Preliminary Comparison of Empirical Performance Between DSRC and CV2X for Emergency Response Applications

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***Abstract*—Emergency response services rely on optimizing response times to be effective, necessitating priority on the road. However, current techniques involving non-adaptive traffic control systems can be dangerous and inefficient. Automating ERV prioritization using V2X technology can enhance response times and improve safety during emergencies. To this end, this paper empirically compared two competing V2X technologies, DSRC and C-V2X, in terms of latency, RSSI, and reliability in the context of emergency response applications such as ERV prioritization. These performance metrics were evaluated across highway and urban environments, as well as LOS and NLOSv link states, varying separation distance between a simulated ERV and traffic control infrastructure that actuates ERV prioritization. Preliminary findings suggest that DSRC outperforms C-V2X across all metrics, demonstrating its advantage for automating emergency response applications, particularly ERV prioritization.**

***Index Terms*—V2X, Vehicle to Everything, V2I, Emergency Response, NLOSv**

I. Introduction

The effectiveness of emergency response heavily relies on delivering these services in an efficient and timely manner, especially in Emergency Medical Services (EMS), where every second counts for a critical patient. In many countries, such as the Philippines, Emergency Response Vehicles (ERV) are given the right of way and, in some cases, allowed by law to bypass traffic laws during emergencies to ensure timely response. Commonly, traffic control infrastructure at intersections are not adaptive to prioritize ERVs prompting the need for traffic enforcers to facilitate prioritization when audio cues such as sirens are not enough to create a corridor for faster passage sometimes requiring the countermanding of the current traffic light cycle. While this mechanism works, the probability of accidents occurring by bypassing the red traffic signal increases, especially in cases where there is no traffic enforcer to facilitate.

This problem can be avoided by automating ERV prioritization with the use of Vehicle-to-Everything (V2X) technology. By equipping ERVs with Onboard Units (OBUs) and traffic lights with Roadside Units (RSUs), wireless coordination between ERVs and traffic lights can be facilitated via Vehicle-to-Infrastructure (V2I). Currently, however, there are two competing technologies, one based on the IEEE 802.11p (Dedicated Short Range Communication, DSRC) and the other based on the cellular telecommunication standards set by 3GPP (Cellular-V2X, CV2X), each with separate ongoing deployments globally [9][10]. Until a clear standard and/or harmonization between both technologies exist, this poses a challenge for countries that have yet to adopt V2X in choosing the appropriate V2X standard [1]. While available relevant work provide insights through simulations, this paper aims to aid decision-making by presenting preliminary empirical performance characterization and comparison between DSRC and C-V2X in the context of targeted emergency response applications such as ERV prioritization. Metrics such as RSSI, latency, and reliability were measured and analyzed between DSRC and C-V2X across highway and urban environments and different link states, specially in Non-Line-of-Sight due to vehicular blockage (NLOSv) condition.

The rest of the paper is organized as follows: Section II presents relevant work on performance characterization between DSRC and CV2X. Section III presents the operational definitions and experimental setup. Section IV presents the results and findings post-data analysis. Section V presents a summary of this work and recommendations. Finally, Section VI presents next steps based on these findings.

II. Review of Related Work

DSRC and C-V2X have been compared using performance metrics such as latency [1][2], reliability [1]-[6][14], and coverage, on both highway and urban settings, and across different link states, particularly under Non-Line-of-Sight due to vehicular blockage (NLOSv) conditions. NLOSv is of particular interest because the majority of the obstructions to Line-of-Sight (LOS) V2X communications are vehicles. In fact, the NLOSv link state was standardized due to the unique impairment brought by vehicular blockage to V2X communications [7][8][11] compared to impairments caused by large structures such as buildings. While NLOSv is more related to Vehicle-to-Vehicle (V2V) direct communications, the pathloss models can be extended for V2I [8]. Due to unavailability of COTS V2X

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devices operating in higher frequencies, most characterization has been done with V2X devices operating in the sub-6 GHz frequencies (i.e., 5.9 GHz). Similarly, C-V2X COTS devices operating on the 5G-NR frequencies has yet to have widespread commercial deployments. Therefore, majority of evaluation for C-V2X has been done using LTE-V2X devices operating on the 5.9 GHz band. Aside from work on wave propagation, other work included latency and reliability in evaluating performance because these metrics among others are more reflective of driver experience on the road compared to propagation alone. In the context of emergency response, during ERV prioritization, RSUs must be able to reliably detect ERVs within its vicinity in a timely manner for seamless prioritization. Currently, the incompatibility and lack of standardized mechanisms between DSRC and C-V2X to coexist in deployment scenarios prompts countries to adopt either of the two[1], despite various work demonstrating ways for both technologies to coexist harmoniously [14]-[17].

