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Energy-Aware Routing Minimizing Interference based on The Gravitional Search Algoritm in WSN

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Interference is one of the fundamental challenges in the wireless communication. Reducing the network interference leads to fewer collisions of communication signals and thus packet retransmission will be decreased. Reducing the interference decreases the delays and the power consumption indirectly, thus it makes an increase in the network lifetime. Therefore, How to choose the sensor nodes and the amount of energy consumption are very important in routing methods. In this paper, the idea of using gravitational search algorithm has been proposed in order to reduce the interference and increase the lifetime of the wireless sensor networks. The proposed algorithm selects a link based on GSA among from the nodes that are candidates in energy efficient space with the minimum interference. The simulation results indicate that the proposed algorithm shows better performance compared to EIGR algorithm in terms of signal to noise ratio –plus- Interference and lifetime.

Key words: wireless sensor network, Gravitional Search Algorithm, Geographical routing algorithm, Interference, Energy, Lifetime.

A sensor node is a small electronic device, which has low power and limited computing and communicating capabilities. A wireless sensor network is a set of sensor nodes, which are networked aiming a certain objective. Each sensor can measure certain physical phenomena such as temperature, pressure, light intensity or vibrations around it[1].

The wireless sensor networks have so many of applications such as supervision on the environment, biological detection and so on. Fire detection is an example of supervision application. The task of sensor is rapid and certain detection of fire using noisy data of sensors. Robust communications with very low delay have the highest priority for such applications within alarm status[2].

One of the main challenges of wireless network is interference. Data transmitting nodes are effective on the amount of data receiving capacity of nodes except target ones. As a node in receiving mode receives a signal from another transmitter but main transmitter, then this node is not able to receive information from its neighbors desirably; this mutual jamming in communications called interference. Reducing of interference in network leads to less collision as well less retransmitting of packets, which reduces power consumption and delay indirectly and increases network lifetime[3].

Interference models are divided into two major groups: (1) models that describe the properties of the interference signal (statistical interference models) and (2) models that describe

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the interference effects. In the first group, the emphasis is on the nature and the statistical properties of interference that could be expressed in probability density function. The statistical properties of interference need to analyze the issues related to physical layer, as well as evaluate the performance of Receive and diagnosis techniques. The second group states the interference models that focus on Network performance functions or some aspects of network behavior as long as they are affected by interference. Physical interference and protocol interference models are two general models that fall in this category. The Models in this category are appropriate for analysis of higher layer protocols and for techniques related to them such as routing, Scheduling and topology control[4].

In wireless networks, there are two general models for interference defined as follows[5]:

Protocol interference model: in this model, Each node has a transmission range in Protocol Interference Model, which is normalize to value 1 and fixed interference range is ρ. Each node $v \in V$ with a signal of another node $u \in V$ if $||uv|| \leq \rho$leads to interference, while node v is not target receiver to transmit from node u.

· Physical interference model: in this model, There is a threshold value of $\beta > 0$ in Physical Interference Model in such way that a node v"V can receive information from transmitter u accurately. If signal-to-interference-plus noise ratio is NR=$\frac{P_u \cdot ||uv||^{-k}}{\varepsilon + \sum_{w \in I} P_w \cdot ||wv||^{-k}} \geq \beta$, mean while Euclide and istance between node u and v is called ||uv||. $\varepsilon > 0$ and Gaussian noise are background, while I is a set of active transmitting nodes as node u is being transmitted. k>2 is path loss power and $P_u = p_i$ "u " V is uniform transmitting power of each node u.

Geographic routing is an interesting approach that uses the position information of each node to send data packets rather than overall topology information. These methods create more efficiency and simplicity based on position and they are scalable routing protocols in the wireless sensor networks[6]. In this paper, the Interference Energy- Gravitational Search Algorithm IE-GSA is proposed In line with both interference and energy reduction. The algorithm is first expressed in energy efficient space and then it selects a node with the least amount of interference among from the points that are candidates in the space according to Gravitational Search Algorithm.

