Why 5G may be the Ultimate Winner A Comparison between 5G and DSRC

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***Abstract*—Automobile companies are creating vehicles with automated features to increase safety and provide fuel efficient commutes. Many of these automated features require V2X communication to alert drivers in highly congested areas with little or no delay. DSRC is technology that was designed and created for vehicular safety and automation, outperforming 4G's higher latency and reliability. Cellular's next generation, 5G, addresses the performance concerns of 4G with its low latency, broad bandwidth, and better non-line-of-sight connectivity than its predecessors. These improvements bring 5G on par with DSRC presenting automobile companies with another option. While both technologies can address many concerns associated with V2X communication, when it comes to safety, performance cannot be sacrificed. This paper presents a look at both sides of 5G and DSRC, presenting pros and cons, proposed infrastructures, possibilities of coexistence, and ultimately why 5G may be the winner.**

***Index Terms*—DSRC, Cellular, 5G, LTE, C-V2X, V2X, IEEE 802.11bd, Vehicle networks**

I. Introduction

WITH the rise of smartphones and texting while driving, people are becoming increasingly distracted, causing accidents that could be preventable. As a result, automakers are adding more automated features to reduce the likelihood of incidents, moving toward even more automated features Vehicle to Everything (V2X) communication. Vehicles will be able to communicate with each other and send alerts and status messages using Internet of Things (IoT) to exchange messages between vehicles and their surroundings. Looking forward, this is a first step to auto-pilot vehicles as a means of safer commutes.

Different technologies have been proposed to be the benchmark for the growing interest in automotive communication. With the prospect of safer commutes and reducing congestion, there is emphasis on choosing technology that meets safety concerns; technologies such as Direct Short-Range Communication (DSRC) or cellular as options for communicating between vehicles. Selecting the technology option that meets the requirements is paramount to make commutes not only be greener and efficient, but also to save lives. V2X communication cannot allow occasional dropped network connections and must be able to communicate regardless of the vehicle's location. A dropped connection or a delayed transmission could have catastrophic results.

V2X wireless communications provide cohesiveness between vehicles, pedestrians, and the infrastructure. Critical information needs to be communicated to ensure safety, such as vehicle and pedestrian locations and movements, and road and traffic information. Vehicle communication technologies will need to exhibit low latency to alert vehicles timely and reliability to notify emergency services when needed. With existing technologies, increasing the necessary number of access points to provide continuous communication can be costly.

To address these concerns, research on both DSRC and wireless has been conducted to determine the strengths and weaknesses, while automakers wait eagerly for the latest conclusions. Some automakers, such as Ford have already chosen C-V2X wireless technology, while Toyota remains loyal to DSRC. Others such as Nissan are still weighing both options [1]. DSRC has support from the Federal Communications Commission (FCC), including dedicated bandwidth, which may be the deciding factor. It's likely only one technology will dominate since automakers will need to use the same technology for vehicles to communicate and DSRC and C-V2X are currently incompatible.

II. Technologies

Advanced Driver Assistance Systems (ADAS) technology was developed to reduce the number of accidents. ADAS includes advanced systems such as sensors that detect radio, light, and range, in addition to high definition mapping, signal processing, and artificial intelligence. ADAS technologies include "[c]ommunications for vehicle to vehicle (V2V), vehicle to infrastructure (V2I), vehicle to pedestrian (V2P), vehicle to utility (V2U), and eventually vehicle to everything (V2X) [2]." Figure 1 shows V2V, V2I, V2P, and V2N communications which make up part of V2X communications.

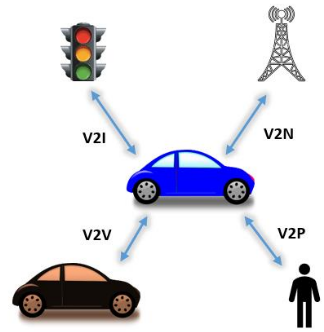

Figure 1: V2X Communications

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Vehicular-to-Everything (V2X) communications are used by the Intelligent Transformation System (ITS) to "enhance the traffic efficiency of reliability of timely data delivery [3]." The V2X paradigm is designed to communicate with all devices involved with traffic control, monitoring, and management to provide safe road travel. To communicate effectively, V2X requires technology that must be fast with low latency to prevent delayed alerts. V2X requires reliable communication, regardless of congestion and blocked viewed, and interference from other technologies, and have adequate range. The two technologies considered to meet these standards are Dedicated Short Range Communication (DSRC) and 5G Cellular.

