A New Energy Consumption Algorithm with Active Sensor Selection Using GELS in Target Coverage WSN

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Abstract

In wireless sensor network, due to impossibility of replacing battery, the problem of energy and network lifetime is one of the important parameters. In asymmetric sensor networks, due to limited range of normal sensors it is not possible to communicate directly with central station by these sensors. In noted network, manager nodes are used which have more energy, processing power and broader telecommunication range. Connectivity and sending information to central station are done through them. The optimal selection and considering the energy of intermediate nodes to select and transmit data and also increasing network lifetime is one of the most important parts of wireless network design. In this paper, a gravitational force algorithm is used to solve the problem that is a power aware Selection algorithm in sensor network.

Keywords: *asymmetric sensor network, point coverage, the network energy, gravitation, velocity, Newton's law*

1. Introduction

Recent technology developments in micro-electro-mechanical systems and in integrated circuits led to development of small sensors with high processing power of information and low power consumption. These sensors have numerous applications such as multimedia, medical, surveillance, military telecommunications and home applications. Pocket PC, pager and cell phones are among them. A set of these sensors make a powerful network as wireless sensor network that is able to sample from local values ,process and send them to other sensors and finally to main observer (user).

Service quality is a versatile combination with multiple meanings and is one of network designer's goals .in order to achieve such design, many mechanisms are designed and evaluated [1,2].

The main challenge in wireless and mobile systems design Originate from two main sources of these systems i.e. telecommunication bandwidth and energy. To solve these limitations it is needed to Design telecommunication techniques to increase bandwidth needed for each user and design powerful protocol for efficient use of energy. Designs will be different Depending on expected capabilities of system and in various applications.

For example, in many applications, the optimal number of nodes and consumed energy in executive rounds, and maximizing network lifetime are basic requirements of network. (In networks classification, Time interval of network activity is divided into certain parts so that each interval just after choosing selected category is activated in size of that time and other nodes of network will turn off. This part is called a round).

Clustering is a solution for this. To collect and aggregate data in a sensor network, the nodes can be organized in small groups called cluster. Each cluster contains a central node called cluster heads and some member nodes. A two-level hierarchy of cluster heads (in high level) and member nodes (in low level) is constructed through clustering [3].

As replacing battery in many applications is not appropriate, low energy consumption is one of the basic needs in these networks and lifetime of each sensor can be effectively increased by optimizing energy consumption [4]. Schemes that are efficient In terms of power have applied more in these networks. These schemes are being investigated in all layers of network in two aspects of hardware designing and algorithm and protocol designing. One way to reduce energy consumption is to decrease the number of sensors in sensing area to ensure identification of each target in the area. If the network is scalable, the Algorithms to decrease number of sensors can be efficiently implemented [5].

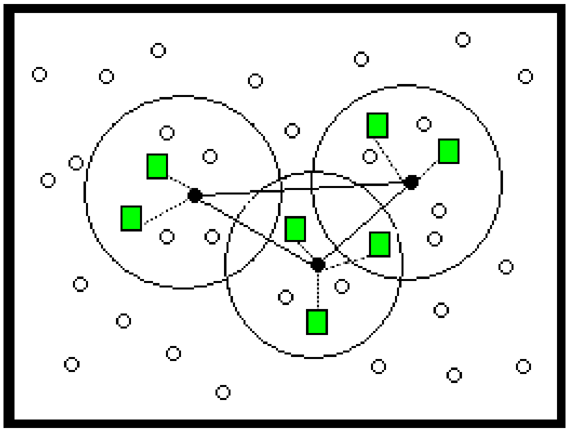

Fig. 1.Point coverage [6]

In point coverage, the aim is to produce coverage in set of points. A set of sensors is shown in figure 1 that are randomly arranged to cover a set of targets (square nodes which are green). The connected black nodes produce a set of active sensors that are result from a timing mechanism [6]. Point coverage scenarios have many applications. In this scenario, a number of targets with certain position are considered that should be controlled. A large number of sensors are randomly distributed Very close to targets. These sensors send collected information to central processing node. Based on this method, each target should be controlled by at least one sensor at any moment, assuming that each sensor is able to control all targets in its sensing rang. One way to reduce energy consumption is to decrease number of active sensors in Coverage area. A method for increasing sensor network lifetime through saving energy is to divide a set of sensors into several separated sets. This classification should be in a way that each set covers all targets completely. These separated sets are activated consecutively so that only one set is active at any moment [7].

