Relative driving direction detection for safety and non safety applications in vehicular communication networks.

Dr. Hamid Menouar and Dr. Massimiliano Lenardi
HITACHI Europe SAS, Information and Communication Technologies Laboratory (ICTL)
955 Routes des Lucioles, 06560 Sophia Antipolis, France
{hamid.menouar, massimiliano.lenardi}@hitachi-eu.com

***Abstract*—In vehicular communication networks vehicles keep exchanging geographical information. A vehicle should periodically inform other vehicles around about its geographical information. Each vehicle must be capable of geolocalization of its self, by using a geolocalization system such us GPS. When an event (e.g. traffic accident) happens on the road, some warnings are transmitted on the air to inform vehicles located around about this event. These warnings inform about the nature of the event and also about its exact location on the road. When receiving these warnings, a vehicle should be able to determine whether the even is geographically relevant to it or not. When having a digital map, the geographical relevance detection becomes relatively easy to manage. When a vehicle does not have access to a digital map, the geographical relevance could be determined just based on GPS information. In this paper we propose a new and efficient mechanism for geographical relevance detection based only on GPS information, which works even when no digital map information is available.**

Keywords- relative direction, driving direction, relevance check, vehicular communication networks.

I. Introduction

The geolocalization is a fundamental feature in vehicular communication networks, where each vehicle needs to know about its own physical location in real time. The geographical information are used by applications, but also by lower layers such as at network layer where data routing protocols use vehicless' position to rout data. To know its own physical position, a vehicle may localy use a geolocalization system such as GPS or coming Galileo. To keep each vehicle aware about the geographical position of surrounding vehicles, each vehicle has to periodically inform its neighbors about its own geolocalization, this is done by means of periodic messages (beacons) exchanges.

The geolocalization capability feature which characterizes the vehicular communication networks makes several safety and non safety related applications possible. Examples of safety related applications have been demonstrated during the forum organized by the Car-to-Car Communication Consortium (C2C-CC) in October 2008 [1], [2]. In case of « Road work » use case, a specific Road Side Unit (RSU) was installed on the road and continuously transmitting on the air information to inform the incoming vehicles about the nature and the location of the road work event. This information is transmitted on the air by means of wireless communication technology. Because of the nature of wireless transmissions, all vehicles located around the RSU, and not only those driving on the road where the RSU is located, may receive the warning information. Among the vehicles located around the RSU, means those who receive the warning information, only those driving toward the road work location are concerned by the warning information, we say the transmitted information are relevant to those vehicles.

To determine the relevance of received information, a vehicle could refer to a digital map to determine whether he is driving or not toward the corresponding event on the road. If the vehicle is driving on the same section of the road as where the corresponding event is located, and it is driving toward this event's location, then it considers this information as relevant and processes it. Otherwise, if the information is not relevant, it should not consider it. In fact, digital maps help in the calculation of the geographical relevance of received information, but unfortunately not all the vehicles are equipped with digital maps. If we want the geographical relevance check mechanism works even when having a vehicle equipped with a basic system, without any digital map, then we should find out a solution which works without the need for a digital map.

In the C2C-CC Demonstrator 2008 [2], a basic solution has been used to calculate the geographical relevance of received information during the the "work on road" use case. The solution consisted on having the RSU attaching to each transmitted information a trace of reference location points (waypoints) that corresponds to the path on the road drawing the relevance area. For the demonstration the number of the waypoints was fixed to eight. When a vehicle receives the transmitted information it calculates the distance from its own location to each waypoint in the trace list, and if it is enough close to one of the waypoints and in the same time driving toward the corresponding event location, then it considers the received information as relevant to it. This solution works fine, and this has already been shown during the C2C-CC demonstration 2008. During the C2C-CC demonstration a simple scenario has been considered, where eight waypoints were enough to represent the geographical relevance area. When dealing with more complicated scenarios, for example when dealing with a geographical relevance area which includes several road sections, then more than eight waypoints will need to be referenced. This may increase quickly the size of the transmitted data when the size of the waypoints list becomes relatively more and more important, which is not suitable in such communication systems where the wireless bandwidth is relatively limited.