A. Dedicated Short Range Communication (DSRC)

Dedicated Short Range Communication (DSRC) is an existing technology based on IEEE 802.11p that was created specifically for V2X communication and is currently available for the automotive industry. Since DSRC uses 802.11, wireless access points are required to establish a connection.

Safer commutes in high dense areas and reducing congestion is a concern in V2X communication. A white paper by A. Filippi et al [4]. explores some of these concerns and why they believe DSRC is a better choice over cellular, including the emerging 5G.

The exchange of data between vehicles, is called V2X communication. An advantage DSRC has over wireless is that DSRC is currently available for V2X deployment, whereas cellular is far from addressing the needs for V2X communication. Modifications in wireless technology need to address performance issues such as cellular's current high need for bandwidth, inconsistent wireless signal, roaming, and lack of support for low latency and high mobility use cases which are associated with safety-related use cases. Modifications in cellular technology take a long time, averaging about six years for an upgrade. Upgrading cellular also includes upgrading modems to meet the standards of the Automotive Safety Integrity Level (ASIL) which is involved in setting and adjusting the cruise control of a vehicle-based transmission of speed limit data. Upgrading these modems can be costly [4].

V2X needs to have technology that can operate in a dynamic environment with high relative speeds between transmitters and receivers, while simultaneously handling multiple interactions between multiple drives without being affected by sometimes highly congested traffic. V2X also needs to be able to differentiate relevant information for each driver, providing only necessary, local information for that driver.

DSRC was designed to meet each of the V2X requirements, having dedicated bandwidth of 75 MHz in the 5.850 to 5.925 band set aside without competition. DSRC is ready for deployment, has already been tested in use cases with success. DSRC is also more secure, since unlike cellular, messages don't go to the cloud where they are vulnerable.

B. 5G Cellular

5G, also known as C-V2X, is an emerging generation of Cellular V2X that evolved from 4G. 5G is newer to the automotive industry and uses existing cellular network infrastructure. 5G has vast improvements in connectivity versus its previous 4G version bringing it up to par with DSRC.

DSRC is the current technology recommended by the Federal Communications Commission (FCC) to be used by ITS mobile and vehicle safety applications [5]. According to Wassom, B. [5], the emerging 5G technology has benefits over DSRC that would provide the capabilities necessary for V2X communication. Since 5G is an emerging technology, it'll use existing cellular infrastructure for communication, therefore, no costly roadside units to be purchased or maintained. 5G has "greater interoperability, wider bandwidth, increased cybersecurity, decentralized network," [5] over DSRC. Because of these advantages, 5G development will continue to progress for other future IoT applications outside of vehicle communication. 5G has a low latency of 5G at 1 ms at up to 310 mph, which surpasses DSRC's already impressive low latency of under 5 ms. The transmission range of potentially greater 450 m dwarfs DSRC's transmission range of 225 m. 5G also have improved non-line-of-sight performance over DSRC and is more capable of avoiding interference with other devices [6].

5G Automotive Association compared congestion control, reliability, and interference between DSRC with 5G C-V2X [7]. Comparison was also done to: measure radio performance under variable power conditions, assess message exchange in line-of-sight (LOS), and obstructed view (i.e., intersection). 5GAA also compared the shadowed view, such as being blocked from a box truck either coming (i.e., Camp), or behind the box truck (i.e., 5GAA).

The results of these tests show that C-V2X exceeded DSRC in radio performance by at least 15 dB, exceeded the LOS test by 500 m, exceeded the obstructed view test, and exceeded both shadowing tests by as much as 950 m for the camp tests as shown in [7, Figure 2].

