International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
Volume 47, Issue 03, Quarter 03 (July-August-September 2018)
(An Indexed, Referred and Impact Factor Journal)
ISSN: 2319-6564
www.ijesonline.com

Efficient Cognitive Radio Routing based on Improved Ant-Lion based

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Publishing Date: September 07, 2018

Abstract

This paper outlines a proficient directing procedure for the cognitive radio by improving a most recent streamlined meta-heuristic approach, Ant-lion optimization. A protocol named improved ant lion based routing in cognitive radio (IALbCr) is proposed in the work. In this algorithm the routing of data is same as done by the ant lion based algorithm while the sensing of channel and transmission of data is modified by using the Ant lion algorithm. The Ant lion has a feature to wait for the ant to get trapped in the pit hole designed by it. The ant lion doesn't attack the ant until the ant reaches at a threshold depth of pit hole. This concept is used to determine the waiting time to sense the channel and transmit the data. The implementation of the IALbCr is done using the network simulator. The performance of IALbCr is compared against ALbCR, SER, ANT-CR and the CbCr for parameters residual energy, PDR, End 2 end delay, Throughput and routing load on different network scenario shows that the algorithm is better in terms of delay, residual energy, PDR as well as throughput.

Keywords: *Cognitive Radio, Ant Lion, Ant, Ant Lion Optimization, Meta-Heuristic.*

I. Introduction

Cognitive radio sensor nodes form wireless communication architecture of CRSN as shown Figure: 1 over which the information obtained from the field is conveyed to the sink in multiple hops. The main duty of the sensor nodes is to perform sensing on the environment. In addition to this conventional sensing duty, CRSN nodes also perform sensing on the spectrum. Depending on the spectrum availability, sensor nodes transmit their readings in an opportunistic manner to their next hop cognitive radio sensor nodes, and ultimately, to the sink. The sink may be also equipped with cognitive radio capability, i.e., cognitive radio sink [1][2].

In addition to the event readings, sensors may exchange additional information with the sink including control data for group formation, spectrum allocation, spectrum handoff-aware route determination depending on the specific topology[3][4]. A typical sensor field contains resource-constrained CRSN nodes and CRSN sink. However, in certain application scenarios, special nodes with high power sources, i.e., actors, which act upon the sensed event, may be part of the architecture as well [5].

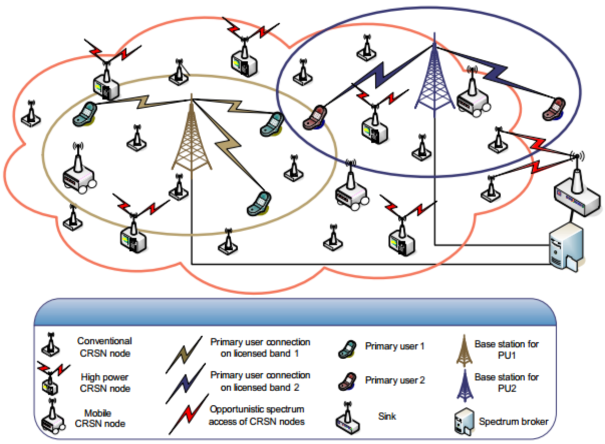

Figure 1: A Typical Cognitive Radio Sensor Network (CRSN) Architecture [1]

These nodes perform additional tasks like local spectrum bargaining, or acting as a spectrum broker. Therefore, they may be actively part of the network topology. It is assumed that the sink has unlimited power and a number of cognitive transceivers, enabling it to transmit and receive multiple data flows concurrently.

CRSN Node Structure:

CRSN node hardware structure is mainly composed of sensing unit, processor unit, memory unit, power unit, and cognitive radio transceiver unit as abstracted in Figure 2. In specific applications, CRSN nodes may have mobilization and localization units as well. The main difference between the hardware structure of classical sensor nodes [1] and CRSN nodes is the cognitive radio transceiver of CRSN nodes. Cognitive radio unit enables the sensor nodes to dynamically adapt their communication parameters such as carrier frequency, transmission power, and modulation.

