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

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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]
- LTE evolution for vehicle-to-everything services [Cite: seo2016] [11]
- Device-to-device communications; functional prospects for LTE-advanced networks [Cite: doppler2009] [12]

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*

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

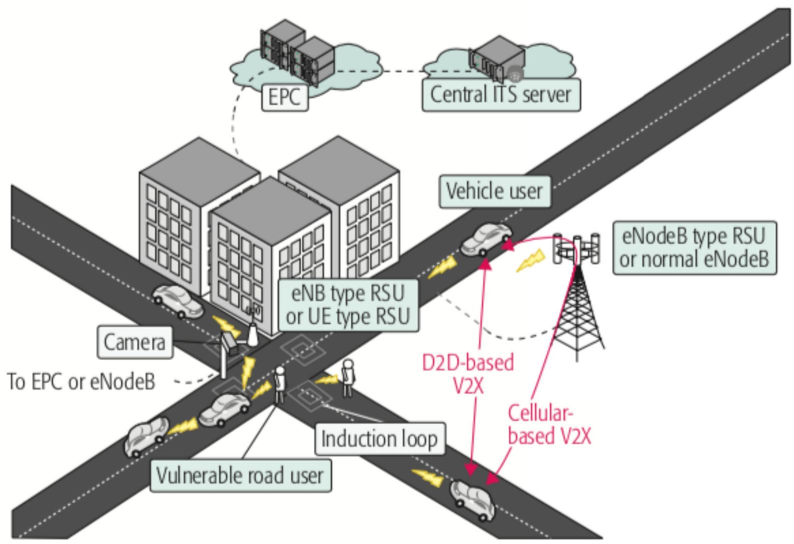

Fig. 1. V2X Deployment Scenario. [11]

TABLE I
V2X SERVICES - APPLICATIONS AND REQUIREMENTS

Service	Applications	Requirements
Infotainment		
Traffic Efficency		
Traffic Safety		
Cooperative Driving		

- 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.

- Safety applications require periodic V2V data exchanges in a vehicle's neighborhood (this is the case of CAMs) [7] - event-triggered V2V and V2I communications (this is the case of DENMs). [7]

Cooperative Driving: Among the applications consid- ered by this paper, some (adaptive cruise control, cooperative platooning, etc.) are sometimes counted as part of traffic safety, above, and sometimes as a distinct fourth category: coopera- tive autonomous driving (see

[60]). Though the case could be made that the requirements for these services are similar enough to traffic safety to merit inclusion in that category, because their requirements are particularly stringent and their applications uniquely suited to autonomous vehicle operation, we choose here to treat them separately. Co-operative platoon- ing (the very tight packing of a group of vehicles travelling in the same direction in a lane, see Figure 2), sometimes also captured under the label of Cooperative Adaptive Cruise Control (CACC), is a cooperative driving application with very strict requirements in terms of communication latency and frequency. Supporting cooperative driving services requires throughput on the order of 5 Mbps and latency as low as 2-10 ms [57], [61].

IV. V2X IN LTE NETWORKS

- maybe use [7]

- there are two opions for V2X communication in LTE networks. Either use direct D2D communicaiton over the pc5 interface or vie the eutran radio interface. Both of the two options allow two ways of communication. D2D ofer pc5 has a mode where the eNB is the controlling instance, making scheduling and where the nodes communicate autonomsly in case of missing eNB connectivity allowing for communication even in RRC-idle mode. The commnication over the Eutran can either take place via MBMS broadcast multicast features or via unicast/boradast using PUSCH and PDSCH channels

- heavy load generated by periodic message transmissions from several vehicles strongly challenges LTE capacity and potentially penalizes the delivery of traditional applications. [7] - Status mode of the device: Latency is also influenced by the status mode of the mobile termi- nal. In order to save resources, cellular networks are configured to keep non-active terminals in idle mode, but the connection setup necessary to switch to connected mode before sending data may take a longer time than the simple transmission delay.1 Vehicles should be in connected mode to send periodic CAMs, whereas the transmission of an event-triggered DENM could require a vehicle to switch from idle to connected mode. [7] - CAM and DENM exchanges in LTE involve transmissions from vehicles to infrastructure nodes, and successive traffic distribution to the concerned vehicles. [7] We can conclude therfore that typically most comminucation whcih is V2V is goging trhough the network.