In this paper we present a new solution for geographical relevance calculation on which we have already filed a patented [3]. This solution also works without having any digital map information, and without attaching any waypoints list to the transmitted information like it was done in the C2C-CC demonstration. Instead of attaching a list of reference points, in our solution we propose to attach only one reference point and one relevance angle for representing each driving direction of interest. This makes the geographical relevance check solution even when there is no access to any digital map, and also without increasing to much the size of the transmitted data.

In the rest of this paper, we first motivate our contribution in Section II by presenting the problems we want to solve, then we present in Section III our solution for geographical relevance calculation, and finally in SectionIV we conclude our paper.

II. Motivations

When using vehicular communication systems, some applications (safety or non safety related) need to filter information received on the air based on geographical relevance. For example, when having an application which provides to the driver traffic information, this application should not deliver to the driver all received information. It should deliver to the driver only information that could be of his interest. If the application receives some information about a traffic accident, it informs the driver about this accident only if the driver is driving toward the accident or its safety could be affected by the presence of this accident.

Let us take as a concrete example an application which informs drivers about traffic signs' information. This application should get information from traffic signs by mean of wireless communication and then show them to the driver by displaying them on an in-dash screen. Suppose we have a speed limitation sign "A" installed on the road and a vehicle "B" driving around as shown in Figure 1. The traffic sign "A", which is considered as Road Side Unit (RSU), and the vehicle "B" are both equipped with a vehicular communication system which allows both of them to communicate and exchange information by means of wireless communication. The traffic sign "A" keeps transmitting on the air information indicating the speed limit (50 Km/h), its location on the road, the road section concerned by this speed limitation, etc. When receiving the information transmitted by "A", "B" should understand whether this information are of its interest or not. (i.e. if he is going to drive on the road section concerned by this speed limitation).

The vehicle "B" may receive different information transmitted from different RSU even if those are located on neighboring roads where "A" is not driving on. As explained in the Introduction, one solution that could be used to make "B" able to calculate the geographical relevance of received information from different traffic signs, is to refer to the digital map of the surrounding are. When having access to digital maps the geographical relevance check process becomes relatively easy, and this is out of scoop in this paper. Let us concentrate on the situation where the vehicle "B" dos not have access to any digital map, but it has access to GPS information. The GPS is considered as a part of any basic vehicular communication system.

The vehicle "B" keeps getting its own geographical location (latitude, longitude...), thanks to GPS. When receiving information from the traffic sign, we want the vehicles "B" to calculate the geographical relevance of that information, only based on its location information and information provided from the traffic sign (GPS information).

The vehicle "B" knows its position (latitude and longitude) and also its movement heading from GPS. Two vehicles moving on different roads could have the same heading. Thus, when based on heading information only, it is not enough to guaranty a reliable geographical relevance check mechanism.

Better than GPS heading, there is the relative direction which tells exactly whether "B" is driving toward or away from "A". To know whether "B" is moving toward "A" or not, we just need to compare the distance from "B" to "A" at two different points in time as shown in Figure 1. If D_2 is bigger than D_1 then "B" is supposed to be driving toward "A". This distance based solution is not enough efficient when we want to know from which direction "B" is driving toward "A". As you can see in Figure 2, from wherever "B" is approaching "A" (driving toward "A"), the distance D_2 is always smaller than distance D_1.

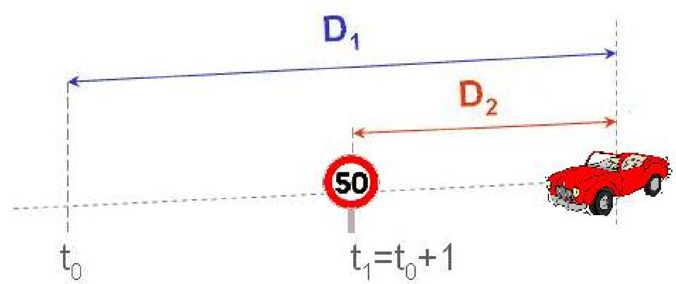

Figure 1. Distance-based relative movement direction detection.

