

# A Study on Millimeter-Wave Vehicular Communication

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**ABSTRACT:** As driving becomes more automated, since they equipped with more sensors generating even higher data rates. Radars used as object detection, the visual cameras as virtual mirrors, and LIDARs for generating high resolution depth associated range maps. Connected vehicles uses wireless communication to exchange sensor data, to enlarge their sensing range and improve automated driving functions. Conventional technologies DSRC and 4G cellular communications do not support the Gb/s data rates. This article makes the case that Mm-Wave communication is the method for bandwidth connected vehicles. The motivations and challenges associated with using Mm-Wave for V2X communication are highlighted. A solution to one key challenge the overhead of Mm-Wave beam alignment is proposed. The critical feature of this solution is to leverage information derived from the sensors or DSRC as side information for the Mm-Wave communication link configuration.

**KEYWORDS:** LIDARs, V2V, V2I, V2X, DSRC, 4G. .

## I. INTRODUCTION

The number of sensors on vehicles and data rate is increasing. The average number of sensors on a vehicle now is around 100, but their number is expected to double by 2020. Automotive radars and visual cameras are the most common safety sensors found in vehicles. By sensing the existence, position, velocity of other vehicles, automotive radars make it possible to realize adaptive cruise control, blind spot detection, lane change assistance so on. Cameras make better driving security, such as they eliminate blind spots and works as virtual mirrors, and provide better night vision with infrared sensors. Autonomous vehicles heavily rely on LIDARs, which use laser technology to generate HD range maps. The amount of data generated by LIDARs is similar to conventional automotive cameras, which will increase the rate of data generated by a vehicle. Safety algorithms needed to work with more sources of data and higher data volumes.

A major challenge associated with current sensor technologies is that they have a limited sensing range. Considering the radars, cameras, and LIDARs provide information only about the objects within the line of sight, which limits the automation capability of vehicles for better safety measures. An alternative methodology is to have wireless communications which enable cars to exchange information called connected vehicles. Various safety-related applications with improved automation capability are enabled by vehicle connectivity, including forward collision warning, do not pass warning, blind intersection warning, and red light violation warning, which may reduce by more than 80 percent of car crashes.

Two potential benefits of vehicles, Firstly, if a suitable carrier frequency is chosen, cars can communicate in non-line of sight. Second, if a high bandwidth communication link is available, cars can share higher rate raw sensor data. Fully connected vehicles can implement powerful active safety applications, that is, "Bird's Eye View" identified in the Fifth Generation. Shared sensor data can be processed by each vehicle. This has the potential to further improve transportation efficiency and safety.

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## II. LITERATURE SURVEY

Protocol for connecting vehicles is called dedicated short-range communication (DSRC). Using DSRC, it is possible to implement preliminary vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) [5]. The National Highway Traffic Safety Administration (NHTSA) is recommended to mandate that all new vehicles include DSRC technology. While DSRC permits vehicles to exchange messages with a range up to 1000 m with a maximum data rate of 2–6 Mb/s. Fourth generation (4G) cellular systems using device-to-device (D2D) mode could be used for V2X communication systems. Maximum data rate in 4G systems is still limited to 100 Mb/s. Current technologies are not enough to handle the tera byte-per-hour data rates in the connected vehicles. The use of millimeter-wave spectrum is on the top of DSRC or 4G V2X for fully connected vehicles. Mm-Wave is already available to consumers in the form of IEEE 802.11ad [7] which is a part of 5G. The use of Mm-Wave provides to access high bandwidth communication channels.

Mm-Wave is not new in automated vehicles. Current automotive radars already use Mm-Wave spectrum [2]. For vehicular communications, Mm-Wave was tested more than a years ago [8]. There is even a standard for vehicular communications at Mm-Wave from the International Organization for Standardization (ISO) [9]. Foundation for Mm-Wave communication in V2X is already available, and it's now time to revisit the use of Mm-Wave for vehicular communications considering much interest in vehicular automation.

Reviewing different automotive sensing techniques which is frequently used. Here it shows why high data rates are required to exchange raw sensor data between vehicles. High data rates could be provided through the use of 5G Mm-Wave cellular system. A modification of IEEE 802.11ad, or the development of a dedicated Mm-Wave V2X networking protocol is the only way for v2x communication. Three main challenges to implementing Mm-Wave V2X communication systems, they are the lack of Mm-Wave vehicular channel model, the penetration rate of Mm-Wave V2X-capable vehicles, and Mm-Wave beam alignment. The beam alignment is the main problem in Mm-Wave, which will be difficult in vehicular environments because of high mobility. By exploiting DSRC and/or sensor information as side information, the Specific examples are used for position information obtained from DSRC. It is used to reduce the beam alignment and tracking overhead in Mm-Wave V2X scenarios.