The rest of this paper is organised as follows. Section 2 provides an overview of Routing algorithms to reduce interference and energy in WSN. Section 3 describes the network models and the energy models. The Proposed method based on the gravity of search optimization algorithms is given in Section 4. Section 5,6 describes the simulations results and conclusion, respectively.

Related work

EBGR[7] propose the energy efficient beaconless geographic routing algorithm for wireless sensor networks. In this algorithm, the geographic information and properties of transceiver Power are involved in decision-making process. If the destination node is in communication radius of the source node, the data packet will be sent directly. Otherwise, the source node will select the neighbors who are close to the optimal position in order to send the data packet. The simulation results show the reduction of energy consumption.

A study was conducted on topology meaning all target possible links are not needed, since they cause to higher power consumption and increase interference[8-9]. Regarding to what above mentioned, some user excluded links can be disconnected and a spread structure can be created. One of the main objective of control is topology. Some of the classic topology control algorithms, such as the Relative Neighbourhood Graph, Gabriel Graph, Yao Graph and the Minimal Spanning Tree.

Chiwewe and Hancke[10], proposed a distributed topology control technique called Yao Gabriel Graph with smart boundaries, SBYaoGG. This technique is inefficient in terms of energy and interference. In order to construct above graph, firstly Gabriel graph is built on unit disk graph. Then, single directed vectors are calculated for neighboring nodes and the average of directed vector is obtained. Mean vector is the axis of the first cone area which resulted in Yao graph. Thus, the corresponding graph is constructed and then used as an input to a routing algorithm for the intended goals.

Two interference models based on the edge called Receiver Based and SINR Models are expressed in[11]. A method for creating a connected graph is suggested with the least edge interference. The basic idea is to find a MST with the criteria of the edge weights based on interference load. By assigning three different levels of power to the graph, the results are examined and it is shown that as long as high levels of power are used, the interference is increased due to high network congestion.

Cheng et al[12], proposed minimization of overall delay jointly using routing optimization and link schedule by cross-layer designs. Cross-layer design is expressed to model interference in multihop wireless networks. If delay is related to the number of hops, interference model is used as the delay index along path which is a better measurement of hops number. If a path has various density levels, different values of delay will be experienced. The problem is modeled to include adequate conditions for collision free communications as linear programming with the aim of minimizing overall routing interference in the network. And, above algorithm guarantees the collision free transmissions.

The problem of minimizing the interference is suggested by a linear problem with two different interference models[13]. Two interference models called main and combination are expressed. In combination model, each node has a circle of communication to each neighbor instead of having a single connection. The main interference for a node is the number of circles that cover the node except itself. The purpose of this problem is to find a graph with the least amount of interference. In The results of simulation conducted on the same structures, natural, mesh and Exponential structures the proposed algorithm result in less interference.

Fereydooni and Sabaei[14], encountered optimization problems viewpoint with minimization of power consumption in topology control context. Traffic- and interference-aware topology control problem is formulated as a non-linear programming algorithm aiming at power consumption reduction in nodes. In the proposed method, sending to the farther node with lower traffic and interference is performed instead of sending to the nearest node among neighbors with higher traffic. Thus, collision and retransmission requirements are reduced, storing more energy.

In[15] interference aware Multipath Routing Protocol is discussed for wireless sensor networks. Routing occurs considering interference model and assuming the interference radius twice the sending radius for each node. First, the shortest path between the source and the destination should be found then two paths are made for each pair of transceiver with minimal interference. The simulation results show the improvement of data delivery, throughput, Energy consumption balance and delay.

