Optimal transmit antenna selection using hybrid algorithm for massive MIMO technology

Charanjeet Singh | Parasuram Chandrasekaran Kishoreraja

Department of Electronics and Communication Engineering, SRM University, Delhi-NCR Sonipat, Haryana, India

Correspondence
Charanjeet Singh, Department of Electronics and Communication Engineering, SRM University, Delhi-NCR, Sonipat, Haryana 131029, India.
Email: charanjeet.research@gmail.com

Summary
Massive multiple input multiple output (M-MIMO) methods make reference to a useful method for using multipath propagation to communicate and receive multiple data signals at once over a single radio channel. To simultaneously transfer numerous data streams, it makes use of various antennas. The quantity of power used grows as the quantity of antennas rises. As a result, choosing the best transmit antennas, which is a major difficulty in M-MIMO systems, becomes important. In this research, “Hybrid Sea Lion-Whale Algorithm (HS-WA)” is introduced by choosing a best transmit antenna while taking into account several objectives. This method optimizes overall capacity and efficiency. The chosen method combines the “Whale Optimization Algorithm (WOA) and Sea Lion Optimization Algorithm (SLnO)” that determines which antenna should be chosen while also optimizing the antenna quantity. Finally, energy efficiency (EE) and capacity analysis results demonstrate that the provided approach is superior to all other models.

KEYWORDS
antenna selection, energy efficiency, HS-WA algorithm, MIMO, SLnO algorithm

1 | INTRODUCTION

Massive multiple input multiple output (M-MIMO) also known as large-scale MIMO (LS-MIMO) depends on varied antennas for transferring various data streams in the network. Thus, it significantly raises the resolution and energy efficiency (EE) by exploiting several antennas at base station (BS). MIMO systems are also employed to transmit/receive the medical data. By deploying numerous antennas at the receiver and/or transmitter, MIMO systems can accomplish enhanced spatial diversity. This improves the reliability during transmission and obtains high multiplexing gains that enhance system capacity and data rate. As either a result, numerous radio frequency (RF) chains are required.

Abbreviation: AS, antenna selection; ASC, average secrecy capacity; AWGN, additive Gaussian white noise; BER, bit-error-rate; BS, base station; BPSO, binary particle swarm optimization; CDF, cumulative distribution function; CSI, channel state information; DF, decode-and-forward; EE, energy efficiency; HS-WA, Hybrid Sea Lion-Whale Algorithm; I-SLnO, improved sea lion optimization; IVM, import vector machine; LS-MIMO, large-scale MIMO; LUs, legitimate users; MF, match filtering; M-MIMO, massive multiple input multiple output; MV-GSA, modified velocity vector based gravitational search algorithm; NB, naive Bayes; OFDM, orthogonal frequency-division multiplexing; OP, outage probability; PSO, particle swarm optimization; RF, radio frequency; SNR, signal to noise ratio; SLnO, sea lion optimization; SVM, support vector machine; SE, spectral efficiency; SM-MIMO-FDR, spatial modulation MIMO full-duplex relaying; SER, symbol error rate; SIC, successive interference cancelation; TAS, transmit antenna selection; VLSI, very large-scale integration; WOA, whale optimization algorithm; ZF, zero forcing.
which quickly raises the software’s hardware complexity and cost. Therefore, to compute the cost and power consumption of the RF chain, transmit antenna selection (TAS) is necessary at both transmitting and receiving ends.

Over the past few decades, TAS on traditional processes has been a major area of research. It reveals the improvements of the system with respect to EE, and moreover it depicts the process of deploying the antenna subset in communication. The spectral efficiency (SE) may also be enhanced, although EE is still a difficult problem for upcoming networks. A promising method that reduces the aforesaid issue is optimal antenna selection. Optimal TAS adopts a sufficient number of antennas on either the transmitter or the receiver, and RF chains’ total gets reduced.

The measure of TAS could be the reduction of the bit-error-rate (BER), the maximization of the signal to noise ratio (SNR), or the channel capacity at the receiver side and so on. The EE is enhanced by selecting the ideal number of active RF chains and representing the antenna formation. In addition, more energy could be saved while the RF chains of inactive antennas are turned off. Several TAS approaches, like exhaustive search and norm-based schemes, were developed for improving EE in MIMO. However, these approaches fail to attain a stable EE with respect to the count of transmission antennas. The following is the work’s primary contribution:

- By examining the multi-objective problem, this work proposes a technique for choosing the best transmit antenna in M-MIMO, increasing the system’s capacity and comparative energy efficiency.
- This work introduces a “Hybrid Sea Lion-Whale Algorithm (HS-WA)” that was a hybridized term of whale optimization algorithm (WOA) as well as sea lion optimization (SLnO) models.

