ITS use case: car overtaking

Proposal (Draft version)

Broadcast GPS positions to neighboring cars

1 Foreword

This document is only an individual Brain Storming based on a use case to take advantage of an ITS framework already developed at the IT of Aveiro. It could contain some useless or wrong information and conclusions and should not be taken into very serious consideration before discussing it with some other specialists.

1.1 Language advertisement

The document is written in English by a non-native English speaker. So, I am sorry in advance for the mistakes (I am sure that some of them are really serious), but the goal of the document is to transmit some written information to other readers, in most of the cases also not English native.

2 Presentation

Cooperative collision avoidance is one of the use-case examples in the new 5G white paper for automotive and mobility [1] and some kind of assisted car overtaking system could be a starting point to achieve it. Assisted car overtaking will make use of Intelligent Transport Systems (ITS), Internet of Things (IoT), Video and other sensed data through different network architectures managed with the Software Defined Networks/Network Function Virtualization (SDN/NFV) to gather all the available environmental information to be sent to the end user/car or even to the cloud. Some kind of information would be video images from the road and from neighboring vehicles, sensed obstacles (through sonars or environment sensors), road conditions, crosswalk, other people and vehicles on the road and even traffic signs such as stops and traffic lights [2].

Apart from it, each vehicle has access to its own sensors, GPS, speed, wheel status, video images etc. Some part of this information or even local processed information could be sent to neighboring vehicles; however, each vehicle will have three sources of information: its local sensor information, environment IoT information and information from other vehicles. The way this information is spread out is the main topic of this proposal, and more specifically the broadcasting of each vehicle's local GPS information.

The start point are studies and implementations of a complex urban V2V infrastructure, using combined Wifi, WAVE and 4G technologies.

In [2] there are identified 5 kinds of interactions, that we will resume in 3 that involves directly the vehicles:

- Vehicles to/from the Edge Cloud. The Edge Cloud has already information from other vehicles, environment sensors and processed smart information from the Big Data. In this case all the available access technologies will be used, particularly Wifi, WAVE and 4G. The sensors will send its data using in some cases wired technologies (Ethernet, MPLS, optical ...), Wifi, LoRa, Bluetooth, ZigBee or even WAVE access technologies.

- Vehicles to Vehicles. In this case only WAVE/DSRC and/or Wifi access technologies will be used. Proposed implementation will deal with GPS information to be shared between vehicles, but other kind of information could be disseminated.
- Environment sensors/actuators to/from vehicles. Some of the sensors/actuators are also connected to the Edge Cloud, and thereby its information could be received/sent by/to the vehicle from/to the cloud.

Figure 1 presents a general topology about the framework.

