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Enhancement of Spectral Efficiency in Massive MIMO System Availing Eagle-Crow Optimization-Based Scheduling Algorithm

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Abstract: The core idea of massive multiple-input multiple-output (MIMO) systems is to raise the throughput and spectral efficiency (SE) of the cell system by placing a huge number of antennas at the base station (BS) to serve multiple users. Since the use of pilots is mandatory for channel estimation, this article discusses the problem of pilot contamination (PC) that affects the SE of the massive MIMO system. Due to the short coherence time in communication systems, the length of the corresponding pilot sequence is limited, and the number of orthogonal pilots that can be assigned to each cell is limited, which will inevitably lead to the repeated use of the pilot sequence in nearby cells which leads to appearance the PC problem. The PC in the networks could be eliminated through the proper scheduling of the pilot sequences and will be achieved by the proper pilot scheduling algorithm. Accordingly, this paper proposes a scheduling algorithm named eagle-crow optimization, which eliminates the contamination and promotes the SE of the massive MIMO system, under different practical constraints and requirements such as the number of antennas and users. The proposed algorithm is a combination of two optimization algorithms that are the crow search (CSA) and bald eagle search (BES) algorithms. Many studies have been performed using crow search (CSA) and bald eagle search (BES) algorithms. However, most of them did not consider PC problems in MIMO systems. The motivation behind the use of these two techniques is that the proposed eagle-crow optimization inherits the hunting characteristics of the eagle and the memory features of the crow in order to prevent the repetition of pilot assignments. The achievements of the proposed scheduling are assessed based on the performance of SE, when the number of antennas in the BS increases to 1000, the SE of the proposed method is 44.91 bps/Hz, and the percentage improvement of the proposed method is high when compared to the existing methods, Random pilot allocation, WGC-PD, and SPRS+WGC-PD.

Keywords: Massive MIMO, Eagle-crow optimization, Pilot contamination, Spectral efficiency, Pilot scheduling.

1. Introduction

To satisfy the exponential growth demand of wireless data services, the future mobile communication system needs to provide a capacity increase of more than a thousand times, massive MIMO has been analyzed so that base stations with multiple antennas can serve multiple users concurrently[1, 2]. Massive MIMO increases the SE of cellular networks through spatial multiplexing of a high number of users (UEs) for all cells [1]. The utility of massive MIMO technology has the capability to enhance the spectral efficiency (SE) and providing better coverage with improved robustness and are highly reliable [3-5]. As a result, MIMO achieves one of the key aims of the future technology by minimizing service delay, which includes both propagation and processing delays [6]. Despite the benefits stated-above, practical massive MIMO implementations confront numerous problems, such as the pilot contamination (PC) [7] as described in Fig. 1. PC is a challenging problem, which occurs during the channel estimation process as a result of user equipment transmitting pilots' sequence in surrounding cells or adjacent cells in a non-orthogonal manner [4, 8].

As a consequence of PC, the data transmission rate of the system is reduced and the occurrence of the pilot sequence in the same cell is the reason for

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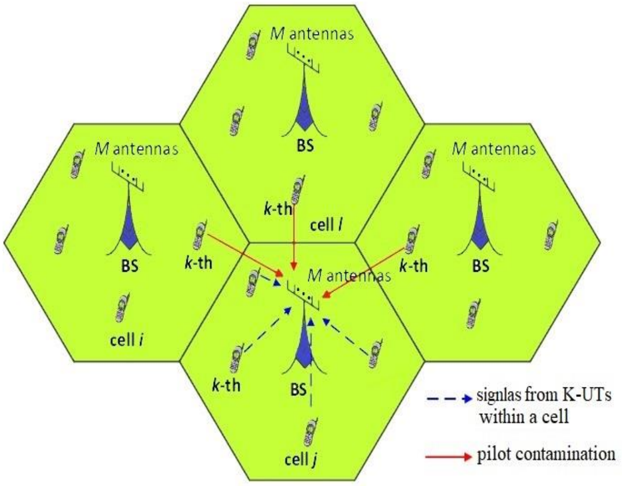

Figure. 1 Effect of pilot contamination on massive MIMO system

this contamination. However, the channel estimation uncertainty is often affected by the pilot reuse sequence sent among the users of surrounding cells [3, 9]. In addition, the PC in the massive MIMO is reduced using the channel estimation techniques [10, 11] that use adaptive methods for the training of pilot sequences. Along with that the precoding techniques [8] and pilot scheduling techniques [12, 13] are also utilized. Though the researchers concentrate in developing the contamination elimination strategies, scheduling the pilots is essential to provide the higher SE. Hence, this research concentrates in developing the pilot scheduling algorithm for rendering higher SE.

Since, the use of pilots is mandatory for channel estimation; this article discusses the problem of pilot contamination (PC) that affects the SE of the massive MIMO system. In this context, an efficient algorithm named eagle-crow optimization for pilot scheduling based on contamination elimination scheme is developed, which leads to improve massive MIMO system performance.

The ultimate goal of this work is to improve the massive MIMO's spectral efficiency by removing the PC caused by the user interference, which improves the quality of wireless transmissions.

In order to simplify the system complexity, the individual antennas in the BS are aggregated though user grouping and the pilot sequence transmission is scheduled using the proposed eagle-crow optimization. The main contributions of the research are as follows:

- The proposed eagle-crow optimization is derived by the hybridization of the bald eagle search optimization (BES) [14] and the crow search optimization algorithm (CSA) [15], where the scheduling of the pilot sequence is performed based on the best position along with its memory obtained from the characteristics of the bald eagle and crow. Many studies have been implemented with crow search algorithm (CSA) and bald eagle search (BES) algorithms. However, most of them did not consider PC problems in MIMO systems.
- The effective scheduling prevented the contamination of pilot sequence that helped in improving the SE of the massive MIMO systems.