Lee *et al.,*[16], are proposed Multi-path pipeline method of reasoning that implements a geographical multipath protocol free of interference by separating the paths of each other. Each pipeline is placed at a certain distance from each other and between the source and destination nodes. And the specified area is divided into three sections: the source node-side area, between the source, and pipeline entry position. The pipeline area that is free of collisions is between the entry and exit of each pipeline. Destination node-side area is between the pipeline exit position and the destination node. The obtained results manifest that the proposed protocol has a good performance over the other protocols reported in literature in terms of data delivery ratio and overall delay.

EIGR[6] is presented with the aim to minimize the interference on the way of data sending. If the destination node is in the communication distance of the source nodes The Algorithm -in the decision making process to send- will send the link directly. Otherwise assuming the expressed interference model in energy efficient area, a link with minimum interference is selected to send the information. The Results include an improvement in energy consumption, data delivery and overall network delay ratio.

Preliminaries

Network model

Consider a wireless sensor network such as a graph G=(V, E) comprising of n nodes placed in a two-dimension region; where $\{V_1, V_2, ...V_n\}$ is a set of n nodes (modeling a set of communication nodes) and for nodes of u and v $E = \{(u,v) | d(u,v) < d_{max},\ u,v \in V\}$, presents edge set of graph G (modeling a set of communication links). Each sensor node determines its position and its neighbors' positions via an internal GPS system and beacon message exchange, respectively. The source node have data to be sent to the destination node using the routing algorithm. All nodes operate in the same frequency level Based on PrIM model, it is assumed that all sensor nodes have maximum transmission distance (d_{max}) and interference distance (d_I), where $d_1 = a\, d_{max}$ ($a \geq 1.5$)[17]. The covering range of directed edge e(u,v) is a set of all nodes placed in sending circle of node u. D(u,d(u,v)) is a circle with center u and radius of Euclidean distance between nodes u and v[6-18].

$$COV(u, e(u,v)) = \left|\{w \in V \mid w \text{ is covered by } D(u, d(u,v)), w \neq u, v\}\right| \quad ...(1)$$

and interference $I^{(u,v)}$ a two-way edge $e^{(u,v)}$is a set of nodes covered by circle D(u,d(u,v)) and D(v,d(u,v)) [6-19].

$$I(u,v) = \left\| COV(u, e(u,v)) \cup COV(v, e(u,v)) \right\| \quad ...(2)$$

Thus, the interference of a graph G=(V, E) is defined as [6]:

$$I(G) = \max_{e(u_i,v_i) \in E} I(u_i, v_i) \quad ...(3)$$

Energy model

Various energy models have been proposed for energy descriptions in sensor networks. The energy modes in LEACH is also considered in this paper. It is assumed that is Eucliden distance between nodes u and v, is path loss constant depends on sending enviroment. equals 2 for the free space distribution model and relatively short distances, While it is considered 4 for the two-way earth distribution model and for farther distances. Thus, to send a message with L bytes within , the energy model can be written as [19].

$$E(L,d) = E_{elec} + E_{amp}(L,d) = \begin{cases} LE_{elec} + L\varepsilon_{friss\text{-}amp}\, d(u,v)^2 & d(u,v) < d_{crossover} \\ LE_{elec} + L\varepsilon_{two\ ray\text{-}amp}\, d(u,v)^4 & d(u,v) \geq d_{crossover} \end{cases} \quad ...(4)$$

where required energy to activate electric circuit (E_{elec}) and activation energy for power amplifiers

Table 1. Stimulation parameters

Size of each data packet	4000 bit
Maximum transmission range (d_{max})	90 meter
d_0 and d_{opt} and $d_{crossover}$	65,79 and 25,56 and 82 meter
Activation energy of electronic circuit (E_{elec})	50 nj/bit
Activation energy of power amplifiers in outdoor space ($\varepsilon_{friss\text{-}amp}$) and multi-path ($\varepsilon_{two\ ray\text{-}amp}$)	10 Pj/bit/m² and 0.0013
Initial energy of each sensor node	05 J
The amount of transmission power of transmitter	p_t = 0.01053
power spectral density of the noise	$N_0 = 10^{-6}$ watt/Mhz

considering open and multi-path space are $\varepsilon_{friss\text{-}amp}$ and $\varepsilon_{two\ ray\text{-}amp}$, respectively.

