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A. Petrescu, Ed.
CEA, LIST
J. Huang
Huawei Technologies
T. Ernst
Mines ParisTech
R. Buddenberg
" "

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Cooperative Adaptive Cruise Control and Platooning at SDOs and Gap Analysis

draft-petrescu-its-cacc-sdo-02.txt

Abstract

This document describes the use-cases of Cooperative Adaptive Cruise Control, and Platooning, as defined by several Standards Development Organizations such as ETSI, IEEE P1609, SAE, 3GPP, ISO and FirstNet.

C-ACC and Platooning involve concepts of direct vehicle-to-vehicle, and device-to-device communications, which are developped at least by 3GPP and precursory by the METIS EU project. They are illustrated very clearly in emergency settings such as FirstNet.

IP messages - instead of link-layer messages - are pertinent for C-ACC and Platooning use-cases because applications for road safety such as WAZE, iRezQ and Coyote (currently involving infrastructure) are IP messages, and proved succesful in deployments. Applications such as Sentinel are direct between vehicles but are not IP, currently.

Status of This Memo

This Internet-Draft will expire on March 21, 2016.

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1. Introduction

Cooperative Adaptive Cruise Control and Platooning are two use-cases described recently at particular Standards Development Organizations. C-ACC is understood as a formation of chains of automobiles following each other at constant speed, in an automated manner. This is to offer more comfort for human drivers on long journeys on straight roads.

Simple 'cruise control' was the automation of speed maintenance at a single automobile (increase torque if uphill, smoothly brake downhill, such as to maintain constant speed). The term "Adaptive Cruise Control" was used earlier in related ISO standards. The concept of C-ACC aims at the same level of automation but in a cooperative manner between several vehicles: while in CC mode, when a vehicle in front slowly decelerates, this vehicle will also do, such as to maintain distance, and relieve driver from taking control over.

Platooning is a concept related to larger vehicles following each other. The goal in this case is more than just comfort - large gains are expected in terms of gas consumption: when large vehicles can follow each other at small distance the air-drag is much lower, reducing gas consumption, tyre use, and more.

Both C-ACC and Platooning must rely on data packet exchanges between vehicles (in addition to more immediate indices like signal echoes - radars and cameras). These exchanges may happen in a direct manner (direct vehicle to vehicle communications) or with assistance from a fixed communication infrastructure (vehicle-to-infrastructure-to-vehicle communications).

This document presents the C-ACC and Platooning use-cases as described at ETSI, IEEE, SAE, ISO, 3GPP and more. These use-cases are widely accepted as Vehicle-to-Vehicle applications.

In emergency settings the concepts of direct vehicle-to-vehicle communications are of paramount importance. FirstNet, an overarching example described later in this document, covers V2V, V2I and V2I2V communication needs, together with strong security requirements.

In the market, several systems for vehicular communications have demonstrated a number of benefits in the context of vehicle-to-vehicle communications. The Sentinel system is used between vehicles to warn each other about approach; the WAZE application on smartphones created a community where users influence others about the route choice; the iRezQ and Coyote applications communicate between vehicles, via infrastructure, about route risks.

In [I-D.petrescu-ipv6-over-80211p] the use of IPv6 over 802.11p is described. This link layer is potentially used in direct vehicle-to-vehicle communications. It is obviously not the only link layer pertinent for V2V.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

C-ACC: Cooperative Adaptive Cruise Control.

V2V: Vehicle-to-Vehicle communications.

3. ETSI ITS C-ACC and Platooning use-case and reqs

ETSI Technical Committee Intelligent Transportation Systems (ETSI TC ITS) is responsible for the development and maintenance of standards, specifications and other reports on the implementation of V2V communications in Cooperative ITS. Its scope extends from the wireless access (excluding issues in radio frequency) to generic services and corresponding applications. Security and tests specifications are also covered. This responsibility is reflected in the organization with five working groups that make up the committee. Among them, WG1 is responsible of the facilities and applications needs.

