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Scheduling Algorithm supporting V2X Communications based on NOMA access

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Abstract: 5G promises very high throughput and low latency. It will be able to support the exchange of large amounts of data with a wide variety of communications, including Vehicle-to-Everything (V2X) services. Conventional resource allocation techniques based on orthogonal multiple access (OMA) appear to be unsuitable for a dense network due to limited resources available. This work presents a new planning algorithm called SAVCN (Scheduling Algorithm for V2X Communication based on NOMA), for the 5G network. The main feature of NOMA is the same resource can be shared by multiple users. The purpose of our algorithm is to improve network performance in terms of throughput, equity, the number of V2X users served and error rates. In fact, SAVCN efficiently allocates available resource blocks (Rbs) to maximize system throughput by taking into account a well-defined criterion on the minimum distance between transmitters and receivers. The simulation results indicate promising performance for SAVCN.

Keywords: V2X, NOMA, Scheduling algorithm, throughput, BER.

1. INTRODUCTION

The exponential progress in cellular networks and the number of connected Vehicle-to-Everything (V2X) is causing a serious problem in the allocation of resources for the next generation network. V2X provides four types of communication: Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle to Network (V2N) and Vehicle-to- Pedestrian (V2P) (Hegde et al. 2019). These applications require high throughput and some exigencies in term of quality of service (QoS). V2X is considered as an important alternative of 5G networks. It is impossible to achieve the requirements of 5G, such as low latency, massive connectivity and high throughput, using orthogonal multiple access (OMA). The orthogonal sharing resources process is not always optimal because it causes serious congestion problems due to the limitation of resources block, Mahmoud. A, et al. (2018). To satisfy the different requirements of QoS for V2X links, it is very important to apply a new access technique.

Non-Orthogonal Multiple Access (NOMA) is promoted as a key component of 5G cellular networks. It can broadly be divided into two major categories, the first one is power-domain NOMA, the second one is code-domain NOMA, Binghong Liu et al. (2019). This technology allows users to share the same resource (time/frequency/code) and exploit different channel power levels. To make the NOMA scheme more practical, a Successive Interference Cancellation (SIC) is applied to the receivers to be decoded to cope with co-channel interference caused by spectrum sharing between different users, Duc-Dung Tran et al. (2018). In fact, radio resource management (RRM) becomes a key design aspect to enable V2X communications. RRM is the central unit in the eNodeB, more precisely at the level of the MAC (Medium Access Control) sub- layer which is responsible for the optimal distribution of the radio resources between the UEs component in the 5G network architecture. RRM aims at maximizing the efficiency of the system radio resource usage while providing and controlling the Quality of Service (QoS) according to the different traffic requirements and the target throughput for V2X links.

In this work, we propose a new scheduling algorithm called SAVCN for the next generation 5G. This algorithm is based on a Block Resource Allocation (RB) policy in a non-orthogonal way. The purpose of the proposed algorithm is to maximize the throughput of the system, to ameliorate the number of users served, to improve equity in the allocation of resources between different users, and to minimize the error rate. The main contributions of our work are listed below:

We propose a scheduling algorithm based on the NOMA technique for V2X system, which aims to optimize the allocation of resources block between all users.

We choose a set of well-defined users who can share the same RB (K_{max}) based on a distance metric.

We have allocated the same resource block to a set of selected k_{max} users to take into account not only the distance between transmitters and receivers, but also the concept of equity between users.

To evaluate the performance of our algorithm, we validated the results by simulations taking into account several parameters such as the number of channels, the number of users that can share the same resource block. We compared the performance of the proposed approach in terms of throughput with the classical OMA process.

The rest of this work is organized as follows in Section II, we present different scheduling algorithms proposed in the literature and related works reviews. In Section III, we present the adopted system model, then we detailed the proposed algorithm SAVCN in Section IV. Some simulation results and performance evaluations of scheduler are discussed in Section V. Section VI presents a conclusion and some perspectives.

2. RELATED WORK

The management of radio resources for V2X has been addressed in many research papers. Several articles have dealt with the resource allocation function based on the classical orthogonal multiple access (OMA) technique. The principle of OMA is to serve one single user in each resources block. In, Zhenhui Situ et al. (2018), and Vinay Kumar Trivedi, et al. (2017), and Pankaj Kumar Dalela, et al. (2018), BER analysis of OMA system has been presented. But, these works do not take into account the throughput criterion.

