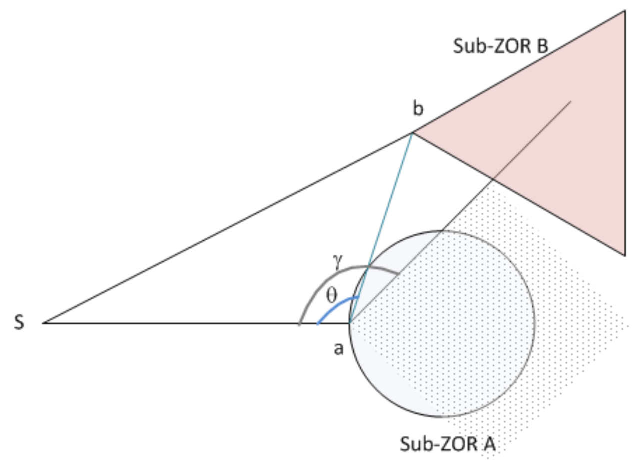


Figure 9: Geometrical vision angles based routing technique.

to different parameters (speed of vehicles, number of vehicles, etc.). Applying the Formula (5) to the scenario above, we conclude that sub-ZOR B is not in the same direction as sub-ZOR A. So, source S sends two occurrences of the geocast message destined to A and B respectively.

$$\frac{Sa^2 + ab^2 - Sb^2}{2 * Sa * ab} \geq cos(\gamma) \tag{5}$$

Where $\frac{Sa^2+ab^2-Sb^2}{2*Sa*ab} = cos(\theta)$ (law of cosines in trigonometry).

If $\theta \leq 90°$, the source S sends two messages to the sub-ZORs A and B. If $\theta \in]90°, 180°]$, S sends one message intended to reach A and B (via A).

7 GeoSUZ Protocol

7.1 Position of the Source

We define S as the source vehicle and ZOR as the destination area. We can highlight two cases of geocast routing: either when S belongs to the ZOR or when S is out of the ZOR. We note that ZOR is a destination area of one of the three forms introduced above (C, T or Q) and can be in a confined area or in different geographical areas. We describe ZOR as :

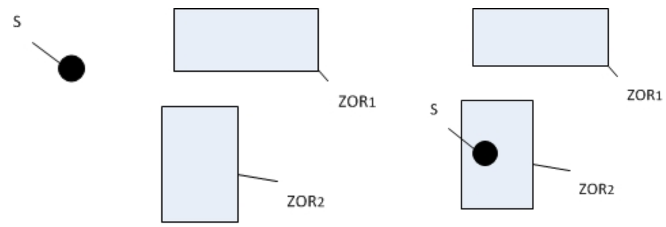
$$ZOR = subZOR_1 \cup subZOR_2 \cup ... \cup subZOR_n \tag{6}$$

where $n \geq 1$

7.1.1 Source S in ZOR

Figure 10b shows the case where the source belongs to the ZOR. In this case, a simple broadcast overcomes to the principal of delivering the geocast message to all the vehicles located in the ZOR. However, in the case of fragmented ZOR, the $subZOR_2$ will be covered while the $subZOR_1$ not, because in simple broadcast, each vehicle around the $subZOR_2$ limits the flooding to the same sub-ZOR surounding it ($subZOR_2$ in this case).

$$S \in ZOR \tag{7}$$



(a) S out of ZOR. (b) S in ZOR.

Figure 10: Position of the source S with respect to ZOR.

7.1.2 Source S out of ZOR

In the case of unique ZOR shape, geocast routing can be ensured either by GeoUnicast routing or by the use of zone of forwarding ZOF [7]. However, in the case of multiple sub-ZORs, it is challenging to provide an optimal routing technique to address the problem.

Figure 10a shows the case where the source is out of the ZOR.

$$S \notin ZOR \tag{8}$$

7.2 Geocast Message structure

The geocast message M is defined as :

$$M[m,S,Z] \tag{9}$$

Where $M[m]$ is the message content, $M[S]$ is the sender ID, and $M[Z]$ the coordinates of the destination area.

7.2.1 Pre-fragmented message

When the same geocast message destined to two sub-ZORs Z_1 and Z_2 (or more) follows the same path due to the use of a recovery mode in greedy forwarding technique, the message M is pre-fragmented and defined as :

$$M_1[m,S,\{Z_1\}].M_2[m,S,\{Z_2\}] \tag{10}$$

We note that all the sub-ZORs are different in each pre-fragmented message.