The paper order is as follows: Section 2 displays the analysis of current models. Regarding optimal TAS, the system model is described in Section 3. A hybrid sea lion-whale method of TAS in M-MIMO is shown in Section 4. Section 5 wraps up the job after Section 6 analyzes the results.

2 | LITERATURE SURVEY

2.1 | Related works

In 2020, Nguyen et al. presented an effectual approach for TAS in “Spatial Modulation MIMO Full-Duplex Relaying (SM-MIMO-FDR) systems”, in which the relay exploits decode-and-forward (DF) protocol. Additionally, the precise symbol error rate (SER) and outage probability (OP) were derived to show how effectively the adopted system was performing. The experiments’ findings demonstrated that the recommended approach’s efficiency was significantly higher compared to the strategies that were being compared.

In 2020, Khalid et al. have designed a joint TAS mechanism along with a pre-coding mechanism. Accordingly, heuristic approaches with minimal complexity were deployed to carry out the antenna selection for limiting active antennas’ total. Therefore, reducing power consumption causes the EE to grow. Additionally, a technique focused on successive interference cancelation (SIC) was used to pre-code the selected transmit antennas. Additionally, the results showed that the proposed framework was successful with little complexity and a large EE.

In 2019, Moualeu et al. have presented an enhanced framework for analyzing the MIMO systems at α-μ fading conditions. Additionally, two new methods for determining a systematic examination of an average secrecy capacity (ASC) were proposed. Furthermore, a high SNR was used to demonstrate the proposed technique’s advantages.

In 2018, Eskandari et al. developed a new solution for solving power allocation issues and for maximizing EE in point-to-point MIMO systems. An ideal solution was subsequently developed, revealing the connection between system constraints, like channel conditions and circuit power situations and the optimal EE. An innovative TAS framework was suggested to achieve an ideal solution on upper bound. Additionally, the intricacy of the created technique’s effectiveness was examined.

In 2018, Asaad et al. have analyzed the impact of TAS on the confidentiality performance of M-MIMO schemes. Additionally, a wiretap configuration was taken into account, in which a preset number of antennae were selected and the hidden information was sent to an authorized receiver. Consequently, the simulated results have accurately shown how the proposed technique has improved.

In 2020, Tran et al. have established two TAS solutions, “Solutions I and II” for modeling a secure TAS communication model. Particularly, these solutions focused on increasing the receiver signal power among nearer users and sources and among distant users and sources. Consequently, asymptotic and accurate expression was derived for the
confidential OP of the overall system and legitimate users (LUs). At last, the attained outcomes illustrated the superiority of Solution II over Solution I in regard to all secrecy.

In 2018, He et al. have focused on the scenario, in which the source adopted TAS as the transmission approach. Therefore, it was presumed that the source knew the CSI of the verified recipient, but the source could know or not know the CSI of an eavesdropper. Moreover, by considering TAS as a classification issue, two techniques named naive Bayes (NB) and support vector machine (SVM) have been suggested. Experimentation was done with the proposed work, and its performance was compared over the traditional method in regard to overhead.

In 2020, Yang and Zhao have presented a novel multi-class import vector machine (IVM)-oriented framework for maximizing the average received SNR. In fact, TAS was known to be a capable approach for cost-reducing, and it also increases the gain of the MIMO system. Furthermore, the analysis has shown the chosen methodologies’ superiority, which has acquired minimal complexity with high SNR over other compared models.

### 2.2 Limitations of existing literature

The most interesting works of TAS in MIMO is discussed in the literature. Table 1 demonstrates features and challenges of different research studies. Among them, the SM-MIMO-FDR model was presented by Nguyen et al., which offers accurate throughput and reduces the error rate. However, hardware damage could happen. Binary particle swarm optimization (BPSO) was developed by Khalid et al., which offers high spatial gain with better SE, but it has to consider more on RF chain selection. In addition, cumulative distribution function (CDF) was used by Moualeu, which provides minimal fading, and it presents high SNR; nevertheless, it should focus on capacity loss. Also, the water-filling algorithm was employed by Eskandari et al., which provides high EE with reduced complexity. But when the distance increases, EE falls. Likewise, a Gaussian-based model was presented by Asaad et al., which offers enhanced secrecy performance with minimal complexity. To increase confidentiality, TAS should be used with noise creation. In addition, the CDF function was deployed by Tran et al., which ensures reduced interference, and it offers enhanced secrecy performance. Nevertheless, it is difficult to accomplish on realistic scenarios. The SVM classifier was