Proposed method

Gravitional search algorithm

Gravitational Search Algorithm is an Optimization algorithm which is based on Newton's Law of Gravity. It states that: "Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of distance between them"[21-22].

Consider that, there are two masses and separated by the distance R which is shown in Fig. 1. By the definition of Newton's Law of Gravity, the Gravitational force can be given by the Eq. 5.

$$F = G\{M_1, M_2/R^2\} \quad ...(5)$$

where is the Magnitude of the Gravitational Force, M_1 and M_2 are masses of particle 1 and particle 2 respectively, G is the Gravitational constant $G = 6.8 \times 10^{-11} m^3\, kg^{-1}\, s^{-2}$ and is the distance between the two particles.

Now, consider a system with N agents (masses). We define the position of the ith agent by:

$$X_i = (X_i^1, \dots, X_i^d, \dots, X_i^n) \quad for\ i = 1, 2, \dots, N \quad (6)$$

where X^d_i presents the position of ith agent in the dth dimension.

At a specific time 't', we define the force acting on mass 'i' from mass 'j' as following:

$$F_{ij}^d(t) = G(t) \frac{M_{pi}(t) \times M_{aj}(t)}{R_{ij}(t)\uparrow + \varepsilon} (X_j^d(t) - X_i^d(t)) \quad ...(7)$$

where $M_{aj}(t)$ is the active gravitational mass related to agent j, $M_{pi}(t)$ is the passive gravitational mass related to agent i, G(t)is gravitational constant at time t, ε is a small constant, and $R_{ij}(t)$is the Euclidian distance between two agents i and j:

$$R_{ij}(t) = \|X_i(t), X_j(t)\|_2 \quad ...(8)$$

The proposed routing algorithm

In the process of selecting interface node

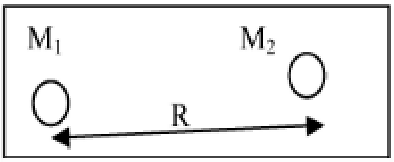

Fig. 1. Newton's Law of Gravity [20]

