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## Research Article

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# Congestion Control investigation into 5G V2V

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## I.ABSTRACT

Congestion control is a hot research topic according to the continuous increase of traffic density together with great mobility of cars. In this context, in this survey we present an overview about the different vehicle to vehicle (V2V) communication enablers by describing the difference between them performing better driving assistance together with efficient congestion control ensuring driving safety. New radio (NR) 5G is the heuristic enabler which provides scalability and reliability towards vehicular communication. Indeed, NR 5G is the best solution supporting the great increase of network density. 5G technology is expected to allow much advanced services and application with a huge capacity of data exchange. Congestion occurrence impacts the quality of service of vehicular network, for this accurate quantification is required. In our analysis we consider channel busy rate CBR as indicator of network density. Channel load control is mandatory to overcome traffic jam which could be highlighted by different metrics. The connectivity between cars is modeled with a game theory framework considering a non cooperative vehicular mobility. Each vehicle adjusts its transmitted power in dynamic way taking into account the traffic density measured by channel busy rate (CBR). Consequently, we follow a theoretical modeling to determine the efficient allocated power ensuring awareness messages exchange without saturating the communication channel under the respect of a fixed threshold. Therefore, channel saturation control is investigated following a theoretical analysis exploiting game theory under the assumption of a non cooperative strategy. Each vehicle acts as a player presenting a specific driving behavior different to the other cars participating into the same scenario. The optimization framework is about determining the optimal allocated power for congestion minimization.

### *Keywords :*

Congestion, Game theory, vehicular communication, NR 5G V2V.

## **II.Introduction**

Due to the continuous growth of traffic density, accident occurrence increases simultaneously. For this the focus of researchers is to find the optimal cellular technology architecture who is able to solve traffic problems and satisfy huge data rate demand together with high reliability level required. Indeed, driving safety is the purpose of many researchers especially following the huge increase of wireless communication systems which requires advanced services with new connectivity of network. Indeed, according to great increase of wireless communication devices, the need of new technologies tools offering much services and features is mandatory as well as the requirement of much safety in traffic. Specifically, real time awareness messages are required to ensure much safety and reliability toward data exchange. Smart vehicles change people's life in the way that safety is improved especially due to dynamic traffic variation. Many researchers are working in the integration of new sensors preventing accident occurrence allowing cooperative communication focusing on driving safety in roads.

A vehicle containing different sensors becomes a smart machine who guide the driver to the safe position in the way to avoid accidents. Vehicle to vehicle communication was performed through different enablers facing migration from technology to another according to the growth of wireless communication systems. Congestion investigation into NR V2V is a recent topic wo requires awareness especially with the increase of sensors integration into each vehicle leading to the broadcast of different notifications. Congestion mitigation is an interesting topic due to the great increase of vehicular density which is based on channel saturation. Correspondly, congestion control is a mandatory criteria to ensure much reliability with better quality of service. Note that in the situation of traffic jam, awareness messages could be lost leading to lack of reliability and delay, in this case the quality of safety into roads is diminishing. According to the continuous increase of severe traffic problems, accidents occurrence grow simultaneously. Facing the continuous progress of cellular technologies, advanced sensors are provided which leads to increase of simultaneous transmission of different awareness messages. Hence, in the case of large network density different cars broadcast notification messages at the same time which ensure traffic congestion. In this regard safety is not ensured due to packet loss occurrence together with latency challenge. In our survey we suggest NR 5G as the suitable cellular technology which allows high quality of service into V2V communication. Traffic saturation management depends on the control of vehicular channel through different metrics such as data transmission packet or the corresponding transmitted power. In particular, the focus

in [1] was about congestion control based on dynamic beacon generation rate. In addition, traffic interference was discussed for the case of different vehicular enabler exploitation. The contribution in [2] presented vehicular communication environment based on 5G. Traffic jam examination towards VANETS was the aim of the paper in [3]. Otherwise, the contribution [4] investigated roads congestion whenever LTE-V (Long Term Evolution Vehicle) Mode 4 was used as enabler for car to car communication. The proposal in [5] investigated V2X (Vehicle to Everything) context following enhanced mobile broadband standardization use case following drive 5G project. The idea in [6] was about diminishing redundancy information in the way to ensure reliable communication towards a highway scenario. A comparison between two vehicular communication enablers such as NR V2V and IEEE 802.11bd was performed in [7]. The paper in [8] evaluated the performance of the NR V2V considering packet error rate and delay. In [9] authors compared the performance of two enablers based on IEEE 802.11p and LTE-V Release 14 by investigating both the MAC and physical layers. The aim in [10] was about discussing packet drop condition for congestion minimization. The effect of numerology modification related to C-V2X (Cellular Vehicle to Everything) communication was discussed in [11]. Moreover, security issue of 5G V2V was investigated in [12] where the authors compared it with the case of C-V2X. The focus in [13] was about investigation of 5G architecture in terms of radio and core part to ensure reliability into the vehicular scenario. In [14] the suggested idea was about developing an algorithm to solve the issue of services positioning following edge scenario to ensure quality of service improvement. In [15], authors compared the efficiency of LTE-V2X and IEEE 802.11 p in terms of packet transmission periodicity. Authors in [16] proposed a solution for V2V cooperative communication for collision diminishing using 5G Release 16 as enabler. In [17] authors proposed both rate and power adaptation to investigate congestion towards cellular V2X. Authors in [18] discussed the possibility of packet retransmission in congestion scenario considering the two enablers NR V2V and C-V2X. In [19] the purpose is to investigate security issue into 5G V2V and compare it with C-V2X. In [20] authors presented the advanced 3GPP transformation into radio and core part towards 5G V2V deployment. The architecture of 5G V2V was depicted in [21] through a review of the design vehicular system as defined by 3GPP Release 16. In [22] the suggested idea was exploiting mobile edge computing approach for vehicular communication, in which authors proposed an heuristic algorithm for quality of service improvement. In [23], authors compared the efficiency of LTE-V2X and IEEE 802.11 p in terms of packet transmission periodicity. Authors in [24] evaluated the performance into NR V2X considering the impact of modulation coding schema, frame size together with the distance separating cars. The

contribution in [25] was about DCC (Decentralized Congestion Control) algorithm examination for congestion mitigation together with the analysis of the efficiency of sensors to ensure traffic safety. Our contribution in [26] was about latency examination considering LTE-V mode 4 approach for V2V communication. The other paper in [27] was about stackelberg game suggestion for power diminishing into LTE-V mode 4.

In this present survey we start by an overview about technologies enablers for car to car communication. Next, we discuss NR 5G application for V2V communication. The aim is to investigate congestion control in vehicular communication enabled by different technologies. In this survey we describe different existing congestion control algorithms following a synchronous scenario with the Global Navigation Satellite System GNSS help. Next, the purpose is to exploit game theory modeling of the NR V2V approach in the way to reduce channel saturation. The idea in this survey is to investigate power allocation adjustment for congestion control exploiting an optimization process based on data rate maximization under the constraint of a limited transmitted power. Furthermore, power allocation depends on the vehicular density and the performance of the network depends on accurate reception of awareness messages that could be lost in the case of congestion occurrence. In this proposal we discuss the applicability of game theory for congestion mitigation assuming that the moving vehicles are players presenting different strategies for safety packet generation.

