Efficient Node Localization Technique in MIMO Networks using AMABC Optimization Algorithm

Fadhil T Alawe 1,2 *, Mahamod Ismail 1 and Rosdiadee Nordin1

1* Department of Electrical, Electronic and Systems Engineering, Universiti Kebangsaan Malaysia (UKM), Bangi, Malaysia.
2 Department of Biomedical Engineering, University of ThiQar, Nassiriyah, Iraq.

Abstract
Device or node localization is one of the important issues to be resolved in 5G Ultra-Dense network. Accurate measurement techniques using conventional Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA) and Received Signal Strength Indicator (RSSI) can be adopted to enhance localization accuracy. However, with the introduction of MIMO to increase spectral efficiency, the techniques will not be very precise in term of localization error. In this paper, we propose an effective Adaptive Mutation based Artificial Bee Colony Algorithm (AMABC) optimization algorithm to reduce the BER (Bit Error Rate). Moreover, beam forming and equalization of the localization error is also computed for varying the number of nodes. The performance is assessed and compared with a GA algorithm in term of elapsed time and localization error for varying ranging errors up to 30%. The simulation results shown that the AMABC algorithm outperform GA algorithm in all simulation cases.

Keywords: AMABC, Artificial Bee Colony, ABC, Beam forming, Mobile Terminal, Node Localization, MIMO, 5G, WSN.

INTRODUCTION
The designing the 5G network architecture is allowed to split indoor and outdoor scenarios so that breakthrough loss through building walls can in someway be avoided [1]. In addition to its physical structures, 5G technologies will require high bandwidths in order to fulfill future capacity necessities. In wireless sensor network (WSN) localization of sensor nodes is a fundamental problem. In the domain of radio systems, a stellar surge in the number of mobile users these days has brought in its train the added hassles of the excessive overlap of signal inputs with the attendant and awesome intricacies of the localization procedure. With an eager eye on eradicating the eventual signal overlapping dilemmas, the Multiple Input Multiple Output (MIMO) Cellular networks has been flagged off as a viable solution. The multiple-input and multiple-output, or its abbreviation MIMO with the phonetic representation of “my-moh” or “me-moh”, has appeared on the arena as an august approach for the advancement in the ability of a radio link applying a host of transmit and receive antennas to take the added advantage of the multipath transmission. It has set its elegant foot as an indispensable segment of the wireless communication patterns such as the IEEE 802.11n (Wi-Fi), IEEE 802.11ac (Wi-Fi), HSPA+ (3G), WiMAX (4G), and the Long Term Evolution (4G). Striking a discordant chord from the smart antenna approaches, it invests itself dedicated for the augmentation in the efficiency of a single data signal, like the beam forming and diversity.

The massive MIMO using a much larger number of antennas also called large scale MIMO. In this way significant beamforming gains become achievable, and can be served more numbers of users in parallel, this can also significantly improve both spectral and energy efficiency [2]. As a result, these main advantages facilitate the massive MIMO system to be a auspicious candidate for 5G wireless networks and also enabling technologies for accurate positioning and device orientation estimation.

Among the emergence of massive MIMO antenna and millimeter wave (mmW) technologies, a large number of small cells can be deployed to form 5G ultra-dense cellular networks UDN [3]. Consequently, 5G ultra-dense networks UDN can offer the high-bit-rate in all cellular coverage regions. It has to be earnestly admitted that the MIMO networks offer a host of fruitful benefits. Nevertheless, it is unfortunate that they fail miserable to effectively address the localization hassles completely. Incidentally, there are four vital constraints habitually employed to appraise the localization approaches, which include the Time of Arrival (ToA), Time Difference of Arrival (TDoA), and Angle of Arrival (AoA), the Received Signal Strength Indicator (RSSI). In the novel approach, the constraints are initialized in advance and a signal is generated for analysis. Further, an efficient optimization technique termed as the Adaptive mutation based Artificial Bee Colony (AMABC) optimization is kick-started to achieve the superior signal by reducing the BER (Bit Error Rate) values. Finally, beam forming and equalization is also performed in the realms of the MIMO cellular technologies.
was hundreds of thousands of times stronger than transmitting from other nodes. Hence it has been generally assumed that one cannot decode a received signal at a radio while it is simultaneously transmitted [6]. Transmission higher data-rate requires more bandwidth. However, due to spectral limitations, it is often sometimes very expensive or impractical to increase bandwidth, therefore using multiple transmit and receive antennas (MIMO system) for spectrally efficient transmission is an substitute solution.[7].