Given the current situation, DSRC and C-V2X performance in the context of emergency response must be compared individually. Comparing DSRC and C-V2X, findings show that DSRC generally has much better latency performance compared to C-V2X [1]-[2][9], found to be a result of the difference in the channel access mechanism of the two protocols [1][9]. DSRC uses the Enhanced Distributed Channel Access (EDCA) which is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). DSRC uses EDCA to sense the channel state and waits until a channel is found idle before transmitting, in addition to a random back-off mechanism to avoid collisions. In contrast, LTE-V2X uses the more proactive Semi-Persistent Scheduling (SPS) scheme which reserves a sub-channel for a certain number of packets and duration rather than dynamic channel contention used by EDCA. Additionally, DSRC latency maintains this advantage with varying Modulation and Coding Scheme (MCS) index [1], Tx power [1][2][9], and payload size [1]. However, DSRC is more affected in cases where signal power is degraded [1]. In terms of reliability, LTE-V2X seems more robust than DSRC in cases of degraded signal power, varying MCS, and longer distances [1]-[5]. However, LTE-V2X suffers as payload size increases which is suggested to be a result of how SPS works [1][9].

To the best of the researchers' knowledge, most of the relevant work considered LOS or NLOS link states without attention to NLOSv conditions. Addressing this gap is one of this paper's contributions. In this paper, DSRC and LTE-V2X are empirically compared using preliminary field tests in terms of latency, reliability, and coverage with varying distance, link state, and environment, in the context of emergency response applications.

III. Methodology

A. Environmental Setup

The experiments were carried out on the University Avenue Fig.1(a),(b) and Magsaysay Ave Fig.1(c) of the University of the Philippines Diliman, to closely represent the urban and highway environments described in [8]. Fig.2 describes the test setup for (a) LOS and (b) NLOSv V2I link states, considered in this work. This work also limited the use of V2X devices primarily between an ERV and traffic light. Therefore, ERV prioritization relies on the traffic control infrastructure to facilitate and manage traffic flow, rather than actively involving other non-priority vehicles. The transmitting OBU used 5dBi peak-gain omnidirectional antennas, onboard a simulated emergency response vehicle dashboard with 1.5 meter elevation (see Fig.1a). The receiving RSU used 7dBi peak-gain omnidirectional antennas, elevated 3.0 meters from the ground using a pole to simulate traffic lights for adaptive traffic control (see Fig.1b).

For each distance point (50m, 200m, and 350m), both technologies are tested individually thrice for latency, rssi, and reliability. These distances were chosen to optimize time without sacrificing granularity of observations. These distances are intentionally below 500m since distances between the nearest roadside unit and vehicle would not exceed this value. For each run of the experiment, DSRC OBUs transmitted 1000, 54 byte, V2X messages using a default message rate of 10Hz, while LTE-V2X OBUs transmitted 100, 44 byte, V2X messages using the default rate of 1Hz, both using out-of-the-box modulation and coding scheme on the COTS device, summarized on I. Due to the unavailability of 5G NR V2X devices on the market as of writing, this work uses COTS devices based on LTE-V2X technology. From here onward, LTE-V2X shall be used interchangeably with C-V2X. Lastlty, LTE-V2X devices were also operated on sidelink mode 4, which uses the sidelink PC5 interface for device-to-device communication and relies on autonomous resource allocation, in contrast to other modes that involve a base station for message routing and/or resource allocation.