2. Related works

Many researches have been investigated in the field of power aware algorithm and optimization of power consumption. Carbunar and et al presented a way to save energy consumption by detecting position of sensors and decreasing their overlapping [8]. In [6], a method is presented to save energy consumption. Based on this method, each area of sensors limit is divided into two sets. Only a set of them are active at any time and they will be activated alternatively. Based on the method presented in [7], at first, nodes are active or inactive distributive to obtain considered coverage range and remain unchanged. In the networks that the nodes distributed statistically, there is problem of heterogeneous distribution of energy in nodes. In fact, as the sensor is closer to target, its energy consumption is more. So, connectivity and network coverage will not be ensured completely [9]. In [10], a method is presented to achieve a scalable coverage. This method is used to enhance energy efficiency when there is high computational complexity and slag. In method proposed in [11], at first the sensors are randomly distributed then a self-healing algorithm is used to produce a complete coverage. Energy optimization is obtained based on energy optimizer algorithm. Numerical simulation verifies lower energy consumption in this network in comparison with initial randomly distributed network. In [12], it is noted that one way to reduce energy consumption is to decrease energy consumption in boundaries of covered regions. In [13], a method is presented to reduce the number of sensors and energy consumption based on biological algorithms. The advantage of this method compared to other methods is uniform distribution of sensors. In [14], a method is presented to increase network lifetime which is based on maximizing the number of sensor classes. In this method, a node is allowed to be a member of more than one group which will increase network lifetime. In [14], a relation is presented for sinks velocity, energy optimization and reduction of data packets Failure possibility. In another research, in paper [15] Using data transmission in multiple paths the network is resistant to node Failure. Here, each node determines its next hop based on a node which has the highest residual energy. In [16], a method is presented for clustering. This method is based on maximum delay and wasted energy by intermediate nodes and cluster size. This algorithm is based on creating a spanning tree whose root is node of cluster head. In another research, in [17], unlike other papers about sensing range of node, a disk with fixed radius around the node is not considered. In this paper, a scheme is presented to reduce network power consumption by establishing cooperation between nodes.

In article [18], Data Compression Problem in wireless networks is formulated according to energy. In this model, a percentage of each sensor data doesn't send; based on data correlation, therefore, result in reduced energy consumption. It is also shown that the greedy method is the most optimal method in terms of energy consumption. In the paper [19], a number of intermediate nodes are distributed in the network to save energy. This paper aims to obtain distribution of intermediate nodes in network So that the network lifetime increases. In [20], hierarchical clustering is used in wireless networks to achieve lower energy consumption. Considering the cluster head, energy consumption needed for communication of each node with processing center will decrease. In many studies including references [5-8], clustering methods are presented to reduce the number of clusters. In [21], methods are proposed to decrease power consumption and increase lifetime of target coverage network. In this paper, the advantage of using an algorithm based on greedy protocol is presented. In [22], to select relay stage, two algorithms based on clustering -the shortest distance and greedy algorithm are compared. In presented greedy algorithm, Classes of nodes that do not have manager node are merged with other classes of nodes. This process continues until all classes will obtain manager nodes. Although this method has low computational and telecommunication complexity, it is not an optimal method to decrease network energy consumption. Another method presented in [22] is the shortest distance algorithm. In [23], a method is presented to increase network lifetime based on gravitational algorithm. This algorithm aims to increase network lifetime by optimizing and decreasing energy consumption and increasing productivity of monitoring network. In this paper, each node that is active in current round finds its shortest distance to closest manager node. The shortest distance Selection decreases network energy consumption.

3. Energy model

This algorithm is based on timing protocol of activity duration networks. Timing protocol is one of the grouping protocols which are placed in sensor networks. It uses two-step mechanism (initiative and executive) and works on the basis of data communication in shape of single-hop or multi-hop Including some super nodes and relay and monitoring sensor. In this protocol, group selection is done by using size function designed in the protocol.
In initiative phase, some nodes which is called "sensor" send their propagation messages to their neighbors. In second phase (executive) which is known as stable phase, data reception or transmission is done from sensor nodes to relay nodes and from relay nodes to destination. Figure 2 shows the plan of protocol operation.
Some nodes of super nodes transmit data carefully, like LEACH algorithm [15], According to the plan The energy is saved by grouping in remaining time of inactive nodes. In grouping protocols, energy consumption is constant in whole network due to periodic circulation of active sensors. Hence, we used this feature in our paper.
As shown in Figure 2 each round includes two phases: initiative phase and executive phase. The initiative phase includes two parts. The former is devoted to monitoring sensors selection. The latter is for relay sensors selection. It is obvious that using super nodes increases network lifetime.

