Efficient Event Dissemination using Bluetooth Protocol

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CReSTIC, Université de Reims Champagne-Ardenne, Reims
Email: {Kevin.Thomas, Geoffrey.Wilhelm, Hacene.Fouchal, Stephane.Cormier, Francis.Rousseaux}@univ-reims.fr

Abstract. A C-ITS is a system where mobile stations OBU (On-Board Units) exchange messages with other ITSS-V or RSU (Road Side Units). Messages are sent through a specific WIFI (IEEE 802.11p) denoted also ETSI ITS-G5. The efficiency of this technology has been proven in terms of latency. However, RSU are common everywhere, for this reason we look for another mean to guarantee this communication.
Today, Bluetooth chips are massively used, especially in smartphones. This protocol can support these communications.
In this paper, we present an architecture which ensures communication between RSUs and mobile stations using Bluetooth protocol.
We have measured some indicators as latency (notification delay), packet delivery ratio (number of messages arrived after a threshold). These indicators confirmed that our proposed architecture has an interesting performances and could be deployed widely.
keywords: C-ITS, VANETs, Cellular Networks, Hybrid communications, BLE.

1 Introduction

The deployment of connected vehicles is an interesting challenge since a decade. The connectivity is one of the most important issue to solve. Indeed, a dedicated WIFI has been designed for connected vehicles: IEEE 802.11p (denoted also ETSI ITS-G5). However, the deployment of ITS-G5 hotspots (denoted Road Side Units) is not generalised. This deployment of such technology takes a lot of time and is an expensive task. Indeed, the penetration rate of the connected vehicles is increasing slowly. Therefore, the coverage of such technology remains limited. However, it is very important to receive the events to avoid accidents and save lives.

To deal with this, the coverage could be enhanced using the Bluetooth communication. In this paper, we intend to use the Bluetooth technology in order to ensure the delivery of warning messages to vehicles. Every vehicle listens continuously BLE channels. If an event is triggered in a zone, BLE beacons broadcast the event in the relevance area. Events are declared and managed by the Road Operator.

Bluetooth on-board device receives the information, identify if the vehicle is concerned and displays it.

The remainder of this paper is organised as follows: Section 2 describes the related works. Section 3 details the architecture of the proposed system. Section 4 presents some performance indicators of our solution and section 5 concludes the paper and gives some hints about future works.

2 Related works

[13] proposes an evaluation of vehicular communications networks through car sharing scenarios. The authors have investigated three parameters. They adopted a specific mobility model which has been imported to a simulator. They have worked on a grid Manhattan network and they observed some performance parameters such as delay, packet loss, etc. The most important objective of the study is to show that vehicular communication is feasible and realistic under some conditions.

[12] studies throughput over VANETs system along an unidirectional traffic for different conditions and transmission ranges of wireless equipments. All studied vehicles are randomly connected. The paper gives few results of simulation studies achieved on NS-2 toolbox. They have measured performances indicators in case of congestion. A comparison of the obtained results with the expected connectivity has been done and have shown that the throughput over simulation is lower due to packet losses caused by collisions.

Authors of [19] presents an alternative to WAVE/DSRC using an hybrid system, which uses Wi-Fi Direct and Cellular Network. They show that such a system could work for C-ITS. However, this paper does not take into account the hybridation between ITS-G5 and Cellular Network.

[20] presents another alternative to WAVE/DSRC solution using here Wi-Fi Direct, ZigBee and Cellular Network. Wi-Fi Direct is used as a direct link between nodes. ZigBee is used to connect roadside sensors and Cellular Network for long distance communication. In this study, the ITS-G5 is also ignored.

In [7], the authors provide their network architecture which has been deployed in Spain , where communicating vehicles are switching between 802.11p and 3G, depending on RSU's availability.

[15] presents a detailed study on performance evaluation of IEEE 80211.p networks versus LTE vehicular networks. The authors analyzed some performance indicators like the end-to-end delay for both networks in different scenarios (high density, urban environments, etc.). Many important issues have been measured as network availability and reliability. The authors have proved through simulations that LTE solution meets most of the application requirements in terms of reliability, scalability, and mobility. However, IEEE 802.11p provides acceptable performance for sparse network topologies with limited mobility support.

