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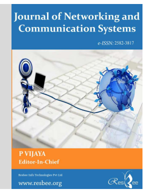

ITS-G5 vs C-V2X for Autonomous Car

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Abstract: Autonomous cars rely on sensors, radars, and lidar infotainment devices to function. They offer a safer solution for road safety, both for the driver and nearby cars. However, they also present a challenge, as ensuring safety requires taking all necessary precautions to ensure the modes of operation and communication of the autonomous car work flawlessly. This is why several research studies have been conducted on the communication protocols used by autonomous cars. These studies have analyzed the weak points of each protocol to propose solutions and improve existing ones. In our previous research papers, we have conducted comparative studies between several communication protocols using software such as OMNETt++. The most important factor that determines the robustness of a protocol is its response time, which ensures communication between the protocols. Some of the protocols that have been studied include C-V2X, DSRC, ITS-G5, and 5G.In this article, a comparative study between the C-V2X and ITS-G5 protocols is conducted based on criteria such as latency, synchronization, resource selection, and response time. This comparison is necessary to improve the operation of the two protocols and ensure the efficiency, reliability, and fluidity of communication between the vehicles and the environment.

Keywords: *ITS-G5, C-V2X, ITS, V2V, V2I, Autonomous car.*

1. Introduction

Driverless technology has long been an attractive idea. It has the potential to transform our experience of commuting and long-distance commuting, pulling people out of high-risk work environments, and streamlining our industries. it plays a very important role in helping to build the cities of the future, and safer travel, in this context we speak about autonomous vehicles which are vehicles allowing driving without human intervention Autonomous Vehicles are expected to lead the next paradigm shift in the field of transportation. While the benefits and issues associated with their introduction are still being critically evaluated and discussed, the active involvement of major technology companies and car manufacturers in a race to build the first operational vehicle is on, for many years now [1], Autonomous vehicles are likely to significantly increase non- drivers' vehicle travel. By increasing passenger comfort and productivity, an autonomous operation can make long-distance trips, including commutes, more endurable, increasing vehicle travel and sprawl [2] the intelligent transport infrastructure makes it possible to present a set of critical digital automation services that can be applied and consumed and capable of responding in real-time to the operational needs of the to mat automates vehicle, these services and automation will also be able to adapt in a way autonomous to improvements in the state of the infrastructure and the situation of each vehicle and element taking into consideration the state of their environment[3], VANETs are necessary for autonomous cars because they help ensure safe driving by developing traffic flow and reducing car accidents. This advantage is ensured thanks to shared information. However, any modification of this real-time of this information can cause a failure of the system affecting the safety of people on the road this is the reason why the response time criterion is very important [4] thus the VANETS create a network of mobile devices-vehicles. they are used for vehicle-to-infrastructure (V2I) and Vehicle-to- Vehicle (V2V) communication. The main objective of this technology is to generate safety on the roads, for example avoiding collisions so that in dangerous conditions such as traffic jams and accidents, vehicles can communicate with each other and with the network to share information. vital and essential information [5] for more effective communication, the autonomous car is based on communication protocols like DSRC (Dedicated short-range communications), C-V2X (Cellular Vehicle to everything), 5Generation, and ITS-5G (5G Intelligent transportation system) in this article, we make an in-depth study of the two protocols C-V2x and 5G-ITS where the response time criterion represents the most important criterion for fast and efficient reception of information allowing communication for the autonomous car and between two vehicles

2. Cv2x

In this first section, we will present the concept of the C-V2X Cellular Vehicle-to-Everything protocol, a powerful technology for providing mobility and security services, and we will discuss the different types of C-V2X applications, services that C -V2X provides C-V2X protocol architecture

2.1 Concept of-V2x

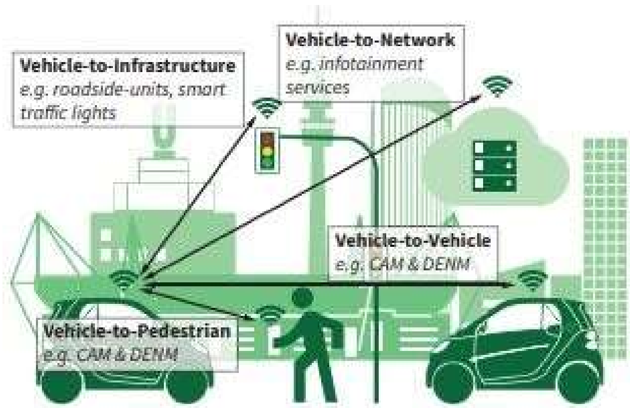

Fig. 1. Caption types of C-V2X applications.