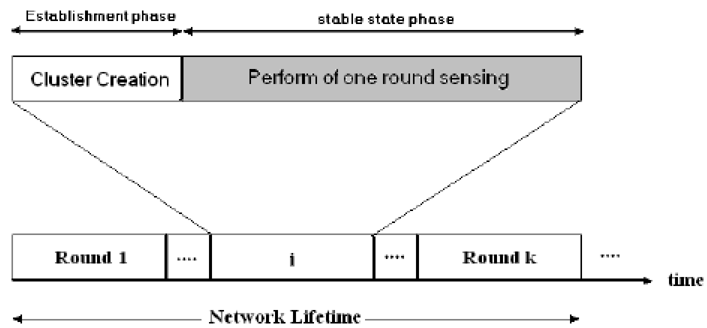

Fig. 2. Timeline of proposed protocol Performance

3.1 Energy Model

The energy model is considered for transmitting and receiving one of data in accordance with LEACH energy model. Assume that the distance between a transmitter and a receiver is d in energy model mentioned above. If d is more than d0, the multi-path model (with less path coefficient 4) is used; otherwise open space model (with less path coefficient 2) is used.

$$E_{Tx}(l,d) = E_{Tx-elec}(l) + E_{Tx-amp}(l,d) = \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2 & d \langle d_0 \\ lE_{elec} + l\varepsilon_{fs}d^4 & d \geq d_0 \end{cases} \quad (1)$$

E_{elect} Is required energy to activate the electrical circuit ε_{mp} and ε_{fs} are activation energies for power amplifiers in multi-path and open space modes, respectively. Its general form is represented:

(1) With constant coefficients p and q

(2) In receiver case

$$E_{Tx}(l,d) = p + qd^{\alpha} \quad (2)$$

The consumed energy is received with one of data sizes (3).

$$E_{Rx}(l) = E_{Rx-elec}(l) = lE_{elec} = p \quad (3)$$

In presented asymmetrical networks, it is assumed that initial energy of super nodes is several times greater than initial energy of normal sensors. The consumption energy of a relay and monitoring node are denoted by $Es1$ and $Ec1$ in each round respectively.

3.2 Sensor Network Protocol Design

The problem is emphasized on how to design a protocol to increase network lifetime and decrease energy consumption in available nodes. The benchmarks are trying to use more from usual energy of sensors.
In covering networks, the physical positions of nodes and times of using them should be considered in designed protocol. The times of using sensor and also the distance between selected node (in fact in relay path) and super nodes have crucial role for energy consumption of that group. Therefore, we should seek for a relation between these two parameters and their energy consumption. At first, we state the problem and considered situations. Then, similar parameters that include timing algorithm based on the super nodes (for point coverage) will be explained below.
Our network contains N sensors named S_1 to S_N . We have M super nodes named S_{u1} to S_{uM} (M<N). The proposed timing algorithm is divided into time intervals with certain rounds and identical intervals T_r .
Selected group is only active during time of T_r and other nodes are off during a round. during round a , T_r can be computed by considered grouping time, the groups of energy estimate physical parameters of lifetime and types of normal sensors is used in network.

3.3 dominating Provisions network

The provisions of network are listed below:
There are K targets with defined positions in network composed of sensor nodes and super nodes. In considered scenario, sensor nodes and super nodes are randomly distributed. This plan of sensor nodes activities must be guaranteed according to following conditions after running algorithm for network lifetime:

- Targets T_{a1} to T_{ak} must be covered.
- There are nodes S_1 to S_N which perform monitoring task and are deployed randomly.
- The super nodes S_{u_1} to S_{u_M} are deployed.
- A set of nodes C_1 to C_j should be selected. Each C_j is set of active nodes and is generated by protocol in each round.
- Each set of C_j is necessary and sufficient to cover k targets.

In fact, the objective is to divide sensor nodes into active and inactive groups. Active sensors must be able to communicate and cover. The objective is to use this algorithm for maximizing the groups, reducing energy consumption and increasing network lifetime. In each executive round, it should be checked whether a node is active as a sensor node or a relay node.

