C-ITS: Three observations on LTE-V2X and ETSI ITS-G5—A comparison

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Abstract

In this document, we detail three observations on LTE-V2X, a proposed vehicle-to-vehicle communication technology positioned to compete with the ETSI ITS-G5 / IEEE802.11p communication standard.

1. ***Readiness:*** *it is stated by a group of stakeholders that the first LTE-V2X release is 'ready'. However, all that has happened is that a first version of the 3GPP LTE standard incorporating LTE-V2X was published by 3GPP in 2017 (LTE Release 14, in short Rel-14). Since the first chipset will only be available at the end of 2018, widescale field-testing can only start from 2019. Already, several flaws have been detected in the Rel-14 specification, which will be addressed in the upcoming Rel-15.*
2. ***Compatibility:*** *the LTE-V2X stakeholders suggest that LTE-V2X has a roadmap for future development. However, future releases beyond Rel-14 (starting with Rel-15) will not be backwards compatible to Rel-14 hardware and applications. Therefore, basic safety messages will either only be broadcasted via Rel-14, thus disabling the potential advantages of further technology development, or vehicles equipped with Rel-14 cellular-based V2X technology will not be able to talk to vehicles with Rel-15 or subsequent releases. Either way, Rel-14 will be obsolete before it is even deployed.*
3. ***Range:*** *in some publications on LTE-V2X, it is stated that the range of LTE-V2X is superior to ETSI ITS-G5 / IEEE802.11p. Range of the current ITS-G5 implementation has been measured in real-life deployments and the results clearly show that ITS-G5 outperforms the claimed range of the simulated LTE-V2X solutions*

In conclusion, it can be stated that the current LTE-V2X is a significant step back in performance compared to ETSI ITS-G5, and maturity and testing levels of LTE-V2X are still very low. The standard has known problems and the claimed range advantage does not materialize. The currently available flawed version will create the reference for all future deployments; no progress will be possible for future LTE-V2X safety critical ITS applications.

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Introduction

Cooperative intelligent transport systems (C-ITS) will allow road users and traffic managers to share information and help to significantly reduce road fatalities. This will be enabled by digital connectivity between vehicles and between vehicles and transport infrastructure, referred to as V2X (vehicle-to-vehicle and vehicle-to-infrastructure) communication. Supporting safety critical applications is at the core of V2X communication. The ITS Directive 2010/40/EU is the basic EU legislation for a coherent and interoperable introduction of ITS. The Directive defines that every vehicle should be able to communicate with any other vehicle or roadside equipment. Interoperability, backwards compatibility and maturity are identified as core principles. WiFi-based V2X technology, ETSI ITS-G5 / IEEE802.11p, has been tested for more than 10 years and is ready for deployment. Recently, a new standard addressing V2X applications has started evolving under the umbrella of 3GPP, focusing on mobile broadband standardization. Because the safety of millions of road users will depend on the performance of these technologies, it is important to compare them when it comes to readiness, compatibility and range.

Readiness

ETSI ITS-G5 (based on IEEE 802.11p) is an extension of the general WiFi standard, which has been modified and optimized for operation in a dynamic automotive environment. ETSI ITS-G5 was defined in 2004, and has undergone a thorough standardization process. This included extensive field testing (starting in 2008 with the German sim[1] field tests with 400 vehicles) and multi-vendor interoperability testing (ETSI plug tests since 2011). Automotive-grade implementations have been available for a number of years to allow OEMs and Tier-1 suppliers to perform extensive tests and validation, which is absolutely key for a safety-related product.

In contrast, LTE-V2X is a relative new extension of cellular 4G/LTE. The work on Rel-14 specification was started by 3GPP just three years ago, under time pressure in order to catch up with the 11p momentum created by the EU C-ROADS and US NPRM activities. As a result, certain key features are not mature, and will only be partially corrected in the upcoming Rel-15 specification (planned to be completed by Q3 2018). Listed below is a selection of the currently known flaws which need to be fixed in Rel-15:

- Channel-interleaver / rate-matching pattern problem due to a reuse of other LTE Uplink and Sidelink schemes, as explained in several 3GPP RAN1 contributions[2], impacting severely the performance of Sidelink data channel (PSSCH) in 28.3%[3] of the RB / modulation coding scheme combinations. Solution incompatible with Rel-15.
- Redesign of the transport block sizes table in Rel-15, with TBS scaling, due to Sidelink having at most 9 data symbols, compared to 12 in LTE Uplink. Solved in an incompatible way in Rel-15.
- LTE-V2X Rel-14 Mode-4 suffers from too long latency, partially due to the latency selection window of 20-100ms in the PHY. Some discussions are ongoing at 3GPP to reduce this window in Rel-15, which will be incompatible with Rel-14.
- Half-duplex problem: due to the multiple-users access scheme, users will miss the safety messages that were transmitted concurrently to theirs. This does not occur in ETSI ITS-G5, which is based on a "listen-before-talk" principle. In Rel-14, this effect is potentially mitigated by retransmission of the signal (HARQ), at the expense of halving the maximum number of cars. This problem is not yet solved in Rel-15, but only 5G NR.
- The small subcarrier-spacing of 15 kHz, carried on from the cellular bands (typically in the 2 or 3 GHz region), is not suited to the 5.9 GHz band. This results in LTE-V2X being very sensitive to frequency offsets. In 5G NR, 3GPP is planning to "unlock" the subcarrier-spacing, making it configurable per deployment.