3GPP completed the standardization of Cellular Vehicle-to-Everything (C-V2X) technology in 2017, this cellular technology, which is based on LTE, allows vehicles to be connected to each other, to road infrastructures, to cloud-based services, as well as other road users and, C-V2X has been developed to be compatible with future 5G mobile technologies, based on 3rd Generation Partnership Project (3GPP) version 14 is one such communication technology which has lately made talk about her attracting considerable attention in order to reply V2X communication needs. on the other hand, for successful operation of C-V2X[6], 3GPP identifies four types of C-V2X applications: V2V (Vehicle-to- Vehicle), V2I (Vehicle-to-Infrastructure), V2P (Vehicle- to-Pedestrian) and V2N (grid vehicle) as shown in Fig. 1.[7]

This protocol will provide robust and reliable communication based on vehicle connectivity. With the growing momentum of a broad stakeholder ecosystem comprised of the automotive industry, SoC manufacturers, and Tier 1 vendors, it represents a strong competitor to DSRC (Dedicated Short Range Communication Protocol), which has been developed following the IEEE 802.11pstandard [8].

2.2 C-V2X Services

- It expands on current cellular network elements and features to ensure low latency
- This protocol can enable high-reliability communications between different communications systems, including vehicle-to-pedestrian (V2P),vehicle-to-vehicle(V2V),vehicle-to-network(V2N), and vehicle-to-infrastructure communications. (V2I).
- Easy understanding of the complete system tosupportvariousV2XapplicationsandamultitudeofV2Xscenarios.
- C-V2X is an important enabling technology, moving from single-vehicle intelligence to connected intelligence [9].

2.3 C-V2X Architecture

Fig 2 demonstrates the basic architecture of the C-V2x protocol is composed of two parts the physical layer and 3GPP Rel- 14 V2x Scope and reuses in the second other standards as shown in the figure, this protocol introduces a new interface called PC5 in addition to the old Uu interface in LTE to allow direct communication between devices with or without the presence of an eNodeB (eNB) interface, V2X communications work thanks to the side link period which vary between 40 ms to 320 ms corresponding to 40-320 subframes. Any vehicle may transmit twice with one blind retransmission on two selected subframes in the time domain during this sidelink subframe period.

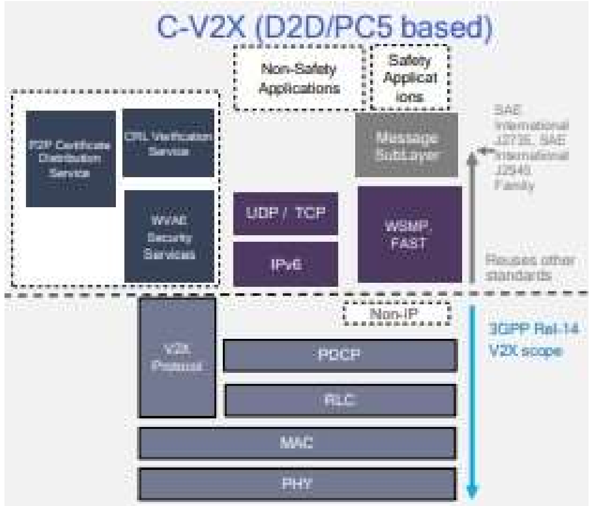

Fig. 2. Basic architecture of the cv2x protocol.

In fact, there are dedicated resource pools for sidelink transmission in each sidelink subframe and the vehicle dynamically selects a subset of these PRB resource pools (physical resource blocks) for transmission[10] to conclude this part to study the weakness of the C-V2x protocol it is important to know its operation history evolution, modes of communication, and especially its architecture and its physical architecture.

3. C-ITS

A wifi variant has been developed, better known as ITS-G5 in Europe, in this second part we will discuss the principle of the ITS-G5 protocol, its services, and ITS-G5 architecture.

