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Problem Statement for Vehicle-to-Infrastructure Networking
draft-jeong-its-v2i-problem-statement-00

Abstract

This document specifies the problem statement for IPv6-based vehicle-to-infrastructure networking. Dedicated Short-Range Communications (DSRC) is standardized as IEEE 802.11p for the wireless media access in vehicular networks. This document addresses the extension of IPv6 as the network layer protocol in vehicular networks and is focused on the networking issues in one-hop communication between a Road-Side Unit (RSU) and vehicle. The RSU is connected to the Internet and allows vehicles to have the Internet access if connected. The major issues of including IPv6 in vehicular networks are neighbor discovery protocol, stateless address autoconfiguration, and DNS configuration for the Internet connectivity over DSRC. Also, when the vehicle and the RSU have an internal network, respectively, the document discusses the issues of internetworking between the vehicle's internal network and the RSU's internal network.

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1. Introduction

Recently, Vehicular Ad Hoc Networks (VANET) have been focusing on intelligent services in road networks, such as driving safety, efficient driving, and entertainment. For this VANET, Dedicated Short-Range Communications (DSRC) [DSRC-WAVE] has been standardized as IEEE 802.11p [IEEE-802.11p], which is an extension of IEEE 802.11a [IEEE-802.11a] with a consideration of the vehicular network's characteristics such as a vehicle's velocity and collision avoidance.

Now the deployment of VANET is demanded into real road environments along with the popularity of smart devices (e.g., smartphone and tablet). Many automobile vendors (e.g., Benz, BMW, Ford, Honda, and Toyota) started to consider automobiles as computers instead of mechanical machines since many current vehicles are operating with many sensors and software. Also, Google made a great advancement in self-driving vehicles with many special software modules and hardware devices to support computer-vision-based object recognition, machine-learning-based decision-making, and GPS navigation.

With this trend, vehicular networking needs to be enabled on top of TCP/IP technologies in order to interoperate with the Internet. IPv6 [RFC2460] is suitable for vehicular networks since the protocol has abundant address space, autoconfiguration features, and protocol extension ability through extension headers.

This document specifies the problem statement of IPv6-based vehicle-to-infrastructure (V2I) networking, such as IPv6 addressing [RFC4291], neighbor discovery [RFC4861], address autoconfiguration [RFC4862], and DNS naming service [RFC6106][RFC3646][ID-DNSNA]. Also, the document analyzes the characteristics of vehicular networks to consider the design of V2I networking.

2. Requirements Language

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].

3. Terminology

This document uses the terminology described in [RFC4861] and [RFC4862]. In addition, four new terms are defined below:

- o Road-Side Unit (RSU): A node that has a Dedicated Short-Range Communications (DSRC) device for wireless communications with the vehicles and is connected to the Internet. Every RSU is usually deployed at an intersection so that it can provide vehicles with

the Internet connectivity.

- o Vehicle: A node that has the DSRC device for wireless communications with vehicles and RSUs. Every vehicle may also have a GPS-navigation system for efficient driving.
- o Traffic Control Center (TCC): A node that maintains road infrastructure information (e.g., RSUs and traffic signals), vehicular traffic statistics (e.g., average vehicle speed and vehicle inter-arrival time per road segment), and vehicle information (e.g., a vehicle’s identifier, position, direction, speed, and trajectory). TCC is included in a vehicular cloud for vehicular networks.

4. Overview

This document specifies the problem statement of vehicle-to-infrastructure (V2I) networking based on IPv6. The main focus is one-hop networking between a vehicle and an RSU or between vehicles via an RSU. However, this document does not address multi-hop networking scenarios of vehicles and RSUs. Also, the problems focus on the network layer (i.e., IPv6 protocol stack) rather than the media access control (MAC) layer and the transport layer (e.g., TCP, UDP, and SCTP).