Test Procedure	Range at 90% Reliability	
	DSRC	CV2X
Line-of-Sight (LOS) Range	675m	1175m
Non-Line-of-Sight (NLOS) Blocker (5GAA)	125m	425m
Non-Line-of-Sight (NLOS) Blocker (CAMP)	400m (200m)[1]	>1350m (625m)
Non-Line-of-Sight (NLOS) Intersection	375m	875m
Co-existence with Wi-Fi 80 MHz Bandwidth in UNII-3	300m (75m)	625m
Co-existing of V2X with Adjacent DSRC Carrier	400m (100m)	1050m

Figure 2: 5GAA Field Results Summary

Cellular technology is continually growing, continuing into future generations, whereas DSRC has no planned future development. As vehicles and other devices become more automated, the technology must continue to grow alongside to handle the upcoming requirements.

III. Concerns

A. Security Concerns with 5G

The emerging 5G wireless technology will be faster and more flexible than its predecessors, but these advancements present increased requirements and concerns about security. Amgoune and Mazri [8] discuss 5G security challenges and possible defenses to these concerns.

5G technology will need to handle 1000 times more traffic than today, 50 to 100 billion connected devices such as autopilot vehicles and provide high speed 10Gbps rates to point-to-point link devices. 5G must also have low latency and high availability for safety concerns. 5G will need to integrate with existing and new technology such as wired and wireless networks, mobile cloud, and internet of things, making 5G technology complex due to the volume of connected devices [8].

The security requirements for 5G technology include authentication, integrity, availability, non-repudiation, and confidentiality. Since 5G requires more authentication between service providers, and because authentication needs to be fast due to the required low latency and high data rates, authentication cannot be based solely on a symmetric key, unlike 4G. Instead, proposed authentication for 5G includes Cyclic Redundancy Check (CRC) which detects random and malicious activity and errors without affecting the bandwidth.

Integrity is crucial since modifying the data could mean manipulating auto-pilot vehicles. Availability includes cell reception, signal scrambling, and denial of service (DoS) attacks, which denies access and service to legitimate users. To combat non-repudiation, asymmetric keys are used to ensure only the sender and receiver are involved in signal exchanges. Confidentiality of vehicle routing data, health records and monitoring data, raises privacy concerns as the amount of sensitive data being transmitted will increase with 5G [8].

Proposed solutions include flexible authentication; requiring secondary authentication only after the primary authentication is successful. The primary authentication provides access to 5G while the secondary authentication controls access between the business and the end user, combining multiple cryptography methods. The end user's (SIM) could possibly also store credentials and create new asymmetric key pairs. Proposed solutions that address confidentiality include the International Mobile Equipment Identity (IMEI), which is a key identity number for each mobile phone and include the user's identification. Mutual authentication methods such as combining asymmetric with symmetric cryptography will help address the security concerns of 5G [8].

With the high requirements and sensitive nature of the data in 5G, security will remain a challenge. So long as data is being transmitted, continually researching for preventative measures will prove to be the best and possibly the only defense against security attacks.

B. Latency concerns with DSRC and 5G

V2X communication may incorporate DSRC, C-V2X, or a combination of both technologies; cellular is expected to be involved at some level, but it struggles with latency issues. The End-to-End (E2E) communication with C-V2X lacks performance, resulting in intolerable delays, focusing efforts on decreasing latency and network utilization. These delays are proportional to the vehicle and pedestrian density of the area. Emara M. et. al., [9] proposes a Multi-access Edge Computing (MEC) technology as part of the C-V2X infrastructure, and because of its closeness to end users, reduces packet delays.

Vulnerable Road User (VRU), which includes both vehicles and non-vehicles (i.e., pedestrians) is used in this study. This study assumes: V2X communication, LTE coverage for the freeway segment, and Uplink (UL) radio communication between the VRUs. Vehicles at the cell edge propose a challenge since they receive low quality signals. To combat this, location-based vehicle clustering requires each VRU to define a cluster of vehicles in the vicinity for a cluster-based multicast transmission.

