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Original Paper

A SURVEY ON SIDELINK CHANNEL AND RESOURCE ALLOCATION

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Abstract

Vehicle communication (V2X) technology will permeate every aspect of our daily lives in the upcoming scenario. It needs to be equipped with several cutting-edge features to increase its efficiency and dependability and enable autonomous driving. The simultaneous release of LTE-Advanced and the launch of Sidelink connectivity could result in an efficient vehicle-to-vehicle communication solution. In the absence of base station intervention, Sidelink communication is direct communication between devices. The dependability, speed, and data rate of safety-critical messages will all rise. In this paper various sidelink releases under the umbrella of 3GPP is been discussed. It includes release 12 to 17 (known as 5G NR V2X). Apart from that all the sidelink channels, signals and their resource allocation in both the transmission mode is elaborated. Then a throughput and BLER (bit length error rate) graphs are generated for multiple SNR points. This paper highlights the importance of Sidelink communication towards autonomous vehicular communication.

Keywords

Sidelink Communication, V2X, Resource Allocation, Throughput, 3GPP

1 Introduction

Vehicles are moving from internal combustion engines to electricity from renewable energy sources, changing the automotive industry. At the same time, user behavior and vehicle expectations are beginning to change, leading to new ways of interacting with vehicles that will affect future vehicle design. Interest in autonomous driving is high, but due to technical and regulatory obstacles, it is still a few years away. Drivers are supported in many ways today, but they need to motivate users to trust full autonomy [1]. The connection between linked and autonomous vehicles is the main motive for Intelligent Transportation System (ITS). To increase safety and mobility, the vehicle can communicate data with other vehicles on the road (V2V) as well as with road infrastructure (V2I) including traffic lights and stop signs [2]. The primary goal of ITS is to create a system for direct vehicle-to-vehicle communication in order to reduce traffic accidents, improve safety, and enhance privacy. Numerous services have been built by the ITS system to assist vehicle communication. Nowadays, vehicle-to-vehicle communication is seen as a beneficial technology. A crucial aspect for any vehicle communication calculation is exact placement and range.

Fast-moving IEEE 802.11p standards [3] [4] has been developed to effectively connect the cars. Vehicles are connected in an adhoc manner and periodically broadcast beacons in Vehicular Adhoc Networks (VANETs) based on 802.11p. At the MAC layer, the CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) technique is employed to prevent channel access collisions. The many hundred-meter range that 802.11p offers is vulnerable to collision. IEEE 802.11p has the additional flaw that only minor changes can be made to it. When there are a lot of vehicles on the road, it is inefficient to address the appropriate circumstances and deliver information. For vehicular communication, this standards IEEE 802.11p is not very effective. [5] Sidelink formally known as Device-to-device (D2D) communication technology was introduced in version 12 as part of the third-generation partnership (3GPP) initiative to address the shortcomings of the IEEE 802.11p amendment. Release 12 is a component of 4G LTE advanced [6] [7]. Direct connectivity between the devices supports Sidelink communication and lessens the need for base station or eNB involvement. When two devices are in close proximity to one another, they can communicate directly between one another without transferring information to a base station. By offloading the eNB, this will decrease latency and boost transmission rate. By serving as a relay between two users, Sidelink users can additionally increase the network service area [8]. With a few updated protocols, it makes advantage of the current cellular infrastructure. The 3GPP has continued to issue new versions, which has led to an advancement in Sidelink communication features. Vehicle communication may now operate in a realistic mode thanks to the inclusion of 4G Cellular-V2X in release 14 [9]. Additional improvements have been made in release 15 and a road map for incorporating 5G in vehicle communication has been established.

A new and developing platform called 5G will enable a variety of applications to offer extremely fast and low-latency connection [10]. One of the groups that stands to gain from the 5G building blocks is vehicular communication. The development of 5G NR V2X Sidelink communication, also known as Sidelink (D2D) communication, has begun as of 2019 in 3GPP release 16 [11]. It is equipped with the most advanced, strictest standards for autonomous vehicle systems. Following those suggestions, release 17 included a number of changes, on which work is currently being done.