### (A) Sensing for next generation vehicles.

The three major automotive sensor for present and next generation vehicles are illustrated in Fig.1.1 The raw sensor data rate for each sensors is summarized in the Table-1 shown below.

	Purpose	Drawback	Data rate
Radar	Target detection and velocity estimation	Hard to distinguish targets	Less than 1 Mb/s
Camera	Virtual mirrors for drivers	Need vision techniques	100–700 Mb/s for raw Images.
LIDAR	Target detection and velocity estimation	High cost	10–100 Mb/s

Table 1. Purposes, drawbacks, and data rates of different sensors

Automotive radars are already operating in Mm-Wave spectrum, between 76 and 81 GHz [2]. Long range radar is used for adaptive cruise control. Medium-range radars supports the cross-traffic alerts, lane change assistance, and blind spot detection. Short range radars helps to assist in parking. Radars engage in active sensing by sending a separate waveform, frequency modulated continuous waveform is used, to derive information about the existence, location, and velocity of neighbouring vehicles from reflections.

The waveforms and antenna structures vary by manufacturer which are typically standardized. The European Telecommunications Standards Institute (ETSI) has defined some waveform-related parameters. Spectrum, peak and average allowable power and so on, but the overall waveforms and signal processing are not specified. Radars are not

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suitable to recognize the types of target objects without modifying their standard signal processing. The data is heavily post-processed to reject clutter and produce point-map information only for relevant targets. Data rates generated by radar vary from kilobits per second to hundreds of megabits per second.

Automotive cameras use visible or infrared spectrum so that they provide the driver an additional view for safety, New computer vision algorithms are required for automotive cameras to work as intelligent safety applications. The amount of data generated from automotive cameras is very large. Data rates vary from 100 Mb/s for low-resolution to 700 Mb/s for high-resolution raw images. Automotive cameras form one of the highest data rate sources of sensor data on the car.

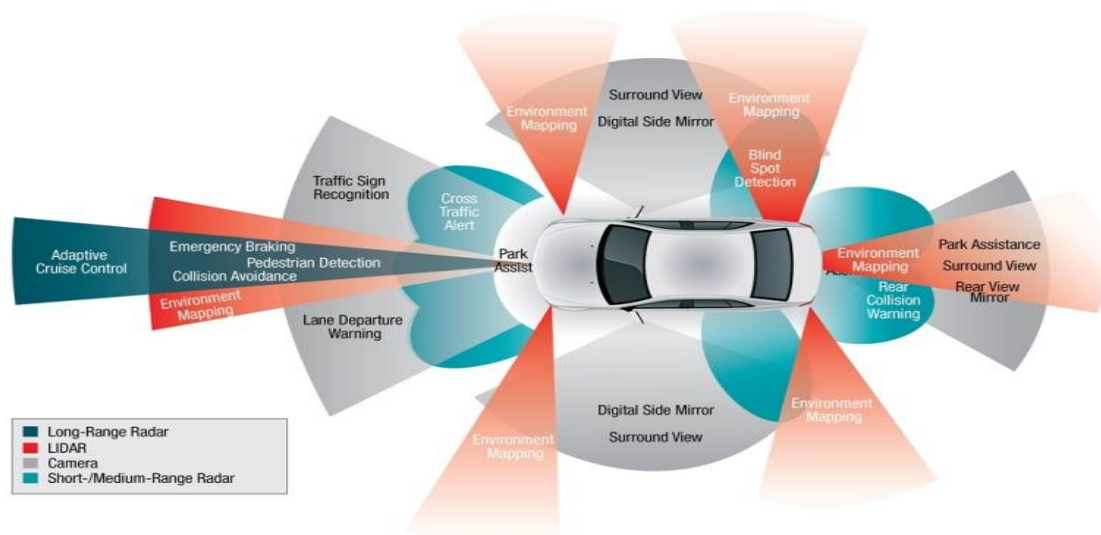


Figure 1.1: A car with many safety-related automotive sensors.

LIDARs use narrow laser beams to generate high resolution 3D digital images, where pixels are also associated with depth, and with a 360 degree field of view by a rotating laser. LIDAR operates by scanning a laser over an area and measuring the time delay from the backscattered signal.

