Cognitive Vehicular Communication for 5G

Shahid Mumtaz, Kazi Mohammed Saidul Huq, Muhammad Ikram Ashraf, Jonathan Rodriguez, Valdemar Monteiro, and Christos Politis

Shahid Mumtaz, Kazi Mohammed Saidul Huq, and Jonathan Rodriguez are with Instituto de Telecomunicações.

Muhammad Ikram Ashraf is with University of Oulu.

Valdemar Monteiro is with Instituto de Telecomunicações and Kingston University.

Christos Politis is with Kingston University.

ABSTRACT

Device-to-device (D2D) is increasingly becoming a prominent technology within the 5G story, portrayed as a means of offloading traffic from the core network. The ever increasing demand for vehicular traffic consumption is providing the impetus for a new architectural design that can harness the benefits of D2D for vehicular users, taking a step toward offloading vehicular traffic from the core network. We propose the notion of extending D2D for vehicular scenarios with the potential to coordinate vehicular traffic using the LTE band. Furthermore, we then extend this approach by investigating cognitive radio in synergy with a geo-location database, to exploit white spaces as a means of further offloading vehicular users. Our simulation results have shown that our approach can outperform the legacy IEEE 802.11p in terms of delay.

INTRODUCTION

Each day the world embraces more devices to connect everything, everywhere, and everyone. This kind of interconnecting concedes a huge volume of data traffic among the connected devices. The newly hyped “fifth generation (5G)” paradigm is anticipated to provide the necessary impetus to carry the burden of achieving massive system capacity, reducing latency, and enormously increasing energy saving for the devices.

In addition to the above mentioned expectations, wireless devices in 5G networks are also expected to be constantly interacting with each other as well as with their environment (e.g. data communications from wireless sensors to devices or vice versa). In addition to human-centric D2D communications, one very important use case for D2D is vehicle-to-vehicle (V2V) communications. Recently [1] it has been shown that the integration of information and communication technologies with transportation infrastructure and vehicles will revolutionize the way we travel. Moreover, vehicles are indeed the third place, after homes and offices, where citizens spend the most time daily. V2V communications have already been of the focus of the wireless communications community for many years. For example, IEEE has already developed the 802.11p standard for V2V communication which is based on dedicated short-range communication (DSRC) technology. DSRC technology is mainly used to support intelligent transportation system (ITS) applications in V2V [2] scenarios, but due to the lack of pervasive infrastructure deployment and sufficient transmission range, the IEEE 802.11p standard is normally considered to offer intermittent and short-lived connectivity between vehicles and roadside infrastructure (V2I) [3]. Using DSRC technology to provide V2V communication in a pure distributed fashion may not always guarantee reliability and efficiency in practical applications.

It is commonly accepted that one solution to this problem relies on Long Term Evolution (LTE) technology. However, LTE does not natively sustain V2V communications [4]. For instance, when vehicle density is high, the beaconing signals of vehicular safety applications may easily overload the serving eNB. To handle this issue, a significant amount of such signals should be distributed directly among vehicles, without going through the eNB. In LTE-Advanced (LTE-A), D2D communication is considered to allow direct message delivery between terminals in proximity to lighten the load of eNB [5]. Hence the infrastructure-aided D2D technologies can serve as a natural approach to enable reliable and efficient V2V communications without negatively affecting conventional cellular systems. Current research considers that D2D would be one of the mainstays for 5G networks. To this end, the Third Generation Partnership Project (3GPP) is already in consensus for studying D2D systems rigorously within the LTE Proximity Services study item. This study item belongs to the timeframes between 3GPP Rel-12 and Rel-13.

In general, LTE based cellular systems have no intra-cell interference due to orthogonal subcarriers, but this orthogonality will disappear when D2D users co-exist with other cellular devices. Therefore, there are two approaches to assign radio resource in D2D-based networks. First approach is to assign orthogonal resources

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between D2D and other cellular devices (static allocation); second approach is to assign concurrent resources between D2D and other cellular devices (dynamic allocation) [5]. Clearly, the second approach permits a more efficient use of the available radio resources, but it also introduces new interference problems [6].

We propose a novel cognitive radio based resource allocation policy when applying D2D techniques in V2V. This allocation policy will control the interference between cellular devices and D2D vehicles. Moreover, the decision about the vehicles' communication mode should account for feasible range under different V2V and eNB distances.

To this end, we propose a novel cognitive radio-based resource allocation policy when applying D2D techniques in V2V. This allocation policy will control the interference between cellular devices and D2D vehicles. Moreover, the decision about the vehicles' communication mode should account for a feasible range under different V2V and eNB distances. By using D2D it is possible to both reduce the latency and to design a solution that works without cellular network coverage. In D2D mode, vehicles in close proximity communicate directly, which eventually decreases the latency and offloads the traffic from eNBs. D2D will be an appealing solution for local data exchange between vehicles. .

The rest of the article is organized as follows. We discuss why we need LTE-A for vehicular communication, and we present the design aspects for V2V. We then discuss the standardization activities of V2V and the state of the art (SoTA). We then present the system model with simulation results, followed by a discussion of future challenges and the conclusion.

IEEE 802.11P VS LTE-A: DEFICIENCY AND REMEDIES

There are several reasons to choose LTE-A for vehicular communication. The major ones are discussed below [3].

Licensed communication: LTE-A communication is based on the licensed band as compared to IEEE 802.11p, so there will be a control for interference on V2V in LTE-A networks that can easily be manageable, either by the operator or the vehicles.

Coverage: LTE-A relies on the deployment of eNBs, which have coverage of approximately 1000 m, which solves the problem of poor, intermittent, and short-lived connectivity in IEEE 802.11p. For instance, in IEEE 802.11p connection performance suffers severely in non-line of sight (NLOS) environments such as metropolitan city areas where big skyscrapers prevent (shadow or scatter) signals frequently, which brings out fading scenarios. On the contrary, the eNBs in LTE-A networks provide much better performance in NLOS environments due to their position in higher stature.