TABLE I: V2X Message Default Parameters

Parameters	**DSRC**	**LTE-V2X**
fc	5.900 GHz	5.915 GHz
BW	10 MHz	20 MHz
Size	54 bytes (BSM)	44 bytes (CAM)
Rate	100 Hz	1 Hz
Msg. Count	1000	100
Distances	50, 200, 350 meters	

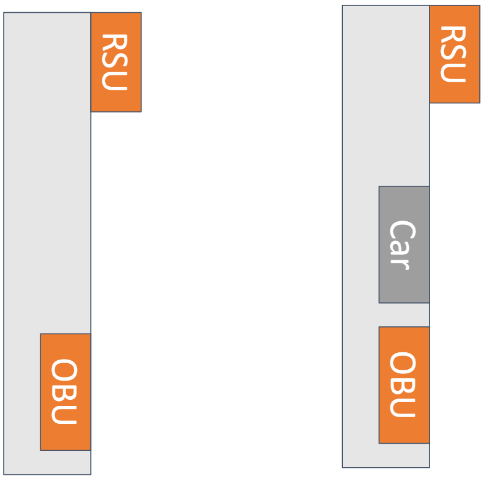
B. Latency Characterization

Latency was measured using (1) as the time difference it takes for the n^{th} transmitted V2X message to be received at the receiver. For both technologies, the maximum acceptable latency is 100ms [10]. Therefore, messages arriving beyond this delay were considered dropped and excluded from the dataset for latency. This was also done to avoid outliers on the dataset.

$$latency(ms) = t_{rx,n} - t_{tx,n} \quad (1)$$

(a) Highway OBU (b) Highway RSU (c) Urban

Fig. 1: V2I Environment



(a) LOS (b) NLOSv

Fig. 2: V2I Link States

The Cumulative Probability Distribution (CDF) of the latency dataset was then computed and plotted for analysis and comparison between DSRC and LTE-V2X in the context of emergency response. The CDF is an indicator where the latency values reside below a certain value most of the time.

C. RSSI Characterization

The RSSI was averaged for every distance point and setup, then curve fitted using a logarithmic model for comparison to 3GPP Rel. 16 pathloss models rather than previously established channel models such as the WINNER channel models. The 3GPP Rel. 16 V2V pathloss model is standardized for V2X communication and can therefore be extended to V2I scenarios like ERV prioritization. From the 3GPP Rel. 16 pathloss model shown on TABLE II, the NLOSv link state uses the LOS equation, except with an additional loss modeled as a normal random variable, depending on the height relationships between Tx antenna, Rx antenna, and the blocking vehicle. In this work, NLOSv Case 3 was applied since the blocking vehicle height is greater than the Tx antenna height, but is less than the Rx antenna height as illustrated in Fig.3. This chosen setup is representative of emergency response applications such as ERV prioritization, where ERvs communicate with RSUs typically deployed on elevated traffic infrastructure such as traffic lights.

TABLE II: Pathloss Models for V2V/V2I Sidelink

Link State	**Pathloss (dB)**	**Shadow Fading stdev** σ_{SF} **(dB)**
LOS, NLOSv	**Highway** $PL = 32.4 + 20log_{10}(d) + 20log_{10}(f_c)$	$\sigma_{SF} = 3$
	Urban $PL = 38.77 + 16.7log_{10}(d) + 18.2log_{10}(f_c)$	

For more details on the 3GPP Rel. 16 models, the reader is encouraged to refer to [7] and [8].

D. Reliability Characterization

$$PDR(\%) = (n_{rx}/n_{tx}) * 100 \quad (2)$$

Similar to other work, reliability was measured using packet/message delivery rate (PDR), shown in (2). A V2X message gets dropped if it does not arrive within the maximum allowable latency of 100ms. The PDR were then averaged per

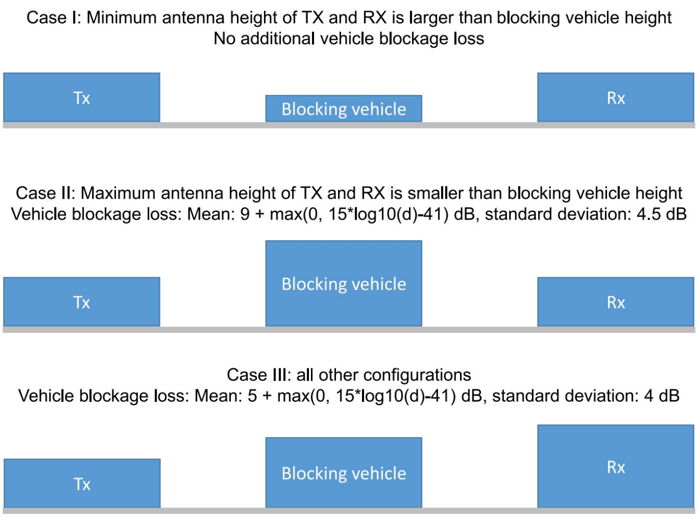


Fig. 3: Additional Blockage Loss due to NLOSv: Scenarios and Calculation [7]