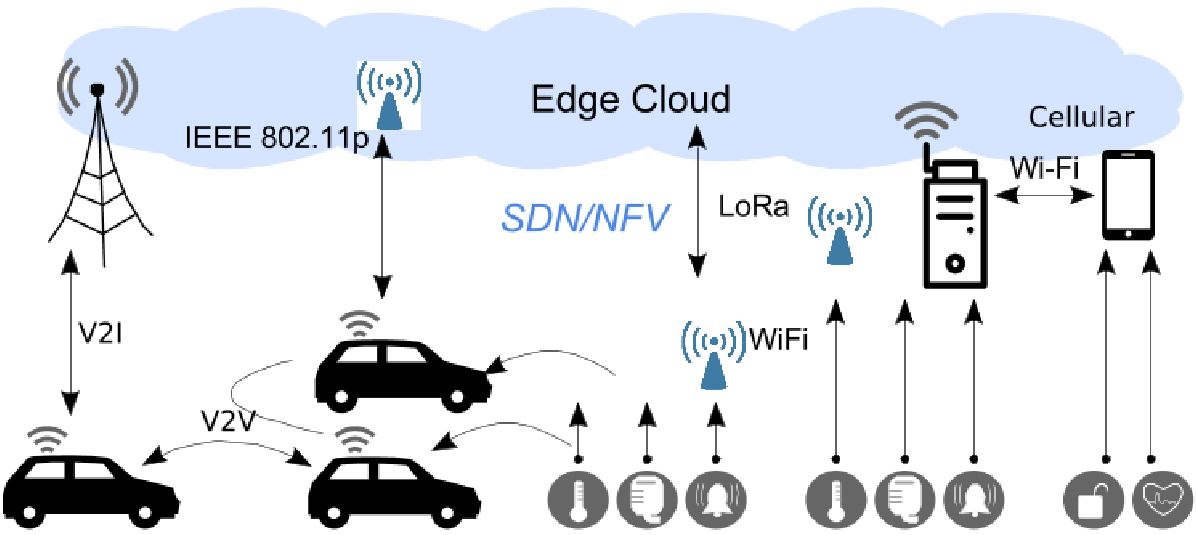

Figure 1: Edge Cloud in an ITS infrastructure

2.1 Proposal

In [2] there are two experiment proposals, the first one is to create a field trial with IoT sensors, Edge Cloud and moving vehicles generating information like images, sensor data or position, and the second one is more related with software development, where an ITS gateway connects to an experimental car and offers information about the correctness of the overtaking decission taken by the driver.

This proposal is more related with the first one, where an urban trial field should exist (or should be simulated) and a specific kind of information should be broadcasted to the traffic environment. This information is the geolocation data (GPS data) of each vehicle. Nevertheless, we could also work on the second one, by developing an overtaking decision framework for the Edge Cloud based on the GPS information of the involved vehicles.

Broadcasting position or geolocation data (like GPS data) seems to be mandatory to implement the main topic of "assisting in car overtaking". The reason is that at the start, the "assisting in car overtaking" will be a kind of geolocation radar to know the neighboring car positions. Once the neighboring car position is known, some kind of "position data mining" would be done to know the overtaking risks. In the future, the cloud could know where the main overtaking-crash risks are, and could assist to the driver in a more predictive way. Broadcasting the geolocation information of a car could be the spearhead to higher uses of the existing infrastructure, as it could make emerge some kind of difficulties or new challenges.

GPS broadcasting may not be a very difficult task if there is a network infrastructure that interconnects sender and receiver, but it would be more difficult if the goal is to do it with low latency between the GPS data acquisition and its broadcast device, and even more difficult if there is not a network infrastructure between both actors. In any case, even if there is a network infrastructure between sender and receiver, the infrastructure should select the receivers to avoid data storms.

Therefore, two broadcasting scenarios would be considered:

- An urban scenario, where a ITS infrastructure is already operational, and
- a rural scenario, where there is no ITS infrastructure available.

3 Objective

The main objective is to create a ground technology to broadcast vehicle geolocation information (GPS position/time) information to neighboring vehicles that would be affected by an overtaking decision. In a first step, this information would be displayed on a screen (like an Android device, tablet or mobile phone) of each vehicle that receives it.

This objective will make use of the available network technologies and the Edge Cloud, as well as it will try to develop some parallel solutions if there is no network infrastructure like in rural areas. Therefore, we will divide the problem into the two broadcasting scenarios presented above.

3.1 Urban scenario

In this case there is an ITS topology available. Available network topologies are Wifi/WAVE/4G. There are some ground technologies developed in the IT in Aveiro for this case, like the Multihoming/Handover and the Mobility technologies in IPv6.

Nevertheless, to simplify the project frame, at the beginning, we will consider only Wifi communications. In this case, the ITS infrastructure will consist on several fixed Wifi Access Points and the vehicles would be connected to one of them.

To disseminate/receive position information to/from the neighbours in an accurate way, the vehicles should remain connected to the Edge Cloud (in this case APs) even in roaming environments. Therefore, the vehicle should always be connected to one AP and it should be able to reconnect to other AP if it starts to lose connectivity from the first one. In any case, to achieve it, the vehicle should scan for other APs during the normal data transmit operation.

There are two solutions: using only one wifi card or using two wifi cards. The first one is cheaper than the second one, but in contrast it may lose some connectivity in roaming environments (while changing from one AP to another AP). This project proposes the use of two wifi cards because they are not so much expensive and permits the roaming capabilities.

3.2 Rural scenario

In this case there is not an ITS topology available, but it usually exists a 4G coverage. Nevertheless, the broadcast of GPS information through 4G networks to the nearby vehicles may be more complex than expected without having the control of an ENodeB. It should include the network operator and this seems to be unapproachable right now.

Therefore, we propose a new broadcasting technology based on the Wifi Beacons. This technology proposal will be outlined below.

4 Tasks

To deal with this project, we want to point out some very specific tasks. The tasks have been divided into two groups, related to the above described scenarios: the urban and the rural ones.