The components of the CAM transmission include, radio latency, network latency, which are disregarded since they don't affect the CAM routing, transport and core latency, and execution latency. These components are modeled to significantly reduce the network latency by "processing the CAM packets at the MEC host, collocated with the connected eNB [9]." Evolved Node B (eNB) allows the connection between the network and the device.

In the setup, the vehicles are set at random speeds, sending messages/packets at random times. The results of the study show that the effect of MEC utilization reduces E2E latency by an average of 80%. As the density increases, the availability to handle the delay increases. These significant reductions apply to both VRU and vehicle densities [9].

5GAA compares latency between C-V2X and DSRC, showing that C-V2X still outperforms DSRC regarding latency. DSRC's latency becomes unpredictable at high system loads, while C-V2X's latency is less affected. One of the key differences between C-V2X and DSRC is how they transfer packets. C-V2X uses distributed scheduling to allocate to available resources, helping to keep latency low. DSRC relies on channel access, which can be limited once system loads increase [10]. The below charts in [10, Figure 3] show the mean latency of C-V2X as lower and for a longer range than DSRC.

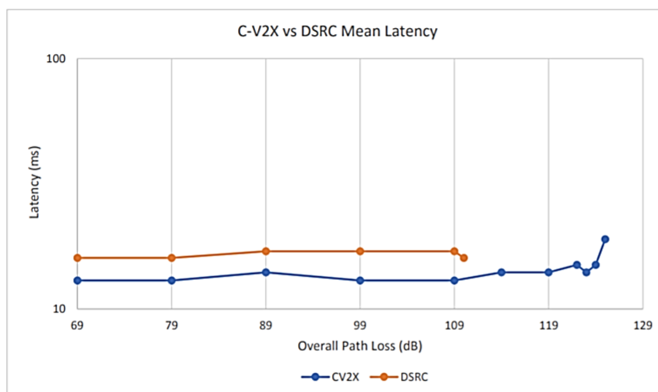

Figure 3: C-V2X vs DSRC Mean Latency

5GAA's latency lab result show that "[b]oth C-V2X and DSRC satisfy SAE J2945/1 requirements [7]." Efforts still focus on increasing the performance of cellular technology, an expectation of its involvement in V2X, either in conjunction with DSRC or by itself as low latency and network availability continue to be concerns as V2X expectations and requirements are high for as a means for communicating safety critical messages.

IV. Previous Work

Interest in V2X communications has introduced architectures that utilize 5G, DSRC, or a combination of both technologies as a solution to communicate with optimum performance utilizing the strengths of each technology.

A. *Dynamic Intersections with Coexisting Technologies*

Full self-driving vehicles requires real-time interaction and negotiation to guarantee safety. Most research on automotive communications and traffic concerns focus on stationary intersections such as traffic lights, round-abouts, and stop signs. S. Aoki et al. [11] proposes a protocol that addresses dynamic intersections which are unpredictable, such as road construction and lane merges. A dynamic intersection is an area on the road where more than one vehicle can occupy simultaneously, potentially causing a conflict. Dynamic intersections are usually temporary and are not included in a map database.

Seven examples of dynamic intersections are described: “one-way alternative due to construction, turning left through traffic into a parking lot or driveway, single-track lane or narrow bridge, merge point, lane changing, passing on a lane usually used by oncoming traffic, and center turn lane [11].” Other examples that are excluded in this protocol include: potholes and damaged roads, roads containing crashed vehicles, and parking garages.

The proposed protocol uses V2V communications and internal sensor-based perception systems, and a wireless communication interface such as 5G and an onboard unit using DSRC. The vehicles are equipped a traffic manager, Cyber Traffic Light (CyberTL) which uses V2V during heavy traffic to allow for consistent traffic flow and avoiding long wait times for vehicles. This proposal assumes that vehicles have an OBU that supports DSRC and the WAVE protocol stack. The OBU is also involved with the sending of approval or rejection functions of the CyberTL in response to other vehicles. It is also assumed that all system components on a vehicle are functional and the vehicle has good GPS reception [11].

