

# On the 5GAA comparison between LTE-V2X and DSRC/IEEE 802.11p

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## Introduction

This paper challenges the assumptions, conclusions and selected measurement conditions of a 5GAA report titled "V2X Functional and Performance Test Report; Test Procedure and Results". NXP's position is that the paper's performance comparison of LTE-V2X and DSRC/IEEE802.11p vehicle-to-vehicle communication is based on low-performing equipment and poor operating parameter choices. This paper demonstrates that when appropriate "apples to apples" comparisons are made, DSRC outperforms LTE-V2X by around 2 dB, rather than being 15dB inferior.

The significance of this matter should not be taken lightly: the 5GAA report is a fundamental part of the organization's aggressive efforts to claim spectrum in the 5.9GHz band, a spectrum that is now allocated to DSRC. As a result, its methodology should be held to a high standard.

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## Introduction

In October 2018, 5GAA published, "V2X Functional and Performance Test Report; Test Procedure and Results". Among the report's claims is that LTE-V2X has superior performance compared to DSRC/IEEE 802.11p. In this paper, we aim to demonstrate that under comparable conditions, DSRC is actually 2 dB better than LTE-V2X.

NXP disagrees with the conclusions of the 5GAA paper. We believe that the test set its benchmark using a sub-optimally configured DSRC module with below-market performance, and that it used inappropriate parameters for the test's comparisons. In fact, 5GAA published revised results that narrowed the performance gap between the two technologies. However, we still dispute the test procedure and the way results are presented.

## Sensitivity Tests

IEEE802.11p ('DSRC') and 4G LTE Release 14 ('LTE-V2X') both define radio technologies that enable direct vehicle-to-vehicle communication. Both are intended to be used in the 5.9 GHz band, one that is reserved for road traffic safety communication. The technologies are not interoperable. On top of this radio technology access layer, applications (such as collision avoidance) are able to operate even in the absence of a direct line-of-sight between vehicles, for example when blocked by a truck or building. DSRC is an available and tested technology, while LTE-V2X is a relative newcomer.

The aforementioned report claims LTE-V2X has superior performance to DSRC/IEEE 802.11p based on tests it performed. This report is referenced by 5GAA in communications directed to the Federal Communications Commission. This is significant because superior performance within the band could bolster efforts to secure bandwidth for LTE-V2X use. To make such a performance claim requires strong evidence and we take issue with the report's conclusion. In our professional opinion the measurement setup, method, and result interpretations are flawed.

To obtain a representative comparison of both technologies, we've taken a closer look at the performed measurements and conditions, and the configurations used in the 5GAA comparison. We then performed tests using the same or comparable settings used in the 5GAA test setup. The generic parameters used in the test are as described in the 5GAA report, see figure 1.

Access Layer Technology	DSRC	LTE-V2X PC5 Mode 4
Packet size	193 Bytes	193 Bytes
Channel	Channel 172 (10 MHz BW)	Channel 172 (5 subchannels)
Hardware	Savari MW1000	Qualcomm Roadrunner
Modulation scheme	QPSK rate 1/2	QPSK rate 0.46 (MCS5)
Antenna configuration	1 Tx, 2 Rx	1 Tx, 2 Rx
HARQ	Not applicable	Enabled
Tx power	21 dBm	21 dBm

Figure 1: Selected parameters from table 3 page 23 from 5GAA report "V2X Functional and Performance Test Report; Test Procedure and Results".

## Initial claim of 5GAA and current hardware

The hardware DSRC configuration used by 5GAA is not representative of state-of-the-art DSRC equipment. We suggest using a current, commercially available system that employs chips dedicated to and optimized for IEEE802.11p, such as those based on the NXP chip set. By using this configuration the mobility features defined in IEEE802.11p, can offer improved performance compared to using chip sets developed for generic WiFi<sup>1</sup>.

5GAA acknowledged that the initial measurements did not correctly exploit the DSRC hardware used in the testing, in particular by not enabling the antenna diversity<sup>2</sup> in an appendix in an additional 5GAA submission to the FCC request for comment. There are additional technical improvements in modern DSRC hardware, not taken into account in the 5GAA test; for this reason, we use our setup as indicated.