The survey is structured as following. In the first section we present the evolution of V2V communication enabler from IEEE 802.11p to NR 5G V2V. Section II presents existing congestion control algorithms discussing the possibility of exploiting them. We discuss the applicability of congestion control solution algorithms such as Linear Message Rate Integrated Control LIMERIC and DCC. Section V is about interaction between cars modeling through game theory approach where the purpose is power allocation.

## **II. Overview about IEEE802.11p as enabler for V2V Communication**

The first enabler for car to car communication was IEEE802.11p allowing data exchange at a short distance which was firstly appeared over 2010. IEEE802.11p principle is similar to that of IEEE802.11a but without the need of base station infrastructure. Note that IEEE802.11p allows different type of MCS ranging between 3 Mbps and 27 Mbps. IEEE802.11p refers to a WIFI technology exploited for vehicular communication. We should mention that IEEE802.11p is based on Orthogonal Frequency Division Multiplexing OFDM approach. The communication between cars is based on safety message exchange such as : position, velocity.

Vehicle's information is provided by a generated message by advanced sensors. Each car is assimilated as a smart machine incorporating different sensors in the way to exchange information about localization, acceleration through a defined infrastructure. Besides vehicles are able to predict any collision probability. Awareness messages are performed through the different sensors incorporated into a smart car. The most drawback of IEEE802.11p is the limited QoS (Quality of Service) allowed. In addition, IEEE802.11p can't satisfy the communication between vehicles considering a large density of cars.

## **II.LTE-V enabling Method**

Different enablers of V2V communication was suggested by different researchers such as IEEE 802.11p based on OFDM system and LTE-V [28]. LTE-V exploits the features of Long Term Evolution LTE standardized following 3GPP Release 14 technology. LTE-V adopts LTE performance in terms of resource block RB allocation and Single Carrier Frequency Division Multiple Access SC-FDMA principle exploitation. Since LTE-V2X is based on LTE principle, the channel is divided on resource blocks in which each RB contains 12 OFDM symbols. The resource assignment unit for LTE-V is performed through RB. A RB in LTE-V is defined through 12 subcarriers spaced by a 15 KHz with 0.5 ms of duration which corresponds to 180 KHz of bandwidth. Each sub-frame is composed of a set of sub-channels dedicated for both control and data information delivery. The data information is transmitted according to block of transmission exploiting 16QAM or QPSK modulation where the coding is performed by Turbo. Note that the block of transmission (TB) is accompanied by two other resource block representing SCI sidelink control information allowing signaling functions sent through Physical Sidelink Control Channel PSCCH. Therefore, for each broadcast of a TB performed by Physical Sidelink Shared Channels PSSCH, the channels a SCI is transmitted at the same time and at the same sub-frame. In addition, LTE-V supports between 10 MHz to 20 MHz of channels. The transmission of SCI is performed via QPSK modulation following a convolutional coding component. Note that LTE-V is specified by its synchronization since all users have the same time of reference provided by GNSS system. LTE-V presents two mode of operation following the infrastructure exploitation such as mode 3 in which resource block are assigned via ENodeB, mode 4 ensures autonomous allocation of resources in sidelink context performed with PC5 protocol. Phase I of LTE-V corresponding to Release 14 allowing basic performance results towards vehicular safety. For this comes LTE-V Phase II following Release 15 ensuring enhancement of the integrated sensors. Note that LTE-V is based on

Hybrid Automatic Repeat Request HARQ improving the transmission link but it will be disabled in the case of channel saturation. We define two communications mode depending on infrastructure exploitation. LTE-V mode 4 corresponds to a direct communication through PC5 protocol where the resource block are shared without the help of ENodeB. The switching between mode 3 and mode 4 depends on coverage availability. LTE-V mode 4 allows direct communication between vehicles through PC5 interface where resource blocks are assigned autonomously. LTE-V mode 4 corresponds to a decentralized scenario where resource block are assigned randomly without coverage requirement. In the case of lack of coverage sidelink communication is required allowed by LTE-V mode 4. Specifically, LTE-V mode 3 depends on ENodeB coverage availability. We should mention that LTE-V ensures better quality of service than IEEE 802.11p.

## **II.OVERVIEW ABOUT NR V2V**

In this section we present an overview about NR 5G V2V. NR 5G provides network transformation following a broadband transmission due to exploitation of advanced methods such as Network Functions Virtualization NFV, Multi access Edge Computing MEC and Software Defined Networking SDN providing advanced smart devices allowing driving safety based on Enhanced Mobile Broadband eMBB, Massive Machine Type Communications mMTC and Ultra Reliable Low Latency Communication URLLC 5G services. By this way, NR 5G is a prominent enabler allowing improvement towards the transportation network ensuring massive connectivity which is a required characteristic following the continuous increase of traffic density. Due to important increase of accident probability, smart cars are mandatory to alert its neighbors, but it requires advanced devices able to support high data rate to broadcast driving information related to position, direction and speed for long range. Thus, NR 5G is the efficient technology to satisfy the growing demand of huge data rate with scalability changing the driving way. In this context, authors in [37] suggested an approach based on Software Defined Networking SDN to improve the vehicular network toward notification messages exchange at accurate time.

In fact, following the continuous increase of traffic density, we require new technology tools to manage the communication between cars ensuring much safety with high quality of service as the packet exchange is performed efficiently. The transmitted messages are classified following its severity whether it is a simple notification about the driving condition such as localization, velocity or critical information corresponding to specific driving status. Following the

continuous increase of traffic density, LTE-V can't allow the required reliability together with high spectral efficiency to ensure safety into roads. For this NR 5G, according to phase II of Release 16, could be the suitable enabler with advanced numerology offering high quality of service allowing 256 range of QAM modulation. In the way that each vehicle is able to interact with anything flexibly and rapidly thanks to the features provided by 5G. The purpose of NR 5G suggestion for V2V communication is high data rate ensuring very low latency which provides reliability and efficiency toward information exchange especially that 5G technology allows the exploitation of different antennas at the same equipment, more details are provided in [36]. Otherwise, NR 5G provides enhancement towards PC5 interface in which both information data together with control messages are transmitted. In addition advanced features are enabled with the help of Mobile Edge Computing MEC and SDN. The selected enabling communication technology depends on its ability to ensure much security and reliability. We require powerful sensors, NR V2V shows its ability toward driving efficiency and it is expected to provide advanced services opening the door to new innovation features offering smart driving highlighted through the high data rate with safe driving. The selected enabling communication technology depends on its ability to ensure much security and reliability. NR V2V is expected to provide advanced services opening the door to new innovation features proving smart driving highlighted through the high data rate with safe driving. In addition, NR V2V shows his ability toward driving efficiency. Specifically, real time awareness messages are required to ensure much safety and reliability toward data exchange. We should mention that to avoid interference, synchronization between vehicles should be performed. We should mention that 5G NR is suggested as an heuristic enabler for vehicle to vehicle cooperation promising awareness enhancement due to broadband performance allowed by millimeterwaves mmWaves frequencies. NR 5G technology provides services with high reliability and with very high efficiency following the offered advanced features. For this we investigate the suitability of 5G NR for car to car communication. NR V2V is a prominent solution providing efficient communication between cars with very high data rate. Consequently, the goal of NR V2V is to improve the available vehicular communication enablers. Regards to the great features of NR 5G we exploited it as enabler for car to car communication. 5G technology enables new connectivity possibility allowing huge data rate with very low delay. NR V2V changes the driving style by providing much safety, in the way that each car sends messages about their position, velocity and direction. Each car is able to react facing to traffic problems ; each car moves following the received driving data which implies a network transformation and evolution to provide new services allowing much safety towards driving. In such connectivity