## III. PROPOSED METHODOLOGY

### (A) :MILLIMETER-WAVE COMMUNICATION

Mm-Wave communication system is the new trend in vehicular communication. V2V and V2I architectures implemented using Mm-Wave which support fully connected vehicles that share their raw sensor data. Mm-Wave refers to the spectrum between 30 and 300 GHz. Using Mm-Wave carrier frequencies for communication, it is possible to exploit larger spectral channels. Combined with higher order modulations and multiple-input multiple-output techniques to enhance spectral efficiency, Mm-Wave can achieve higher data rates than those provided by current wireless communication systems operating at below 6 GHz carrier frequencies [10]. For example, IEEE 802.11ad uses 2.16 GHz of bandwidth in the unlicensed 60 GHz band and supports data rates up to 7 Gb/s [7]. Recently, the Federal Communications Commission (FCC) has proposed to authorize the operation in 28, 37, and 39 GHz of the licensed band and made 64–71 GHz available for unlicensed spectra for mobile use, which would facilitate the use of Mm-Wave for various wireless communication scenarios including V2X. In Mm-Wave communications, it is essential to have a large number of antennas at the transmitter and the receiver to form sharp transmit and receive beams and establish good communication links. Due to small wavelengths of Mm-Wave frequencies, it is possible to deploy a large number of antennas in a small form factor. Millimeter wave spectrum is the band of spectrum between 30 GHz and 300 GHz. Wedged between microwave and infrared waves, this spectrum can be used for high-speed

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wireless communications as seen with the latest 802.11ad Wi-Fi standard (operating at 60 GHz). WiGi(Wireless Gigabit alliance) is multi-gigabit per second wireless technology over unlicensed spectrum of 60GHz. The spectrum is shown in Fig 3.1.

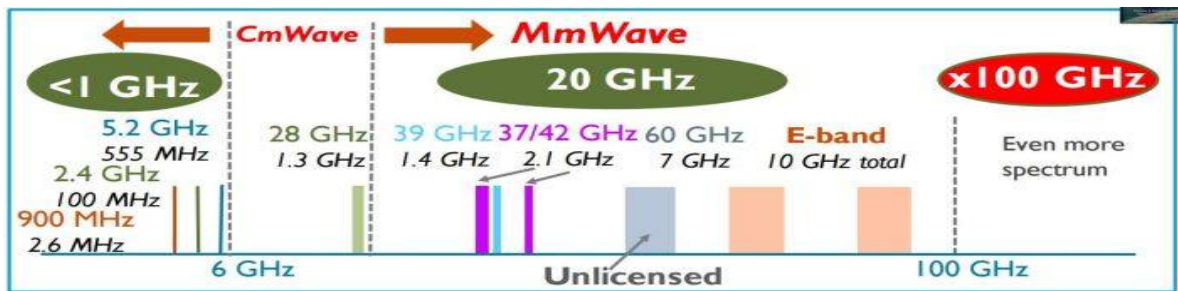


Fig 3.1: Millimeter-wave spectrum

From the spectrum it can be seen that an unlicensed spectrum of 7GHz bandwidth with a centre frequency of 60GHz exists. This 7GHz bandwidth is used for mobile applications and is supported by IEEE 802.11ad. It aims at multi-gigabit wireless network. The key features of IEEE 802.11ad is shown in below Table 3.1

PARAMATERS	VALUES
SPECTRUM	57-64GHz
NO: OF CHANNELS	4
BAND WIDTH	2.16GHz
BIT RATE	693Mb/s - 6.76Gb/s
MODULATION	OFDM
TRANSMISSION RATE	<10M
COST	CHEAP

Table 3.1: Features of IEEE 802.11ad

Because of the large number of antennas, however, it may not be cost efficient to have high-quality signal processing components for all antennas. Therefore, analog beam forming and hybrid beam forming have drawn significant interest for Mm-Wave communication systems. There has been much work demonstrating that the performance of hybrid beam forming is similar to that of full digital beam forming. We refer to [11] for details about general Mm-Wave communication technologies. Figure 2 illustrates Mm-Wave V2X communications at a conceptual level. For Mm-Wave V2X communications, there should be multiple Mm-Wave transceivers to overcome the blockage of Mm-Wave signals by nearby vehicles or even pedestrians. For example, a vehicle may have Mm-Wave transceivers on front and rear bumpers and sides for V2V, and on its rooftop for V2I communications, because infrastructure will be placed at high elevations to ensure good link conditions.

