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Research Article

Multiple Interference Cancellation in MIMO-NOMA-D2D Network

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Abstract

We look into using Non-Orthogonal Multiple Access (NOMA) with Mul- Tiple Interference Cancellation (MIC) techniques in a downlink multiple- input multiple-output (MIMO) cellular system where the total number of receive antennas in a cell is higher than the total number of transmit antennas at the base station (BS). In this article, we take into account device-to-device (D2D) communication in MIMO-NOMA systems with perfect Channel State Information (CSI). The network comprises a base station (BS) and D2D devices. Multiple devices can be served by the power-domain NOMA (PD-NOMA). The D2D communication in the cluster improves Spectral Efficiency (SE) and Energy Efficiency (EE) even more in comparison to the MIMO-NOMA network without D2D communication. Most of the work engaging the MIMO system focuses on inter-cluster interference. This paper not only focuses on inter-cluster interference, but with the MIC technique, intra-cluster interference is also significantly reduced. Instead of Successive Interference Cancellation (SIC), we use Mul- Tiple Interference Cancellation (MIC) strategies at the receiver, focusing on optimizing network resources and improving SE and EE. For the pro- posed MIMO-NOMA-D2D system, a thorough performance evaluation is conducted, and the outcomes are compared to those for traditional MIMO systems based on Orthogonal Multiple Access (OMA) and MIMO-NOMA solutions already in existence.

Keywords: NOMA: Non-Orthogonal Multiple Access; MIC: Mul- Tiple Interference Cancellation; MIMO: Multiple- Input Multiple-Output; BS: Base Station; SE: Spectral Efficiency; EE: Energy Efficiency; SIC: Successive Interference Cancellation; OMA: Orthogonal Multiple Access

Introduction

The average monthly usage per smartphone is expected to be 46 GB by the end of 2028. The percentage of mobile data traffic using 5G is expected to reach 69% by 2028 [1]. These progressively move towards fifth-generation (5G) wireless communication networks (WCNs), putting forward the need for high throughput performance and massive connections. The spectral efficiency of a system can be greatly improved by using NOMA technology, which is re- garded as an encouraging multiple access method [2-4]. To manage the growing demands of mobile user traffic, 5G networks are expected to include a significant number of technologies, covering MIMO and D2D communication [5], spectrum sharing [6], and ultra-dense networks (UDNs) [7]. Serving sev- eral users concurrently across the same spectrum of resources at the expense of inter-user interference is the core tenet of NOMA. Unlike conventional Orthogo- Nal Multiple Access (OMA), which serves each user in a cell on exclusively given communication resources (time and frequency), NOMA superimposes multiple users' message signals in the power domain. This is done by taking advantage of the individual channel gain differences between users. At the receiver end, NOMA uses the successful interference cancellation (SIC) technique to cancel inter-user interference. However, MIMO communications with multiuser beamforming have drawn much interest as a potential solution for achieving substantial gains in over- all system throughput [8]. Inter-cluster interference in MIMO communication can be completely eliminated when the number of send antennas is more than or equal to the number of receive antennas.An individual beamforming vector that is orthogonal to the channel gains of the other receivers on the same sys- tem supports each receiver in a classic multiuser MIMO system. In a downlink multiuser system, several receive antennas from diverse devices with different channel gains are combined into MIMO-NOMA clusters. A NOMA schedule is used to schedule the devices in each cluster. Typically, the number of clusters, also referred to as transmit beams, equals the number of BS transmit antennas. The NOMA network's receivers, which are all clustered together, use the same beam. The clusters may share a beam yet use orthogonal spectrum resources if there are more clusters than BS transmit antennas. On the other hand, tradi- tional MIMO-OMA refers to the distribution of orthogonal spectrum resources among the users of each cluster. Furthermore, a normal general NOMA system is one that has only a single antenna base station. A promising aspect of 5G technology is device-to-device (D2D) communica- tion, which enables user-to-user communication without the base station's (BS) involvement. Direct links for communication reduce power consumption and improve EE. Additionally, it skillfully increases spectral efficiency (SE), and the system's throughput [9]. It has the ability to set up a secure network [10]. Inter- ference between devices in the 5G MIMO-NOMA network is a serious problem associated with the use of D2D communication. This is lessened by carefully managing power and resource distribution. Energy conservation is crucial for the research community as a result of the exponential rise in mobile traffic and the corresponding rapid increase in energy consumption. Green communica- tion is crucial since information and communication technology is a significant sources of greenhouse gases in the environment. In the MIMO-NOMA network, integration with D2D communication will calm the power-hungry 5G cellular network and reduce energy consumption. However, the interference brought on by SIC reduces the system's performance. Most of the work of MIMO-NOMA focuses on inter-cluster interference, while at the same time, intra-cluster interference is a challenging task to mitigate while the SIC technique is used at the receiving end. Therefore, this paper uses the MIC [11] approach to improve the performance of the MIMO-NOMA-D2D networks by canceling the intra-cluster interference.