scenario, each car is similar to a smart machine delivering its status related to its position, direction, velocity. The idea is that vehicles are equipped with advanced sensors in the way to support 5G NR features. Nevertheless, the connectivity is improved compared to C-V2X proposal. The behavior of each car is controlled by its neighbor who broadcasts its position, velocity, direction which is useful to save driver life and diminish road accidents. These outcomes are enhanced with considering NR V2V as enabler. Vehicles act as a smart machines broadcasting alerting messages which is relied to the ability of NR V2V to provide much novelties compared to LTE-V allowing better scenario for vehicular communication. NR V2V principle is based on providing better coverage into a high density of the vehicular network. NR V2V is defined as a new technology exploiting 5G communication providing very high density of connection between cars offering advanced components able to detect any challenge into roads. 5G communication enables and maintains a very large connectivity between vehicles. Following the great importance of reliability toward vehicular communication, NR V2V is an heuristic enabler providing efficient cooperation. NR V2V provides services which outperforms C-V2X vehicular communication method of cooperation and allow NR-V2X existence following Release 16 of 3GPP. NR 5G is adopted due to the high reliability and huge bandwidth, in addition reliability depends on accurate exchange of information in real time between cars. By this way congestion overcoming is a great topic to ensure much safety. NR 5G is adopted due to the high reliability and huge bandwidth, in addition reliability depends on accurate exchange of information in real time between cars. By this way congestion overcoming is a great topic to ensure much safety. Different enablers was proposed to ensure car to car communication, the suitable solution provides more use cases according to many specification such as dynamic subcarrier spacing SCS. The transmitted waveform according to NR 5G network follows two kind of frequencies such as sub 6 corresponding to subcarrier separation following these frequencies 15 KHz, 30 KHz and 60 KHz, mmWaves frequencies range between 30 and 300 GHz with 120 KHz of subcarrier spacing. The idea is that vehicles are equipped with advanced sensors in the way to support 5G NR features. NR V2V defines new network connectivity architecture by providing advanced services where the performance is highlighted through safety into roads enhancement. Hence, the connectivity is improved compared to C-V2X proposal. Channel saturation is much remarkable in urban scenario where interferences increase. In other side, Channel availability is based on packet transmission rate, transmitted power in the way that each car broadcasts the information gained by the sensors to reduce traffic jams. The idea is to incorporate more advanced sensors providing much ability to avoid traffic problems. 5G NR is suggested as an heuristic enabler for vehicle to vehicle

cooperation. Regards to the great features of NR 5G we exploited it as enabler for car to car communication. The focus of NR V2V is to improve the available vehicular communication enablers. Following the continuous increase of traffic density, we require new technology tools to manage the communication between cars to ensuring much safety with high quality of service as the packet exchange is performed efficiently. In the way that each vehicle is able to interact with anything flexibly and rapidly thanks to the features provided by 5G. NR 5G proposal improves the communication between vehicles due to the features allowing high data rate according to the characteristic of Enhanced mobile broadband eMBB, very low delay ensuring with Ultra Reliable Low Latency URLLC, ver high connectivity through Massive Machine Type Communication Mmtc. The efficiency of NR V2V is highlighted through the heuristic connectivity with very high reliability allowed by mmWaves frequencies. Compared to LTE-V, NR V2X presents two communications mode such as mode 1 corresponds to resource block assignement via gNodeB. Especially that resource block allocation is an important metric to avoid latency toward packet exchange. Mode 2 coressponds to sidelink context in which communication between cars is allowed by PC5 interface. NR V2V is based on OFDM features aspect, it supports a large range of Modulation Coding Scheme MCS offering enhancement toward reliability due to the massive number of antenna. The exploitation of mode 1 or mode 2 of NR V2V depends on the coverage availability. Reliability is performed through Low Density Parity Check LDPC and polar encoder adoption in physical layer especially that alerting messages should be send in real time at an accurate time. NR V2X is expected to offer new applications, better coverage and use cases than C-V2X. NR V2V is a prominent solution providing efficient communication between cars with very high data rate. In such connectivity scenario, each car is similar to a smart machine delivering its status related to its position, direction, velocity. The challenge of Channel saturation happens whenever all cars send awareness messages simultaneously. Note that cars are expected to be more smart following the migration of NR V2V from Release 16 corresponding to the initial version of sidelink proposal of NR to Release 17. Phase II of 5G corresponding to Release 16 related to initialization of NR 5G providing much efficiency of data transmission according to the exploitation of LDPC coding. In other side phase III of 5G corresponding to Release 17 provides much reliability following URLLC enhancement. According to Release 17 new advanced features are added such as multicast transmission allowing more flexibility. NR V2V presents a great potential in the way to enable new connectivity way due to the new sensors features especially that congestion implies packet drop. Specifically, V2V communication enhancement depends on the offered services. NR V2V presents a great potential in the way to

enable new connectivity way due to the new sensors features especially that congestion implies packet drop. Note that NR V2V has the potential to ensure high data rate with low delay. NR V2X allows alerting messages broadcasting following two frequencies corresponding to sub 6 Ghz and mmWaves ranging from 10 GHz to 300 GHz ensuring very high data rates. The purpose is to exploit mmWaves bands for car to car interaction. The frequency application of NR V2V depends on the application whether it is short range with huge data rate we require mmWaves range. The aim of the transmitted messages is to alert the neighbor car in the way to dynamically change its behavior to avoid traffic problems. The requirement is very high data rate together with very low latency. In [29] authors presented the ability of communication ensured by NR 5G in a range of THz frequencies by discussing physical numerology. 5G communication enables and maintains a very large connectivity between vehicles in the way that whenever the distance between vehicles is important transmission data rate still high. Each vehicle broadcasts its identity in the way to inform its neighbor about the status of the traffic which is useful especially in a platoon context. In addition, NR V2X uses high MCS ranges which provides high data rates which could be more efficient to avoid accident. Therefore, each PC5 interface is divided into a set of subchannels in the way that the active vehicles can exchange information at the same time providing V2V enhancement. PC5 protocol allows direct exchange of packet without any feedback. NR 5G features are enhanced from phase to another allowing very high modulation ranges providing an overall slicing of the network. Thanks to NR 5G features of broadband enhancement the connectivity could be improved. Latency is reduced due to the important space between subcarriers. With NR V2V new features, cars become smarter where different applications are performed. New advanced sensors features are defined allowing traffic accident reduction. In this part we present an overview about NR 5G V2V as an enabler for vehicular cooperative communication enhancing the communication between cars. Alerting messages should be sent in real time at an accurate time. Thanks to NR 5G features of broadband enhancement the connectivity could be improved. With NR V2V new features, cars become smarter and the driving is facilitated. To avoid interference, synchronization between vehicles should be performed. The synchronization is performed through GNSS. NR 5G V2V provides better features than LTE-V which is standardized for this new cars are equipped with both of the two technologies. The promise of applying NR V2V is to ensure very high data rate with very low latency toward vehicular network. The quality of driving is improved since the purpose is to ensure wide range of vehicle to vehicle interaction. If we compare the two vehicular enablers we deduce that LTE-V ensuring

safety, for the case of NR V2V more use cases and flexibility is allowed as reliability and data rate are very important to ensure efficient communication between cars.