The organization of this paper is enumerated as follows: the related works is provided in section 2. Section 3 introduces the system model. The proposed methodology for the improvement of SE of the massive MIMO system using the proposed eagle-crow optimization is interpreted in a distinct manner in section 4. The results attained through the proposed eagle-crow optimization are depicted in section 5, and at last the research is concluded in section 6.

2. Related works

The existing methods based on the improvement of SE along with its advantages and disadvantages are enumerated in this section.

In [3], the authors used orthogonal pilot sequence and gained knowledge about the large scale fading factor to reduce PC. The impressive data rate is obtained by the technique due to the estimation of better channels and the reduced performance loss. However, there is no enhancement in pilot reuse sequence, which leads to the enhancement in the interference that remains as the significant limitation of the system.

In [4], the authors utilized an efficient sectorization-based pilot allocation model to alleviate PC. Here the edge weighted interference graph was utilized to refine the low interference user. The experimental evaluation demonstrates that model provides preferable outcomes and increases the channel estimation.

The authors in [9], suggested a channel estimation model to eliminate the PC that occurs in the massive MIMO system. The channel estimation techniques utilized the orthogonal pilot reuse sequence based on approximation to reduce PC in edge users with reduced channel quality. It is illustrated that the channel estimation method significantly reduces the performance loss, maximize preferable data rate and enhance the channel quality estimation. This method was not suited for the more complex signal.

In [16], the authors introduced a deep learning-based pilot allocation, the main idea is to obtain an

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optimal pilot allocation scheme as a training sequence through an exhaustive method, and obtain a pilot allocation model through the training sequence, when a pilot allocation is required, the optimal pilot is obtained according to information large scale fading coefficient for every user, the limitation of this method is the high complexity of obtaining training data.

In [17], a presented scheme known as fractional pilot reuse (FRP) that effectively reduced the contamination in the systems. The FPR increase the throughput of the massive MIMO networks by increasing the optimal threshold distance. However, the pilots are reused only for the large number of users.

In [18], another approach is developed where a pilot rescheduling technique relying on degradation to diminish the PC issues in MIMO. The pilot rescheduling scheme is optimized through the additional utility of the orthogonal pilot sequences. The effect of the shadow fading was greatly reduced by the optimization model and it attains the preferable sum rate. However, the pilot overhead cost nullifies the performance gain achieved by the user grouping for the large number of edge user.

In [7], the spatial filter based pilot decontamination model is used to alleviate PC. The theoretical and the experimental evaluation demonstrates that PC approach based on spatial filter provides the fruitful solution to mitigate PC problem as it achieves preferable signal to interference and the noise ratio (SINR) and the data rate.

The authors in [19], explores the advantage of rate splitting (RS) in the single cell MIMO system. The pre-coding schemes and the power estimation schemes were utilized for private and common messages. The experimental evaluation demonstrates that RS solution attains higher SE. However, this model requires further enhancement to fit in multi-cell setting and the effective RS scheme to mitigate intra-cell and inter-cell interference.

The graph coloring algorithms (GCAs) have been extensively employed to decrease intercarrier interference (ICI) in mobile communications [20-22]. In [23], a novel pilot decontamination scheme based on soft pilot reuse scheme (SPRS) and a weighted graph coloring based pilot decontamination (WGC-PD) is proposed , SPRS is firstly applied to separate users and cells normally, then the focus is on the pilot decontamination between the cell centered users, and WGC-PD is applied to solve this issue more comprehensively than the last solution. This approach represents pilot decontamination scheme which combines the two existing schemes: SPRS and WGC-PD scheme. The uplink massive MIMO users are separated into cell centered users and cell edged users, and their pilot assignments are generally based on SPRS. Furthermore, WGC-PD is introduced to improve the decontamination of the cell centered users, this combination outperforms than some existing schemes.

Zhu [21], proposed a pilot assignment scheme based on WGC to mitigate PC for multi-cell massive MIMO systems. Firstly, an edge weighted interference graph (EWIG) is constructed to depict the potential PC relationship among all users. After that, inspired by classical graph coloring algorithms from graph theory, the (WGC-PD) scheme is proposed to mitigate PC by greedily assigning different pilots to connected users with a large weight in the EWIG. The proposed WGC-PD scheme outperforms the existing schemes

The major challenges of the research are enumerated as follows:

- Obtaining the SINR from all UEs at the central controller or the BS for user classification is difficult [17]. When two users in adjoining cells send or receive at the same time, the asynchronous transmission technique may cause significant interference and eliminating this interference is a strenuous task [18].
- As number of user equipment grows, the pilot scheduling strategy becomes increasingly complex [4] and scheduling the pilot sequence with optimal delay and high efficiency is a difficult task to be proceeded, but it provides significant improvements in the massive MIMO system [7].
- Traditional PC reduction solutions require more OFDM training symbols and presume that the power delay profile (PDP) of different antenna channels is the same [24].

3. System model

Massive MIMO systems provide virtuous service to the wireless terminals and the data are transmitted simultaneously to multiple users through the antennas present in the BS. Massive MIMO are entirely scalable networks due to the fact that the channel learns in both directions by employing channel estimates received from uplink pilots transmitted by the terminals. The antennas present in the massive MIMO have the capability to work individually without sharing the payload with other cells.