| Author          | Methods                  | Features                                      | Challenges                                      |
|-----------------|--------------------------|-----------------------------------------------|------------------------------------------------|
| Nguyen et al.   | SM-MIMO-FDR              | • Throughput is good.                         | • Hardware damage could happen.                |
|                 |                          | • Error rate was minimized.                   | • Self-interference is not entirely eliminated.|
| Khalid et al.   | Binary particle swarm    | • SE was best.                                | • No thought was given to choosing the RF      |
|                 | optimization (BPSO)      | • High spatial gain providence.               | chain.                                         |
| Moualeu et al.  | Cumulative distribution  | • SNR increases.                              | • There is no thought given to various fading  |
|                 | function (CDF)           | • Fading was decreased.                       | conditions.                                    |
|                 |                          |                                               | • Need to pay more attention to capacity loss |
| Eskandari et al.| Water-filling algorithm  | • EE rises.                                   | • EE reduces the rise in distance.             |
|                 |                          | • Complexity was decreased.                   |                                                |
| Asaad et al.    | Gaussian-based model     | • Complexity was minimal.                     | • To increase confidentiality, noise creation  |
|                 |                          | • Secrecy performance was raised.             | should be paired with TAS.                     |
| Tran et al.     | CDF function             | • Reduced interference                        | • Difficult to accomplish on realistic scenarios|
|                 |                          | • Enhanced secrecy performance                |                                                |
| He et al.       | SVM classifier           | • Minimal overhead                            | • Performance gets degraded if only partial CSI|
|                 |                          | • Reduced complexity                          | is available.                                  |
| Yang and Zhao   | IVM                      | • Minimal complexity                          | • No consideration on error factors.           |
|                 |                          | • High SNR                                    |                                                |

Abbreviations: BPSO, binary particle swarm optimization; CDF, cumulative distribution function; CSI, channel state information; EE, energy efficiency; IVM, import vector machine; RF, radio frequency; SE, spectral efficiency; SM-MIMO-FDR, spatial modulation MIMO full-duplex relaying; SNR, signal to noise ratio; SVM, support vector machine; TAS, transmit antenna selection.
deployed by He et al.,\textsuperscript{28} which provides minimal overhead and reduced complexity; however, performance gets degraded if only partial CSI is available. The IVM was presented by Yang and Zhao,\textsuperscript{18} which offers reduced complexity with high SNR, but there is no consideration on error factors. Therefore, to overcome the limitations, a new hybrid optimization-based optimal TAS is introduced in this work. The hybrid optimization is known as the HS-WA model, and it is the hybrid version of the WOA and SLnO algorithms. Also, the multi-objective issue is investigated, which improves the capacity and comparative energy efficacy of the method.

3 | OPTIMAL TAS FOR MIMO TECHNOLOGY

3.1 | System model

Keep in mind one BS as well as $A$ terminals. $O_t$ The transmitter (TX) antenna total was integrated in the BS, and total $A$ contains receiver (RX) antennas as separate. A receipt signal vectors $A$ is displayed in Equation (1); here $E$ oriented to $A \times O_t$ (simple tiny scale Rayleigh fading channel matrix), $s$ oriented to $A \times 1$ receipt vector for total $A$, $P_{tx}$ oriented to TX in forward link energy, $\zeta$ oriented to factor normalize of TX power, that was displayed as $\zeta \approx \sqrt{\frac{O_t}{A}}$. $sv$ oriented to $A \times 1$ signal vector, $nv$ relates to $A \times 1$ additive Gaussian white noise (AWGN) noise vector, and $V$ relates to $O_t \times A$ pre-coding matrix for decreasing inter-user interference (IUI). For LS-MIMO, pre-coding matrices were formed in accordance with this, called, MF $\left( MF : V = O_t^{-1}B^0 \right)$ and ZF $\left( ZF : V = B^0 \left( BB^0 \right)^{-1} \right)$.

\[
s_m = \sqrt{P_{tx}} B_{\zeta} V_{sv} + n_v.
\]

Here this technique is referred to as LS-MIMO if the reception has the best CSI. A consistent approach for power consumption should be used for calculating the EE of LS-MIMO BS. Equation (2) depicts sum power $P_{sum}$ as a tractable power utilization methodology, where $P_{PA}$ and $P_{BA}$ related to the power usage of a power amplifier (PA) and baseband (BB), and RF front-end power consumption was displayed as $P_{RF_{front}}$.

\[
P_{sum} = P_{PA} + P_{BA} + E_t P_{RF_{front}}.
\]

Additionally, power usage $P_{cp}$ was assessed, which maximized with an increase in $O_t$ displayed in Equation (3). As a result, Equation (3) is changed to correspond to Equation (4).

\[
P_{cp} = \left( P_{BA}/O_t + P_{RF_{front}} \right)
\]

\[
P_{sum} = P_{PA} + O_t P_{cp}.
\]

Accordingly, consider the orthogonal frequency-division multiplexing (OFDM) design (10 MHz) having “Class-B efficiency (78.5%) with subcarriers (1024), and IBO as 11dB". This values lead to the assumption that the PA efficiency is 22%. A group among $P_{PA}$ and $P_{tx}$ was given in Equation (5).

\[
P_{tx} = \eta P_{PA}
\]

As $P_{BA}$, the LS-MIMO BB evaluation design $sv( Uflops)P_{BA}$ was addressed by Hu et al.\textsuperscript{7}

\[
z = O_t S. \left[ \frac{C_{gi}}{C_{sd}} \log_2 \left( \frac{C_{gi}}{C_{sd}} \right) + \left( \frac{C_{gi}}{C_{sd}} \right) \left( 1 - \frac{C_{pt}}{C_{st}} \right) A + \left( \frac{C_{gi}}{C_{sd}} \right) \right].
\]
The explanations that follow each constraint were shown in Equation (6).