3.1 Concept of C-ITS

Recently cooperative intelligent transportation systems (ITS-C) have been proposed to improve vehicular communication systems. These systems are studied in order to guarantee a set of services allowing the optimization of traffic management, thus ensuring road safety, these services operate by generating data exchanges between vehicles, also between vehicles, and other road users. Road such as pedestrians, and between vehicles and centralized infrastructure. Currently, many wireless technologies are available to support these vehicular network communications. Two of the most efficient wireless technologies developed for ITS services are ITS-G5 and LTE-V2X. ITS-G5 is the European standard for vehicular communications, proposed by the European Telecommunications Standards Institute (ETSI) and based on IEEE[11] ITS-G5 is an access technology designed by ETSI designed for communications vehicle-to-vehicle, vehicle-to-infrastructure and communications between infrastructure and vehicle. Messages from ITS services such as safety or non-safety applications are encapsulated in a Cooperative Awareness Message (CAM) and a Decentralized Environmental Notifications (DENM) message, which in turn are encapsulated in Geographic Networking messages and transferred via the Basic Transport Protocol (BTP) to the access layer, go through Decentralized Congestion Control (DCC) [12]

Cv2x ensures the development of Cooperative Intelligent Transport Systems (C-ITS) which allow the reduction of pollution and congestion which represents a major problem for efficiency and road safety, cities will be smarter and would support transport systems of increasingly secure, automated, and efficient.

3.2 ITS-5G Services

Among the services offered by STI-C

• Warning of road hazards

• Driving facilities

The objective of these services is to inform vehicles in real-time of incidents in the same way as variable information signs installed on the road, but with the flexibility of sending personalized dynamic information to areas selected geographies. The Traffic Ahead service was cited, which considers the sending of messages concerning the incidences of traffic detected by the TMC. These incidents are sent directlytothespecificallyselectedgeographicalareasviaDENmessages. The availability of these services allows the TMC to send C-ITS notifications to connected, autonomous vehicles. Regardless of the level of automation of connected vehicles, these services provide information to overcome the visual horizon that limits vehicle sensors as well as human drivers and ensure the safety and increase the efficiency of road transport at levels at all levels [13][14].

3.3 ITS-G5 Architecture

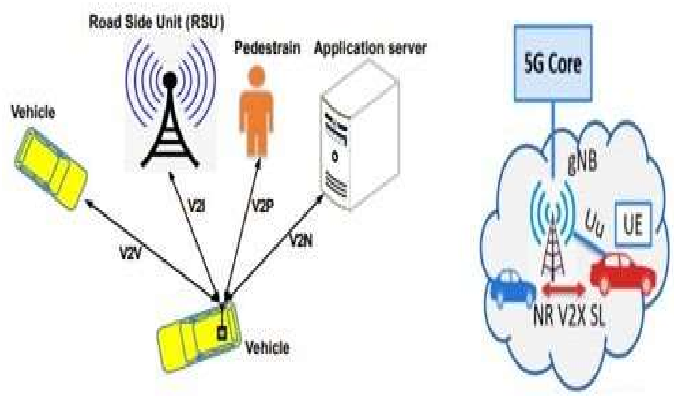

Fig. 3. Architecture of ITS-5G architecture.

The frequency band defined by ITS-G5A is used by ITS road safety applications, with the Control Channel (CCH). Other services use other channels, such as Service Channel (SCH). today, the ITS-G5 technology makes it possible to broadcast traffic messages called Cooperative Awareness Message (CAM) and event messages called Decentralized Environmental Notification Message (DENM) [15].

Different situations are studied to guarantee the associated services and road safety according to the use cases [16], The IEEE 802.11p MAC layer is based on the OCB Offset codebook mode of operation where association, authentication, and data confidentiality services are not used. OCB is a mode that adapts to the rapid dissemination of short messages and it allows great mobility [17].

Finally, ITS-G5 defines the MAC and PHY layers of the Open Systems Interconnection (OSI) architecture which is based on Orthogonal Frequency Division Multiplexing (OFDM) carrier sense multiple accesses with collision avoidance (CSMA/CA).