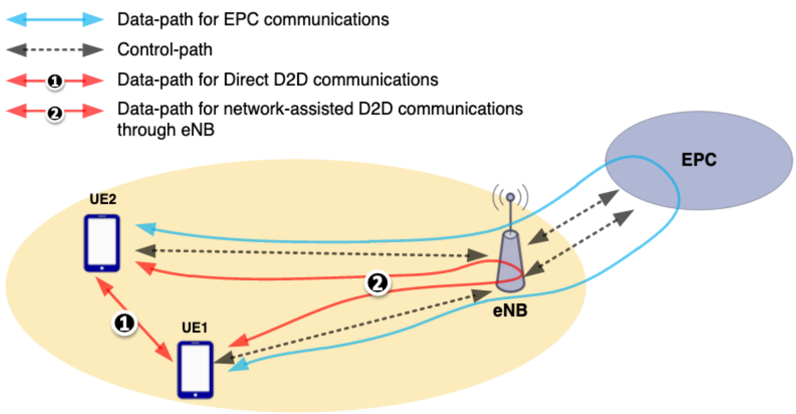

Fig. 2. Possible D2D Connection Scenarios in LTE. [13]

- downlink can be per user, choosing an appropritae lte channel using physcial downlink shared channel (PDSCH) for specific user based information unicast transmission and for broadcast the typical physical braodcast channel (PBCH) - NETWORK: ETSI specifications foresee the presence of a special-purpose back-end server that supports geocasting, by inter- cepting traffic from vehicles and processing it before redis- tributing it only to the concerned vehicle(s) in a given geographical area [7] - This is important as messages need to be delivered to vehicles in close proximity. - There are two possible options how a geo-server can be deployed. 1. in the EPC core network, this allows the server to use data from the MME module or in the internet. For option two it is possible two lower the amount of connections neeeded for UE, as the MME already is aware of the location and needs to track it anyways. When the internet holfs the server each car needs to hold an active connection to the server. - special backend server, which serves as an intelligent coordinator. - In order to identify the concerned vehicles in a given area and act as a reflector [7], the back-end server has to know the list of geographical areas, their coordinates, the cars in any area at all times, and their IP addresses and position - especially for infotainment Multimedia Broadcast Multicast Service (MBMS) and its associated physical channels can be used as it allows for nice resticted broadcast in given geographcal area, while it still has overhad for session setup [6] which restrict or even permits its use for low latency applications. - unicast messages also introduce a high overhead for the network as they have to be transmitted reduntlay thrugh multiple bearer connections, while a MBMS connection will ease the load of hte EPC network. - A main challenge for the network will be to handle high loads of periodic CAM, e.g. periodic status messages boradcasted to vehicles in close proximity, messages especially in dense areas, like cites [6]. - here are mainly two technical challenges in ful- filling the V2X service requirements: high vehi- cle speed and high UE density. It is noteworthy that UE capability may be different for vehicles and pedestrians. [11] - Also, in the D2D- based V2V scenario, the transmitter and receiver may be driven at very high velocity in opposite directions, which reaches a very high relative velocity. With such high carrier frequency and relative velocity, Doppler effects, including fre- quency error and inter-carrier interference, and insufficient channel estimation due to shorter coherence time, become much more serious, and current PHY design may not satisfy all scenarios [11] - differnec of UE in cars and pedestrancs are different. One is battery restraint the other is not. - to cope with high doppler effects V2X changes the symbol configuration of RB, allowing for more RS signals to be embedded to reduce time intervall between reference signals [11]. - as serving cells and eNbs change quite frequently for vehicles driving with high velocity, handover processes take place more often. thus introducing more latency. But as many security feateures require very low latency (see II) under 100 ms, V2X should be resilient to latency ntroduced through handovers. [11] - challenge: traffic characteristics of CEM are different than natural cellular traffic, with peridoic and oftern but small packages [11] - D2D in Lte was primary defined for voice calls with tens user per cell [11] making it not perfectly fit to serve as V2V usage. - LTE-Advanced, if anysystem, offers opportunities for D2D communications due toits time-frequency flexibility in allocations [12] - LTE is especially applicable for V2I/N as its nature is typically point-to-multipoint, eMBMS perfetly suitable for this. USE CASES AUS VORLESUNG HIER [11] - still overhead and need to be in connected mode for eMBMS