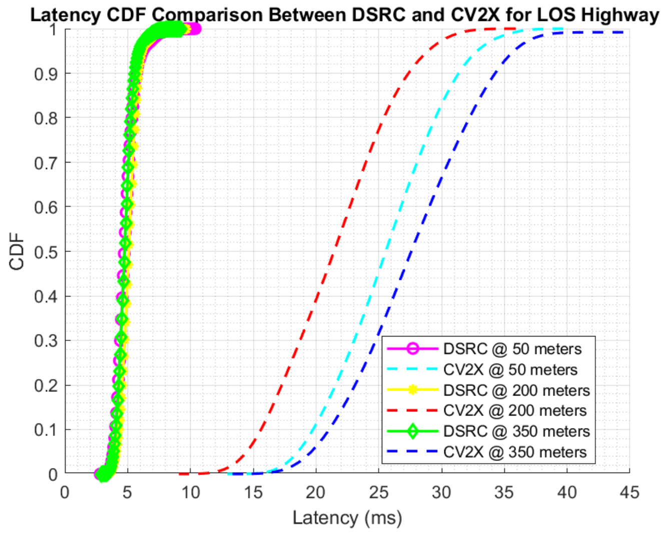


Fig. 4: Latency CDF Comparison between DSRC and C-V2X in Highway LOS Scenario

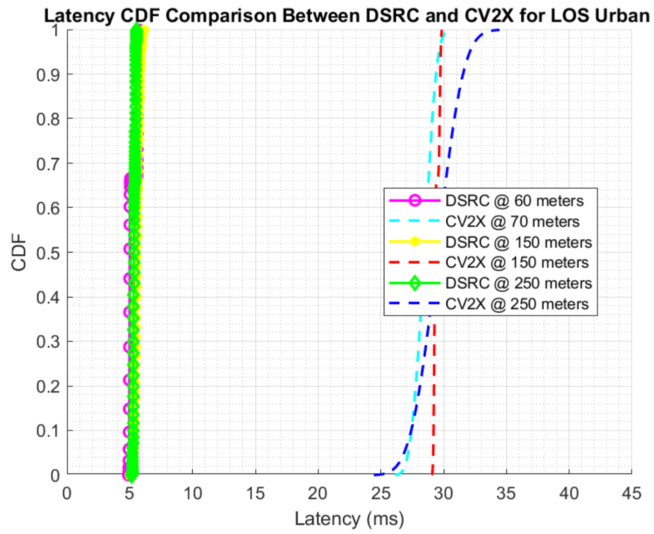


Fig. 5: Latency CDF Comparison between DSRC and C-V2X in Urban LOS Scenario

distance point and scenario, and compared for DSRC and LTE-V2X in the context of emergency response applications.

IV. Results and Findings

A. *DSRC vs. LTE-V2X V2I Latency*

In general, preliminary data agree with previous observations in the literature where DSRC experiences much lesser latency in general compared to LTE-V2X. This has been linked to the difference in the channel access mechanism used by DSRC and LTE-V2X (EDCA vs. SPS) where SPS tends to have higher delay due to its channel selection window, compared to EDCA where transmission is prioritized once an idle channel has been found [7][9]. Because V2X devices were only equipped on the ERV and traffic light, no contention in channel access was expected contributing to the low latency experienced by DSRC. This trend is maintained across different environments and link states as illustrated in Fig.4 to Fig.6. This means that the channel access mechanism contributes most for V2X latency performance observed for both technologies. Furthermore, as illustrated in Fig.4 and Fig.6, LTE-V2X shows more variance in latency for various distances in highway LOS conditions, possibly due to the longer paths taken by signals on highway scenarios, but most likely due to how SPS works [14]. These findings suggest an advantage for using DSRC over LTE-V2X on emergency response, where ERV prioritization requires swift responses by traffic actuators.