[17] gives an efficient solution for routing messages over VANETs by using the vehicle's heading.

[6] gives an overview of how research on vehicular communication evolved in Europe and, especially, in Germany. They describe the German field operational test sim TD. The project sim TD is the first field operational test that evaluated the effectiveness and benefits of applications based on vehicular communication in a setup that is representative for a realistic deployment environment. It is, therefore, the next necessary step to prepare for an informed deployment decision of cooperative systems.

[16] is dedicated to routing over VANETs in an urban environments. [14] is a study about vehicles prediction movement. Indeed, an adapted routing algorithms are proposed in [10] and in [11] . [9] gives an overview of strategies to use for routing on VANETs. [18] reviews much more actual strategies on vehicular networks.

All the works presented below handle the communication between vehicles using cellular networks or ETSI ITS-G5 networks. There is no approach about the Bluetooth Communication, technology massively used in advertising or home automation, etc ... But in vehicles communications, is it possible ?

3 Event dissemination

In order to propose an alternative solution to cellular or ETSI ITS-G5, we provide the possibility to send information, thanks to the Bluetooth Low Energy (BLE). So, the following architecture is proposed to allow this kind of event dissemination.

Some Bluetooth Low Energy Senders (BLETransmitter) are installed on roadside. They transmit information which comes from the Road Operator like an event on the road (DENM), parking information, etc ...

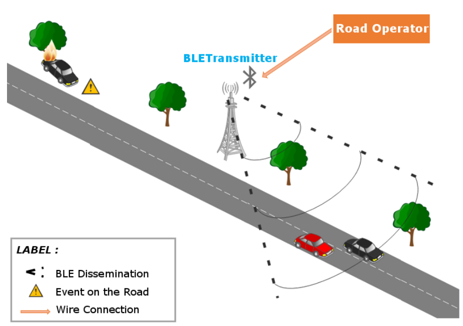

Fig. 1. BLETransmitter on the Road.

As we can see in figure 1, the Road Operator can send some information to the BLETransmitter which forward them to adjacent vehicles. For this purpose, the BLE antenna will broadcast information thanks to the advertise data, with Standard BLE Beacon.

But it is necessary to identify if a vehicle is concerned by the message or not. Indeed in figure 1 the black car has to receive the DENM because the event is on its lane, but, the red car must not receive the message, it is on the opposite lane.

We experimented 3 solutions to identify Traffic Direction :

3.1 Solution 1 : Measure the RSSI

The first solution is based on measure of the BLE signal power. Indeed, we can deploy unidirectional BLETransmitter and just save some received messages when a car passes near an antenna. With some message, thus some RSSI measure, we can establish a trend : increasing or decreasing.

Case 1 : The RSSI increase.

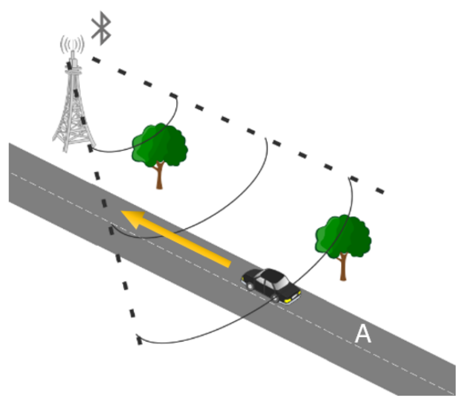

Fig. 2. An increasing RSSI measure of an unidirectional BLETransmitter.

In the case presented in figure 2, the measure will probably increase because the black car is getting closer to the BLETransmitter.

Case 2 : The RSSI decrease.
In the case presented in figure 3, the measure will probably decrease because the red car goes away from the BLETransmitter.