In this paper a survey has been done on all the Sidelink channels, signals and their enhancements from release 12 to release 16. It is distributed in five divisions. Introduction about the Vehicular Communication is elaborated in section 1. A key component of V2X communication is Sidelink communication. The standardization, comparison, and releases of it are covered in section 2. Section 3 covers all the physical Sidelink channel and signals. Resource allocation for control and data channel is elaborated in section 4. Final throughput and BLER calculations are done in section 5.

2 3GPP Sidelink Standardization

The present LTE-A (long term evolution-advanced) design can be combined with the 3GPP's (third generation partnership project) fairly straightforward architecture. The cellular ecosystem can easily accommodate 3GPP integration from the cellular carriers. [12] Other than DSRC and D2D, Wi-Fi Direct, Bluetooth, and Ultra-Wide Band (UWB) are other technologies that have been suggested for use in vehicle-to-vehicle communication. They are all created for a wireless local area network architecture, which is their common flaw. They therefore have very little support for moving vehicles and a very limited communication range, which does not meet the requirements for vehicular communication. In addition, LTE-advanced D2D networks have greater data speeds and transmission coverage areas. Real-time requirements are also essential for V2V. The details of the 3GPP standardization releases for V2X are provided in Figure 1 [13].

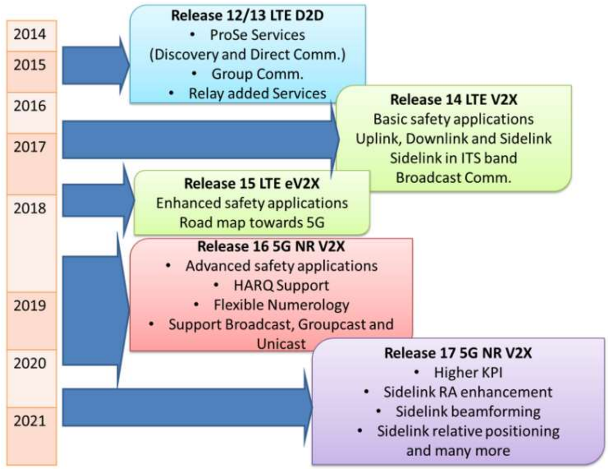

Figure 1. 3GPP Releases timeline Sidelink D2D communication

2.1 Release 12

The LTE Advanced standard 3GPP Release 12 defines the proximity-based services (ProSe) idea. In this, devices that are close to one another can find one another and connect directly for communication. [8] ProSe idea is meant for both commercial and public safety applications, whereas release 12 emphasizes just public safety. Direct communication and D2D discovery are the two stages of ProSe communication. The user equipment (UE) will identify another UE at the EPC (Evolved Packet Core) or by himself that is nearby. Direct communication takes place between the UEs after UE discovery, bypassing the base station.

Another addition in version 12 is group/broadcast messaging, or one-to-many dialing [5]. A message can be sent to a group at once using this. It aids in vehicular communication and public safety since vehicles regularly send broadcast service messages (BSMs) to other vehicles informing them of their speed, location, and other information. The improvement of group communication has received more attention in later 3GPP standards releases. The downlink channel is shared by all UEs in a group to increase the overall resource utilization in group communication. Because they are less crowded, downlink channels are chosen over uplink channels.

2.2 Release 13

Multihop relay network functionality is available in 3GPP Release 13 at layer 3 [14]. It aids in extending the network's reach. Additionally, scenarios for in, partial, and out-of-coverage areas were added to the network discovery process. Additionally, it offers standardization for priority control for PTT (push to talk) services that are mission-critical.

2.3 Release 14/15

C-V2X (Cellular-V2X), the LTE (Long term evolution) V2X standard, was established by 3GPP in Release 14, after that updated in Release 15. For communication, it makes use of the Long-Term Evolution Air Interface. It improves direct and network communication in ways like:

V2V (Vehicle to Vehicle Communication): To prevent a collision, a vehicle will communicate with another vehicle. It has use cases for improved safety [15].