4.1 Urban tasks

In an urban environment, we could count with an important ITS infrastructure, such as Wifi Hotspots, WAVE OBUs and RSUs, and 4G high coverage. Nevertheless, we initially only use Wifi technology for simplicity. First identified tasks are:

1. Identify the access connection possibilities and its challenges. Developed solutions at the IT Aveiro are the Multihoming and Mobility in access/network layers using Wifi/WAVE/4G technologies. Nevertheless, to make the project more affordable, at a first step we consider only Wifi communications.
2. Define the communication process/application between sender and receiver. It could be a client/server process, a TCP/UDP transport, a WebService or other kind of communications. This implies to define the sockets and the programming language.
3. Define the data format to spread out. It should contain at least VehicleID, the vehicle GPS coordinates with a resolution of at least 0,3 meters and a timestamp. It could also contain the velocity and a tag that informs if there will be an overtaking decision. The data/packet size is of importance.
4. Develop a "position generator (PosGen)". The goal is to make experiments without depending on the availability of real mobile devices. This PosGen should be able to be parametrized with vehicle speeds and 2D routes. It should generate a time|position table. In place of this PosGen, we can create a time|position table almost manually (https://www.plotaroute.com/routeplanner).
5. Develop a Wifi handover device. This device should have 2 wifi interfaces and it should have the ability to send/receive information on one interface and scan on the other one simultaneously. A trigger function should select if the device should change its associated AP. The main CPU where the function runs could be a RaspberryPi, and the wifi devices could be ESP8266. At the end, to do some tests and be able to publish some results we will need at least two of these Wifi handover devices.
6. Develop a "GPS broadcast neighbor solution". This task is a complex task that would have some child tasks:
   - Define technically what a neighbour is. For example vehicles connected to same AP are neighbours. May be we need to define AP neighbours, and in this case we can extend the neighbourhood to the vehicles connected to AP neighbours.
   - Study the multicast possibilities in place of broadcast.
   - Study the possibility that a central server at the cloud could decide what a neighbour is and unicast to him the GPS information.
   - Study the possibility to relate the vehicle (end device) neighbour concept to the SDN/NFV.
7. Develop a data presentation prototype. An initial suggestion is the transmission of the data from the CPU via BlueTooth to an Android device, tablet or mobile phone and take advantage of its screen and BT drivers. In this case a simple 2D position presentation app should be developed.

Figure 2 shows a simple schematics about this scenario and the involved elements. The basic GPS broadcast device (from now on GPS-BR-Dev) is on the vehicle and is a little bit more detailed in figure 4. Basically, each vehicle has a GPS-BR-Dev that is associated to one AP through one of the two Wifi devices and periodically scans for other APs to reconnect if necessary.

4.2 Rural tasks

If there is not an ITS infrastructure, each vehicle has to send/receive (broadcast/scan) with its own available technologies. The Wifi technology is a connection-oriented technology at layer 2, that is, it need to have an association process to be allowed to send/receive upper layer packets. In addition, it usually has an authentication process, to improve the security. In any case, this process makes that the topologies to connect the vehicles may become a real nightmare, in Infrastructure or even in Ad-Hoc operation modes. That is one of the main reassons to develop the 802.11p/WAVE technology.

