Dynamic Resource Allocation Approach for Interference Mitigation based on NOMA in Network Operating in Both Uplink and Downlink

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Abstract

The new notion of Internet of Vehicles (IoV) supports Vehicle-to-Everything (V2X) communications, which play a very important role in 5G systems. Ultra-Dense-Network (UDN) and the new scheme Non-orthogonal multiple access (NOMA) are two important concepts to meet the requirements of V2X services with their remarkable capacity. However, the concept of NOMA technology, which allows multiple vehicles to be served by the same resource, can lead to interference between different active users. In addition, the extensive placement of small base stations (SBS) in UDN causes severe interference and degrades the network performance. To solve these problems, interference mitigation is widely used to avoid interference in NOMA-based UDN. In this document, we suggested a dynamic resource allocation method named Intra-cell-Inter-cell Interference Mitigation for V2X communication for UDN in uplink and downlink sense (Intra-Inter IMVN). Our algorithm aims to achieve five principals objectives, namely applying the same algorithm for both downlink and uplink modes, reducing the degree of interference, improving network performance in aspects like error rates and throughput, minimizing cost and delay when using this alternative, combining dynamic metrics to support many V2X scenarios and requirements, and dealing with two categories of interference such as inter-cell interference and intra-cell interference. Numerical results demonstrate that our suggested Intra-Inter IMVN approach offers higher performance compared to other existing algorithms as a function of various parameters.

Keywords: NOMA, UDN, V2X, Interference Mitigation, Resource Allocation, BER, Throughput, Dynamic Metrics, Intra-cell Interference, Inter-cell Interference.

1 Introduction

The Internet of Vehicles (IoV) is a particular interest for the improvement of 5G-based communication between vehicles (V2X) and a new trend resulting from the Internet of Things (IoT) (Lei Liu et al.,

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2023). V2X systems are designed to ameliorate road safety and comfort by allowing them to communicate with other network components. V2X permits communications between V2H, V2N, V2C, V2P, V2V, V2I, V2G and V2B correspondingly as Vehicle-to-Home, Vehicle-to-Network, Vehicle-to-Cloud, Vehicle-to-Pedestrian, Vehicle-to-Vehicle, Vehicle-to-Infrastructure, Vehicle-to-Grid and Vehicle-to-Building (Huisheng Ma et al., 2020; Rahmat et al., 2022). This type of connections need low latency and highly reliable message flows to assure road safety and traffic efficiency.

Therefore, the fifth generation (5G) communication system needs to support massive user connectivity, high throughput demand, low latency and various enhanced applications (Qimei et al. 2023). In this regard, some technologies have been adopted as promising solutions for 5G, namely NOMA and UDN (Yiming et al., 2018).

Unlike traditional cellular networks, the disposition density of SBS in UDN is significantly important and can reach the denseness of users. The high density of the network significantly reduces the transmission distance of SBSs. Therefore, when inter-site distances are reduced, not only is there a noticeable amplification of the desired signal strength, but also a significant increase in interference from other base stations. This type of interference is called inter-cellular (Dick et al., 2022; YU GU et al., 2018).

To deal with the interference problem, several works were carried out on interference mitigation (IM) and resource allocation (XinchenLyu at al., 2017; Yiming et al., 2017). In fact, resource competition is becoming a major problem because of limited available radio resources.

This problem can degrade system performances, so it is very interesting to establish a novel access technology to unleash fierce competition from resources and improve massive connectivity.

NOMA is considered as the most efficient radio access technology for UDNs (Boccuzzi J et al., 2019). As its name suggests, NOMA, serves several users on the same frequency at the same time. The NOMA is capable of increasing the number of connected vehicles, providing a lower latency time through simultaneous transmission, and increasing spectral efficiency. The concept of NOMA is as follows: SBS can send signals in a non-orthogonal way with various power levels to a group of entities on the same resource block (Rb) simultaneously (Jianyue Zhu et al., 2017). In this way, the concept of sharing resources causes intra-cellular interference between users. In this respect, the interference mitigation mechanism and the resource optimization phenomenon are becoming more important and interesting in NOMA-based UDNs. Highly competent scheduling mechanisms are essential for the successful sharing of limited resources, reduce interferences and guarantee an important throughput to satisfy QoS exigencies.

To surmount mentioned problems, for our work we suggested an efficient resource allocation algorithm with the concept of interference mitigation for both uplink and downlink senses. The proposed work takes into account two types of interference, respectively intra-cellular and inter-cellular, for the NOMA-based UDN network. The principle of our approach is to allocate resources to different users through the NOMA access technique with an interference mitigation mechanism. The allocation strategy is based on a well-defined criterion, namely “the maximum value of the estimated SINR”. The goal of our system is to reduce the level of intra-cellular and inter-cellular interference to improve system throughput, maximize the considered number of served users and reduce the BER. The Intra-Inter IMVN algorithm involves the following steps:

- We select a group of users based on three dynamic conditions for uplink and downlink mode.
- We select the first user based on a measurement of the maximum SINR value.

- We choose a second user based on the minimum value of intra-cellular interference or intercellular interference.
- We have allocated the same resource to a select group of users. (One user has a maximum SINR value and another has a minimum interference value.)
- We demonstrate the effectiveness of our algorithm by validating some simulation results when examining different parameters. In addition, we show the improvement made to our algorithm compared to another approach.
- The challenging aspects and the contributions of our suggested algorithm compared with other existing literature are:
- The proposed work is suitable to apply for NOMA based networks. The basic concept of NOMA is to use the power domain to provide several users simultaneously with a single block of time-frequency resources.
- Based on the concept of the NOMA technique, our solution can reuse and share the available resources of the cellular spectrum between them, which improves the number of connected users and reduce the delay.
- The algorithm parameters are adjustable according to the requirements.
- The Intra-Inter IMVN algorithm can combine three conditions to dynamically configure the network topology for optimal interference mitigation in UDN. Concerning the first condition, users sharing the identical Rb are those who admit a SNR value exceeds or equals to an average interference value. The objective of the second condition is as follows: The candidates that verify the constraints are those that have a value of SINR is exceeds or equals to a threshold of average SINR can be candidates for sharing the same Rb. With a view to improvement the performance of our system, a third condition is proposed. The idea is as follows: only users with SINR value more than or equal to a minimum SINR threshold of the minimum throughput value can be candidates for sharing the same Rb.

In contrast to most of the previous works, our algorithm can be applied in uplink and even downlink. It’s very important to use the same algorithm to support the two communication modes in order to reduce latency and improve the usage.

- The adopted approach treats two different interference types; intra-cellular and inter-cellular interferences.
- The proposed approach focuses on the problem of intra-cellular and inter-cellular interference, which must be controlled to avoid degradation of the communication performance of vehicles such as high throughput.
- The algorithm ‘s resource allocation is based on two well-defined criterion, which are the estimated SINR value and the minimum interference among users sharing the same Rb.
- The performance analysis of the suggested approach is evaluated via various performance metrics such as throughput and BER.
- We performed extensive simulations and compared the results with the reference (Arsla Khan et al., 2021) and (Osama Abuajwa et al., 2022) based on several simulations, we have approved that our contribution can achieve better performance compared to other existing works.

The remaining of the work is structured as follows: in Section 2, some related work is introduced. The system model is elaborated in Section3. Section 4 explains the steps of the suggested approach. The simulation results are provided in section 5, while Section 6 finally draws conclusion of the paper.