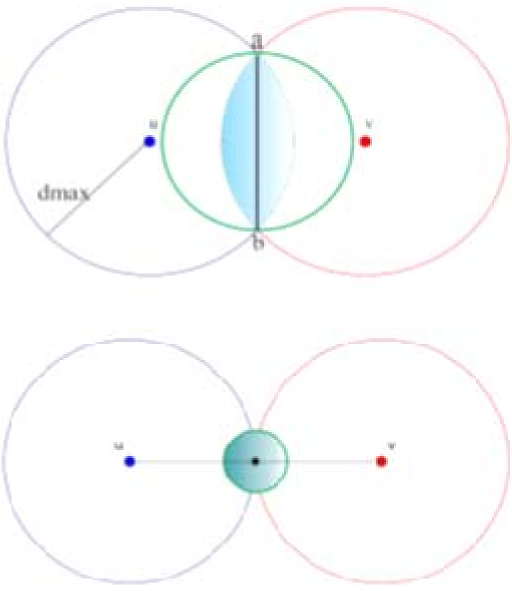

Fig. 2. Search area based on condition ii

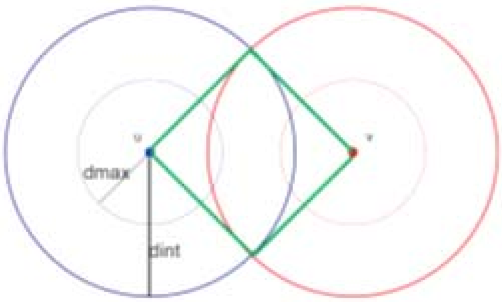

Fig. 3. Search area based on condition iii

in Routing, the interference parameter and Energy levels of sensor nodes should be involved In line with both interference and energy reduction. The remaining energy of sensors must be calculated to consider and involve energy. The main challenge of reducing interference is the minimum overlap in radio area of those sensors, which transmit data simultaneously. If we want to maximize network lifetime, the state of energy consumption must be regarded too. A tradeoff is required to consider all these two parameters simultaneously. First, a certain area for candidate sensor range for transmission is determined to set a tradeoff over proposed method. Then the three following stages are evaluated to find search area based on the number of hops between source and destination: First, a covering area and an interference area are illustrated for source and destination nodes, which are equal to a circle with center of target node, and a radius with the maximum amount of transmission range (d_{max}), a circle with the center of target node and a radius with the amount of interferences range (d_I)respectively[24]. The search area is formed regarding the three following status. Then the cost function are evaluated for the available nodes.

i) If $d(u,v) \geq d_{max}$, The source node to the destination node sends a data packet directly.

If $d(u,v) \leq d_{max}$, a circle centering of that point which is placed at forwarding line between source and destination nodes and in the middle of subscription area induced of two nodes covering areas, with a diagonal equal to the distance between two points of occurred intersection are circled by the covering areas of source and destination based on fig.1a. A space with wider range than subscription area as a specific area for selecting candidate sensor range is formed. If two covering areas of source and destination nodes are crossed only in one point in line to source and destination mid line, then an area will be formed to select forwarding node in a circle space centering cross point and the radios showing in fig.1b.

If $d(u,v) > 2d_{max}$, then an area is formed to find the forwarding node for both source and destination nodes, of course after illustrating covering and interference areas in a semicircular space facing to each other for two nodes and regarding the areas of points' interferences. The occurred area in square form with side length, which is equal to radius of interference area around subscription area obtaining intersection of the two areas of interference areas between source and destination nods. Regarding fig.2, two opposite angles in the occurred square are the

intersection of interference areas related to source and destination nodes, while two other angels are accorded to source and destination nodes.

After the formation of energy efficient area and selection of several nodes that are candidates in the search space, a node with minimum interference is selected by gravitational search algorithm. The Interference criteria for nodes available in the search space is examined by GSA Based on the following equation:

[illegible] ...(9)

Where n is the number of sensor nodes in energy efficient search space and $d_{u,wi}$ is the Euclidean distance between the source node and the i-th node in this area. The coefficient δ is based on the sending areas, overlapping each node and average of network density (ρ). The value of α has been considered 87.3.

Each node obtain the maximum transmission range to efficiently utilize energy of those sensor nodes, which are on border of dying, as well preventing early omission of these nodes (sensors) from transmission process if they have data to be transmitted. While ach sensor follows transmission conditions, but the target sensor node supposed as died one if it is not able to transmit data up to no distance or no node exists in transmission radios.

Simulation

In this part, the performance of expressed algorithms is evaluated using conducted stimulation of MATLAB. The appropriate stimulation environment is considered as a square space of wireless sensor. The stimulation parameters are mentioned in table 1.

Evaluation function

The signal-to-interference-plus-noise ratio

SINR is evaluated based on the following formula [23]:

$$SINR_{ij} = \frac{p_t . d_{ij}^{\ -\alpha}}{N_0 + \sum_{k \neq i} p_t . d_{kj}^{\ -\alpha}} \quad ...(10)$$

pt is transmission power of transmitter, N_0 is power spectral density of the noise, d_{ij} is Euclidean distance between transmitter and receiver nodes, d_{kj} is Euclidean distance between simultaneous transmission nodes, main transmitter (i) and receiver.