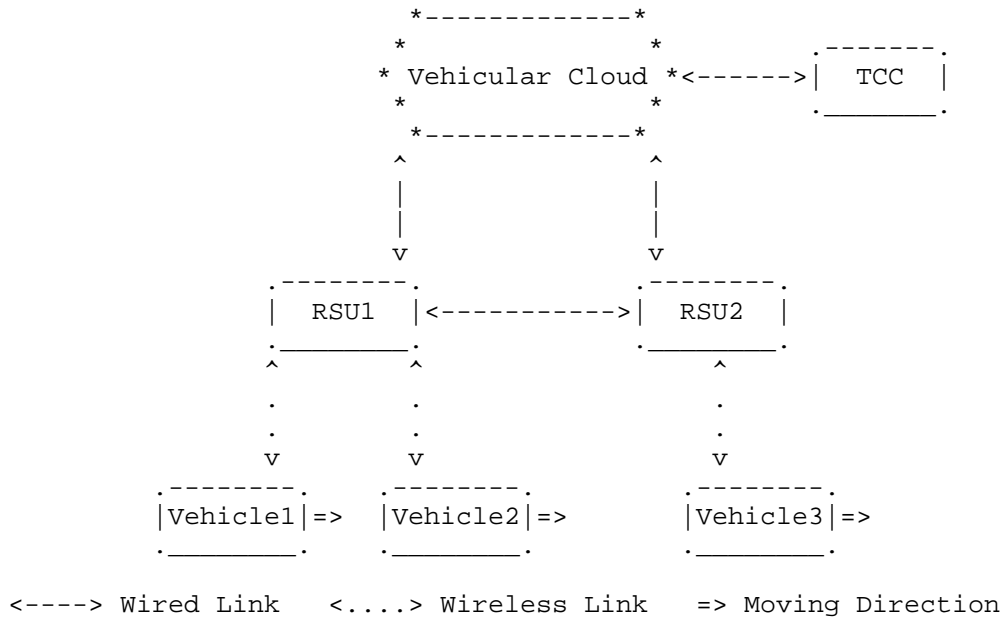


Figure 1: The Network Configuration for V2I Networking

Figure 1 shows the network configuration for V2I networking in a road network. The two RSUs (RSU1 and RSU2) are deployed in the road network and are connected to the Vehicular Cloud through the Internet. The TCC is connected to the Vehicular Cloud and the two vehicles (Vehicle1 and Vehicle2) are wirelessly connected to RSU1, and the last vehicle (Vehicle3) is wirelessly connected to RSU2. Vehicle1 can communicate with Vehicle2 via RSU1. Vehicle1 can communicate with Vehicle3 via RSU1 and RSU2.