Algorithm 1 : Pre_fragment($M[m,S,\{Z_1,Z_2\}]$)

IF [not($GF(Z_1)$) and $GF(Z_2)$ and $RM(Z_1)$==$GF(Z_2)$] or [$GF(Z_1)$ and not($GF(Z_2)$) and $GF(Z_1)$==$RM(Z_2)$] or [not($GF(Z_1)$) and not($GF(Z_2)$) and $RM(Z_1)$==$RM(Z_2)$] THEN
return ($M_1[m,S,\{Z_1\}].M_2[m,S,\{Z_2\}]$) ;
ENDIF

The pre-fragmentation case is given in Algorithm 1 where $RM(Z_1)$ is the recovery mode procedure applied to the sub-ZOR Z_1, and $GF(Z_2)$ the greedy forwarding procedure applied to the sub-ZOR Z_2. We can read the first test as: if there is no neighbor using greedy forwarding method to reach the first sub-ZOR Z_1 while there is a neighbor to reach Z_2, and the recovery mode of Z_1 gives us the same neighbor to reach Z_2 using greedy forwarding, then we pre-fragment the message M and send it to that neighbor.

7.2.2 Fragmented message

When the current node is able to perform the greedy forwarding technique, it fragments the message into different sub-messages addressing the different sub-ZORs. The Formula 9 becomes :

$$M_1[m,S,\{Z_1\}],M_2[m,S,\{Z_2\}] \quad (11)$$

Here, we note that the two messages $M_1$and M_2 are forwarded separately in different paths.

The Algorithm 2 illustrates the fragmentation case.

Algorithm 2 : Fragment($M_1[m,S,\{Z_1\}].M_2[m,S,\{Z_2\}]$)

IF [$GF(Z_1)$ and $GF(Z_2)$ and $GF(Z_1)$=!$GF(Z_2)$] or [not($GF(Z_1)$) and $GF(Z_2)$ and $RM(Z_1)$=!$GF(Z_2)$] or [$GF(Z_1)$ and not($GF(Z_2)$) and $GF(Z_1)$==$RM(Z_2)$] or [not($GF(Z_1)$) and not($GF(Z_2)$) and $RM(Z_1)$==$RM(Z_2)$] THEN
return ($M_1[m,S,\{Z_1\}],M_2[m,S,\{Z_2\}]$);

7.2.3 Defragmented message

Pre-fragmented messages can be defragmented in the case when the sub-ZORs are currently able to be addressed sequentially. The formula 9 becomes :

$$M[m,S,\{Z_1,Z_2\}] \quad (12)$$

We note that a fragmented messages cannot be defragmented.

Defragmentation case is presented as shown in Algorithm 3.

Algorithm 3 : Defragment($M_1[m,S,\{Z_1\}].M_2[m,S,\{Z_2\}]$)

IF [$GF(Z_1)$ and $GF(Z_2)$ and $GF(Z_1)$==$GF(Z_2)$] THEN
return($M[m,S,\{Z_1,Z_2\}]$);

7.3 GeoSUZ Algorithm

Algorithm 4 presents our GeoSUZ routing protocol. The source vehicle (or intermediate relay vehicles) defines its γ angle then calculates and orders all distances between itself and the different sub-ZORs. At this time, it generates the geocast message M intended to reach all the sub-ZORs. Here, the test if the current node belongs to the nearest sub-ZOR is done. If it is true, then it broadcasts (only in the current sub-ZOR) the message M, removes the current sub-ZOR from M and tries out the pre-fragment procedure which processes the geomertical vision angle. After that, a set of tests on the message M are made. When M is pre-fragmented, it is geoUnicasted. When it is fragmented, two messages M_1 and M_2 are GeoUnicasted. Now, if it is neither one nor the other case, the message is defragmented and GeoUnicasted to the last or the unique sub-ZOR.

Algorithm 5 shows the pre-fragmentation procedure based on our vision angle technique presented in 6.

8 Numerical results

Figure 11 presents numerical results of the application of two routing protocols to the scenario of figure 8. The first is GPSR (Greedy Perimeter stateless Routing for wireless networks) [3] based on Greedy

Algorithm 4 : GEOSUZ algorithm

Define γ
Calculate all D_{SZ_i} where Z_i the sub-ZOR $i : i = 1, 2, ..., n$
Ascending order of D_{SZ_i} into D_{SZ_k} where $k = 1, 2, ..., n$
GENERATE($M[m,S,Z_k]$); // S generates or receives M
IF Current_Node in $M[Z[1]]$ THEN
GeoBroadcast($M[m,S,Z[1]]$);
SUB($Z[1]$, M); // $M[m,S,Z \setminus Current\_subZOR]$
PREFRAGMENT(M); //$M_1[m,S,Z].M_2[m,S,Z]$ in Algorithm 5
END IF
\\ Pre-fragmentation
IF (pre_fragment(M)) THEN
GeoUnicast(M);
ELSE \\ Fragmentation
IF (fragment(M)) THEN
GeoUnicast(M_1);
GeoUnicast(M_2);
ELSE \\ Defragmentation
IF (defragment(M)) THEN
GeoUnicast(M, GF($M_1[Z[1]]$));
END IF
END IF
END IF