The massive MIMO consists of a hexagonal cell that comprises of a BS and this BS contains of L cells, each cell consisting of a BS with M antennas and

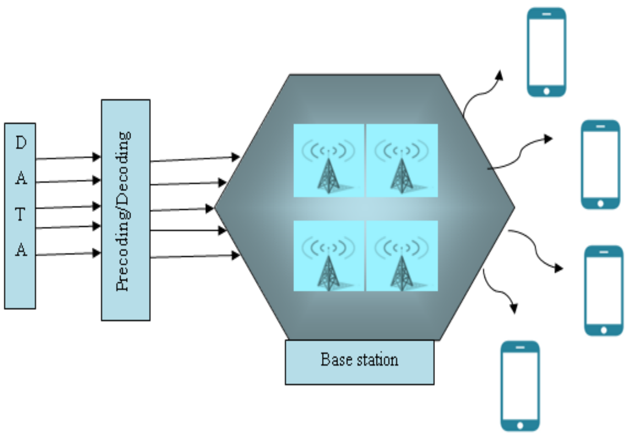

Figure. 2 System model of massive MIMO

Usingle antenna users such that *(U << M)*[25], the channel vector from the z^{th}user in the y^{th}cell to the BS in the x^{th}cell is formulated as [26],

$$h_{xyz} = g_{xyz}\sqrt{\gamma_{xyz}} \tag{1}$$

Here, the channel vector is represented by h_{xyz}, such that $h_{xyz} \in \rho^{M\times 1}$,$g_{xyz}$ is a small-scale fading factor that are statistically independent for the user u. Along with that the small-scale fading is Gaussian distributed with zero mean vector along with a covariance matrix$I_M$such that$g_{xyz} \in (0, I_M)$. A user dependent functionγ_{xyz} is introduced, which is same for all antennas in the BS and can be varied according to the user known as large scale fading coefficient and furthermore, it relates the path loss and shadow fading that are formulated as follows [27]:

$$\gamma_{xyz} = \frac{z_{xyz}}{\left(\frac{r_{xyz}}{Rad}\right)^{\alpha}} \tag{2}$$

Where z_{xyz} indicates shadow fading, r_{xyz} expresses the dimension inter the user z^{th} of they^{th}cell and the BS of the x^{th}cell, Raddenotes the radius of the cell, and α indicates the path loss fading coefficient. Hence, the matrix modeling of the cells present in the massive MIMO is given by,

$$I_{yw} = K_{yw} L_{yw}^{1/2} \tag{3}$$

Where, K_{yw} the matrix of the fast-fading coefficients that takes place between the Mantenna in the BS of the w^{th}cell and the users Uin the y^{th}cell. $L_{yw}^{1/2}$ is the diagonal matrix such that $L_{yw} \in \rho^{U\times U}$and the diagonal elements present in the matrix are γ_{ywz}. During the coherence time the channel vectors are assigned to constant and at varying coherence time the channel vectors vary independently.

The effective transmission of data through a particular time depends on the SE or in other words, when the SE is at its maximum, the transmission is more efficient. Assuming that the BS consists of perfect channel state information and there is a possibility of inter user interference. The SE of the massive MIMO is highly affected by the inter user interference, which should be eliminated for the effective transmission of data and it can be attained by the application of precoding scheme. Precoding is the process of gaining the information about the channel that helps in transmitting the data more efficiently by determining the availability of the channel. In this research, the PC is eliminated by the proper scheduling of the pilot sequence through the application of the proposed eagle-crow optimization. The baseband precoding matrix is given by,

$$F = D_{eq}^{S}\left(D_{eq} D_{eq}^{S}\right) D^{n} \tag{4}$$

$$D_{eq} = D^{S} H \tag{5}$$

Where, D_{eq} is the equivalent low dimension matrix and is given by the product of the channel matrix D^S and analog matrix H . D^n denotes the normalized equivalent diagonal matrix. The achievable SE of the f^{th}user in terms of bits/Hz is given by,

$$SE_f = E\left\{log_2\left(1 + \frac{SNR}{U[(D_{eq}D_{eq}^{S})]_{f\times f}}\right)\right\} \tag{6}$$

Where, E represents the expectation of the logarithmic values of the attributes. $SNR$is the signal-to-noise ratio and U denotes the number of users. Initially, the number of channels is estimated by the channel estimation and when there is an occurrence of channel overhead, the pilot sequence is shared by one or two users that cause inter-user interference known as PC. When all users in each cell send uplink data to their corresponding BS, The signal received by the user at the BS in the x^{th} cell can be modelled as [28]:

$$y_x^{ul} = \sqrt{\rho_u}\sum_{y=1}^{L}\sum_{z=1}^{U} h_{yzx}\, x_{yz}^{ul} + n_x^{ul} \tag{7}$$

Where x_{yz}^{ul} represents the uplink data information sent by the z^{th} user in the y^{th} cell with $E\left\{\left|x_{yz}^{ul}\right|^2\right\} = 1$,$\rho_u$ designates the uplink data transmission power, and $n_x^{ul} \in \mathbb{C}^{M\times 1}$ is the additive white Gaussian noise (AWGN) vector at BS with $E\left\{n_i^{ul}\left(n_i^{ul}\right)^H\right\} = I_M$.

