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STACKELBERG GAME EXPLOITATION FOR POWERMINIMIZATION OVER LTE-V MODE 4

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Background. Due to the great increase of accident into roads, vehicular communication becomes the focus of many researchers. Therefore vehicular communication is becoming an active topic of search. That's why safety driving is the main concern of many researcher to mitigate congestion problems specifically following urban scenario. Due to the requirement of URLLC, we investigate in this paper the importance of power diminishing. In fact, power minimization is an interesting metric due to the requirement of high data rates.

Objective. The aim of the paper is to investigate power allocation into LTE-V system following a decentralized scenario.

Methods. The idea is to consider a platoon with a set of vehicles interacting together for network resources without the help of ENodeB. Power consumption minimization is a promising solution for interference diminishing since vehicles communicate according to a decentralized way. In this regard the theoretical analysis is based on applying stackelberg game policy for power control in the way to minimize interference.

Results. We conclude that stackelberg game policy is a powerful tool for interference and power consumption management. Computer results highlight the efficiency of SK game for power allocation into a decentralized scenario.

Conclusions. Vehicular Autonomous communication attracted the attention of many researchers according to increasing number of congestion together with traffic problems. In addition, to ensure better safety we adopt platooning scenario which enables mitigations of many problems such as collisions, congestion. Inter-car communication is an interesting topic of search to ensure safety into-roads. In addition, platooning has the potential to ensure safety with low energy consumption specifically towards urban traffic. In addition, LTE-V is a heuristic solution for vehicular communication where the connectivity is performed in a decentralized context without the requirement of the ENodeB.

Keywords: stackelberg game; LTE-V; platoon; interference.

I. INTRODUCTION

Due to the great increase of accident into roads, vehicular communication becomes the focus of many researchers. Therefore vehicular communication is becoming an active topic of search. That's why safety driving is the main concern of many researcher to mitigate congestion problems specifically following urban scenario. Due to the requirement of URLLC, we investigate in this paper the importance of power diminishing. In fact, power minimization is an interesting metric due to the requirement of high data rates.

The enhancement of traffic congestion joint with accident occurrence motivates many researchers to focus on vehicular communication.

In [1], the idea was to exploit resource allocation for latency minimization together with reliability ensuring. Authors in [2] presented an accurate description of the physical layer structure relied to LTE-V R14. Examination work presented in [3] was about performance analysis of LTE-V platooning scenario in terms of latency and throughput for differents layers. In [4], authors investigated the performance of LTE-V in terms of different indicators such as packet error rate and delay. In our previous work [5], the objective was to investigate the latency for LTE-V mode 4 by considering an urban scenario. The contribution in [6] was stackelberg game tools exploitation for power expenditure minimization into small cells according to an uplink scenario. Stackelberg game (SK) was also proposed in [7] for power minimization and throughput enhancement for D2D system. In [8], authors investigated differents types of platoon 's stabiltiy for latency examination. In [9], the idea is interference examination through power control into a device to device scenario using stackelberg game tools. Reference [10] exploits SK game for power allocation and interference management for a heterogeneous scenario. SK game principle is exploited in [11] for power allocation into small cell for interference reduction.

In particular, in this paper we investigate power consumption into LTE-V system.

In this contribution, we examine the challenges of power expenditure and interference into LTE-V Mode 4 system.

The rest of this paper is structured as the following. Section II presents LTE-V system description. The modelling is explained in section III. We state the theoretical analysis and problem formulation in section IV. Simulation results will be the purpose of section V. At the end, we state the conclusion in section VI.

II. LTE-V SYSTEM DESCRIPTION

Since LTE-V technology was recognized by the high data rates, it is adopted as a powerful technology enabling vehicular communication. Indeed, LTE-V is considered as a cellular enabler providing connectivity between cars. In other side, LTE technology is a promising technology allowing high data rates.

LTE-V R14 is defined following two types such as mode 3 where vehicles communicates with the help of ENodeB, mode 4 stands for an autonomous context in which cars interacts in decentralized way without the requirement of ENodeB. The communication is performed through smart devices incorporation ensuring safety into roads.

The driver is alerted frequently for each detected problem whether it is related to possibility of collision or other type of accident. In this regard, the considered vehicle broadcasts the information to its neighbors. The communication between cars is performed directly through PC5 without the help of the ENodeB. Safety requires reliability in the regard of information exchange especially when the considered scenario is side link. The periodic messages' exchange is about velocity, position, road's behavior. Note that the transmitted messages are updated during the travel. The exchanged information prevent from traffic jamming avoiding collision. The communication is enabled through On Board Units (OBU) integration. Otherwise, the

interaction between vehicles is performed in sidelink way where the driver receives instantaneous warning messages. The communication between vehicles is performed in direct way according to a decentralized scenario following a platoon scenario.