Algorithm 5 : PREFRAGMENT vision angle based procedure

$h = 1$; // Z_h the nearest sub-ZOR
$M_1[Z] = Z_h$;
$M_2[Z] = \phi$;
$j = 1$;
WHILE $j < k$ THEN
IF $S\hat{Z}_h Z_{j+1} \geq \gamma$ THEN
ADD(Z_{j+1}, M_1); // $M_1[m,S,\{Z_h, Z_{j+1}\}]$
ELSE // $S\hat{Z}_h Z_{j+1} < \gamma$
ADD(Z_{j+1}, M_2);
END IF
$j = j + 1$;
END WHILE

Forwarding technique, and the second is our GeoSUZ protocol which is an adaptation of GPSR to the context of geocast routing with multiple sub-ZORs. In this scenario, we assume that the source S sends 3000 different packets to sub-ZORs A, B and C. These packets cross p and q nodes since all sub-ZORs are in the same direction. We note here that GeoSUZ allows a considerable gain of bandwidth compared to GPSR, by decreasing significantly the number of messages sent over the network.

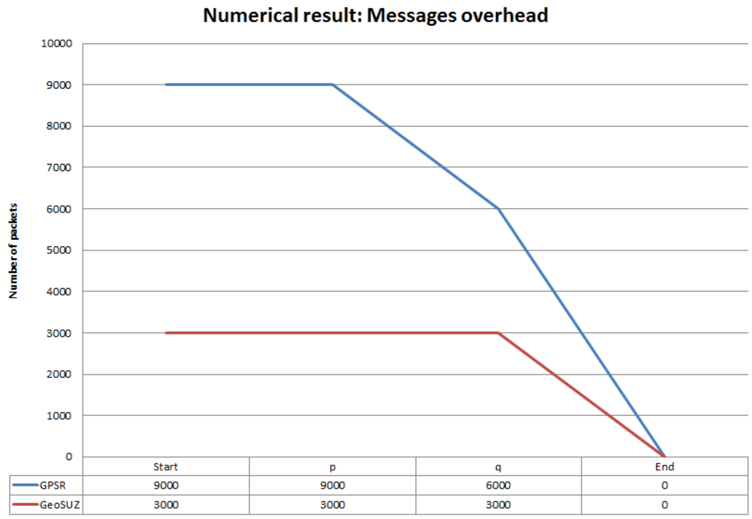


Figure 11: Messages overhead

9 Conclusion

In this paper, we have presented different categories of routing protocols in VANET networks with a particular interest in geocast routing techniques. We have then provided a classification of some known geocast routing protocols mainly according to the relay selection technique they use. We introduced a new geocast routing protocol in Sub-ZORs (GeoSUZ) for VANETs based on a geometrical vision angles technique which allows to know if two sub-ZORs are in the same direction in order to send them a single message and hence, reduce messages overhead. For that purpose, we have choosen simple geometrical forms of sub-ZORs so that they would be easy to implement and represent mathematically. Compared to a well known geocast routing protocol GPSR [3], some numerical results show that GeoSUZ segnificantly reduces the number of messages sent over the network. To confirm the obtained numerical results, we are in phase of implementing and evaluating the performances of GeoSUZ protocol on NS2 Simulator. Finally, the next step in our study is an optimized diffusion technique inside the sub-ZORs.

References

[1] S. Allal and S. Boudjit. Geocast Routing Protocols for VANETs: Survey and Guidelines. In *Proc. of the 6th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS'12), Palermo, Italy*, pages 323–328. IEEE, July 2012.

[2] T. Atechian and L. Brunie. DG-CastoR: Direction-based GeoCast Routing Protocol for query dissemination in VANET. In *Proc. of the 4th International Workshop on Localized Communication and Topology Protocols for Ad hoc Networks (LOCAN'08), Atlanta, Georgia*. IEEE, September 2008.

[3] K. B. and K. H. T. GPSR: greedy perimeter stateless routing for wireless networks. In *Proc. of the the 6th annual International Conference on Mobile Computing and Networking (MobiCom'00), Boston, Massachusetts, USA*, pages 243–254. ACM Press, August 2000.

[4] A. Bachir and A. Benslimane. A multicast protocol in ad hoc networks inter-vehicle geocast. In *Proc. of the 57th IEEE Semiannual Vehicular Technology Conference (VTC 2003-Spring), Seogwipo, Korea*, volume 4, pages 2456–2460. IEEE, April 2003.