Background and Motivation

D2D communication uses resources to communicate via direct link construc- tion. There are several resource-sharing strategies that ensure the users' needs for Quality of Service (QoS) are met. The tactics for allocating resources main- Tain SE as well as EE. In order to facilitate information transfer from BS to devices through cooperation, this study takes advantage of direct linkages of D2D communications. Combining methods such as Amplify-And-Forward (AF), Decode-And-Forward (DF), Compress-And-Forward (CF), and variants of these can be used to increase the coverage area. CF-based receive cooperation is a modern approach to boosting system capacity that use single-antenna devices to generate a fictitious Multiple-Input Multiple-Output (MIMO) configuration [12-15]. In [8-13], the physical layer designs for an AP supporting two devices with two antennas are taken into consideration, which uses the CF- based receive cooperation. In [16], the usage of Dinkelbach theory and convex optimisation was used to study a resource reuse strategy in a D2D network that maximises energy efficiency. Game theory is used by the authors of [17] to examine resource-sharing strategies in a D2D communication network. Energy- efficient resource sharing results in a considerable improvement in performance. The research in [18] shows that the system's cumulative rate is increasing while still maintaining the SINR restrictions for all devices, including D2D devices in the NOMA network. An alternative strategy is suggested in [19] for increasing the system total rate in a D2D-NOMA network. This scheme proposes co- operative sub-channel and power allocation. The non-convex power allocation problem is transformed into a convex one via sequential convex programming. In a D2D-NOMA network, the cooperative relaying method suggested in [20] is implemented to increase system capacity. For a downlink cellular network with underlying D2D communications, the authors of [21] introduced beamforming- based multi-user MIMO-NOMA. Two techniques for multiuser MIMO beam- forming were developed. The second approach was created to eliminate inter- ference from BS to D2D communications, whereas the first method was created to remove interference from inside beams. The base station (BS) employs a number of transmit antennas to generate a variety of spatial beams, each of which uses the underlying NOMA technology [22]. In order to accommodate multiple devices in a NOMA cluster, multi-user clustering using a single antenna beam must be designed. Each beam in MIMO- OMA beamforming serves a single device, and its frequency is orthogonal to the other beams. Because the greatest number of devices that the BS can handle simultaneously is equal to the number of beams, and because the number of beams cannot be greater than the number of antennas, the MIMO-OMA net- work needs more hardware and energy [23]. Using MIMO-NOMA becomes a natural choice for 5G networks due to the increased need for bandwidth nec- essary to accommodate enormous users with high data rates and lower energy consumption.

Motivation

There are limitations on the overall number of transmit antennas that can be utilised to service devices. NOMA must be integrated into the MIMO network in order to get around this restriction and enhance the number of devices. Additionally, D2D communications must be integrated with MIMO-NOMA in order to deliver services that can manage the data streaming requirements of the antic- ipated high density of linked devices. This integration can exert significant strain on BS and makes use of the available spectrum by offering proximity-based ser- vices and applications. Additionally, it considerably raises the network's overall spectrum and energy efficiency.

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Contribution

NOMA is a low-cost technique that can increase cell spectrum efficiency without requiring any extra resources or infrastructure. The fundamental barrier to NOMA is inter-user interference, however effective user clustering and power distribution can reduce this interference and offer high spectral efficiency per- formance. The MIMO approach, on the other hand, has the ability to quadruple the spectral efficiency gain in proportion to the spatial multiplexing order by employing multiple antennas at the transmitter and receiving ends. When the entire number of receive antennas in a cell is equal to or less than the total number of broadcast antennas, inter-cluster interference in MIMO can be totally avoided. Our goal is to create a ground-breaking multiuser MIMO-NOMA-D2D system using the Multiple Interference Cancellation technique, which can max- imise system capacity (or throughput) and energy efficiency while minimizing net interference (inter-cluster interference and intra-cluster interference). This will eventually make green communication essential.

The following is a summary of this paper's main contributions:

a) For the MIMO-NOMA-D2D network, this paper suggests an effective re- source allocation strategy based on correlated channel gains. Employing MIC instead of SIC, the ideality is attained in terms of reducing intra- cluster interference in the MIMO-NOMA network.

b) Relay devices are selected for subchannel allocation and optimal resource sharing based on channel state information, which raises the spectral and energy efficiency of the D2D pairs. To further eliminate interference, MIC is utilized at the receiving end in place of SIC. An enhanced sum rate is the final result. In a MIMO-NOMA-D2D network, general formulations for the signals received with MIC have been discovered.

c) The EE maximization challenge is also discussed. By taking into account power allocation restrictions, elevated EE is attained.

d) MIMO-NOMA network significantly consumes power due to the involve- ment of massive antennas, decoders, detectors, and regenerator circuits. In this work, the elimination of the decoder and regenerator at the receiver end can help to emphasize green communication and a less power-hungry network. This lessens the system's hardware complexity as well.

e) The general expression shows that the proposed solution overcomes net interference (intra-cluster and inter-cluster) in a significantly better way than the existing MIMO-NOMA solutions.

f) Additionally, a user clustering and relay selection approach is also pro- posed based on correlated coefficients with little complexity.

g) The simulation demonstrates that the suggested scheme outperforms the conventional MIMO-NOMA and MIMO-OMA in terms of sum rate and energy efficiency. We investigate MIMO-NOMA, MIMO-OMA, and MIMO- NOMA-D2D solutions at various power and antenna levels to substantiate our claims.