- ✓ Each normal sensor has initial E_i and high processing power. Common sensors Dissimilar to super nodes have higher energy, greater lifetime and higher processing power.
- ✓ All super nodes are connected to each other by a path between two super nodes.
- ✓ Each active sensor exists in one of C_j groups and connected to a super node by relay nodes. Each sensor is connected to one of super nodes through Data transmission path.
- ✓ Sensor nodes possess initial energy E_i , communication range R_c , and sensing range $R_s\,(R_{c\geq}R_s)$.
- ✓ This selection must be located and distributed. Decision making is done for using data in neighboring node with fixed multi-hop distance.

Definition 1:
In defined point coverage, it should be said that when the Euclidean distance between nodes and target is Less than or equal R_s , the target is covered.

Definition 2:
Sensors can connect to each other or super nodes if the Euclidean distance is less than R_s .

Definition 3:
Network lifetime is defined as time interval in which all k targets will be covered by a set of active sensor nodes that are connected to super nodes.

3.4 Sensor Nodes Selection Algorithm

As indicated before, designed grouping algorithm which are executed at the beginning of each performance round, includes two sections. The first section is selected active nodes. The second section is attributed to data collection from nodes and data transmission through relay nodes.
In the first section, one of C_j groups is formed in a way that must be satisfied in above provisions. When this group is active, all other nodes are inactive (Sleep Mode) and consume little energy.
They should be evaluated in next phase. This evaluation is done by considering a series of physical factors of sensors during a round.

3.5 System Specifications

The network is offered a squared environment. There are T_{a_k} targets in the environment that are covered with connection of covering network.

$Tars_n$ Includes all targets in sensing domain S_n. They are covered by nodes. The number of targets is located in sensing range of node S_1 which is shown by m_1.

The initial energy of common sensors is E_i and initial energy of super nodes is three times greater than E_i. The energy consumed in each round is called Es_1 and the consumed energy of a relay in each round is called Ec_1.

The first section include sensor node selection, checking size function for evaluation and selecting active monitoring nodes that are w time units (the Second is the time unit here). The waiting time of node S_n is computed by a function measuring physical parameters of sensor S_n. Waiting time is stated as a multiple coefficient for total time of a round by using the parameters of a node: remaining energy, initial energy and number of targets seen in the range of a sensor.

A sensor decides to sleep or awaken after passing remaining time.

If $E_n < E_{s_1} + E_{c_1}$ (E_n is remaining energy of sensor node S_n) then the node cannot be converted to a sensor node.

So waiting time is not computed and t_n is waiting time of node n which is equivalent to w. It means that the node is not a sensor.

Otherwise, when $E_n > E_{s_1} + E_{c_1}$, t_n is computed and inspected. When t_n is finished $Tars_n \neq \phi$, S_n introduces itself as a sensor node and joins active nodes in the group.

Then, new selected node shows the position of two-hop neighboring nodes. If there is a node such as S_j at the end of the round that $Tars_n \neq \phi$ and $E_n < E_{s_1} + E_{c_1}$, the node sends the "no coverage" message to super node. It means that network lifetime is terminated. At this time, a message containing "no completed coverage" is sent to super nodes and the network sends this message to final monitoring destination.

4. Gravitational force

In 1995 for the first time vadoris and Tsang [24] proposed GLS algorithm to search and solve NP-complete problems and in 2004 Barry Webster [25] presented it as a robust algorithm and named it GELS.

The idea of this algorithm is based on gravitational force principle that causes objects are attracted to each other in the nature, So that the heavier object has more gravitational force and imposes it on other objects and attracts the objects with lower weight toward itself. However, the Distance of two objects is very effective on size of this force; consider two objects with same weight and different Distance compared to object with less weight, the Object which has less distance to low weight object can impose more gravitational force on it. In GELS, Newton's law of gravity formula between two objects is:

$$F= \frac{Gm1m2}{r2} \qquad (4)$$

Where m_1 and m_2 are mass of first object and second object respectively. G Equals to gravitational constant value 6.672, R is the radius parameter and the distance between two objects.

Also GELS imitates this process of nature to search through a search space. So that search space, world and objects in this world are possible responses to search. Each object has a weight, the weight of each object is the performance or the search criteria, in which the best response has maximum weight and none of objects, cannot hold a zero weight [26- 28].