By using a detector of the matched filter (MF) based on the channel estimate outcome $\widehat{H}_{xx}$, the symbol detected for the z^{th}user in the x^{th}cell can be expressed as:

$$\hat{x}_{xz}^{ul} = \hat{h}_{xzx} y_x^{ul} = \sqrt{\rho_u}\left(h_{xzx}^H h_{xzx} x_{xz}^{ul} + \sum_{y \neq x} h_{yzx}^H h_{yzx} x_{yz}^{ul}\right) + \varepsilon_{xz}^{ul} \quad (8)$$

Where ε_{xz}^{ul} indicate the intra-cell interference and uncorrelated noise. During the pilot transmission, the users transmit the uplink pilot sequence simultaneously and if there exists a lack of orthogonal pilot sequences, the cells use the pilot group of the adjacent cells. The received of the pilot sequence in the BS of the x^{th}cell is denoted by:

$$Y_x^p = \sqrt{\delta_p}\left(\sum_{y=1}^{c} H_{xy} P_{seq}^x\right) + N_x^p \quad (9)$$

Where, H_{xy} is the channel matrix and the transmitting power of the pilot sequence is represented by δ_p,N_x^pdenotes the noise vector of the pilot sequence. The matrix $P_{seq}^x = P_{seq}^1 + P_{seq}^2 + P_{seq}^3 \ldots\ldots\ldots P_{seq}^u$, that contains the pilot sequences that are transmitted and these sequences satisfies the condition of power constraints $P_{seq}^u P_{seq}^I = M^u$. The estimation of the channel matrix of the x^{th}cell in the BS is represented by x^{th} $H_{xx}$and here the least square approach is used for the correlation, the received pilot matrix with the local pilot matrix and is given by:

$$\widehat{H}_{xx} = \frac{1}{\sqrt{\delta_p}} Y_x^p \Phi^H = H_{xx} + \sum_{y=1, y \neq x}^{L} H_{xy} + v_x \quad (10)$$

Where $v_x = \left(\frac{1}{\sqrt{\delta_p}}\right) N_x^p P^H$ represents equivalent noise after the correlation process. The channel estimate of the z^{th}user in the x^{th}cell $\hat{H}_{xxz}$is a linear combination of the channelH_{xyz}that consists of the channels from other cells, which initiates PC.

4. Proposed Eagle-crow optimization

The ultimate aim of the research is to enhance the SE of the massive MIMO due to the fact that the improvement in the SE enhances the quality of the transmissions through wireless channels. The SE of the massive MIMO is improved by eliminating the contaminated pilots that occur due to the user interference. The PC is avoided by the transmission of signals through proper scheduling of the pilot sequence assigned for transmission. At the beginning, the individual antennas present in the BS are grouped by the user grouping in order to minimize the complexity of the system. Then, the transmission of pilot sequence is scheduled using the pilot scheduling algorithm, which is performed using the proposed eagle-crow optimization, where the transmission of the pilot sequence takes place with high SE. The efficiency of the research is proved using the uplink achievable rate and SINR and the schematic representation of the proposed method is shown in Fig. 3.

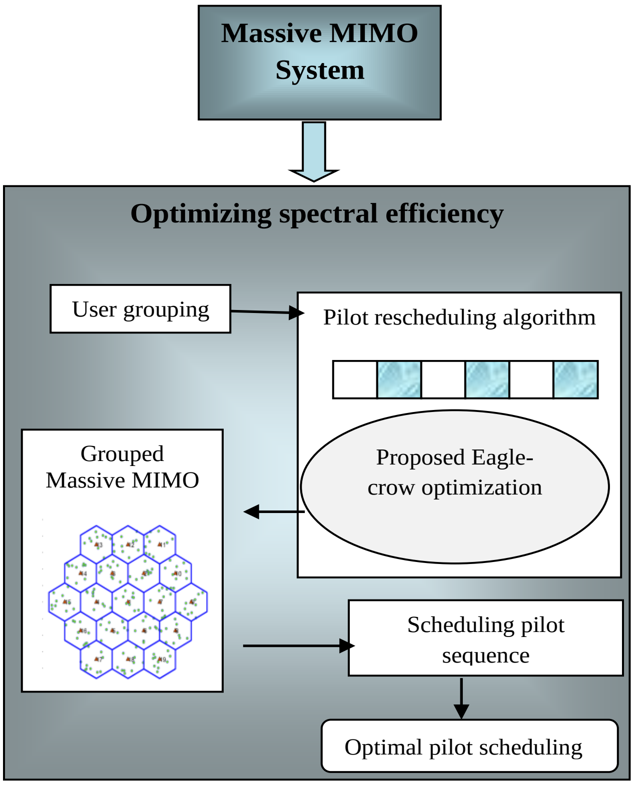

Figure. 3 Schematic representation of the proposed eagle-crow optimization-based pilot scheduling

4.1 User grouping

The intergroup interference is eliminated by forming the group of massive MIMO that consists of the beam matrix $W_r$and the center of the matrix is given by X_r and the value of r ranges from $1,2,3,4\ldots\ldots\ldots n$. The group center can be obtained by either averaging all the cells or by randomly selecting a group center from the cells. The user grouping is significant because it has impact on the scheduling process that performed by the proposed Eagle-crow optimization, because the grouping is performed within the group. The efficient user grouping improves the storage capacity of the massive MIMO.

4.2 Pilot sequence assignment

The pilot sequence assignment gains information

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about the respective cells before the transmission process for reducing the interference occurs during the transmission. The pilot sequence assignment is used for the determination of the performance degradation of the cell, where there is a lack of pilot sequence and after determination of the degradation of the cell the pilot sequence is arranged in a certain order using the pilot index that transmits the sequence in an orderly manner that improves the efficiency of transmission. The proper scheduling improves the SE of the transmission process and is attained using the pilot scheduling algorithm.