- Parameter $S$ related to bandwidth with 10 MHz power usage.
- Parameter $C_{st}$ related to slot size with 0.5 ms power usage.
- Parameter $C_{pt}$ relates to pilot length as single slot, having 0.214 ms power usage.
- Parameter $C_{sd}$ related to symbol period, having 0.214 ms power usage.
- Parameter $C_{gi}$ refers to guard interval (GI) with $4.7 \mu s$ power utilization.
- Parameter $C_{gd}$ related to GI has $66.7 \mu s$ power usage.
- Parameter $C_{di}$ depicts delay spreading of GI, having $4.7 \mu s$ power usage.

The relationship between $P_{BA}$ and $sv(U \text{ flops})$ was displayed in Equation (7); here very large-scale integration (VLSI) efficacy denotes $\varpi$, and $\varpi = 5U \text{ flop}/R$ and $50U \text{ flop}/R$ were picked.

$$P_{BA} = \frac{sv(U \text{ flops})}{\varpi(U \text{ flops}/R)}$$  \tag{7}

### 3.2 Optimal selection of transmit antenna

The $m^{th}$ user captured the action, which was depicted in Equation (8); here $m^{th}$ user $1 \times E$, channel vector was manifested as $g_k$, and $m^{th}$ user pre-coding vector was manifested as $p_i$, $k$. Inter-user interference is the name of the final term in Equation (8).

$$q_k = \sqrt{\frac{P_{tx}E_t}{B} g_k, p_i} + \sqrt{\frac{P_{tx}E_t}{B} \sum_{l \neq k} g_k, p_i} + e_k + \sqrt{\frac{P_{tx}E_t}{B} \sum_{l \neq k} g_k, p_i}.$$  \tag{8}

Equation (9) reveals the capacity of a single isolated cell, $\alpha$ depicts the scaling factor, and $O_0S$ signifies the power of sound at $S$ bandwidth.

$$M = \alpha S \sum_{k=1}^{K} \left[ \log_2 \left( 1 + \frac{P_{tx}O_t}{\alpha A g_k, p_i} \right) \right].$$  \tag{9}

As soon as the system goes to the LS-MIMO region, Equation (9) is created, (i.e., $O_t > 10A$). In Equation (10), $X$ signifies inter-user interference. Equation (11) is used to simulate the EE. And the optimal TX antenna total $Oopt_t$ gives satisfaction in Equation (12).

$$S_{\text{approx}}^{\text{LS-MIMO}} \approx \alpha A \left[ \log_2 \left( 1 + \frac{P_{tx}O_t}{(X + O_0S)A} \right) \right].$$  \tag{10}

$$EE = \frac{M}{P_{\text{sum}}}$$  \tag{11}

$$\frac{\partial}{\partial E_t} EE = \frac{\partial}{\partial E_t} \left( \frac{M_{\text{approx}}}{P_{\text{tx}} + O_t + P_{\text{cp}}} \right) = \frac{SAP_{\text{tx}}}{(X + O_0S)A} \left( 1 + \frac{P_{tx}O_t}{(X + O_0S)A} \right) P_{\text{sum}} \log_2 P - \frac{SAP_{\text{cp}} \log_2 \left( 1 + \frac{P_{tx}O_t}{(X + O_0S)A} \right) P_{\text{sum}} \log_2 P}{P_{\text{sum}} \log_2 P} = 0.$$  \tag{12}

Here $Oopt_t$ computing is done in Equation (13); here $\Gamma = \frac{P_{tx}^2 - AO_0SP_{\text{cp}} - AXP_{\text{cp}}}{A(X + O_0S)P_{\text{tx}} \exp(1)}$ and $R$ signify the Lambert function that is depicted as $R = R(\Gamma) \exp(R(\Gamma))$. 


\[ O_{\text{opt}}^t \approx \frac{(X + O_0S)A}{P_{tx}} (-1 + \exp(1 + R(\Gamma))). \]  

(13)