### **III. Overview about Congestion control algorithms**

In this section we present, at first, an overview about the existed congestion control algorithms and discuss, next, their usefulness considering NR V2V as enabler. Channel saturation appears since each vehicle requires a resource block to occupy to send the notifications messages, the problem happen whenever another vehicle try to use the same channel. Traffic Congestion examination allows efficiency in terms of reliability as in the case of density increasing highlighted through a broadcast of different messages at the same time there is a strong probability of latency and lost of information. A congestion could be identified whenever all cars exchange information at the same time which could implies latency toward transmitted packet leads to lack of safety. Note that efficient mitigation of congestion problem improves vehicular connectivity. In addition, congestion mitigation depends on message exchange rate restriction. Efficient selection of transmission power together with MCS implies better management of channel load. Indeed, better selection of data rate manages the subchannels exploitation. Generally, congestion control algorithms manage the exchange of information method between vehicles.

#### **III.1. LIMERIC Algorithm Description**

Linear Message Rate Integrated Control LIMERIC was identified in [30] as an efficient algorithm which is based on rate adaptation following a feedback according to the evaluated CBR corresponding to a reactivity context. The efficiency of a congestion control algorithm is the ability of cars' convergence to a specific target rate since each vehicle predict the channel capacity at a specific time before start broadcasting. Congestion into the channel implies degradation toward quality of service due to loss of packet and collision possibilities. The idea toward LIMERIC algorithm is awareness message exchange adaptation where the purpose is to converge to a determined target rate under the respect of a defined CBR threshold. The adapted packet transmission rate for each instant  $t$ , following LIMERIC algorithm, is adapted according to this relation [30] :

$$R_k(t) = (1-\alpha) R_k(t-1) + \beta (R_k - R(t-1)) \quad (1)$$

Being :

$R_k$  : instantaneous data rate of each vehicle indexed with  $k$

$\alpha$  : adaptation's parameter ranging between 0 and 1

$\beta$  : adaptation's gain parameter

$R$  : total rate of all cars interacting at the same area

Note that both  $\alpha$  and  $\beta$  parameters controlling equal sharing of resources between vehicles and stability in adaptive way. The scenario could be described by a set of cars moving in the same road and to provide more reliability the interference should be mitigated. In particular, LIMERIC algorithm follows traffic dynamic change in adaptive method since CBR is checked and compared instantaneously to a specific CBR target. Congestion control depends on cars density, otherwise, it could be better managed considering NR 5G as enabler due to its ability to control huge number of vehicles offering heuristic communication's opportunities in real time. A way to mitigate congestion is to reduce packet broadcasting. Congestion is the result of interference into roads which happens in the case of saturation in the way that exchange of packets isn't possible at that moment which implies accident occurrence. Congestion control is based on checking the availability of the channel to perform efficient connectivity. In addition, the time separating consecutive transmission of messages should be controlled to avoid channel saturation. Different parameters could be used to describe traffic saturation as indicator of congestion such as channel busy ratio CBR serving in channel exploitation control. CBR criterion defines channel occupancy and gives an idea about channel status. Congestion control is based on performance criterion improvement such as data rate, Packet Error Rate PER, Bit Error Rate BER. Additionally, LIMERIC algorithm was standardized by ETSI according to [30] which is based on listening to the channel load at a specific time to adapt the transmission rate after that. Moreover, LIMERIC was identified in [30] as an efficient algorithm which is based on rate adaptation following a feedback according to the evaluated CBR corresponding to a reactivity context. We assume that all cars controlling congestion are synchronized toward notification packet transmission. The purpose is that all vehicles should converge to a determined threshold data rate. Each car checks the availability of the channel to send its notification. The principle is to control the amount of transmitted packet such that once the density increases LIMERIC ensures data rate diminishing. Each car measures the channel load

before sending its awareness packet. Each vehicle checks the channel's status before sending each awareness message.

#### **IV. Overview about DCC algorithm**

The purpose of Distributed Congestion Control DCC algorithm is to adjust the packet transmission rate in the way to keep the channel load below a given target threshold taking into account fairness toward resource block sharing. DCC approach is based on reactivity where the idea is to adapt different metrics such as message rate, power transmission taking into account fairness between cars toward resource assignement. DCC congestion mitigation method is an efficient way which keeps the channel at a given threshold. In other side, Data rate adaptation depends on the channel status. The goal of DCC algorithm application is power and data rate adaptation in the way to overcome congestion. Before transmitting each information, each vehicle compares its CBR with a defined target. In [31] authors suggested DCC algorithm for congestion control considering C-V2X technology as enabler. Specifically, congestion control methods are based on MCS or transmitted power adaptation. In addition, DCC proposal is mandatory for channel exploitation. The drawback of DCC approach is the lack of fairness where more details are provided in [32].

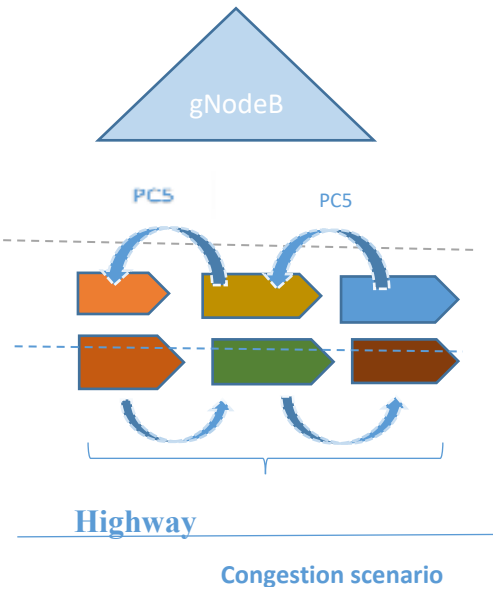
#### **VI. Channel load control into NR V2V**

Quality of service improvement relies on high data rate depending on the transmitted power enhancement but it leads to interference occuring. Channel congestion is identified through awareness packet loss since all cars broadcast information at the same moment. In addition, notification messages are updated following driving scenario situation such as it could be simple information or alerting messages in case of critical status. Indeed, each active vehicle transmits periodically notification to modify the behavior of its neighbor interacting in the same scenario and to give it a better view of the network. Congestion is the result of the great increase of cars in roads which implies a latency and collision towards the exchange of packets.

Each vehicle broadcast a set of information defining its position, speed, direction at a specific rate. Otherwise, facing the great demand of road safety, traffic congestion avoidance improves vehicular communication network which requires a quantification to ensure successful management. NR 5G support huge connectivity of nodes or vehicles exchanging information at high data rate with better coverage and reliability towards the offered services. NR 5G is adopted due to the high reliability, great support of cars mobility and huge bandwidth offered, in addition reliability depends on accurate exchange of information in real time between cars.

Channel saturation becomes challenging especially considering vehicular communication according to sidelink scenario of NR 5G mode 2 following millimeterWave frequencies.