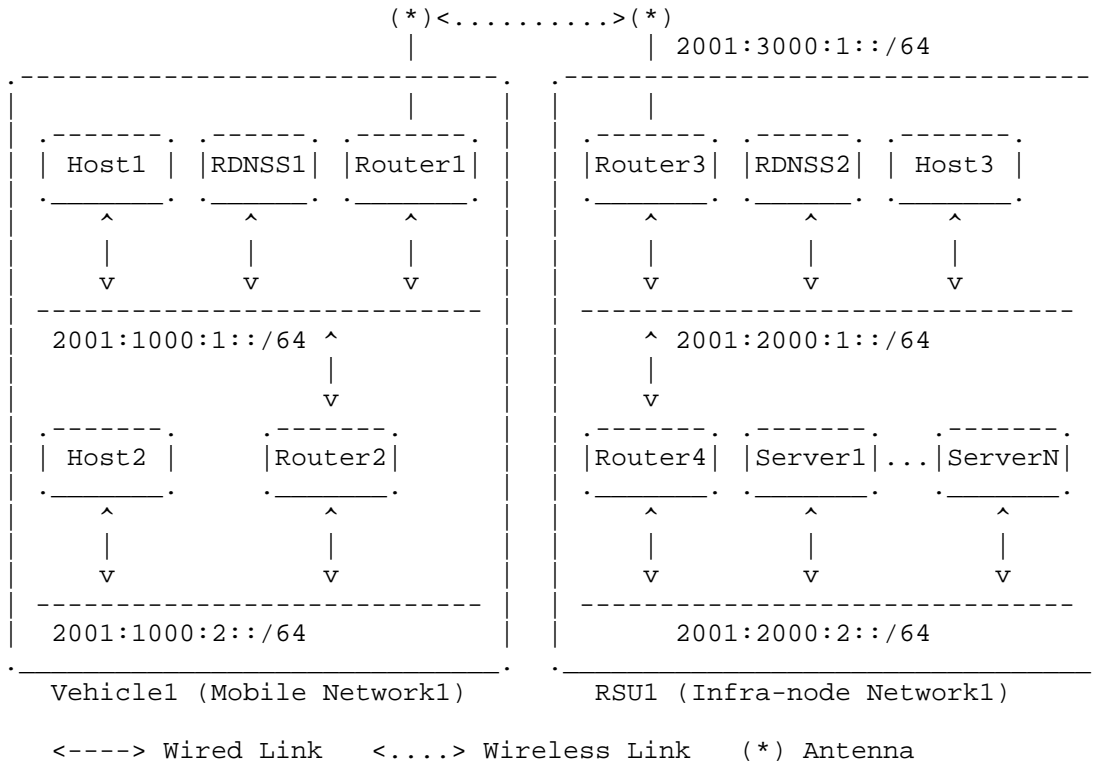


Figure 2: Internetworking between Vehicle Network and RSU Network

Figure 2 shows internetworking between the vehicle's mobile network and the RSU's infra-node network. There exists an internal network (Mobile Network1), which is located inside Vehicle1. Vehicle1 has the DNS Server (RDNSS1), the two hosts (Host1 and Host2), and the two routers (Router1 and Router2). The internal network (Infra-node Network1) is located inside RSU1. RSU1 has the DNS Server (RDNSS2), one host (Host3), the two routers (Router3 and Router4), and the collection of servers (Server1 to ServerN) for various services in the road networks, such as the emergency notification and navigation. Vehicle1's Router1 and RSU1's Router3 use `2001:3000:1::/64` for an

external link (e.g., DSRC) for I2V networking.

This document addresses the internetworking between the vehicle's mobile network and the RSU's infra-node network in Figure 2 and the required enhancement of IPv6 protocol suite for the V2I networking service.

5. Internetworking between the Vehicle and RSU Networks

This section discusses the internetworking between the vehicle's mobile network and the RSU's infra-node network. As shown in Figure 2, it is assumed that the prefix assignment for each subnet inside the vehicle's mobile network and the RSU's infra-node network through a prefix delegation protocol. Problems are a prefix discovery and prefix exchange. The prefix discovery is defined as how routers in a mobile network discover prefixes in the mobile network. The prefix exchange is defined as how the vehicle and the RSU exchange their prefixes with each other. Once these prefix discovery and prefix exchange are established, the unicast of packets should be supported between the vehicle's mobile network and the RSU's infra-node network. Also, the DNS naming service should be supported for the DNS name resolution for a host or server in either the vehicle's mobile network or the RSU's infra-node network.

6. IPv6 Addressing

This section discusses IP addressing for V2I networking. There are two policies for IPv6 addressing in vehicular networks. The one policy is to use site-local IPv6 addresses for vehicular networks [RFC4291]. The other policy is to use global IPv6 addresses for the interoperability with the Internet [RFC4291]. The former approach is usually used by Mobile Ad Hoc Networks (MANET) for a separate multi-link subnet. This approach can support the emergency notification service and navigation service in road networks. However, for general Internet services (e.g., email access, web surfing and entertainment services), the latter approach is required.

For the global IP addresses, there are two policies, which are a multi-link subnet approach for multiple RSUs and a single subnet approach per RSU. In the multi-link subnet approach, which is similar to a site-local IPv6 address for MANET, RSUs play a role of L2 switches and the router interconnected with the RSUs is required. The router maintains the location of each vehicle belonging to an RSU for L2 switching. In the single subnet approach per RSU, which is similar to the legacy subnet in the Internet, RSUs play a role of L3 router.

7. Neighbor Discovery

The Neighbor Discovery (ND) is a core part of IPv6 protocol suite [RFC4861]. This section discusses the extension of ND for V2I networking. The vehicles are moving fast within the communication coverage of an RSU. For the external link between the vehicle and the RSU for V2I networking, as shown in Figure 2, ND time-related parameters such as router lifetime and Neighbor Advertisement interval should be adjusted for high-speed vehicles.