B. *DSRC vs. LTE-V2X V2I RSSI*

Fig.7 to Fig.9 illustrate the RSSI measurements for DSRC and LTE-V2X in the Highway LOS, Urban LOS, and Highway NLOSv scenarios. The measurements are curve-fitted and compared to established models by 3GPP release 16 [8], depending on test conditions. In every scenario, LTE-V2X experiences higher path loss compared to DSRC, with DSRC almost following the prediction by the 3GPP model. In addition, LTE-V2X experiences higher loss, while DSRC appears to experience lesser loss compared to the model prediction shown in Fig.9. This apparent lack of fit could be due to the low quantity of data used for curve fitting. On the other hand, it can be observed in Fig.8 that in Urban LOS scenarios, the RSSI experienced by both DSRC and LTE-V2X becomes more similar as the separation distances become larger. These findings suggest an advantage of DSRC over LTE-V2X for emergency response since it reflects better range, with ERVs being detected faster by road side units making prioritization faster.

C. *DSRC vs. LTE-V2X V2I Reliability*

DSRC shows better reliability compared to LTE-V2X across all scenarios on average, with LTE-V2X reliability degrading

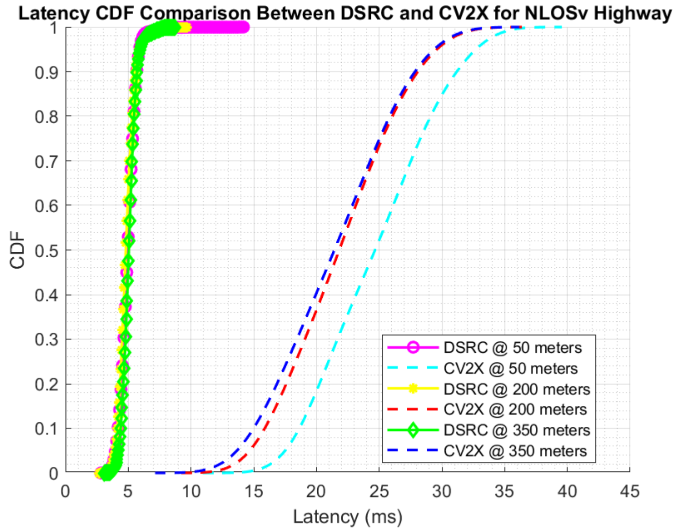


Fig. 6: Latency CDF Comparison between DSRC and C-V2X in Highway NLOSv Scenario

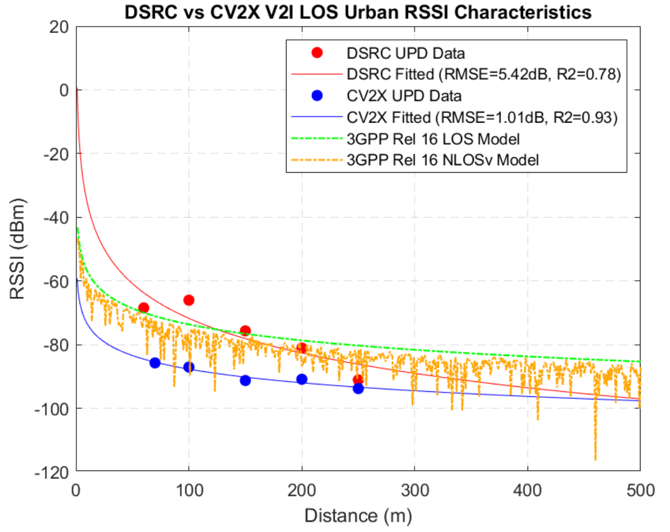


Fig. 8: RSSI Comparison between DSRC and C-V2X in Urban LOS Scenario

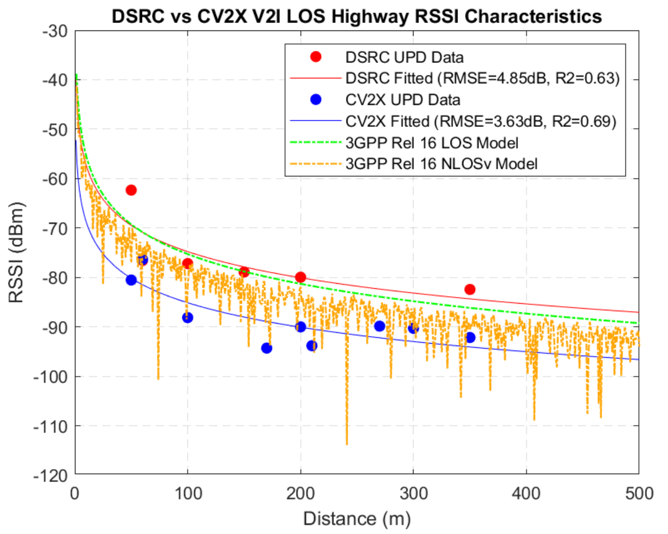


Fig. 7: RSSI Comparison between DSRC and C-V2X in Highway LOS Scenario

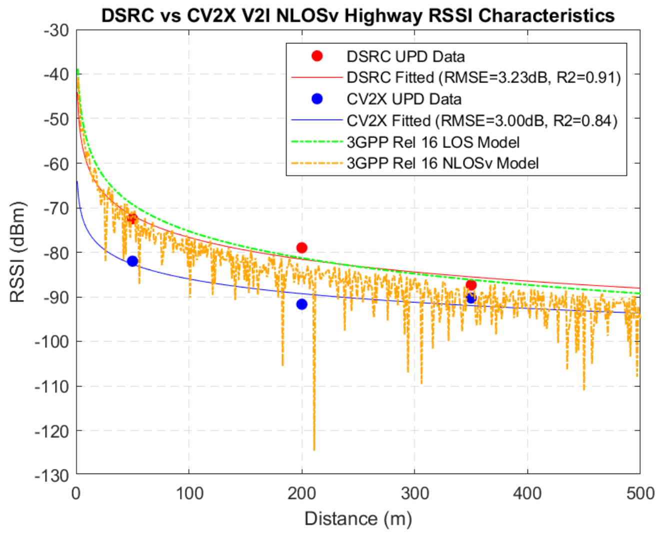


Fig. 9: RSSI Comparison between DSRC and C-V2X in Highway NLOSv Scenario

faster as separation distance increases, as shown in TABLE III, possibly due to the GNSS lock requirement for LTE-V2X devices to transmit. It must be noted however that DSRC experiences a more drastic drop in reliability at farther separation distance compared to LTE-V2X. This supports previous observations where worse signal quality affects DSRC reliability far worse compared to LTE-V2X. While DSRC shows better robustness for longer