Intelligent Transport System Based on Bluetooth

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Abstract. A Cooperative Intelligent Transport System (C-ITS) is a system where mobile stations OBU (On-Board Units) exchange messages with other ITSS-V (Intelligent Transport System Station Vehicle) 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 and stations equipped with G5 interface are not widely deployed. For this reason we look for another mean to guarantee this communication. Bluetooth Low Energy (BLE) is deployed on smartphones. We take advantage of this deployment to propose an architecture based on this protocol in order to build a Cooperative Intelligent Transport System. Cellular networks are widely deployed and can support these communications. We have adapted the ITS stack provided by the ETSI (designed for G5) to the BLE protocol.

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 BLE protocol. In this paper, we intend to use Bluetooth protocol for the delivery of warning messages to and from vehicles. Every vehicles send continuously it Cooperative Awareness Messages (CAM) to the Central ITS Station (ITSS-C, or *National C-ITS Station*). The latter maintains the location of the vehicles up-to-date. If an event is triggered in an area, a Decentralized Event Notification

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Message (DENM) is then automatically forwarded to the nodes that are in the relevance area.

The remainder of this paper is organised as follows: Sect. 2 describes the related works. Section 3 details the architecture of the proposed system. Then, Sect. 4 and Sect. 5 presents the Vehicle to Infrastructure communication and the Vehicle to Vehicle communication. Finally, Sect. 6 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 environment. [14] is a study about movement prediction of vehicles. 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 ...

3 Proposed Architecture

3.1 Environment

This architecture intends to provide another type of communication in Cooperative Intelligent Transport System (C-ITS) project. This model uses the Bluetooth technology and more precisely the Bluetooth Low Energy (BLE) advertise data.

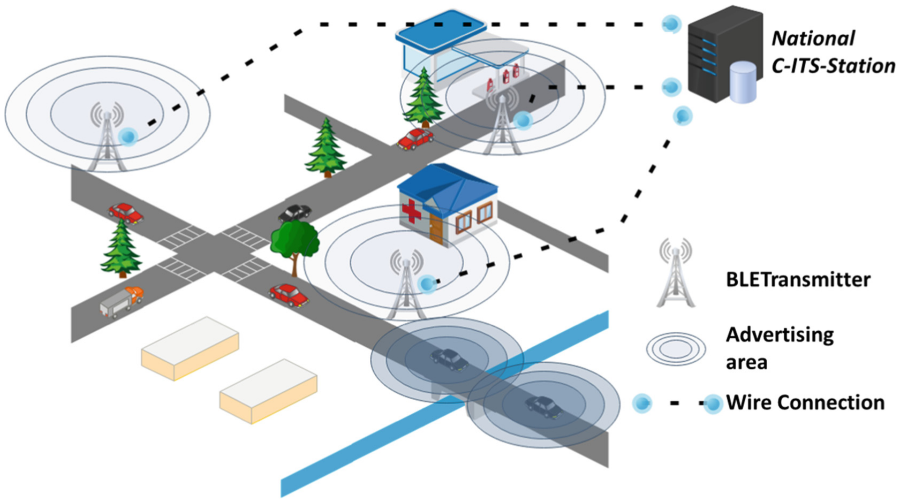

Fig. 1. Global BLE architecture

As we can see in Fig. 1, some BLE antennas, denoted BLETransmitters, are dispatched on the road, and connected to the *National C-ITS Station* which controls them. They broadcast information and listen to messages which come from vehicles driving around. However, some BLE On Board Units are installed in vehicles, they can also broadcast information and listen to messages which come from other vehicles or BLETransmitters.

3.2 Messages Format

A Cooperative Awarness message (CAM) and Decentralized Environmental Notification Message (DENM) are described by the ETSI Standard C-ITS. The objective of this kind of messages is, respectively, broadcast the vehicle's position with other information which concern the vehicle's structure and announces events on the road. Here we will use a light version of this kind of messages. We intend to be compatible with Bluetooth 4.x and 5. We are limited to 31 bytes on an advertise message's payload.

Light CAM. We define the following packet structure. This allows to respect the size limit and to upload all required geographic information to the server to locate the vehicle.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
MT	Station ID				Lat				Long				H	GDT		Security							

In this structure, we have:

- *Message Type (MT)* - To identify if it is a light CAM or a light DENM.
- *Station ID* - This is the vehicle's pseudonym, it allows to identify the vehicle and protects its privacy. Indeed this pseudonym changes every 5 min according to privacy requirements.
- *Latitude/Longitude* - The GPS location.
- *Heading (H)* - It is the angle between the vehicle's direction and the North. This information is necessary to identify the lane where the vehicle is.
- *Generation Delta Time (GDT)* - The build time of the message, necessary for event management on the National C-ITS-Station.

Light DENM. Here we define the light packet for an event, a light DENM. However we distinguish two kind of light DENM: "light DENM declaration" and "light DENM targeted".