In this way, the possible responses in search space based on the criteria that depends on type of problem are divided into categories that each category is known as a dimension of problem response and a value called initial velocity is considered for each dimension of problem response which will be explained below.

GELS include a vector whose size specifies the number of response dimensions. The values of this vector represent relative velocity in each dimension. The algorithm starts with an initial response, initial velocity vector and movement direction. For each dimension in velocity vector, a random number between one and maximum speed is selected and it is the value of each element in each dimension. The initial response is generated by user or randomly as current response.

For each dimension in initial velocity vector, according to initial velocity vector of response dimensions, a direction is selected to move which is equals to response dimension that has maximum initial velocity in initial velocity vector.

The algorithm consists of a pointer object that can move in search space and the weight considered for object pointer is fixed in all calculations and the object always refers to a response with maximum weight. The algorithm is completed with occurrence of one of two conditions: All components of initial velocity vector are zero, or number of algorithm iterations reaches its maximum.

In used Newton's formula, by replacing two mass in numerator of equation and replacing with difference between cost of candidate response and current response, the gravitational force between two objects is calculated using the following equation:

$$f = \frac{G(CU - CA)}{R^2} \quad (5).$$

Where CU and CA are cost of current response and candidate response respectively .This formula has a positive value if cost of current response is greater than cost of candidate response and has a negative value if cost of candidate response is larger. Then value of this force, positive or negative, is added to velocity vector in status of current path. If this action causes the value of velocity parameter exceeds the maximum setting, it takes a maximum value. If the update results in negative value, it takes zero.

The available Parameters in GELS:

Maximum Velocity: The maximum value that can be allocated to each element of initial velocity vector and this parameter prevents from getting too big.
Radius: the Radius which is used in the formula to calculate the gravitational force.
Iteration: Defines the maximum number of algorithm iterations which Ensures that the algorithm is terminated [26].

5. The proposed algorithm

In new proposed method, gravitational emulation local search algorithm (GELS) is used as a strategy to select optimal sensors. The choice is done for monitoring in Point coverage wireless sensor network. The goal of this algorithm is to increase network lifetime by optimization and reducing power consumption and increasing monitoring network efficiency. At first For each executive rounds in network, a number of sensors are activated to monitor, they Will lose some of their energy For each activation and These sensors must be chosen in a way To ensure that these sensors will cover all points needed for monitoring and Also there will be a distance from these nodes to the sink which has a cost.

To solve the problem of optimal sensor selection for monitoring in Point coverage wireless sensor network ,at first we consider three distance matrix, initial velocity matrix and time matrix which distance matrix, initial velocity matrix are randomly produced. In velocity matrix, an initial velocity will be given to each available sensor in the network which is considered as a mass and then in later stages the speed will change besides the time matrix is obtained from following equation Based on distance matrix and velocity matrix:

$$T = \frac{\sqrt{(Y_B - Y_A)^2 + (X_B - X_A)^2}}{V_{in\ A,B}} \quad (6)$$

Then After creation three mentioned matrices, Sensors will be placed randomly within an array and For each executive rounds in network, the sensors which cover limitations of problem and have greater mass and speed and shorter distance compared to targets of network and also have less frequent than other sensors and they Have been selected with this condition that they perform Monitoring in network, will be activated. At this time, a solution has created for problem and then the Suitability of solution will be calculated and will be recognized as a mass of that solution. According to law of gravity, the best solution must be the largest mass.

Next solution will be created from current solution based on problem limitation that the suitability of this solution is calculated and will be known as mass of solution and In the case of optimization to current solution, created Solution is chosen as current solution I.e. the problem will go toward optimization.

If created solution is not optimal compared to current solution, The algorithm does not consider created solution and then makes another solution from current solution and examines it And this action is repeated until the algorithm return the optimal solution. The algorithm is completed with occurrence one of two conditions:

All components of initial velocity vector are zero, or the number of algorithm iterations reaches its maximum.

6. Simulation results

To evaluate the performance of proposed algorithm, the software C# is used. Sensor network is simulated in various modes. Selection methods to simulate and compare interface distance Selection, include a method based on greedy algorithm for distance selection, a method based on clustering -the shortest distance Selection and the method proposed in this paper. Table 1 is used for above simulations and proposed algorithm is compared with sources [22] and [23] and [29] and [30].