For code domain schemas as detailed in Michel Kulhandjian, et al. (2017) and Lei Liu, et al. (2018), the authors examined the fragmented code multiple access method called non-orthogonal multiple access (SCMA). This technique uses code books for multiplexing. Bit error rate (BER) was analyzed in Michel Kulhandjian, et al. (2017) and performance analysis of spectral efficiency (SE) was performed in Lei Liu, et al. (2018). However, the criteria of throughput are not considered.

The Power-Domain NOMA (PD-NOMA) was originally proposed as Power Division Multiple Access (PDMA) by assigning users a different power.

Yingyang Chen et al. (2017), proposed a power allocation algorithm to provide better reliability and improve bandwidth efficiency for inter-vehicle (V2V) communication. Indeed, the algorithm designed NOMA-SM is a compromise between two techniques non-orthogonal multiple access (NOMA) and spatial modulation (SM). The proposed algorithm is robust against the harmful effects of V2V environments. The authors analyzed the performance of the algorithm via simulations that take into account the bit error rate (BER) and the spectral efficiency. However, this approach does not consider the throughput criterion. According to the simulation, the distance between two vehicles is very small.

Sonam Rai, et al. (2018), designed a non- orthogonal access method (NOMA) resource allocation algorithm and compared it with the orthogonal multiple base (OMA) method. The proposed algorithm consists of combining Multiple Input Multiple Output (MIMO) schemes with downlink NOMA communication systems. The main objective of this approach is to reduce reliability and improve spectral efficiency. The limitation of this approach does not take into account the bit rate criterion and the bit error rate criterion. Moreover, according to the simulations, the number of V2X users is very limited.

Harshini N.M. et al. (2018) studied the concept of NOMA technology for the Spatio temporal Coding MIMO (STC-NOMA) technique. The proposed algorithm aims to improve the reliability of data transfer and to minimize the bit error rate. To achieve this goal, the authors used the (STBC) method of transmitting multiple data streams over multiple antennas to exploit different versions of data. In addition, a comparison of the STBC-mono user system with a NOMA-STBC multi-user system is implemented. But, this approach does not consider the throughput criterion

Hong Xing et al. (2018), have designed a two-user downlink non-orthogonal multiple access technology (NOMA) allocation algorithm in attenuated channels with delay-tolerant data, and compared it with another algorithm based on the orthogonal multiple access (OMA) technique. This approach aims to maximize spectral efficiency and to ensure better user equity. However, in this work throughput is not considered. It can be noted that not all works take into account the throughput criterion.

The following table gives a summary of the mentioned papers.

Table1. Comparison between the different algorithms studied above.

	BER	Latency	Reability	SE	SIC	Type of allocation
Zhenhui (2018)	X	X				OFDMA
Kumar (2017)	X					SC-FDMA
Pankaj (2018)	X			X		BDMA
Michel (2017)	X					SCMA
Lei Liu (2018)				X		SCMA
Yingyang (2017)	X		X	X		NOMA-SM
Sonam (2018)			X	X	X	NOMA
Harshini (2018)	X		X		X	NOMA
Hong (2018)				X	X	NOMA

The variable parameters used for the system model are given below.

Table 2. Notations

Symbol	Description
N	Number of V2X
I	Set of V2X
N_{Tx}	Number of Tx
V	Set of Tx
N_{Rx}	Number of Rx
E	Set of Rx
M	Number of available RBs
U	Set of RBs
K	Number of available channels
K_{max}	Number of users that can share the same RB
W	Bandwidth
η	Spectral density of noise
i	Number of time slot
r	Distance threshold
$Nm = \{1 \leq j \leq N / d_{j,m} \leq r\}$	Indicates the set of users verifying the condition on the threshold distance r and subsequently belonging to the receiver communication range Rx (m).
$\gamma_{j,k}$	It is a binary matrix to indicate that the transmitter j can share the sub-channel k for the time slot (i).