System Model

Consider a single-cell downlink MIMO network where the base station (BS) has M broadcast antennas and k devices have N receive antennas on each of them., whereas $M \geqslant 2N$, which are frequently seen in real-world settings involving IoT devices of low complexity and high-complexity BSs. All the devices can be equipped with one or more receiving antennas. The devices are grouped into M clusters. Wireless channels may be subject to any distribution, such as the Rayleigh distribution, assuming that fading is assumed to be quasi-static independent and identically distributed (i.i.d.). The network considers MIMO- NOMA transmission with D2D communication to serve multiple D2D pairs. For the l -th D2D pair in the m -th cluster denoted as dl d1, d2, . . . , dl and m 1, 2, . . . , M . In this paper, we assume there are a maximum of up to two D2D pairs being assigned different power levels on the same cluster denoted as d1, d2 where d1 denotes (w, x) pair and d2 denotes (y, z) pair. The MIMO- NOMA network with D2D device communication is broadly described herein Figure 1. In this paper, tm,i indicates i-th D2D pair of m-th cluster where i ∈ {w, x} and tm,j indicates j-th D2D pair of m-th cluster where j ∈ {y, z}. The mod- ulated transmit symbol vector tm,i for D2D cooperation may be utilised for symbol transmission for device w alone, device x only, or both, depending on the resource allocation. In this scenario, resource allocation implies time sharing method. The time slot can only be used for symbol transmission for device w if $t_{m,i}$ is dedicated to that device; otherwise, it can be used for device x, or in rare circumstances, for both devices in the m th cluster. In this paper, since NOMA is used superposition coding (SC) is used at the transmitting end, and each D2D pair uses the SIC technique to decode its own messages at the receiver end. In this work, we take into consideration that each cluster holds two D2D pairs which reduces the computational complexity. In the case of a downlink transmission from BS to users, licensed spectrums are being used, and for D2D transmission, all the devices use an unlicensed bandwidth spectrum. The D2D communication is for short-range communication relative to downlink commu- nication from BS to users.

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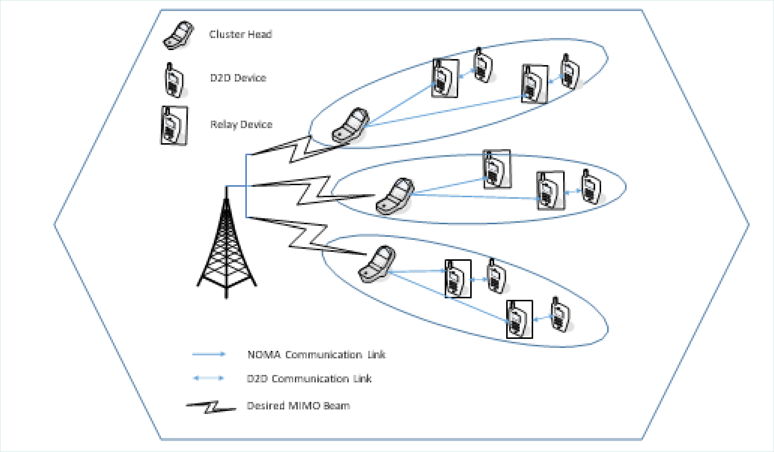

Figure 1: General MIMO-NOMA D2D network.

$It\ is\ assumed\ that X = [x_1, x_2, ..., x_M]^T \in C^{M\times 1}$ is the broadcast data vector, where $x_m = \Sigma dl_{l=1} p_{m,l} t_{m,l}$

is the data stream for m-cluster in which pm,l and tm,l are the transmit power and modulated symbol, individually for the l-$_{\text{th}}$ D2D pair in the m-$_{\text{th}}$ cluster.cluster.Where

$$t_{m,l} \in C^{M\times 1}, l \in \{\{i\},\{j\}\} and m \in \{1,2,...,M\}.$$

$$t_{m,l} = \begin{array}{l} \circ \\ t_{1,i} + t_{1,j} \\ . \\ t_{M,i} + t_{M,j} \end{array} \tag{1}$$

Let’s further assume that a beamforming precoding matrix modulates the data vector, abbreviated as B, and denotes the M × M . The channel response matrix for device k in m-th cluster denoted as $H_{m,k} = [h_{mk,1}, h_{mk,2}, ..., h_{mk,N}]^T$. The dimension of $H_{m,k} is N \times M$. Therefore, the transmitted superposed signal $x = BX$, $where x \in C^{M\times 1}$. The channel m˜ atrix provides information about the D2D link between devices.