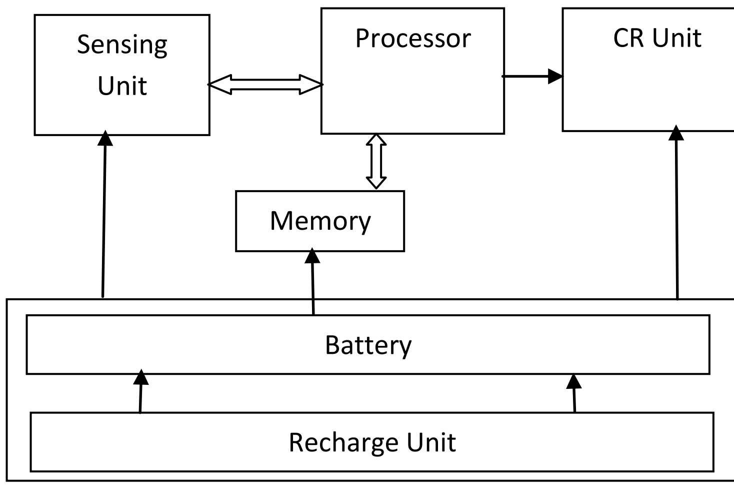

Figure 2: Hardware Structure of a Cognitive Radio Sensor Node [5]

CRSN nodes also inherit the limitations of conventional sensor nodes in terms of power, communication, processing and memory resources. These limitations impose restrictions on the features of cognitive radio as well. CRSN nodes may perform spectrum sensing over a limited band of the spectrum due to processing, power, and antenna size constraints. Consequently, CRSN nodes are generally constrained in terms of the degree of freedom provided by the cognitive radio capability as well.

II. Cognitive Radio Routing Protocol

In [6] three current location service, Grid Location Service (GLS), Simple Location Service (SLS), and Reactive Location Service (RLS) are introduced. Grid Location service: In GLS, a node chooses a set of node in the network (i.e. location servers) to maintain the node's current location. Nodes that require the location of a node query the node's location servers [7]. Simple Location Service: In SLS, a node periodically transmits its location table to its neighbors. Thus, a node in the network learns the location of all other nodes in the network. Here each location packet (LP) updates location tables, contains the location of several nodes, the speed of each of nodes, and the time the LP was transmitted. The rate a mobile node transmits LPs adapts according to location change [1]:

$$\left(\frac{Trange}{\propto}\right).\left(\frac{1}{v}\right) = \frac{Trange}{\propto v}$$

Where *Trange* is the transmission range of the node, $\propto v$is the average velocity of the node, and $\propto$ is a constant optimized through simulation is a scaling factor. **Reactive Location Service:** RLS is a reactive location service that queries location information on an as needed basis. **An Improved Map-Based Location Service For Vehicular Ad Hoc Networks:** In [8**]** a distributed hierarchical location service called Density aware Map-Based Location Service (DMBLS) for Vehicular adhoc Networks. DMBLS makes use of the street digital maps and the traffic density information to define a three level hierarchy of locations servers. The location service uses a density aware server selection policy which selects servers at high density regions of a city. DMBLS, for vehicular urban environments, based on the traffic density. In this, they have assume that each vehicle knows its own geographic position and the use of the Global Positioning System (GPS). **Updating Location Information:** Due to the high mobility, the vehicles positions keep changing very fast and therefore, the location server should be informed to update the information it stores. the location information are valid for a period *T* equal to the time required for the vehicle to reach the next waypoint plus a threshold time Tc and it can be predicted by the following formula:

$$\mathrm{T} = \mathrm{Dint}/\mathrm{Savg} + \mathrm{Tc}$$

Where *Dint* is the distance between the current intersection and the next intersection and *Savg* corresponds to the average speed of the vehicle. *Tc* represents the time spent by the vehicle near the intersection before it moves away with a distance *R* equal to the transmission range [1]. **Search Protocol - Spectrum Aware Routing Protocol:** The SEARCH protocol uses the geographic forwarding. This protocol jointly considers the path and the channel selection to avoid the regions of the Primary User activity during the route formation. Minimization of hop count to reach the destination is done by using the optimal path found by geographic forwarding [6]. The idea of the geographic forwarding is used in this protocol. It is able to deal with reasonable levels of PU activity changing rate. Also, a mechanism for disseminating the destination location both at the source and at each intermediate node is required. The protocol assumes the primary users‟ activities in an ON/OFF process. The functions followed by the protocol are (1) Route setup phase (2) Joint Channel – Path optimization phase and (3) Route Enhancement, in order to improve the route during its operation. **SEARCH mainly works on following two concepts:** PU Activity Awareness: In CR network, route must be constructed to avoid region affected by active PU. When PU activity affect region, SEARCH provides hybrid solution, it first uses greedy geographic routing on each channel to reach destination by identifying and circumventing PU activity region [7]. The path information from different channels is combined at destination in series of optimization steps to decide on optimal end-to-end route in a computationally efficient way. CR user mobility: Cognitive user mobility results into frequent route disconnections. Thus for each node, through periodic beacons, updates its one-hop neighbors about it current location SEARCH ensures performance as well as less interference in cognitive radio network. **SER - Spectrum and Energy Aware Routing Protocol:** The main aim of this protocol to establish a bandwidth guaranteed QoS routes in small CR networks where the topological changes are low. The protocol uses Time Division Multiple access [9]. The QoS requirement considered here is the number of transmission timeslots for a packet on its route from source to reach the destination [10]. The SER is an on demand routing protocol proposed for multihop CR networks. The basic operation of SER includes route discovery, data transmission and route maintenance.

III. Existing Work

Ant lion algorithm (ALO) exhibits the hunting behavior of the Ant lion also known as doodlebugs. Ant lion attacks the ant in strategic manner by building the traps which is explained in the ant lion algorithm. The ALO completes its processing in five steps i.e. random movements of the ant , building traps by the ant lion, entrapment of ant in to traps designed by ant lion, catching prey i.e. ant and rebuilding of the trap with better fitness. These five phases completes the process of ALO elaborated below:

Random Movements of the Ant: Each ant moves in a random direction and the other ants follow it by the pheromone generated by the ant. This section describes the ant lion- optimization algorithm as follow: In the ALO, n ant lions are travelling towards the ant in d dimensions then the position matrix can be given shown as eq. 1.

$$P_m = \begin{bmatrix} P_{1,1} & \cdots & P_{1,d} \\ \vdots & \ddots & \vdots \\ P_{n,1} & \cdots & P_{n,d} \end{bmatrix} \quad (1)$$

The best position in the matrix of equation (1) can be found by analyzing the corresponding values in fitness function (best solution can be minimum or maximum value depending upon the problem). The fitness function can be given as (2)

$$F_{v\_f} = \begin{bmatrix} F_{v\_f1} \\ \vdots \\ F_{v\_fn} \end{bmatrix} \quad (2)$$

When the ant lion reaches nearer to the ant then the ant lion starts to follow the spiral motion which can be specified by using eq.(5) as shown:

$$P_{m_{i,f_j}} = F_{v\_fj} + d * cos(2\pi r) * e^{br} \quad (3)$$

The P_{mi,f_j} denotes the updated position using the spiral motion while the b is a constant to define shape of the motion. The r is used to define the ant lion and relationship if the value of r is 1 then the ant lion follows the , resulting the best possible position near the is selected otherwise the ant lion selects the best far position from the . This updated position is used to move towards the optimization. The distance d is given by eq. (4).

$$d = \left|F_{v\_fj} - F_{v\_mi}\right| \quad (4)$$

The above algorithm describes the ALO algorithm. The next section discusses the implementation of ALO in our work.

IV. Optimization based on Ant lion Algorithm

In this work the algorithm is optimized by using the ant lion algorithm. The ant lion are replaced by the nodes i.e. there is one ant lion for each node and the position of the node is considered as the position of the ant lion. The position matrix representing the ant lion based on nodes is given by eq. (5).

$$M_N = \begin{bmatrix} M_{N_{1,1}} & M_{N_{1,2}} & M_{N_{1,n}} \\ M_{N_{2,1}} & M_{N_{2,2}} & M_{N_{2,n}} \\ \vdots & \vdots & \vdots \\ M_{N_{n,1}} & M_{N_{n,2}} & M_{N_{n,n}} \end{bmatrix} \quad (5)$$

Here, n is the number of nodes in the network. The distance of current node from the destination is used to generate the corresponding fitness value. The fitness value is generated by using the eq. (6).

$$M_{N_1} = \sqrt{\left(M_{N_{d,1}} - M_{N_{1,1}}\right)^2 + \left(M_{N_{d,2}} - M_{N_{1,2}}\right)^2 + \left(M_{N_{d,3}} - M_{N_{1,3}}\right)^2} \quad (6)$$