distances, this may not practically translate to better ERV prioritization since the same V2X message used to indicate prioritization request is sent repeatedly, typically at a rate of 10Hz, with the traffic actuators needing to detect the ERV only once. On another hand, no inference can be made for Urban NLOSv scenarios as of writing due to the time and resource constraints in gathering data.

V. Conclusions and Recommendations

In this paper, COTS DSRC and LTE-V2X devices were empirically compared in terms of RSSI, latency, and reliability performance in various scenarios, in the context of emergency response applications such as ERV prioritization. Based on preliminary findings, DSRC promises better RSSI, latency, and reliability performance suited for emergency response applications. This translates to the traffic control infrastructure (i.e., traffic lights) reliably detecting ERVs faster and farther to facilitate ERV prioritization when using DSRC, assuming that V2X devices shall be equipped only on traffic control infrastructure and ERVs, excluding other non-priority vehicles.

TABLE III: DSRC vs. LTE-V2X V2I PDR on Various Scenarios

Link State	Distance	Highway		Urban	
		DSRC	LTE-V2X	DSRC	LTE-V2X
LOS	50	99.93%	89.67%	96.07%	95%
	200	99.97%	49.33%	95.40%	59%
	350	99.87%	39%	34.53%	44%
NLOSv	50	99.60%	87%	—	—
	200	99.93%	41%	—	—
	350	65.80%	40%	—	—

VI. Future Work

Preliminary results, has demonstrated DSRC to be more advantageous for emergency response applications, in which only ERVs and RSUs on traffic control infrastructure interact. However, the upcoming advancements brought by 5G NR-V2X to solve the limitations of DSRC, including capacity and stronger resistance to effects of interference must be investigated to test the validity of these findings when extended to scenarios where high volume of non-priority vehicles are equipped with V2X devices, aside from increasing the quantity of measurements to improve models. Another future work may involve V2V comparison between the two technologies.

Acknowledgment

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