A DETECTION TECHNIQUE OF SIGNAL IN MIMO SYSTEM

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Abstract

MIMO techniques are based on multiple antennae in receiving and transmitting signals and also used in multipath propagation for the transformation of entire channel into many independent virtual channels. In MIMO system multiple antennae can increase the spectral efficiency/ reliability of radio channel without increasing bandwidth or transmit power. Commercially, it is not feasible in case of MIMO systems. So, simple and efficient receiver that can harness MIMO architecture benefits without draining mobile receiver battery power or long time to decode transmitted symbols was required. In this paper problem of receiver design for MIMO system in spatial multiplexing scheme that is Maximum likelihood detection problem also known as NP hard combinatorial optimization problem, which need an exponential search over the space of all possible transmitted symbols in order to find closest point in Euclidean sense to received symbols, has been considered. A metaheuristic algorithm for detection of MIMO wireless system based on the Ant colony optimization (ACO) technique using MATLAB give the best solution to the problem and find the optimal path for the receivers.

Keywords: *ACO, CO- combinatorial optimization, MATLAB, Metaheuristic, MIMO, NP Hard-non deterministic polynomial time hard, QAM- quadratic amplitude modulation*

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1. INTRODUCTION

In wireless mobile communication the demand for multimedia services as well as an number of subscribers is increasing briskly. As the current air interfaces are incapable of supporting the high data rates and quality of services, designers have been looking into techniques that would improve average and peak bit rates, latency, service coverage, spectral efficiency and system capacity. One of the most hopeful techniques is the use of multiple antennae at both transmitting and receiving sides of the radio channel. The use of multiple antennae helps to mitigate the impairing effects of fading. Actually MIMO model exploits the very presence of the rich scattering environment to provide diversity and improve performance of wireless channel. To harness potential diversity and multiplexing gains of MIMO system the receiver and transmitter should be optimally designed.

According to Berbineau (2004), new technologies of communication and information are regarded as two key components for the transmission of systems based on applications namely video on demand, embedded surveillance, control, command and maintenance reporting, etc. The wireless systems are deployed by using multiple antennas for radiating cables or wave guides in free propagation through tunnels. It is significant for the basic wireless systems to increase high data rate and robustness and also to prevent the increase of transmitting power or transmission bandwidth [12].

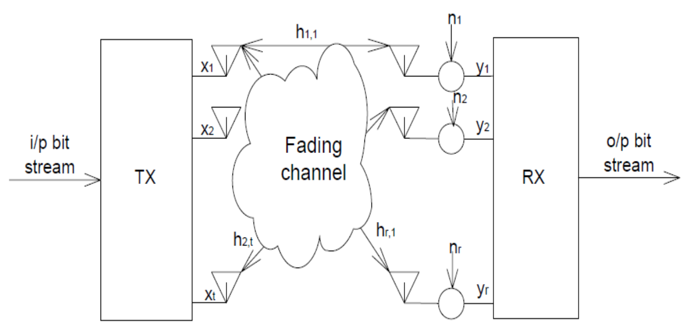

Fig.1: MIMO system schematic representation Source: [20]

According to Acan (2004) a probabilistic technique for resolving several issues which can be limited to predict better paths through graphs is referred to as the ant colony optimization algorithm. Although true ants are blind, they are capable of predicting the smallest path from sources of food to their nest by utilizing a liquid material referred to as a pheromone, which they discharge on transit route. The Ant Colony Optimization algorithm is an ant colony algorithms family member in swarm intelligence processes and it forms some met heuristic optimizations [1].

Dorigo and Blum (2005) has mentioned that Ant Colony Optimization is also a general search technique based on population for complicating repetitive problem's solution which is affected by the pheromone track preventing real ant colonies behavior. In artificial ant colonies the ant behavior is inhibited for the evaluated solutions search to discrete optimization issues to repetitive optimization issues and to significant issues in telecommunications, such as load balancing and routing [9]. In the Ant Colony Optimization the first algorithm was targeted to search for graph's optimal path based on the ants behavior viewing for a path between their food source and colony. The ant colony optimization is a metaheuristic algorithm of an artificial ant colony in detecting better solutions to critical discrete optimization issues. The option is to allot the resources of computation to a series of commonly simple agents that interacts stigmergy indirectly [8].