Resource block allocation is performed randomly between cars without the help of the ENodeB. Indeed, the platoon leader manages resource block assignement. Hence, the interference represents a challenging problem in this case.

III.   MODELING

The considered scenario is based on urban traffic where vehicles communicate exploiting LTE-V technology following a platoon approach. LTE-V is the adopted cellular technology allowing vehicular communication following a platoon scenario. In addition, platoon scheme helps on energy efficiency improvement and congestion minimization.

We consider a set of cars denoted by $S_k=\{1,2,…, K\}$ arranged following a platoon scenario. Each vehicle is identified by its velocity, position and acceleration. Vehicles interact in noncooperative way where the inter-vehicle distance is the same.

The coordination between followers is enabled by the leader since coordination is important to ensure stability of the platoon. The platoon scenario is composed of a leader and K followers in which the leader moves firstly. Note that Platoon represents a cluster of vehicles exchanging information related to road status such as speed, traffic. We denote by K the size of the considered platoon. Note that Platooning is a prominent solution which manages the traffic. The spacing between vehicles is assumed the same in which the leader starts by sending the required actions that follower should do in the second step. The leader starts by sending its own velocity to the follower to know how to react. Therefore, the communication between cars is done directly through PC5 protocol without the requirement of ENodeB. Furthermore, decentralized approach is interesting since it shows the behaviour of each vehicle.

Platooning arrangement is a powerful schema for power expenditure mitigation but the space between vehicles should be maintained to ensure stability. The communication is performed through sensors integration. The considered platoon model is represented by Figure 1.1 which is composed of a leader responsible of transmitting strategy to the other followers. Note that since we consider autonomous communication without the need of the ENodeB , exchange of information between cars is performed via PC5 protocol.

Stackelberg game method is based on a leader with a set of follower moving in a noncooperative way. We assume that the leader moves at first followed by the other cars.

We consider a leader and a set of follower S_k moving following a platoon scenario which provides efficiency in driving. We denote by the first car as the leader of the platoon exchanging information with the other vehicles acting as follower. The aim of platoon exploitation is driving stability. The shared messages are transmitted via PC5 interface.

Otherwise, follower strategy is based on the leader reaction. The leader starts by sending its own position, velocity to the other follower which reply by acting by the same acceleration to keep the platoon stability. In addition, interference implies traffic problems especially in the case of information exchange since data should be transmitted in real time. That's why the power consumption diminishing is the key indicator for interference reduction. In other side, energy expenditure depends on cars' speed. Therefore, the coordination between the leader and the followers into the platoon has the potential to minimize fuel expenditure and it's a better solution for traffic management.

The set of vehicles is indexed by k where each vehicle transmits a packet of information following a given transmitted power P_k.

Moreover, the first vehicles represents the leader which is responsible of broadcasting safety messages related to speed, distance and position. Afterwards, the driving strategy is planned by the leader in which the outcome is to reach the Stackelberg equilibrium (SE).

We should mention that communication between cars is done without the help of the ENodeB according to a decentralized scenario.
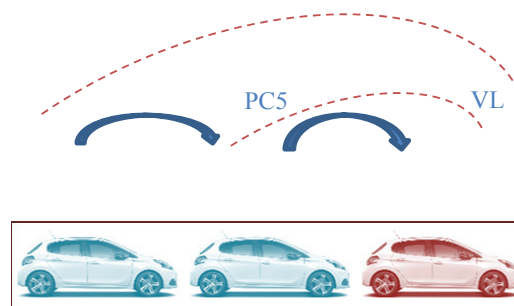

Figure 1.1. Platooning LTE-V model

IV.   PROBLEM FORMULATION

Vehicles' behaviour into the platoon scenario is highlighted following a theoretical analysis where we start by defining the channel model by :

$$Y_{k,i} = h_{k,i}\, x_{k,i} + N_o \qquad (1)$$

Where :

- $Y_{k,i}$: corresponds to the kth vehicle's received signal following the ith RB.

- $h_{k,i}$: channel gain

- $x_{k,i}$: transmitted signal related to the kth vehicle.

- N_o : Noise variance

The aim is utility maximization under the constraint of power. The set of vehicles is defined by $S_k = [1,2…K]$. We exploit stackelberg game tools to define the non cooperative interaction between cars. Stackelberg game (SK) is exploited for power consumption minimization purpose. Indeed, SK

game is based on a leader who states the strategy for a set of follower , which is a powerful tool to investigate the interaction between cars.