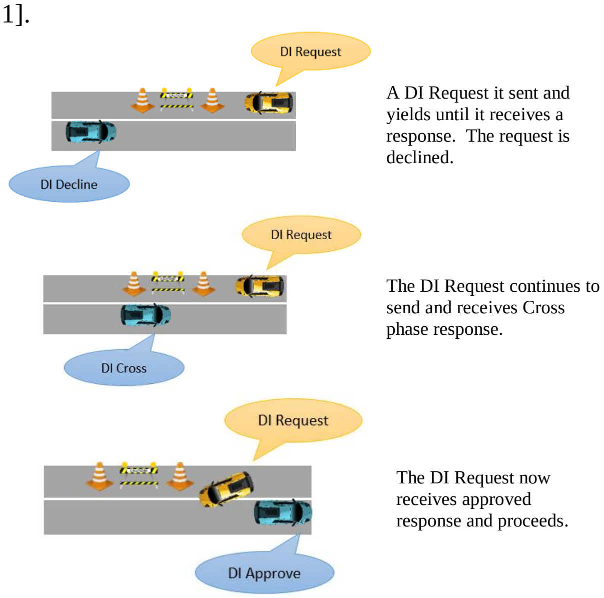

Figure 4: Communication Request Scenario

The protocol divides dynamic intersections into five different types: Temporary DI, Unmapped DI, Mapped DI, Moving DI, and Variegated DI. The vehicles send and receive size types of messages, depending on which vehicle takes precedence which is dependent on vehicle position. The seven types of messages used to communication between vehicles are: DI Request, DI Approval, DI Interrupt, DI Yield, DI Decline, DI Cross. The communication of these messages is managed by the CyberTL by acting as an impromptu traffic light for dynamic intersections (Figure 4).

Packet loss is addressed and expected and not a concern for conflict since the messages are sent continuously until the appropriate response is received. The vehicle remains in a waiting period which means a longer wait time but causing no collision. To test the protocol, the experiment was performed with a hybrid simulator-emulator called AutoSim. The trip time, trip delay, average trip delay, and worse trip delay were calculated for the simulation. The protocol was compared with two baseline protocols: Temporary Traffic Light Method and Stop or Yield Control Method. Results show that the proposed cooperative dynamic intersection protocol has the shortest average trip delay and the shortest worse trip delay in all cases and compared with both baseline protocols [11].

The results of this experiment apply to roads containing only fully self-driving vehicles and does not account for sharing the road with human drivers. The results also assume that all vehicles have good GPS reception and no component failures. The design of this protocol provides safe traffic control with decreased wait time while using a combination of DSRC and wireless communications collaboratively.

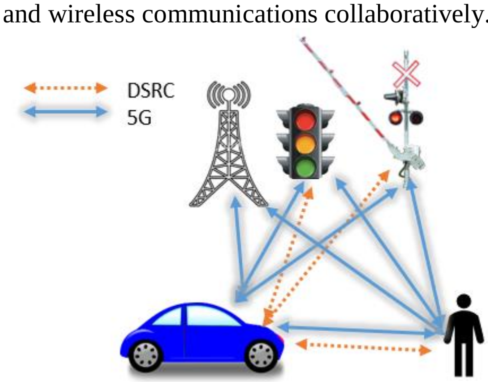

Figure 5: Collaboration 5G and DSRC

Cellular does not currently have the performance and consistency necessary for V2X communication and may be better suited for non-safety related cases. Although changes in wireless technology and the emergence of 5G may address these concerns, co-existence of both DSRC and wireless may utilize the benefits of both technologies providing optimum functionality of V2X as shown in Figure 5.

B. *Social Architecture with 5G*

Keysight Technology [2] discusses the limitations of current technologies, Dedicated Short Range Communications (DSRC) and 4G-cellular. DSRC is currently ready for the automatic industry and demonstrates low latency but requires additional gateways at great expense. DSRC also doesn’t have any evolution plans. Cellular V2X technology uses existing network infrastructures and provides long-range communication but does not provide the low latency required for safety critical communication. Neither technologies provide high-speed mobility support, nor do they provide high-speed mobility support and able to handle massive machine communication.