Glover and Kochenberger (2002) have described that the developed As strategy tries to simulate real ants behavior with the addition of numerous artificial features such as discrete time, visibility and memory to solve several complicate issues successfully such as the vehicle routing problem, best path planning and travelling salesman problem, even though several modifications have been applied to the Ant Colony Optimization algorithms during the past years, their major behavioral mechanisms of ant i.e. process of positive feedback explained by ants colony is still common. The algorithm of ant has several numbers of networking applications such as in electrical distribution networks and in communication networks [13].

2. PROBLEM REPRESENTATION

In a spatial multiplexing mode assume a n × n multi input multiple output system with transmit symbols chosen from a complicate M-QAM constellation, the researcher needs the receiver to detect the t transmitted messages correctly using the algorithm of Ant multi input multiple output algorithm (Catreux et al, 2002) [7].

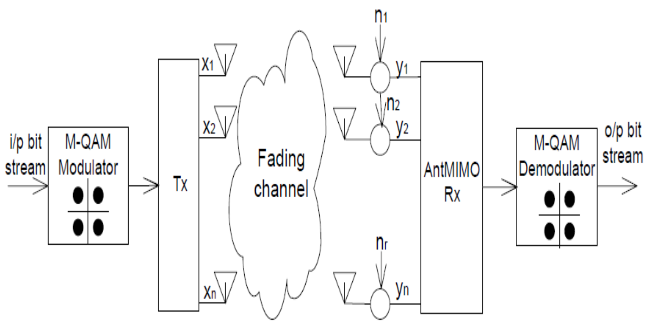

Fig.2: n × n Multi Input Multiple Output schematic representation using a configuration of SM using Ant Multi Input Multi Output Algorithm at the receiver Source: [2]

From the above figure the complicate n × n Multi input multiple output system can be indicated by the model of real system of equation:

$$Y = Hx+n \text{ ;--(1)}$$

Where $y \in R^{2n}$, $H \in R^{2n \times 2n}$ with $h_{ij} \sim N(0,0.5)$, $x \in Z^{2n}_{\sqrt{M}}$, and $n \in R^{2n}$ with $n_i \sim N(0,\sigma^2)$. The detection problem of Multi Input Multiple Output is common to resolve the minimization problem of integer least-squares.

$$min_{x \in Z^{2n}_{\sqrt{m}}} \ ||Y - Hx||^2 \text{ --------------------------------- (2)}$$

The minimization problem of integer-least squares of the equation (1) are indicated by combinatorial optimization problem $P_{MIMO} = (f, S, \Omega)$ where f the objective function must be reduced is the Euclidean distance $||Y - Hx||^2$, S is all possible transmit vectors x, and the series of constraints indicates the element integrality constraint of x, where $Z\sqrt{M} = \{0,1,\ldots.\sqrt{M}\}$ (Glover and Kochenberger, 2002) . The CO issue is associated to P_{MIMO} an entire tree T = (C, E) described by [13]:

- For n × n multi input multiple output system, height h = 2n.
- R a dummy node indicating a root.
- The set E indicates the corners linking nodes of parent to nodes of children.
- The finite set $C=\{c_1,L_0,c_2,L_1,\ldots..,c_N,L_{\sqrt{M}}\}$ indicate the tree's labeled nodes where label L_i linked with node c_j,L_i is chosen from the series $Z\sqrt{M}$ (Randall, 2004).
- Every node of parent has √M children when the transmit symbols are chosen from an M-QAM constellation.
- $w = < c_i,L_j , \ldots , c_h,L_k >$ path of 2n length that initiates at the 1st tree level tree where h = 1 and continues down the tree choosing an individual node at every level till the node of a leaf is attained is representative of probable solution to $\hat{x} = (j, \ldots, k)$ to P_{MIMO} problem (Spencer, Swindlehurst and Haardt, 2004) [18]. The below figure represents the P_{MIMO} problem tree representation for a 4QAM, 2 × 2 Multi Input Multiple Output system:

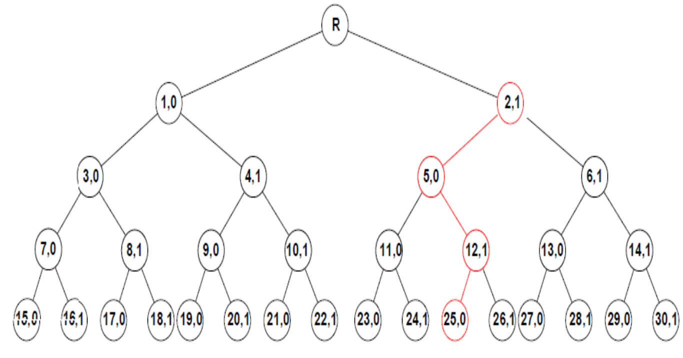

Fig.3: P_{MIMO} problem tree representation for a 4QAM, 2 × 2 Multi Input Multiple Output system Source: [8]