The MIMO system makes use of multiple antennas both at the receiver as well as the transmitter end thereby taking advantage of multipath propagation. The advantages, such as gain and spatial diversity, have been known and monopolized for some time. [8]. However, when the transmitted signal bandwidth is large compared to the coherence bandwidth of the channel, the high transmission rates may consequence in severe frequency selective fading and inter symbol interference (ISI) [9].

The information of Mobile Terminal position is a demand in many wireless systems. Various, applications have been proposed for wireless networks that require knowledge of the terminal location [11]. The rule in FCC (Federal Communications Commission) for detection of emergency calls requires all wireless providers to locate an E-911 caller with an accuracy of 100 meter and 300 meter for 67% and 95% of calls.[10] There are four methods commonly used to measure the localization: Time of Arrival (ToA), Angle of Arrival (AoA), Time Difference of Arrival (TDoA), and Received Signal Strength Indicator (RSSI).

The information of terminal localization can be used to provide user navigation, supplying location context for web browsing, and aiding network resource allocation [13] The accuracy of localization is restricted by the noise measurement. This noise is created by thermal noise and random variations of the RSS created by multipath propagation which cause two separate locations to appear identical with respect to RSS measured .[12]. Low cost GPS receivers have been proven to provide good localization accuracy in outdoor. However, the signals, GPS satellite are received only occasionally in these locations, therefore, they cannot be used indoors or in dense urban environments.[12] In this paper, an effective AMABC Optimization based Mobile Node Localization Technique in MIMO Networks is used to minimize the localization problems.

OVERVIEW OF NODE LOCALIZATION TECHNIQUE
In accordance with the systems employed, various localization techniques may be broadly categorized into three types such as range-based Localization, angle-based Localization and the range-free or proximity-based Localization.

- **Range-based Localization:**
  This mode of localization furnishes measurements depend on the entire distance data among the nodes.

- **Angle-based Localization:**
  In this type of localization, measurements are offered by attaining the angle data among the nodes.

- **Range-free or proximity-based Localization:**
  In this case, only the connectivity data are presented. Basically, all current localization procedure encompasses of two stages the distance estimation and the position calculation.

**Distance Estimation in Localization**
Ranging between the two nodes is unearthed by bringing in two nodes in a network and subsequently locating the distance between them. In this regard, there are four general techniques for measuring in the localization approaches, which are shown below.
- The Angle of Arrival (AoA)
- The Time of Arrival (ToA)
- The Time Different of Arrival (TDoA)
- The Received Signal Strength Indicator (RSSI)

- **Time of Arrival:**
The Time of arrival (TOA or ToA), at times termed as the Time of Flight (ToF), represents the travel time of a wireless signal from a single transmitter to a far-off single receiver. The travel time taken by a radio signal to travel from the single transmitter to the far-flung single receiver is represented by means of Equation 1 shown below.

\[ t_{\text{ToF}} = t_T - t_R \]  \hspace{1cm} (1)

- **Angle of arrival (AoA):**
The Angle of Arrival (AOA) invariably entails a minimum of two towers, identifying the caller at the point of intersection of the lines along the angles from each tower. This type of measurement represents a technique for ascertaining the direction of transmission of a radio-frequency wave incident on an antenna array. The AoA decides the direction by evaluating the Time Difference of Arrival (TDOA) at individual elements of the array and from the corresponding delays the AoA is effectively evaluated.

- **Time Difference of Arrival (TDOA):**
The Time Difference of Arrival (TDOA) functions by means of the multilateration, with the exception that the networks play a vital role in calculating the time difference and hence the distance from each tower (as with seismometers).

Let the receiver be positioned at a distance \( T_R \) from the transmitter. The transmitter is placed at the distance \( T_T \). The Time Difference of Arrival is estimated by means of the following Equations 2 and 3.

\[ t_{\text{TDoA}} = v t_R - v t_T \]  \hspace{1cm} (2)

\[ t_{\text{TDoA}} = T_R - T_T \]  \hspace{1cm} (3)

Where, the distance \( T_R \) represents the wave speed \( v \) times the transmit time \( t_R \).
**Received Signal Strength Indicator (RSSI):**
In the domain of the telecommunications, the received signal strength indicator (RSSI) constitutes a measure of the power existing in a received radio signal.

The RSSI is habitually invisible to a user of a receiving device. Nevertheless, as the signal strength is capable of fluctuating significantly and having a significant impact on the functionality in the wireless networking, IEEE 802.11 tools generally make the measure accessible to users.