w and device x denoted as Gwx = [gwx,1, gwx,2, , . . . , gwx,N]. In D2D connec-

tions, the channel reciprocity is maintained as Gw,x = Gx,w. This essay makes the supposition that the BS has the ideal CSI on the channels. The channel matrix provides information about the D2D link between device w and device x denoted as the decoding scaling weight factor, dsm,l, is what multiplies the received signal before it is decoded at the l-th pair in the m-th cluster. Because of this, the signal that was received for the lth pair in the mth cluster is expressed as follows:

$$y_{m,l} = ds_{m,l} h_{\tilde{h}_{m,l}} BX + n_{m,l} \tag{2}$$

Where, $\tilde{h}_{m,1} 2 \geq \tilde{h}_{m,2} 2 \geq \cdots h_{m,d1} 2 . n_{m,l} \in C$ represents circularly symmetric complex Gaussian noise with variance σ2. However, if bm denotes the n-th column of the BF precoding matrix B, then (2) can be expressed as follows:

$$y_{m,l} = ds_{m,l} \tilde{h}_{m,l} b_m p_{m,l} t_{m,l} + ds_{m,l} \tilde{h}_{m,l} b_m \frac{d_1 \Sigma 1}{j=1} p_{m,j} t_{m,j} + ds_{m,l} h_{m,l} \frac{M \Sigma}{i=1, i=m} b_i x_i + ds_{m,l} n_{m,l} \tag{3}$$

The received signal-to-intra-cell interference-plus-noise ratio (SINR) for the lth pair of the mth cluster is as follows:

$$SINR_{m,l} = \frac{ds_{m,l} \tilde{h}_{m,l} b_m{}^2 p_{m,l}}{I_1 + I_2 + ds_{m,l} n_{m,l}} \tag{4}$$

where I1 implies Intra-cluster interference, I2 implies Inter-cluster interference and dsm,lnm,l implies Noise. I1 can be expressed as followswhere I1 implies Intra-cluster interference, I2 implies Inter-cluster interference and dsm,lnm,l implies Noise. I1 can be expressed as follows:

$$I_1 = ds_{m,l} \tilde{h}_{m,l}{}^2 mb \frac{\Sigma^{dl-1}}{j=1} p_{m,j} \tag{5}$$

I2 can be expressed as follows:

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$$I_2 = \frac{\sum M}{i=1, j=m} ds_{m,l}\tilde{h}_{m,l} b_i^2 p_i \quad (6)$$

In the case of MIMO-NOMA-D2D communication, Intra-cluster interference can be expressed as $I_1 = I_{m,l}(1) + I_{m,l}(2)$ which is the n-th pair's interference with the l-th pair on the same subchannel at a distance of dmax, and because the pair has larger channel gains than the l-th pair, respectively. Where

$$I_{m,l}(1) = \frac{\sum}{l' \in D, l'/=l} p_{m,l'} \backslash h_{m,l'} \backslash^2 \quad (7)$$

and $$I_{m,l}(2) = | h_{m,l}' | 2 \frac{\sum}{j \in \{d_k l'/=l\}} p_{m,k} \quad (8)$$

In this study, the number of D2D pairings in each cluster is fixed. Also, the distance between two different pairs also considered as the constraint during pair formation to minimize intra-cluster interference. Thus, we are able to eliminate Im,l(1) interference level which proves that our proposed scheme outperforms the conventional network. In Algorithm 1, we determine the D2D communication in the MIMO-NOMA network. The D2D pair formation technique using correlated channel gain is depicted in Algorithm 2.

Algorithm 1: D2D Communication in the Downlink MIMO-NOMA Network

Input: Number of D2D devices: k

Number of transmit antennas or clusters: M

Number of receive antennas of each device: N

Channel response matrix: H

Number of clusters and cluster-heads: M

a) Initialization: All the higher channel gain devices are the cluster-head (within 150 metres of BS).

b) Generate locations of each device randomly (minimum distance from BS = 200 metres).

c) The total transmit power from BS is equally divided into all clusters.

d) Taking an average of all channel gains of all antennas for each device in the network : hi,1, hi,2, . . . , hi,N , hi, = Average channel gain of i-th device $i \in \{1, 2, \ . \ . \ . \ , \ k\}, n \in \{1, 2, ..., N\}$.

e) Device locations are sorted by channel gain in ascending order $h_1 \ge h_2 \ge .... \ge h_k, h_{i=i-th}$ device's channel gain.

f) Select set $A = \{1, 2, ..., M\}$ of relay nodes for pair d1 (closest to BS) depending on the channel gain the higher channel gain devices are set as a relay device, $h_1 \ge h_2 \ge ... \ge h_M, h_i = i-th$ device's channel gain.

