

Towards Supporting GPS-unequipped Vehicles in Inter-Vehicle Geocast¹

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Abstract

IVG (Inter Vehicle Geocast) is a GPS-based Inter-Vehicle Communication mechanism used for alarm message dissemination among vehicles in a highway in risk situations. In this paper, we propose an improvement to IVG towards supporting its interoperability in environments where "GPS-U" GPS-unequipped vehicles are present. They are vehicles that are not equipped with GPS devices or they have some problems to obtain their positions, via GPS, due to some obstacles. The proposed solution allows GPS-U vehicle to compute its position with the help of its neighbors that are equipped with GPS devices, called GPS-E neighbors. Analyses show that the optimal performances of IVG can be reached even when the rate of GPS-U vehicle is 40%.

1. Introduction

Intelligent transportation Systems (ITS) have been investigated for many years in Europe, Japan and North America, with the aim of providing new technologies able to improve safety and efficiency of road transport [1]. In the past 15 years, major research programs have been involved in Inter Vehicle Communication (IVC) based on wireless cellular networks.

Recently, the democratisation of GPS technology and the progress in mobile ad hoc networking have led to the appearance of new inter vehicle communication protocols [2, 3, 4]. Based on the use of GPS devices, these protocols have been mainly designed for safety driving by the dissemination of urgent information, called alarm messages, in the case of accidents, fogs, etc, among the vehicles. In [2], the proposed solution called RBM Role Based Multicast was designed to overcome fragmentation in the ad hoc network composed by the vehicles and to reduce the number of redundant broadcasts of alarm messages. In [3], two other solutions were proposed, Track Detection (TRADE) and Distance Defer Time

(DDT). In TRADE, each vehicle wanting to disseminate an alarm message has to determine positions and driving directions of its neighbors. DDT does not rely on neighbors maintenance, but inserts distance-based defer time slots for each rebroadcast alarm message. When a vehicle executing DDT receives an alarm message, it sets-up a timer in order to determine if it is useful to rebroadcast that message. In [4], we proposed IVG, Inter Vehicle Geocast, an inter vehicle message dissemination protocol that improves bandwidth utilization, reduce delays and packet loss since it avoids neighbors maintenance signalling, and overcomes fragmented networks by the use of dynamic relays.

Since all proposed algorithms: IVG, DDT, RBM and TRADE are based on geographical positioning system (i.e. GPS), we analyze in this paper the possibility of the interoperability between GPS-equipped and GPS-unequipped vehicles in IVG, with the aim to give GPS-unequipped vehicles pertinent information about the accident. The solution is based on cooperation between GPS-E vehicles in order to help GPS-U vehicles to get their positions. Although the knowledge of the exact position is not always possible, the GPS-U vehicle can obtain some useful information such as driving direction and distance from the accident.

2. IVG Overview

IVG is mainly designed for effective alarm message dissemination in the ad hoc network of vehicles in a highway. IVG is based on geographical multicast, which consists in determining the multicast group according to the driving direction and the positioning of the vehicles. The multicast is restrained to the so-called risk areas. First, broken vehicle (or accident) begins to broadcast an alarm message to inform the other vehicles of the situation. Since the accident vehicle can just inform its one-hop neighbors, some other vehicles have to rebroadcast the alarm message to inform the vehicles located at more than one hop from the accident. The vehicle that performs the rebroadcast is called relay.

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Relays in IVG are designated in fully distributed manner. The way with which a node is designated as relay is based on distance defer time algorithm. The node that receives an alarm message does not rebroadcast it immediately but has to wait some time to take a decision about rebroadcast. When the defer time expires, if it does not receive the same alarm message from another node behind it, it deduces that there is no relay node behind it. Thus it has to designate it self as a relay and starts to broadcast the alarm messages in order to inform the vehicles which could be behind it.

The process of message dissemination with IVG depends on the rate of vehicles equipping GPS in the road. We believe that the success of IVG depends on its performances with GPS-unequipped vehicles. In the next section, we propose a solution that allows the well functioning of IVG even with GPS-unequipped vehicles. The performances of that solution depend on the rate of GPS-unequipped vehicles and on the density of vehicle in the highway.

3. GPS-Unequipped Algorithm

Since each vehicle executing IVG relies on the periodic computation of its driving direction, previous and current positions, some modifications have to be envisaged to make GPS-U vehicles know these positions when the communication with the GPS satellite is not possible. IVG can be executed normally if these positions are accurately known. However, in some situations GPS-U vehicles can't obtain their exact previous and current positions. In that case, these vehicles can't participate in the process of alarm message dissemination. However, they can obtain some information about the driving direction and the distance from the accident. This can help the driver to take decisions. For example, if the accident happens in the opposite driving direction according to the accident in a divided highway there will be no need to brake.

In order to obtain and refresh its position, a GPS-U vehicle, say S, periodically broadcasts a PREQ (Position Request) message to its one-hop neighbors. When a GPS-E vehicle receives a PREQ, it creates a PREP (Position Reply) message, includes its current position in that message, and sends it back to S. The knowledge of the exact position of S depends on the number and the positions (not all aligned) of neighbors sending PREP messages. S can compute its exact position if it receives at least three PREP from three different vehicles (Fig 1).

When $S(x,y)$ receives three PREP messages from three different vehicles, say $V_1(x_1,y_1)$, $V_2(x_2,y_2)$ and V_3 , it uses a radiolocation method (i.e., signal strength) in order to determine the distances d_1, d_2 and d_3 from V_1, V_2 and V_3 . In this case the exact position of S can be easily calculated.

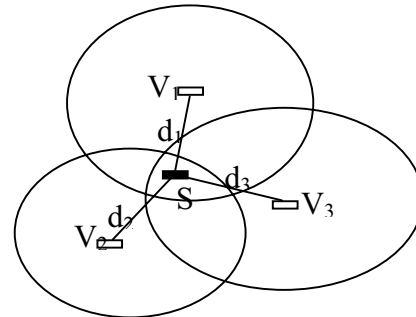


Fig. 1 - Location using three non-aligned GPS-E vehicles

The algorithm of IVG can be executed normally if the GPS-U vehicles can compute their positions. In fact, GPS-U vehicle uses PREP messages in order to get its position instead of GPS satellite. However this is not always possible because in some cases, where the number of PREP messages is less than three, the exact position cannot be known. We have studied these cases: when S receives two, one, or zero PREP. To allow computation of positions and driving direction of vehicles, we distinguished the case where the exact position and the driving direction can or cannot be known.

4. Conclusion

We have proposed an improvement to the basic IVG algorithm towards supporting its interoperability in environments where GPS-U vehicles are present. We show that the performances of IVG are optimal with a GPS-E rate is 60%. We have also showed that we can improve the performances of our method when GPS-E rate is 40% by the augmentation of the transmission range.

References

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