Under the EU Mandate M/453, TC ITS has developed a minimum set of standards (Release 1) for systems interoperability during initial deployment. The list of standards and specifications are provided in the publicly available report ETSI TR 101 607. A second release of the standards is being prepared. It should support more complex use case, possible integration with other technologies as well as a more elaborate consideration of access networks other than the ITS-G5 (European profile of IEEE 802.11p). The TC ITS WG1 is currently working on two separate work items for pre-standardization studies on C-ACC (DTR/ITS-00164) and Platooning (DTR/ITS-00156). The scope of the target technical reports is to describe the relevant use cases that could be enabled by Cooperative ITS, to survey the existing related standards and to identify what new features and standards are needed to support these use cases.

4. IEEE P1609 perspective on communications for C-ACC and Platooning

One perspective from IEEE P1609 is that Cooperative Adaptive Cruise Control (CACC) represents an "application". An application is typically software whose communication needs are situated at the

upper layers of a communication stack - e.g. the Application Layer. As such it is little relevant to IEEE P1609; P1609 is concerned more with physical, data-link and network communication layers. On another hand, a perspective well considered in IEEE P1609 is that C-ACC and Platooning may be more relevant to the Society of Automotive Engineers.

5. SAE perspective on C-ACC and Platooning

The Society of Automotive Engineers (SAE) concerns itself with data exchanges and host system requirements for applications. The SAE DSRC Technical Committee (DSRC: Dedicated Short-Range Communications) is working on C-ACC within the Cooperative Vehicle Task Force. In addition, the SAE On-Road Vehicle Automation Committee is working on a use-case relevant to C-ACC (under development) towards realization of a reference architecture.

The SAE DSRC TC activities are in cooperative agreement to ETSI ITS WG1, as there are information exchanges between the two bodies.

6. 3GPP SDO and EU projects using LTE Device-to-Device concepts

6.1. 3GPP

Proximity Service (ProSe) allows a UE to discover and communicate with other UEs that are in proximity directly or with the network assistance. This may also be called as Device-to-Device (D2D) communication. ProSe is intended for purposes such as public security, network offloading, etc [GPP-TR-22-803].

The ProSe Communication path could use E-UTRAN or WLAN. In the case of WLAN, only ProSe-assisted WLAN direct communication (i.e. when ProSe assists with connection establishment management and service continuity) is considered [GPP-TS-22-278].

The work on ProSe is initiated in 3GPP Release 12. Some enhancements are being added in Release 13, e.g. Restricted ProSe Discovery. Some use cases are identified in [GPP-TR-22-803], but most of which are intended for common mobile users, e.g. walking people, not for vehicles moving at high speed, for example the latency in ProSe communication may be a problem for V2X.

Although ProSe does not support V2X communication before Release 14, but it has some very good characteristics which makes it a good candidate for V2X besides DSRC. ProSe communication does not have to go through the EPC, which will significantly reduce the latency. ProSe also support group and broadcast communication by means of a common communication path established between the UEs.

There are some efforts at 3GPP Release 14, trying to address V2X communication. The efforts are proposed by experts in the industry, and may be subject to change. These efforts include the following:

1. To address the V2X use cases in 3GPP. The use cases may have been defined by other SDOs, e.g. ETSI ITS, 3GPP can reference to them. Requirements for V2X communication should also be considered, for example network delay, packet loss rate, etc. [METIS-D1.1] already propose some requirements, but those are intended for future mobile network, which may be too critical for LTE.

2. To address V2X applications and messages. The messages may include message defined in SAE J2735, ETSI Cooperative Awareness Message (CAM) and ETSI Decentralized Environmental Notification Message (DeNM). The messages defined by different SDOs might be similar to each other.

3. Study of possibility to add enhancements to ProSe, and to make it able to support and enhance DSRC.

4. Study of using existing LTE technologies for unicast/multicast/ broadcast communication.

The above are just some examples, not an exhaustive list.