8. IP Address Autoconfiguration

This section discusses the IP address autoconfiguration for V2I networking. For the IP address autoconfiguration, the high-speed vehicles should also be considered. The legacy IPv6 stateless address autoconfiguration [RFC4862], as shown in Figure 1, may not perform well because vehicles can pass through the communication coverage of the RSU before the address autoconfiguration with the Router Advertisement and Duplicate Address Detection procedures. DHCPv6 (or Stateless DHCPv6) can be used for the IP address autoconfiguration [RFC3315][RFC3736]. In the case of a single subnet per RSU, the delay to change IPv6 address through DHCPv6 procedure is not suitable since vehicles move fast. Some modifications are required for the high-speed vehicles that quickly crosses the communication coverages of multiple RSUs. Some modifications are required for both stateless address autoconfiguration and DHCPv6.

9. DNS Naming Service

This section discusses a DNS naming service for V2I networking. The DNS naming service can consist of the DNS name resolution and DNS name autoconfiguration.

The DNS name resolution translates a DNS name into the corresponding IPv6 address through a recursive DNS server (RDNSS) within the vehicle's mobile network and DNS servers in the Internet [RFC1034][RFC1035], which are distributed in the world. The RDNSSes can be advertised by RA DNS Option or DHCP DNS Option into the subnets within the vehicle's mobile network.

The DNS name autoconfiguration makes a unique DNS name for hosts within a vehicle's mobile network and registers it into a DNS server within the vehicle's mobile network [ID-DNSNA]. With Vehicle Identification Number (VIN), a unique DNS suffix can be constructed as a DNS domain for the vehicle's mobile network. Each host can generate its DNS name and register it into the local RDNSS in the vehicle's mobile network.

10. IP Mobility Support

This section discusses an IP mobility support in V2I networking. In a single subnet per RSU, vehicles keep crossing the communication coverages of adjacent RSUs. During this crossing, TCP/UDP sessions can be maintained through IP mobility support, such as Mobile IPv6 [RFC6275]. Since vehicles move fast along roadways, this high speed should be configured for a parameter configuration in Mobile IPv6.

To support the mobility of a vehicle's mobile network, Network Mobility (NEMO) protocol can be used [RFC3963]. Like Mobile IPv6, the high speed of vehicles should be considered for a parameter configuration in NEMO.

11. Security Considerations

The security is very important in vehicular networks for V2I networking. Only valid vehicles should be allowed to use V2I networking in vehicular networks. VIN and a user certificate can be used to authenticate a vehicle and the user.

This document shares all the security issues of the neighbor discovery protocol. This document can get benefits from secure neighbor discovery (SEND) [RFC3971]

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Cooperative Adaptive Cruise Control and Platooning at SDOs and Gap
Analysis
draft-petrescu-its-cacc-sdo-04.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 developed by 3GPP following on work done within the METIS EU project. They are illustrated very clearly in emergency settings such as FirstNet.

IP packets - instead of link-layer frames - are pertinent for C-ACC and Platooning use-cases because applications for road safety such as WAZE, iRezQ and Coyote (currently involving infrastructure) make use of IP messages, and have proved successful in deployments. Applications such as Sentinel operate directly between vehicles, but currently use messages not carried over IP.

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1. Introduction

Cooperative Adaptive Cruise Control (C-ACC) and Platooning are two use-cases described recently by other Standards Development Organizations (SDOs). C-ACC [CACC-def] is understood as a automated formation of chains of automobiles following each other at constant speed. This offers 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 the literature [ACC-def]. 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 another 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 wireless communications between vehicles (in addition to more immediate indicators 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 V2V-based C-ACC and Platooning use-cases as described at ETSI [ETSI-CACC], SAE [SAE-V2V], ISO [ISO-CACC], 3GPP [GPP-TR-22-885], ITU [ITU-V2V], ITS Info-communications Forum of Japan [its-infocomm-CACC] and more. These use-cases are widely accepted as examples of Vehicle-to-Vehicle applications.