-cams are especially problematic, typically the are of broadcast nature resticted by geographical location of vehicles. as the messages will go through network and then be resdistributed to cars. - analyses show that LTE is not able to handle the load in dense areas if it restransmitts all messages [7] - use of MBMS broadcasting in cell could ease load, but still in studies to heavy. They only checked for only CAM traffic without any other traffic [7].

- dams are of different nature. only when hazard happens. Hereby it is important again to solve load on network, when many cars send redundant infomration. The backendserver needs to filter and agregate the redundand messages to one big one to allow neteowrk to handle load. [7] - The central back end server can aggegrate knowledge out of multiple messages received, which is a strengt of the centralized system architecture [7] - As an addi- tional benefit, the wide cellular coverage guaran- tees the event dissemination also when there is no nearby vehicle to relay the message. central architecture pro - interference management in D2D improtant - not natively in LTE, only in LTE-A via pc5 interface regarded

- conclusoion for LTE In this case, the design of efficient schedulers is especially crucial for the uplink channel, which could be a bottleneck in densely populated net- works. On the downlink, instead, the effort is to provide efficient and reliable broadcasting that coexists with the conventional unicast mode. Closely linked to scheduling issues is the mapping of vehicular applications onto LTE QoS classes. - denms should be high - currently no devices specified for lte in v2x. as smartphones are everywhere, first idea, but battery contrained. so deciated devices in cars should be used. [7] -

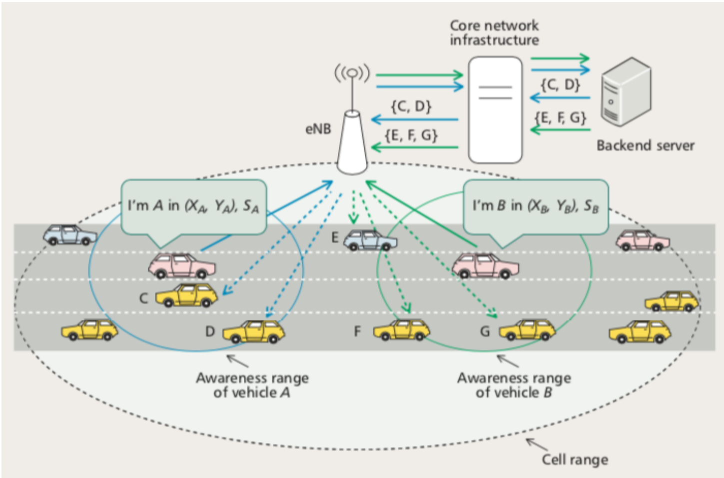

Fig. 3. Multicast CAM Delivery in LTE with Backend Server Coordinating Awareness Range. [7]

TABLE II
V2V MESSAGE TYPES - REQUIREMENTS AND APPLICATIONS. (DEFINED BY ETSI) [7]

Message	Requirements	Applications
Cooperative Awareness Messages - CAM's	Periodic time-triggered Frequency: 1 - 10 Hz Max. latency: 100 ms Length: 800 bytes	Emergency vehicle warning Slow vehicle indication Intersection collision warning Motorcycle approaching indication Collision risk warning Speed limits notification Traffic light optimal speed advisory
Decentralized Environmental Notification Messages - DENM's	Event driven warnings Max. latency: 100 ms Length: Shorter than CAM's	Emergency electronic light warning Wrong way driving warning Stationary vehicle accident Traffic condition warning Signal violation warning Road work warning Collision risk warning

V. EVOLUTION FROM LTE TO 5G

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

VI. 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 fast 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 III.