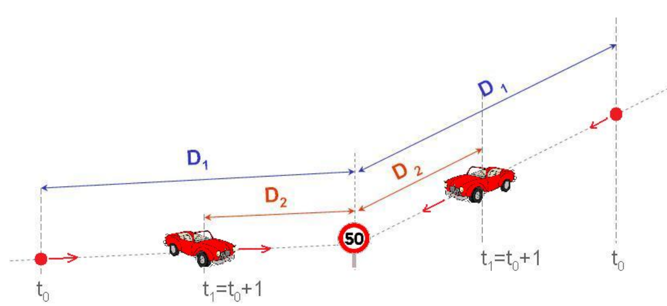

Figure 2. Limitation of distance-based relative movement direction detection.

If the traffic sign “A” is transmitting information that should be for interest of only vehicles moving on a certain road and within a certain direction, then we need to find out a complementary solution. A solution that allows the detection of the movement direction of “B” relatively to “A”, but also the detection the exact direction (road section) from where the driving vehicle “B” is approaching the traffic sign “A”. In this paper we propose such a solution which, only based on GPS information, is able to calculate the relative driving direction which is then used for geographical relevance check. This solution is described in the following section.

III. Relative Driving Direction Detection

To explain our relative driving direction detection mechanism, let us adopt the same example of speed limit sign (RSU) as shown in Figure 3. We have a speed limitation sign “A”, and a red car “B” driving around. Suppose “A” is continuously transmitting data on the air (wireless transmission), and this information is only for interest of vehicles driving on the same road from “Direction 1” as shown in the same Figure3. As you can see, in the area surrounding the traffic sign we have mainly three different roads. We assume that from wherever a vehicle is located on any of those three different roads, it may hear the transmissions of the RSU “A”.

Figure 3. Solution explanation - Scenario 1.

When receiving the speed limit information from the traffic sign “A”, a vehicle should not consider it if it is not driving toward “A” from “Direction1”. Means, if a vehicle is not driving on the same road where the traffic sign is located, or driving in the opposite direction of “Direction1”, it should not consider the speed limit information sent from the RSU as relevant.

To make the vehicle “B” able to know whether the information of speed limit transmitted by “A” is relevant to it or not, we propose that “A” includes to the transmitted information a “Reference position” information. The reference position is a point (latitude and longitude) in the space chosen around the traffic sign in a specific way to indicate the relevance driving direction as shown in Figure 3. The new transmitted information will get the new packet format as shown in Figure 4.

Reference position	RSU position		Related information (e.g. speed limit)
Reference Point (Latitude, Longitude)	RSU Position (Latitude, Longitude)	α_{max}	DATA ...

Figure 4. Transmitted information format when one single information and one single direction is supported.

When receiving information from the traffic sign “A”, the vehicle “B” calculates the distance from its actual own position to the position of the traffic sign, $D_{B2A}(t_1)$, the distance from its actual position to the position of the related reference point, $D_{B2R}(t_1)$), the distance from its position at one second ago to the position of the traffic sign, $D_{B2A}(t_0)$), and the distance from its position at one second ago to the position of the reference point, $D_{B2R}(t_0)$. Once these four distances are calculated, vehicle “B” makes a comparison between them to know relevance of the related received information.

If $D_{B2A}(t_0) > D_{B2A}(t_1)$ and $D_{B2R}(t_0) > D_{B2R}(t_1)$, call it all together condition D, then “B” is supposed to be moving on the direction concerned by the information transmitted from “A”. As shown in Figure 5, when “B” is moving toward “A” from the wrong direction, the condition D is not satisfied.

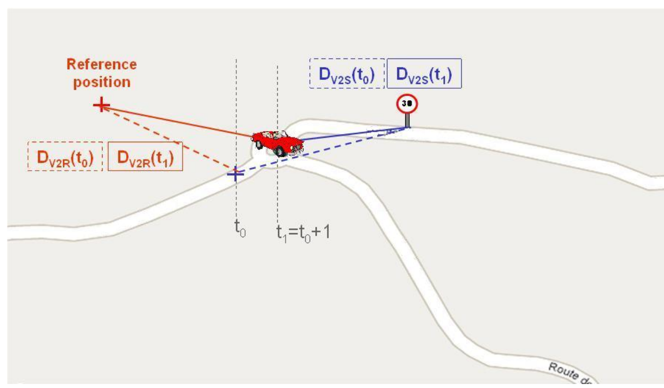

Figure 5. Solution explanation - Scenario 2.