Utilizing Equation (13), \( O_{\text{opt}}^t \) must be obtained, nevertheless, the issue is “how to choose the \( O_{\text{opt}}^t \) antennas on antenna total \( O_{\text{total}}^t \). A channel capability of \( O_{\text{opt}}^t \) while picking columns of \( B \) is \( \{b_1, b_2, ..., b_{O_{\text{opt}}^t}\}; \ M \{b_1, b_2, ..., b_{O_{\text{opt}}^t}\} \) is depicted in Equation (14); here, \( 1 \times O_{\text{opt}}^t \) channel vector of \( k^{th} \) user was signified as \( g_{k}\{b_1, b_2, ..., b_{O_{\text{opt}}^t}\} \), and \( O_{\text{opt}}^t \times 1 \) pre-coding vector was signified as \( p\{b_1, b_2, ..., b_{O_{\text{opt}}^t}\} \), if \( \{b_1, b_2, ..., b_{O_{\text{opt}}^t}\} \) \( i^{th} \) is picked.

\[
M \{b_1, b_2, ..., b_{O_{\text{opt}}^t}\} = a_{SD} \left[ \log_2 \left( 1 + \frac{P_{tx}O_{\text{opt}}^t}{A} \left[ \frac{d_{k}\{b_1, b_2, ..., b_{O_{\text{opt}}^t}\} p\{b_1, b_2, ..., b_{O_{\text{opt}}^t}\}}{1} + O_0S \right] \right) \right].
\]  

(14)

Instead of increasing the capacity while taking into consideration greener BS, EE should be maximized. The ideal AS for EE and channel capacity, as originally chosen from Equation (11), was equal Equation (13). Here, \( P_{\text{sum}} \) becomes antenna selection independent. For the best antenna selection, \( O_{\text{opt}}^t \) columns having maximum EE were picked as per Equation (15); here, total feasible collections of \( O_{\text{opt}}^t \) antennas were signified as \( L \).

\[
\{b_1, b_2, ..., b_{O_{\text{opt}}^t}\} = \arg \max_{\{b_1, b_2, ..., b_{O_{\text{opt}}^t}\}} \frac{M \{b_1, b_2, ..., b_{O_{\text{opt}}^t}\}}{P_{\text{sum}}}. 
\]  

(15)

4 | HYBRID SEA LION-WHALE ALGORITHM FORTAS IN M-MIMO

4.1 | Solution encoding

A suggested study focuses on determining “which antenna must be selected” and choosing the best number of antennas. A new hybrid method is used to solve this optimization problem, and Figure 1 shows the input solution for the method. The \( b \) was an antenna given an outcome, and chromosome length is influenced by antenna number \( E_t \). In Figure 1, “0” denotes antennas that are not selected, whereas “1” shows antennas that are selected. As a result, the optimum count and the best antenna to choose are established.

4.2 | Proposed HS-WA algorithm

For enhancing the traditional WOA,\textsuperscript{29–33} it is intended to hybridize the concept of SLnO\textsuperscript{34} with WOA. In fact, the hybrid optimizations are reported to be capable for solving search issues.\textsuperscript{22,35} The arithmetical model of the adopted HS-WA algorithm is described here.
Encircling prey: As per the presented HS-WA model, the update occurs depending on the random number $\phi$. If $\phi$ is lesser than 0.5 ($\phi < 0.5$), if $(|I| < 1)$, and if random integer $ra$ is min than 0.5 (i.e., $ra < 0.5$), an update takes place as per the encircling phase of WOA, i.e., as shown in Equation (17). In Equation (16) and Equation (17), $I$ and $H$ refer to the coefficient vectors, and the present step is signified by $t$.

$$
\vec{G} = |\vec{H}.\vec{Q}_p(t) - \vec{Q}(t)| \tag{16}
$$

$$
\vec{Q}(t + 1) = \vec{Q}_p(t) - I.\vec{G}. \tag{17}
$$

And then, $\vec{Q}$ signifies the position vector, and $\vec{Q}_p$ depicts good location. Lastly, $I$ and $H$ were calculated in Equation (18) and Equation (19). In Equation (18), the $\vec{a}$ component was acquired from 2 to 0 for future steps. $ra_1$ and $ra_2$ were arbitrary vectors that lie between 0 and 1.

$$
\vec{I} = 2\vec{a}.ra_1 - \vec{a} \tag{18}
$$

$$
\vec{H} = 2ra_2. \tag{19}
$$

After, if $ra > 0.5$, the updating occurs as per the detecting phase of SLnO as given in Equation (20), $D$ depicted the distance between target prey and sea lion, $H$ refers to a random integer, and $M(t)$ relates to the target prey position.

$$
\vec{Q}(t + 1) = \vec{M}(t) - D.\vec{H}. \tag{20}
$$

If $(|I| > 1)$ and $ra < 0.5$, an update happens in accordance with the WOA exploration phase as given in Equation (22), where a symbol for the arbitrary vector field is chosen from the current population $X_{(rand)}$.