[1]Sichere Intelligente Mobilität Testfield Deutschland, www.simtd.de

[2]3GPP contributions: NXP R1-1717046 and R1-1717096, Huawei R1-1717003

[3]3GPP contribution Huawei R1-1717003

There is also a lack of actual field testing. Most of the presented LTE-V2X data is based on numerical simulations, which means that at best, the specification is immature (e.g. reducing efficiency), or worse potentially not fulfilling the targeted safety applications required to reduce road fatalities. Additionally, the evolution of the LTE-V2X technology (Rel-14, Rel-15, …) will de-facto introduce different performance classes, meaning that LTE Rel-15 cars will be safer than Rel-14 cars. This will lead to an unfair situation amongst customers / citizens.

It should also be noted that even if LTE-V2X Rel-14 specs are completed, defining the deployment profiles (which are region/country-specific), still needs to take place, and could take years considering the complexity of fine-tuning the upper layer parameters (number of subchannels, HARQ, allocation scheme policies…), each of which addresses very specific and narrow types of deployments (highways vs crowded areas etc…). ETSI ITS-G5 does not have this problem as it is naturally designed to cope with a variety of scenarios.

Compatibility

As ETSI ITS-G5 has already been field-tested in many trials, and matured considerably over many years, no major revisions are required nor foreseen formally. Informal discussions are ongoing to see whether extensions or higher data rates are needed for additional services.

LTE-V2X Rel-15 will not be backwards compatible with all the services introduced in Rel-14. Likewise, 5G NR technology will not be backwards compatible with the LTE-V2X Rel-15 nor Rel-14. One reason for this is a structural change in several parameters to correct the flaws as indicated in the previous section. Other reasons include the improvements integrated in Rel-15 which are not backwards compatible with Rel-14, such as the non-transparent transmit diversity scheme (STBC or SFBC), and 64-QAM modulation. As a result, a Rel-14 device will not be able to decode Rel-15 transmissions (PSSCH), they will only be able to see the scheduling assignment (PSCCH), which is not modified.

This means an LTE-V2X implementation will always have to carry and use legacy versions of the standard, as long as it relies on services from previous releases. Unfortunately, this is especially the case for the basic safety messages, which will be amongst the first services to be rolled out using Rel-14. Due to the broadcast nature of safety messages, there is no way to know if legacy devices are in the surrounding neighborhood. Instead, you will always have to fall back to Rel-14 version (with its flaws and inefficiencies). Only newer services may make use of Rel-15 and the implied performance improvement.

Range comparison

ETSI ITS-G5 makes use of technologies selected for high mobility. For example, even though the use of 'old-fashioned' convolutional encoders seems a disadvantage, it offers the possibility to use a 'turbo-codec'-like scheme to dynamically adapt the channel estimation per symbol, to follow the changing channel characteristics typical of mobile environments[4]. Such a scheme, which is not implemented in normal WiFi systems, has already been described and implemented[5] in 2011. The more recent block-based codecs (like LDPC) which are used in LTE-V2X, cannot provide the same robust performance at high speed since they cannot be decoded per symbol, but per block.

[4] "Properties of the vehicle-to-vehicle DSRC channel, and equalization strategies to optimize the performance of 802.11p", Joey Fernandez a.o., Carnegie Mellon Vehicular Information Technology, 2011

[5] "Cooperative Intelligent Transport Systems: 5.9-GHz Field Trials", Proceedings of the IEEE Vol 99, July 2011

Combined with the aforementioned robustness of the channel access mechanisms, ETSI ITS-G5 technology is also capable of handling high mobility in combination with long distances. The extended range is also confirmed in field-testing by OEMs. For example, in an interview in Traffic Technology Today it is stated: “In high-speed challenges, V2V-enabled Audi vehicles equipped with the NXP RoadLINK chipset drove towards one another at relative speeds of up to 310mph (500km/h), communicating across distances of more than 1.2 miles (2km).”[6]

This simulated range performance shown in Figure 1 (red-dotted line), is based on real measured performance of the NXP DSRC chipset, and gives a best-in-class figure of >500m (90% PRR) compared with 240m for LTE-V2X.