We first define the structure of the message to be sent to the National C-ITS-Station (communication Vehicle To Infrastructure: see Sect. 3) or to an other vehicle (communication Vehicle to Vehicle: see Sect. 4):

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
MT	DC	Lat				Long				H	T		Security							

In this structure, we have:

- *Message Type (MT)* - To identify if it is a light CAM or a light DENM.
- *DENM Code (DC)* - Event Code maps from the ITS CauseCode/SubCauseCode Table.

– *Latitude/Longitude* - The GPS location.
– *Heading (H)* - It is the angle between the vehicle's direction and the North. This information is necessary to identify the lane where the vehicle is.
– *Timestamp (T)* - mod 2^{16} of the ITS timestamp. The build time of the message, necessary to determine the validity duration of the event.

Here we define the message to be received from the National Central Station.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
MT	Station ID				HL	DC	Lat				Long				
H	T		VD			Security									

In this structure, we have:

– *Message Type (MT)* - To identify if it is a light CAM or a light DENM.
– *Station ID* - It allows to identify the vehicle targeted by the message.
– *Hop Limit (HL)* - Number of hop which can be done by the denm. Foreach hop, the value is decremented.
– *DENM Code (DC)* - Event Code maps from the ITS CauseCode/SubCauseCode Table.
– *Latitude/Longitude* - The GPS location.
– *Heading (H)* - It is the angle between the vehicle's direction and the North. This information is necessary to identify the lane where the vehicle is.
– *Timestamp (T)* - mod 2^{16} of the ITS timestamp. The build time of the message, necessary to determine the validity duration of the event.
– *Validity Duration (VD)* - life time of the event.

So, in this part, we have seen which infrastructures are necessary to provide this new type of communication for C-ITS Stations, and which messages can be exchanged according to size limits of the BLE.

4 Vehicle to Infrastructure Communication

As we can see in Fig. 2, (1) a vehicle broadcasts its BLE message. It can be a light CAM or a light DENM but in this example, we consider that it is a light CAM. (2) This one is received by the BLETransmitter which forwards this message to the National C-ITS-Station thanks to wire connection (3). (4) The National C-ITS-Station has the location of the vehicle, determines what are information which concerns it and forwards information to BLETransmitter (5) which are on the potential path of reach it. This one requires an analysis of the cartography. Then BLETransmitter advertises information for the vehicle (6) during the validity duration's event.

For a DENM upload from the vehicle, it is more or less the same process, we just do not have the step (5) and (6) because the vehicle already knows this event.

Let us focus on the step (4) the National C-ITS-Station process.

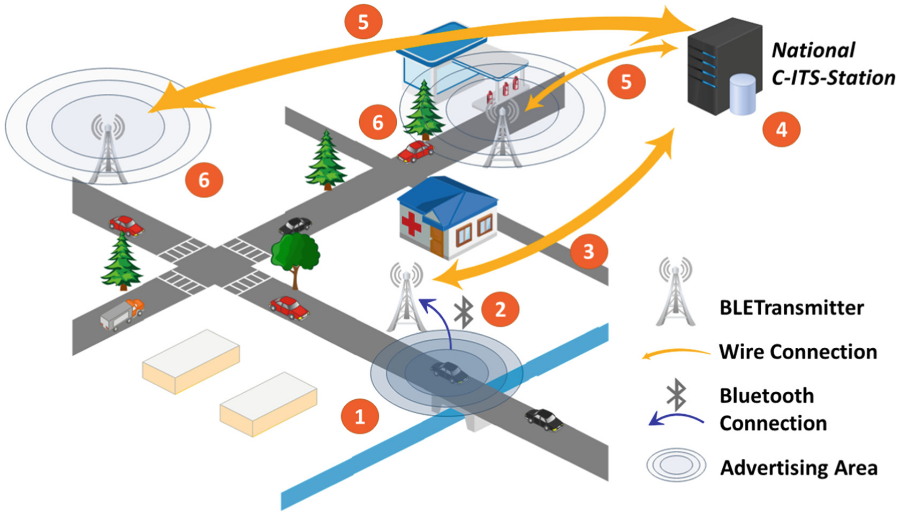

Fig. 2. Vehicle to infrastructure communication

Figure 3 shows income information on the National C-ITS-Station. When the vehicle moves on the Road, it can send some CAMs or DENMs according to the Fig. 2. After that a message is received by a BLETransmitter and forwards to the National C-ITS-Station, the message is decoded. Its geographic position is identified. Then 2 options are available:

– The message is a *light CAM*: if the station ID of the vehicle is already known, the position is updated. If the station ID is unknown, a new Mobile Node manager is started. Then the routine is run.
– The message is a *light DENM*: it is localized on a cartography and, corresponding to its event code, a relevance distance is applied on it. Then it is stored on the DENMs Database. If the DENM is already known, the message is discarded.

Now how the process works? We are based on the process describes in [21].

As we can see in Fig. 4, for each iteration, two process are engaged onto the Mobile Node Manager:

– picks the last position and last heading of the vehicle to identify DENM(s) which concerns our vehicle. If some DENMs are identified, they are saved in local database and been prepared to the sending.
– picks the last position and last heading of the vehicle to analyse the cartography and identifies what are BLETransmitters which will be on the way of the vehicle.