Scalability: LTE-A networks are accessible for a large number of cellular devices, thanks to its scalable bandwidth, as compared to IEEE 802.11p, which is not scalable for high vehicle density scenarios and also lacks a mechanism to quickly disseminate messages over an increased coverage range.

CAPEX/OPEX: LTE-A uses only one eNB for coverage, which saves CAPEX/OPEX as compared to IEEE 802.11p, which needs many road side units (RSUs) for coverage and to communicating with the Internet.

Capacity: LTE-A offers high downlink and uplink data rates (up to 1 Gps and 500 Mpbs), applying advanced antenna techniques, which eventually supports a higher number of vehicles inside a cell compared to IEEE802.11p, which only supports data rates up to 27 Mb/s.

Infotainment streaming: Future modern vehicles will be capable of exchanging infotainment content (i.e. audio/video streaming, email, software updates) between them, and this will be possible by using D2D communication over the LTE-A band.

Delay: One of the major concerns when considering LTE-A for vehicular communication is delay. LTE-A traffic always crosses infrastructure nodes, even though devices are close to each other. Recent advances in D2D communication in LTE-A mode will solve this problem and offload traffic from infrastructure nodes.

Please see Table 1 [7] for a detailed comparison of LTE-A with other technologies.

D2D DESIGN ASPECTS FOR VEHICULAR COMMUNICATION

Most of the D2D design aspects described in [5] directly apply to V2V communication in addition to the following enhancements.

The **communication environment** in V2V is quite different than in D2D due to the high mobility of the vehicles. Thus, network connectivity may play a more important role in vehicular communications, compared with system throughput. These characteristics can significantly affect D2D resource allocation strategies and system performance, and thus should be reexamined for V2V.

Scheduling mechanisms envisioned for D2D communications can be used for vehicular communications, but to accommodate these mechanisms in vehicular systems is a not a trivial task. Both uplink and downlink channels must be taken into account while applying D2D scheduling mechanisms to vehicular applications. For the uplink, efficient schedulers must be developed to avoid congestion in crowded networks. For the downlink, a new cross-layer based scheduling is needed in LTE-A to cope with vehicular applications. This can be done by designing a new efficient LTE-A QoS class scheduler [3].

Control plan latency is the time required to perform the transitions between different LTE states. A D2D in LTE is always in one of three states: connected (active), idle, or dormant (battery saving mode). 3GPP specifies that the transition time from the idle state to the connected state should be less than 100 ms, excluding downlink paging and non-access stratum (NAS) signaling delay. Furthermore, it is specified that the transition time from the dormant state to the connected state should take less than 50 ms. Similarly, one way user plan latency in D2D is approximately 5 ms. These latency requirements should be re-redesigned for more strike constraint in the context of vehicular communication where safety applications require every vehicle to transmit a periodic safety message.

Standardization bodies, e.g. ETSI ITS, must rectify their presently available **standards** along

Feature Name	LTE-A	802.11p	Wi-Fi Direct	NFC	ZigBee	Bluetooth	UWB
Standardization	3GPP LTE-A	IEEE	802.11	ISO 13157	802.1504	Bluetooth SIG	802.1503a
Frequency Band	Licensed band	5.86–5.92 GHz	2.4, 5 GHz,	13.56 MHz	868/915 MHz, 2.4 GHz	2.4 GHz	3.1–10.6 GHz
Max transmission distance	1000m	200m	200m	0.2m	10–100m	10–100m	10m
Max data rate	1 Gb/s	27 Mb/s	250 Mb/s	424 kpbs	250 kpbs	24 Mb/s	480 Mb/s
Mobility support	Up to 350 Km/h	Up to 60 Km/h	low	low	low	low	low
QoS	QCI and bearer classes	Enhanced distributed channel access (EDCA)	Enhanced distributed channel access (EDCA)	Enhanced distributed channel access (EDCA)	Enhanced distributed channel access (EDCA)	Enhanced distributed channel access (EDCA)	Enhanced distributed channel access (EDCA)
V2V	**Through D2D**	Ad hoc	Ad hoc	Ad hoc	Ad hoc	Ad hoc	Ad hoc
Vehicle-to-infrastructure (V2I)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Uniformity of service provision	Yes	No	No	No	No	No	No
Application	Offload traffic, public safety, context sharing, local advertising, cellular relay	Context sharing	Context sharing, group gamming, device connection	Contactless payment, Bluetooth and Wi-Fi connections	Home entertainment and control, environmental monitoring	OBject EXchange peripherals connection	Wireless USB, high-definition video, precision location and tracking systems
Infrastructure	Users transfer data directly in licensed band	Users transfer data directly in un-licensed band					
Expenses	CAPEX: no costs as users are using the same terminal. OPEX: very low costs in terms of battery usage.	CAPEX: No costs as users are using the same terminal. OPEX: very low costs in terms of battery usage.					

Table 1. Comparison of various technologies.

with **architectures** to enable D2D to support onboard vehicular applications that provide the impetus for road safety and intelligent vehicular systems.

Economic issues should also be considered when deploying D2D mechanisms onto vehicular applications, because D2D uses licensed spectrum which is not free of charge while exchanging data among the vehicles' owners. Therefore, new business models compatible with market pricing must be envisioned.