g) Include the second set of relay nodes for pair d_2 (far from BS), B = {M + 1, M + 2, . . ., 2M }. $R_{i,j}$ = correlation coefficient between h_i and h_j

h) for t ← 1 to M do

i)

t−th cluster

j) update A ← for s ← M + 1 to 2M do

k) if $R_{t,s} > R_{t,r} \ge 0.5$, ∀r/= s ∈ B then

l) add s−th device into A − {t}, B ← B − {s}

Algorithm 2: D2D Pair formation

Input: Number of devices: k

Number of transmit antennas or clusters: M

Number of receive antennas of each device: N

Channel response matrix: H

Number of relay devices: L

Relay set: C = A + B, A = 1, 2, . . ., M and

B = {M + 1, M + 2, . . ., 2M}

Non-relay set: D = {L + 1, L + 2, . . ., k}

Number of D2D pairs in each cluster: 2

Maximum distance between two D2D pairs = 20 metre.

1. **Initialization**: Generate locations of each D2D device randomly.
2. 2Set D2D pair count d to zero.
3. for p←1 to number of relay devices: L do
4. for q←L + 1 to k do
5. Measure the distance between devices:

√dist = $(x_p - x_q)^2 + (y_p - y_q)^2$

6. if dist ≤ 20 AND d ≤ 2 then
7. Device p and device q will form pair.
8. Set D2D count ← d + 1

Algorithm 3: Computing performance indicator data

Input: Number of clusters: M

1. for i =← 1 to M do
2. for j =← 1 to d_l

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3. Compute t_1 and t_2 from Equation (22) and (24)
4. Compute R
5. Compute SE
6. Compute EE

Problem Formulation

This section initially introduces the computation of the MIMO-NOMA-D2D network's spectral efficiency (SE) and energy efficiency (EE).

Sum Rate

The data rate of the l-th D2D pair may be given as follows using the formulas derived for SINR at the receiver of the l-th D2D pair, as in (4) of the m-th cluster:

$$R_{m,l} = log_2(1 + SINR_{m,l}) \tag{9}$$

Therefore, the total sum rate achievable for all M clusters in the system can be expressed as:

$$R_T = \frac{\sum M \sum dl}{m = 1 l = 1} Rl \tag{10}$$

Energy Efficiency

Through efficient resource management and improved EE, the goal of an energy- efficient network is accomplished. As a result, a MIMO-NOMA-D2D network performs EE calculations as the sum of the proportion of the total sum rate achieved from a cluster to the total power assigned to the cluster. In this paper, we assign an equal power allocation to all clusters. Inside each cluster, the power allocation assignments are different, depending on the channel gain for each device. The sum of the l-th pair's transmission power and circuit power consumption is used to determine how much power it uses overall. The formula for the overall amount of power used by all pairings in a cluster is:

$$p_m = \zeta \frac{\sum dl}{l = 1} p_{m,l} + p_{ckt,1} \tag{11}$$

where ζ denotes the drain efficiency of the amplifier, pckt,l implies the total amount of power used by the regenerator, decoder, and detector, and the total power from BS is denoted as PT :

$$P_T = \frac{\sum M}{m = 1} p_m \tag{12}$$

The EE maximization problem of the network can be formulated as:

$$EE_T = \max \frac{\sum M}{m = 1} \frac{\sum_{dl_{l=1}} R_{m,l}}{p_m} \tag{13}$$

$$C1 : p_m \le P_T \tag{14}$$

$$C2 : \frac{\overset{d1}{\sum}}{l = 1} p_{m,l} \le p_m \tag{15}$$

Multiple Interference Cancellation

The pairs in each cluster get the super-positioned signal from the cellular user. The signal that the m-th cluster receives at each of the D2D pairings is as stated in (2). The suggested approach focuses on extracting the information of pairs with the maximum channel gain from the received signal because the n-th pair experiences interference from other pairs for $| h_{1,m}{}^2 | \ge | h_{2,m}{}^2 | \ldots h_{n,m}{}^2 | \ge \ldots . \ge | h_{n,m} |^2$. As a result, the interference is removed.

The matrix form of the signal received at the receiving end is thus represented as:

$$y_{m,l} = ds_{m,l}{}^h \tilde{H}_{m,l} BX' + n_{m,l}{}^i \tag{16}$$

Where

$$x \quad x \quad p \quad t \quad \ldots \quad \sum d_{l\text{-}1}\ p\ t$$

$$x_2 \quad x_2\ \text{-}\ p_{2,1} \quad t_{2,1} \ldots \quad dl\text{-}1\ p_{2,1} t_{2,1} \tag{17}$$