[GPP-TR-22-885] studies many V2X services using LTE. These services include V2V communication (e.g. Cooperative Adaptive Cruise Control, Forwarding Collision Warning, etc), V2I/V2N communication (e.g. Road Safety Services) and vehicle to pedestrian communication. The services' pre-condition, service flow, post-condition, including some network communication requirements, such as delay, messages frequency and message size, are ayalyzed.

In [GPP-TR-22-885], Cooperative Adaptive Cruise Control (CACC) allows a vehicle to join a group of CACC vehicles, and the benefits are to improve road congestion and fuel efficiency. Member vehicles of CACC group should periodically broadcast messages including the CACC group information, such as speed and gap policies, etc. If a vehicle outside the group wants to join, it should send a request to the group. If a member of the CACC group accepts the request, it should send a confirm message and provide necessary distance gap; and members of the group will update their group information. When a Member wants to leave the CACC group, it should broadcast a goodbye message, and the driver assumes control of the vehicle.

6.2. METIS

METIS is co-funded by the European Commission as an Integrated Project under the Seventh Framework Programme for research and development (FP7).

METIS defines test cases and requirements of "Traffic safety and efficiency", as depicted in [METIS-D1.1], which is intended for 5G in 2020 but may also be applicable for LTE and beyond.

The use cases include:

1. Dangerous situation that can be avoided by means of V2V communications.

2. Dangerous situation with vulnerable road users (i.e. pedestrians, cyclists,...) that can be avoided by means of V2D communications. "D" can denote any cellular device that the vulnerable road user may carry (e.g. smart phone, tablet, sensor tag).

3. Assistance services that can improve traffic efficiency by means of V2X communications, e.g. traffic sign recognition and green light assistance.

4. Platooning (or road trains) in an autonomous manner to increase traffic flows and reduce fuel consumption and emissions.

5. Highly automated vehicles.

To support the above use cases, METIS works out the corresponding network requirements, such as E2E latency should be within 5ms, required data rates for various scenarios, service ranges in highway/rural/urban scenarios, etc.

7. ISO perspective on V2V

The International Standards Organization's Technical Committee 204 "Intelligent transport systems" (ISO TC204, in short) has specified a communication architecture known as the "ITS station reference communication architecture" [ISO-21217]. This communication architecture covers all layers (access technologies, network, transport, facilities and applications) of a typical communications protocol stack. It is designed to accommodate communications between ITS stations engaged in ITS services. ITS stations can be deployed in vehicles of any type, roadside infrastructure (traffic lights, variable message signs, toll road gantries, etc.), urban infrastructure (parking gates, bus stops, etc.) nomadic devices (smartphones, tablets) and control centers (traffic control center,

emergency call centers, data centers and services centers). The ITS stations can be distributed in several nodes (e.g. an in-vehicle gateway and a set of hosts attached to the internal in-vehicle network). The ITS station architecture is designed to support many kinds of wired and wireless access technologies (vehicular WiFi 802.11p, urban WiFi 802.11b/g/n/ac/ad; cellular networks; satellite; infra-red, LiFi, millimeter wave, etc.)

The ISO ITS station architecture can thus support both broadcast and unicast types of communication, vehicle-to-infrastructure communications (road infrastructure using e.g. WiFi, or cellular infrastructure using e.g. 3G/4G) and, most notably, direct vehicle-to-vehicle communications.

The architecture includes the possibility to communicate using IPv6 [ISO-21210] or non-IP (ISO FNTP, currently being harmonized with IEEE WAVE).

The ISO TC204/WG14 (Work Group 14 "Vehicle/Roadway Warning and Control Systems") is developing a draft of international standard for C-ACC systems. The focus is on vehicular system control, rather than on communication media. The potential work item is in an early stage of development; it may describe performance requirements or validation through test procedures. It is considered that "C-ACC" to be an expansion to the existing ACC concepts which have been previously described in the document ISO 15622 "Adaptive Cruise Control Systems". The potential C-ACC work item may require the specific involvement of Vehicle-to-Vehicle communications and other types of communications (I2V and more), in addition to requiring active sensing involving radars and camera systems.