· **Delay:** Delay is measured by the number

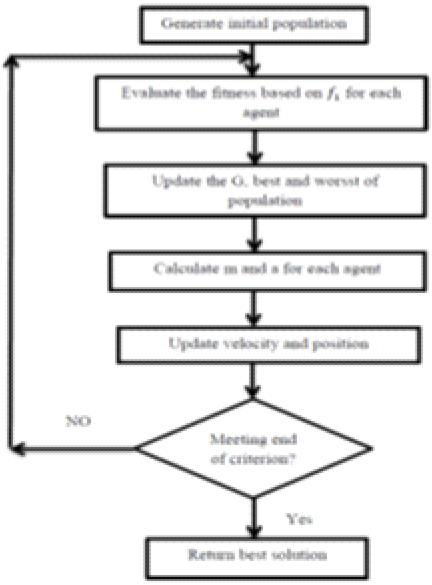

Fig. 4. The proposed algorithm based on GSA flowchart

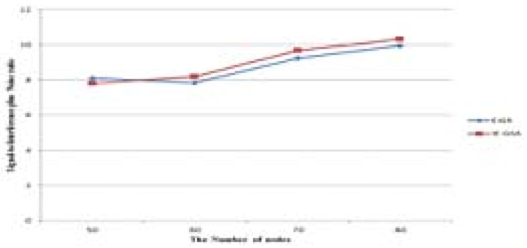

Fig. 5. Signal-to-interference-plus-noise ratio versus the number of nodes

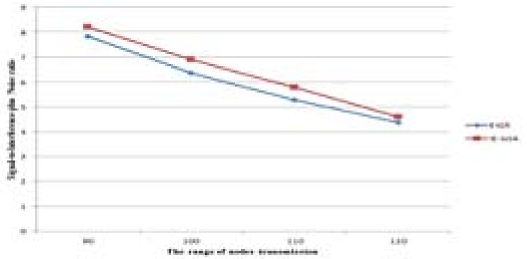

Fig. 6. Signal-to-interference-plus-noise ratio versus versus transmission range

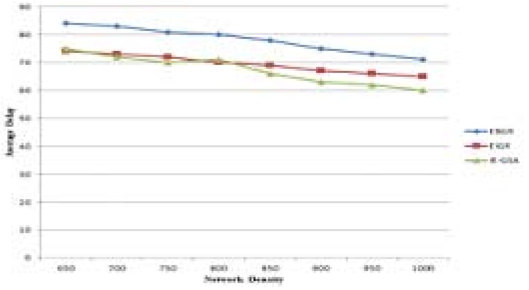

Fig. 7. Average Delay versus network density

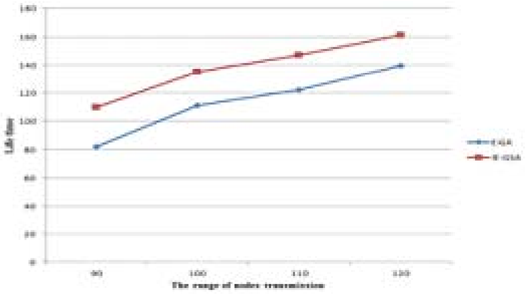

Fig.8. Network lifetime versus transmission range

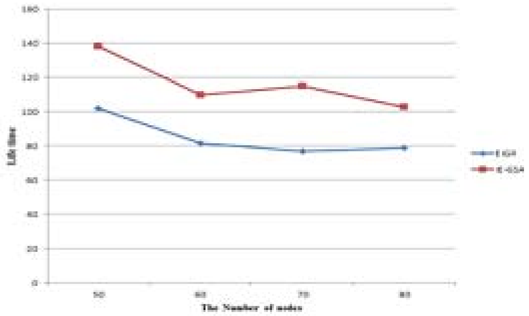

Fig. 9. Network lifetime versus the number of nodes

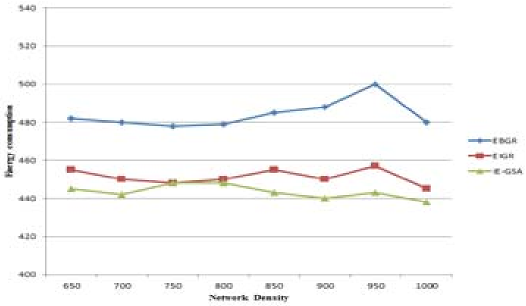

Fig. 10. Energy consumption versus network density

of hops to transmit a data packet from a source to a destination.