2 Related Work

The resources allocation for V2X system with interference mitigation constitutes a significant challenge in 5G, hence it has been tackled several times in very recently literature (Kim, H., 2020). Several works have been done on the resource allocation with interference mitigation of only single type of interference, either intra-cellular or inter-cellular interference using a single Uplink or Downlink mode.

Wee Kiat Newet et al in (Wee Kiat et al., 2021), examined the performance of Non-Orthogonal Access in downlink for UAV connected to cellular. In this work, the authors developed a schema based on stochastic geometry for the coexistence of AU and TU in cellular networks, where BSs are distributed using a Poisson process while incorporating the intercellular interference coordination technique (ICIC). Subsequently, they demonstrated that the proposed NOMA algorithm exceeds conventional orthogonal multiple access (OMA). This work does not take into account the BER criterion.

The authors in (Licheng et al., 2022), have designed a learning approach to resolve one important problem related to transmission power and tethered Unmanned Aerial Vehicles (TUAV) altitudes named NSATC based on MADDPG. The goal of this algorithm is to improve overall throughput while increasing the number of users in service and to provide interference management against intercellular interference. The authors take into consideration a limited number of users who are able to share the same Rb for simulation results.

The authors in (Tianwei Hou et al., 2022), developed a new STAR-RISs approach using NOMA in a coordinated multipoint transmission network (CoMP). They used the RIS elements to cancel intercellular interference and improve the signal. Based on the simulation results, the authors demonstrated that the SSECB algorithm is able of outperforming SEB and SCB algorithms.

In (Wenli Li et al., 2022), a resource management scheme for D2D communications is presented to address resource allocation and power control issues. The goal of this algorithm is to optimize user access rates and system throughput and reduce intra-cellular interference. The simulations revealed an optimization of the system's operating parameters, resulting in a significant improvement in throughput and access rates of D2D users.

The authors in (Yurong et al., 2021), studied a resource allocation approach for V2X systems in a cellular uplink network based on the Stackelberg game theory. Based on the simulation results, the suggested algorithm can enhance the efficiency of the vehicle diffusion spectrum. In addition, it minimizes interference to base stations and cellular user equipment (CUEs).

In another part, the researchers suggested approaches for interference mitigation of both inter-cellular and intra-cellular interferences types in cell networks.

The authors in (Asmaa et al., 2021), have studied the application of full duplex cooperative NOMA with D2D system for cooperation networks on a downlink sense. The purpose of this contribution is to maximize the sum rate and improve the number of assigned D2D pairs. They implemented simulations to show the performance of their system using different metrics.

The authors in (Yurong et al., 2021), proposed an association of users and resource allocation, for Device-to-Device (D2D) based NOMA technology (ISHU). The purpose of this article is to maximize network throughput. For this, they have integrated a NOMA of the uplink in the mobile groups D2D (DMG). The simulation results demonstrate that the ISHU offer better performances as compared to algorithms OFDMA and NOMA. This work does not analyze the BER variation.

To minimize the energy consumption of sensor devices SDs, the authors in (Daosen Zhai et al., 2022) proposed a network of air-to-ground cooperative wireless sensors network (AGWSN) in uplink. They used the NOMA technique to coordinate inter-cellular and intra-cellular interference. To overcome the channel allocation problem, they developed an algorithm based on K- CUT. To assess the effectiveness of the suggested algorithms, they performed simulations and demonstrated that the proposed algorithm can reduce energy consumption compared to the traditional terrestrial network and enhance the probability of successful decoding.

Table 1 compares the above-mentioned works regarding resources allocation with interference mitigation.

Table 1: Metric Comparisons between the Suggested Approach and Others Related Papers

Paper	Mode U/D	Throughput	BER	SE	Treated interference types
(Wee Kiat, 2021)	Downlink	x			Inter-cell interference
(Licheng et al. 2022)	Downlink	x			Inter-cell interference
(TianweiHou et al. 2022	Downlink	x			Inter-cell interference
(Wenli Li et al. 2022)	Uplink	x		x	Intra-cell interference
(Yurong et al. 2021)	Uplink				Intra-cell interference
(Asmaa et al. 2021)	Downlink			x	Inter-cell interference
(Yurong et al. 2021)	Uplink		x		Inter-cell +Intra-cell interference
Intra-Inter IMVN	Uplink/ Downlink	x	x		Inter-cell +Intra-cell interference

3 System Model

In this sub-section of the paper, we present in detail the adopted system model. Consider a V2X communication network in the uplink and downlink direction based on the NOMA technique supporting a UDN system as illustrated in Fig. 1 which includes of a group of SBSs J with various coverage. In UDN, each user must choose a single SBS to obtain services. In order to simplify the notational, we designate b as index for the b-th SBS where $b \in \{1, 2, \ldots B\}$, denote u as index for the u-th user where $u \in \{1, 2, \ldots U\}$. Note that {Ub} as the set of users served by the b-th SBS. Note that {Ub} refers to the group of users allocated by the b-th SBS. The total bandwidth is divided into h sub-channel indexed as $h = \{1, 2, \ldots, H\}$.

We assume that the distances between SBS and u are variables. This work also assumes that the vehicle devices are randomly positioned in the cell. For our approach, we assume that the noise value is the same for all channels (MdSahabul Alam et al., 2021).

The innovations of our paper compared to previous studies are summarized as follows:

In our contribution, the same algorithm can play several roles. It can combine three different conditions. In addition, it can use both Uplink and Downlink directions. It can use two different types of interference. Indeed, our solution is multifunctional; it can combine several aspects in the same algorithm, which allows a gain in terms of time, a gain in terms of performance and a gain in terms of cost.

In fact, the innovation compared to other related work can be observed for many aspects. The first innovation is to use the same algorithm for many objectives. The first objective is to apply the same algorithm for downlink and uplink modes. The second one is to ameliorate the system performances in term of throughput and BER, which is validated by several simulations especially when compared to other references. The third goal is to minimize cost and delay when using such alternative. Another objective can be noticed for our approach is to use dynamic metrics for this algorithm in order to support many scenarios and V2X exigencies.

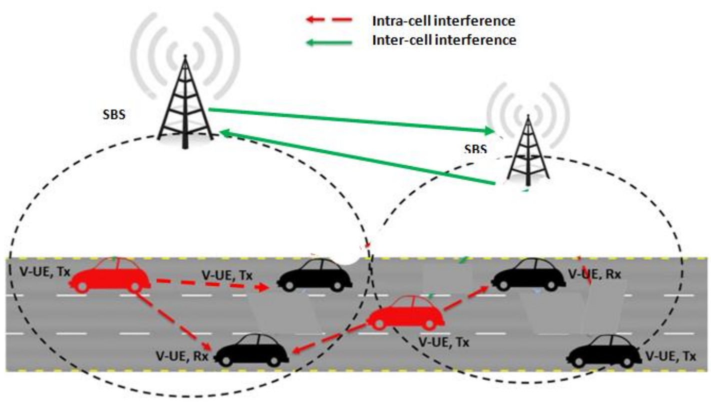

Figure 1: System Model

The used parameters for the system model are listed below.