$$x_M \;\; x_M - p_{M,1} t_{M,1} \ldots \sum_{l=1} dl - 1 p_{m,l} t_{m,l}$$

$$y_{1,1} \quad y_{1,2} \quad \ldots \quad y_{1,dl}$$

$$y_{2,1} \quad y_{2,2} \quad \ldots \quad y_{2,dl}$$

$$Y_{m,l} = \tag{18}$$

$$y_{M,1} \quad y_{M,2} \quad \ldots \quad y_{M,dl}$$

$$h_{1,1} \quad h_{1,2} \quad \ldots \quad h_{1,dl}$$

$$h_{2,1} \quad h_{2,2} \quad \ldots \quad h_{2,dl}$$

$$\tilde{H}_{m,l} = \tag{19}$$

$$h_{M,1} \quad h_{M,2} \quad \ldots \quad h_{M,dl}$$

$$n_{1,1} \quad n_{1,2} \quad \ldots \quad n_{1,dl}$$

$$n_{2,1} \quad n_{2,2} \quad \ldots \quad n_{2,dl}$$

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$$\mathrm{n}_{m,l} = \tag{20}$$

$$n_{M,1} \quad n_{M,2} \quad \ldots n_{M,d_l}$$

Since each device has N antennas at the receiving end, at device k ∈ {w, x, y, z}, the corresponding received signal vector is represented as yk = $[y_{k,1}, y_{k,2}, \ldots, y_{k,N}]^T$, where $y_{k,n}$ represents the signal received at k-th device's n-th (n = 1, 2, . . . , N) receive antenna and $h^*_{k,n}$ represents the channel between k-th device's send antenna and n-th receive antenna. The received signal at device k is denoted as:

$$yk = \frac{\sum N_{n=1} h^{*}{}_{k,n} y_{k,n}}{\sum N_{n=1} h_{k,n}{}^{*2}} \tag{21}$$

where k ∈ {1, 2} are the relay devices. The signal detected at the closest pair of BS which is here d1 can present as:

$$t_1 = \frac{yk - {}^{\Sigma_{di-1}}{}_{l=1} \sqrt{p_l t_l}^{+}}{p_1} \tag{22}$$

Here, $\langle \cdot \rangle$ denotes the detection of the symbol as well as its demodulation and decoding.

The signal received at d2 is given by the first pair's signal, which is canceled

after reception.

$$y_2 = y_k - \surd\, p_1 t_1 \tag{23}$$

The signal at d2 (farthest pair from BS) is the demodulated signal because SIC receivers do not decode the signal at the second pair. Thus d2 is represented as:

$$t_2 = {}^{\frac{'y_2'}{\sqrt{p_2}}} \tag{24}$$

The last pair only receives its own signal with MIC, therefore in this case. stands for symbol demodulation. Decoders and regenerators are no longer nec- essary because of this. This also signifies $I_{m,l}(2)$ has been eliminated from the received signal because the decoding mechanism eliminates higher gain pairs to interfere with the lower gain pairs [24]. Elimination of $I_{m,l}(2)$ significantly improves the SINR performance. It also reduces the power consumption by the decoder and regenerator circuits.

Simulations Results and Discussion

In this part, we give simulation results to illustrate the spectrum and energy efficiency gain of the proposed MIMO-NOMA-D2D system and contrast the findings with those of conventional MIMO-OMA and MIMO-NOMA networks. The relay and non-relay devices are dispersed at random throughout the cellular network. All cluster heads are believed to be within 150 metres of the BS. The 400-meter cell radius is commonly accepted, and it is presumed that the perfect CSI is available. Also, all the devices have been scattered a minimum of 200 metres from BS and formed NOMA networks with a parameter restriction of $R_{i,j}$ 0.5 mentioned in Algorithm 1, i e., device i, and device j, the correlation coefficient should be greater or equal to 0.5. All the transmissions transpire in two phases. Data is sent from BS to the relay device during the first phase. In a specific cluster, the relay device transmits data to the non-relay devices in the network during the second phase of transmission. In order for all of the clusters to utilise full spectrum resources, it is also anticipated that the number of BS transmit antennas will be equal to the number of MIMO-NOMA-D2D clusters. We consider all MIMO-NOMA-D2D cluster sizes to be the same for a given simulation. In this work, MATLAB simulations are used to look into the effectiveness of the suggested MIMO-NOMA-D2D strategy. Comparisons are made between the performance of the proposed system and that of conventional MIMO-NOMA and MIMO-OMA. The spectral efficiency of the MIMO-NOMA system greatly increases when strongly correlated users are grouped, as shown in Figure 2. Based on Equation [10], Figure 2 analyses the overall sum rate per- formance for various numbers of clusters. The image makes it obvious that the MIMO-OMA network will have the lowest attainable sum rate. The experiment takes place in three different transmit power scenarios from the BS. It is clear that increasing the transmit power also improves the overall spectral efficiency of the whole network.