$$
\vec{G} = |H\vec{Q}_{(rand)} - \vec{Q}| \tag{21}
$$

$$
\vec{Q}(t + 1) = \vec{Q}_{(rand)} - I.\vec{G}. \tag{22}
$$

Next, if $ra > 0.5$, this update was predicated on the SLnO exploration phase as depicted in Equation (23), where $\vec{Q}_{md}(t)$ relates to the arbitrary sea lion picked from the present population.

$$
\vec{Q}(t + 1) = \vec{Q}_{md}(t) - D\vec{H} \tag{23}
$$

Like that, if $\phi > 0.5$ and if $ra < 0.5$, its update happens in accordance with WOA’s exploitation phase or as specified in Equation (24). $G'$ relates to the $i^{th}$ distance, whale to prey, and was depicted in Equation (25), $b$ signifies a “logarithmic spiral shape,” and $l$ was an arbitrary variable among $[1, 1]$.

$$
Q(t + 1) = G.e^{ibl}.\cos(2\pi l) + \vec{Q}_p(t) \tag{24}
$$

$$
G' = |\vec{Q}_p(t) - \vec{Q}(t)|. \tag{25}
$$

Conversely, if $ra > 0.5$, an update happens as per the exploitation phase of SLnO as given in Equation (26); here the estimated distance between the sea lion and the potential prey was signified by $\vec{M}(t) - \vec{Q}(t)$, the absolute value was depicted as $||$, and a random number among 1 was signified by $l$.

$$
\vec{Q}(t + 1) = |\vec{M}(t) - \vec{Q}(t).\cos(2\pi l)| + \vec{M}(t). \tag{26}
$$
### Algorithm 1: Proposed HS-WA model

Assign the population of whales \( Q_i (i=1,2,\ldots,n) \)

Evaluate each exploring agent's fitness.

\( Q^* \) is the best agent for exploring

**While** \( t \) is less than the number of iterations

**for** every search agents

Update \( a, l, H, \phi \) and \( l \)

**if** \( \phi < 0.5 \)

**if** \( |l| < 1 \)

**if** \( ra < 0.5 \)

Update position as in Eq. (17)

else

Update position in accordance with Eq. (20), Depends on SLnO phase detection

**end if**

**else if**

**if** \( ra < 0.5 \)

Update position as in Eq. (22)

else

Update position in accordance with Eq. (23), i.e. depending on SLnO phase exploration

**end if**

**end if**

else

**if** \( ra < 0.5 \)

Update position as in Eq. (24)

else

Update position accordance with eq. (26), i.e. depending on SLnO exploitation

**end if**

**end if**

**end for**

Assess the exploring agent's fitness using Eq. (15)

If getting better solution, update \( Q^* \)

\( t = t + 1 \)

**end while**

return \( Q^* \)

5 | RESULTS AND DISCUSSIONS

5.1 | Simulation setup

The suggested optimum TAS design was implemented in “MATLAB,” and the outcomes were displayed. Accordingly, the supremacy of the presented HS-WA model was evaluated over existing models, namely, the modified velocity vector-based gravitational search algorithm (MV-GSA),\(^{36}\) the improved sea lion optimization (I-SLnO),\(^{37}\) the SLnO,\(^{34}\)
the WOA, and the particle swarm optimization (PSO). Here, two sets were used for the analysis. The 1st setup is $P_{tx} = 40W, sv(U\text{flop}/R) = 5U\text{flop}/R, P_{RF_{front}} = 975mW$, and the 2nd setup was $P_{tx} = 10W, P_{sum1sv(U\text{flop}/R) = 50U\text{flop}/R, P_{RF_{front}} = 97.5mW}$. Additionally, an investigation of relative effectiveness and capacity of match filtering (MF)/zero forcing (ZF) coding was conducted.

5.2 Analysis on capacity

Figure 2 compares the chosen HS-WA scheme's capacity to those of the MV-GSA, I-SLnO, SLnO, WOA, and PSO existing systems. By changing the number of customers from 1 to 8, the analysis is performed for MF and ZF within two different settings. Based on the analysis, the offered model has a larger capacity value than the other models that were examined. The capability is initially smaller for a lower number of users; however, the capacity has grown as the amount of users has risen. The HS-WA system, in particular, has produced a larger capacity for ZF under Setup 2 (from Figure 2D), although the proposed study has demonstrated somewhat lower capacity values for other experiments. More particularly, when the user count is 10, the constructed model for MF on Setup 1 outperforms conventional MV-GSA, I-SLnO, SLnO, WOA, and PSO by 21.20%, 4.09%, 7.05%, 1.65%, and 25.82%. When there are 25 users, the performance of ZF under Setup 1 is 44.28%, 11.12%, 11.18%, 2.80%, and 48.92% better than that of traditional MV-GSA, I-SLnO, SLnO, WOA, or PSO methodology. Similarly, Figure 2D shows the capacity comparison of the created HS-WA model to traditional schemes for ZF in the second setup, with the suggested HS-WA scheme achieving a greater capacity of 7.3. When there are 15 users, the performance of the offered model is 50.92%, 27.21%, 27.96%, 22.56%, and 5.29% better than that of the classic MV-GSA, I-SLnO, SLnO, WOA, and PSO. When there are 35 users, classic MV-GSA, I-
SLnO, SLnO, WOA, and PSO techniques are 63.26%, 0.41%, 17.55%, 10.65%, and 15.92% superior to MF under Setup 2. Overall, the research shows that the proposed method is efficient and has a larger capacity.