Table 2: List of Key Notations

Symbol	Description
B	Group of SBSs.
U	Group of users.
U_b	Group of served users by the b-th SBS.
Is	Set of interfering SBS b to SBSs.
R	Group of Rb.
r	Number of available Rb.
h	Available channels.
h_{max}	Considered users sharing the similar Rb.
BW	Bandwidth.
N_0	Additive White Gaussian Noise (AWGN).
ts	Number of time slot.
d_{bu}	Distance between SBS b and user u.
$MP^{(ts)}_{buh}$	Matrix of power transmission
$MH^{(ts)}_{buh}$	Matrix of channel coefficient.
$s^{(ts)}_{buh}$	Transmitted symbol.
sh	Shadowing fading.
pth	Pathloss exponent.
SNR_u	Indicate the signal-to-noise ratio of user u.
$INR_{u'u}$	Interference-to-noise ratio between the user u and another interfering user u'.
I	Inter-cell interference.
I'	Intra-cell interference.
$\mathscr{R}$	Throughput if inter-cellular interference is considers.
$\mathscr{R}$'	Throughput if intra-cellular interference is considers.
$SINR_{buh}^{(ts)}$	SINR of u-th served user by the b-th SBS on the h-th sub-band for inter-cellular interference.
$SINR'^{(ts)}_{buh}$	SINR of u-th served user by the b-th SBS on the h-th sub-band for intra-cellular interference.

Downlink Signaling Model with NOMA

Unlike the OMA technique, the principle of non-orthogonal access modulation (NOMA) is based on the exploitation of multiplexing in the power domain, enabling the simultaneous superposition of several signals on the same resource block. Successive Interference Cancellation (SIC) method is used at receivers' users to decode superposed signals. Then for the downlink, each SBS multiplexes and sends a group of signals simultaneously to users on the same sub-band. For a user u served by b-th SBS the received signal $y^{(ts)}_{buh}$ of the user for the time slot ts over the h-th sub-band can be mathematically expressed as

$$y^{(ts)}_{buh}= \sqrt{MP^{(ts)}_{buh}}MH^{(ts)}_{buh}s^{(ts)}_{uh}+\underbrace{\sum_{n\neq b,n\epsilon S}\sum_{u'\in Un}\sqrt{MP^{(ts)}_{nu'h}}MH^{(ts)}_{nuh}\,s^{(ts)}_{uh}}_{I}+N_0 \quad (1)$$

The $MP^{(ts)}_{buh}$ is the transmitted power from SBS b to user u over sub-band h and the $s^{(ts)}_{uh}$ is the transmitted symbol of the user u for the time slot ts on the sub-channel h. The first term in the equation corresponds to the desired signal, the second term I denotes the inter-cell interference provoked by some users in the same cell, the last term N0 is the AWGN, with zero mean and variance δ2.

The coefficients of the channel $MH^{(ts)}_{buh}$ can be defined by equation (2):

$$MH^{(ts)}_{buh} = H^{(ts)}_{buh}G^{(ts)}_{bu} \quad (2)$$

With,

$H^{(ts)}_{buh}$: is a complex gaussian variable (0,1) reflecting the Rayleigh fading effect. The channel coefficient matrix is defined as follows:

is a complex Gaussian random variable with zero mean and unit variance, reflecting the Rayleigh fading effect.

$$\text{Channel coefficient matrix } H_{u,h}= \begin{pmatrix} h1,1 & \cdots & h1,h \\ \vdots & \ddots & \vdots \\ hu,1 & \cdots & hu,h \end{pmatrix}$$

The gain of the channel is expressed as follows (3):

$$G^{(ts)}_{bu} = sh\left(d^{(ts)}_{bu}\right)^{-pth} \quad (3)$$

Pathloss refers to the reduction of the power density or attenuation of a wave as it propagates in a channel linking the transmitter and the receiver. Path-loss is defined as follow:

The concept of path loss refers to the decrease in power density or attenuation of a wave as it propagates through a transmission channel linking the emitter to the receiver. Pathloss is defined as follows:

$$\text{Pth(dB)}=10\log_{10}\left(\frac{Pt}{Pr}\right) \quad (4)$$

with;

Pt: Transmitted Power

Pr: Received Power

In UDN, communications suffer from interferences due to spectrum reuse and the random location of small base stations (SBSs). These interferences influence the offered quality of service and result in a degradation of the performance of the UDN network. To meet the needs of users, they must be protected against interference generated by other SBS using the same sub-band. Note that {Is} is the group of neighbor interfering other SBS to SBS b. So, the inter-cell interference that SBS caused to its neighboring SBS on the h sub-band can be presented by the following equation:

$$I = \sum_{n\neq b,n\epsilon Is} \sum_{u'\in U_b} MP_{bu'h}^{(ts)} \left|MH_{bnh}^{(ts)}\right|^2 \quad (5)$$

Subsequently, the SINR received from the u-th user served by the b-th SBS on the h-th sub-band is calculated by the following equation:

$$SINR_{buh}^{(ts)} = \frac{MP_{buh}^{(ts)}|MH_{buh}|^2}{\delta^2+I} \quad (6)$$

By applying the Shannon theorem, the corresponding throughput of the u-th served user by the b-th SBS is represented as the following equation:

$$\mathscr{R} = BW * \log_2(1 + SINR_{buh}^{(ts)})) \quad (7)$$

Uplink Signaling Model with NOMA

Using the NOMA technique, the same SBS can serve several users who share the same resource at the same time. In this case, users suffer from intra-cellular interference generated by other users whose signal strengths are important.

SIC is an essential approach for NOMA technique. It can be performed on the user level to cancel interference and maintain signals of interest (Kaidiet al., 2023). Each SBS sends a combination of signals with various power levels to a set of users with distinct channel gains. The principle of the SIC technique is the following: the user with the best channel gain must be decoded then subtracted the desired signals and undergoes no intra-cell interference while being allocated to the lowest power level. Instead, the highest power level will be assigned to the user with a lower channel gain (Tsuzuki et al., 2021).

To perform the SIC efficiently, each user decodes the received signals taking into consideration a descending order of channel gain. Indeed, the order of channel gains between users and SBS b on the sub-band h for the time slot ts is expressed as:

$$\left|MH_{b1k}^{(ts)}\right|^2 \geq \ldots \left|MH_{buh}^{(ts)}\right|^2 \ldots \geq \left|MH_{bUh}^{(ts)}\right|^2 \forall u \in \{U_b\} \quad (8)$$

The intra-cellular interference of user u, which is served by SBS b on the sub-band h can be represented by the following equation.

$$I' = \sum_{u'\neq u, u'\in U_b} MP_{bu'h} |MH_{buh}|^2 \quad (9)$$

Subsequently, the SINR received from the u-th user served by the b-th SBS on the h-th sub-band is calculated by the following equation:

$$SINR'^{(ts)}_{buh} = \frac{MP_{buh}^{(ts)}|MH_{buh}|^2}{\delta^2+I'} \quad (10)$$

The updated throughput equation (7) is shown below

$$\mathscr{R}' = BW * \log_2(1 + SINR'^{(ts)}_{buh}) \quad (11)$$

4 Proposed Algorithm

In this section, we will present our contribution in allocating resource for V2X communication to address the problem of interference in downlink and uplink mode. The algorithm is aimed to reduce interference level in order to improving the throughput and reduce the BER value. The main contributions of our suggested solution are:

Our approach allows developing the number of connected entities by the fact that the available resources of cellular spectrum can be reused and shared.