Figure 3 shows the improvement of EE as the number of clusters, which is equivalent to the number of transmit antennas, grows. The graph shows that compared to MIMO-NOMA and MIMO-OMA networks, MIMO-NOMA-D2D networks are much more energy-efficient. The experimental setup for calculat- ing energy efficiency takes a transmit power = 30 dBm for different antenna configurations. Also, our pivotal attention is on cell-centered devices since all the devices are located at a significant distance from BS. The value of circuit power decreases due to the power savings realized with the suggested approach's regenerator circuit as mentioned in Equation (22) and (24). The EE benefits from this in a favorable way. Figure 4 illustrates the spectral efficiency of MIMO-OMA, MIMO-NOMA, and MIMO-NOMA-D2D networks at various transmit powers. Energy efficiency comparison in different antenna setup shows in Figure 5.

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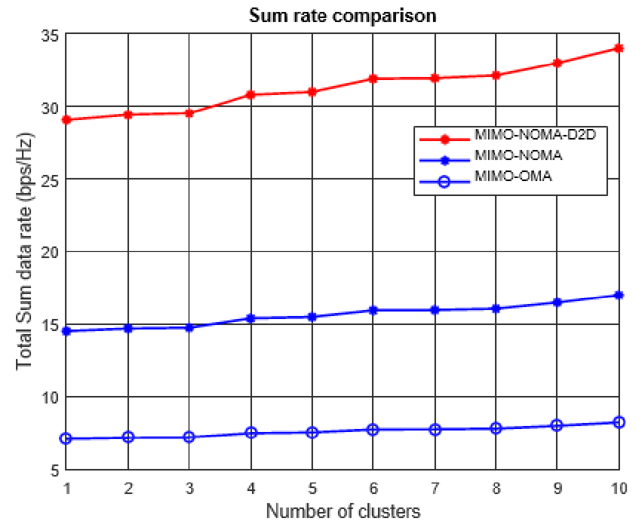
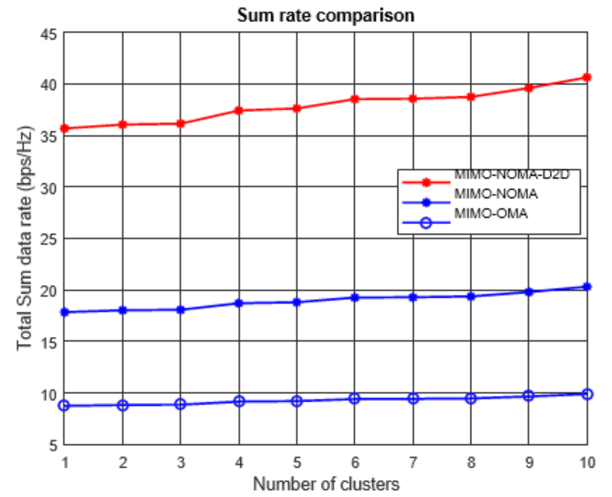
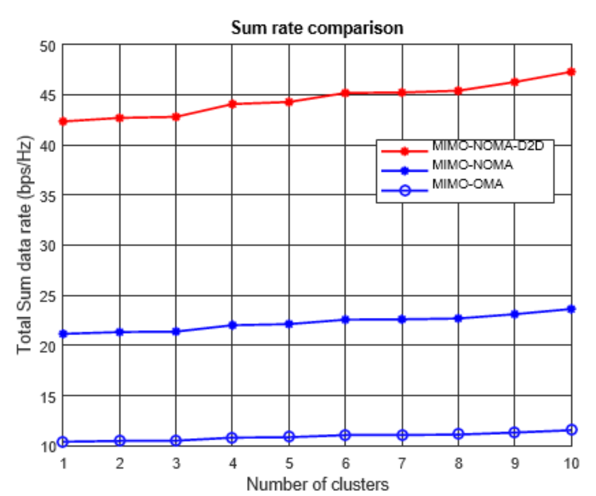


(a) Spectral Efficiency, Transmit Power = 30 dBm



(b) Spectral Efficiency, Transmit Power = 40 dBm



(c) Spectral Efficiency, Transmit Power = 50 dBm

Figure 2: Spectral efficiency comparison under different transmit power.