8. ISO-IEEE Harmonization

The intent is to harmonize the IEEE 1609 and ISO FAST protocols at 5.9GHz to avoid having to support region-dependent protocols (e.g. different protocols in Europe and the US), and this intention is not dependent on any particular application or service.

For example, the IEEE 1609.3 WSMP and WSA messages have recently been harmonized with ISO 29281-1 FNTP and ISO 24102-5 FSAP.

C-ACC and Platooning are (C-)ITS services that will get deployed as ITS applications involving ITS application instances being installed on ITS stations in vehicles. These applications can and will make use of any and all available ITS station communication services (network and transport protocols, data link layer protocols, and physical layer protocols) that have the necessary characteristics/ properties (e.g. V2V, low-latency, moderate bandwidth, etc.) to

achieve their goals. The IEEE 1609 and ISO protocols and communication services, whether or not they are ultimately "harmonized", can be used by either or both of these ITS applications as they generally meet the requirements for these apps.

Some communication tasks in C-ACC and Platooning will use IPv6, whereas others will not. For example some vendors of WAVE devices and ITS station units consider the use of the short messages protocol (not IPv6) for C-ACC and Platooning scenarios.

9. FirstNet EMS use of LTE and IP in V2I2V

FirstNet is a corporation housed inside the US Department of Commerce. It gets capitalization budget from, among other sources, sale of spectrum by the US FCC. It gets operating budget from sale of services to state emergency services entities.

The specific use-cases for FirstNet include vehicle-to-vehicle, vehicle-to-infrastructure and vehicle-to-infrastructure-to-vehicle communications using in certain cases LTE and IP:

1. Emergency communications to vehicles from government entities conveying, for example: weather warnings, road conditions, evacuation orders. The government entities might include PSAPs or mobile vehicles such as police cruisers.

2. Instrumented emergency services vehicles such as ambulances. An example is the ability to telemeter casualty (patient) data from sensors attached to the casualty to a hospital emergency room.

3. Emergency communications from vehicles' occupants to government entities such as Public Safety Access Points (PSAPs, also known as 911 operators in US).

The National Public Safety Telecommunications Council describes FirstNet as an emergency communications system (largely viewed through the prism of the familiar Land Mobile Radio systems most emergency services use.) The cellular telephone industry views FirstNet as supplementary to an existing commercial cellphone system (e.g. reusing the same towers and backhaul). Perhaps a better view of FirstNet is as an extension of the Internet to emergency services vehicles (including foot-borne).

It is clear that FirstNet overlaps to a large extent to the concepts that have been discussed in vehicle-to-vehicle communications for other purposes.

FirstNet has not been clear about its communication technology choices to date. But LTE has been discussed as the most likely layer 2 protocol. A segregated segment of spectrum in the 700MHz band has been set aside by Congressional action for emergency services and control of that spectrum has been passed to FirstNet. There appear to be no new protocols, development of which is fostered by FirstNet. Several Internet applications would need rework to handle high availability, security and assured access needs of emergency services.

10. Internet apps: WAZE, iRezQ, Coyote, Sentinel

Applications using the Internet have been developped in the particular context of vehicular communications. These applications are designed for parties situated in vehicles. Their profile is less of client-server kind, but more of peer-to-peer kind (vehicle to vehicle).

Some use vehicle-to-infrastructure-to-vehicle IP paths, whereas others involve direct vehicle-to-vehicle paths (without infrastructure).

These applications are described in more detail in draft-liu-its-scenario-00.txt issued on March 9th, 2015, authored by Dapeng Liu.