4.3 Proposed pilot scheduling algorithm

The rescheduling algorithm is used to plan the appropriate instance for each individual pilot sequence, ensuring that the sequences approaching the BS do not overlap, and reducing system interference. This will effectively reduce the PC and here the pilot scheduling is designated as an optimization problem and the optimization is performed using the proposed Eagle-crow optimization and the detailed description of the Eagle-crow optimization along with its mathematical model is described in the below section.

4.3.1. Mathematical model for the proposed Eagle-crow optimization

The eagle possesses the characteristics of effective hunting by properly monitoring the position of the target prey and the hunting is performed. Here, the process of hunting is designated as the transmission process and the eagle makes multiple attempts to hunt the prey, where the energy gets reduced. When the intelligence and memory of the crow is fused with the characteristics of the eagle the search space is not repeated and the number of attempts in determining the prey also gets reduced which improves the efficiency.

4.3.2. Motivation

The eagle-crow optimization is the nature influenced metaheuristic algorithm, which combines the important characteristic feature of predatory birds, such as bald eagle and crow. The predatory birds adopt some special hunting skills to attain the food source, some predatory birds such as crow inherits the special memory characteristics to update the best position of the food source. The prime significance of the proposed eagle-crow optimization lies in the integration of hunting skills along with the memory characteristics of the predatory birds. The hunting characteristics of the eagle help to attain effective balance between the exploration and the exploitation phase, while the memory characteristics of the crow helps to attain the best global solution with faster convergence rate. Hence, this algorithm is effective in producing the global best solution with faster convergence rate.

4.3.3. Mathematical model

The proposed eagle-crow optimization algorithm is classified into four phases such as selecting the search space, searching phase, swooping phase and the integration phase.

a) Selection of search space

In this phase the search agents explore and find out the best search space within the limited search area and this could be utilized for the determination of the cell needed for the transmission of the pilot sequence. The new location is mathematically represented as,

$$P_i^{new} = P_{best} + AR(P_m - P_i) \tag{11}$$

The controlling parameter is represented as A, that obtains the value from 1.5 to 2, the R represents the random number, which possess the value between 0 and 1. The selection of the area is done mainly based on the availability of the food sources. The position is also updated based on the food sources. P_i^{new} and P_i are the new and current search locations, respectively; P_{best} in the above equation denotes the current best solution selected by the predatory bird. P_m indicates that these eagles have used up all information from the previous points.

b) Searching phase

The predatory birds now search for their food in the selected search space and moves in different location to speed up their searching process that are designated as the process of determining the availability of the cell that provides the service to the user. The best position for the search is mathematically represented as:

$$P_i^{new} = P_i + a(i)(P_i - P_{i+1}) + b(i)(P_i - P_{mean}) \tag{12}$$

where

$$\begin{cases} a(i) = \frac{aR(i)}{max(|aR|)} \\ b(i) = \frac{bR(i)}{max(|bR|)} \end{cases} \tag{13}$$

and

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$$\begin{cases} aR(i) = R(i)\, sin\big(\theta(i)\big) \\ bR(i) = R(i)\, cos\big(\theta(i)\big) \\ \theta(i) = A \times \pi \times rand \\ R(i) = \theta(i) + p \times rand \end{cases} \quad (14)$$

Where $\theta(i)$ and $R(i)$ represent the polar angle and polar diameter of the spiral equation, $p$represents the parameter for change in the spiral shape, $rand$is a random number from 0 to 1, $a(i)$and $b(i)$indicate the position of the bald eagle in polar coordinates.

c) Swooping phase

In this phase the predatory birds shift their position to the best location to obtain its prey. Hence the identification of the best cell that is suitable for the transmission process takes place in this phase. This characteristic is mathematically represented as:

$$P_i^{new} = rand \times P_{best} + a_1(i)(P_i - C_1 P_{mean}) + b_1(i)(P_i - C_2 P_{best}) \quad (15)$$

where

$$\begin{cases} a_1(i) = \frac{aR(i)}{max(|aR|)} \\ b_1(i) = \frac{bR(i)}{max(|bR|)} \end{cases} \quad (16)$$

and

$$\begin{cases} aR(i) = R(i)\, sinh\big(\theta(i)\big) \\ bR(i) = R(i)\, cosh\big(\theta(i)\big) \\ \theta(i) = A \times \pi \times rand \\ R(i) = \theta(i) \end{cases} \quad (17)$$

Where $C_1$and C_2 represent the exercise intensity of the bald eagle to the best and centre position that takes the value between 1 and 2.

d) Integration phase

The search space of eagle is wide and there is a possibility of repetition and the eagle hunts the prey through various attempts that can be considered as the pilot contamination. The integration of the best position is obtained by the intelligence and memory constrains of the predatory bird hence the final updated equation provides the proper search space without repetition and is mathematically expressed as follows:

$$P_i^{new} = rand \times M_i^{new} + a_1(i)(P_i - C_1 P_{mean}) + b_1(i)(P_i - C_2 M_i^{new}) \quad (18)$$

Where, M_i^{new} represents the updated memory based on the best position.