In addition, the parameters algorithm is settable depending to the requirements. The Intra-Inter IMVN algorithm can dynamically set up the network topology for interference mitigation in UDN by the mix of three conditions. In fact the use of three metrics in an auto configurable way allows to significantly improve the system throughput to support many V2X scenarios and requirements. By comparing to the previous approach, our solution can be used in uplink and downlink. Furthermore, two types of interference can be treated with our algorithm: intracellular and intercellular interferences. Our contribution treats especially the problem of interference, which must be managed to prevent the decrease of vehicles communication performances such as the high throughput. The resource allocation of our algorithm is based on two metrics which are the estimated SINR value and the minimum interference between users sharing the same Rb. Compared to the existing literature, our proposed algorithm can achieve greatest performance in term of throughput and can minimize the BER.

The importance of our proposed solution is explained as follows:

Our proposed algorithm is based on dynamic metrics and can be applied in uplink and even in downlink independently, which allows a gain in terms of time by minimizing the delay caused by the transition from one algorithm to another. The suggested algorithm treats two types of interference such as; intra-cellular and inter-cellular, which allows a gain in terms of treatment time. The proposed algorithm allows combining three conditions to dynamically configure the network topology, which allows a very important gain in terms of performances. In addition, the fact of using the same algorithm for both uplink and downlink provide a cost optimization aspect.

Our proposed approach is based on four main steps.

In the following sub-sections we will explain in detail the four phases of our suggested algorithm.

Step1: Choose the Mode Type

First of all, we choose the considered mode type. So, we introduced a variable α to justify the chosen mode type thus the adopted link uplink or downlink.

If we have chosen α=0, then we use the equations in the Uplink signaling model with NOMA subpart, otherwise we use the equations in the downlink signaling model with NOMA part.

In this context, the process of choose the mode type is described by algorithm1.

```
Algorithm1 Choose the mode type

{Inputs}
α=0
{main}

If α=0
  Intra-cell interference => Uplink
elseif α=1
      Inter-cell interference => Downlink
end
```

Step2: Dynamic Thresholding

As the increase of throughput is the most important aim to our work, we choose three conditions to reach it. Using these conditions will provide more performance to our algorithm and will satisfy a huge number of users. In this context, we will detail these conditions in the next step:

This step is named dynamic thresholding. Its consists of defining three proposed conditions in order to select the candidate users for sharing the same Rb for the next step. In this context, we have defined a variable Ω to show the condition adopted as shown in the expressions below:

$$\begin{cases} \text{if } \Omega=01 \\ \quad \text{SNR} >= \text{average (INR)} \quad \text{(condition 1)} \\ \text{else if } \Omega=10 \\ \quad \text{SINR} >= \text{average (SINR)} \quad \text{(condition 2)} \\ \text{else} \\ \quad \text{SINR} >= \text{SINR}_{\text{ThrMin}} \quad \text{(condition 3)} \end{cases} \tag{12}$$

With

$$INR_{u\prime u} = MP_{bu} \times |H_{u\prime u}|^2/(N_0)^2 \tag{13}$$

If we choose the uplink mode, the three conditions are available but just we need to consider the SINR' values instead of SINR one.

The first condition states that only users with a signal SNR value greater than or equal to an average interference value are allowed to share the same Rb. The advantage of this condition is that we can choose candidates with the minimum of interference to guarantee an important throughput. But, this condition can only be applied to the small network where the density of users is not important. Nevertheless, as the number of users grows, the probability that this condition is satisfied decrease because the users that can satisfy the threshold decrease also.

The proposed idea for the second condition is: only users who have a SINR value greater than or equal to an average SINR threshold can be candidates to share the same Rb. The advantage of this condition is to elevate the number of candidates in order to satisfy the requisites of the high throughput and the low rate of BER for the V2X communications. In this context, there are papers that use the second condition in order to not decline the network performance. They are based on achieved simulations (Emna et al., 2020).

We proposed another condition to ameliorate our system performance. The main idea is: Candidates who verify the 3rd imposed constraint, are those who have a SINR value greater than or equal to a minimum SINR threshold of the minimum throughput value. This condition allows to satisfy more users so we obtain a higher throughput.

In our work, we have combined the three conditions to configure the network dynamically for the purpose of optimizing the interference mitigation. In fact, the SBS can be configurable according to the case chosen by it.

We detailed the three dynamic conditions in algorithm 2

Table 3: Adopted Notations

Noatations	**Description**
M-cond(i)	Matrix contains SNR, SINR, SINR value respectively. i designated the condition adopted 1,2 or 3.
$M_{u\text{-}Cond(i)}$	Matrix includes only users gratifying the constraint i identified the condition adopted 1,2 or 3.
$M_{SINR\text{-}cond(i)}$	Matrix includes SINR values for all users who comply with the imposed constraint. i={1,2,3} identified the condition adopted.
M_{IntraC}	Matrix formed by the value of intra-cell interference estimation.
M_{InterC}	Matrix formed by the value of inter-cell interference estimation.
$M_{ou\text{-}cond(i)}$	Matrix includes only candidates sharing the same resource according to the imposed condition.

Algorithm2 Dynamic thresholding

{Inputs}
α=0
Ω=00

{main}
%creation of matrices according to the choice of conditions
Create matrix *M-cond(1) %* Matrix contains SNR values for condition 1
Compute INR values for condition 1
Create matrix *M-cond(2) %* Matrix contains SINR values for condition 2.
Compute SINR values for condition 2
Create matrix *M-cond(3) %* Matrix contains SINR values for condition3.
Compute $SINR_{ThrMin}$ values for condition 3
If Ω=01
SNR>=average(INR)
else if Ω=10
SINR>= average(SINR)
else
SINR>= $SINR_{ThrMin}$

End

Step3: Candidates Selection

Depending on one of the conditions proposed in the previous step, the third step is about choosing the candidate users who can share the same resource. This phase is indispensable before passing to resource allocation phase because the choice of candidates is important to find users sharing the same resource with the minimum interference.

Concerning the first condition, its goal is to look for the users sharing the same Rb having the values of SNR higher or equal to the average value of interference. With this condition, we can choose the candidates with a minimum of interference therefore, we ensure a high throughput.

The second condition allows to satisfy a higher number of users so that the throughput is also high.

In order not to degrade the performance of our system, we propose a 3rd condition. This condition offers a better throughput compared to the other two conditions.

The process of selecting candidates from users is described by algorithm 3.

Algorithm 3 Candidates selection

{Inputs}
U = n, B=x ,R=r % Number of users , SBSs and resource block respectively.
h_{max}*%* User's number sharing simultaneously one Rb
{main}
For *x=1 : R*
For *n=1 :U*
%Condition 1
If *M-cond(1)(u,r) ≥ average (INR)*
Find *(u,r)= M-cond(1)(u,r) ≥ average (INR) %* obtain SNR values that exceed or equal to the average interference value
Find SNR values that exceed or equal the average interference.
Calculate $M_{u\text{-}Cond1}$ *(u,r)=f (M-cond(1)(u,r)) %* matrix contains only users who meet the imposed requirements.
%Condition2

if *M-cond(2)(u,r) ≥mean(M_{SINR})*
Find *(u,r)= M-cond(2)(u,r) ≥ average (*SINR*))* % find SINR values that exceed or equal to the average SINR value
Calculate $M_{u\text{-}Cond2}(x,n)=f\,(M\text{-}cond(2)(u,r))$ % matrix includes only users who meet the criteria imposed by condition 2.
%Condition3
if*M-cond(3)(u,r) ≥M-SINR**ThrMin***

Find *(u,r)= M-cond(3)(u,r) ≥ ($SINR_{ThrMin}$)* % find SINR values that exceed or equal to the minimum SINR threshold of the minimum throughput value
Calculate $M_{u\text{-}Cond3}(u,r)=f\,(M\text{-}cond(3)(u,r))$ % matrix includes only entities who meet the criteria imposed by condition 3.