V2I (Vehicle to Infrastructure): In contrast to V2V, where communication is only possible between vehicles, it enables UE on the road to communicate with the road structure [16]. Traffic lights, roadside cameras, street lighting, digital signage, RFID readers, pedestrian lane markings, parking meters, and many other road structures and units are examples of different road structures and units. V2I sensors in the ITS can gather data on infrastructure and give traveler's real-time advice by making them smart gadgets. They can offer a variety of information, such as on the state of the roads, the flow of traffic, available parking spaces, congestion caused by accidents, nearby construction sites, and much more. All of these details can aid the UE in improving their driving.

V2N (Vehicle to Network): The real-time traffic is communicated with the cloud via a network mode.

V2P (Vehicle to Pedestrian): A pedestrian can warn a vehicle about the state of the road and potential collisions.

2.4 Release 16/17

Release 14 C-V2X and DSRC provide low latency and dependable message exchange between vehicles and infrastructure in order to increase safety and efficiency [17]. But this is just the start of a trip toward future cars that will become more and more autonomous and have a wide range of enhanced secure and insecure characteristics. This development will necessitate the addition of new V2X communication capabilities, such as expanded capacity, very low latency, extremely high dependability, longer range, and quicker transfer rates. V2X technology must advance in order to meet new criteria. There are several use cases and applications that have strict requirements for service quality. The NR should offer this QOS. The following use scenarios, which form the basis for NR-V2X learning, are particularly crucial [13]:

Extended Sensors and Data Sharing: There are several sensors whose data must be transferred via V2X network communication with a low latency and high throughput between cars, pedestrians, traffic lights, and all other traffic participants. High reliability in this use case enables each vehicle to see the surroundings holistically.

High Density Platooning: A platoon is a group of vehicles that keep a close yet secure spacing between one another. Low latency and high throughput communication are required between them in order to prevent any mishaps.

Remote Driving: In unsafe areas/locations with fewer road changes, such as public transportation bus lines, remote driving is particularly useful. The more recent concept of remote driving involves controlling a bus via cloud-based instructions. in order to prevent accidents at certain locations.

Advanced Driving: In this scenario, vehicles coordinate their trajectories and execute better maneuvers by exchanging local sensing data with one another and, if one is present, with a Road Side Unit (RSU).

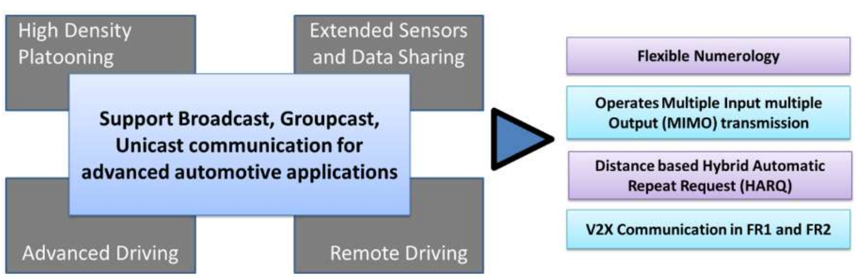

Figure 2. 5G NR V2X 3GPP use cases

3 3GPP Physical Sidelink (SL) Channels and Signals

Since broadcast transmission of messages is a good method for delivering BSM, CAM, DENM, and related traffic, the V2X sidelink supports it in the physical layer. A broadcast address in the MAC layer can be implemented mapped to either a single UE or a collection of UEs. The following Sidelink Physical channels and signals are supported by 3GPP [19]:

3.1 PSSCH (Physical Sidelink Shared Channel)

The SL-SCH transport channel, which transports the TBs of data for transmission across SL, is sent by PSSCH. The resources over which PSSCH is sent can either be predetermined by an eNB and given to the UE by a DCI, or they can be discovered via an autonomous sensing process carried out by the transmitting UE. A certain TB may be communicated either once or twice, with the second transmission taking place after a time interval that is specified in the scheduling SCI.

3.2 PSCCH (Physical Sidelink Control Channel)

Physical layer sidelink control information (SCI), also known as a scheduling assignment, is transmitted by PSCCH. In two frequency-adjacent PRBs, PSCCH is sent for V2X and always carries SCI format 1. A UE must continuously check each defined pair of PRBs to see if PSCCH has been transmitted in them in order to receive it. PSCCH can be transmitted in PRBs that are either frequency adjacent to the PSSCH or frequency non-adjacent to it. It is transmitted in the same subframe(s) as the related PSSCH.