By this way congestion overcoming is a great topic to ensure much safety. The probability of collision increases whenever all the cars wants to send notification simultaneously which implies a saturation towards the communication channel. Cars send a notification about their position, velocity to its neighbor in the way that the driver could be easily guided ensuring safety. Thus, the idea is to incorporate more advanced sensors providing much ability to avoid traffic problems. Notification is allowed through the different sensors who detect the situation of the road and generates the corresponding alert. Each vehicle broadcasts its identity in the way to inform its neighbor about the status of the traffic especillay in a platoon context. In this section we present a theoretical model of NR V2V for congestion management based on game theory exploitation which is a useful mathematical tool for multi-user scenario management since power transmission and throughput are considered efficient method for channel saturation investigation. Furthermore, game theory is used to analyze the interaction between vehicles in the case of NR V2V system. Specifically, NR V2V scenario is assimilated to gaming framework where a set of players move with a determinated strategy in non cooperative way. The dynamic movement of vehicles leads to instability into the network. The aim is congestion mitigation considering quality of service. In fact, congestion schema is assimilated in the way that each send packet is an interference compared to an other transmitted packet. In addition, to ensure much safety we need much transmitted power together with high data rate which provides channel saturation due to simultaneous exchange of information. In addition, in high density of vehicles there is a strong probablity that two cars share the same channel to send information which implies congestion as shown in figure (1).



### **Figure 1. Congestion architecture of NR 5G V2V model**

Congestion control algorithms are applied whenever channel saturation is detected which depends on the simultaneous transmission of safety messages. In other side, safety into roads depends on real reception of awareness messages requiring high data rate under the constraint of a limited transmitted power to overcome channel saturation. Otherwise, the aim is to improve the efficiency of vehicular network through data rate improvement avoiding interference happening which is a challenging issue especially in case of high vehicular mobility. Therefore, channel saturation could be defined by limited exploitation of resources serving for information notification exchange related to direction, speed and position. In addition, traffic jam leads to much accident with collision occurrence since in high density the distance separating the vehicles is slow which requires less transmitted power. Congestion control investigation is an important metric that requires investigation especially that the communication between vehicles is performed in sidelink way considering NR V2V mode 2. Congestion could happen whenever vehicular channel reaches its limit toward subchannel occupancy.

In addition, congestion management improves the performance of vehicular network in terms of bandwidth exploitation and reliability towards packets' safety. Traffic jamming leads to latency and packet drop which is a threat towards driving safety since congestion occurrence is due to different vehicles try to exploit the same channel transmitting safety messages in different directions. Channel congestion measure is based on the comparison between the instantaneous CBR, considered as traffic jam indicator, and the threshold. Whenever the measured CBR is superior than the threshold the channel is considered as busy and no transmission could happen that moment. CBR is considered as the returned feedback congestion indicator which allows efficient communication between cars. We should mention that the dynamic mobility of cars related to speed and position have an impact into congestion occurrence. Power adaptation is an important metric which is responsible for packet transmission that ensures channel saturation mitigation taking information from the connectivity status between vehicles. In particular, for efficient performance of decoding process the transmitted packet should be well received but in case of interference it will be very challenging task due to huge mobility of cars. Due to advanced features of NR V2V each vehicle is able to detect a non autonomous car and send awareness information about it to the other vehicles existing in the same area.



Additionally, transmission feedback is allowed whenever NR V2V is considered which is not possible if we exploit LTE-V for vehicular communication. Whenever all cars transmit with different data rate and power randomly a congestion could happen especially if two vehicles separated by a short distance exploit the same channel. Indeed, each car send the safety messages under the respect of a specific threshold especially that driving with high speed requires much consumed power. In this context game theory could be a powerful tool to manage the cooperation between cars regarding NR V2V scenario. Each car participating in the multiuser scenario is assimilated as an active player where the purpose is data rate enhancement which reminds the idea introduced in [33] where authors suggested non cooperative game theory for channel load diminishing in ad hoc vehicular context. In other side, each car try to send the awareness packet with high data rate to gain the priority which is constrained by the equal exploitation of the bandwidth. Note that, awareness messages change following the scenario behavior in dynamic way and have to be received at an accurate time to avoid accidents and collision. Congestion detection is measured by comparing the channel occupancy according to a threshold which could be better highlighted through game theory proposal representing a powerful tools to define vehicles' behavior. Congestion control depends on packet and power transmission in the case of traffic's density. We should mention that all vehicles cooperate through PC5 interface. Channel jamming depends on the optimal data rate or transmitted power allocation, for this we investigate game theory for power allocation. Considering that each vehicle is defined following a velocity  $v$  corresponding to a localization  $x$ , the idea is to determine the accurate utility function in the way to ensure much safety satisfaction. Let  $K$  the set of the overall vehicles denoted by  $k$  where  $S = \{1, 2, \dots, K\}$  moving in a highway context where the purpose is data rate maximization under the respect of a determined  $CBR_{Threshold}$ . The data rate of a vehicle  $k$  is denoted by  $R_k$ . The focus is to attend the Nash Equilibrium where the strategy is based on the way that each vehicle representing a player occupies a channel for notification's message. The idea is to adapt the transmitted power according to channel density status. Let the vector of transmitted power by  $K$  vehicles is defined by :  $P = \{P_1, \dots, P_k\}$ . There is a required data rate for each vehicle to send its notification which is denoted by  $R_k$  where  $k$  is the index of the  $k$ th car. Thus, the vehicle's transmitted rate could be expressed by :

$$R_k(p_k, p_{-k}) = W \log_2(1 + \gamma_k) \quad (2)$$

Being :

$W$  : the bandwidth

$\gamma_k$  : the reachable SINR of the kth vehicle represented by :

$$\gamma_{k(p_k, p_{-k})} = \frac{P_k h_k}{\sum_{i \neq k} p_i h_i + \sigma^2} \quad (3)$$

where  $\sigma^2$  stands for the additive gaussian white noise and  $h_k$  corresponds to the channel gain.  $P_k$  is the transmitted power of the kth vehicle.  $P_{-k}$  refers to the transmitted power different than the kth vehicle. In particular, the overall data rate of all vehicles cooperating in a highway scenario is expressed by :

$$R = \sum_{k=1}^K R_k \quad (4)$$

where  $K$  refers to the total number of cars moving in the same area. By this way the optimization problem could be expressed by :

$$\begin{aligned} & \max_{P_k} R_k \\ & \text{under the respect of } \sum_{k \in K} P_k \leq P_{\max} \end{aligned} \quad (5)$$

Which implies that the overall transmitted power by the  $K$  vehicles is limited by the maximum threshold  $P_{\max}$  which is helpful to ensure energy efficiency improvement which reminds waterfilling approach. Correspondly, the resolution of the optimization problem relies on Waterfilling policy performed in iterative manner such that the power is allocated with enhancing the data rate. Therefore, power control framework could be modeled through game theory in which each car try to find the best strategy allowing transmitted power minimization. Nash equilibrium is performed once optimal power control of non cooperative game is achieved. In addition, high data rate is required for better quality of service highlighted through vehicular communication efficiency. Knowing the status of the channel is mandatory to avoid congestion. In addition, congestion occurrence depends on the instantaneous measured CBR corresponding to the channel occupancy of the kth vehicle compared to a fixed threshold  $CBR_{\text{threshold}}$  such that once CBR is superior than  $CBR_{\text{threshold}}$  the transmitted power is minimized. Thus, once the determined CBR is inferior than  $CBR_{\text{threshold}}$  maximum transmitted power is exploited which allows notification messages optimization. The goal is to transmit notification with high data rate following lower congestion taking into account fairness toward resource sharing. The idea is based on data rate of each car management in the way to reach the Nash

