Vehicle-to-Everything Communications (V2X) in 5G

Hugo Rummlinger, Frederik Schulz, Theo DDDDDDD, Anthony DDDDDDD
Universitat Politecnica de Cataluna
Master of Science
5G Mobile Communication Systems

Abstract

In the abstract, you write 2-3 paragraphs which summarize the key parts of your report.

I. Papers Used & How To Cite Them

- V2X access technologies: Regulation, research, and remaining challenges [Cite: machardy2018] [1]
- Dedicated short-range communications (DSRC) standards in the United States [Cite: kenney2011] [2]
- Standards for vehicular communication—from IEEE 802.11p to 5G [Cite: festag2015][3]
- Ready to roll: Why 802.11 p beats LTE and 5G for V2x [Cite: filippi2016] [4]
- Heterogeneous Vehicular Networking: A Survey on Architecture, Challenges, and Solutions [Cite: zheng2015] [5]
- LTE-advanced in 3GPP Rel -13/14: an evolution toward 5G [Cite: lee2016] [6]
- LTE for vehicular networking: a survey [Cite: araniti2013] [7]
- Use cases, requirements, and design considerations for 5G V2X [Cite: boban2017] [8]
- Design aspects for 5G V2X physical layer [Cite: boban2016] [9]
- Non-Orthogonal Multiple Access for High-Reliable and Low-Latency V2X Communications in 5G Systems [Cite: di2017] [10]

II. Introduction

- Cooperative intelligent transportation systems (C-ITS) gained a lot of interest from different groups. V2X, short for Vehicle to Everything communication, is a specific case of ITS, dealing with wireless communication and coordination between vehicles and their environment. - V2X can be taken in this paper to refer specifically to communication between overland road vehicles and other con- cerned entities, be they pedestrians, infrastructure, or other vehicles. [1] - Communication in V2X cases happens in a frequently changing vehicular ad-hoc networks (VANET)s, where nodes of the network leave and join the network at a specific location as frequently as the traffic floads. This VANET is supported by a static network. Nodes of this network a typically referred to as road side units (RSU), helping to coordinate non-static nodes communication traffic, distributing data and providing additional services [1]. - V2X technology tries to increase safety, efficiency and reduce economic costs of the current and future transportation system. [1]

III. Use-Cases

A. *Vehicle-to-Vehicle*

B. *Vehicle-to-Infrastructure/Network*

C. *Vehicle-to-Person*

IV. Services

- Services can be grouped into 4 major categories: Infotainment, Traffic Efficency, Cooperative Driving [1]

- Infotainment: - usually non-driving related topics. - geo-realated advertisment - messaging - general media transfer, like internet services, netflix, etc. - Infotainment services are characterized by relatively low min- imum latency requirements (latency on the order of 500 - 1000 ms, minimum transmission frequency on the order of 1 Hz) and throughput comparable to conventional mobile broadband services, up to around 80 Mbp [1]

- Traffic Efficency: - Broad application, generally tries to optimize traffic flow [1] - intersection timing handling - real time route planning and changing, dependent on current/live situtation - needs to exchange all information about current speed, current possition, as also destiny of a car - usually not safety critical [1] - medium latency and throughput [1]

-Traffic Safety: - goal is to reduce frequency, severity of collision in our current transportation system, with regards vehicles involved. - need for critical decision making, coping with non-standard behaviour of traffic participants, increase safety of especially, cyclist, pedestrians - clearing roads for emergency cars - Including not only crash prevention, but also knowing when an inavoidable crash will happen (pre-crash sensing) and taking all needed steps to reduce the impact of that event [1] - pre-crash sensing has highest requirements in this category: minimum round-trip latency of 50ms with 10Hz broadcast frequency [1]. - requirements for troughput will increase in the future, up to 700 mbps between vanet nodes estimated [1] - leads to a need for a high throughput, ultra reliable robust network.

V. V2X in LTE Networks

- maybe use [7]

A. Network

Access Technologie from LTE point of vi

B. Requirements

Ffrom LTE point of view

C. Services

VI. Evolution from LTE to 5G

- maybe use [6] - maybe use [8] - maybe use [9] - maybe use [10]

A. Network

Something about new infrstucture

B. Requirements

C. Services

VII. Other Access Technologies

The following section deals with access technologies for V2X communication besides or in cooperation with cellular networks. We will only refer to the access technologies itself, if at all mentioning the eventually necessary infrastructure only briefly.