<sup>1</sup> Proceedings of the IEEE Vol. 99, No. 7, July 2011, "Cooperative Intelligent Transport Systems: 5.9-GHz Field Trials", Paul Alexander a. o., <http://ieeexplore.ieee.org/document/5771026/>

<sup>2</sup> 5GAA Ex Parte 2.22.19, <https://ecfsapi.fcc.gov/file/102221524815309/5GAA%20Ex%20Parte%202.22.19.pdf>

Compensating for this results in a sensitivity change of +7 dBm compared to the 5GAA report.

#### **Parameter selection: Transmit Power**

The 5GAA publication states that LTE-V2X and DSRC use the same output power (21 dBm). What is not made explicit is that LTE-V2X and DSRC have different ways to allocate resources to the users. In the case of LTE-V2X, multiple users can transmit in the same time slot, using different subchannels in the 10 MHz channel. As the user sends the message over a smaller bandwidth, the total transmission time per user increases. Therefore, at the same output power, the LTE user is effectively sending at higher total energy per message compared to the DSRC user. Note this also results in a higher total transmitted power per time slot, increasing the chance of creating interference to other bands, as multiple users can simultaneously transmit at 21 dBm each<sup>3</sup>.

In the case of the tests performed with the selected parameters, 5 out of 10 subchannels are used for a single user (i.e. 2 users could use the channel at the same time). Half of the bandwidth at the same output power means 2 times the power allocated to the data carriers, and twice the energy per transmission compared to DSRC.

Compensating for this results in a sensitivity change of +3 dBm compared to the original 5GAA publication.

#### **Parameter selection: HARQ**

HARQ is an LTE technique where a message is transmitted twice and receivers can perform a combining of the received messages to reconstruct the information in case of reception errors. This works nicely in a test scenario with only a few cars, as sufficient bandwidth is available in the channel. In realistic traffic situations however, this bandwidth will not be available and the HARQ option is expected to be automatically disabled. For these reasons, in our view the use of HARQ in comparisons are not realistic. To compensate for this, we estimated the gain achieved by using HARQ: in an AWGN channel (so in the presence of Additive White Gaussian Noise), the combination of the original signal with its repetition gives a 3 dB gain; in realistic fading channel situations the undue gain will be even higher<sup>4</sup>.

Compensating for this results in a sensitivity change of at least +3 dBm compared to the original 5GAA publication.

#### **Parameter selection: effective data rate**

The 5GAA paper selects the same modulation and coding rate for DSRC (QPSK 1/2) and LTE-V2X (QPSK 0.46), suggesting this will be a comparable data rate. At first sight this may look reasonable. However, DSRC is more efficient in terms of resource utilization. With QPSK 1/2, DSRC has a nominal rate of 6 Mbps translating to an effective data rate of 4.5 Mbit/s. In comparison, LTE-V2X using QPSK 0.46 has an effective data rate of only 3 Mbit/s (1.5 Mbps per user).

In a technology benchmark the two technologies should be compared at the same effective data rate (allowing for the same number of vehicles). Based on 3GPP Rel-14 specifications, 4.5 Mbit/s are approximately obtained with MCS7 (QPSK 4/5) which has roughly 4 dB worse performance than MCS5 (QPSK 0.46).

Compensating for this results in a sensitivity change of +4 dBm compared to the original 5GAA publication.

<sup>3</sup> Note that within Europe, at maximum allowed output power (23 dBm) due to a too high energy per MHz. "Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 5855 MHz to 5925 MHz frequency band; Harmonized Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU", ETSI European Norm EN 302 571, [https://portal.etsi.org/Portals/0/TBpages/edithelp/Docs/en\\_302571v2.1.1\\_Compared%20with%20previous%20version.pdf](https://portal.etsi.org/Portals/0/TBpages/edithelp/Docs/en_302571v2.1.1_Compared%20with%20previous%20version.pdf)

<sup>4</sup> This is even the case when disregarding HARQ. Note that using HARQ will effectively halve the effective bandwidth compared to the situation in the explanation, as all information is transmitted twice. <https://www.nxp.com/docs/en/white-paper/ROADLINK-TECH-WP.pdf>

## Different results

If we combine these results, we see a clear shift of the DSRC sensitivity curve with respect to the LTE-V2X values, indicating a very comparable performance. If we look specifically at the 10% Packet Error Rate value (i.e. 90% Packet Delivery Rate), we can see DSRC outperforms LTE-V2X.