The condition D allows us to determine from which side “B” is moving toward “A”, but this is not enough in certain scenarios. For example, look at the scenario shown in Figure 6. The condition D is satisfied for “B” even when it is not driving toward the traffic sign from the right direction (Direction 1).

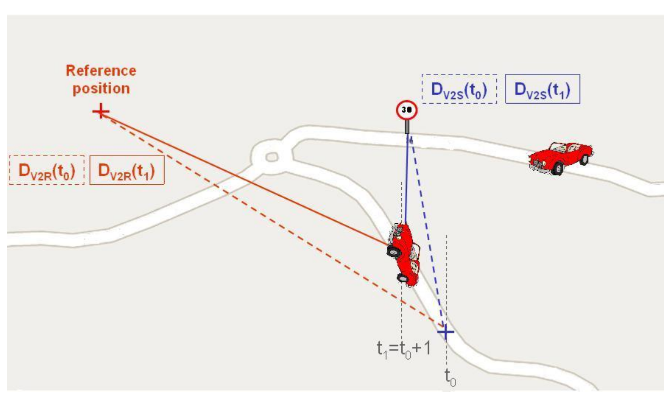

Figure 6. Solution explanation - Scenario 3.

To resolve this limitation we propose to consider also the angle α (relevance angle) formed between [BR] and [AR] as shown in Figure 7. This angle α must be lower than a predetermined maximum angle α_{max} which is fixed depending on the road topology nature. By increasing α_{max} we increase the size of the geographical relevance area.

Therefore, the vehicle "B" should consider the information received from "A" as relevant to it (i.e. "B" is considered as driving toward the traffic sign "A" from the direction "Direction 1"), if, and only if it satisfies the following three conditions:

$$\begin{cases} D_{B2A}(t_0) > D_{B2A}(t_1) \\ D_{B2R}(t_0) > D_{B2R}(t_1) \\ \frac{D_{B2A}(t_0) - D_{B2A}^2(t_1) + D_{B2R}^2(t_1)}{2.D_{B2A}^2.D_{B2R}(t_1)} > \cos(\alpha_{max}) \end{cases}$$

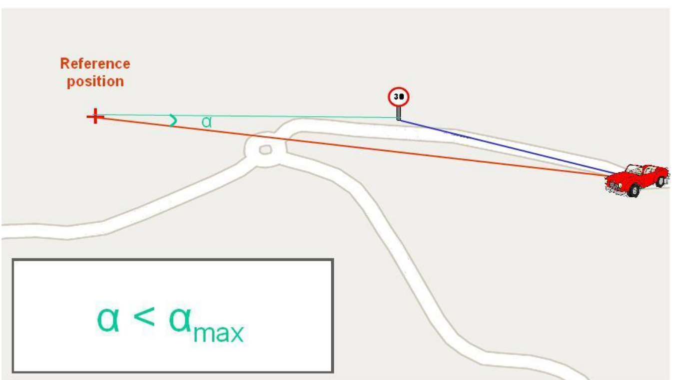

Figure 7. Solution explanation - angle consideration.

The same information transmitted from "A" could be relevant to more than one direction and/or more than one road section. For example, in the same scenario of speed limitation sign as shown in Figure 8, we suppose that the speed limit indication is valid for "Direction 1" on the road where the traffic sign is installed, and also for "Direction 2" on the nearby road. In stead of installing two communication traffic signs (one on each road), with our solution we may install only one traffic sign on one of the two roads which transmits the same information (speed limit) with several reference points and relevance angles (one reference point and relevance angle for each direction of interest) and information on the location of other traffic signs that are located on the other roads (we consider them as virtual RSUs because those traffic signs are not transmitting information). In this specific case where the speed limit is valid for only two directions "Direction1" and "Direction2", two reference points (R1 and R2) are attached to the transmitted information, with the corresponding RSU positions (real limitation speed sign position and the virtual RSU position).

When transmitting the same data which is relevant to different directions and different road sections, the transmitted packet should look like what is shown in Figure .9. It should include DATA which indicates the information of the traffic sign (e.g. speed limit), the geographical location of the RSUs, and the corresponding reference points and relevance angles.