A. Dedicated Short Range Communication

Most scientific papers refer to dedicated short range communication (DSRC) as systems using IEEE 802.11p and IEEE 1609 (WAVE) standards together for communication[1]. Hereby the 802.11p standard allows for a setup of vehicular ad-hoc networks (VANET's) taking care of the physical (PHY) layer and the medium access (MAC) layer while the WAVE standard defines networking and some application related parts like security and authentication. As an amendment to the Wi-Fi specification 802.11 defined by the IEEE organisation, 802.11p allows for inter device communication and is especially developed with V2X communication in mind. It facilitates the communication without the usual need for an basic service set (BSS, e.g. access point or something similar), allowing for D2D communication without a central coordinator [1]. The standard itself does not define a specific operational frequencies, rather it defines the procedure of communication, leaving the choice of the used frequency to the authorities. As requirements for in V2X communication differ highly from typical Wi-Fi communication, 802.11p introduces a new medium access method called tiered contention multiple access (TMAC). This MAC technique allows for a prioritization of messages which is not possible with the typically used CSMA/CA technique [1]. Especially for safety critical messages, relate to traffic safety like pre-crash sensing a prioritization of data flows is essential. As with most wireless communications synchronization is needed for communication in DSRC [2]. With the lack of an central coordination entity routing of multi-hop is a hard task in VANET's when mobility of nodes is high. Due to the fastly changing topology of the network, routes can be already obsoleted when found i[1]. To which degree this affects communication depends heavily on the used routing protocol. Another aspect in V2X communication is safety, as it is critical to have reliable communication partners. Users acting maliciously can spam the network or trying to insert wrong data into the network. DSRC uses a private key infrastructure for this aspect. Hereby a central authority distributes autonomous and temporal certificates to vehicles. Those are then used to sign messages. As malicious users can not be detected upfront there exist an entity, misbehaviour authority, which is entrusted with detecting malicious vehicles and adding them to a blacklist. For this system to work, vehicles need to regularly update their own list of blacklisted certificates. As this list can be relatively large, this system imposes requirements in terms of throughput and latency [1].

Summarizing it can be said, that DSRC allows for an low-end-to-end latency, a flexible organisation of nodes and relatively low cost for deployment in the V2X use-case. But it also entails a number of issues, including throughput problems in congestion situations, security issues and difficulties to handle non-line-of-sight communication [1]. The U.S. Department of Transportation (USDOT) already specified DSRC for deployment. In the following this specification is used exemplary.

Standardization U.S. Department of Transportation: As an exemplary standardization the following proposal of the USDOT for V2X communication is taken. As the standardization entity is the U.S. Government, the choice are not compulsory, but rather shell show how a specification for DSRC can look like. The USDOT choose to 10 MHz channel, as a result of taken measurements. Those indicated that 10 MHz channel width is well suited to deal with delay problems and Doppler spreads [2]. These have to be taken into account due to the different mobility properties of cars, compared to pedestrians. Though safety critical messages can be faster transmitted, with respect to delay not bandwith, in broader channels (e.g. 20 MHz), those typically have more noise in vehicular environment [2]. Similar to celleular networks DSRC uses orthogonal frequency-division multiple access (OFDMA) as its multiple access transmission technique. Hereby the proposition by the USDOT proposes multiple modulation rates I.

TABLE I
MODULATION OPTIONS IN DSRC 10 MHZ OFDMA CHANNELS. [2]

Modulation Technique	Coded Bit Rate (Mbpcs)	Coding Rate	Data Rate (Mbps)	Data Bits per OFDMA Symbol
BPSK	6	1/2	3	24
BPSK	6	3/4	4.5	36
QPSK	12	1/2	6	48
QPSK	12	3/4	9	72
16-QAM	24	1/2	12	96
16-QAM	24	3/4	18	144
64-QAM	36	2/3	24	192
64-QAM	36	3/4	27	216

The coding used is forward error correction (FEC), which is less effective than turbo codes and therefore lowers the bit rate but has the positive property of increasing the probability of successful decoding of messages [2]. As 802.11p does not define the frequency spectrum the USDOT allocated seven 10 MHz channels in the 5.9 GHz spectrum for V2X communication purposes. One aspect the DSRC technology also changes with respect to normal Wi-Fi systems is the medium access technology. As stated above the typically used CSMA/CA technique does not allow for a prioritization of messages, making it incompatible for V2X communication, as emergency situation impose a need for fast unscheduled transmissions. Therefore TMAC is used instead. This protocol misses the beaconing, synchronization, authentication and association functions of typical MAC and leaves this functionalities open for higher layers [2], making the MAC protocol simpler. Some kind of synchronization is still needed. TMAC uses Timing Advertisment (TA) frames which allow to propagate information about the time source of the sender. To allow a prioritization of messages, TMAC allows for "more" important messages to access the medium with a lower backoff interval, which implicitly leads to faster access and earlier transmissions. A further change compared to most protocol stacks is the new layer 3 protocol. While it is still possible to use the most commonly used protocols at this layer, e.g. TCP/IP (see 1), the USDOT mostly wants to WAVE short message protocol (WSMP) for network and transportation. The reason to change from TCP/IP is the overhead associated with it. Even a small change of header size can have an impact on performance in vehicular communication environments [2] and more importantly as DSRC is vulnerable to throughput degradation in case of channel congestion, smaller packets are a way to cope with this problem[1], [2]. As the description of DSRC here is only very briefly and shall serve for an easier comparison between C-V2X and DSRC, the authors refer to [2] for a detailed view of a DSRC specification which includes authentication and encryption properties of messages by WAVE.