In addition, power allocation is an important metric for interference minimization especially as vehicles' speed varies according to the traffic condition. The idea is to adjust dynamically the transmitted power according to the SK policy.

Furthermore, if we consider a set of vehicles where each one trying to increase its own power, the interference could be enhanced. For this reason, a transmitted power algorithm should be applied.

In stackelberg game, each vehicle selects its own power strategy depending on the leader activity.

We denote by P_k, $=[P_1, P_2, \ldots P_K]$ the transmitted power vector of K vehicles which respects a maximum transmitted power Pmax. Therefore, each vehicle should control its transmitted power for interference mitigation since data exchange between cars requires more energy. The purpose is to determine the optimal transmitted power serving for utility maximization. Indeed, the leader exploits more transmitted power to send information about the required strategy for the follower.

To achive this objective,the utiliyy function is defined as a function of the throughput and transmit power.

The Stackelberg game is defined by $F=\{ S_k, P_k, U_k\}$ in which S_k corresponds to the set of players or cars in our case P_k the the transmitted power strategy corresponding to the kth player, U_k stands for the utiliy function. Let $U_L(P_L)$ is the utility function of the leader and $U_k (P_k, P_{-k})$ is the utility function of the followers. The transmitted power of the kth vehicle is denoted by P_k which is limited to a maximum threshold denoted by P_{max}.

Hence, the optimization problem could be represented respectively by:

Problem I :

$$\max U_L(P_L) \qquad (2)$$
$$P_L < P_{max}$$

Problem II :

$$\max U_k (P_k, P_{-k}) \qquad (3)$$
$$P_k < P_{max}$$

where P_{max} : represents the maximal transmitted power of cars. To ensure fairness between cars, a limited total transmitted power P_{max} should be respected. Otherwise, fairness between cars is mondatry feature into a platoon due to the data exchanged between vehicles. In addition, resource blcok assignement is performed with the help of the platoon leader.

Note that utility function denotes the satisfaction of a player, the optimization problem is analyzed using stackelberg game tools. Furthermore, the exchanged information between cars is performed by defining a packet with a length L and a transmitted data rate R expressed in (bit/s). Thus, the throughput is expressed by [9]:

$$T_{v,k} = R_{v,k} \, f(\gamma_{v,k}) \qquad (4)$$

where $f(\gamma_{v,k})$ is the efficiency function representing the successful reception of packets which is defined by $[0,1]$ values. According to [13] the efficiency function $f(\gamma_k)$ could be expressed by :

$$f(\gamma_k) = (1 - \exp(-\gamma_k))^L \qquad (5)$$

where γ_k stands for the received SINR by the kth car towards the corresponding resource block which could be represented by :

$$\gamma_k(P_k, P_{-k}) = \frac{P_k \, h_k}{\sum_{j \neq k}^{J} P_j \, h_j + \delta_k^2} \qquad (6)$$

where :

- P_{-k} the corresponding transmitted power of another vehicle different of the kth car.

- h_k represents the channel gain of the kth vehicle

Note that the reliability is performed whenever $\gamma_k \geq \gamma_0$ in which γ_0 refers to the threshold SINR. We should mention that this condition is defined with the maximum limited transmitted power P_{max}.

The utility function of each car is maximized independently following non cooperative game. The utility function is expressed by [12]:

$$U(P_k, P_{-k}) = T_k / P_k = (R_k * f(\gamma_k)) / P_k \qquad (7)$$

where:

P_k corresponds to the transmitted power of the kth vehicle. P_{-k} corresponds to the power of a car other than vehicle k. Otherwise, the utility function stands for the amount of the transmitted information. By the way the Stackelberg equilibrium (SE) for the considered stackelberg game is defined by (P_L^*, P_f^*) where P_L^* corresponds to problem I solution and P_f^* stands for problem II solution. We should mention that the utility's expression depicted in (7) is expressed in bits/Joule.

Firstly, the following condition should be respected:

$$U_L(P_L^*) > U_L(P_L) \qquad (8)$$

$$U_f (P_f^*, P_{-f}^*) > U_f(P_f, P_{-f}^*)$$

Note that the followers' startegy is to adjust the transmitted power in the way to maximize the utility in noncooperative way.