11. Gap Analysis

It is generally agreed that an entire IP network is embedded in an automobile. The embedded network is formed by at least two (and generally up to 5) distinct IP subnets. In each of the subnets several IP-addressable computers are currently enabled with IP stacks.

The realization of V2V communications can happen by connecting together two such embedded networks, each carried by a distinct vehicle. With a direct connection, an IP Router in one vehicle connects to an IP Router in another vehicle nearby. The maximum distance between two such vehicles is dictated by the link layer technology (e.g., with IEEE 802.11p OCB mode the distance may be up to 800 metres). On another hand, an indirect connection may involve the use of a Road-Side Unit fixed along the road, or a longer IP path through a cellular network. It is expected that the shortest latencies to be obtained with the most straightforward (direct) connections rather than through-fixed-RSU through-cellular.

When two vehicles are connected to each other in this way, an IP subnet is formed between the egress interfaces of Router embedded in

vehicles. There are several ways in which the IP path can be established across this 1-hop subnet.

11.1. Neighbor Discovery protocol

Routers exchange Router Advertisement messages. An RA message contains prefixes announced to be valid on one link. On another hand, the prefix announced by an RA can not be equal to the prefix of a same router but of one of its other interfaces. And this represents the gap of the ND protocol - it can not realize V2V topologies.

11.2. Mobile IP protocol

There are two modes of operation of a V2V topology. With a link technology like IEEE 802.11b it is possible that one vehicle attaches to another vehicle in "Access Point" mode, or alternatively in "ad-hoc" mode. In "Access Point" mode (or Client-Server), the first vehicle allocates an address, and potentially a prefix, to the second vehicle. This latter may then use the Mobile IP protocol to inform the first vehicle about is in-car prefix (use a Binding Update message as if the Access Point vehicle were a Correspondent Node). The gap is in that currently the Mobile IP protocol is not fully specified to send BUs in that way.

11.3. AODV protocol

The AODV protocol is a routing protocol used to build and find IP paths in a MANET network. However, this protocol does not take into account default routes. Default routes are extensively used in current networks carried in vehicles. The good administration of these routes simplify to a large extent the routing in such networks. This represents a gap.

12. Security Considerations

All government-to-vehicle and vehicle-to-government communications require authenticity; there will be no exceptions.

Some, but not all, communications from government-to-vehicle and vehicle-to-government require confidentiality (some of these requirements, such as medical data, have the force of law, many have custom or respect as the requirements base).

These requirements pertain to the content.

13. IANA Considerations

mandatory

14. Contributors

Jim Misener (Qualcomm, SAE DSRC TC Chair), Masanori Misumi (Mazda, ISO TC204/WG14 Convenor), Michelle Wetterwald (FBConsulting, ETSI active member), Hans-Joachim Fischer, Richard "Dick" Roy.

15. References

15.1. Normative References

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15.2. Informative References

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Appendix A. ChangeLog

The changes are listed in reverse chronological order, most recent changes appearing at the top of the list.

From -01 to -02:

- o Added perspectives on C-ACC and Platooning from ETSI, SAE, IEEE P1609 and ISO-IEEE Harmonization. Updated the perspective from ISO.

- o Added Gap Analysis: what are the gaps between what existing protocols ND, Mobile IP and AODV can do and what is needed to realize a C-ACC and Platooning use-case with a V2V topology?

From nil to draft-petrescu-its-cacc-sdo-00.xml:

- o initial version

Authors' Addresses

Alexandre Petrescu (editor)
CEA, LIST
CEA Saclay
Gif-sur-Yvette , Ile-de-France   91190
France

Phone: +33169089223
Email: Alexandre.Petrescu@cea.fr

James Huang
Huawei Technologies
Shenzhen
China

Email: james.huang@huawei.com

Thierry Ernst
Mines ParisTech
Paris   75006
France

Email: Thierry.Ernst@mines-paristech.fr

Rex Buddenberg
" "
US

Email: buddenbergr@gmail.com