V2V STANDARDIZATION

To achieve V2V safety communications, many consortia involved in industrial, governmental, and university research have created significant opportunities in many projects such as US IntelliDrive, CAMP/VSC-2, CICAS, SafeTrip21, and California PATH [8]. In these projects a category of protocol standards for a special mode of operations in IEEE 802.11 for vehicular networks is designed, called wireless access in vehicular environments (WAVE). These protocols are standardized by IEEE in the IEEE 802.11p and IEEE 1609 protocol set. The IEEE 802.11p [9] is an extension to IEEE 802.11 which includes physical (PHY) and (MAC) layer specifications as well as upper layer protocols for such vehicular networking applications. It inherits simplicity among several characteristics and distributes medium access control mechanisms. Furthermore, these standards are mostly utilized in vehicular on-board units (OBUs) and roadside units (RSUs) such as traffic signals which are normally fixed with transport infrastructure. Apart from the USA, such projects in Japan trying to investigate the deployments aspects of vehicular infrastructure consists of ETC (electronic toll collection) and ongoing rollout for vehicular safety communication. Moreover, such research activities are contributing to ARIB (Association of Radio Industries and Business) and ISO CALM (continuous air-interface long and medium range) standardization. On the other side in the EU, the outcome of such projects is mainly used for standardization activities carried out by industry consortia e.g. C2C-CC (Car 2 Car Communication Consortium) and standardization bodies such as ETSA (European Telecommunication Standards Institute) ITS and ISO (International Organization for Standardization) CALM standardization. In contrast, V2V communications are not natively supported in 3GPP standardization, but given the diverse performance requirements from the wide spectrum of vehicular communication, LTE-A can be an emerging solution for such V2V communication. It has been envisioned to exploit the very existing LTE-A infrastructure to support vehicular networking applications either through advanced LTE-A-enabled OBRs (on-board radios) or using smartphones with LTE-A connectivity. However, the key challenge is to deliver time critical data and efficient resource

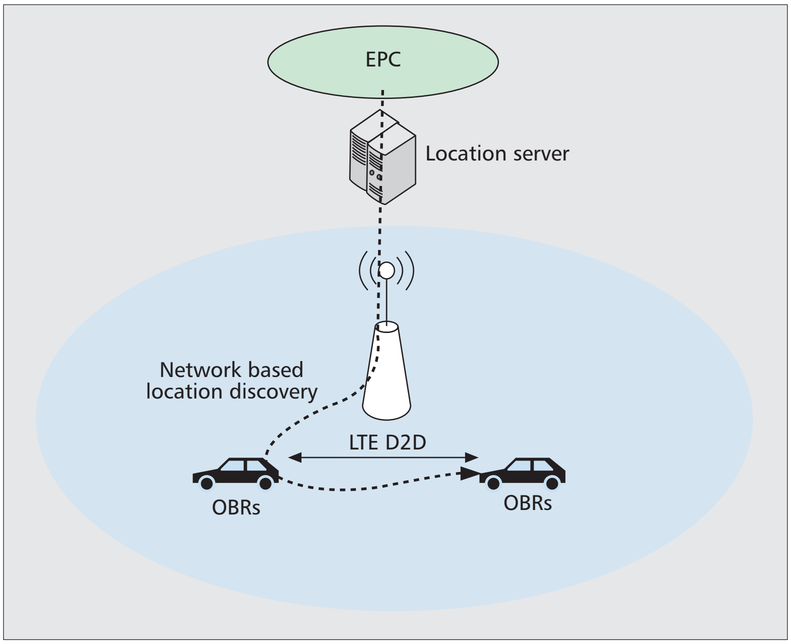

Figure 1. Core architecture V2 V communication.

sharing between vehicles and users over the LTE-A interface.

V2V STATE OF THE ART

There have been quite a few works done so far for V2V communication in the LTE-A band, but to the best of our knowledge, no works have been conducted on D2D communication for vehicular technology. D2D communication would be an interesting candidate for local data exchange among vehicles. In [8] the authors provide a detailed review and survey on LTE-A for vehicular networking applications. Different aspects of the suitability of LTE-A over HSUPA cellular networks have been presented in [10]. Similarly, the authors in [11] provide a unified framework to offset the scalability issues by combining LTE-A and cloud-based architecture. In [12] the authors analyze capacity of such LTE-A based vehicular communication networks. Moving on, the authors in [13] devise a software based framework for designing and developing vehicular network applications on smartphones. The authors in [14] anticipated a methodology for 3G cellular network-assisted data delivery for vehicular ad hoc network. The authors in [15] present a heterogeneous network architecture to address smartphone-based information dissemination issues. The authors in [3, 9] present an excellent performance evaluation of IEEE 802.11p and LTE-A.

V2V FUNCTIONAL BLOCK IN THE LTE-A SAE ARCHITECTURE

As described in the previous section, there has not been any specific architecture proposed in 3GPP to support V2V communication in LTE-A. In order to do so, we reuse the architecture of D2D communication presented in Fig. 1. In our model, we divide the location services into two parts: location discovery and direct communication. The location discovery mechanism can be network-assisted or vehicle-assisted. It involves the discovery of neighborhood vehicles that are within the LTE-A coverage area. Moreover, location discovery can act as a stand-alone service to vehicles in case of accidents and does not require direct communication. Direct communication enables vehicles to communicate directly without an eNB, within their coverage area. Furthermore, vehicles may initiate direct communication without location discovery. However, location discovery is considered a natural process for direct communication, which reduces the need for manual interaction. Indeed, network supported location discovery is the foremost step for direct communication underlying cellular networks.

In order to assist the existing infrastructure to support V2V communication, it is assumed that vehicles are equipped with advanced LTE-A enabled OBRs. The proposed architecture consists of vehicles, a radio access network, and a core network. To enable the location discovery services, "location server" is embedded into the core network. The location server provides the following functionalities to the proposed V2V based infrastructure:

- Connect between OBRs and the mobile network.
- Identify proximity between vehicles and inform the OBRs about the opportunities.
- V2V session initiation.