Algorithm 1. Pseudo code of proposed eagle-crow optimization

S.No	Pseudo code of proposed Eagle-crow optimization
1	**Input:** P_i
2	**Output:** P_i^{new}
3	Initialize the total population P_i
4	Initialize the coefficients, $A$and R
	Swooping stage
5	Update the position according to the controlling parameter $P_i^{new} = P_{best} + AR(P_m - P_i)$
	Searching stage
6	Update the position $P_i^{new} = P_i + a(i)(P_i - P_{i+1}) + b(i)(P_i - P_{mean})$
7	Estimate $a(i)$ $a(i) = \frac{aR(i)}{max(\|aR\|)}$
8	Estimate $b(i)$ $b(i) = \frac{bR(i)}{max(\|bR\|)}$
9	Evaluate $aR(i)$ $aR(i) = R(i) * sin\big(\theta(i)\big)$
10	Evaluate $bR(i)$ $bR(i) = R(i)\, cos\big(\theta(i)\big)$
	Swooping stage
11	Update the position $P_i^{new} = rand \times P_{best} + a_1(i)(P_i - C_1 P_{mean}) + b_1(i)(P_i - C_2 P_{best})$
12	Estimate $a_1(i)$ $a_1(i) = \frac{aR(i)}{max(\|aR\|)}$
13	Estimate $bR(i)$ $b_1(i) = \frac{bR(i)}{max(\|bR\|)}$
14	Evaluate $aR(i)$ $aR(i) = R(i)\, sinh\big(\theta(i)\big)$
15	Evaluate $bR(i)$ $bR(i) = R(i)\, cosh\big(\theta(i)\big)$
	Integrating phase
16	Update the position$P_i^{new} = rand \times M_i^{new} + a_1(i)(P_i - C_1 P_{mean}) + b_1(i)(P_i - C_2 M_i^{new})$
17	**Return:** P_i^{new}

Figure. 4 shows the flowchart of the proposed Eagle-crow optimization:

5. Results and discussion

The proposed algorithm is implemented and

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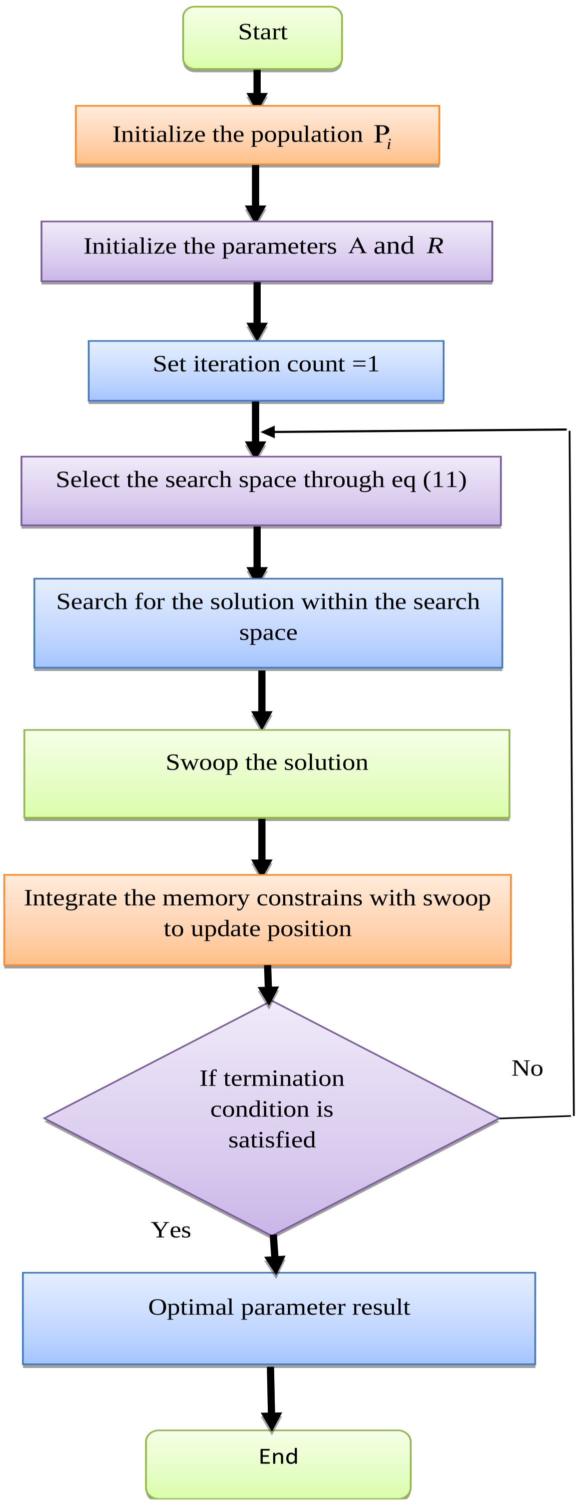

Figure. 4 Flowchart of the proposed method

analyzed with MATLAB 2020a, the performance of the developed method is verified by considering the number of antennas and users, which is compared with the other existing methods. The particular parameters of the simulation are given in Table 1.

Table 1. Simulation parameters

Parameter	Value
Cells number L	19
Number of users U of a cell	10
BS antennas number (M)	$10 \leq M \leq 1000$
Cell radius Rad	500 m
Transmission bandwidth	20 MHz
Transmit power ρ	15 dB
An exponent of Path loss	3.8
The shadowing fading σ	8 dB

5.1 Parameters for evaluation

The metrics utilized for the performance evaluation of the proposed eagle-crow optimization method is SINR and uplink achievable rate.

5.1.1. SINR

The SINR is evaluated to determine the quality of the signal obtained by the proposed method. The uplink SINR of the o^{th} cell for the t^{th} user is determined by,

$$SINR_{xz}^{up} = \frac{|h_{xxz}^{I} h_{xxz}|^2}{|\lambda_{xz}^{up}|^2 + \sum_{y \neq x} |h_{xyz}^{I} h_{xyz}|^2} \quad (19)$$

Here, the channel vector is represented by h_{xyz}, besides $|\lambda_{xz}^{up}|^2$ denotes the uncorrelated noise and interference.