Corresponding fitness value matrix is given by the equation (7):

$$O_{M_N} = \begin{bmatrix} O_{M_{N_1}} \\ \vdots \\ O_{M_{N_n}} \end{bmatrix} \quad (7)$$

The matrix gives the position matrix of the best neighbor node to be selected in the route by any node. The complete process can also be understood by the following algorithm:

Algorithm (Source, Destination)

1. Initialize the Network:
   For i=1: N
   For j=1: N
   $M_{Ni,j}$= random position between given network area
   End
   Calculate fitness value
   End

   $$M_{N_i} = \sqrt{\left(M_{N_{d,i1}} - M_{N_{i,1}}\right)^2 + \left(M_{N_{d,2}} - M_{N_{i,2}}\right)^2 + \left(M_{N_{d,3}} - M_{N_{i,3}}\right)^2}$$

2. F_N=Best(M_N)
3. O_{FN}= Best(O_{MN})
4. $Current_{node}$=Source
5. While $Current_{node} \neq Destination$

   i. $d = \left|F_j - M_i\right|$

ii. $M_{M_{i,F_j}} = d * e^{bt} * cos(2\pi t) + F_j$
iii. Generate the Distance matrix by using eq. (6)
iv. Select Next Node in The route
v. F_N=Best($M_{Current_{node}}$, $F_{Current_{node}}$)
vi. O_{FN}= Best($M_{Current_{node}}$, $F_{Current_{node}}$)
vii. End if
viii. Update b and t
ix. Update $Current_{node}$

End while

6. Exit

The above algorithm is used to generate an optimized path. The algorithm has been improved discussed in next section.

V. Proposed Work

This section discusses the proposed protocol IALbCr i.e. improved ant lion based routing in cognitive radio. The ALbCr algorithm routes the data on the basis of ant lion algorithm that optimizes the performance of the routing as shown in previous section. In this algorithm the routing of data is same as done by the ALbCr algorithm while the sensing of channel and transmission of data is modified by using the Ant lion algorithm. The Ant lion has a feature to wait for the ant to get trapped in the pit hole designed by it. The ant lion doesn't attack the ant until the ant reaches at a threshold depth of pit hole. This concept is used to determine the waiting time to sense the channel and transmit the data. Here similar of ALbCr algorithm, the ant lion are replaced by the nodes i.e. there is one ant lion for each node and the position of the node is considered as the position of the ant lion. The position matrix representing the ant lion based on nodes is given by eq. (8).

$$M_N = \begin{bmatrix} M_{N_{1,1}} & M_{N_{1,2}} & M_{N_{1,n}} \\ M_{N_{2,1}} & M_{N_{2,2}} & M_{N_{2,n}} \\ \vdots & \vdots & \vdots \\ M_{N_{n,1}} & M_{N_{n,2}} & M_{N_{n,n}} \end{bmatrix} \quad (8)$$

Here, n is the number of nodes in the network. The distance of current node from the destination is used to generate the corresponding fitness value. The fitness value is generated by using the eq. (9).

$$M_{N_1} = \sqrt{\left(M_{N_{d,1}} - M_{N_{1,1}}\right)^2 + \left(M_{N_{d,2}} - M_{N_{1,2}}\right)^2 + \left(M_{N_{d,3}} - M_{N_{1,3}}\right)^2} \quad (9)$$

Corresponding fitness value matrix is given by the equation (10)

$$O_{M_N} = \begin{bmatrix} O_{M_{N_1}} \\ \vdots \\ O_{M_{N_n}} \end{bmatrix} \quad (10)$$

The matrix gives the position matrix of the best neighbor node to be selected in the route by any node. Here, the sensing of the channel is based on the fitness value as well as on the state of the channel i.e. position of the packets within the network. The complete process can also be understood by the following algorithm

Algorithm (Source, Destination)
Initialize the Network
For i=1N
For j=1N
MNi,j= random position between given network area
End
Calculate fitness value

$$M_{N_i} = \sqrt{\left(M_{N_{d,i1}} - M_{N_{i,1}}\right)^2 + \left(M_{N_{d,2}} - M_{N_{i,2}}\right)^2 + \left(M_{N_{d,3}} - M_{N_{i,3}}\right)^2}$$