In emergency settings the concepts of direct vehicle-to-vehicle communications are of paramount importance. FirstNet, as 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.

- o The Sentinel system is used between vehicles to warn each other about approach;
- o WAZE on smartphones created a community where users influence others about the route choice;
- o iRezQ and Coyote 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 to be used in direct vehicle-to-vehicle communications, among several other possibilities.

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].

3GPP: Third Generation Partnership Project.

3G: Third Generation.

4G: Fourth Generation.

5G: Fifth Generation of mobile networks.

apps: applications.

AODV: Ad-hoc On-demand Distance Vector.

ARIB: Association of Radio Industries and Businesses.

BSS: Basic Service Set.

C-ACC: Cooperative Adaptive Cruise Control.

CAM: Cooperative Awareness Message.

CC: Cruise Control.

CEN: European Committee for Standardization (Comite europeen de normalisation, fr.)

DeNM: Decentralized Environmental Notification Message.

DMM: Distributed Mobility Management.

DSRC: Dedicated Short Range Communications, as referenced in the United States FCC Report and Order for the frequency allocation for 5.9GHz band in North America, which refers to "DSRC" as the ASTM (earlier "American Society for Testing and Materials") standard "E2213". Other interpretations of "DSRC" include the DSRC standard developed in ISO TC204 WG17 and CEN TC278 which uses a different frequency spectrum than the one used in North America.

E2E: end-to-end.

EMS: Emergency and Medical System providers.

EPC: Evolved Packet Core.

ETSI: European Telecommunications Standards Institute.

E-UTRAN: Evolved Universal Terrestrial Radio Access Network.

EU: European Union.

FAST: fast.

FCC: Federal Communications Commission.

FNTP: Fast Networking and Transport layer Protocol.

FSAP: Fast Service Advertisement Protocol.

I2V: Infrastructure to Vehicle.

ICT: Information and Communication Technologies.

IEEE: Institute of Electrical and Electronics Engineers.

IoT: Internet of Things.

IP: Internet Protocol.

IPv6: Internet Protocol version 6.

IPTV: Internet Protocol Television

ISO: International Organization for Standardization.

ITS: Intelligent Transportation Systems.

ITS-G5: ITS Gigahertz Five.

ITU: International Telecommunication Union.

ITU-T: Telecommunication Standardization Sector of the International Telecommunication Union.

IVC-RVC:

LiFi: Light Fidelity.

LTE : Long-Term Evolution.

METIS: Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society.

OBU: On-Board Unit.

OCB: Outside the Context of a BSS identifier.

PHY: physical layer.

ProSe: Proximity Service.

PSAP: Public Safety Answering Points.

RA: Router Advertisement.

SAE: Society of Automotive Engineers.

SDO: Standards Development Organization.

SG: Study Group.

TC: Technical Committee.

TR: Technical Report.

UE: User Equipment.

US: United States.

V2V: Vehicle-to-Vehicle communications.

V2X: Vehicle-to-'other' communications. E.g. Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P), Vehicle-to-Nomadic[device] (V2N), Vehicle-to-Device (V2D) and more.

V2I2V: Vehicle to Infrastructure to Vehicle.

WAVE: Wireless Access for Vehicular Environments.

WG1: Work Group 1.

WiFi: Wireless Fidelity.

WLAN: Wireless Local Area Network.

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 cases, 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.

The C-ACC definition in TR 103 299 will soon be made public.

4. The C-ACC Use of Protocols specified by IEEE 1609 Standards

The C-ACC interacts with the presentation layer services which in turn use the communication protocols specified in IEEE 1609 standards.

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 towards realization of a reference architecture.

In addition to C-ACC, SAE is completing performance requirements for V2V Safety Communications to profile a probable US-mandated implementation. The concept is that a vehicle would send a link-layer message set (Basic Safety Message, plus path history and path prediction extensions) to a host vehicle to enable the host vehicle to use the transmitted information in a driver warning or alert algorithm. Because it is used for safety, it is of paramount importance that the messages are authenticated through a Security Credential Management System.

The SAE DSRC TC activities are in cooperative agreement to ETSI ITS WG1, as there are information exchanges between the two bodies [SAE-V2V].