According to Stutzle and Hoos (2000) [19] the above figure represents the complete tree linked with a 2 × 2 multi input multiple output system utilizing a 4-QAM constellation. w = < c2, 1, c5, 0, c12, 1, c25, 0 > path for example is common to the probable solution ˆx = (1, 0, 1, 0). The Ant Colony Optimization metaheuristic algorithm can be adapted easily to solve P_{MIMO} problem using this representation.

3. THE METAHEURISTIC APPROACH

The following algorithm illustrates the Ant Colony Optimization (ACO) metaheuristic in pseudo-code[5]. All Ant Colony $x \in Z_{\sqrt{m}}$ optimization algorithms are described by Schedule Activities construct and its procedures:

- Construct Ants Solutions
- Update Pheromones
- Daemon Actions.

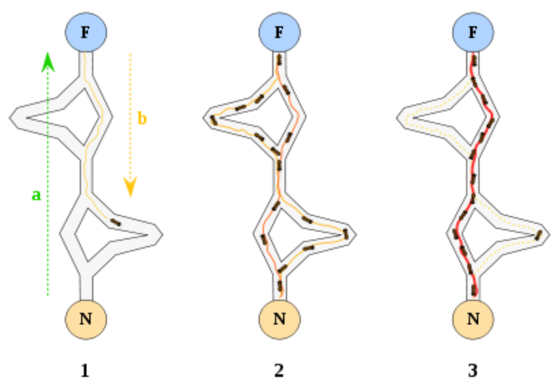

Fig.4: Basic ACO phenomenon Source: [14]

3.1 The Ant Colony Optimization Metaheuristic in Pseudo-Code:

- Procedure ACO Metaheuristic
- Schedule Activities
- Construct Ants Solutions
- Update Pheromones
- Deamon Action (optional)
- End Schedule Activities
- End - procedure

Construct Ants Solutions: This allows ant colony to build solutions to the problems by moving the nodes of construction graph G by applying the stochastic local decision policy.

Update Pheromones: This process is responsible for modifying pheromone trails. Trail values may increase, while the ants deposit the pheromones on connections or components that they used to build the solutions. The trail values are mostly decreased by the evaporation.

Daemon Actions: This procedure is mainly used to implement the centralized action that was not performed by the single ants. The daemon actions will use local search algorithm and this is to improve the quality of ants' solutions. This may also include the mechanism to penalize and reward the worst and best solution by either decreasing or increasing the corresponding pheromone trail values [13].

3.2 Ant System Algorithm:

Ant System was the example of Ant Colony Optimization algorithm [6]. It consisted of procedures: Construct Ants Solutions and Update Pheromones; and there is no Daemon Actions was employed.

Given, the combinatorial optimization problem

$$P = (S, f, \Omega), \text{--------------------------------- (3)}$$

With the corresponding construction graph $G = (C, L)$. The outputs as a feasible solution $\hat{s} \in S$ and $\hat{s} \in \widetilde{X}$. Let $s_p^k = < c_{l,} c_h, \ldots c_j >$ will denote k^{th} ant's partially constructed solution which it walks on the construction graph G. Assume pheromones as τ_{ij}, heuristic information as η_{ij} are associated with the connections l_{ij} without the loss in generality:

3.2.1 Algorithm: Ant System (AS) [6]:

- Input: a CO problem instance P = (S,f,Ω)
- Initialize τ_{ij} and η_{ij} (i,j)
- While termination condition not met do
- For each ant k=1,…., m do
- Repeat
- Choose in probability the next component c_i to add to s_p^k by means of (4.1)
- Append the choosen component c_i to the k^{th} ant's k list of visited nodes.
- Until ant k has completed its solution
- End for
- Update for pheromone values τ_{ij} on all the connections of G=(C,L)
- End while
- Output : s

The probability of which ant k chooses to add the component c_j to its partially constructed solution $s_p^k = < c_{l,} c_h, \ldots c_j >$ was given by random proportional rule,

$$\rho_{ij}^k = \begin{cases} [\tau ij]\alpha [\eta ij]\beta \,/\, \sum_{l \in N^K} [\tau_{il}]\alpha [\eta_{il}]\beta, & \text{if } j \in N_i^k \\ 0 & , \text{if } j \neq N_i^k \end{cases} \text{-- ----------- (4)}$$

Where α and β are 2 user defined parameters which may determine the relative influence of pheromone value; N_i^k is neighborhood of ant k and set of allowable components c_j is to be added to s_p^k.