Thus, our assumption is that DSRC performs better than LTE-V2X under realistically equal conditions:

- Realistic sensitivity of DSRC products
- Same transmission power
- Realistic assumption on the effectiveness of the repetition scheme, and
- Same effective data rate

In fact, based on a realistic use-case comparison, we deduce that DSRC performs slightly better than LTE-V2X.

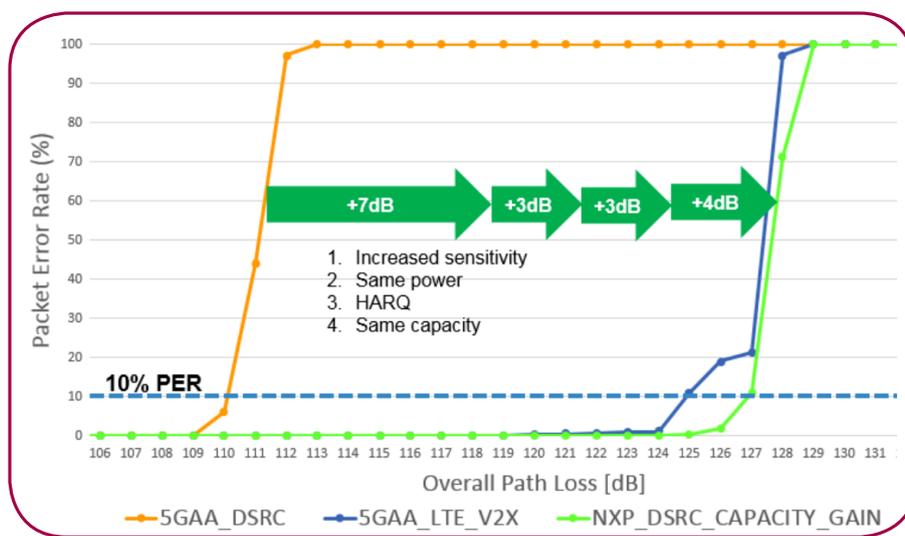


Figure 2: PER versus overall path loss

## Field test confirmation

### Test conditions

To establish real-life outcomes and not simply undertake a theoretical comparison, we performed a field measurement using a current commercially available system from Cohda Wireless. In this test, we kept the rest of the setup as close to the 5GAA setup and settings as possible, while taking into account the issues described in the first chapter. As we unfortunately did not have access to a LTE-V2X system, this field test will not allow an exact 1:1 comparison as the environment is different, but is a qualitative test indicating the achieved performance using DSRC.

To compensate for what we believe are inappropriate parameter selections for transmission power, data rate etc. of the 5GAA setup, we do employ the same output power of 23 dBm however without the 5GAA-applied 10 dB attenuation. This compensates for the effects as explained in the previous section (as we use our own hardware, we do not have to compensate the 7 dB for receiver sensitivity).



Figure 3: Line-of-sight setup

### Test site and equipment

In order to have a test site with a sufficiently undisturbed line-of-sight road, we performed the measurements with help of our site in Singapore. This allowed us to use a stretch of road with >2 km undisturbed line of sight (Lim Chu Kang Road, see figure 3).

### Line of Sight results

From the measurements performed, the Line-of-Sight (LOS) results are in line with our previous experience, having a range of up to 1.4 km before any drop of Packet Delivery Rate below 90% (PER of 10%). This is significantly more than reported in the 5GAA report, and even beyond the reported value of LTE-V2X within the report. Beyond the 1.4 km reception varies, due to well-known multi-path reflection effects.