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

TABLE III
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

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 4), 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.

B. *Visible Light Communication*

C. *Bluetooth*

VII. 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

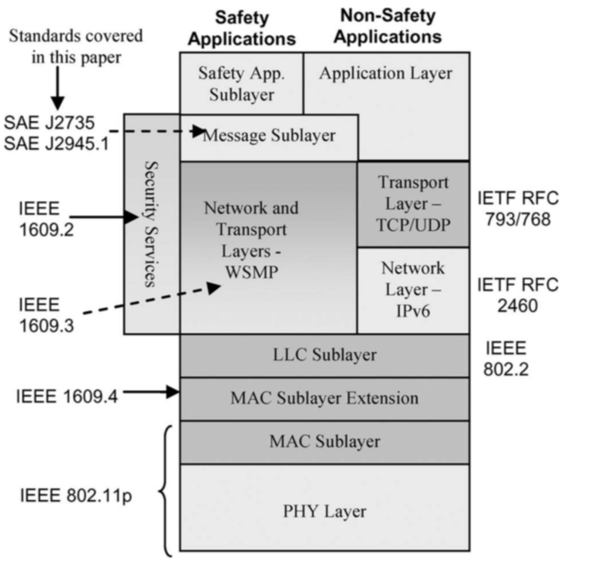

Fig. 4. Architecture of Layer Structure in DSRC (by USGOT). [2]

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] -Nonetheless, this tech- nology suffers from scalability issues, unbounded delays, and lack of deterministic quality of ser- vice (QoS) guarantees [7] - transmission range very limited, therfore need for a lot of Road Side Units (RSU) [7] - Coverage and mobility: LTE will rely on a capillary deployment of eNodeBs organized in a cellular network infrastructure offering wide area coverage [7] - higher market penetration and incentive for telecom companies to build infrastrcutre, etc. because they can get money from services offered [6] - above point might also be a bad one, cause some parts of the network are safety critical and should not be non supervised by the state. - 5G allows for different status mode of devices, where nodes are not disconnected when in idle, this reduces latency a lot and solves the issue that exist with this mode in LTE [7] - Boradcasting in 802.11p is done via one single transmission in VANET, while in LTE network (5G I do not know) this is not possible. options are a) v2v for every car in proximity (latency probably to high, because of need for estabhlishing communication first) or b) via infrastructure, but then also the infrastructure will need to distribute the messages to relevant cars in proximity. [7] - Meanwhile, effective business models should be specified to support the widespread use of LTE for cooperative ITS applications. No one would agree to pay unless highly reliable safety services and attractive traffic applications can be provided. [7] Might also hold for 5G. No expensive hardware and traffic cost for signalign will be accepted if there is no use

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]

TABLE IV
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.

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].

TABLE V
V2X MAIN CANDIDATES FOR ACCESS TECHNOLOGY PROPERTIES. [7]

Feature	802.11-p DSRC	LTE	LTE-A	5G
Channel Width	20 MHz	1.4, 3, 5, 10, 15, 20 MHz	Up to 100 MHz	???
Frequency Band(s)	5.86-5.92 GHz	700-2690 MHz	450 MHz-4.99 GHz	???
Bit Rate	3-27 Mbps	Upt to 300 Mbps	Up to 1 Gbps	???
Range	Up to 1 km	Up to 30 km	Up to 30 km	???
Capacity	Medium	High	Very High	???
Coverage	Intermittent	Ubiquitous	Ubiquitous	???
Mobility Support	Medium	Very high (350 km/h)	Very high (350 km/h)	???
QoS Support	Enhanced Distributed Channel Access (EDCA)	QCI and bearer selection	QCI and bearer selection	???
Broadcast / Multicast	Native Broadcast	Through eMBMS	Through eMBMS	???
V2I Support	Yes	Yes	Yes	???
V2V Support	Native (ad hoc)	No	Potentially, through D2D	???
Market Penetration	Low	Potentially High	Potentially High	???

VIII. CONCLUSION

The conclusion goes here.

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