5.3 | Energy efficiency analysis

The comparative effectiveness of the developed HS-WA model is examined in this section compared to the other models. Analysis is done for ZF and MF for a variety of user counts, including 5, 10, 15, 20, 25, 30, 35, and 40. Looking at Figure 3, it is clear that the accepted approach has achieved greater efficiency than the comparable models for both setups. The accepted HS-WA model in particular has a greater efficiency of 0.979, whereas the comparing techniques have a somewhat lower efficiency. The selected model for MF under Setup 2 is, according to Figure 3C, 0.71%, 0.001%, 0.01%, 0.03%, and 0.03% superior than the other models that are currently in use when there are 40 users, including MV-GSA, I-SLnO, SLnO, WOA, and PSO. Additionally, according to Figure 3D, the compared models have a significantly lesser efficiency of 0.97 compared to the applied method of ZF on Setup 2. It is more efficient, with a score of 0.979. When there are 40 users, the developed model outperforms the other schemes called MV-GSA, I-SLnO, SLnO, WOA, and PSO by 0.72%, 0.01%, 0.01%, 0.01%, 0.001%, and 0.05%. Therefore, HS-WA model's increased efficiency has been successfully shown.

5.4 | Analysis on optimal transmit antenna count

In this part, an ideal number of migrated antennae and their corresponding relative efficiency for various user counts of 5, 10, 15, 20, 25, 30, 35, and 40 users are shown. The ideal transmit antennas for this experiment are chosen from the transmit antennas' total (in this case, total antennas = 1000). An ideal number of antennas and their accompanying

\[ \text{Relative Efficiency} = \frac{\text{Efficiency of Ideal Antenna}}{\text{Efficiency of Current Antenna}} \]

Figure 3: Relative efficiency analysis of the accepted model compared to the previous models for (A) MF (B) ZF for Setup 1 and (C) MF (D) ZF for Setup 2.
relative efficiencies achieved by the new HS-WA and current algorithms for ZF and MF on Setup 1 are shown in Table 2. An ideal amount of antennas and its associated relative efficiencies are also shown in Table 3 for the proposed and existing designs for ZF and MF in Setup 2. The findings showed that depending on the number of users, different ideal antenna counts exist for ZF and MF.

In Setup 1, the suggested model chooses 3796 ideal transmit antennae for MF with an effectiveness of 0.84412 at five users. A presented model chooses 7752 transmit antennas using 0.95248 efficiency when 20 users are taken into account.
account. This is 0.46%, 0.05%, 0.05%, 0.02%, and 0.76% better than the conventional MV-GSA, I-SLnO, SLnO, WOA, and PSO approaches, respectively. When there are 40 users, the suggested HS-WA model for ZF in Setup 1 chooses 7737 ideal transmit antennas with relative efficiencies that are 0.60%, 0.11%, 0.29%, 0.01%, and 0.67% higher than those of conventional MV-GSA, I-SLnO, SLnO, WOA, and PSO approaches. Table 3 shows that when there are 40 users, a suggested model chooses 9024 optimal transmit antennas with MF under Configuration 2, and its relative efficiency is 0.71%, 0.001%, 0.01%, 0.03%, and 0.03% higher than that of the MV-GSA, I-SLnO, SLnO, WOA, and PSO techniques.

| Match filtering | MV-GSA | I-SLnO | SLnO | WOA | PSO | HS-WA |
|-----------------|--------|--------|------|-----|-----|-------|
| Number of users |        |        |      |     |     |       |
| 5               | 9156   | 4919   | 4919 | 9121| 9139| 9142  |
| 10              | 9088   | 4981   | 8084| 9071| 9075| 9076  |
| 15              | 9065   | 4906   | 4976| 9052| 9053| 9053  |
| 20              | 9052   | 7523   | 4982| 9042| 9042| 9042  |
| 25              | 9044   | 9035   | 7507| 9035| 9035| 9035  |
| 30              | 9038   | 9030   | 7707| 9030| 9030| 9030  |
| 35              | 9034   | 9026   | 4987| 9026| 9026| 9026  |
| 40              | 9030   | 8726   | 7462| 9023| 9024| 9024  |