$P^{(i)}_{j,k}$	It is the transmission power of the transmitter Tx (j)on the sub-channel k for the time slot (i).
$H^{(i)}_{j,m,k}$	Denotes the matrix of the channel formed by sub-channels K between the transmitter Tx (j) and the receiver Rx (m) in the time slot (i).
$s^{(i)}_{j,k}$	Represents the transmitted symbol of the transmitter Tx(j) for the time slot(i).
β	Representing a constant defining the shadowing fading
$d^{(i)}_{j,m}$	The distance between two users (j) and (m) for the time slot (i).
α	Representing a constant defining the pathloss exponent

3. SYSYTEM MODEL

In this section, we describe our NOMA-based V2X cell system model, as shown by Figure 1. The V2X network consists of a single eNodeB and several N vehicles whose transmitters are indicated by Tx and receivers are represented by Rx. The distances between Tx and Rx are variable. Note that V= $\{1,2,,N_{Tx}\}$ represents the set of Tx, while E=$\{1,2,,N_{Rx}\}$ represents the set of Rx. N_{Tx} and N_{Rx} represent the number of Tx and Rx, respectively. We assume that the V2X is randomly arranged in the cell to cover all possible distances in the cell and there is no large dynamic speed variation for each vehicle.

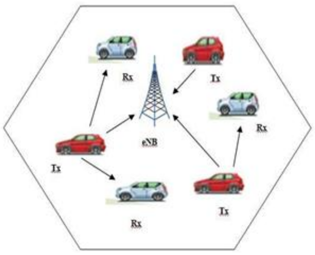

Fig.1. System model.

Each vehicle may send a data packet containing high priority information generally of the safety type around its vicinity. Neighboring users can transmit data in a direct way using D2D mode. The available bandwidth is divided into K sub-channels to ensure data transmission.

Each Rx receiver is more likely to decode the received signals using the SIC (Successive Interference Cancellation) technique. The signal received by Rx for the time slot i on the channel K can be modeled by the following equation:

$$y^{(i)}_{m,k} = \sum_{i \in Nm} \gamma^{(i)}_{j,k} \sqrt{p^{(i)}_{j,k}}\, H^{(i)}_{j,m,k} s^{(i)}_{j,k} + n^{(i)}_{m} \quad (1)$$

The value of time slot number (i) is equal to one.

Equation (2) represents the additive white Gaussian noise for a receiver Rx, where σ2n is the noise variance

$$n^{(i)}_{m} \approx CN\left(0, \sigma^2_n\right) \quad (2)$$

The coefficients of the channel $H^{(i)}_{j,m,k}$ can be defined by equation (3):

$$H^{(i)}_{j,m,k} = h^{(i)}_{j,m,k} * g^{(i)}_{j,m} \quad (3)$$

With,

$h^{(i)}_{j,m,k}$ **:** Complex Gaussian variable (0,1) representing Rayleigh fading. The gain of the channel is given by equation (4):

$$g^{(i)}_{j,m} = \beta(d^{(i)}_{j,m})^{-\alpha} \quad (4)$$

The successive interference cancellation (SIC) is considered an indispensable technical for NOMA technology because it improves network capacity by eliminating inter-channel interference Ningbo Zhang, et al. (2019). For NOMA, each receiver Rx (m) decodes the received signals taking into account a decreasing order of the channel gain. Consider, for example, two transmitters Tx (j) and Tx (j ') occupying the sub-channel k in the time slot i transmitting to the same user Rx (m) and satisfying the condition imposed by the equation (5):

$$\left|H^{(i)}_{j,m,k}\right|^2 \langle \left|H^{(i)}_{j',m,k}\right|^2 \quad (5)$$

The receiver Rx (m) uses the SIC technique to decode and subtract the signal Tx (j) before decoding the Tx (j'). Therefore, the user who has a better SINR (Signal- to-Interference-plus-Noise Ratio) must be decoded. Then subtract the signals of the users who have the lower SINRs. The SINR on the Rx receiver is calculated as follows, Boya Di et al. (2017):

With:

$$SINR_{j,m,k} = P^{(i)}_{j} \rho^{(i)}_{j,m,k} \Big/ 1 + \sum_{j' \in S^{(i)}_{j,m,k}} P^{(i)}_{j'} \rho^{(i)}_{j',m,k} \quad (6)$$

With,

$$\rho^{(i)}_{j,m,k} = \left|H^{(i)}_{j,m,k}\right|^2 \Big/ (n^{(i)}_{m})^2 \quad (7)$$

$\rho^{(i)}_{j,m,k}$: denotes the SINR of the sub channel k between the links Tx (j) and Rx (m).