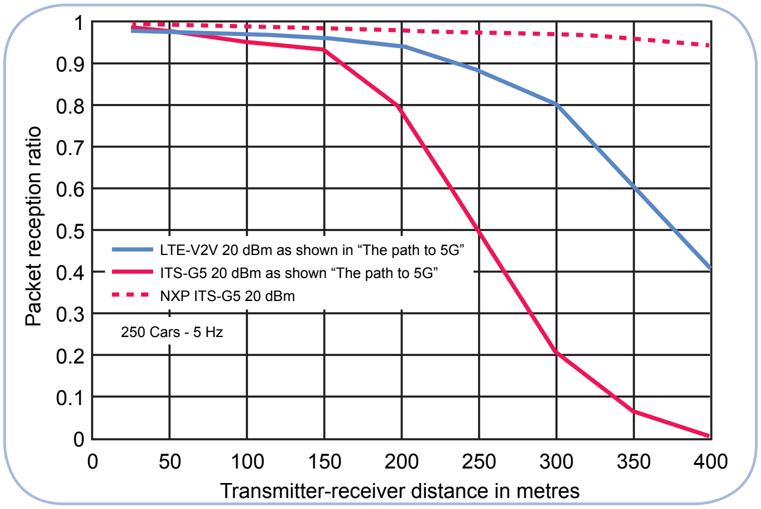

Figure 1. Comparison between the simulation results shown in “The path to 5G”[7] and our own simulation results based on real measured[5, 12] performance of the NXP DSRC chipset[8]. State-of-the-art ITS-G5 performance is much better than LTE-V2X. Scenario: highway (6 lanes, 3 lanes in each direction of 2 km, cars after reaching end, loop around in opposite direction, mobility simulated by a realistic traffic simulator) with a traffic load of 4 packets with 190 bytes followed by 1 packet with 300 bytes, 6 Mbps data rate. Transmit power is set at 20 dBm, with 3 dBi gain used for transmission and reception, receiver sensitivity of -95 dBm. Channel setting: Dual slope path loss, Nakagami-m model.

Additional open questions on LTE-V2X

The lack of a clearly defined communication profile for LTE-V2X (given the myriad of configuration possibilities of LTE), unrealistic timing requirements[9], unclarities regarding the number of supported vehicles[10] as well as latency limitations[11] are additional open questions which haven’t been solved yet. These points underline the different maturity levels of LTE-V2X compared to ETSI ITS-G5.

[6]“New chipset achieves top performance in Audi V2V field trials”, traffic technology Today January 7, 2015, http://www.traffictechnologytoday.com/news.php?NewsID=65107

[7]“The path to 5G”, https://www.qualcomm.com/documents/path-5g-cellular-vehicle-everything-c-v2x

[8]“V2X Application-Reliability Analysis of Data-Rate and Message-Rate Congestion Control Algorithms” C.B. Math, H. Li, S. Heemstra de Groot, and I.G. Niemegeers, in IEEE Communications Letters, Jun 2017

[9]“IEEE802.11p Ahead of LTE-V2V for Safety Applications”, Filippi a.o., http://www.electronics-know-how.com/article/2542/car-to-car-communication-ieee80211p-ahead-of-lte-v2v-for-safety-critical-applications

[10]“How many vehicles in the LTE-V2V awareness range with half or full duplex radios?”, Bazzi, Masini and Zanella, IEEE 2017 15th International Conference on ITS Telecommunications (ITST)

[11]“Performance Comparison Between IEEE 802.11p and LTE-V2V In-coverage and Out-of-coverage for Cooperative Awareness”, Cecchini a.o., 2017 IEEE Vehicular Networking Conference

[12]“Cohda Wireless White Paper DSRC Field Trials”, http://www.cohdawireless.com/m/periodical-files/2017/0819191007024191.pdf

Conclusions

As outlined in the sections above, it can be concluded that LTE-V2X is a step back in V2X communication performance. LTE-V2X (based on Rel-14) is not ready yet and does not bring the big gains and improvements as suggested by the LTE-V2X stakeholders. The comparison clearly indicates the immaturity in the LTE-V2X proposal, the untested and unproven state of the technology, and the lack of real backwards compatibility in future LTE-V2X releases, especially relevant for safety-critical use.

The ITS Directive 2010/40/EU defines backwards compatibility, interoperability and maturity as key principles for specification and deployment of ITS, as well as the issuing of mandates for standards. This is clearly not the case in LTE-V2X, neither for the cellular industry in general.

In our view, the best way forward to decrease road fatalities and increase road safety is a hybrid communication approach in which both technologies work together:

- ETSI ITS-G5 delivering safety messages in the 5.9 GHz spectrum allocated to V2X applications
- LTE-V2X providing I2V information for more infrastructure related services like traffic management information in the 3.2-3.8 GHz spectrum allocated to cellular.

This view is shared by most of the automotive industry and road infrastructure industry as shown for example in the recent "Coalition for Safety Sooner" letter by US state DOTs and industry partners to the US-DOT & FCC[12].

[12] "Coalition for Safety Sooner", https://news.transportation.org/Documents/spectrum%20letter.pdf

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