The Road Operator knows how their BLETransmitter are oriented, what is the lane A or B, and identifies the lane concerned by the event. With all of this information, the Road Operator can indicate, in the BLE message, if the message concerns decreasing signals or increasing signals.

So in figure 2 and figure 3 :

- the black car is on lane A and is concerned by the message, so it will consume it.

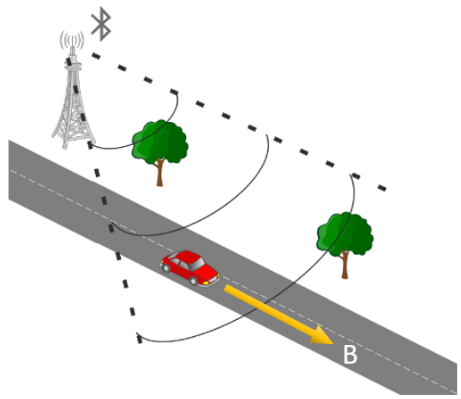

Fig. 3. A decreasing RSSI measure of an unidirectional BLETransmitter.

- the red car is on lane B and is not concerned by the message, so it will discard it.

3.2 Solution 2 - Two BLETransmitters

The second solution use two unidirectional BLETransmitters. The main idea of this solution is to use the reception order to establish traffic direction.

The Road Operator just needs to define and save which sequence corresponds for lane A or B.

Case 1: The vehicle is on lane A.

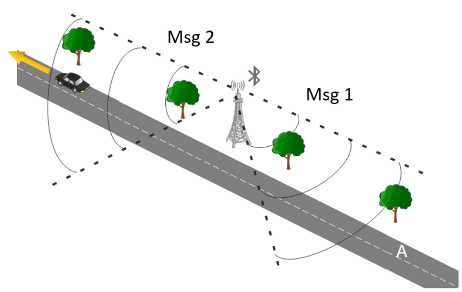

Fig. 4. Receiving two messages on lane A.

In the case presented in figure 4, the application will receive the message 1 and after the message 2 that indicates that the vehicle is on lane A.

Case 2: The vehicle is on lane B.

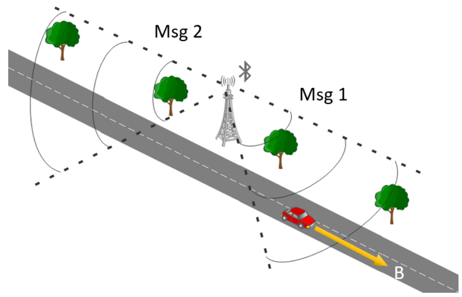

Fig. 5. Receiving two messages on lane B

In the case presented in figure 5, the application will receive the message 2 and after the message 1 that indicates that the vehicle is on lane B.

This solution constrains the operator to put two information in a message :

- a message identifier to establish the "Msg1" and the "Msg2".
- the sequence concerned by the event. "Msg1 then Msg2" or "Msg2 then Msg1" concerns the event.

3.3 Solution 3 - Heading of the Road

The third solution is to give the Heading (angle between a vector and the north) of the lane which is concerned by the event where the BLETransmitter is.

When a vehicle receives a BLE message, it compares it to the GPS heading of the vehicle (or compass heading - it depends on enable sensors) within +/- 90 degrees in order to anticipate a potential curve.

Case 1: The vehicle is on lane A.

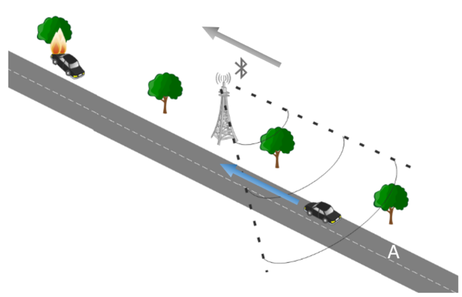

Fig. 6. Corresponding of the road's Heading with the vehicle's Heading.

In the case presented in figure 6, the Headings of the lane and of the vehicle are the same (more or less 90 degrees). That indicates that the vehicle is on lane

A.

Case 2: The vehicle is on lane B.