The emerging 5G-cellular is expected to support advanced ADAS systems. 5G will be able to provide enhanced mobile multi-gigabit broadband, reliable low latency, and be able to provide peak data rates during high density conditions, such as, "ultra-low latency of 1 ms at up to 310 mph, high peak data rate of 20 gbps at up to 310mph, extreme density up to 1,000,000 connected vehicles and devices [2]."

IEEE 802.11p fails to provide the low latency and reliability necessary for V2V communications. Y. Hu et al. [12] proposes a solution that an LTE-Cellular-Based V2X solution that includes two transmission modes: network assistance communication and autonomous direct communication. Combining the two modes brings an integrated V2X solution that provides increased quality such as reduced packet loss and low latency. This can be done by extending LTE-V to include LTE-V-direct along with LTE-V-cell on the same shared platform allowing direct communication between vehicles [12].

While both modes operate in ITS bands, network assistance communication, now known as PC5 mode 3, is the centralized configuration using LTE topology, while the autonomous direct communication mode, now known as PC5 mode 4, is the decentralized framework that uses but is not dependent on the cellular network.

A comparison of PC5 mode 3 and PC5 mode 4 was performed along with an integrated solution between the two modes sharing the same platform on V2X communications. Challenges addressed include: how to provide reliable V2X communications between vehicles, how to avoid heavy traffic congestion, how to simply the equipment such as the OBU and RSE, and how to ensure security.

The results show that, "Complementary to each other in LTE-Cellular-Based V2X, network assistance communication and autonomous direct communication are coordinated systematically to support the vehicular network applications effectively [12]." When comparing the two modes, the Packet Reception Rate (PRR) of the mode 3 outperformed the autonomous direct communication method, which was more evident as the distance increased. Overall, the merging of mode 3 and mode 4 proposed as LTE-Cellular-Based V2X, provides a systematic and integrated solution for V2V communication.

An integrated LTE solution is unique from other V2X communication studies that either compare DSRC with cellular or explain the benefits of DSRC and cellular coexisting to cover each other's shortcomings, as this article proposes a combination of using two modes of the same technology cohesively with little or no shortcomings.

C. 5G Social Application

Another 5G proposed infrastructure by N. Raza et al. [3] proposes a Social V2X Communication Model. This model introduces social behavior with the current technology of surveillance and automated information to act as a trigger of responses. With the use of 5G, these triggered actions will be high-speed and low latency. The existing technologies include networking such as Cloud Computing and Mobile Edge Computing, with entities such as vehicles, roadside infrastructure, and Road Side Units (RSU). The social network includes Vehicle to Vehicle (V2V), Vehicle to Pedestrian (V2P), Vehicle to Infrastructure (V2I), Vehicle to Network (V2N), Vehicle to Everything (V2X).

For the social behavior aspect to be effective, end-devices such as: smartphones or other hand-held devices carried by pedestrians, wheelchairs, motorcyclists, and onboard vehicle user equipment (UE), roadside units including bus stops and train crossings, need to have the V2X application installed to allow for social interaction between the units.

Combining this data with Google maps and with other vehicles with the same area creates a cooperative awareness that can aid in traffic management. 5G technology's long-range communications allow for inter-vehicle communications. N. Raza et al. [3] proposes a methodology that incorporates the social aspect which may be used for future research: vehicular environment formation, communication environment formation, social application environment formation, integration, simulation run and result gathering, analysis of the proposed model, and real time deployment as shown in Figure 6.