End if
End
End
End

Step 4: Resource Allocation

Once we have selected the candidates, the fourth step is triggered. We start by calculating the SINR values for all users by checking the imposed constraint using the equation (SINR). Next, we sorted the SINR values of the users in descending order. The NOMA technique allows the sharing of Rb by several users at the same time, this allocation depends on several criteria, in our proposed algorithm we choose two criteria for selecting users such as SINR and minimal interference between users sharing the same Rb. These two criteria guarantee the required performance for a NOMA-based system. Then, among the candidates we selected a first user with a maximum value of the SINR. The first selected user can share one Rb with another after checking the minimum imposed interference value. The number of user that shares the same Rb is configurable. So, we have chosen the case of 2 users. The following algorithm 4 explains the resource allocation step for all h_{max}.

Algorithm 4 Resource allocation

// Selecting the (u,r) pair with the max-SINR value in M_{SINR}.
// Depending to the value of h_{max}, select the user with a minimum
interference value in M_{IntraC} or M_{InterC} depending on the interference type chosen to share the same Rb.

{Inputs}
$M_{SINR\text{-}cond(i)}$**:** matrix includes SINR values for all users meeting the required criteria with i identified the condition adopted 1,2 or 3.
$M_{ou\text{-}cond(i)}$: The matrix includes only those users who satisfy the precondition of a shared Rb.
h_{max}: Number of users able to share the same Rb.
{Main}

% Allocation of Rbs when h_{max} = 2
Calculate $M_{SINR\text{-}cond(i)}(u,r)= f(M_{u\text{-}Cond(i)}(u,r))$ % matrix includes SINR values for all users meeting the required criteria.
Calculate $M_{IntraC}$with equation *(8) %* matrix contains intra-cellular interference values
Calculate M_{InterC} with equation (4) % matrix includes inter-cell interference values

For *g=1:R*
Tri SINR value $M_{SINR\text{-}cond(i)}(u,r)$ % sort values in descending order
Tri Interference value M_{IntraC}% sort values in ascending order
Tri Interference value M_{InterC}% sort values in ascending order

End

***For** k=1 to U do*
Find *(u1, r1) = max (* $M_{SINR\text{-}cond(i)}$*((u1,r1))*, with *(u1,r1)*∈U x R
% Determine the maximum value present in the r^{th} column (on the same Rbr) of the matrix
Find *m1= max*($M_{SINR\text{-}cond(i)}$)% identify the first user with a maximum SINR value in $M_{SINR\text{-}cond(i)}$
Duplicate *selected m1 in* $M_{ou\text{-}cond(i)}$
Remove *the* $u1^{th}$ *row from* $M_{SINR\text{-}cond(i)}$ *U=U \ {u1} %*Update U
% If α=0 =>uplink sense is chosen:
Find *m2 = min (*M_{IntraC}*)* % identify the second user with the minimum value of intra-cell interference in M_{IntraC}
Duplicate *selected m2 in* $M_{ou\text{-}cond(i)}$
Remove *the u2 th row from* M_{IntraC} *U =U \ {u2} %* Update U
%if α=1 => if downlink sense is chosen:
Find *m2 = min (*M_{InterC}*)* % identify the second user with the minimum value of inter-cell interference in M_{InterC}
Duplicate *m2selected in* $M_{ou\text{-}cond(i)}$
Remove *the u2 th row from* M_{InterC} *U=U \ {u2} %* Update U

Assign *Rbk à m1 and m2*
R=R \ {r1} % Update R
End for

In the final instance, the performance of the proposed algorithm needs to be verified. In this regard, we have approved our results through simulations in terms of throughput and BER.

We explain the concept of our approach by the diagram below, which summarizes our proposed algorithm.

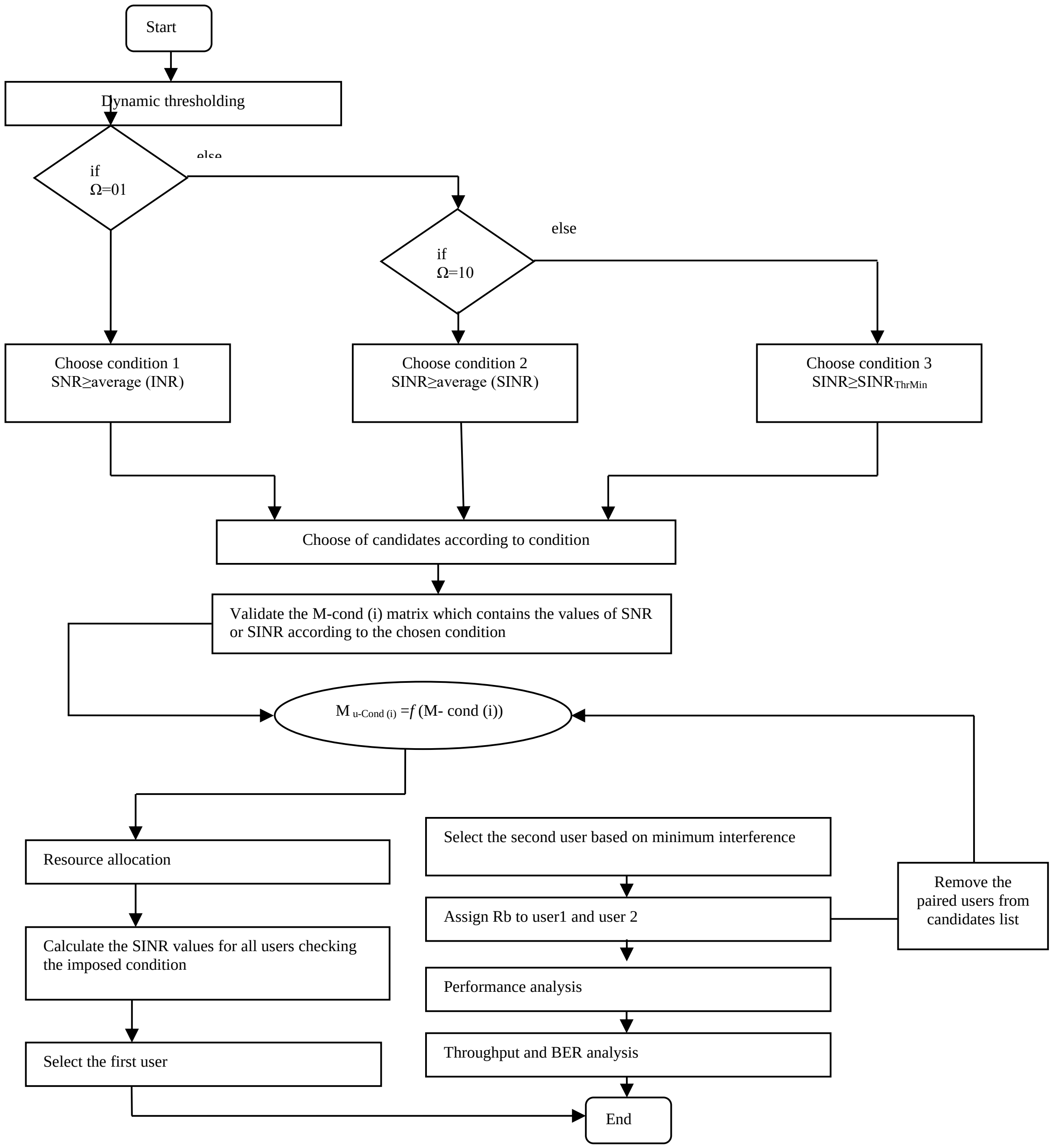

Figure 2: The Proposed Algorithm's Flow Chart

5 Simulations and Results

In this paragraph, the proficiency of our suggested algorithm for 5G-V2X in the NOMA-based UDN will be established by Matlab simulations. For the evaluation of our presented algorithm, we analogize our suggested approach with others works and the 3GPP standard. Simulation results validate that our addition can accomplish appropriate performance, where the efficiency of our solution has been proven by various performance measures such as throughput and bit error rate.