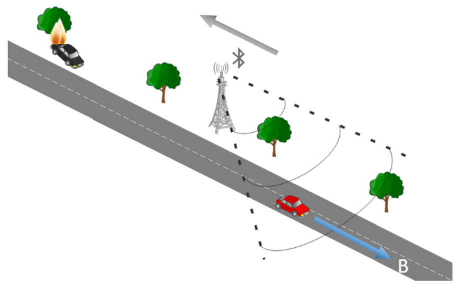

Fig. 7. Opposition between the road's Heading and the vehicle's Heading.

In the case presented in figure 7, the Heading of the lane is not the same as the vehicle (more or less X degrees). That indicates that the vehicle is on lane B.

Here, the Road Operator is constrained by the cartographic analysis. Indeed, when it declares a BLE broadcasting, it needs to anticipate, in their internal process, the cartography to establish the correct Heading.

How to compare ?

After the reception of a message, a comparison is started. The system will decode the message, extract the Heading of the lane that is concerned and fetch the vehicle's Heading from the GPS or the compass.

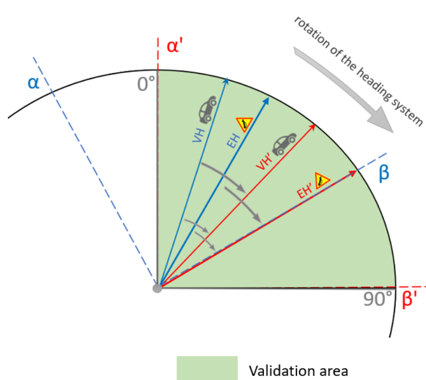

Fig. 8. Rotation of the comparison system in order to validate the event.

In figure 8, we have two Headings : for the vehicle (VH) and the event (EH). They are projected on a trigonometric circle (blue system). Then, the difference of 90 degrees is built, those are angles α and β. In order to make the calculation easy, we rotate the system, and put α on 0 degree, this action builds two new angles : α' and β' and two new vectors VH' and EH' (red system). The interval α' β' contains the validation area and if the EH' is between them, the event concerns our vehicle.

4 Evaluation and performance analysis

Here, the purpose is to estimate limits for each solutions, develop and challenge them. We deployed the following architecture on a testing road.

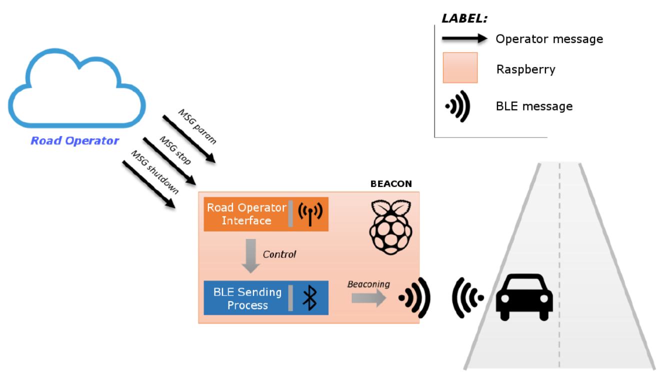

Fig. 9. BLETransmitter Architecture in Testing phase.

In fig. 9, we use a Raspberry Pi 3 Model B+ as BLETransmitter, some Samsung Galaxy tab in vehicle as receiver (with an adhoc Android application which receives BLE messages). A computer, which emulates the Road Operator system, sends orders to the BLETransmitter thanks to TCP connection. The Raspberry Pi constructs the advertising packet and enable the dissemination of it. The dissemination is set to 5 messages per second. We can also transmit control message like a "stop" message to stop the broadcast or a "shutdown" message to shutdown the program. Then the application (on tablets), which receives messages, identifies if the message concerns the vehicle and prints it.

Obviously, we have a Universally Unique Identifier (UUID) in order to distinguish messages sent by other devices. We choose : 00009999-0000-1000-8000-00805f9b34fb.

In order to emulate the unidirectional BLETransmitter, we placed the beacon on a side of a bridge which acted as a shield.