Equilibrium. Specifically, each vehicle tries to send an efficient message with high data rate and power which ensures channel saturation. Therefore, transmitted power is adjusted in the way to diminish channel saturation. The utility function  $U_k$  corresponds to the amount of satisfaction of the  $k$ th car. Due to non-cooperative driving behavior of each vehicle we consider a game theory defined through  $G = \{S, C_k, U_k\}$  where  $S$  stands for the set of cars indexed by  $S = \{1, \dots, K\}$  moving in a highway scenario,  $C_k$  corresponds to the strategy defined by  $C_k = \{\sum_{k \in K} P_k \leq P_{\max}, P_k \geq 0\}$ . The idea is to determine the accurate utility function, corresponding to user's satisfaction. Congestion ensures serious problems especially whenever emergency messages should be sent at an accurate time. In other side, safety into roads requires huge exchange of notification messages which in the case of high density results in interference problems leading to drop of information packets for the case of cars presenting lower range of utility. In this regard, in the case of channel saturation CBR shows high rate due to the interference high rate. For this we suggest game theory policy for modeling the set of vehicles moving into a highway scenario in the way that each vehicle has a data rate of  $R_k$  where the utility function could be represented as [34] :

$$U_k(P_k, P_{-k}) = R_k(P_k, P_{-k}) - \lambda P_k \quad (6)$$

Let  $\lambda$  represents the cost of the transmitted power where more details are presented in [35]. Nash equilibrium corresponding to the optimal solution determination relies on the respect of the following condition :

$$U_k(P_k^*, P_{-k}^*) \geq U_k(P_k, P_{-k}^*) \quad (7)$$

Where  $P_k \in C_k$  and  $P_k \geq 0$

The optimal solution is determined by setting the derivative of the ratio between  $U_k(P_k, P_{-k})$  and  $P_k$ , to zero yields :

$$\frac{\partial U_k(P_k, P_{-k})}{\partial P_k} = 0 \quad (8)$$

Following (8) we obtain :

$$\frac{h_k}{\sum_{i \neq k} p_i h_i + \sigma^2} - \lambda = 0 \quad (9)$$

The solution is similar to Water-filling policy could be expressed by :

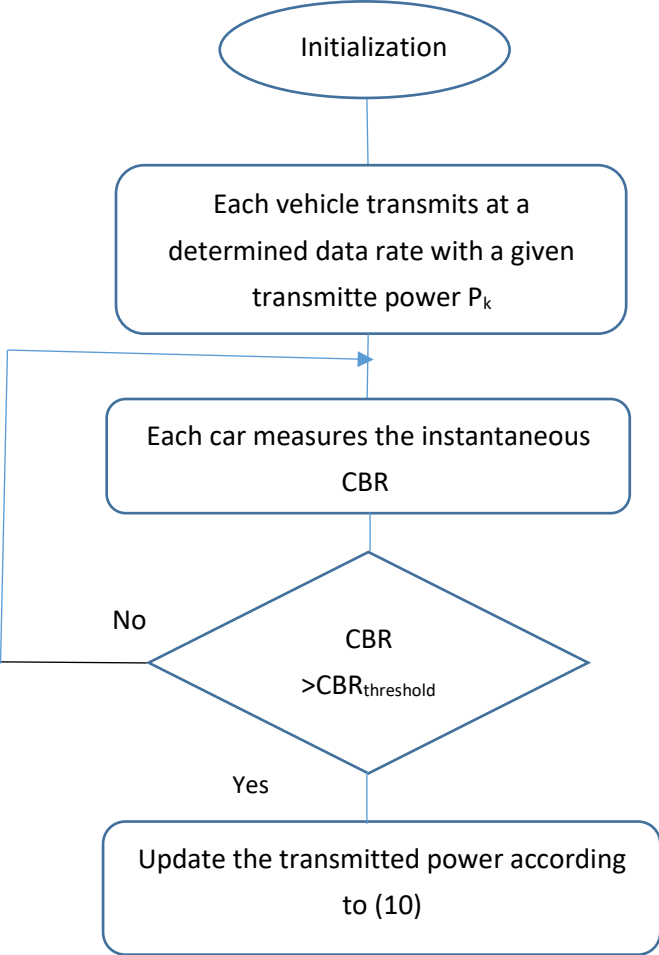
$$P_k^* = \left( \frac{1}{\lambda} - \frac{\sum_{i \neq k} P_i h_i + \sigma^2}{|h_k|^2} \right)^+ \quad (10)$$

The equation (10) allows to determine the overall power by :

$$P = \sum_{k \in K} P_k \quad (11)$$

The idea is that each vehicle measures channel loading through CBR metric instantaneously and compares it to  $CBR_{target}$  whenever  $CBR > CBR_{target}$  the power should be allocated through the obtained solution (10). CBR criterion is an important metric measuring the channel occupancy at a specific time could be represented by a ratio of channel loading time and the overall time of observation. The proposed algorithm is illustrated following the graph in Figure 2 showing that once congestion is detected each vehicle provides selfish behavior in terms of power allocation. Specifically, CBR metric is efficient metric for dynamic power allocation in terms of vehicular interference information especially for vehicles moving in high speed requiring much power. In addition, whenever vehicles are separated with high distance the transmitted power increase. Transmitted power adjustment is based on channel status allowing further efficient transmission of awareness messages. The idea is to ensure fairness towards spectrum sharing without exceeding the limited transmitted power especially that vehicles transmit with different data rate at different transmitted power  $P_k$  in which safety messages are transmitted with a data rate  $R_k$ . In fact, the aim of the proposed algorithm is to ensure efficiency toward vehicular network with the maintain of CBR metric at the specified  $CBR_{threshold}$ . The graph in figure 2 shows the different steps of CBR measurement to adjust the transmitted power. The transmitted power is assigned to each car in the way to maximize the utility and avoid channel saturation. In other side, the proposed approach is about fairness ensuring towards channel assignment to the different cars participating in the same scenario. The aim is that the vehicles cooperating in the same scenario send messages with different powers which results in better resource assignment. In fact, cars transmitted with high power requires large bandwidth for this adaptation is required to overcome channel saturation. Otherwise, efficient management of the transmitted power leads to successful decoding process. In fact, the transmitted power is adapted following the received feedback measured via CBR criterion. Therefore, each active vehicle transmitted periodically its CBR corresponding to the occupied channel which helps further to adapt the transmitted power and the speed further. Otherwise, channel saturation avoidance depends on the respect of the  $CBR_{threshold}$ . Whenever congestion is detected

transmitted power have to be adapted following (10) in the way to allow the broadcast of critical messages transmission.



**Figure 2: Congestion control approach**

We should mention that if the different vehicles participating in the scenario transmit at different levels it could affect the communication range. In this regard, power allocation method could be a suitable solution for a platoon scenario.