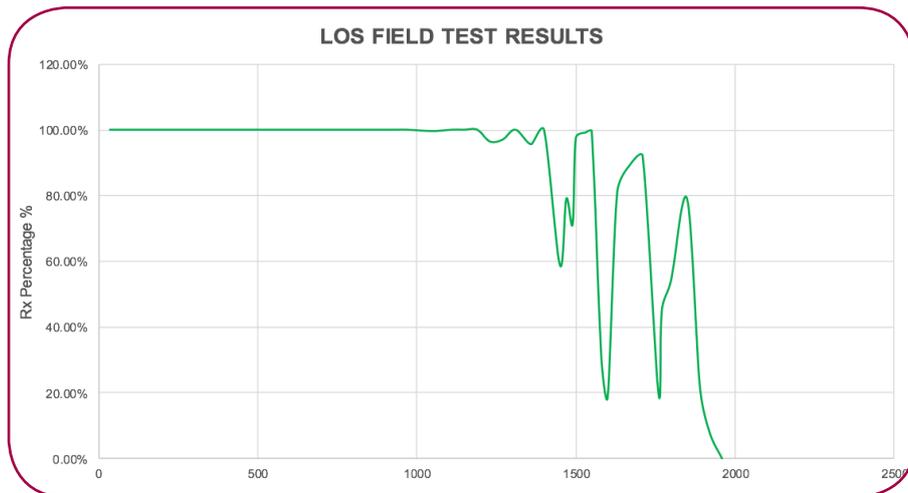


Figure 4: Line-of-sight result

**Non-Line of Sight Results**

For the non-LOS measurements, we used a passenger bus as obstruction, as shown in figure 5. Being bigger than the cars, it effectively blocks the antennas from seeing each other.

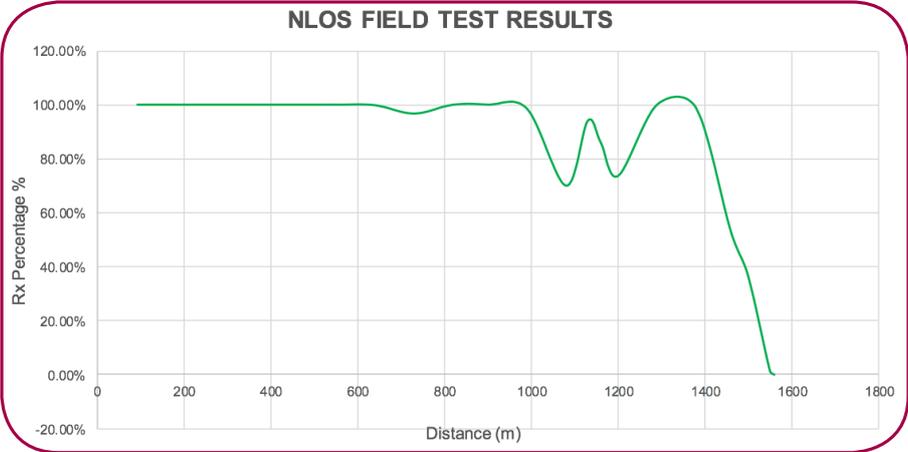


Figure 6: Non-line-of-sight result

Results are in line with our previous experience, up to 1 Km before any drop of Packet Delivery Ratio below 90%. Again, this is significantly more than reported in the 5GAA report, and beyond the reported value of LTE-V2X within the report.



Figure 5: Non-line-of-sight setup

## **Conclusions**

As shown in this document, we have demonstrated that DSRC is 2dB better in range compared to C-V2X, as opposed to what is claimed in the 5GAA report.

In the additional field measurements done, the sensitivity of DSRC is confirmed. This does not provide yet a measured comparison between DSRC and LTE-V2X, for which we are looking to cooperate with LTE-V2X players to actually do this real-life comparison.

NXP's conclusion is that under the same circumstances, DSRC achieves better range performance over long distances. This enables drivers more time to respond to events happening on the road and thus improves road safety even further.

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