4. Comparison ITS-G5 vs. CV2X

In this section,, we have carried out a comparative study between the two protocols C-V2X and ITS-G5 based on main criteria such as latency and Data rate also a study on the possibility of coexistence between these two protocols on the same band.

4.1 Coexistence between c-v2x and ITS-G5

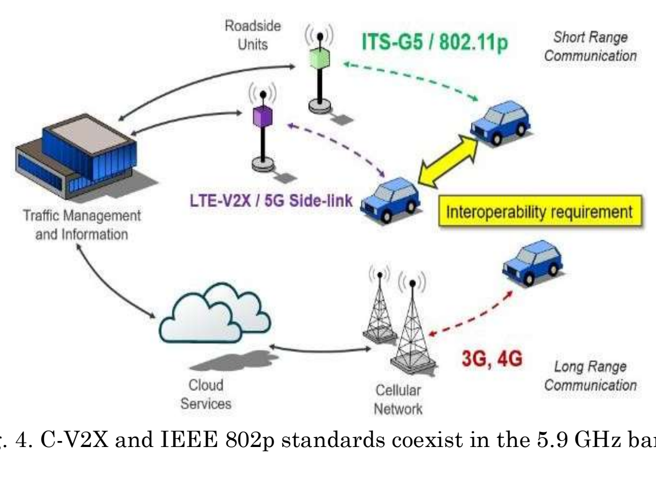

Fig. 4. C-V2X and IEEE 802p standards coexist in the 5.9 GHz band.

C-V2X can broadcast a message over a longer duration than ITS-G5 it has more flexibility on the code rate, which makes it more efficient and robust, with a lower effective transmission rate. [18], In addition, the organization of radio resources into orthogonal slots imposed a higher bounded access delay, thus the overall performance efficiency of C-V2X is based on the allocation process [19].

4.2 Data Rate and Latency

The autonomous driving system needs to receive real-time information for efficient connectivity between the cellular network and the vehicles, among this information we can mention locations, video streaming, and speeds. Applications with ultra-low latency require short microsecond-scale delay and ten times the data rates per second. New 5G techniques have been proposed and tested to support ultra-high data rate and ultra-low latency and communications, while all testing in static low-mobility scenarios.

V2X requirements and system architecture have some differences from cellular networks, in mobile communications low latency is a requirement for secure autonomous driving. Vehicles must detect road situations, pedestrians, and neighbors [20].

- *C-V2Xvs.ITS-G5*

Table 1. Comparison study between C-V2X and IT5- G5 based on parameters.

Parameters	C-V2X	ITS-G5
Waveform	Single-Carrier Frequency Division Multiple Access SC-FDM	Orthogonal Frequency Division Multiplex OFDM
Modulation support	UP to 64 QAM	Up to 64 QAM
Mimo-Support	Rx: diversity for 2 antennas mandatory Tx: diversity for 2 antennas supported	No support standardized
Resource- selection	Semi-persistent transmission with relative energy-based selection	CSMA-CA(Carrier Sense Multiple Access with Collision Avoidance)
Data channel coding	Turbo	Convolution
Latency	20 ms	<5ms
synchronization	Synchronous	Asynchronous
Data rate	150Mbps	10Gbps
Harq Retransmission mechanism	Harq (Hybrid Automatic Repeat Request)	No Harq
Channel size	Rel 14 :10,20 Mhz Rel 15 :Nx20,10,20 Mhz	10/20 Mhz
Resource multiplexing across vehicles	frequency-division multiplexing (FDM)and Time Division Multiplexing (TDM)	Time Division Multiplexing (TDM)
Applications	V2I,V2N,V2V	V2I,V2N,V2V
Cloud services support	Yes	Yes

- *Advantages and disadvantages C-V2X vs. ITS-G5*

Table2. Resume Benefits and Drawbacks of C-V2X and ITS-G5

	Benefits	Drawbacks
C-V2X	It offers superior direct communication between vehicles and 5G NR C-V2X Rel-16 is backward compatible with Rel- 14 for safety. It offers a higher level of safety to users compared to alternate technologies. It offers higher spectral efficiency. Hence it serves more users on the road. For safe autonomous driving use case, it provides 360-degree NLOS awareness and works at night and in bad weather conditions.	Vehicles in C-V2X are connected to the internet and hence it is prone to hacking. The privacy of users of vehicles is at risk due to their locations and other details being collected by the system. An autonomous driver system leads to critical accidents due to the failure of the system. Such autonomous system used by human beings needs to be tested well before they are installed for driving. Malfunctioning of sensors or cars lead to faulty communications
ITS-G5	Hyperconnectivity Process Optimization Its G5 can increase download speeds by up to 20 times (from 200 Mbps (4G) to 10 Gbps (5G)) and decrease latency (response time between devices).	Risks in security and proper data handling Determining monetization value of sensors used in 5G network self-driving cars is hard as sometimes data aggregated by OEMs is really poor quality or overestimated value Insufficient