The RSSI is usually performed in the intermediate frequency (IF) stage before the IF amplifier. In the zero-IF mechanisms, it is carried out in the baseband signal chain, before the baseband amplifier. The RSSI output is frequently a DC analog level. It may also be sampled by an internal ADC and the resultant codes accessible directly or through the peripheral or internal processor bus.

**Received signal strength (RSS):**

The received signal strength represents the easiest and the cost-effective metric in order to estimate the distance between the sensor nodes for the localization objectives. In the RSS based localization techniques, the received signal strength at the sensor node is mapped into distances by means of a certain channel model. The most well-acknowledged channel model is the lognormal shadowing model. The received power at the sensor nodes employing the lognormal shadowing model is represented by means of the following Equation 4.

\[
P_r = P_t - 10\log P_{Loss} \left( \frac{r}{r_0} \right) + \delta
\]  

The sensor nodes are arbitrarily employed in a square region. All the anchor nodes and unidentified nodes comprise an identical communication radius of 15 m.

In our proposed model, a signal is generated with some of the localization parameters. At transmitter side the signal is OFDM modulated. While transmission through the channel, thermal noise is added. In between this, the propagation loss (path loss) and the interferences are measured.

**Mobile position calculation in Localization**

The Location information of Mobile node constitutes a demand in several wireless mechanisms. In this regard, the localization error is evaluated by means of Equation 5 shown hereunder.

\[
L_{error} = \frac{1}{r_{ss}} \sum_{j=1}^{N_s} \left( p_j - p_j \right)^2 + (q_j - q_j)^2
\]

In the captioned equation for the node \(j\), \((p_j, q_j)\) represents the real coordinate of the unidentified node and \((p_j, q_j)\) signifies the approximate coordinate of unidentified node. \(r_{ss}\) corresponds to the communication radius of the sensor nodes. \(N_s\) indicates the total number of the sensor nodes in the sensor field and \(A_N\) reveals the total number of anchor nodes. The lower value of the localization error exhibits superlative efficiency in accomplishment. The efficiency of the localization technique is significantly affected by the number of unidentified nodes, anchor nodes and the communication radius of the sensor nodes. In the document, the replication outcomes are assessed and appraised for the total number of nodes. In the authentic WSN, radio signals are adversely affected by the environment through which they are disseminated.

**PROPOSED AMABC TECHNIQUE**

**System Architecture**

The proposed architecture is shown through in Fig. 1. In our proposed model, a signal is generated with some of the localization parameters. At transmitter side, the signal is OFDM modulated, while transmission through the channel, thermal noise is added. In between this, the propagation loss (path loss) and the interferences are measured.

The overall procedure diagram is colourfully pictured in Fig.1, where the MIMO cellular network going through the data-sharing procedure is elegantly exhibited. At the receiver side, the signal will be OFDM demodulated. Then in order to reduce the noisy content, AMABC algorithm is employed.

**Path loss measurement**

The wireless sensor networks are fundamentally affected by the path loss impact and the path loss incidence is different for diverse directions. The power loss, in turn, is largely triggered by the hindrances by the parallel objects in the vicinity of the receiver and is habitually labelled as the Shadow fading or large-scale fading. The log-normal shadow model surfaces as the ideal candidate for the wireless sensor networks both in respect of the indoor and outdoor applications thanks to its global character and the innate skills of getting duly shaped in accordance with the ecosystem.

The mathematical equation for the Path Loss Function evaluated and expressed in decibel is represented by the following Eqn. (6).

\[
P_{Loss}(dB) = P_{Loss}(r_0)(dB) + 10\gamma \log_{10} \left( \frac{r}{r_0} \right) + \delta(dB)
\]

where \(r\) is the distance between the sending and receiving nodes, \(r_0\) is the near earth reference distance, \(\gamma\) is the path loss index, and \(\delta\) is the zero-mean Gaussian random noise.

Eqn. (6) can be simplified in term of Path Loss Transmitter and Receiver as follows:

\[
P_{Loss}(dB) = 10\log \left( \frac{P_T}{P_R} \right)
\]

Where,

- \(P_T\) symbolizes the Transmitted Signal Power
- \(P_R\) represents the Received Signal Power.

The basic edition of Equation 6 may be expressed with respect to the received power as shown by Equation 8 given hereunder.
The value of path loss index is invariably dependent on the environment or the transmission scenario. The distance $r_o$ is considered as one meter for the sake of easy evaluation.

$$\frac{P_s(r)}{P_s(r_0)} = \left( \frac{r}{r_0} \right)^\gamma + \delta \quad (8)$$

**AMABC Algorithm**

The Adaptive Mutation based Artificial Bee Colony Optimization Algorithm is introduced in our proposed method to reduce the BER by optimizing the input signal. The Artificial Bee Colony (ABC) algorithm and its drawbacks are explained below.