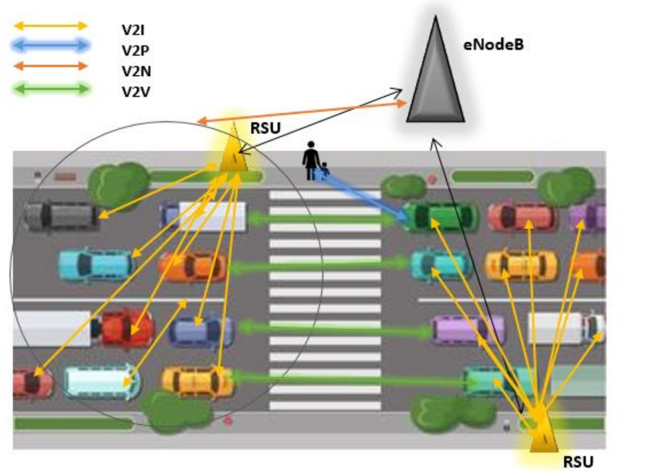

Figure 6: Social V2X Architecture

Introducing social behaviors is not an entirely new concept since V2X already considers different communication types. One aspect of social communication that was introduced was the delegation and categorization of communication between entities, not simply what entities can communicate.

V. Evolution

Evolution of 5G and DSRC technologies, also referred to as Radio access technologies (RATs), introduces 802.11bd for DSRC and NR V2X for C-V2X. Neither DSRC and C-V2X provide the low latency and reliability necessary for safety critical abilities within automobile communication, but evolution in these technologies may address those issues. Naik G. et. al. [13] explores the next generation of DSRC and Cellular V2X communication as the enhancements address some of the handicaps in the current RATs.

Both DSRC and C-V2X operate in the 9.5 GHz band, although C-V2X can also operate in the operator's cellular carrier. Although DSRC was created for V2V communications, studies show that C-V2X outperforms DSRC in terms of additional link budget, better non-line-of-sight (NLOS) capabilities, and resistance to interference. Both DSRC and C-V2X fall short in areas of high congestion, reducing the end-to-end latency in safety critical applications. DRSC decreased performance is due to packet collisions caused by hidden nodes, and concurrent transmissions, while C-V2X performance suffers from interference between users.

Emerging technologies 802.11bd and NR V2X must be backwards compatible to be able to communicate with existing DSRC and C-V2X. Advanced features such as maneuver changes, trajectory alignments, and platoon formations require reduced latency and reliability than basic safety messages. These advanced features would also require variable sized packets sent sporadically rather than being transmitted periodically [13].

Enhanced features of 802.11bd include relative velocities with one mode achieving relative velocities up to 500 km/hr., which is double that of 802.11p, and achieves a communication range double that of 802.11p. 802.11bd and 802.11 are expected to coexist and detect each other's transmissions and defer channel access, as well as share equal access to channels. 802.11bd include mechanisms such as Midambles, which aids in channel tracking, retransmissions which are resent based on congestion level, and dual carrier modulation. Backward compatibility and interoperability are challenges with 802.11bd as the frame format will depend on whether an 802.11p device is in the vicinity. Devices must be able to communicate with each other to ensure the frame format switches back to support 802.11bd once there are no 802.11p devices in the area [13].

NR V2X is currently under development by the 3rd Generation Partnership Project (3GPP) to provide communication that supports applications with reliability of over 99% and require end-to-end latency under 3 milliseconds. NR V2X is an addon to existing C-V2X for features not currently supported by C-V2X. Although NR V2X is not backwards compatible since enhancements aren't possible for C-V2X, NR V2X and C-V2X and can communicate using a dual-radio system, one for each technology. Both technologies will need to coexist, some vehicles already including C-V2X technology.

Newer vehicles will be equipped with both C-V2X and NR V2X. Mechanisms for enhancements include use of NR Numerologies, which helps reduce latency. NR V2X will also introduce mini-slot and multi-slot scheduling to allow small slots of safety critical to be sent without delay and without wasting large packet sizes, while multi-slot allows the exchange of large packets, increasing efficiency. Side-link feedback channel helps prevent blind re-transmissions – a feature still being studied. NR V2X will feature four sub-modes for side-link mode 2 which will assist with the selection and allocation of resource [13].

C-V2X and DSRC are not compatible with each other, and therefore NR V2X and 802.11bd will not be compatible with each other. Backward combability and coexistence is a must as older vehicles will be sharing the road with newer vehicles with multiple technologies. The choice of technology may be based on the region or regulations, but to permit all vehicles to communicate with each other, the choice will come down to wireless versus cellular.