· **Life time:** The lifetime of a sensor node is considered as its establishment time until considering the node of remain energy to transmit based on conducted discussion in part. The node is called alive during this period but dead after that time. The lifetime of network is a time between start of network to a time while 10 percent of nodes are alive[24]. The lifetime is evaluated by the number of active sensor sets in a specified time interval called round.

Energy Consumption

This is defined as the total energy consumption by all sensor nodes which have participated in data forwarding.

The result of simulation

To examine how to function the proposed algorithm, the network was simulated in various situations then it was compared and examined. Change in the number of network nodes, increasing sending range of the sensor nodes and change in network density, are the cases that were evaluated. As results shown on the diagrams, the average output of 30 times simulations is affected by changes in sensor order, which is supposed to be a random parameter.

In Fig. 5, increasing the number of nodes makes a better choice in terms of interference criteria, thus makes an increase in signal to noise ratio –plus - interference. Increased sensing range or sending radius leads to increase in interference areas and overlap created by the sensor nodes and also there have been increases in amount of occurred interference, that result in SINR reduction. This process is shown in Fig. 6. IE-GSA shows interference reduction more than EIGR algorithm due to optimal selection of interface node in routing by gravitational search algorithm.

As can be seen in Fig. 7, increasing network density makes more sensor nodes to be used in the routing and therefore the sending time of the entire network will be decreased. Reducing interference, leads to Decreases in packets retransmission and consequently the overall delay of the network. Thus, both geographic routing algorithms EIGR and IE-GSA show reduction in delays.

Fig. 8 shows the changes in the lifetime for changes in sending radius of sensors. The larger the sending radius of the transmitter node, because of the increased sensing range of the source node; the less interface node will be involved in each stage. Besides, based on the definition of the search area which has a direct relationship with coverage areas of each node and somehow the same sending range, a larger area is created to explore and search. For the stated reasons, increasing the network lifetime is obtained by increasing the sending range of the sensor node. Based on GSA the proposed routing algorithm makes the network to survive longer and network lifetime to increase due to optimal selection of interface node.

From the perspective of two criteria of power and interference An Increase in network density, leads to an increase in optimal sensor nodes. As a result, the geographic routing algorithm EIGR and IE-GSA consume less energy than EBGR due to considering interference and energy parameters in process of interface node selection,. This can be seen in Fig. 10.

According to the simulation results, the proposed geographic routing algorithm IE-GSA enjoys energy consumption and delay reduction similar to EIGR algorithm, while from the perspective of interference criteria, an acceptable improvement is seen compared to EIGR algorithm Due to applying optimization algorithm in routing process. In addition, using GSA in The process of interface node selection, results in optimal decisions of objective function therefore makes an increase in the network lifetime.

CONCLUSION

Interference imposes potential negative impact on the performance of wireless networks. Interference causes collisions in communication signals of the receiver and also packets loss, which subsequently makes packet retransmission and delay in data delivery. In addition, it will lead to increase in energy consumption and decrease in the lifetime. This article, examines two goals: reducing the interference and increasing the lifetime in a wireless sensor network. In order to fulfill the desired goals, first, the energy efficient area is formed then the interface node is selected in the routing process in the created search space based on gravitational search algorithm. Geographic routing Algorithms EIGR and IE-GSA make reduction in delay and energy consumption closer to each other. IE-GSA Algorithm shows an acceptable increase in signal to noise ratio -plus-interference compared To EIGR algorithm while the proposed algorithm has higher lifetime because of using optimization gravitational.

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