In addition, for comparison, we take as an example the article (Arsla et al., 2021) and (Osama et al., 2022) to evaluate our algorithm in terms of throughput: We chose these papers because they use resource allocation with interference mitigation. The papers are recently published. In addition, they consider almost the same parameters treated for the evaluation. Our algorithm complies with the conditions imposed by 3GPP which will be detailed in the following paragraph in the direction uplink and downlink.

Table 4 highlights simulation parameters.

Table 4: Parameters Setting

Parameter	Value
Bandwidth	15 MHz
Available Rb	[15,75]
Considered users	[50,80]
Considered number of SBSs	[1,7]
h_{max}	[2,5]
Duration of ts	1ms
Maximum power of one SBSs	24dBm
Distance between SBSs and user u	[10,50m]
pth	3dB (Ron Levie et al., 2020)
sh	[0,8dB] (Nikolaos I et al., 2015)
Noise power	-174dBm/Hz

Uplink Mode

In this subsection, we investigate the performance of our proposed algorithm regarding of throughput and BER in uplink mode.

Throughput Analysis

The system throughput refers to the rate of successful data transmission over a communication channel in a network (Gunhee et al., 2020).

Figure 3 illustrates the average throughput versus the number of resource blocks for different conditions. For simplicity, we consider the number of users sharing the same Rb h_{max}=2.

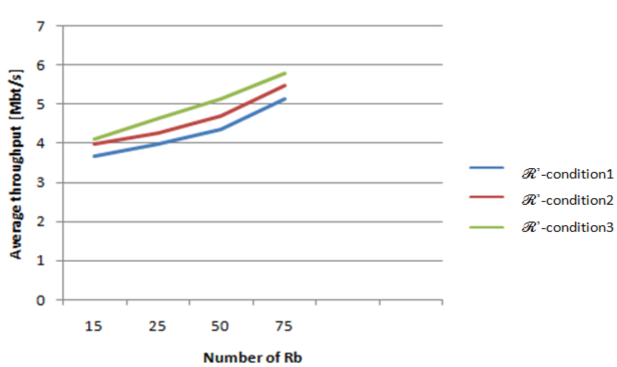

Figure 3: Throughput Performances for Different Conditions in the Presence of I'

We notice from the figure above, with the increment of the number Rb, all the graph lines elevate significantly: the more consumed spectrum resource, the higher average throughput can be acquired. The curve associated to the third condition represents the better throughput because the number of candidates that satisfy the threshold is higher than the numbers of users related to the two others conditions. Our proposed algorithm is able to provide a better throughput compared to work (Arsla et al., 2021). This indicates that our proposed schema can uses the three conditions with an auto configurable way in the users selection phase, might considerably improve the average throughput compared to the case where all the users share the same Rb in a random manner.

Figure 4 studies the variation of the average throughput as a function of h_{max}, with the number of Rb=75. We can notice that when the h_{max} number increases the throughput also increases.

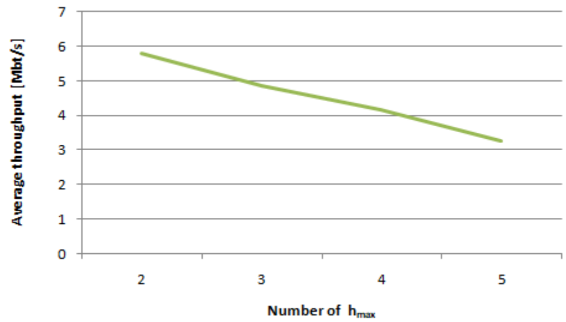

Figure 4: Average Throughput Versus of Different h_{max}

For this simulation, we used the third condition to select the candidates that can share the same Rb. The figure shows that the minimal throughput value equal to 3.2 Mb/s when the number of h_{max}=5.

It is very important to have an elevated number of h_{max} because in this case, we can serve more of users simultaneously with the use of the concept of the sharing thanks to the NOMA technique and we can also decrease the latency but the interference become higher with the increase of h_{max}. Despite the significant h_{max} value, we found an acceptable throughput compared to the imposed performance by the 3GPP.

BER Analysis

BER is a key parameter used to review the efficiency of our algorithms because it is very important to consider such parameter for NOMA based allocation. The binary error rate is specified as the rate at which errors produce in a transmission system. BER is the number of bit errors divided by the total number of bit transferred (Hamad et al., 2021). The equation of bit error rate can be formulated into this formula:

$$\text{BER}=\frac{\text{Number of bit errors}}{\text{Total number of bits transferred}} \quad (14)$$

For our proposal we used the BPSK type modulation.

The BER calculation model is explained in the following figure.

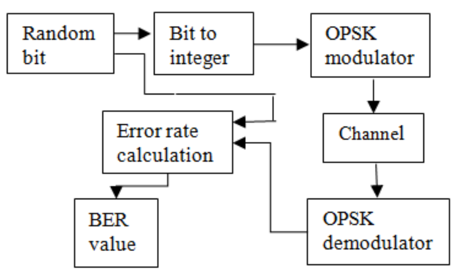

Figure 5: BER Calculation Model

Figure 6 represent the BER as a function of SINR

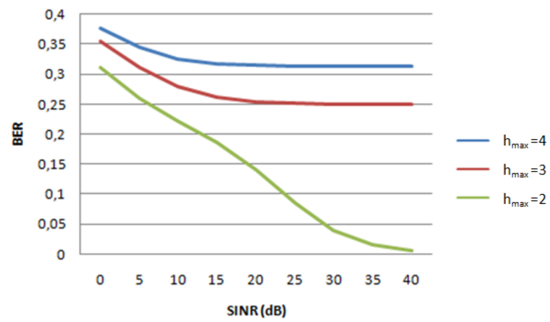

Figure 6: BER Performance Via Different h_{max} in Uplink

The figure above shows that when the SINR value increases, the BER decreases. We note that the curve concerning the number of users who can allocate the same Rb which is equal to 2, has the smallest values compared to the curves corresponding to the values 3 and 4.

If the number of users that share the same Rb is important, the BER value is also important. In fact, in the first condition named the candidate selection, we have taken into consideration the interference of the users that can share the same Rb, that's why we ended with satisfying results despite of the elevated number of the users who will share the same Rb.

Downlink Mode

In this subsection, we present our numerical analysis to examine the performance of our proposed interference mitigation algorithm concerning of throughput and BER in downlink mode.

Throughput Performance

In this subpart, we will show the throughput performance in the presence of intercellular interference. In addition, we will show that our algorithm ensures the performance required by the 3GPP standard (Imadur et al., 2021; David et al., 2020).

The figure below represents the average throughput as a function of the number of resources blocks the three mentioned conditions in the presence of intercellular interference with a significant number of cells=7 and h_{max}=2.