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

6.1. 3GPP

The 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. pedestrians, but not for vehicles moving at high speed. The latency in ProSe communication may be a problem for V2X.

ProSe does not support V2X communication until at least 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 supports group and broadcast communication by means of a common communication path established between the UEs.

There are some efforts within 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, not an exhaustive list:

- o To address the V2X use cases in 3GPP. Some use cases 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.
- o 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.
- o Study of possibility to add enhancements to ProSe, and to make it able to support and enhance DSRC.
- o Study of using existing LTE technologies for unicast/multicast/broadcast communication.

[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 analyzed.

In [GPP-TR-22-885], Cooperative Adaptive Cruise Control (CACC) allows a vehicle to join a group of CACC vehicles; 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 broadcasts a goodbye message, and the driver once again 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 subsequent systems.

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. Autonomous platooning increase traffic flow and reduce fuel consumption and emissions.
5. Automated vehicles.

To support the above use cases, METIS works out the corresponding network requirements. For instance, for some applications the E2E latency must be within 5ms; other requirements include 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 protocol stack layers (access technologies, network, transport, facilities and applications). 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.

The IEEE 1609.3 WG developed a version 3 draft of 1609.3 such that after publication of this version 3, and after subsequent appropriate updates of ISO 29281-1 and ISO 24102-5 an interoperability mode with

ISO 29281-1 v2 FNTP and ISO 24102-5 v2 FSAP will be given. This interoperability in the first step will be limited to broadcast of messages (e.g. for road safety) such that an ITS station unit can properly receive messages sent out by a WAVE device, and vice versa.

C-ACC and Platooning are (C-)ITS services that will be deployed as ITS applications on ITS stations in vehicles. These applications can and will make use of 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. V2V communications at ITU

The International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies. It is an early standards development organization known for example, among other things, for spectrum or stationary orbit allocations to countries.

Within ITU, the Telecommunication Standardization Sector (ITU-T) is composed of Study Groups (SGs) which make Recommendations which lead to standards for countries' Information and Communication Technologies (ICT) networks.

The ITU-T SG 16 leads ITU's standardization work on multimedia coding and it is also the lead group for promising topics such as the Internet of Things activities (IoT), Internet Protocol Television (IPTV) and Intelligent Transportation Systems (ITS).

The Question 27/16 of ITU-T SG 16 titled "Vehicle gateway platform for telecommunication/ITS services/applications" is a group motivated by the observation that, among others, the information generated by vehicles has an important role in the chain of telecommunications and ITS.

Currently under discussion, the proposed study items include the definition of a gateway (aka OBU) and the functions and requirements to support vehicle-to-vehicle and vehicle-to-infrastructure

tellecommunications. Another study item is to define scenarios for such gateways acting as bridges (presumably "IP routers" , Ed.) between cars and between cars and the infrastructure.

The description of ITU-T Question 27/16 is publicly available on the web on the itu.int website.

10. ARIB and ITS Info-comm use of CACC and V2V concepts

In Japan, the Association of Radio Industries and Businesses (ARIB) and the ITS Info-communications Forum produce standards and guidelines for Intelligent Transportation Systems. Whereas US and EU standards focus mainly on the 5.9GHz bands for ITS, the Japanese standards operate initially in a 700MHz band.

The publicly and freely available document RC-013 version 1.0 titled "Experimental Guideline for Inter-Vehicle Communication Messages" considers that inter-vehicle communications (presumably V2V, Ed.) are realized with Basic Messages. A Basic Message is generated by an application layer running on top of a "IVC-RVC" layer (at the typical network-layer place, Ed.) which runs itself on top of a Layer 2 "data-link" and of a Layer 1 PHY. The contents of a Basic Message can be any one of the following: time information, position information, vehicle status, and more. A particular data frame representing status information is the "DE_CooperativeAdaptiveCruiseControlStatus" represented on 2 bits.

11. 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 communications architectures for FirstNet include vehicle-to-vehicle, vehicle-to-infrastructure and vehicle-to-infrastructure-to-vehicle communications using, in certain cases, LTE and IP:

- o 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.
- o 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.