The pheromone of update rule used in Ant System is given by,

$$\tau_{ij} = (1-\rho)\tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \quad \forall (i,j) \in L \quad \text{-------(5)}$$

Where $\rho \in [0,1]$ is pheromone evaporation rate and $\Delta\tau_{ij}^k$ is amount of the pheromones that deposited by ant k on connection l_{ij},

$$\Delta\tau_{ij}^k = \begin{cases} F(sk) & \text{if ant k used lij when constructing sk} \\ 0 & otherwise \end{cases} \quad \text{--(6)}$$

Where, $F: S \rightarrow R^+$ is the function and it satisfies

$$f(s) < f(s') \Rightarrow F(s) \geq F(s'), \forall s \neq s' \in S \quad \text{-----------(7)}$$

Where, P is the minimization problem. $F(\cdot)$ is called as quality function.

4. ANT MIMO SOLUTION:

On the basis of paradigm of ACO (ant colony optimization); Ant MIMO involves three main procedures such as Construct Ants Solutions, Apply Local Search and Update Pheromones.

4.1 Construct Ants Solutions:

This is regarded as first procedure in Ant MIMO. A number of 'm' ants are randomly visible at the primary level of the tree. The 'm' ants are build solutions iteratively for P_{MIMO} problem as a result it moves below the tree in parallel. The ant 'k' presently placed at parent node c_i^l selects to move into one of $\sqrt{M}$ children nodes as cj based on random proportional rule is given by [10]:

$$P_{ij}^{k} = \tau_{ij} / \sum l \in N_i^k \tau_{il} \quad \text{---------------------- (8)}$$

Where, τij – level of pheromone present at the edge of eij associating node from ci node to cj node;

N_i^k - The set of all children of node ci.

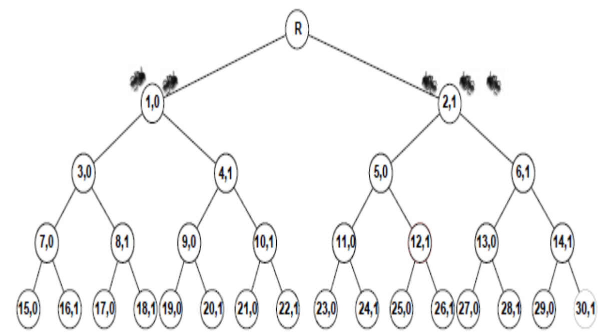

Fig.5: First level of construction tree – a colony of five ants Source: [11]

When an ant attains a leaf node, the completion of construction phase and the ant evaluates the cost for constructed solution $f\left(x^k\right)$. A single ant is able to store a list of nodes in constructing $\left(x^k\right)$. This type of list permits the ant to retrace its traverse path and deposit a suitable amount of pheromones with its edges to reflect in this procedure.

4.2 Apply Local Search:

In this procedure, the solutions are constructed by 'm' ants to be carried in local optima by using in a 1-opt local search algorithm which is characterized by one flip neighborhood[15]. In this neighborhood, a solution x is a neighbor of a solution x0; where x and x0 vary exactly in one solution component.

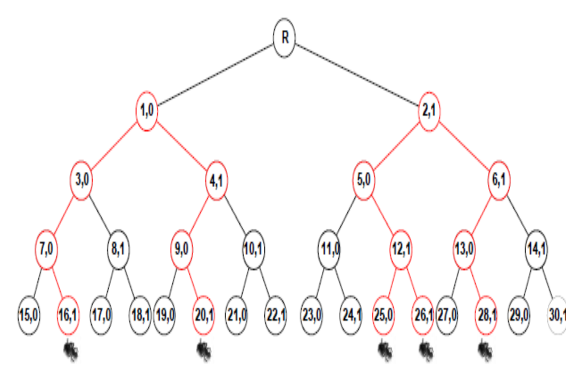

Fig.6: End of construction phase – Ant MIMO Source: [11]

For instance, suppose x = (1, 1, 1, 1) thus the one-flip neighborhood N(x) involves (0, 1, 1, 1),(1, 0, 1, 1), (1, 1, 0, 1) and (1, 1, 1, 0).