**V.Conclusion**

According to great improvement of cars mobility and due to the requirement of advanced services to ensure high reliability, vehicular communication enablers are migrating from phase to another to satisfy the requirement of driving safety. The rapid progressing of wireless

communication systems together with the growing density of traffic implies a requirement of advanced vehicles supporting new sensors providing quick detection following much reliability. Automotive enablers are improving in the way to provide new experience of driving. The most challenging problem for V2V communication is congestion due to great enhancement of cars' density in roads. In this survey we concentrated on congestion mitigation considering V2V communication enabled by NR 5G allowing huge connectivity. In this survey we presented an overview about existing congestion control algorithms such as LIMERIC, DCC and we formulated channel saturation with game theory where the goal is transmitted power adaptation. We started by presenting an overview about the different exploited congestion control algorithms. Next, the aim was to suggest a power adaptation proposal based on water-filling policy depending on channel occupancy. Thus, channel occupancy is measured by CBR metric such that congestion is detected whenever CBR reaches a convergence. Generally, traffic jam avoidance allows efficient bandwidth exploitation which is based on a defined features examination, for our investigation the heuristic solution is defined following Water-Filling policy. In fact, the idea is to exploit dynamic power allocation method to control channel loading based on the instantaneous measured CBR that will be compared to  $CBR_{Threshold}$  further. Game theory proposal is exploited to show power adaptation impact for channel saturation diminishing. We exploited CBR criterion as indicator reflecting the behaviour of traffic load. Furthermore, whenever CBR value converges power is adapted in dynamic way which enhances the energy efficiency. An important issue should be examined is the allocation of resource block between cars if we exploit NR 5G as enabler for V2V. Another challenge should be investigated is the security toward data information exchange. Expected new advanced features for connectivity with huge energy efficiency could be enabled considering 6G future technology through THz spectrum possibility.

## **V.Declaration**

Not applicable

## **VI.REFERENCES :**

[1] Wenfeng Lia, Wuli Songa, Qiang Lua, Chao YueWenfeng Lia, Wuli Songa , Qiang Lua , Chao Yue, » Reliable Congestion Control Mechanism for Safety Applications in Urban VANETs, » Journal of Ad Hoc Networks 2019.

- [2] Yang Yang, Kun Hua, » Emerging Technologies for 5G-Enabled Vehicular Networks », IEEE Access 2019.
- [3] Balawal Shabir, Muazzam A. Khan, Anis U. Rahman, Asad W. Malik, and Abdul Waæhid, » Congestion Avoidance in Vehicular Networks: A Contemporary Survey, » IEEE Access 2019.
- [4] Adel Mansouri, Vincent Martinez, Jérôme Härri, » A First Investigation of Congestion Control for LTE-V2X Mode 4, »15TH IEEE WOS conf. 2019.
- [5] Alexandros Kostopoulos, Ioannis Chochliouros, Jaime Ferragut, Yi Ma, Matti Kuttila, Anastasius Gavras, Seppo Horsmanheimo, Kai Zhang, Latif Ladid, Athanassios Dardamanis, Michail-Alexandros Kourtis, » Use Cases and Standardisation Activities for eMBB and V2X Scenarios, » ICC workshop 2020.
- [6] Hui Huang, Huiyun LI, Cuiping Shao, Tianfu Sun, Wenqi Fang and Shaobo Dang, » Data Redundancy Mitigation in V2X Based Collective Perceptions, » vol 8, IEEE Access 2020.
- [7] Gaurang Naik, Biplav Choudhury and Jung-Min (Jerry) Park » IEEE 802.11bd & 5G NR V2X: Evolution of Radio Access Technologies for V2X Communications, » IEEE Access 2019.
- [8] Tommaso Zugno, Matteo Drago, Marco Giordani, Michele Polese and Michele Zorzi,» Towards Standardization of Millimeter Wave Vehicle-to-Vehicle Networks: Open Challenges and Performance Evaluation, » arXiv:1910.00300 2020.
- [9] Valerian Mannoni, Vincent Berg, Stefania Sesia and Eric Perraud, » A Comparison of the V2X Communication Systems: ITS-G5 and C-V2X, » IEEE Vehicular Technology Conference Spring VTC2019 .
- [10] Miguel Sepulcre , Jorge Mira , Gokulnath Thandavarayan and Javier Gozalvez, » Is Packet Dropping a Suitable Congestion Control Mechanism for Vehicular Networks, » 91st IEEE Vehicular Technology Conference Spring 2020.
- [11] Claudia Campolo , Antonella Molinaro, Francesco Romeo, Alessandro Bazzi and Antoine O. Berthet, » 5G NR V2X: On the Impact of a Flexible Numerology on the Autonomous Sidelink Mode, » IEEE 5G World Forum 2019.
- [12] Vishal Sharma, Ilsun You, Nadra Guizani, » Security of 5G-V2X: Technologies, Standardization and Research Directions, » arXiv :1905.09555 2019.
- [13] Syed Husain , Andreas Kunz , Athul Prasad and Emmanouil Pateromichelakis, » Ultra-High Reliable 5G V2X Communications, » vol 3, issue 2, IEEE Communications Standards Magazine 2019.
- [14] Abdallah Moubayed, Abdallah Shami , Parisa Heidari , Adel Larabi and Richard Brunner, » Edge-enabled V2X Service Placement for Intelligent Transportation Systems, » IEEE Transactions on Mobile Computing 2020.

- [15] Rafael Molina-Masegosa, Javier Gozalvez and Miguel Sepulcre, « Comparison of IEEE 802.11p and LTE-V2X: An Evaluation with Periodic and Aperiodic Messages of Constant and Variable Size, » IEEE Access 2020.
- [16] Nestor Bonjorn, Fotis Foukalas, Ferran Cañellas and Paul Pop, » Cooperative Resource Allocation and Scheduling for 5G eV2X Services, » IEEE Access 2019.
- [17] Yeomyung Yoon, and Hyogon Kim, » Balancing Power and Rate Control for Improved Congestion Control in Cellular V2X Communication Environments, » IEEE Access 2020.
- [18] Gaurang Naik, Jung-Min (Jerry) Park and Jonathan Ashdown, » C2 RC: Channel Congestion-based Re-transmission Control for 3GPP-based V2X Technologies, » IEEE WCNC 2020.
- [19] Vishal Sharma, Ilsun You and Nadra Guizani, » Security of 5G-V2X: Technologies, Standardization and Research Directions, » arXiv :1905.09555 2019.
- [20] Syed Husain, Andreas Kunz , Athul Prasad and Emmanouil Pateromichelakis, » Ultra-High Reliable 5G V2X Communications, » vol 3, issue 2, IEEE Communications Standards Magazine 2019.
- [21] David Garcia Roger, Edgar E. González, David Martín Sacristan, and Jose F. Monserrat, » V2X Support in 3GPP Specifications: From 4G to 5G and Beyond, » vol 8, IEEE Access 2020.
- [22] Abdallah Moubayed , Abdallah Shami, Parisa Heidari, Adel Larabi, and Richard Brunner, » Edge enabled V2X Service Placement for Intelligent Transportation Systems, » IEEE Transactions on Mobile Computing 2020.
- [23] Rafael Molina-Masegosa, Javier Gozalvez and Miguel Sepulcre, « Comparison of IEEE 802.11p and LTE-V2X: An Evaluation with Periodic and Aperiodic Messages of Constant and Variable Size, » IEEE Access 2020.
- [24] Tommaso Zugno, Matteo Drago, Marco Giordani, Michele Polese and Michele Zorzi, » NR V2X Communications at Millimeter Waves: An End-to-End Performance Evaluation, » IEEE Globecom 2020.
- [25] Gokulnath Thandavarayan, Miguel Sepulcre, and Javier Gozalvez, » Cooperative Perception for Connected and Automated Vehicles: Evaluation and Impact of Congestion Control, » Vol 8, IEEE Access 2020.
- [26] H. Chihi, R. Zitouni, R. Bouallegue and A.R. Cherif, » Latency Aware Into LTE-V2X Mode 4 System, IEEE 14th SITIS 2018.
- [27] H. Chihi, R. Bouallegue, » stackelberg game exploitation for power minimization over LTE-V Mode 4, » vol.11, Journal of information and telecommunication sciences, 2020.
- [28] Giammarco Cecchini, Alessandro Bazzi, Barbara M. Masini and Alberto Zanella, » Performance Comparison Between IEEE 802.11p and LTE-V2V In-coverage and Out-of-coverage for Cooperative Awareness, » IEEE Vehicular Networking Conference 2017.