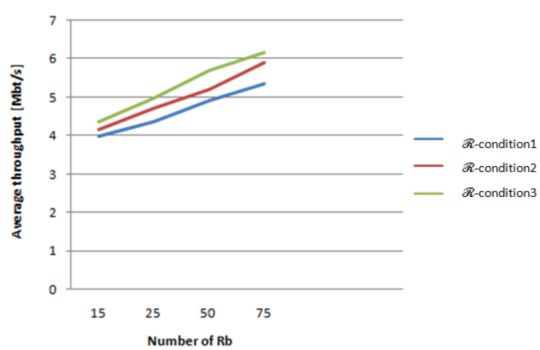

Figure 7: Throughput Performance Versus the Number of Rb with the Presence of the Inter-cell Interference

As shown in Figure 7, the average throughput increases as the number of Rb increases. We notice with the third condition that we obtain a higher throughput relative to the two others conditions because, by using the third condition, we achieve a higher number of users sharing the same Rb. Therefore the throughput will be better.

According to (Imadur et al., 2021) and (David et al., 2020), the safety type of traffic necessitates ultra-reliability, low latency and a packet size of 50-2000 Bytes for V2X communications. In fact, when the bit rate is 6.154 Mbps, our algorithm permits a message transfer of 384 Bytes. Nevertheless, our approach in the presence of interference intercellular satisfies the 3GPP recommendations.

We can observe the minimal throughput presented by the curve related to the first condition is equal to 3.978 Mb/s. This value indicates that we have found an acceptable throughput that obeys to the performance imposed by the 3GPP. This shows that the use of conditions with an auto configurable way in the selection step of candidates will help to ameliorate considerably the throughput compared to the case where no condition is involved.

Figure 8 clearly shows the superiority of Intra-Inter IMVN over the compared scheme in terms of average throughput for four to 20 users, with the number of Rb=25 and h_{max}=2.

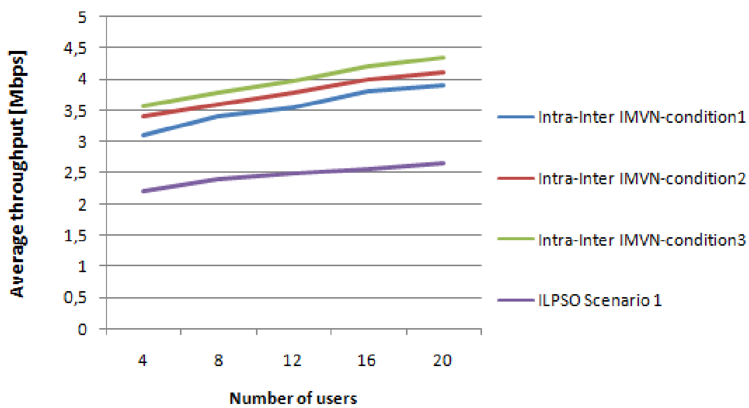

Figure 8: Average Throughput Analysis

Our approach for the third condition always achieves higher throughput than the other two conditions, as the number of users reaching the threshold exceeds the number of users used to the two others conditions.

According to this figure, one can notice a gradual increase in throughput compared to the ILPSO algorithm. The ILPSO scheme with scenario 3 is suggested to optimize the resource assignment considering the minimum throughput and fairness constraints. We chose the ILPSO approach to evaluate our algorithm because it is based on resource allocation using NOMA. It also takes into account the same parameters for assessment. In the user selection process, Intra-Inter IMVN is able to combine three different conditions to dynamically configure the network topology for interference mitigation in the UDN network, which justifies the throughput progression compared to the existing work (Osama et al., 2022).

BER Performance

Figure 9 presents BER as a function of SINR in the downlink with different h_{max}={2,3,4}.

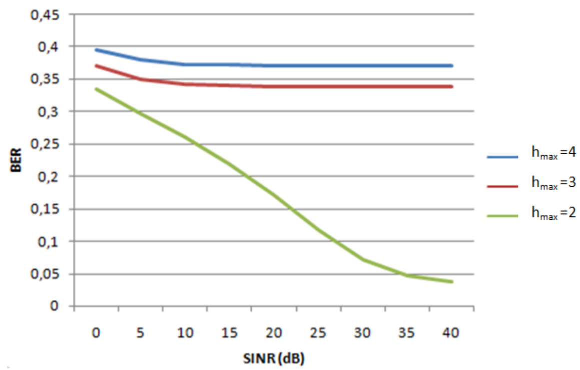

Figure 9: BER Performance Versus the Different Values of h_{max} in Downlink

Figure 9 shows the BER obtained by 7 cells with the existence of inter-cell interference with two, three and four users sharing the same Rb. We observe that the curve for two users who can use the same Rb is lower than the curve for h_{max} is equal to 3 and 4.

In fact, the forwarded information quantity in the downlink direction is more important than the forwarded information quantity in the opposite direction.

We have achieved satisfying results despite the large number of users who will use the same Rb.

Our algorithm will be implemented at the cloud level, especially for the cloud RAN, which is the novel radio access network architecture. It is anticipated to deliver higher performance and lower costs for new generation mobile networks.

6 Conclusion

In this article, we tried to enhance some performance of an UDN system based on NOMA by integration the mechanism of interference mitigation. Therefore, we presented a dynamic resource allocation and sharing algorithm derived from NOMA in a UDN system named Intra-Inter IMVN. Our approach reduces the level of interference in order to maximize throughput and minimize bit error rate. The contributions of this article can be generalized as follows: our suggested approach allows for two different types of interferences, such as intra-cellular and inter-cellular interferences. Our algorithm makes it possible to reuse and share the available resources of the cellular spectrum between them, thereby improving the number of connected users. It is able to combine three conditions for dynamically configuring the network topology, which provides a considerable performance gain. It can be used in uplink and even downlink. The resource allocation strategy used several interference mitigation parameters, which are the estimated SINR value and the minimal interference between users sharing the same Rb criterions. Therefore, the user with a maximum SINR value can share the same Rb with another user with a minimum interference value. The performance of our approach has been evaluated in terms of BER and throughput.

Extensive simulation results were displayed to prove the considerable performance of the suggested algorithm in contrast to the current literature.

In subsequent studies, we will study the computational complexity of our proposed algorithms. In addition, we can integrate the Coordinated Multi-Point (CoMP) techniques. Then, we will ameliorate this work by merging the Artificial Intelligence with Intra-Inter IMVN to obtain the best resource allocation solution with interference mitigation while adding some power control approaches.

References

[1] Abuajwa, O., Roslee, M.B., Yusoff, Z.B., Lee, L.C., & Pang, W.L. (2022). Throughput fairness trade-offs for downlink non-orthogonal multiple access systems in 5G networks. *Heliyon*, *8*(11).

[2] Alam, M.S., Selim, B., Ahmed, I., Kaddoum, G., & Yanikomeroglu, H. (2021). Bursty impulsive noise mitigation in NOMA: A MAP receiver-based approach. *IEEE Communications Letters*, *25*(9), 2790-2794.

[3] Amer, A., Ahmad, A.M., & Hoteit, S. (2021). Resource allocation for downlink full-duplex cooperative NOMA-based cellular system with imperfect SI cancellation and underlaying D2D communications. *Sensors*, *21*(8), 1-23.

[4] Boccuzzi, J. (2019). Introduction to cellular mobile communications. *Multiple Access Techniques for 5G Wireless Networks and Beyond*, 3-37.