$S^{(i)}_{j,m,k}$: represents the set of transmitters Tx (j) generating interference when the receiver Rx (m) decodes the signal of the transmitter Tx (j) on sub- channel k.

Following the above calculation of the SINR in equation (6), the data rate R obtained from Rx (m) for a time slot i on the sub-channel k can be formulated by the equation (8).

$$R^{(i)}_{j,m,k} = W * (\log_2(1 + SINR_{(j,m,j)})) \quad (8)$$

4. PROPOSED ALGORITHM

The main goal of our algorithm is to propose a new opportunistic and efficient scheduling algorithm.

Our scheduling algorithm for V2X communications based on NOMA access (SAVCN) consists of finding a compromise between different performance criteria. The objective of this approach is to maximize the throughput, increase the number of served users, ensure equity between different users, and minimize the bit error rate.

The diagram of our proposed algorithm is based on three major steps.

For the first step, we try to find the minimum distances between the Tx transmitters and the Rx receivers in the proposed system in order to choose the set of Tx that can share the same RB (k_{max}). For this, we insisted on imposing a constraint on the distance between transmitters and receivers.

Indeed, the transmitters authorized to send messages to the receivers are those which admit a distance less than or equal to a distance threshold. Of all the transmitters satisfying this condition, we choose only the two possessing the minimum distance as a first approach.

Then, the second step of assigning RB to all selected Tx (k_{max}) is started. In this context, the main idea is to allocate resources block when taking into account the minimum distance between the Tx and the Rx, as well as the quality of the Tx channel on each RB expressed by the Signal-to-Interference-plus-Noise Ratio (SINR) value. Indeed, if the scheduler has already assigned a RB to the current time slot (i) at the set Tx (k_{max}), it will have no more RB in the same (i) only if all are served. This simultaneously increases the capacity of the system in the cell and ensures a better equity between the different users.

The purpose of the third step is to evaluate the performance of our algorithm, we validated the results by simulations taking into account several parameters such as the number of RBs, the number of users able to share the same resource block, the number of transmitters and the number of receivers. The performance of the proposed approach was compared with a resource allocation based on convention OMA algorithm.

The concept of our algorithm is to allocate sub-channels for a set of transmitters. For this, we created a matrix containing the distances between transmitters Tx and receivers Rx. Then, we insisted on putting a constraint on the distance between transmitters and receivers. In fact, the transmitters authorized to send messages to the receivers are those which admit a distance less or equal than a threshold one. The process of allocating resources if only two users can share to same RB is explained by algorithm1.

Table 3. Parameters setting

Symbol	Description
M1	Matrix contains distances between Tx and Rx randomly
M2	Matrix contains users satisfying the condition
M3	Matrix contains only users who can share the same RB

Algorithm 1

{Inputs}
N_{Tx} = x, N_{Rx} = y % Number of Tx and Rx
r % distance threshold
K_{max} % Number of users that can share the same RB.
{main}
% Choose K_{max}
Create matrix M1(x,n) =randi [x',n'] % Matrix contains distances between Tx and Rx
***For** x=1 : N_{Tx}* ***For** n=1 :N_{Rx}* ***If** M1(x,n) < r*
Find (x,n)= M1(x,n) < r % find for distances that are less than the threshold distance
Calculate M2(x,n)=f (M1(x,n)) % matrix contains only users satisfying the desired condition
End if
End
End
***For** h=1 : Nrx*
Tri dist M2 (x,n) % sort users in ascending order
End
// selecting the (Tx,Rx) pair with the min-dist in M2.
// according to value of k_{max}, selecting the Tx which can be sharing the some RB in M2.
End

The main purpose of assigning BRs in our proposed algorithm is to share the same RB with a predefined set of k_{max} users according to a well defined criterion. The idea is to find the combination ($Tx_{i'}$, RB_j) with $1\leq i'\leq N_{Tx}$ and $1\leq j\leq M$, with the smallest value of the metric $m_{i',j}$ expressed by the following equation:

$$m_{i',j} = \min\{M2\} \tag{9}$$

The process of allocating radio resources for k_{max} is summarized by algorithm 2.