The V2V session initiation process is triggered by the location server by sending initiation requests to the MME, while the MME is accountable for the V2V radio bearer setup and delivery of IP addresses of V2V terminating devices, as illustrated in Fig. 2. Moreover, MME provides seamless connectivity operations among higher protocol layers and the mobility process between V2V and cellular networks. Finally, OBRs gather relevant information through periodic exchange of data messages among vehicles controlled by eNBs. However, these data messages are directly communicated over the LTE-A band.

From a data flow perspective, OBRs gather relevant information and periodically exchange date messages with other vehicles via direct communication over the LTE-A band. Please note that vehicles are always under the control of eNBs.

SYSTEM DESCRIPTION AND MODEL

This section presents the system description, modelling, and sensing algorithm

SYSTEM DESCRIPTION

LTE-A operates in two modes: a frequency division duplex (FDD) mode and a time division duplex (TDD) mode. The TDD mode supports duplexing UL/DL (uplink/downlink) by allocating time slots in a common band as a function of the service asymmetric level. Therefore, LTE-A TDD is suited to fit the asymmetric services without wasting system capacity. The LTE-A-A FDD mode uses paired uplink and downlink bands and is currently being adopted by European and American operators. In the case of Internet based applications, the traffic patterns are asymmetric with much lower usage of the uplink band in comparison to the downlink band, which is used for downloading high speed data. This means that LTE-A FDD is a downlink capacity-limited system and consequently UL bands have been underutilized by cellular operators. To confirm this, recent spectrum occupancy measurements performed in Europe pointed out that a power spectrum density (PSD) measured on the UL bands is 20 dB below the DL bands.

SYSTEM MODEL

The proposed V2V system exploits the LTE-A-A UL bands; the victim device is the LTE-A eNB, which is likely to be far from the V2V radio (each car has an LTE-A radio) which creates local opportunities due to the transmit power between the V2V transmitter and the LTE-A eNB. These potential opportunities in LTE-A FDD UL bands are in line with the interference temperature metric proposed by the FCC's Spectrum Policy Task Force. The interference temperature model manages interference at the receiver through the interference temperature limit, which is represented by the amount of new interference that the receiver could tolerate. As long as vehicles do not exceed this limit by their transmissions, they can use this spectrum band. However, handling interference is the main challenge in V2V networks, when they are operating on the same band as cellular users. Therefore, the interference temperature concept should be applied in LTE-A-A licensed bands in a very careful manner.

We envisage that a V2V network is able to sense its path loss (i.e. LTE-A radio) between the LTE-A-A eNB and its location. This sensing information is then used by the LTE-A eNB to control the transmit power of a V2V radio in order to avoid harmful interference with the LTE-A-A UL bands. The key issue to enable this is to implement a reliable sensing algorithm and define a strictly non-interference rule for V2V and LTE-A-A coexistence. The resources are centrally controlled by the eNB. In uplink transmission, V2V networks cause interference on the LTE-A eNB if they are operating on the same band or radio resource, as shown in Fig. 3.

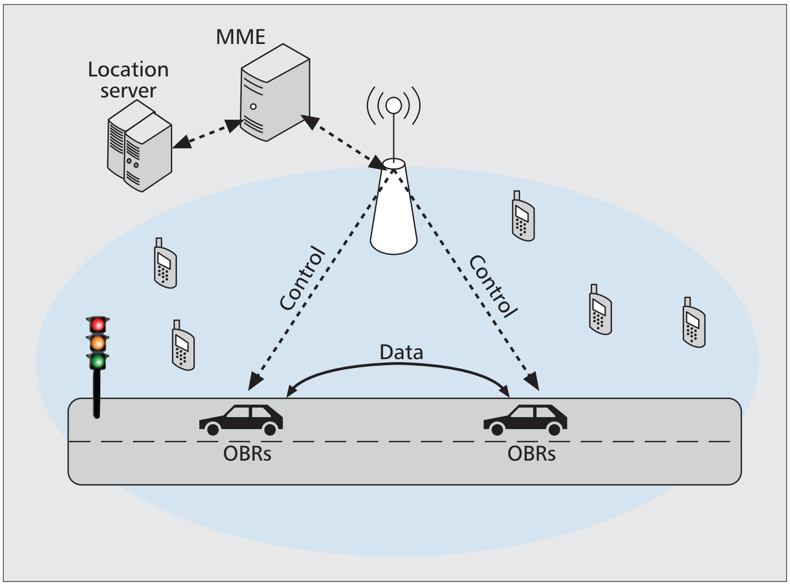

Figure 2. Access architecture for V2V communication.

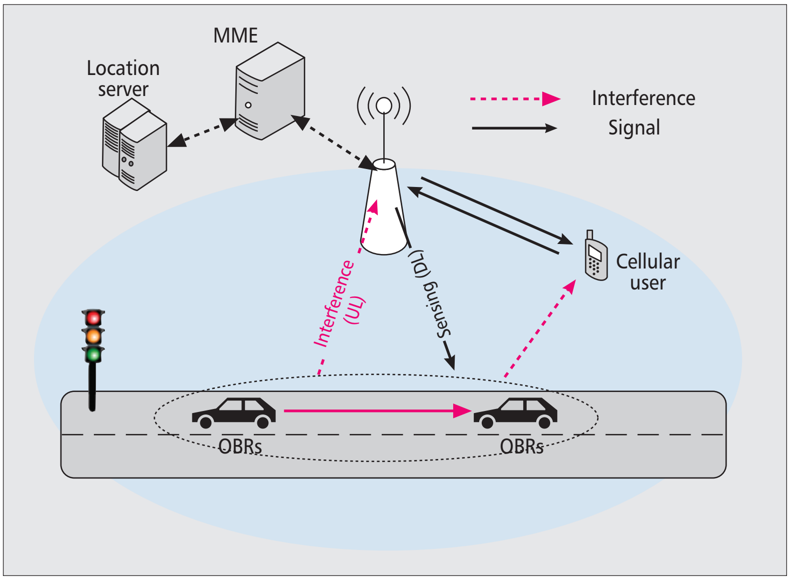

Figure 3. Network scenario.