First, we challenge the solution 3.1 at 130km/h. For this testing phase, on the first lap, we improve the situation where the vehicle is on lane A, according to the figure 2. On the second lap, we improve the situation where the vehicle is on lane B, according to the figure 3.
In the table 1 :

	Device 1	Device 2	Device 3	Device 4
1st lap	-43 -38	-38 -38	-45 -46 -43 -43 -43 -45 -38 -45 -43	-38 -37
2nd lap	-45 -45	-38 -38	-42 -43	-38 -32 -33

Table 1. RSSI measure during test phase

- Tablet 1 was powered by a battery.
- Tablet 2 was connected to the car.
- Tablet 3 and Tablet 4 were standalone.

The first lap was on the same lane as the DENM and, in theory, the signal should increase. The second lap was on the opposite lane and, in theory, the signal should decrease.

Then we test the solution 3.2 at 130km/h. For this session, we put two Raspberry on both sides of the Bridge. They are respectively identified by "1" and "2" in the message.

	Beacon code sequence records	Results
1st lap	1 1	inconclusive
2nd lap	2 2 2	inconclusive

Table 2. Sequences during test phase

As we can see in table 2, we received messages from only one BLETransmitter, none from the Raspberry on the other side of the bridge. It is due to the driving speed.

After we test the solution 3.3 at 130km/h.
In table 3, the event was displayed every time we were on the concerned lane, and we received some duplicate packets.

4.1 Quantitative analysis

First, we identify the quantitative cost.

	Lane concerned	NB messages records	Displayed on screen
1st lap	Yes	2 messages	Yes
2nd lap	No	3 messages	No
3rd lap	Yes	3 messages	Yes
4th lap	No	2 messages	No

Table 3. Heading Messages during test phase

For solution 3.1, we generally receive between 1 and 3 messages with an RSSI measure too close to determine a correct trend, so, we can not determine if we have an increase or decrease signal power, therefore, we do not know if we are getting closer to the antenna or if we go away from it.

Also with solution 3.2, as the previous solution, we have not enough message when we are getting closer to the BLETransmitter, so we can not ensure enough information to determine if the traffic direction correspond with the sequence.

With solution 3.3, received messages are enough in order to identify the traffic direction of the vehicle, so, identify if an event must be treated or not.

4.2 Implementation complexity

Now, we see the most complex solution.

In the solution 3.1, distally, the Road Operator put only an information in the message, and, proximally, we use the advertise data header so we do not have a lot of process but for the Road Operator, it is a little bit more complex because it needs to orientate a directional BLETransmitter when it installes it.

For the solution 3.2, distally, two messages must be identified as "message 1" and "message 2" so we need to duplicate and synchronize two BLETransmitters from the Road Operator Controller. It also needs to determine and transmit the correct sequence thanks to the cartography. Therefore, proximally, we need to have two directional BLETransmitters installed, which is difficult.

And so, in solution 3.3, as solution 3.1 the Road Operator just put an information in the message. Proximally, we totally depend of a embedded system's sensor (compass or gps) but we do not need a directional BLETransmitter.

4.3 Autonomy

We based our analysis on the previous section 4.2.

The solution 3.1 just needs to determine which is the orientation of the BLE-Transmitter and an analysis of the cartography, so it is relatively self-contained solution.

For the solution 3.2, it is totally dependent of the Road Operator process which determines the good sequence relative to the orientation of local BLE-Transmitters.

Finally, the solution 3.3 is probably the most standalone solution because, The Road Operator will just determine which lane is concern by the event thanks to the cartography. The rest of the process will be assumed by embedded system's sensor (compass or gps).

5 Conclusion

In this paper we have presented an architecture for intelligent transport system based on the bluetooth protocol. The most important issue of such a study is to show that a simple protocol could be used very simply with low cost to deploy cooperative intelligent transport systems. We have only presented an architecture and some brief tests on the road et as a next step we intend to experiment such a solution on real vehicles within the project SCOOP (supported by the EC).

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