[5] bouhamed Rigane, E., Marouane, H., Trabelsi, A., & Zarai, F. (2020). Interference mitigation based on NOMA for scheduling algorithm in V2X environments. *In IEEE International Wireless Communications and Mobile Computing (IWCMC)*, 1952-1957.

[6] Budhiraja, I., Kumar, N., & Tyagi, S. (2021). ISHU: Interference reduction scheme for D2D mobile groups using uplink NOMA. *IEEE Transactions on Mobile Computing*, *21*(9), 3208-3224.

[7] Chen, Q., Wu, J., Wang, J., & Jiang, H. (2022). Coexistence of URLLC and eMBB Services in MIMO-NOMA Systems. *IEEE Transactions on Vehicular Technology*, *72*(1), 839-851.

[8] Cheng, Y., & Zhao, Y. (2021). Price-based resource allocation scheme for v2x communications underlying uplink cellular network. *In IEEE 7th Annual International Conference on Network and Information Systems for Computers (ICNISC)*, 801-806.

[9] Garcia-Roger, D., González, E.E., Martín-Sacristán, D., & Monserrat, J.F. (2020). V2X support in 3GPP specifications: From 4G to 5G and beyond. *IEEE access*, *8*, 190946-190963.

[10] Gu, Y., Cui, Q., Chen, Y., Ni, W., Tao, X., & Zhang, P. (2018). Effective capacity analysis in ultra-dense wireless networks with random interference. *IEEE Access*, *6*, 19499-19508.

[11] Hou, T., Wang, J., Liu, Y., Sun, X., Li, A., & Ai, B. (2021). A joint design for STAR-RIS enhanced NOMA-CoMP networks: A simultaneous-signal-enhancement-and-cancellation-based (SSECB) design. *IEEE Transactions on Vehicular Technology*, *71*(1), 1043-1048.

[12] Jang, G., Lee, C., Kim, N., Kang, W., Nguyen, T.V., & Cho, S. (2020). Throughput maximization for uplink IoT NOMA systems with efficient resource allocation. *In IEEE International Conference on Information and Communication Technology Convergence (ICTC)*, 1763-1765.

[13] Khan, A., Usman, M.A., Usman, M.R., Ahmad, M., & Shin, S.Y. (2021). Link and system-level NOMA simulator: the reproducibility of research. *Electronics*, *10*(19), 1-25.

[14] Khezri, R., & Steen, D. (2022). Vehicle to Everything (V2X)-A Survey on Standards and Operational Strategies. *In IEEE International Conference on Environment and Electrical Engineering and IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)*, 1-6.

[15] Kim, H. (2020). 5G core network security issues and attack classification from network protocol perspective. *Journal of Internet Services and Information Security (JISIS)*, *10*(2), 1-15.

[16] Levie, R., Yapar, Ç., Kutyniok, G., & Caire, G. (2020). Pathloss prediction using deep learning with applications to cellular optimization and efficient D2D link scheduling. *In ICASSP IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, 8678-8682.

[17] Li, W., Qin, X., Jia, Z., Bi, J., & Li, X. (2022). Resource sharing for cellular-assisted D2D communications with imperfect CSI: a many-to-many strategy. *IEEE Systems Journal*, *16*(3), 4454-4465.

[18] Liu, L., Li, C., & Zhao, Y. (2023). Machine Learning Based Interference Mitigation for Intelligent Air-to-Ground Internet of Things. *Electronics*, *12*(1), 1-12.

[19] Liu, Y., Li, X., Ji, H., & Zhang, H. (2017). A multi-user access scheme for throughput enhancement in UDN with NOMA. *In IEEE International Conference on Communications Workshops (ICC Workshops)*, 1364-1369.

[20] Liu, Y., Yu, F. R., Li, X., Ji, H., Zhang, H., & Leung, V.C. (2018). Self-optimizing interference management for non-orthogonal multiple access in ultra-dense networks. *In IEEE Wireless Communications and Networking Conference (WCNC)*, 1-6.

[21] Lyu, X., Tian, H., Ni, W., Liu, R. P., & Zhang, P. (2017). Adaptive centralized clustering framework for software-defined ultra-dense wireless networks. *IEEE Transactions on Vehicular Technology*, *66*(9), 8553-8557.

[22] Ma, H., Li, S., Zhang, E., Lv, Z., Hu, J., & Wei, X. (2020). Cooperative autonomous driving oriented MEC-aided 5G-V2X: Prototype system design, field tests and AI-based optimization tools. *IEEE Access*, *8*, 54288-54302.

[23] Medeiros, R., Fernandes, S., & Queiroz, P.G. (2022). Middleware for the Internet of Things: a systematic literature review. *JUCS: Journal of Universal Computer Science*, *28*(1), 54-79.

[24] Melgarejo, D.C., Da Costa Filho, L.Q.R., De Medeiros, Á.A.M., Neto, C.L., Figueiredo, F.L., & Rodríguez, D.Z. (2022). Dynamic Algorithm for Interference Mitigation Between Cells in Networks Operating in the 250 MHz Band. *IEEE Access*, *10*, 33803-33815.

[25] Miridakis, N.I., Vergados, D.D., & Michalas, A. (2015). Performance analysis of successive decoding based on shadowing side information under non-identical composite fading/shadowing channels. *IEEE Transactions on Wireless Communications*, *14*(9), 4835-4846.

[26] New, W.K., Leow, C.Y., Navaie, K., Sun, Y., & Ding, Z. (2021). Interference-aware NOMA for cellular-connected UAVs: Stochastic geometry analysis. *IEEE Journal on Selected Areas in Communications*, *39*(10), 3067-3080.

[27] Rahman, I., Razavi, S.M., Liberg, O., Hoymann, C., Wiemann, H., Tidestav, C., & Gerstenberger, D. (2021). 5G evolution toward 5G advanced: An overview of 3GPP releases 17 and 18. *Ericsson Technology Review*, *2021*(14), 2-12.

[28] Tsuzuki, Y., Shimamoto, S., & Pan, Z. (2021). Evaluations of SIC by Power Difference in IM-NOMA. *In IEEE Wireless Days (WD)*, 1-5.

[29] Wang, K., Li, H., Ding, Z., & Xiao, P. (2022). Reinforcement learning based latency minimization in secure NOMA-MEC systems with hybrid SIC. *IEEE transactions on wireless communications*, *22*(1), 408-422.

[30] Yahya, H., Alsusa, E., & Al-Dweik, A. (2021). Exact BER analysis of NOMA with arbitrary number of users and modulation orders. *IEEE Transactions on Communications*, *69*(9), 6330-6344.

[31] Zhai, D., Wang, C., Zhang, R., Cao, H., & Yu, F.R. (2022). Energy-saving deployment optimization and resource management for UAV-assisted wireless sensor networks with NOMA. *IEEE Transactions on Vehicular Technology*, *71*(6), 6609-6623.

[32] Zheng, L., Nguyen, K.K., & Cheriet, M. (2022). NSATC: An interference aware framework for multi-cell NOMA TUAV airborne provisioning. *In IEEE Wireless Communications and Networking Conference (WCNC)*, 2226-2231.

[33] Zhu, J., Wang, J., Huang, Y., He, S., You, X., & Yang, L. (2017). On optimal power allocation for downlink non-orthogonal multiple access systems. *IEEE Journal on Selected Areas in Communications*, *35*(12), 2744-2757.

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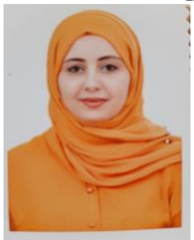

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