End
FN=Best(MN)
OFN= Best(OMN)
$Current_{node}$=Source
While $Current_{node} \neq$ Destination

$$d = \left|F_j - M_i\right|$$
$$M_{M_{i,F_j}} = d * e^{bt} * \cos(2\pi t) + F_j$$

Generate the Distance matrix by using eq. (6)
TT=rand*$M_{M_{i,F_j}} * d$
If User=UL
Then, Sense after TT
Else sense after TT/FN
End if
Select Next Node in The route

FN=Best($M_{Current_{node}}$, $F_{Current_{node}}$)
OFN= Best($M_{Current_{node}}$, $F_{Current_{node}}$)
End if
Update b and t
Update $Current_{node}$
End while
Exit

The above algorithm is used to generate an optimized path based on intelligent MAC. The implementation and results of the algorithm are discussed in next section.

VI. Results

The modified chain based cognitive radio is compared with existing chain based cognitive radio protocol using various parameters that are explained below.

1. **1.** Energy Consumed: It is amount of energy consumed for transferring the data from source to destination. The mean of energy of energy consumed by each node is the average energy consumption in the network. ∑ Energy consumed by each node/number of nodes

2. **2.** Residual Energy: It is the difference of total energy and the energy consumed by the network.
   ∑ Energy of each node - ∑ energy consumed by each node
3. **3.** Network Life time: It is the time until all nodes within the network get dead. In other words, it is the operating time of the network.

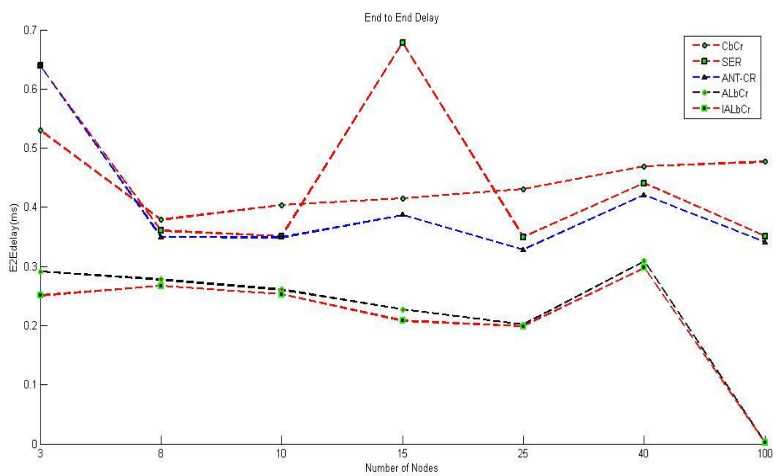

Figure 3: Analysis of E2Edelay

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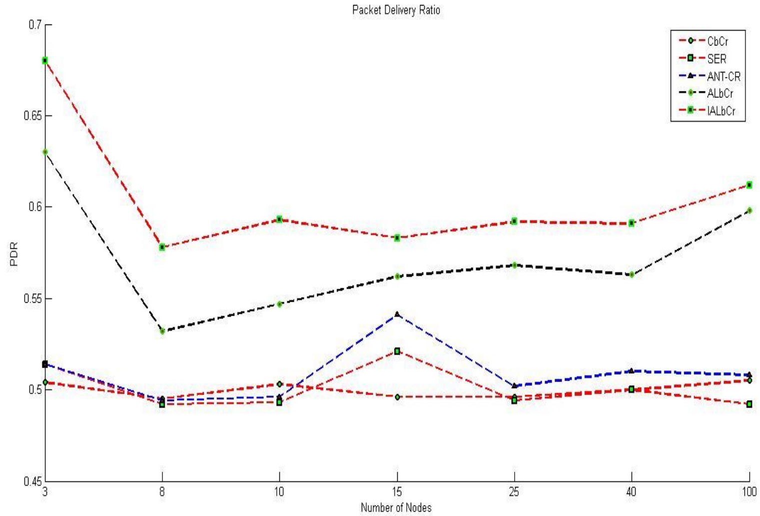