In order to avoid harmful interference caused by a V2V network, we propose a simpler approach, i.e. fill part of the available interference temperature with a certain amount of extra interference caused by the D2D network. For simplicity, we consider that the aggregated signals coming from the D2D network are AWGN and cause a noise rise of equal dB, as shown in Fig. 4.

We are considering an LTE-A system operating at FDD 5 MHz of bandwidth, as shown in Fig. 4. An eNB is located in the center of the hexagonal cell. The cellular users act as primary users and the V2V network acts as a secondary user. The LTE-A eNB have an opportunity management entity (OME) which computes the maximum allowable transmit power of each V2V network in order not to disturb the eNB.

The maximum transmit power allowed to a particular V2V network (P_{V2V}) is computed using a non-interference rule that takes into account the aggregated interference of the entire V2V network,

$$10\log\left(\sum_{k=1}^{K}10^{\frac{P_{V2V}(k)+G_{V2V}+G_{eNB}-L_p(k)}{10}}\right) \leq 10\log\left(10^{\frac{Nth+\mu}{10}}-10^{\frac{Nth}{10}}-\Gamma\right) \qquad (1)$$

where G_{V2V} and G_{eNB} are the antenna gains of the V2V network and the eNB, respectively, P_{V2V} is the transmit power of the V2V performed by a sensing algorithm, L_p is the estimated path loss between the V2V network and the eNB, K is the number of V2V networks, and Nth is the thermal noise floor. μ is a margin of tolerable extra interference that, by a policy decision, the eNB can bear. Finally, Γ is a safety factor to compensate shadow fading and sensing impairments. Notice if the margin of tolerable interfer-

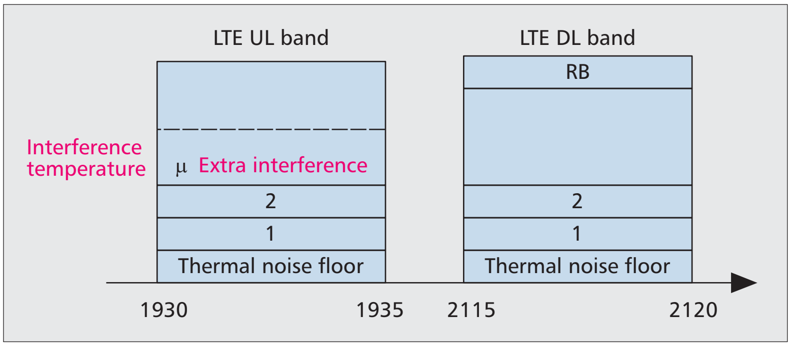

Figure 4. Example of LTE-A-A FDD spectrum band with asymmetric load.

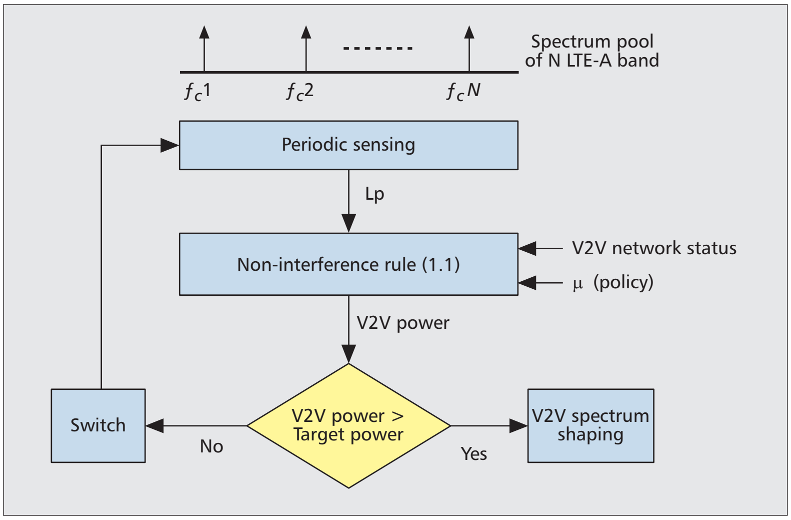

Figure 5. LTE-A spectrum pool mechanism..

ence is set μ = 0, the V2V network must be silent.

It is straightforward to extend this scenario to a 4G multi-operator scenario where several LTE-A UL frequencies cover the same region, as shown in Fig. 5. In this case, the V2V can exploit a spectrum pool of some LTE-A UL carriers. Figure 5 shows a spectrum pool mechanism. As a basic principle, the V2V network is to rent the most appropriate LTE-A UL band to transmit the required power to meet a QoS target. Whenever the required power is sufficient, the V2V signal is formatted by a spectrum shaping module, e.g. using an OFDM modulator. If during the D2D transmission the allowed power becomes lower than the target, the V2V leaves that frequency and switches to another frequency. Sensing is done on a periodic basis to follow the V2V's movement and the correspondent path loss change.

Inter cell interference is computed assuming six adjacent cells, each of them with LTE-A cellular users transmitting its maximum power (21 dBm) in a cell border. The path loss of L_p is calculated as [5] *Path loss* (L_p) $= 40\log_{10}d + 30\log_{10}f_c + 49$, where d represents the distance between a sender and a receiver in meters and f_c is the carrier frequency.