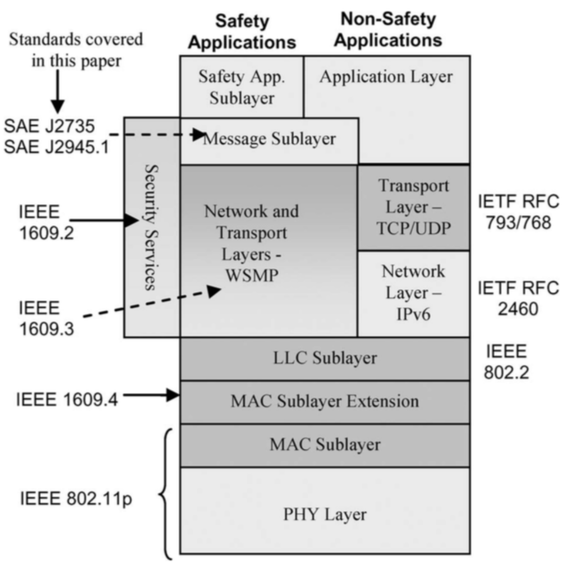

Fig. 1. Architecture of Layer Structure in DSRC (by USGOT). [2]

B. Visible Light Communication

C. Bluetooth

VIII. Results and Discussion

A. Cellular V2X versus DSRC

- DSRC: need for a dense deployment to cope with line of sight problems, service degradation in congestion scenarios to name a few [1] - Who will pay for theses as IEEE 802.11p networks are typically not used outside, therefore networks typically do not have access control as cellular networks [1] New use case for IEEE 802.11 protocol - DSRC mandated standard by U.S. Department of Transportation (USDOT), European Telecommunications Standards Institute (ETSI), the European Committee for Standardization (CEN) [14], and the Association of Radio Industries and Businesses (ARIB) [1] - Cellular V2X (C-V2X) Compared to DSRC, these technologies offer a number of advantages, including a much larger coverage area, pre-existing infras- tructure, deterministic security and QoS guarantees, as well more robust scalability [1] - C-V2X has on negative side: Centralized architecture, higher price for network, higher end-to-end-latency!, dependency on network connectivity [1] - Latency is a major obstacle for C-V2X deployment. Services with high need for time sensitivity, e.g. cooperative platooning or pre-crash sensing need low latency [1] - Relate here somehow to Ultra Reliable Low Latency stuff from lecture. - How is price determined in DSRC? - Dependency of network connectivity should be able to be done by D2D sidelink without eNB or gNB beeing available. Source here. - Would D2D sidelink also solve latency issues? - evelopment of a Channel Congestion Control algorithm, especially for the safety channe [2]

TABLE II
Summary of Challenges for C-V2X and 802.11p-based DSRC. [1]

KPI	802.11p-based DSRC	Cellular V2X
Latency	Not a cause for concern for 802.11p-based DSRC under normal operating conditions. An elevated packer error rate and the consequent need to retransmit messages can cause increased latency under sub-optimal conditions	When operating through infrastructural nodes (e.g. eNB,EPC), processing delay is potentially problematic. Sidelink D2D and the provision of local edge resources are potential solutions to the problem of high latency
Capacity	Vehicular traffic congestion (several hundred vehicles within a 300m radius) can quickly cause high channel congestion and severely impact packer error rate. A potential path toward solving congestion issues may lie in improved congestion control schemes and controlling rate of transmissions. Optimal data-rates in the ballpark of 6 to potentially 27 Mbps are troublingly low, and may be insufficient to support many forthcoming V2X applications	Depending on the size of the cell, frequent unicast transmissions via eNB from hundreds of vehicles can cause significant congestion. Using eMBMS or sidelink D2D may solve this problem. 5G aims to support data-rates measured in Gbps, which should be sufficient for all considered V2X applications
Coverage	LOS and relatively short communication range have implications for effective coverage for 802.11p-based DSRC. Communication through intermediate infrastructural nodes (e.g. RSUs) is one potential solution to the LOS communication problem.	Coverage, particularly in mountainous and rural areas, can be inconsistent. Sidelink D2D is one potential solution to providing ubiquitous V2V coverage.
Security	Due to its ad-hoc nature, DSRC is vulnerable to a number of potential attacks on availability, authenticity, confidentiality and integrity. Some of these problems may be ameliorated by the implementation of vehicular private key infrastructure and decentralized misbehaviour detection, but many theoretical attacks, like vehicular worms and wormhole attacks, remain hard to defend against.	Cellular V2X, the outgrowth of a centralized and long-commercialized communications technology, is somewhat less vulnerable to many security problems. Some attacks, particularly attacks on availability like jamming, remain difficult to defend against.
Privacy	The use of temporary pseudonymous certificates for authentication V2V communication provide a measure of privacy for DSRC nodes. Sophisticated eavesdropping and data interception may still pose a risk to driver privacy.	The association of cellular communications with subscriber ID represents a potential compromise of UE privacy, particularly regarding authorities and network operators.
Infrastr. & Cost	The lack of existing DSRC infrastructure and requirement for an extra DSRC-capable module in each vehicle stand to incur significant costs, both for municipal authorities and end users.	The existing cellular infrastructure eases potential costs on municipal authorities, but high mobile data rates and cellular radios in each vehicle mean potentially high costs for end users.