The blockage effect in the Mm-Wave V2V scenario might be mitigated by using the gap under vehicles as waveguide, which allows a vehicle to communicate with vehicles other than adjacent ones. Although blockage is usually considered a defect, it can be beneficial for V2V communications because the effect (combined with narrow Mm-Wave beams) can reduce inter-vehicle interference and enable better spatial packing, as demonstrated by using directional antennas in lower frequencies in [12]. In fact, blockage may not be a serious problem in mmWave V2V because only the vehicles in proximity would share their raw sensor data, while basic safety information such as position and velocity can be broadcast using DSRC or 4G V2X. will likely be connected to the central controller of a vehicle via a controller area network (CAN) bus (or more advanced in-vehicle network protocols that can support high data rates) to exploit high data rate information from neighbouring vehicles. Comparison of vehicular communication standards is shown below,

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	DSRC	Wi-Fi	Bluetooth	4G
Spectrum	5.9 GHz	2.4/5.8GHz	2.4GHz	2-6GHz
Bandwidth	10 Mb/s	20,40MHz	1MHz	1.75-20MHz
Bit rate	3-27 Mb/s	6-600Mb/s	1-24Mb/s	Up-56Mb/s Down-300Mb/s
Range	<300m	<100m	<100m	<10km

Table 3.2: Comparison of vehicular communication standards

To avoid significant cable loss at Mm-Wave frequencies, both RF and some baseband processing components should be integrated into a single Mm-Wave transceiver. For example, the medium access control (MAC) protocol can be divided into two layers, that is, distributed lower MACs at each transceiver connected to a centralized upper MAC by a lower-rate CAN bus. 5G cellular systems may use Mm-Wave spectrum to provide gigabit-per-second data rates. It is possible that Mm-Wave V2X communications are supported through 5G communication systems, that is, 5G base stations serve as infrastructure for V2I communications, and 5G D2D mode supports V2V communications. To help set up Mm-Wave links, a low-frequency control plane can be exploited.

In this way, it is possible to leverage existing cellular infrastructure and the ability of mass production of consumer cellular devices to manufacture low-cost Mm-Wave V2X transceivers. Using 5G for V2X communications, however, needs a clever strategy to share the spectrum with many other cellular devices and must support high mobility. However, IEEE 802.11ad was originally designed for indoor use, and the standard needs some modifications to support high mobility. For example, hierarchical beam sweeping in IEEE 802.11ad may work for indoor environments, but it is questionable whether the technique would work for high mobility scenarios.

The MAC protocol should also be revisited to support intermittent connectivity in vehicular environments. DSRC may give insight on adapting IEEE 802.11ad to vehicular environments. Instead of relying on 5G systems or existing Wi-Fi standards, it is also possible to have a new standard with dedicated spectrum for Mm-Wave V2X communication similar to DSRC. Having a separate Mm-Wave V2X standard will enable flexibility to optimize vehicular communication systems while requiring additional efforts on manufacturing Mm-Wave V2X equipment.

## (B):MILLIMETER WAVE BEAM ALIGNMENT

Due to common use of sharp transmit and receive beams in Mm-Wave systems, the beam alignment between the transmitter and the receiver is critical in Mm-Wave communications. Once beams are properly aligned, standard communication protocols (i.e., effective channel estimation and data transmission) can be performed using sufficient link margin. The brute force approach to perform beam alignment is testing all possible transmit and receive beams sequentially, which has high overhead. There has been much work on reducing the beam alignment overhead in cellular and Wi-Fi systems. Mm-Wave V2X communications, however, may require very advanced beam alignment techniques considering the high mobility of vehicles. Mm-Wave V2I and V2V communications may require different approaches for beam alignment. Because the infrastructure is stationary, the fast initial beam alignment would be important in mmWave V2I communications. In Mm-Wave V2V communications, beam tracking after the initial beam alignment would be more important because neighboring vehicles are likely to be moving at similar speeds. In both Mm-Wave V2I and V2V cases, beam realignment caused by blockage should be properly handled.

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### IV. WORKING(EXAMPLE)

#### ➤ V2X MMWAVE BEAM ALIGNMENT USING DSRC AND/OR AUTOMOTIVE SENSORS

Scenarios where the proposed idea of using DSRC and/or automotive sensors is beneficial to reduce the Mm-Wave beam alignment overhead. Then we evaluate the proposed idea with numerical results considering practical vehicular environments.