VI. Conclusion

Evidence shows growing interest in 5G over DSRC as 5G combats concerns about low latency and loss of network connection. Some automotive industries have already committed to a specific technology, such as DSRC due to the cost of the equipment, although research is showing that 5G is on equal ground with DSRC compared to its predecessor, 4G. Figure 7 shows the comparison between DSRC and C-V2X, with clear advantages with C-V2X. The channel size and range are huge factors, especially when dealing with less populated areas that don't have as many towers. Multiple-input multiple-output (MIMO) allows the transfer of more than one data signal on the same channel at the same time. C-V2X has support up to 8 channel antennas, while DSRC has no standardized support.

Using the existing infrastructure for 5G will save money versus installing required access points and modems for DSRC. Both technologies have low latency, but 5G consistently shows a wider range. Continued research for 5G's emerging technology proposes possible configurations and infrastructures for C-V2X even before the technology is released, including automobile industries. Some of these architectures include combining both technologies in delegated jobs.

	DSRC 802.11p	5G C-V2X
Readiness	Currently available	5G emerging
Cost Effectiveness	Requires deployment of access points, modems	Uses existing cellular network infrastructure
Evolution	No current path	5G
Latency	< 5ms	1 ms at up to 310 mph
Positioning	Only V2V, V2I	V2V, V2N, V2I, V2P, V2G
Data Rate	27 Mb/s	300 Mb/s
High Density Support	Yes	Can guarantee no packet loss
Transmission Range	< 225 meters	Potentially > 450 meters
Frequency	5.9 GHz	600 MHz to 6 GHz
Coexistance	3GPP	11p, >R14, WiFi
Channel Size	10/20MHz	10/20 MHz and wideband (40/60/80... MHz)
Synchronization	Asynchronous	Synchronous
Modulation Support	Up to 64QAM	Up to 256QAM
MIMO Support	No standardized support	Support up to 8 tx/rx antenna
Line-of-Sight (LOS) Range	675m	1175m
NLOS Blocker (5GAA)	125m	425m
NLOS Blocker (CAMP)	400m	> 1350m
NLOS Intersection	375m	875m

Figure 7: DSRC & 5G Comparison

Only one technology can dominate if vehicles are to communicate with each other. For DSRC and wireless to coexist and communicate with each other, automobile industries must choose the same technology to allow vehicles to communicate. If vehicles made in the US communicate are equipped with 5G and Toyota equips their vehicles with DSRC, these vehicles will be unable to communicate with each other. In addition, the chosen technology must be backwards compatible and communicate with all versions of each technology and be able to recognize the version it's communicating with and switch back and forth between technologies and versions of each technology. If both technologies are installed in all vehicles, automobile companies would need to install technology for both DSRC and 5G, plus any technology that allows both versions to communicate with other versions.

Applying the benefits of both DSRC and 5G would be the safest option, combining the benefits of both technologies, but managing both technologies would prove difficult. Although the focus of V2X communication is to reduce accidents and create efficient and safer commutes, cost and convenience will play a main role in choosing technology since adding access points and modems for DRSC connectivity would be costly.

Automobiles companies will need to be on the same page, even if it means scrapping old ideas and equipment for collaborative efficient equipment. The focus goes back to which technology will save the most lives, and since the answer is likely to be for both technologies to coexist, provided DSRC and 5G are designated to dedicated regions of the network, some coexistence is possible, but it'll ultimately come down to choosing one technology to be the main communicator for V2X communications.

Currently the FCC allocates a portion of bandwidth to DSRC, but lately FCC has also shown interest in allocating bandwidth for 5G [14]. Having dedicated bandwidth for 5G will allow automobile industries the freedom to choose their technology and allow increased performance such as better speed and lower latency for 5G.

C-V2X will continue to be researched as 5G technology is applied to other areas, such as drones, smart homes, and other IoT devices, regardless if 5G is used in the automotive industry. 5G is already in the hearts and minds of researchers and is not going anywhere. If loyalties to previous investments does not influence the judgement of key decision-makers, 5G will likely win over DSRC.

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