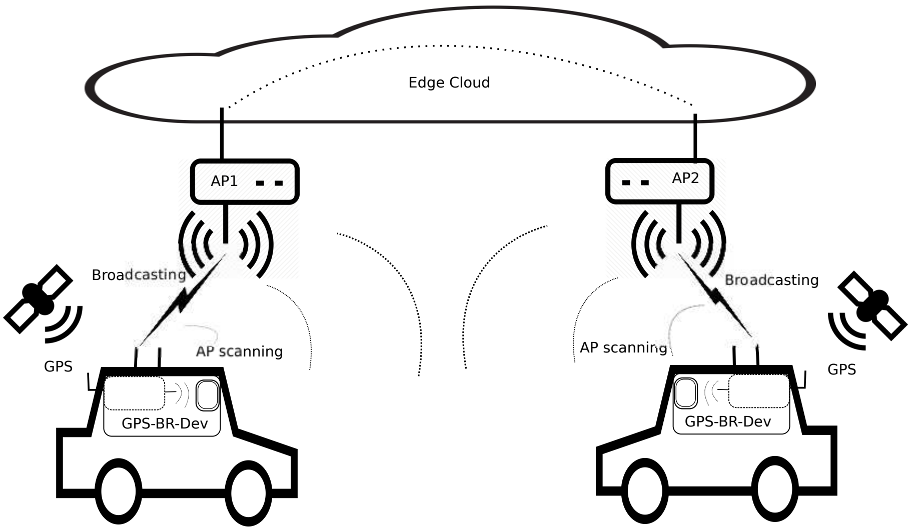

Figure 2: Urban scenario to broadcast GPS data

The proposed solution would take advantage on the control messages that, in Wifi technologies, the AP and the STA shares to start the association process in the Infrastructure mode of operation. This kind of messages is layer 2 messages and therefore they are spread out. In particular, we would take advantage on the beacon messages that an AP sends to advertise his SSID, and that the STA scans and processes every beacon received without establishing any kind of association.

Some of the tasks in this scenario are the same as in the Urban scenario.

1. Study the wifi beacon process, the announcement period, the beacon format and its possibilities.
2. Define the data format to spread out. It should contain at least VehicleID, the vehicle GPS coordinates with a resolution of at least 0,3 meters and a timestamp. It could also contain the velocity and a tag that informs if there will be an overtaking decision. The data size is of importance because of the limits in the 802.11 b/g/n beacon frame format.
3. Develop a "position generator (PosGen)". The goal is to make experiments without depending on the availability of real mobile devices. This PosGen should be able to be parameterized with vehicle speeds and 2D routes. It should generate a time|position table. In place of this PosGen, we can create a time|position table almost manually (https://www.plotaroute.com/routeplanner). This task is the same as in the Urban scenario.
4. Develop GPS Wifi-broadcast and GPS Wifi-scan prototype. This device should have 2 wifi interfaces and it should have the ability to broadcast beacons (work in AP mode) on one interface and scan on the other one (to receive beacon broadcasts with GPS information) simultaneously. The main CPU could be a RaspberryPi, and the wifi devices could be ESP8266. At the end, to do some tests and be able to publish some results we will need at least two of these GPS Wifi-broadcast/scann devices.
5. Develop a data presentation protoype. An initial suggestion is the transmission of the data via BT to an Android device, tablet or mobile phone and take advantage of its screen and BT drivers.

Figure 3 shows a simple schematics about this scenario (like in figure 2 for the urban scenario) and the involved elements. In this case, the same GPS-BR-Dev as in the urban scenario is broadcasting its GPS information through one of the two wifi interfaces and scanning to receive the GPS position from other vehicles through the second wifi device.

The wifi-broadcast and wifi-scan prototype could be the same device. We suggest the use of Raspberry Pi as the main prototype device. Nevertheless, it could be complemented with ESP8266 devices to have more control of the wifi devices and drivers.

Figure 4 proposes a basic GPS broadcast/scan device that may be useful in both scenarios. It consists of two Wifi devices, one CPU, one GPS receiver, one BlueTooth device and one Android compatible screen.