[5] Y. S. Chen, Y. W. Lin, and S. L. Lee. A mobicast routing protocol for vehicular ad hoc networks. *ACM/Springer Mobile Networks and Applications (MONET)*, 15(1):20–35, 2010.

[6] A. Festag, W. Zhang, L. Le, and R. Baldessari. *Geocast in Vehicular Networks*, chapter 14, pages 377–407. 2009.

[7] H. P. Joshi, M. L. Sichitiu, and M. Kihl. Distributed robust geocast multicast routing for inter-vehicle communication. In *Proc. of the 1st WEIRD Workshop on WiMAX, Wireless and Mobility, Wireless and Mobility, Coimbra, Portugal*, pages 9–21, May 2007.

[8] J. Kakarla, S. S. Sathya, B. G. Laxmi, and R. B. B. A Survey on Routing Protocols and its Issues in VANET. *International Journal of Computer Applications*, 28(4):38–44, August 2011.

[9] M. Kihl, M. Sichitiu, T. Ekeroth, and M. Rozenberg. Reliable geographical multicast routing in vehicular ad hoc networks. In *Proc. of the 5th International Conference on Wired/Wireless Internet Communications (WWIC'07), Coimbra, Portugal, LNCS*, volume 4517, pages 315–325. Springer-Verlag, May 2007.

[10] R. Kumar and M. Dave. A comparative study of Various Routing Protocols in VANET. *International Journal of Computer Science Issues (IJCSI)*, 8(1):643–648, July 2011.

[11] M. Lakas and A. Shaqfa. Geocache: Sharing and Exchanging Road Traffic Information Using Peer-to-peer Vehicular Communication. In *Proc. of the 73th IEEE Vehicular Technology Conference (VTC-Spring'11), Budapest, Hungary*, pages 1–7. IEEE, May 2011.

[12] C. Maihofer and R. Eberhardt. Geocast in vehicular environments: Caching and transmission range control for improved efficiency. In *Proc. of 2004 IEEE Intelligent Vehicles Symposium (IV'04), Parma, Italy*, pages 951–956. IEEE, June 2004.

[13] C. Maihöfer, T. Leinmüller, and E. Schoch. Abiding geocast: time–stable geocast for ad hoc networks. In *Proc. of the 2nd ACM international workshop on Vehicular ad hoc networks (VANET'05), Cologne, Germany*, pages 20–29. ACM Press, September 2005.

[14] B. Paul, M. Ibrahim, and M. A. N. Bikas. VANET Routing Protocols: Pros and Cons. *International Journal of Computer Applications*, 20(3):28–34, April 2011.

[15] H. Rahbar, K. Naik, and A. Nayak. DTSG: Dynamic Time-Stable Geocast Routing in Vehicular Ad Hoc Networks. In *Proc. of the 9th IFIP/IEEE Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net'10), Juan-les-Pins, France*, pages 198–203. IEEE, June 2010.

[16] Y. Wang and F. Li. Vehicular Ad Hoc Networks. Guide to Wireless Ad Hoc Networks, Computer Communications and Networks. Springer, London, pp. 503–525, 2009.

[17] W. K. Wolterink, H. Geert, and K. Georgios. Constrained Geocast to Support Cooperative Adaptive Cruise Control (CACC) Merging. In *Proc. of the 2nd IEEE Vehicular Networking Conference (VNC'10), Jersey City, New Jersey, USA*, pages 41–48. IEEE, December 2010.

Salim ALLAL received his MSc research degree in networks, Internet and Multimedia Applications from Galilée Institute - University of Paris 13 (France) in 2010. Since, Salim is a PhD student working on vehicular ad hoc networks (VANETs) within the network team of the L2TI Laboratory (Laboratoire de Traitement et Transport de l'Information), Galilée Institute - University of Paris 13. His interests are centered on mobility management in heterogeneous networking environments, location-based services and networking security.

Saadi BOUDJIT is Associate Professor (Maître de conférences) and member of the L2TI laboratory (Laboratoire de Traitement et Transport de l'Information) at the university of Paris 13 since September 2007. He is working on Wireless Mesh, Sensor and Ad hoc Networks and involved in several research projects. From November 2006 to July 2007, Saadi joined the network and computer science department of TELECOM ParisTech in Paris as a Post-Doctoral researcher. He was involved in a research project focusing on support of rapid/massive mobility and of multi frequency in OLSR routing protocol. Saadi has prepared his PhD thesis in Computer Science within Hipercom Research Team at INRIA from September 2003 to September 2006. His research interests include wireless networks, operating systems, parallel and distributed computing.