Algorithm 2

{Inputs}
M2: Matrix contains users satisfying the imposed condition
M3:Matrix contains only users who can share the same RB
K_{max}: Number of users that can share the same RB.
{Main}
% Allocation of RBs when K_{max} = 2
***For** k=1 to M do*
Find (x1, n1) = min M2(x1,n1), with (x1,n1) ∈ V x U
% Find the minimum of the n[th] column (on the same RB_n) of the matrix
Find Tx1 = min(M2) % find the first user who has a minimum distance in M2
Copy Tx1 selected in M3
Remove the x1[th] row from M2 V =V \ {x1} % Update V
Find Tx2 = min (M2) % find the second user who has the minimum distance in M2
Copy Tx2selected in M3
Remove the x2 [th] row from M2 V =V \ {x2} % Update V Assign RB_k à Tx1 and Tx2 U=U \ {n1} % Update U
End for

The performance evaluation of our proposed algorithm is a very important part of our work. This step is explained in detail in the following section V.

5. SIMULATIONS RESULTS

The simulation results are obtained by evaluating our proposed scheduling policy on Matlab simulator. We vary several parameters in the system in order to evaluate system performance. We consider that the distances between transmitters and receivers are variable. We therefore compared the performance evaluation of the proposed scheme with the conventional OMA method, Ala DinTrabelsi.et al. (2019). The parameters used for the simulations are listed in the following Table 4.

Table 4. Parameters setting

Parameter	Value
System bandwidth	10 MHz
Number of RBs	[30, 50]
Number of Tx	[50, 70]
Number of Rx	[30, 50]
Number of eNodeB	1
Number of K_{max}	[2, 5]
Duration of t	1ms
Power of each Tx user on each K channel	[20, 23db]
r	150m

The purpose of this simulation is to analyze the performance of our proposed algorithm.

5.1 Throughput analysis

Maximizing system throughput is one of the main goals of our project. Indeed, it is defined as the amount of information transmitted on the radio interface in a given time interval, Nasim. F. et al. (2015). We study the behavior of the throughput according to the number of resources blocks RBs and the number of users who can share the same channel simultaneously K_{max}.

5.1.1 *Throughput depending on the number of RB*

We have studied along this section the throughput behavior as a function of the number of channels. "Fig. 2" shows the performance of SAVCN and the traditional OMA scheduler in terms of throughput as a function of the number of resources blocks, with the number of transmitter Tx=50 and k_{max}=2.

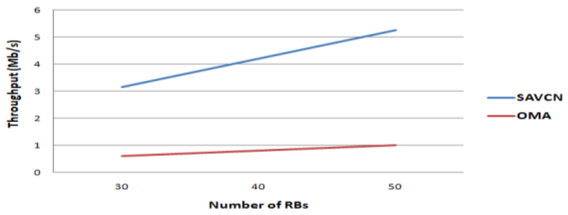

Fig. 2. Throughput analysis.

When the number of resources blocks increases, the throughput increases. The results indicate that SAVCN reaches an important value compared to the OMA scheduler. Note that the performance of this scheme is better than the conventional OMA, especially in terms of throughput. Our algorithm is able to support many sizes of messages compliant with the 3GPP standard. According to, 3GPP. (2015), and 3GPP. (2017), the transmitted messages have a size of 50 to 400 bytes. The results of the simulation show by "Fig. 3 "indicates that the rate obtained may support variable message sizes. In fact, the proposed algorithm allows a message exchange of 657.5 bytes when the bit rate is 5.26 Mbps. The results satisfy the 3GPP recommendation when the minimum message size is 50 bytes.

5.1.2 Throughput depending on the number of K_{max}

We study the behavior of the throughput depending on the number of users sharing the same sub-channel. "Fig.3" shows the throughput depending on the number of users sharing the same sub-channel, with Tx=70 and Rx=30.