The vital objective of the optimization method is to find a set of fittest values for the input parameters. The Artificial bee colony (ABC) optimization represents a swarm intelligence based algorithm which replicates the foraging character of the honey bees. An enormously huge number of bespoke and superior versions like the G best guided ABC, binary version of the ABC known as the DisABC, differential ABC, interactive ABC, and the cooperative ABC have been flagged off and are in vogue at present.

In the ABC model, foraging honey bees are classified into three vital categories such as the Employed bee, Onlooker Bee and the Scout bee.

In accordance with the two essential leading modes of the forages such as the employment to a food source and refusal of a source, the procedure of bees on the hunt for sources with an elevated amount of nectar is the one deployed to ascertain the optimal solution for the specified optimization issue.

The steps involving in AMABC algorithm is detailed in the below section.

**Step (1): Initialization**
- An initial population of $T_N$ individuals is created.
- For each and every individual, $t_j$ represents a food source (i.e. solution) consisting of $D_N$ attributes (i.e., dimensionality).

**Step (2): Fitness Evaluation of $T_N$ Individuals**
- In this phase, the fitness of each individual solution is estimated.

**Step (3): Obtain Neighborhood position**
- Here, the neighbourhood of the current position of each employed bee is attained to locate a superior food source.
Step (4): New Solution Generation
- Hence, in respect of each and every employed bee, a new solution \( s_{j,k} \) is produced around its current position, \( t_j \) with the help of Equation 9 given below.
\[
s_{j,k} = t_{j,k} + \chi_{jk}(t_{j,k} - t_{l,k}) \quad (9)
\]
Where,
\[
j \in [1, 2, ..., N_E] \quad \text{and} \quad k \in [1, 2, ..., D_N]
\]
a arbitrarily selected list
\( N_E \) - number of employed bees
\( \chi_{jk} \) - even arbitrary number within range \([-1, 1]\).

Step (5): Selection of Best probability based on Fitness Function
- In this step, the fitness of both \( t_j \) and \( s_j \) are determined and the selection method is initiated to shortlist the superior among them.
- Step (5a) : Selection Probability

Now, the selection probability values, \( S_p \) are estimated and standardized for each and every employed bee, \( t_j \) with the assistance of the roulette-wheel selection approach.
The selection probability \( S_p \) of the \( k^{th} \) parameter is given as,
\[
S_p = \frac{t_k}{\sum_{k=1}^{D_n} t_k} \quad (10)
\]
The adaptive mutation function in the food source position (solution) generation procedure enhances the efficiency in performance of the ABC technique. The novel adaptive mutation function in the AMABC is illustrated as follows.
\[
S_{AM} = \delta \left( 1 + \text{rand} \left( \frac{t_{jk_{\text{max}}} - t_{jk_{\text{min}}}}{t_{jk_{\text{avg}}}} \right)^m - \frac{t_{jk_{\text{avg}}}}{t_{jk_{\text{avg}}}} \right) \quad (11)
\]
\[
\delta = \left( \frac{t_{jk_{\text{max}}} - t_{jk_{\text{min}}}}{t_{jk_{\text{avg}}}} \right)^m \quad (12)
\]

When the evaluation of \( S_p \) of the entire \( k \) is finished, average of Equation (10) is estimated and \( k \) which exceed the valued of the average probability is shortlisted. If \( S_p > \text{avg}(S_p) \) then \( k \) is modernized by means of onlooker bee phase.

Step (6): Assigning Onlooker Bee
Here, each and every onlooker bee is allocated to an employed bee, \( t_j \) arbitrarily with probability in direct proportion to \( S_p \)
- Step (6a) :
In this stage, new food positions, \( s_j \) for each and every onlooker bee, \( t_j \) are generated deploying its employed bee as \( t_j \) in (6).
- Step (6b) :
Thereafter, the fitness of each onlooker bee \( t_j \) is estimated together with the new solution \( s_j \). Now the greedy selection method is followed to retain the superior bee, after rejecting others.

When the evaluation of the best \( k \) is finished, the best \( k \) outcomes from the onlooker bee phase and employed bee phase are analysed, assessed and contrasted one by one.

Step (7): Replacing with Scout Bee
In case a specific \( t_j \) has not been enhanced even after a number of iterations, it has to be abandoned. The solution is replaced by introducing a scout bee at a food source at the search space by means of Equation 10 illustrated as follows.
\[
t_{jk} = k_{\text{min}} + \text{rand}(0,1)* (k_{\text{max}} - k_{\text{min}}). \quad (13)
\]

Step (8): Placing Final Best Solution
In this step, the best food source position (solution) discovered till now, has to be tracked.