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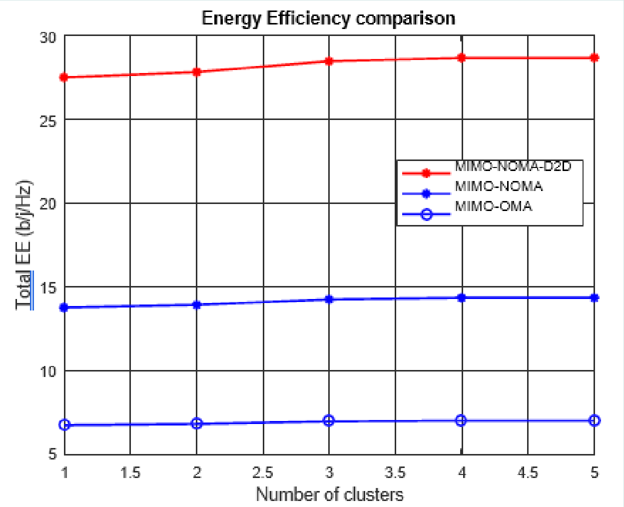
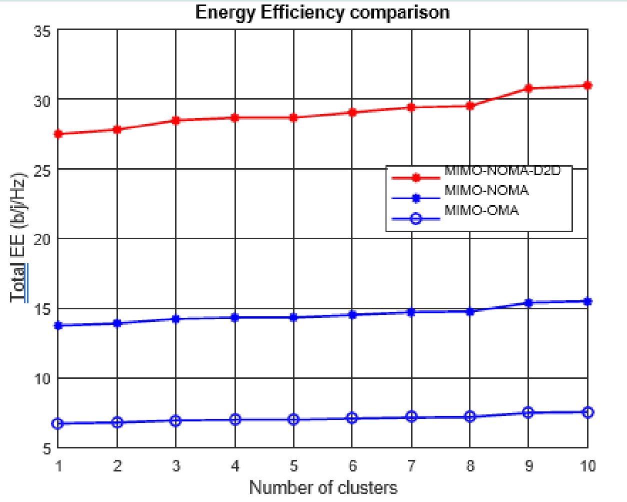
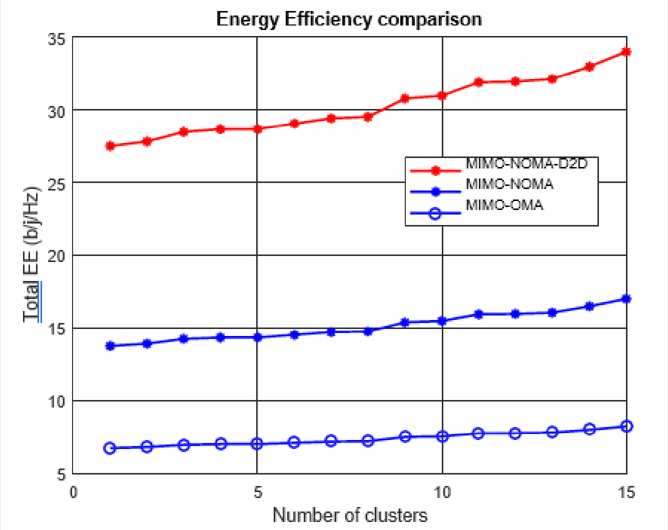


(a) Energy Efficiency, Antenna = 5



(b) Energy Efficiency, Antenna = 10



(c) Energy Efficiency, Antenna = 15

Figure 3: Energy efficiency comparison under different antenna setup.

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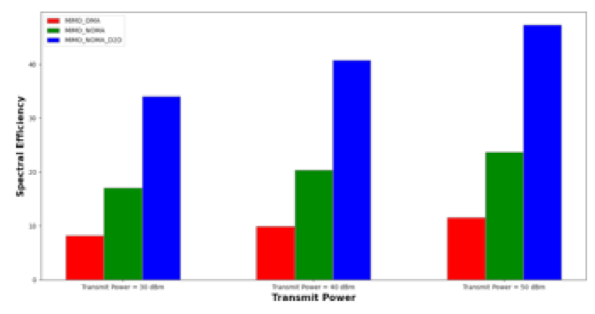

Figure 4: Spectral Efficiency Comparison.

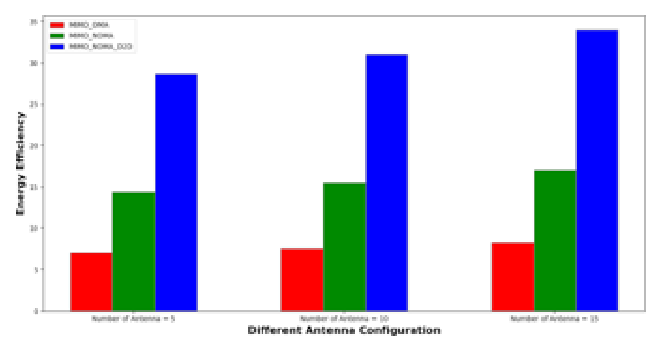

Figure 5: Energy Efficiency Comparison.

Conclusion

A viable strategy for improving spectral and energy efficiency performance is the use of the MIC technique in MIMO-NOMA wireless cellular systems Figure 5. This work focused on the downlink multiuser MIMO-NOMA, in which there are many more devices with receiving antennas than BS broadcast antennas in a cell. Each MIMO-NOMA cluster is supplied by a single MIMO beam that is orthogonal to the beams of the other clusters, and all users in a cluster are scheduled in accordance with NOMA. Most of the MIMO-NOMA solutions in the literature address inter-cluster interference; very little work has been done to address intra-cluster interference. Our work using the MIC technique and applying it to the MIMO-NOMA network significantly improves spectral and energy efficiency. Also, we have used the correlation coefficient to form the NOMA network inside each cluster, which significantly enhances the system's SE and EE performance. In Algorithm 1, we determine the relay nodes based on the channel state information of the device and work on two-time stamps. The future direction of this study could be taken from the imperfect channel state information for further improvement.

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