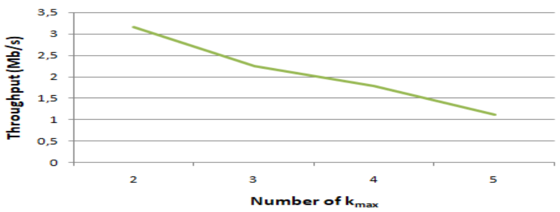

Fig.3. Throughput depending the number of k_{max}.

When the number of users sharing the same RBs increases, the throughput decreases, because the interference between the users increases, so a complexity at the receiver in the SIC decoding will occur and errors on the detection of the receiver side will be added. So the SINR decreases so the throughput will decrease.

5.2 Bit error rate

The causes of error are numerous and depend mainly on the nature of the used transmission media. The propagating signal can be deformed by the mobile radio channel. Therefore, the binary element can be received with a different value from the originally one sent, the entire associated message will be declared as erroneous. Indeed, the error rate depends on several factors such as the number of transmitters, the number of receivers, the number of users sharing the same sub-channel and the threshold distance.

5.2.1 BER depending on the number of receivers

The number of receivers still influences the BER. Indeed, we have to study the behavior of the BER according to the number of receivers. "Fig.4" represents the variation of the BER as a function of the number of Rx with Tx=50 and k_{max}=2.

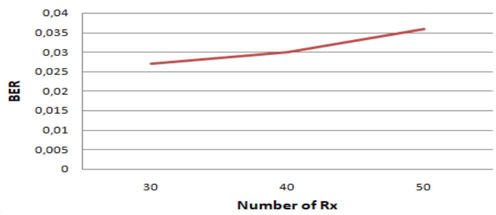

Fig.4. BER depending on the number of Rx.

When the number of receivers Rx increases, BER also grows, because the interference also increases, thus a complexity in the decoding will occur SIC and errors at the detection on the receiving side will be added.

5.2.2 BER according to K_{max}

In addition, the number of users sharing the same sub-channel (K_{max}) influences BER. "Fig.5" shows the variation of the BER based on the number of users sharing the same channel with Tx=50 and Rx=30.

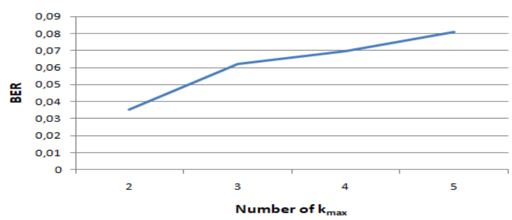

Fig.5. BER depending on the number of k_{max}.

When the number of users sharing the same channel increases, the BER grows. As the amount of information elevate, the risk of interference between users also increases, so that the BER increases.

5.2.3 BER according to the distance threshold

We studied the behavior of the BER according to the value of r. “Fig.6” below shows the variation of the BER as a function of the distance threshold between transmitters and receivers with Tx=60 and k_{max}=2.

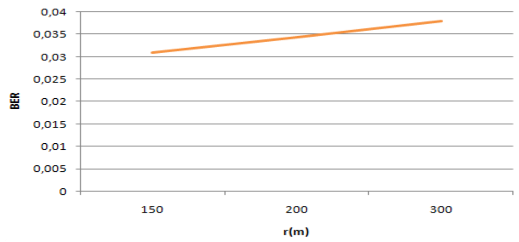

Fig.6. BER depending on the r.

We note that as the distance threshold r increases, the error rate also increases. This is normal because the channel disruption becomes stronger, messages sent by a transmitter to a receiver may have significant changes, so errors will appear at the reception. For this, the error rate grows.

6. CONCLUSION

In this document, we present a new scheduling scheme called SAVCN based on NOMA access for 5G networks. Our goal is to maximize system throughput, improve the number of users served, ensure greater fairness in allocating Rbs, and minimize bit error. The result of the simulation shows that the system performance of the proposed strategy is better than that of the conventional OMA in terms of throughput. In future work, we plan to make many improvements to the proposed SAVCN algorithm, such as a comparison of our proposed algorithm with another NOMA-based algorithm and integration of an interference management mechanism.

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