Figure 4: Analysis of Packet Delivery ratio

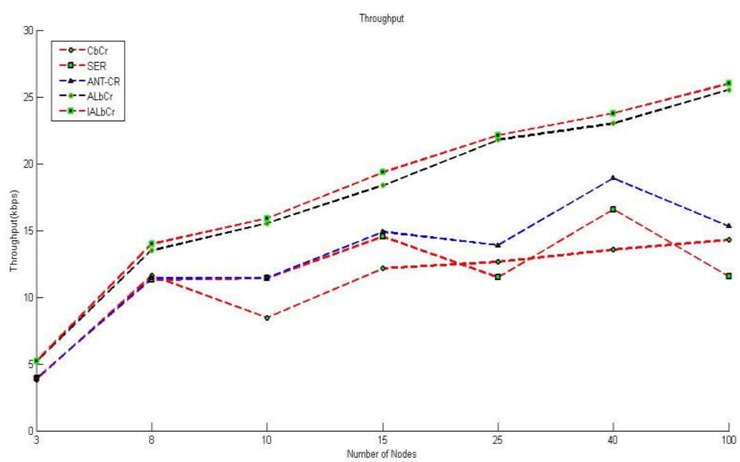

Figure 5: Analysis of Throughput

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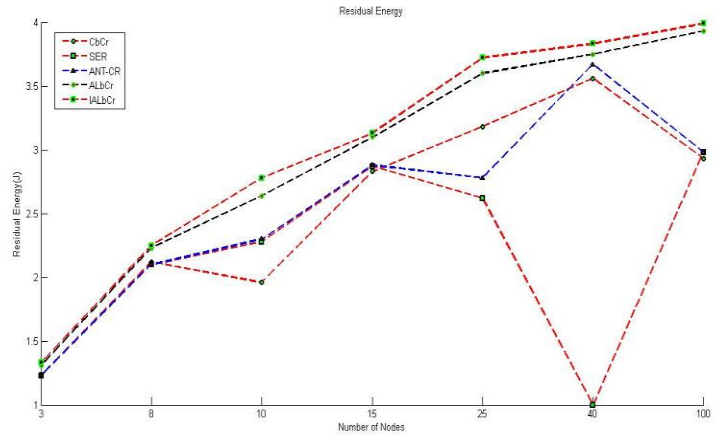

Figure 6: Analysis of Residual Energy

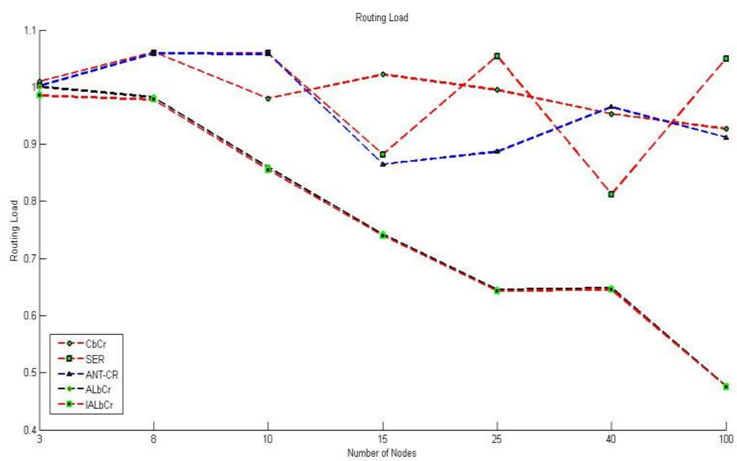

Figure 7: Analysis of routing load

The above figures show that the performance of the IALbCr is better as compared to the existing state of art techniques. It means the improved ant lion based protocol consumes less energy as compared to the other protocols. It can be viewed from the figures shown above that the throughput, PDR and Residual energy has been enhanced in ALbCr as compared to CbCr while the routing load and delay has been reduced. Overall we can say that improved ant lion based cognitive radio protocol is more efficient as compared to the other state of art protocols.

VII. Conclusion

This paper designs an optimized algorithm based on the ant-lion by using the hunting behavior of the ant lion. The implementation of the IALbCr is done using the network simulator. The performance of IALbCr is compared against ALbCR, SER, ANT-CR and the CbCr for parameters residual energy, PDR, End 2 end delay, Throughput and routing load on different network scenario having nodes 3, 5, 8, 10, 15, 25, 40, 100. The performance analysis clearly signifies that the algorithm is better in terms of delay, residual energy, PDR as well as throughput. The performance enhanced is due to the exploration and exploitation search within the search space. The improved performance gives the significance of the algorithm. In future this work can be extended for other area of applications.

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