5.1.2. Uplink achievable rate

The performance of the proposed Eagle-crow optimization method mainly depends on the uplink achievable rate and is determined based on two different categories as number of antennas and users.

$$R_{xz}^{up} = (1 - \mu_0) E\{log_2(1 + SINR_{xz})\} \quad (20)$$

Here, the reduction in the SE takes place in the massive MIMO represented by $\mu_0$and the PC causes a significant influence on achieving the higher uplink achievable rate.

5.2 Comparative methods

The performance of the developed method is compared with the various recent methods that considering eliminating the PC and thus enhancing the signal involved in massive MIMO. The reviewed methods are Random pilot allocation, WGC-PD [21] , and SPRS+WGC-PD [23].

5.3 Comparative analysis

The performance evaluated of the proposed

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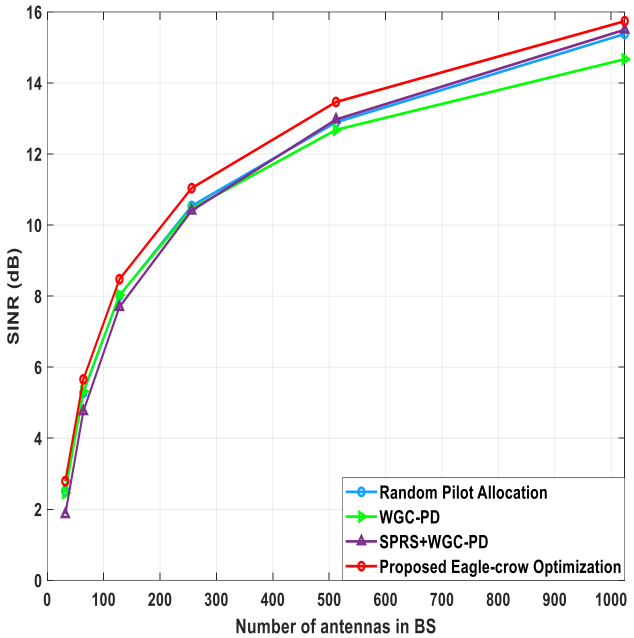

Figure. 5 SINR against number of BS antennas for different methods

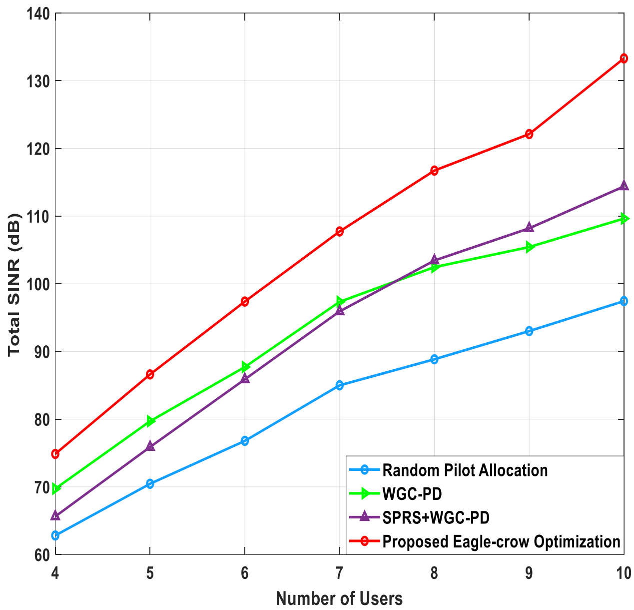

Figure. 6 Total SINR versus number of users

method using the SINR rate and the uplink achievable rate concerning the number of users and antennas.

5.3.1. Comparison based on SINR

The performance of the developed eagle-crow optimization method is exposed in Fig. 5 with respect to the number of antennas and users.

The performance of the proposed eagle-crow optimization method based on the number of antennas is revealed in Fig. 5, when the number of antennas in the BS increases to 1000, the SINR of the proposed method is 15.74 dB, and the percentage improvement of the proposed method is 4.54 when compared to the existing SPRS+WGC-PD method for considering 500 antennas. The performance of the developed method is increased by assuming a maximum number of antennas compared to other existing methods.

In the comparative analysis of the proposed method with the existing model, the Fig. 6 shows that the proposed method attains the highest the signal to the interference-pulse-noise ratio in comparison with other conventional algorithms. The highest performance in terms of the SINR of the proposed methodology is due to the best and the finest path selected by the proposed Eagle-crow optimization.

5.3.2. Comparison based on the spectral efficiency

The performance of the developed eagle-crow optimization method is exposed in Fig. 7 with the number of antennas.

Fig. 7, shows the uplink SE of the various methods with the number of BS antennas, where L=19, U= 10, and ρ =15 dB are considered. It can be shown from Fig. 7 that when we rise the number of antennas the uplink SE increases obtained of the various methods, and if the number of antennas is small, the uplink SE increase gradient is relatively large, and the small-scale fading effect gradually disappears. Under the same conditions, the developed method is better than other methods in this case.

5.3.3. Comparison based on the uplink achievable rate

The performance of the developed eagle-crow optimization method is exposed in Fig. 8 with respect to the number of users.