SENSING ALGORITHM

In order to obtain the maximum allowable power for V2V communication, the V2V nodes need to estimate the path loss between the eNB and its particular location. Although we exploit opportunities in the LTE-A UL band, we propose to sense DL signals. This is possible because there is a significant correlation between the average pathloss of the uplink and downlink bands of LTE-A-A. Since the eNB antenna is typically situated in a high location, the DL signal is easier to detect than the multiple UL signals coming from different users. In addition, the DL signal arrives at the sensing antenna in a synchronized manner, which facilitates detection through cyclostationary features of the LTE-A signal. Moreover, sensing and transmission in different bands avoids the allocation of special quiet periods for sensing, as is done in IEEE802.22 systems, booting the D2D spectrum efficiency.

Figure 6 depicts the block diagram of the cyclostationary detector implemented. After a FFT operation, a sliding window of samples performs frequency shifts of $+\alpha/2$ and $-\alpha/2$. The shifted spectrums are then multiplied to obtain the spectrum cyclic density function (SCD). After that, a time smoothing operation is performed through an averaging process during the observation time. The complex values are then squared and integrated over the f domain. Finally, the detection statistic, d, is given by the ratio between the power of the cyclostationary feature, measured at cyclic frequency, α_c, and the estimated noise floor, measured at α_n. In order to estimate this noise floor we take a measurement of the noise at any cyclic frequency, where it is guaranteed there will be no cyclic features present. Notice that as the LTE-A symbol rate is a known cyclic frequency, the algorithm needs to compute only two spectral lines of the SCD functions, α_c and

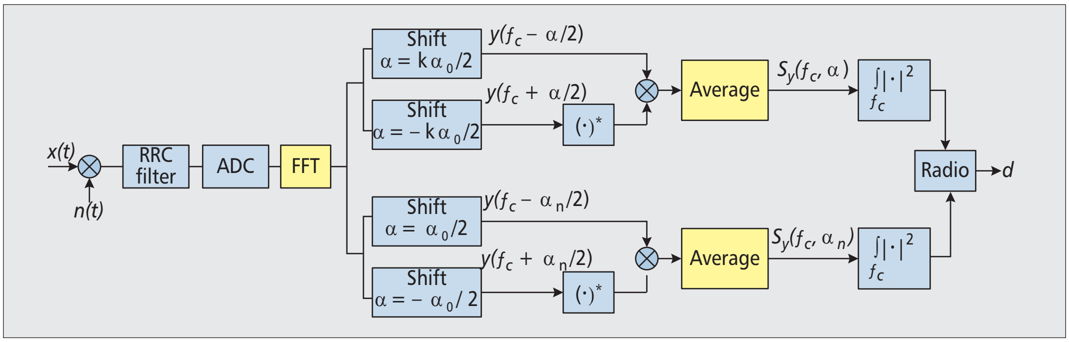

Figure 6. Cyclostationary detector of OFDM signal.

Parameter	Value
eNB transmission power	43 dBm
V2V node transmission power	4 dBm
V2V node speed	50 km/h
Antenna type	Directional (eNB)
Noise power density	–170 dBm/Hz
Noise figure	4 dB
Inter-eNB distance	1000 m
Inter-D2D pair distance	100
V2V pair distance	20 m fixed
Number of cells	7
Carrier frequency	2.6 GHz
System bandwidth	5 MHz
Bandwidth of a channel	180
Number of channels	25

Table 2. Simulation parameter.

α_n, which keeps the detector at a low complexity level.

V2V nodes sense the pathloss between their locations and the eNB. Based on the sensing result and by comparing it with the non-interference rule in Eq. 1, we will categorize the D2D users as interfering and non interfering users.

START:

Step 1: Cognitive Sensing Stage

1) All V2V nodes sense their pathloss from their location to a nearby LTE-A eNB.
2) Compare the transmission power of the V2V nodes with the non-interference rule in Eq. 1.
   a) If $P_{V2V} >$ Eq. 1
   D2D → interfering list
   b) If $P_{V2V} <$ Eq. 1
   V2V → non-interfering list
3) The interfering lists of the V2V nodes are fed back to the eNB.

Step 2: Resource Allocation Stage

1) The LTE-A eNB allocates resource blocks (RBs) to the cellular users and the V2V nodes in the non-interfering V2V list.
2) Based on the unused white space in the LTE-A UL band, the LTE-A eNB allocates available RBs to the V2V nodes in the interfering list.

End.

Figure 7 shows the flow diagram of the sensing algorithm.

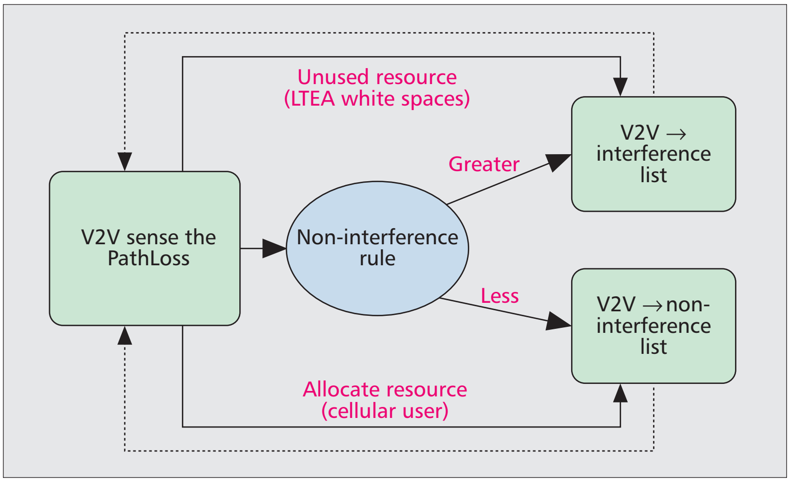

Figure 7. Sensing algorithm flowchart.