It is also possible to use our solution to transmit from the same RSU different information (speed limit, stop...) with keeping the possibility that each information could be valid for several directions and/or several road sections. In this case the transmitted information from the RSU will look like what is shown in Figure 10.

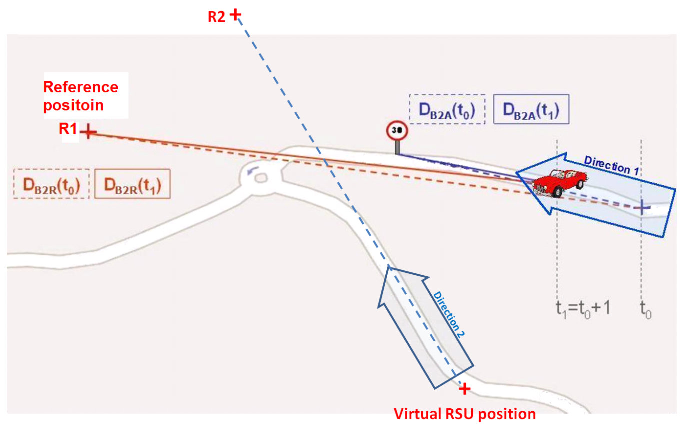

Figure 8. The same RSU information is valid for tow different directions.

Reference Point 1 (Latitude, Longitude)	RSU Position 1 (Latitude, Longitude)	$\alpha1_{max}$	Reference Point 2 (Latitude, Longitude)	RSU Position 2 (Latitude, Longitude)	$\alpha2_{max}$
. . .			Reference Point N (Latitude, Longitude)	RSU Position N (Latitude, Longitude)	αN_{max}
DATA ...					

Figure 9. Transmitted information format when one single information for several directions.

Reference Point 1 (Latitude, Longitude)	RSU Position 1 (Latitude, Longitude)	$\alpha1_{max}$	Reference Point 2 (Latitude, Longitude)	RSU Position 2 (Latitude, Longitude)	$\alpha2_{max}$
. . .			Reference Point N (Latitude, Longitude)	RSU Position N (Latitude, Longitude)	αN_{max}
DATA 1					
Reference Point 1 (Latitude, Longitude)	RSU Position 1 (Latitude, Longitude)	$\alpha1_{max}$	Reference Point 2 (Latitude, Longitude)	RSU Position 2 (Latitude, Longitude)	$\alpha2_{max}$
. . .			Reference Point N (Latitude, Longitude)	RSU Position N (Latitude, Longitude)	αN_{max}
DATA 2					
. . .					
Reference Point 1 (Latitude, Longitude)	RSU Position 1 (Latitude, Longitude)	$\alpha1_{max}$	Reference Point 2 (Latitude, Longitude)	RSU Position 2 (Latitude, Longitude)	$\alpha2_{max}$
. . .			Reference Point N (Latitude, Longitude)	RSU Position N (Latitude, Longitude)	αN_{max}
DATA N					

Figure 10. Transmitted information format when when several information with several directions is supported.

IV. Conclusion

In this paper we present a new mechanism for the calculation of geographical relevance of information received by mean of wireless communication systems. This mechanism is based on GPS information, without the need for any digital map. It allows to indicat the relevance area (driving direction and/or road section) by including to the corresponding information a reference point and a relevance angle. This mechanism could be used at the application layer to support applications in the calculation of the geographical relevance of received information. This mechanism can be also used in mobile networks where nodes exchange their movement information together with application related information; for example in military ad-hoc networks or in semi-static sensor networks. The main feature in this proposal is to include in each data packet the information on the reference position and angle that correspond to the direction(s) of interest, and this is of course only if there is a need to restrict the transmitted information to a specific direction and/or area on the road. This method could be used by safety and non safety related applications, to restrict the disseminated information to only vehicles driving on a specific direction and/or on a specific road.

References

[1] http://www.car-to-car.org
[2] ETSI TR 102 698 V1.1.1 - "Intelligent Transport Systems (ITS); Vehicular Communications; C2C-CC Demonstrator 2008; Use Cases and Technical Specifications", June 2009.
[3] Hamid Menouar and Massimiliano Lenardi, "Method and apparatus for determining whether a moving entity is moving in a predetermined direction", patent filed on February 2008 (to be published soon).