B. Bluetooth and VLC

- several other technologies, including Bluetooth, satellite radio, and visible light communications have been considered for use for V2X applications. While each of these technologies has features which make it potentially promis- ing, each also has some unavoidable limitations, as covered in Section III-D, [1]

C. Heterogeneous Network

- maybe something about our opinion if this solution is viable. - good source [5] - Choice of wireless technology need not be an either-or proposition; many analyses have shown that a het- erogeneous solution can outperform either technology alone [1]

D. Standardization

- While much of the technology involved in V2X communi- cation has been well-coordinated internationally, a number of regional differences have arisen. One of the most pointed difference between the U.S. and EU V2X standards are the mes- sage sets defined for communication between vehicles [1] - could be a problem for traveling, common standard would be necessary to enable easier production and easier traveling. - For detailed message evaluation see [1].

IX. Conclusion

The conclusion goes here.

References

[1] Z. MacHardy, A. Khan, K. Obana, and S. Iwashina, "V2x access technologies: Regulation, research, and remaining challenges," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 1858–1877, 2018.

[2] J. B. Kenney, "Dedicated short-range communications (dsrc) standards in the united states," *Proceedings of the IEEE*, vol. 99, no. 7, pp. 1162–1182, 2011.

[3] A. Festag, "Standards for vehicular communication—from ieee 802.11p to 5g," *e & i Elektrotechnik und Informationstechnik*, vol. 132, no. 7, pp. 409–416, Nov 2015. [Online]. Available: https://doi.org/10.1007/s00502-015-0343-0

[4] A. Filippi, K. Moerman, G. Daalderop, P. D. Alexander, F. Schober, and W. Pfliegl, "Ready to roll: Why 802.11 p beats lte and 5g for v2x," *white paper by NXP Semiconductors, Cohda Wireless, and Siemens, 2016*, 2016.

[5] K. Zheng, Q. Zheng, P. Chatzimisios, W. Xiang, and Y. Zhou, "Heterogeneous vehicular networking: A survey on architecture, challenges, and solutions," *IEEE Communications Surveys Tutorials*, vol. 17, no. 4, pp. 2377–2396, Fourthquarter 2015.

[6] J. Lee, Y. Kim, Y. Kwak, J. Zhang, A. Papasakellariou, T. Novlan, C. Sun, and Y. Li, "Lte-advanced in 3gpp rel -13/14: an evolution toward 5g," *IEEE Communications Magazine*, vol. 54, no. 3, pp. 36–42, March 2016.

[7] G. Araniti, C. Campolo, M. Condoluci, A. Iera, and A. Molinaro, "Lte for vehicular networking: a survey," *IEEE Communications Magazine*, vol. 51, no. 5, pp. 148–157, May 2013.

[8] M. Boban, A. Kousaridas, K. Manolakis, J. Eichinger, and W. Xu, "Use cases, requirements, and design considerations for 5g v2x," *arXiv preprint arXiv:1712.01754*, 2017.

[9] M. Boban, K. Manolakis, M. Ibrahim, S. Bazzi, and W. Xu, "Design aspects for 5g v2x physical layer," in *2016 IEEE Conference on Standards for Communications and Networking (CSCN)*, Oct 2016, pp. 1–7.

[10] B. Di, L. Song, Y. Li, and G. Y. Li, "Non-orthogonal multiple access for high-reliable and low-latency v2x communications in 5g systems," *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 10, pp. 2383–2397, Oct 2017.