When DENMs must be sent and BLETransmitters are identified, the *National C-ITS Station* commands the start advertising of the information. Then the Mobile Node Manager waits the next light CAM received from the vehicle.

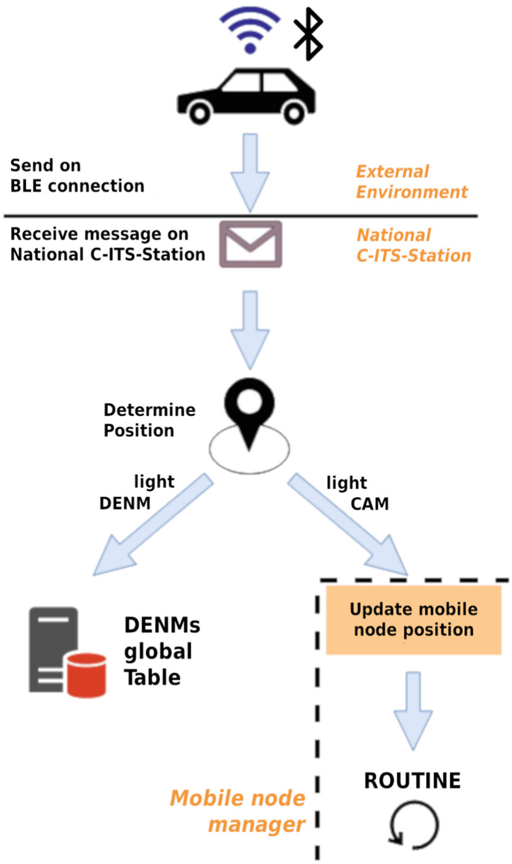

Fig. 3. Messages incoming on National C-ITS-Station.

So, in this section, we have seen how the vehicle is managed on the *National C-ITS Station* and how information are identified and sent to the vehicle concerned. We have based our approach on [21] for the Mobile Node Manager on the *National C-ITS Station*, it is slightly the same process, we have just provided another communication protocol.

5 Vehicle to Vehicle Communication

This architecture also allows to transmit some DENMs to other vehicles.

Here, Fig. 5 shows (1) where the vehicle notifies a new event (2) if another vehicle is in the advertise area, (3) the vehicle, which follows, will receive the message and add the event to its database. If the DENM is already known, the message is discarded.

This Section shows that this architecture can also provide communication between vehicles. This feature is very limited by senders devices (the sending

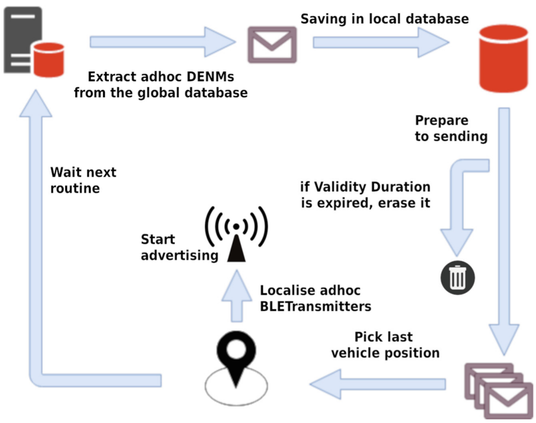

Fig. 4. Sending process on Mobile node manager on National C-ITS-Station.

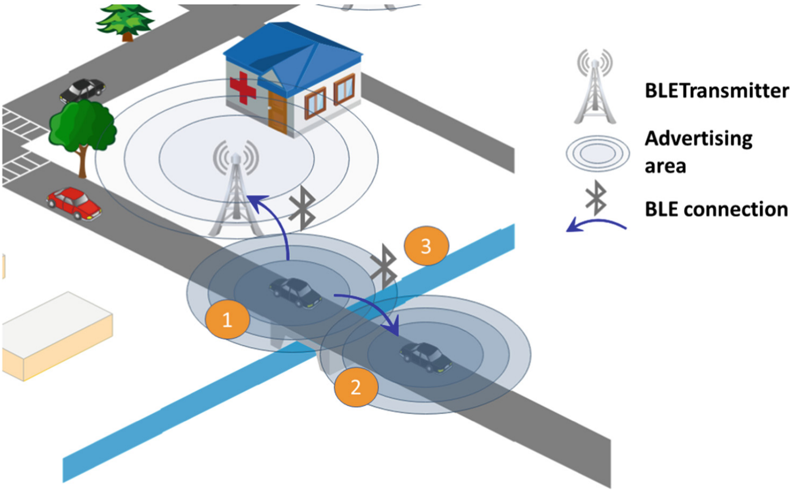

Fig. 5. Vehicle to Vehicle communication

area is very limited in BLE for smartphone or other Class 2 Bluetooth Chip) but it provides a good alternative for ITS G5 vehicle to vehicle communication.

6 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 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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