		Infrastructure

To conclude C-V2X performs better at high vehicle speeds. This better performance of C-V2X is related to the use of a turbo coder mechanism which represents the best channel estimation mechanism that uses a higher number of DMRS symbols so we can also recognize that ITS-5G allows a low latency while latency is a very important criterion for the fluidity of communication so there is more flexibility on the code rate.

5. Discussions

e can see from the first table that there are several points of difference between the C-V2X and ITS-G5 protocols, these comparisons are the results of several searches and simulations of the two protocols on OMNET++, we can start with the Waveform criterion for C-V2x it is Single-Carrier Frequency Division Multiple Access SC-FDM wish is a promising technique for high data rate uplink communications and for ITS-G5 Orthogonal Frequency Division Multiplex OFDM which allows modulation of digital signals by distribution we can also see a big difference in the latency criterion, C-V2x allows high latency which is an inconvenience, on the other hand the ITS-G5 protocol represents low-latency which is a strong point for effective communication between vehicles and road infrastructure, for modulation support both up to 64 QAM also for applications both use V2I , V2V and V2N for channel size both use 10.20 Mhz but the difference is on C-V2X Rell Nx20, we can mention a big difference at the level data rate for C-V2X 150Mbps and for ITS-G5 10Gbps, but there is another strong point of the C-V2x protocol which works on the band of mobile operators and the 5.9 GHz band which is impossible for ITS-G5 which just uses the 5.9 Ghz band It remains to choose between ITS-G5 and C-V2X (or both)

Currently, C-V2X only uses 4G, so we are talking about LTE- V2X, however, we are in the 5th generation, and C-V2X should improve to integrate 5G (5G-V2X), and thus benefit from the performance in terms of throughput, latency, and reliability, and the main idea of thisproposal is to combine the two in a single protocol which will be robust and efficient and combining the strong points of the C-V2X and ITS-G5 protocol and above all improve the response time for ensure reliable road safety.

According to several researchers studying the comparison of the performances of the ITS-G5 and the C-V2X by deriving the performances of the physical layer two communication solutions have shown that for the same flow, C-V2X is more efficient than ITS-G5.

The wide variety of C-V2X settings makes it possible to accentuate this gain with an improvement in the range of communication, especially when retransmission is envisaged.

On the other hand, in this case, the performance gain is based on time and frequency, Based on the performance of the physical layer, the behavior of the two protocols in a network without cellular coverage and including several key vehicles was evaluated by testing the MAC layers of the two systems according to the network congestion, several simulations showed that C -V2X exceeds ITS-G5 when the user density is less than 150 users/km2. On the other hand, C-V2X performance decreases compared to ITS-G5 protocol when the level of congestion increases. Latency, which is a very important indicator for V2X scenarios, the comparison of resource access times gives an advantage to ITS-G5on the other hand the overall latency is not clearly better for a single system because its efficiency depends greatly on the operating FM range, and user density.

6. Conclusion

In this section, C-V2X offers multiple commercial and economic advantages over other dedicated vehicle connectivity technologies except that it can support a very wide range of use cases ensuring navigation, security, and integrated transport systems so it uses all V2X applications from end to end with the same technology, which makes it very scalable and future-proof, in general, direct communication allows exchanges in the absence of coverage cellular, and redundancy when necessary. While waiting for 5G, communication direct ITS-G5 achieves better latency when crossing the core network in case 5G is used with hybridization or backward compatibility with the ITS-G5, Several types of research are dedicated to studying a possible co-existence between the two protocols on the same band it is that the subject of my future work where the coexist between these two protocols will be tried thus to combine the strong points of each protocol.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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