SIMULATION RESULTS AND ANALYSIS

We are considering an LTE-A simulation using a system level simulator [7]. Detailed simulation parameters are shown in Table 2. The number of cellular users in each cell is 30, and they are uniformly distributed. There are a total of 20 V2V pairs in each cell, and they are separated from each other at 20 m. Figure 8 shows the E2E delay experienced by the vehicles. It is interesting to know that for a higher number of vehicles, the delay also increases in LTE networks, where traffic goes through eNBs, while in D2D mode the delay stays almost constant as the number of vehicles increases. With these results one can conclude that D2D in LTE mode has good delay constraint for V2V communication.

We also compared (Fig. 9) the proposed resource allocation scheme with a random scheme (i.e. resources are assigned randomly), with the horizontal axis indicating the simulation step in TT1 (i.e. one TT1 in LTE-A is one subframe). As the number of vehicles increases, our proposed scheme has less interference because it uses the unused white space in the UL band.

RESEARCH CHALLENGES

There are several challenges and future perspectives that should be considered when designing new efficient V2V communication approaches for 5G, described below.

- 5G networks are expected to contain highly heterogeneous vehicular networks. Therefore, it is important for vehicles to have seamless connectivity across different heterogeneous nodes under time-varying network topology. Hence, next generation vehicles should be more intelligent to support the coexistence of multiple different co-located wireless networks to provide ubiquitous and universal access to broadband services.
- As the volume of V2V communication increases in 5G networks, this will impact the huge data transfer between vehicles and will pose new and unique challenges to data management of vehicular networks.
- Currently GPS is used as a localization system in automobiles. GPS is vulnerable to several

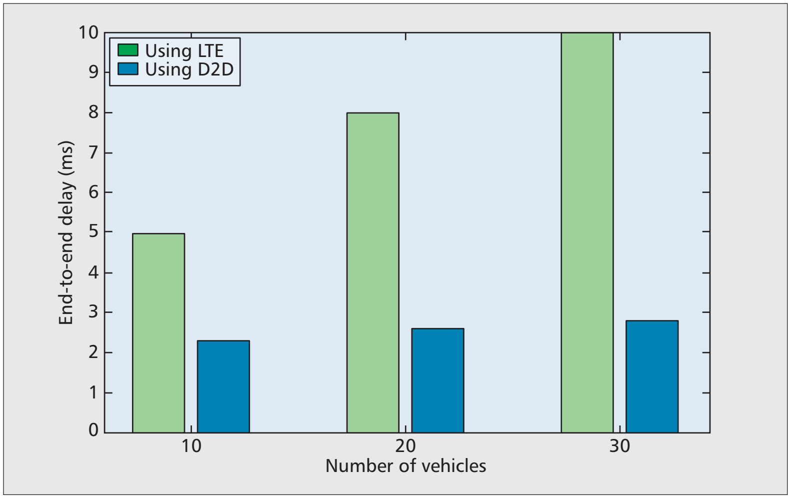

Figure 8. V2V communication delay.

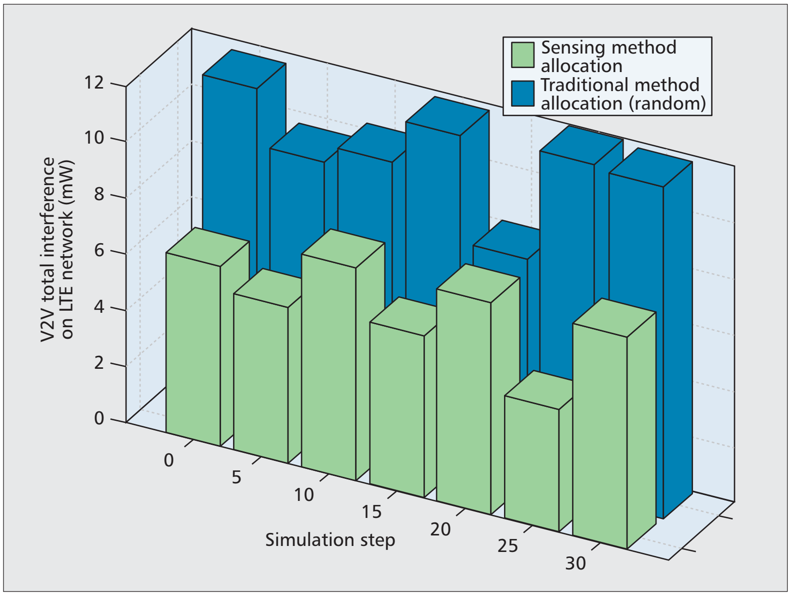

Figure 9. V2V interference analysis.

types of attacks, such as spoofing and blocking. Moreover, GPS signals are unavailable in tunnels and during bad weather. Therefore, there should a new localization system for the vehicles, rather than depending on conventional GPS.

- Due to the greater number of vehicles in future heterogeneous networks, security and privacy of these networks will be a major concern. Therefore, new secure communication protocols must be investigated, taking into consideration the unique characteristics of heterogeneous vehicular networks.
- To decrease the E2E delay in future heterogeneous vehicular networks, D2D should be a part of vehicular communication, i.e. control will be over the licensed band and data between vehicles can be transfered via D2D (either using IEEE 802.11p or the licensed band). This approach increases the coverage and the capacity of future heterogeneous vehicular networks.

CONCLUSION

In this article we presented the idea of D2D communication for vehicular technology. We showed that D2D communication is a good candidate to decrease the delay constraint in vehicular communication. Then we presented a novel resource allocation scheme that decreases the interference between vehicular nodes and normal cellular users. Finally, we showed by simulation that our scheme outperformed conventional schemes, and that vehicular communication in LTE-D2D mode is a good application for 5G technology. In the future our plan is to provide a comparative study between the proposed schemes and the IEEE802.11p standard.