3.3 PSBCH (Physical Sidelink Broadcast Channel)

In order to transmit the sidelink V2X Master Information Block (MIB-V2X) from the RRC layer, PSBCH sends the SL-BCH transport channel. When in use, PSBCH sends MIB-V2X in the middle 72 subcarriers of the SL bandwidth every 160 milliseconds. The subframe's fifth, seventh, and tenth symbols all carry DMRS related to PSBCH.

3.4 PSSS and SSSS (Primary and secondary sidelink synchronization signals)

When other UEs do not have another source of synchronization available, PSSS and SSSS are broadcast to help them achieve sidelink synchronization. Together, they transmit the SLSS ID that the UE has chosen. The sidelink subframe border can also be detected by UEs using PSSS/SSSS, thanks to MIB-V2X signals for the subframe number and frame number.

3.5 DMRS (Demodulation Reference Signal)

Each of the three physical channels has a demodulation reference signal (DMRS). The third, sixth, ninth, and twelfth symbols in a subframe are used to transmit DMRS related to PSSCH and PSCCH.

3.6 PSFCH (Physical Sidelink Feedback Channel)

There is a lot more reliance on broadcast messages as a result of the absence of feedback in earlier editions. Therefore, feedback for unicast and groupcast talks is provided by the receiver in NR V2X to increase the efficiency of transmission. When a unicast or groupcast broadcast takes place in a PSSCH, the receiver UE will transmit the HARQ feedback via the PSFCH. The receiver also communicates channel state information (CSI) to the transmitter UE in place of the feedback content over PSFCH.

3.7 SCI Format

It is a part of PSCCH channel. Two subframes of SCI format are broadcast, with one physical resource block per slot in each of the two subframes. The following parameters are need to be set in SCI format [20]:

1. “Modulation and coding scheme” field in accordance with the Modulation and coding scheme indicated by the higher layer parameter.
2. "Frequency hopping flag" bit should be specified.
3. "Resource block assignment and hopping resource allocation" field is given through SCI.
4. "Time resource pattern" field specified.

4 PSCCH and PSSCH Resource Allocation

Two modes are defined for the resource allocation as defined below:
Mode 1: The resources are allocated by eNodeB.
Mode 2: The resources are allocated by UE itself within the available resources.

These physical layer parameters are required for the allocation of PSCCH and PSSCH resources [20]:

1. NPSCCH for the number of subframes and resource block allocated to PSCCH. For transmission mode 1 & 2:

$$0 \leq \eta_{PSCCH} \leq \lfloor (M_{RB}^{PSCCH\_RP})/2 \rfloor . L_{PSCCH} \quad (1)$$

   Where: MRBPSCCH_RP = Number of available resource blocks in the resource block pool
   LPSCCH = Number of available subframes in the subframe pool
2. ITRP (Time resource pattern index) for the number of subframes allocated to PSSCH. For a given UL/DL configuration, mapping among bitmap (b0`, b1`, ………bNTRP-1`) and ITRP is given by the table [20].

$$b_j = b^{`}_{j mod N_{TRP}} \quad (2)$$

   Where: b0, b1……bLPSSCH-1 is required bitmap.
3. RIV (Resource Indication Value), Hopping bits for the number of resource blocks allocated to PSSCH. RIV corelate to a RB`START and a length of continuous allocated resource block $L^{`}_{CRB} \geq 1$.

if

$$(L^{`}_{CRB} - 1) \leq \left\lfloor \frac{N_{RB}^{SL}}{2} \right\rfloor \qquad NRBSL = Number\ of\ sidelink\ resource\ block$$

$$RIV = N_{RB}^{SL}(L^{`}_{CRB} - 1) + RB^{`}_{START} \quad (3)$$

else

$$RIV = N_{RB}^{SL}(N_{RB}^{SL} - L^{`}_{CRB} + 1) + (N_{RB}^{SL} - 1 - RB^{`}_{START}) \quad (4)$$