4.2.1 1-opt Local Search algorithm:

Input: Let us consider an ant solution x^k with equivalent path as w^k.
$x_{LS}^k \leftarrow x^k$
$w_{LS}^k \leftarrow w^k$ $\forall\ x' \in N\ (x)$ do
Compute cost of solution $x', f(x')$.
If $f(x') < f(x_{LS}^k)$ then
{construction phase starts}
$x_{LS}^k \leftarrow x^k$
$w_{LS}^k \leftarrow w^k$
end if
end for
{construction phase ends}
Output: x_{LS}^k, w_{LS}^k

4.3 Updates Pheromones:

In this third procedure of Ant MIMO, by applying the global update pheromone rules of ant colony system (ACS), if only the best solution in the beginning of the algorithm x^{bs} is permitted to update the trails of pheromone on their edges equivalent to its traversed path.

$\tau_{ij} = (1-\rho)\ \tau_{ij} + \rho\ \Delta\tau^{bs}$ $\forall e_{ij}$ transversed while building x^{bs} ---------(9).

Here, $\rho \in [0, 1]$ is the rate of evaporation and $\Delta\tau^{bs}$ is defined by:

$\Delta\tau^{bs} = 1/f(x^{bs})$ ------------------------------------(10)

Above three main procedures permits tha algorithm to initialize again in an array of pheromone through the procedure of Reinitialize pheromones existing only in this case when it returns a "bad solution". The term "bad solution" defines $\hat{x}$ as its cost function $f\ (\hat{x}) > fth$, in this equation, fth denotes the value of pre computed threshold.

In this section, it obtain a pseudo code or false code description of the algorithm of Ant MIMO; where its parameter T indicates an array pheromone store the values of pheromone such as τij and x^{ib} indicates the best effective solution returned by ants in an iteration of single construction phase.

5. RESULTS

The following is the result of the application of ant colony optimization algorithm in order to detect of MIMO channel using the software MATLAB

Begin Ant Colony Optimization demo

Number of nodes in problem = 60
Number of ants = 5
Maximum time = 500
Alpha (pheromone influence) = 3
Beta (local node influence) = 2
Rho (pheromone evaporation coefficient) = 0.01
Q (pheromone deposit factor) = 2

Initialing dummy graph distances
Initialing ants to random trails
1: [29 25 43 35 . . . 31 42 19 12 21] len = 218
2: [1 39 3 5 . . . 51 30 2 11 36] len = 246
3: [59 9 42 55 . . . 10 36 20 60 26] len = 267
4: [34 42 1 30 . . . 43 53 38 46 22] len = 246
5: [22 14 26 23 . . . 18 32 12 47 44] len = 283

Best initial trail length: 218
Initializing pheromes on trails

Entering UpdateAnts - UpdatePheromones loop
New best length of 207.000000 found at time 63
New best length of 205.000000 found at time 96
New best length of 199.000000 found at time 108
New best length of 196.000000 found at time 109
New best length of 190.000000 found at time 118
New best length of 176.000000 found at time 136
New best length of 175.000000 found at time 149
New best length of 170.000000 found at time 179
New best length of 158.000000 found at time 180
New best length of 146.000000 found at time 197
New best length of 142.000000 found at time 230
New best length of 137.000000 found at time 251
New best length of 136.000000 found at time 260
New best length of 128.000000 found at time 261
New best length of 126.000000 found at time 271
New best length of 121.000000 found at time 288
New best length of 115.000000 found at time 300
New best length of 113.000000 found at time 334
New best length of 111.000000 found at time 357
New best length of 109.000000 found at time 358
New best length of 108.000000 found at time 360
New best length of 98.000000 found at time 370
New best length of 95.000000 found at time 381
New best length of 92.000000 found at time 383
New best length of 90.000000 found at time 386
New best length of 84.000000 found at time 397
New best length of 83.000000 found at time 402
New best length of 78.000000 found at time 404
New best length of 77.000000 found at time 406
New best length of 76.000000 found at time 422
New best length of 74.000000 found at time 429
New best length of 70.000000 found at time 441
New best length of 66.000000 found at time 458
New best length of 65.000000 found at time 472
Time complete