| Relative efficiency |          |          |          |          |      |       |
|---------------------|----------|----------|----------|----------|------|-------|
| 5                   | 0.84544  | 0.88001  | 0.88092  | 0.87898  | 0.86075| 0.85817|
| 10                  | 0.91091  | 0.92934  | 0.92898  | 0.92922  | 0.92515| 0.92366|
| 15                  | 0.9349   | 0.94779  | 0.94769  | 0.94764  | 0.9472 | 0.9465 |
| 20                  | 0.94834  | 0.95815  | 0.95815  | 0.9584   | 0.95808| 0.95787|
| 25                  | 0.95616  | 0.96531  | 0.96517  | 0.96502  | 0.96508| 0.96508|
| 30                  | 0.962    | 0.97011  | 0.97009  | 0.96999  | 0.97001| 0.9701 |
| 35                  | 0.96634  | 0.97376  | 0.97363  | 0.97372  | 0.97369| 0.97372|
| 40                  | 0.96947  | 0.97643  | 0.97658  | 0.97669  | 0.97617| 0.97644|

| Zero forcing |          |          |          |          |      |       |
|--------------|----------|----------|----------|----------|------|-------|
| Number of users |        |        |          |          |      |       |
| 5            | 9159    | 8256    | 9750     | 9121     | 9140 | 9145  |
| 10           | 9090    | 4184    | 9072     | 9072     | 9075 | 9077  |
| 15           | 9065    | 7403    | 8838     | 9053     | 9054 | 9054  |
| 20           | 9052    | 7487    | 9042     | 9042     | 9042 | 9042  |
| 25           | 9044    | 9035    | 4991     | 9035     | 9035 | 9035  |
| 30           | 9038    | 6436    | 9030     | 9030     | 5077 | 9030  |
| 35           | 9034    | 8357    | 9026     | 9026     | 5033 | 9027  |
| 40           | 9030    | 6968    | 9024     | 9024     | 5038 | 9024  |

| Relative efficiency |          |          |          |          |      |       |
|---------------------|----------|----------|----------|----------|------|-------|
| 5                   | 0.84285  | 0.88058  | 0.88147  | 0.87851  | 0.86022| 0.85495|
| 10                  | 0.91031  | 0.92837  | 0.92826  | 0.92821  | 0.92471| 0.92283|
| 15                  | 0.93533  | 0.94742  | 0.9473   | 0.94694  | 0.94636| 0.94581|
| 20                  | 0.94792  | 0.95771  | 0.95798  | 0.95784  | 0.958  | 0.95766|
| 25                  | 0.95601  | 0.96495  | 0.96491  | 0.96495  | 0.96495| 0.9649 |
| 30                  | 0.96176  | 0.9699   | 0.96985  | 0.9698   | 0.9698 | 0.96982|
| 35                  | 0.96592  | 0.97362  | 0.97359  | 0.97357  | 0.97331| 0.97336|
| 40                  | 0.96938  | 0.9764   | 0.97631  | 0.97647  | 0.97595| 0.97645|
With the ideal number of transmit antennas, ZF under Setup 2 also achieves improved relative efficiency. As a result, the results show how effective the suggested model is.

5.5 CDF analysis

The CDF graphic shows the data’s empirical CDF. The percentile rank of the data points in your sample is compared from lowest to highest using the empirical CDF graphic. Figure 4 depicts the CDF plot again for suggested and known approaches for Setups 1 and 2. By altering the user count, the capacity may be calculated from this graph. Each method’s capacity value is raised to accommodate an increase in users.

6 CONCLUSION

In order to maximize capacity and relative efficiency, a unique algorithm for selecting the best transmit antenna was devised in this study. A revolutionary method called HS-WA was devised in order to perform optimal TAS; it optimally picked the antenna count as well as the “best antenna to be chosen.” Finally, it was demonstrated that the given system outperformed the current methods in terms of capacity and efficiency. When 40 users were involved, the accepted model for MF under Setup 2 outperformed the other old models, such as MV-GSA, I-SLnO, SLnO, WOA, and PSO by 0.71%, 0.001%, 0.01%, 0.03%, and 0.03%. Furthermore, whereas the contrasted designs have a very low efficiency of 0.97, the performed strategy for ZF in Setup 2 has a higher efficiency rating of 0.979. This means that when there were 40 users, the advanced model outperformed the other old systems like MV-GSA, I-SLnO, SLnO, WOA, and PSO by 0.72%, 0.01%, 0.01%, 0.001%, and 0.05%. Thus, the created model’s superiority to earlier works has been demonstrated.

DATA AVAILABILITY STATEMENT
Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID
Charanjeet Singh https://orcid.org/0000-0001-6598-8150

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