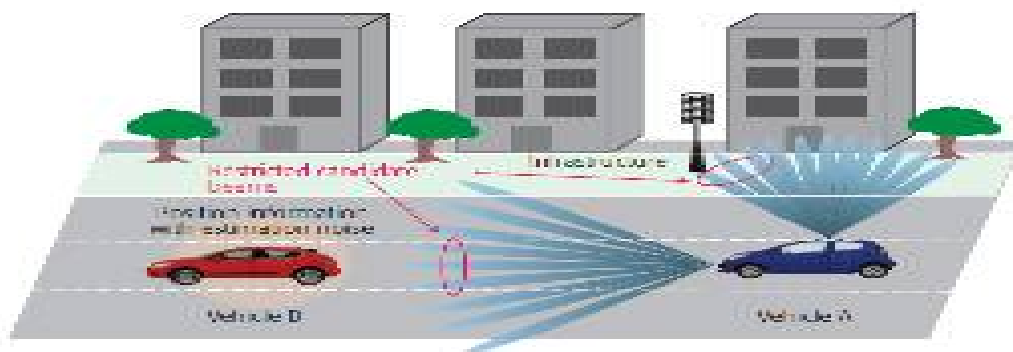


FIG 5.1: V2V communication scenario

Consider a V2V communication scenario where a vehicle A wants to establish a communication link with another vehicle B in front, as shown in Fig. 5.1. Assume vehicle A knows the existence of vehicle B using automotive sensors but does not know the exact relative position of vehicle B. To establish an Mm-Wave communication link by beam alignment in this case, vehicle A may need to test many beams to select the best beam for communications. Considering the narrow beams in Mm-Wave communications, the beam alignment overhead will be quite large. It is possible to exploit advanced beam alignment techniques to reduce the beam alignment overhead. The fast moving nature of vehicles will require novel beam alignment techniques for V2X. If vehicle A knows the relative position of B in advance by using DSRC signals or automotive sensors, it is possible for A to restrict the candidate beams for the beam alignment.

The restricted beam search space will effectively reduce the beam alignment overhead without any performance loss. Advanced beam alignment techniques can be exploited on top of the restricted beam search space to further reduce the beam alignment overhead. In the V2I case, the benefit of using position side information for Mm-Wave beam alignment will be even greater. Usually, infrastructure will be located at the side of roads, which leads to a wider angular region for searching the best beam than in the V2V case.

Because of the different heights of vehicles and infrastructure, 3D beam forming that controls beam patterns in both azimuth and elevation will be necessary for Mm-Wave V2I communications, which also increases the beam search space. Since infrastructure is stationary, it may have prior knowledge of its neighbouring environments, which can be further exploited. Using DSRC signals from infrastructure or accurate real-time 3D map data, vehicles entering the serving area of infrastructure may know the position of the infrastructure in advance and thus effectively restrict the beam search space. Advantages of the considered system is shown below.

- **Large bandwidth:** The large bandwidth translates to better data transfer rates, attaining speeds of about 10Gbps or more compared to the 1Gbit/s limit when using the microwave frequencies. This makes high-quality video streaming, real-time gaming, and other bandwidth intensive applications a reality.
- **Small components sizes:** The components and antennas for the higher millimeter wavelengths are usually very small compared to those for lower frequencies. This makes it possible to design physically smaller circuitry and equipment. For example, a half-wave dipole operating at a 900MHz cellular frequency is about six inches long but this would reduce to 2.5 mm at 60GHz in free space or less if on a dielectric substrate. As

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such, it is possible to make very small and lightweight radio equipment comprising the radio and antenna or build multiple elements phased arrays on a chip.

- **Greater resolutions:** The narrow beam could allow the ability to achieve greater resolutions.
- **Low interference and increased security:** The narrow beam and short range can be a benefit since there is less interference from nearby radios. In addition, it is much harder to intercept the signals and there is also increased security since the signal is only restricted to a small area.

## V. CONCLUSION

This paper is a study, why current technologies for vehicular communications such as DSRC and 4G cellular systems will be insufficient for future connected vehicles that wish to share raw sensor data on a large scale. To exchange the large amount of data from automotive sensors (e.g., cameras and LIDARs), we propose three ways in which Mm-Wave can be used in future vehicular networks: 5G cellular, a modified version of IEEE 802.11ad, or a dedicated new standard. Reason that a vehicle should have multiple Mm-Wave transceivers to mitigate blockage and have better spatial packing in vehicular environments. Here also discussed that the using DSRC or automotive sensors as side information to reduce the Mm-Wave beam alignment overhead. The exploiting side information obtained from various out-of-band sensors will play a key role not only for Mm-Wave V2X communications but also for all Mm-Wave communication systems in general to achieve sufficient link quality with a reduced control overhead.

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