- [29] Oskari Tervo, Toni Levanen, Kari Pajukoski, Jari Hulkkonen, Pekka Wainio, and Mikko Valkama, » 5G New Radio Evolution Towards Sub-THz Communications, » IEEE 6G Wireless Summit 2020.
- [30] John B. Kenney, Gaurav Bansal, Charles E. Rohrs, » LIMERIC: A Linear Message Rate Control Algorithm for Vehicular DSRC Systems, » vol 62, IEEE Transactions on Vehicular Technology , Issue 9, Nov. 2013.
- [31] Behrad Toghi , Md Saifuddin , Yaser P. Fallah , M. O. MughalBehrad Toghi , Md Saifuddin, Yaser P. Fallah and M. O. Mughal, » Analysis of Distributed Congestion Control in Cellular Vehicle-to-everything Networks, » IEEE 90th Vehicular Technology Conference 2019.
- [32] Ali Rostami, Bin Cheng, Gaurav Bansal, Katrin Sjoberg, Marco Gruteser and John B. Kenney, « Stability Challenges and Enhancements for Vehicular Channel Congestion Control Approaches, » IEEE Transactions on Intelligent Transportation Systems 2016.
- [33] Hayder Amer, Hayder Al-Kashoash, Mohammed J Khami, Martin Mayfield, Lyudmila Mihaylova, » Non-cooperative game based congestion control for data rate optimization in vehicular ad hoc networks, » vol 107, Elsevier Ad Hoc Networks, October 2020.
- [34] Yanxiang Jiang, Hui Ge, Mehdi Bennis, Fu-Chun Zheng, and Xiaohu You, Fellow, IEEE, » Power Control via Stackelberg Game for Small-Cell Networks, » Journal of Wireless Communications and Mobile Computing 2019.
- [35] Y. Li, L. Xiao, J. Liu, and Y. Tang, “Power control Stackelberg game in cooperative anti-jamming communications,” 5th IEEE Gamenets, china, 2014.
- [36] Emre Gures, Ibraheem Shayea, Abdulraqeb Alhammadi, Mustafa Ergen, and Hafizal Mohamad, » A Comprehensive Survey on Mobility Management in 5G Heterogeneous Networks: Architectures, Challenges and Solutions, » vol 8 Access.2020
- [37] Omar Sami Oubbati, Mohammed Atiquzzaman, Pascal Lorenz, Abdullah Baz, and Hosam Alhakami, « SEARCH: An SDN-enabled Approach for Vehicle Path-Planning, » IEEE Transactions on Vehicular Technology 2020.





# Figures

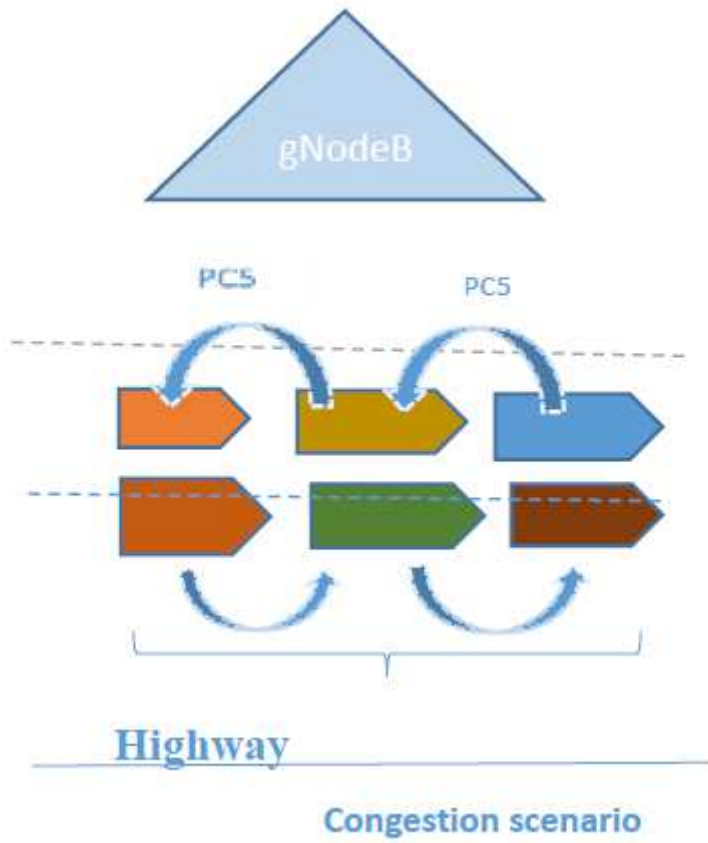


Figure 1

Congestion architecture of NR 5G V2V model

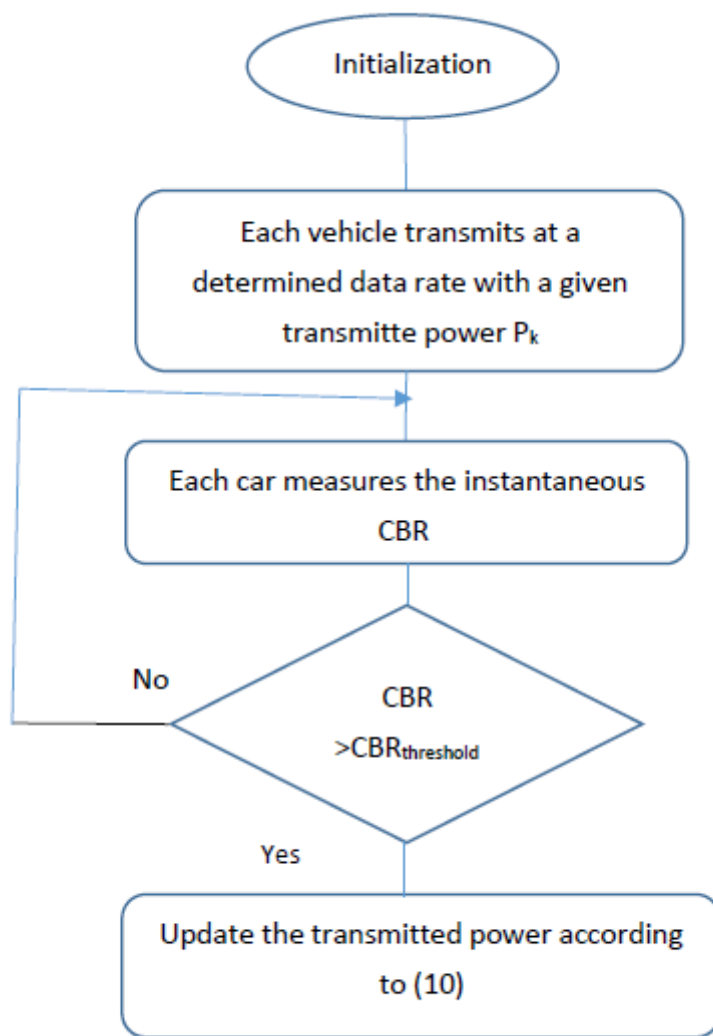


Figure 2

Congestion control approach