It should be noted that in proposed algorithm the run time of each round of proposed algorithm due to algorithm simplicity and low slag Is very low and very substantial compared to other algorithms that are simulated ,in addition it reduces energy consumption And lifetime that can be seen in the simulation.

Table 1: The values used in simulation

Parameter	Value
Network Size	**500 * 500 m**
SNodes Location	**Random**
Nodes Location	**Random**
Nodes Initial Energy	**0.1 J**
SuperNode Initial Energy	**0.5 J**
Communication Range	**90 m**
Sensing Range	**60 m**
Number of Nodes	**300**
Number of SNodes	**25**
Number of Target	**20**
Eelec	**50 nJ/bit**

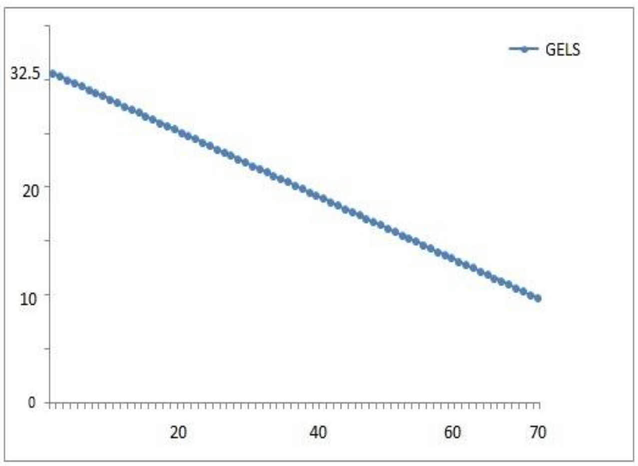

Fig. 3. Results of gravity algorithms for 200 Normal sensors, 25 Manager Sensor and 20 targets

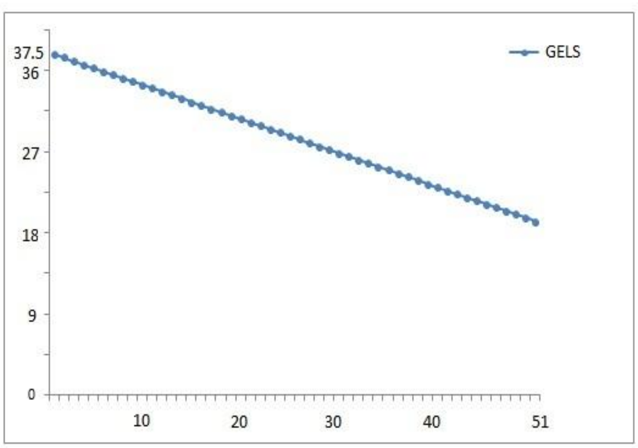

Fig. 4. Results of the gravity algorithm for 300 Normal sensors, 15 Manager Sensor and 30 targets

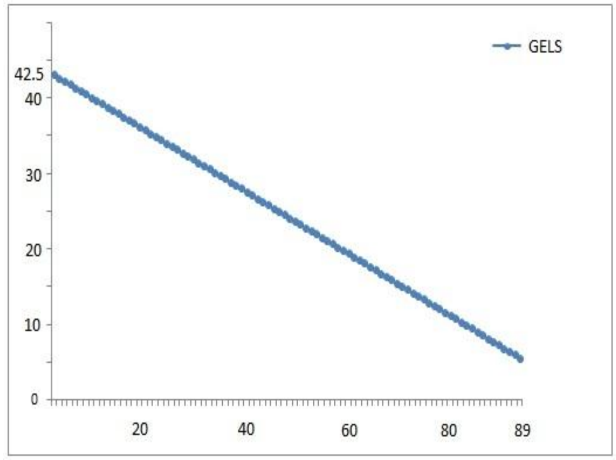

Fig. 5. Results of the gravity algorithm for 300 Normal sensor, 25 Manager Sensor and 20 o target

7. Conclusions

In this paper, a gravitational emulation local search algorithm is used to solve Optimal sensor selection for monitoring in point coverage wireless sensor network .as Well as a New Method is proposed To Calculation suitability And evaluate presented Solutions To solve Optimal sensor selection problem for monitoring in point coverage wireless sensor network. The advantages of this algorithm are speed, low run time, increase lifetime of network by optimization and reduce energy consumption and increase monitoring network efficiency. The results shows improvement and superiority of proposed algorithms compared to sources [22] and [23] and [29] and [30]. This improvement is more apparent in large-scale systems.

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