Step (9): Termination
At this juncture, the termination has to be verified. If the best solution discovered is satisfactory or a maximum number of iterations have been reached, the process has to be stopped. When the stoppage standard is satisfied, the best \( k \) are shortlisted and replaced in Equation (9) to achieve the ultimate clustered outcome. Or else, return to step 2 and continue the process.

In the long run, the AMABC Optimization technique is carried out for the purpose of reducing noisy contents so as to achieve the lucid communication of the radio signal through the transmitter/receiver units. Subsequently, the MIMO networks are facilitate to carry out the beam forming to evaluate the signal strength at any direction.

Beam forming & Equalization
The beam forming or spatial filtering represents a signal processing approach extensively employed in the sensor arrays for the directional signal conduction or reception. It is attained by integrating the elements in a phased array in order that the signals at specific angles are subjected to constructive
interference while others undergo destructive interference. It is effectively utilized at the communicating and receiving ends so as to attain the spatial selectivity. It is beneficially employed for radio or sound waves. It is widely accepted in a number of applications in the domains of the radar, sonar, seismology, wireless communications, radio astronomy, acoustics, and the biomedicine. Finally, the process of equalization is performed within the MIMO cellular system in order to balance the frequency components of the received signal.

RESULTS AND DISCUSSION
The proposed technique is implemented in MATLAB using initial parameters summarize in Table 1The distance is predicted with the help of 4 Anchor Nodes (Known Nodes) and each being placed at the distance of 100 m. Figs. 2 (a), (b) and (c) shows the position of anchor nodes, sensor nodes and the evaluated Position of Sensor Nodes respectively. Moreover, the evaluated position of Sensor Nodes from the Anchor nodes (known Nodes) taken over the area of 100mx100m and the original position of mobile terminal location is as shown in Fig. 3.

<table>
<thead>
<tr>
<th>Initial Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interference Power</td>
<td>-20 dBm</td>
</tr>
<tr>
<td>Mobile Range</td>
<td>2750 m</td>
</tr>
<tr>
<td>Mobile Angle</td>
<td>3°</td>
</tr>
<tr>
<td>Transmission Power</td>
<td>-8 dBm</td>
</tr>
<tr>
<td>Interference Range</td>
<td>9000 m</td>
</tr>
<tr>
<td>Interference Angle</td>
<td>20°</td>
</tr>
<tr>
<td>Number of Transmitting Elements</td>
<td>4</td>
</tr>
<tr>
<td>Steering Angle</td>
<td>0°</td>
</tr>
<tr>
<td>Receiver Gain</td>
<td>108.8320 – Transmit Power dB</td>
</tr>
</tbody>
</table>

The graph in Fig (3) shows the deviation in mobile location prediction, where the Anchor nodes (location known node) are placed at the four corners. In this, graph the predicted mobile location as well as the original mobile location is distinguished. The Received Signal Strength Indicator Value and the elapsed time for the proposed AMABC and existing GA values are tabulated in Table 2.
The Localization error is obtained for the sensor with varying number of anchor nodes. Fig (4) shows the Localization error obtained for both proposed and existing method by varying the number of nodes at ranging Error (0-10) %. Fig 5 shows the Localization error obtained for both proposed and existing method by varying the number of nodes at ranging Error (0-20) %.

The simulation studies as is described in the sections above are carried out to compare the performance of the AMABC algorithm with the GA algorithm. The results presented have shown that when the number of nodes is increased, the localization error decrease for both algorithms fig (4 to 6). But at the same number of nodes, the localization error of the AMABC algorithm is lower than GA algorithm. The results presented proving that in all simulation cases the AMABC algorithm outperform GA algorithm. The proposed AMABC is a suitable technique for Localization and is found to be a better solution in comparison to GA and the conventional methods. The process of beam forming is performed finally to increase the SNR and to reduce the BER for the input signal. The beam formed is plotted and is given in the below figure.
CONCLUSION

In 5G UDN supporting huge sensor nodes, conventional localization techniques will not be very effective. We propose an AMABC technique to complement those techniques in high node localization accuracy. For this the localization error is obtained for varying the ranging error of (0-10) %, (0-20) % and (0-30) %. Using the received signal strength and time measurements, it is shown that better efficacy have been achieved from our proposed AMABC nodes localization technique as compared to GA optimization algorithm.

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