ACKNOWLEDGMENTS:

This work was carried out under the E-COOP project (PEst-OE/EEI/LA0008/2013), funded by national funds through FCT/MEC (PIDDAC) and CARCODE project N. 30345, co-financed by the European Funds (FEDER) by COMPETE, Programa Operacional Factores de Competitividade (POFC) of QREN

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BIOGRAPHIES

SHAHID MUMTAZ [M'13] (dr.shahid.mumtaz@ieee.org) received his M.Sc. degree from the Blekinge Institute of Technology, Sweden, and his Ph.D. degree from the University of Aveiro, Portugal. He is now a senior research engineer at the Instituto de Telecomunicações, Pólo de Aveiro, Portugal, working on EU funded projects. His research interests include MIMO techniques, multi-hop relaying communication, cooperative techniques, cognitive radios, game theory, energy-efficient framework for 4G, position information assisted communication, and joint PHY and MAC layer optimization in the LTE standard. He is the author of several papers published in conferences and journals, and of several books.

KAZI MOHAMMED SAIDUL HUQ (kazi.saidul@av.it.pt) is a research engineer at the Instituto de Telecomunicações, Pólo de Aveiro, Portugal. He received his bachelor's degree in computer science and engineering from Ahsanullah University of Science & Technology, Bangladesh, in 2003. He obtained his master's and Ph.D. degrees in electrical engineering from Blekinge Institute of Technology, Sweden, in 2006 and the University of Aveiro, Portugal, in 2014, respectively. His research activities include 5G paradigm, backhaul, D2D communication, energy-efficient wireless communication, radio resource management, and MAC layer scheduling. He is the author of several publications including papers in conferences and journals, and book chapters.

MUHAMMAD IKRAM ASHRAF (ikram@ee.oulu.fi) received his M.Tech degree in telecommunication systems from the University of Oulu, Finland in 2008, and MSc in communication network with distinction (Gold Medal) from Bahria University, Pakistan in 2004. He worked as a research engineer at the Centre for Wireless Communication, Oulu, Finland from 2006 to 2011. From 2011 to 2012 he worked as a senior software engineer at Nokia Oulu, Finland. Currently he is pursuing his Ph.D. degree in communication engineering at the Centre for Wireless Communications, University of Oulu, Finland. His research interests are in the field of heterogeneous networks, D2D communication, radio resource management, social-aware networks, and game theory.

JONATHAN RODRIGUEZ [SM'13] (jonathan@av.it.pt) received his master's degree in electronic and electrical engineering and a Ph.D. from the University of Surrey, United Kingdom, in 1998 and 2004, respectively. In 2002 he became a research fellow at the Centre for Communication Systems Research and was responsible for coordinating Surrey's involvement in European research projects under Frameworks 5 and 6. Since 2005 he has been a senior researcher at the Instituto de Telecomunicações, where he founded the 4TELL Wireless Communication Research Group in 2008. He was the project coordinator and technical manager of the FP7 C2POWER and FP7 COGEU projects, respectively, and currently acts as coordinator of several national and international projects. He is the author of more than 200 scientific publications, has served as general chair for several prestigious conferences and workshops, and has carried out consultancy for major manufacturers participating in DVB-T/H and HS-UPA standardization. He is a chartered engineer (IET). His research interests include green communications, network coding, cognitive radio, cooperative networking, radio resource management, and cross-layer design.

VALDEMAR MONTEIRO (vmonteiro@av.it.pt) received his degree (five years) and master's degree in electronic and telecommunications from the University of Aveiro (Portugal), in 1999 and 2005 respectively. After his graduation in 2000 he became a research fellow at the Instituto de Telecomunicações–Aveiro, and has worked for international research projects that include IST SAMBA, IST MATRICE, 4MORE, and UNITE. In 2008 he joined CV Movel (Cabo Verde), Cape Verde main mobile operator to work as a switch engineer. He is the author of several papers published in conferences and journals, and has carried out consultancy for operators (Portugal Telecom Inovação) and HSDPA standardization. His research interests include radio access networks for legacy and beyond3G systems with specific emphasis on IP networking, cooperative radio resource management, and PHY/MAC optimization strategies. He is researcher fellow at the Instituto de Telecomunicações and a Ph.D. student at the University of Kingston, UK.

CHRISTOS POLITIS [SM] (c.politis@kingston.ac.uk) is professor (chair) of Wireless Communications at Kingston University London, Faculty of Science, Engineering and Computing (SEC). There he is the co-director (enterprise) of the newly established Digital Information Research Centre (DIRC) with a staff of 25 academics, 20 postdoctoral researchers, and more than 60 Ph.D. students, making it one of the largest in the field in the UK. Upon joining KU as a senior lecturer in 2007, he co-founded and led a research group on wireless multimedia & networking (WMN). He was promoted to reader in 2010 and to full professor in 2015. He teaches modules on wireless communications and networks. Prior to this post, he worked for Ofcom, the UK Regulator and Competition Authority, as a senior research manager. While at the University of Surrey, UK, he undertook a postdoc working on virtual distributed testbeds in the Centre for Communication Systems Research (now the 5G Innovation Centre). This was preceded by placements with Intracom-Telecom SA and Maroussi 2004 SA in Athens, Greece. He has managed to raise several millions of funding from the EU and UK research and technology frameworks under the ICT and Security programs. He holds two patents and has published more than 170 papers in international journals and conferences and chapters in nine books. He sits on the Board of Directors (BoD) of a couple of technology start-ups and advises several governmental and commercial organizations on their research programs/agendas and portfolios. He holds a Ph.D. and MSc. from the University of Surrey, UK, and a B.Eng. from the Technical University of Athens, Greece. He is a senior member of the IEEE, UK chartered engineer, and member of the Technical Chamber of Greece.