The next purpose is to determine the Nash equilibrium (NE) of SK ensuring no deviation. NE is defined through optimal power strategy. Therefore, NE is determined by taking the first derivative of utility function with respect to transmit power P_K as:

$$\frac{d\gamma_k \, (PK, P-K)}{dp_K} = 0, \text{ where k=1,} \ldots K \qquad (9)$$

Note that γ_k (P_k, P_{-k}) is defined in (6). Equation (9) relies to the derivation of γ_k According to [12]. By this way (9) could be expressed by:

$$\frac{\partial U_k}{\partial P_k} = \frac{R}{P_k^2} \left(\gamma_k \; \frac{df(\gamma_k)}{d\gamma_k} - (\gamma_k) \right) \tag{10}$$

By this way the optimal transmitted power P_k^* required for utility maximization corresponds to:

$$f\,'(\gamma_k)\gamma_k - f(\gamma_k) = 0 \tag{11}$$

Note that utility's vehicle could be maximized whenever SINR denoted by $\gamma k = \widetilde{\gamma_k}$ representing equilibrium status which implies that the transmitted power is expressed by:

$$P_k = [\widetilde{\gamma_k} * (\sum_{k \neq j}^{K} h_k * p_{ki} + \sigma^2)]/h_k \tag{12}$$

Being:

σ^2 stands for the received noise's power reception.

V. NUMERICAL ANALYSIS

In this section, we evaluate the performance of the decentralized platoon scheme. Figure 2 highlights the utility function of different follower versus the iteration number. The potential of the optimization problem is shown through simulation results.We consider each packet composed of 100 Kbits of information bits. The considered maximum threshold power is 2 W. We consider 4 number of vehicles interacting into a decentralized scenario.We have to mention that we adopt the pathloss model related to urban scenario detailed in [14]. The noise variance is stated at 5.10^{-13} W.
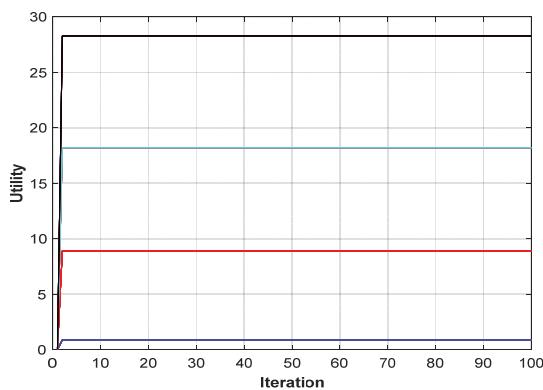

Fig1.Utility illustration vs iteration

We remark from the obtained results that the utility improves until a constant value as the iteration number enhances. It is highlighted different utility levels corresponding to different vehicles occupying different resource blocks at variable positions. The primary follower shows best utility's level. Let us sup up the energy efficiency increases, as the follower is closer to the leader.

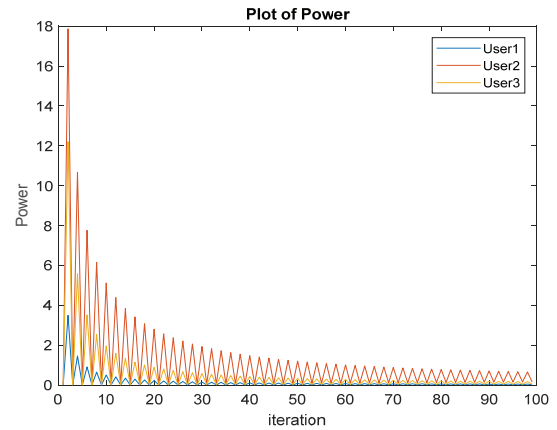It is illustrated high value of utility performed by the first follower.

FIG.2   TRANSMITTED   POWER   ILLUSTRATION   VERSUS ITERATION NUMBER

Fig.2 highlights a comparaison of the transmitted power of different followers versus iteration number. We observe a diminishing into the transmitted power whenever the iteration number is progressing under the respect of maximum threshold P_{max}. The proximity of the follower compared to the leader implies that the transmitted power depends on the pathloss in this case. We should mention that whenever the distance between the leader and the follower is important, the transmitted power is minimized due to the delay of exchanged information such that resource block assignement requires much time. In addition, the set of cars interacts in non cooperative way.