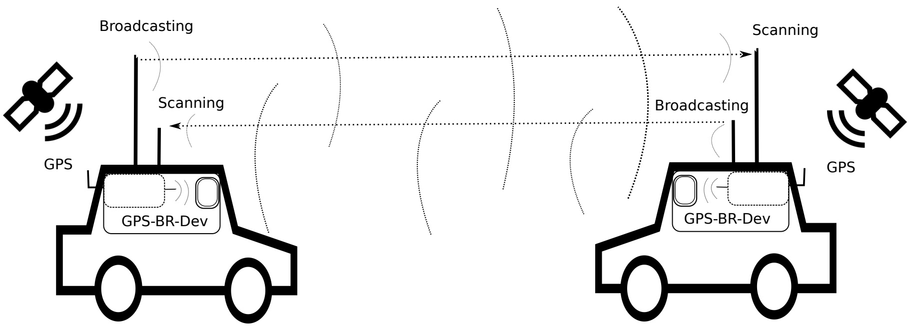

Figure 3: Rural scenario to broadcast GPS data

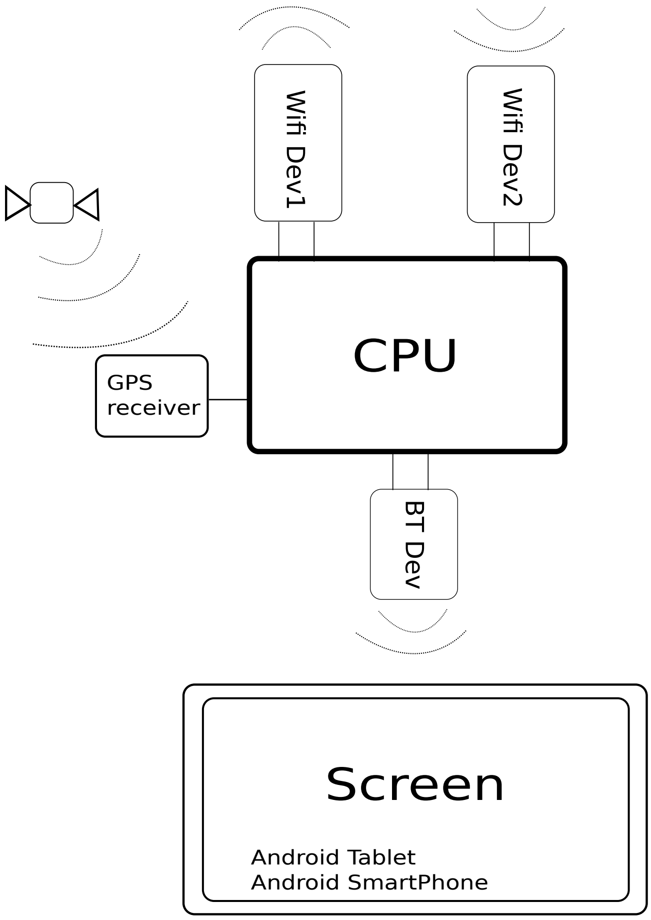

Figure 4: Basic GPS broadcast wifi device (GPS-BR-Dev)

5 Identified problems

1. GPS updating frequency. Identify a reasonable updating frequency and latency. For 5G networks, the latency should be in the range $[100\mu s, 10ms]$. The most used 802.11 beacon period is of $100ms$. In both scenarios, the latency should not overtake $1ms$ without processing data.
2. Processing capacity. For 5G networks the density of devices should be up to $100/m^2$. In this case it is non applicable.
3. GPS resolution. For 5G networks the position accuracy is of $0'3m$.
4. Scanning:
   - Select only one channel to scan. This will deeply improve the behaviour of the system.
   - Multiplex broadcasting/scanning at the same radio-interface. It can happen that a receiver would never see a sender because there are synchronized (scanning and broadcasting at the same time on both vehicles). In our case it should not apply because were are using two interfaces.

6 Future work

There are a lot of future work possibilities, but let us know that we have to do this work before!. In any case, there are some general ideas:

- GPS broadcasting can be very useful for collision avoidance and may be a way of "Emergency Message Dissemination" if some kind of emergency message based on position variation (speed) can be included into the broadcast frame.
- Environmental information like wind, temperature (and ice risks), could be gathered by the Edge Cloud and sent to the decision makers at the cloud core or sent back directly to the vehicles.
- We can use of the OBD-2 interface to broadcast other information of the vehicle, like speed, or some diagnostics. There are some OBD-2 -> Wifi and BlueTooth adapters. This would be a general CAM (Cooperative Awareness Message) wifi based broadcasting system.
- The information (in particular GPS positioning, but also other useful information about car overtaking) should be managed by some servers or data mining software. This information could be gathered and managed using Kaa [3] in real-time on urban areas or deferred (storing and forwarding) in rural areas.
- GPS-Broadcast can take advantage of the SoD (Send on Delta) sampling strategies.
- More a benefit than a future line: A car can know its position in tunnels based on the last GPS data received and its speed. It can broadcast all this information to the neighboring cars.

7 Previous knowledge

- Theory and practice interest in vehicular communications.
- Theory and practice interest in networking.
- Preferably Linux knowledge.
- Preferably C/C++ knowledge.
- Preferably Android programing knowledge.

8 Previewed knowledge to be acquired

- C/C++, Arduino and Android programming, as well as sockets.
- Linux operating
- Basic electronics and telecommunications
- Networks and protocols

References

[1] E. Commission, “5g empowering vertical industries,” pp. 1–9, January 2017.

[2] Unknown, “Use cases and system architecture requirements,” pp. 1–5, January 2017.

[3] “Kaa open-source iot platform,” https://www.kaaproject.org/, accessed: 2017-01-25.