The performance of the proposed eagle-crow optimization method based on the number of users is revealed in Fig. 8, when the number of users increases to 10, the uplink achievable rate of the proposed eagle-crow optimization method is 44 bps/Hz, and the percentage improvement of the proposed method is 6 when compared to the existing WGC-PD method for the 4 number of users in the BS. The performance of the developed method is increased for a maximum number of users compared to other existing methods.

5.4 Comparative discussion

In the comparative analysis of the proposed Eagle-crow optimization with the existing approaches, the methods employed for the comparison are Random pilot allocation, WGC-PD and SPRS+WGC-PD. The results shows that the

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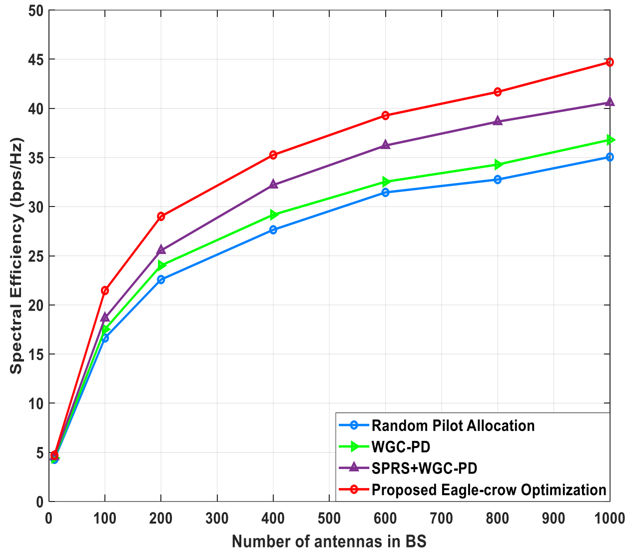

Figure. 7 SE against number of BS antennas for various methods

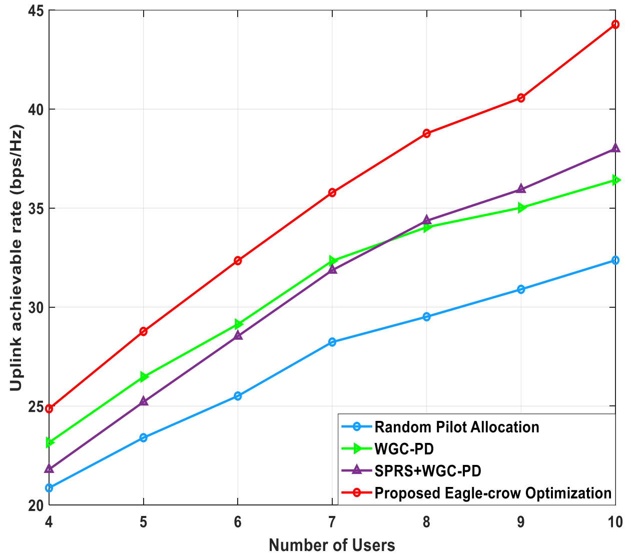

Figure. 8 Uplink achievable rate versus number of users

proposed method attains the highest average in term of uplink SE, uplink achievable rate and the SINR. The highest performance of the proposed methodology is due to the best and the finest path selected by the proposed eagle-crow optimization.

6. Conclusion

Improving the SE through proper pilot scheduling using the proposed eagle-crow optimization is performed in this research. Initially, the massive MIMO are grouped together through user grouping for the purpose of pilot scheduling and then the proposed Eagle-crow optimization is availed for the proper pilot scheduling. The determination of the search space without repetition and the hunting performed with high intelligence characteristics are used to determine the best cell for the transmission without repetition that improved the SE of the classifier. The achievements of the proposed scheduling are analyzed based on the performance of SE. When the number of antennas in the BS increases to 1000, the SE of the proposed method is 44.91 bps/Hz, and the percentage improvement of the proposed method is high compared to some existing methods: Random pilot allocation, WGC-PD, and SPRS+WGC-PD.

Notation

Symbol	Description
L	number of cells
M	number of antennas
U	the number of users
h_{xyz}	the channel vector
g_{xyz}	small-scale fading factor
I_M	covariance matrix
z_{xyz}	shadow fading
α	the path loss fading coefficient
Rad	the radius of the cell
K_{yw}	the matrix of the fast-fading coefficients
$L_{yw}^{1/2}$	the diagonal matrix
D_{eq}	the equivalent low dimension matrix
D^n	the normalized equivalent diagonal matrix
E	the expectation of the logarithmic values of the attributes
x_{yz}^{ul}	the uplink data information
ρ_u	the uplink data transmission power
n_x^{ul}	the additive white Gaussian noise vector
ε_{xz}^{ul}	the intra-cell interference and uncorrelated noise
δ_p	the transmitting power of the pilot sequence
N_x^p	the noise vector of the pilot sequence
A	the controlling parameter
R	the random number
P_i^{new},P_i	the new and current search locations respectively
P_{best}	the current best solution
P_m	indicates that these eagles have used up all information from the previous points
$\theta(i)$,$R(i)$	represent the polar angle and polar diameter of the spiral equation
$rand$	is a random number from 0 to 1
$a(i)$,$b(i)$	indicate the position of the bald eagle in polar coordinates
p	the parameter for change in the spiral shape
C_1,C_2	represent the exercise intensity of the bald eagle to the best and centre

	position that takes the value between 1 and 2
M_i^{new}	the updated memory based on the best position
R_{xz}^{up}	uplink achievable rate

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

The paper background work, conceptualization, methodology, software, investigation, formal analysis, preparing and editing draft, and visualization have been done by the first author. The supervision, review of work and project administration, have been done by the second and the third authors.

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