Best trail found:26 17 30 53 12 9 24 6 14 47 55 48 4 19 40 1 60 3 31 42 15 23 58 36 7 28 56 32 54 57 22 41 2 34 45 5 10 33 27 59 16 39 25 20 29 21 11 8 52 13 43 49 18 44 50 37 35 38 51 46
Length of best trail found: 65.000000
End Ant Colony Optimization demo
>>

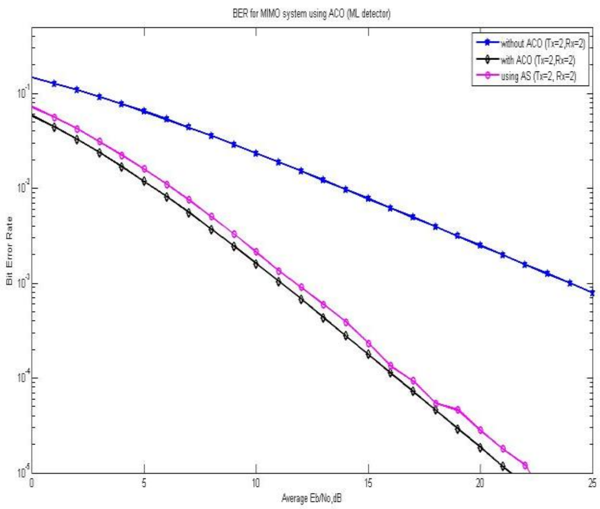

Fig 7 BER plot with and without ACO

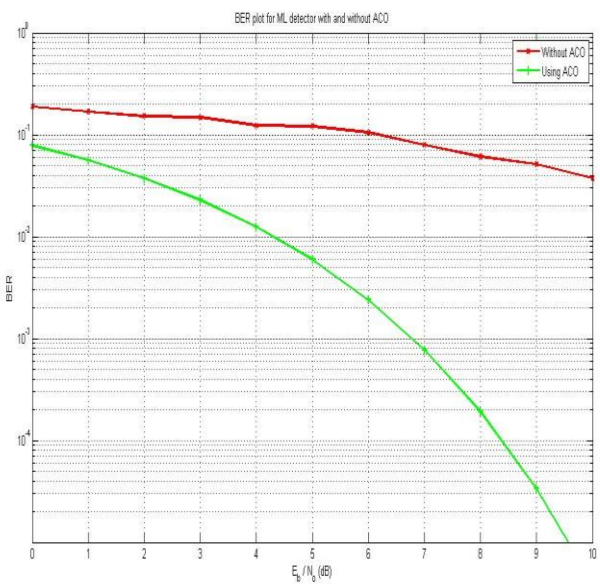

Fig 8 BER plot by using various antennae

Above fig illustrates that bit error rate is decreased using ACO metaheuristic technique. Therefore it better method to detect the signal.

6. CONCLUSIONS

In this paper, the concept of MIMO receiver design has been taken using a spatial multiplexing system. It is equal to solve an integer least square problem i.e. NP-hard; the suboptimal detection algorithms based on polynomial complexity are employed whereas algorithms exactly like sphere decoder algorithm which solve the MIMO detection in case of optimality contain average exponential complexity. The algorithm of an Ant MIMO outperform another technique exhibit the polynomial complexity is generally used for detection of MIMO system. It belongs to the category of ACO (ant colony optimization) metaheuristic; it is a current algorithmic technique which has been motivated by the real ant's behavior to improve strategies to solve hard combinatorial optimization problems. The detection of MIMO optimal channel is an effective technique by performing an analysis of landscape over the problem of integer least squares and identifying the existence of positive correlation among fitness of solution and distance of global optimum. Through MATLAB simulation its better performance based on different n * n MIMO system configuration by using 4-QAM constellation system have been determined. The problem of an integer least squares were created as a binary mixed integer program which was solved by Ant MIMO technique

7. FUTURE WORK

The algorithm of Ant MIMO can be optimized for detecting MIMO systems by using the constellation of 4-QAM system. The often configuration of MIMO makes use of high order of constellation namely 16-QAM.The work in this paper is done on MATLAB software. The study could also be expanded using other forms of software packages and simulators such as simulink, NS2 etc. The complexity of Ant MIMO being estimated to improve the local search algorithm will integrate into itself. Another characteristic feature is to configure this algorithm to detect transmissions of MIMO system codes.

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