- o 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 pedestrian).

It is clear that FirstNet overlaps with 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 developed by FirstNet. Several Internet applications would need rework to handle high availability, security and assured access needs of emergency services.

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

Applications using the Internet have been developed 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 a recent Internet Draft titled "Scenario of Intelligent Transportation System" [I-D.liu-its-scenario].

13. Car manufacturer labels with V2V features

Toyota "ITS Connect" is a feature advertised for high-end automobile models set to hit the roads by the end of 2015. This includes the Crown as well as two other lower level models. The "ITS Connect" features which exhibit V2V characteristics are Right Turn Collision Caution, Red Light Caution and Emergency Vehicle Proximity

Notification. One particular V2V feature which illustrates a possible migration from exclusively radar signals to bidirectional data exchanges is the Communicating Radar Cruise Control. A publicly available description of this feature mentions that it integrates Radar Cruise Control and V2V information from the preceding vehicle to help follow it smoothly. Toyota "ITS Connect" is using Japanese ARIB standards STD-Txxx and ITS Info-communications Forum Guidelines RC-xxx in the 700MHz band.

14. Gap Analysis

It is generally agreed that one or more IP subnets are 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, 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.

14.1. 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 a shortcoming of the ND protocol - it can not support V2V topologies.

14.2. 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 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.

This Mobile IP gap depends largely on the situation (physical location) of the Home Agent entity. The placement of the Home Agent in the fixed infrastructure is assumed by the most common deployments of connected vehicles. The Home Agent in charge of the vehicle is situated in a data center owned and administered by the vehicle manufacturer. Other similar placements consider the fixed network of a regional representative of the manufacturer, or a local dealer. Further, in theory, it can be considered that a Home Agent be placed inside a vehicle as well, although this has not been tested. Depending on this placement of the HA, the Mobile IP gap can vary.

Note a new requirement has been developed recently in the DMM Working Group. The distributed mobility management requirement REQ1 in [RFC7333] states that DMM solutions must enable traffic to avoid traversing a single mobility anchor far from the optimal route. This may help placing a Home Agent nearer to the access network (rather than in a data center). In addition to this requirement, it may be necessary to dynamically migrate the Home Agent to a place near the vehicle, as it moves across borders or travel long distances.

14.3. AODVv2 protocol

The AODVv2 protocol [I-D.ietf-manet-aodvv2] is a routing protocol used to build and find IP paths in an ad hoc network. However, AODVv2 does not take into account preconfiguration of default routes. Default routes are extensively used in current networks carried in vehicles. Good administration of default routes can greatly simplify routing in such networks. This represents a gap.

15. Security Considerations

All government-to-vehicle and vehicle-to-government communications, without exception, require authentication.

Some, but not all, communications from government-to-vehicle and vehicle-to-government require confidentiality to protect the content of the messages. Some of these requirements, such as medical data, have the force of law. Others are customary, or are based on common respect as requirements.

Protocol information shared between the cooperating vehicles MUST also be protected in order to avoid disruption or attack on the vehicles operation. Any modification or malicious insertion of protocol messages would carry with it a high risk of death and injury as well as tremendous disruption of other vehicular traffic.

16. IANA Considerations

mandatory

17. Contributors

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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 -03 to -04:

- o Updated the perspective from SAE with respect to work on V2V requirements for safety.
- o Clarified the IEEE 1609 point of view by which C-ACC use IEEE 1609 protocols.
- o Added authors' point of view of IEEE-ISO harmonization, which may have a relationship to vehicle-to-vehicle communications.
- o Added ITU-T Question 27 of Study Group 16 description mentioning V2V communications.
- o Added a section on Japan's ARIB and ITS info-comm documents which describe C-ACC and other inter-vehicle services in the 700MHz band. Added an example of car manufacturer with product on the market at the time of writing implementing some of these features.
- o Clarification of HA placement conditioning the Mobile IP gap discussion.
- o Editorial improvements, citations added, terminology section improved.

From -01 to -02:

- o Added perspectives on C-ACC and Platooning from ETSI, SAE, and IEEE P1609. 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?

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