VI. CONCLUSION

vehicular Autonomous communication attracted the attention of many researcher accoding to increasing number of congestion together with traffic problems. In addition, to ensure better safety we adopt platooning scenario which enables mitigations of many problems such as collisions, congestion. Inter-car communication is an interesting topic of search to ensure satefy into-roads. In addition, platooning has the potential to ensure safety with low energy consumption specifically towards urban traffic. In addition, LTE-V is a heuristic solution for vehicular communication where the connectivity is performed in a decentralized context without the requirement of the ENodeB. Therefore, safety is more ensured with platooning scenario. We conclude that platooning is a heuristic solution for cars cooperation into a decentralized scenario. We adopt the approach of Stackelberg game principle to maximize the utility function constrained by power allocation. We conclude that stackelberg game policy is a powerful tool for interference and power consumption management. Computer results highlight the efficiency of SK game for power allocation into a decentralized scenario. Further work consider stability into platoon scenario taking into account other performance indicators such as packet error rate.

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Використання теорії ігор Stackelberg для мінімізації потужності в режимі LTE-V 4

Проблематика. Через велику кількість аварій на дорогах автомобільний зв'язок стає предметом уваги багатьох дослідників. Тому безпека водіння є головною турботою багатьох дослідників, щоб пом'якшити проблеми заторів, особливо за міським сценарієм. У зв'язку з вимогою URLLC, в цій статті ми досліджуємо важливість зменшення потужності. Фактично, мінімізація потужності є цікавою метрикою через вимоги високої швидкості передачі даних.

Мета дослідження. Метою даної роботи є дослідження розподілу потужності в системі LTE-V за децентралізованим сценарієм.

Методика реалізації. Ідея полягає в тому, щоб розглянути групу з набором транспортних засобів, що взаємодіють один з одним для мережевих ресурсів без допомоги ENodeB. Мінімізація енергоспоживання є багатообіцяючим рішенням для зменшення перешкод, оскільки транспортні засоби взаємодіють децентралізовано. В цьому відношенні теоретичний аналіз заснований на застосуванні ігровий політики Stackelberg для управління потужністю таким чином, щоб мінімізувати перешкоди.

Результати досліджень. Ігрова політика Stackelberg є потужним інструментом для управління перешкодами і енергоспоживанням. Комп'ютерні результати підкреслюють ефективність гри SK для розподілу потужності в децентралізованому сценарії.

Висновки. Автономний автомобільний зв'язок привернув увагу багатьох дослідників у зв'язку зі збільшенням кількості заторів і проблемами з дорожнім рухом. Зв'язок між авто - цікава тема пошуку, щоб забезпечити задовільну обстановку на дорогах. Крім того, група має потенціал для забезпечення безпеки при низькому енергоспоживанні, особливо в міських умовах. Крім того, LTE-V являє собою евристичне рішення для автомобільної зв'язку, де підключення здійснюється в децентралізованому контексті без вимоги ENodeB.

Ключові слова: гра Stackelberg; LTE-V; інтерференція.

Houda CHIHI, Ridha Bouallegue
Использование теории игр Stackelberg для минимизации мощности в режиме LTE-V 4

Проблематика. Из-за большого количества аварий на дорогах автомобильная связь становится предметом внимания многих исследователей. Поэтому автомобильная связь становится активной темой поиска. В силу этих обстоятельств безопасность вождения является главной заботой многих исследователей, чтобы смягчить проблемы заторов, особенно по городскому сценарию. В связи с требованием URLLC, в этой статье мы исследуем важность уменьшения мощности. Фактически, минимизация мощности является интересной метрикой из-за требования высокой скорости передачи данных.

Цель исследований. Целью данной работы является исследование распределения мощности в системе LTE-V по децентрализованному сценарию.

Методика реализации. Идея состоит в том, чтобы рассмотреть группу с набором транспортных средств, взаимодействующих друг с другом для сетевых ресурсов без помощи ENodeB. Минимизация энергопотребления является многообещающим решением для уменьшения помех, поскольку транспортные средства взаимодействуют

децентрализованно. В этом отношении теоретический анализ основан на применении игровой политики Stackelberg для управления мощностью таким образом, чтобы минимизировать помехи.

Результаты исследований. Игровая политика Stackelberg является мощным инструментом для управления помехами и энергопотреблением. Компьютерные результаты подчеркивают эффективность игры SK для распределения мощности в децентрализованном сценарии.

Выводы. Автономная автомобильная связь привлекла внимание многих исследователей в связи с увеличением количества заторов и проблемами с дорожным движением. Межавтомобильная связь - интересная тема поиска, чтобы обеспечить удовлетворительную обставноку на дорогах. Кроме того, группа имеет потенциал для обеспечения безопасности при низком энергопотреблении, особенно в городских условиях. Кроме того, LTE-V представляет собой эвристическое решение для автомобильной связи, где подключение осуществляется в децентрализованном контексте без требования ENodeB.

Ключевые слова: игра Stackelberg; LTE-V; интерференция.