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Improved Steiner Tree Scheme Applied to Wireless Sensor Networks for Path and Energy Optimization

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***Abstract*—**This research work presents two optimization algorithms to optimize the path and energy in the wireless sensor network. Minimum Spanning Tree (MST) and Particle Swarm Optimization (PSO) algorithms both are utilized to optimize the path and energy of a system, which is connected on a fifty nodes network deployed randomly on 100x100 meters region. The proposed scheme is for the constrained improvement problem, or more explicitly, a weighted spanning tree problem and its appliance to Wireless Sensor Network (WSN) is examined here where definite exploratory discoveries on the energy improvement of the network have been exhibited.

***Keywords*—** Minimum Spanning Tree, Optimization, Particle Swarm, Shortest Path Tree, Wireless Sensor Networks.

I. Introduction

Energy optimization in a Wireless Sensor Network (WSN) has been one of the most researched topics in the field of wireless communication. Numerous recent journals has pointed out to it in the current year, such as [1], which has worked on Ant Colony Algorithm for the optimization of the energy consumption in a WSN. The reason behind using the sensors is to extend the capacities of an individual. For example in the distant magma-based regions, for the search of natural resources and other earth components [2]. Addition to the system some uncommon incentive in a WSN, dormancy, decency just as the nature of administration of the system are of most extreme significance. In a down to earth situation, the parameters of the framework counteract one another and consequently, they become balanced.

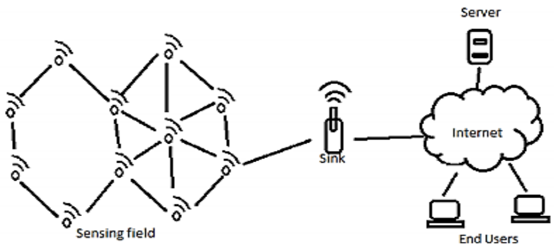

Figure 1. A Wireless Sensor Network

By counterbalancing, it is implied that these measurements are orchestrated in the system so that if we upgrade one parameter it will outcomes in the squalor of some other essential parameters. In this way, finding a parity of the considerable number of measurements of a WSN isn't just significant, yet in addition inescapable.

Effective correspondence system and calculations are eminent with an end goal to diminish the vitality utilization, amplify the lifetime, and improve the working of the system in general [3].

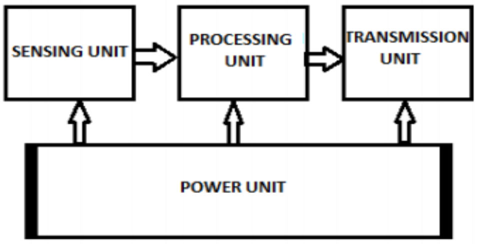

Figure 2. Architecture of a wireless sensor node

MOO calculations can take care of an issue with different parameters compelled by equity or disparity limitations so that the arrangement of the qualities for the parameters of the issue can't be called definitive and completed. It is difficult to observe the answer that is exact fit to the parameters of the issue, this type of the solution is known as Pareto-Optimal (PO) arrangement. The metaheuristic algorithms are normally used to tackle the MOPs. The most generally examined algorithm from the metaheuristic's sub-class Non-Dominated Sorting Genetic Algorithm (NSGA-II) because of their productivity in discovering Pareto-arrangements.

So as to diminish vitality utilization, correspondence plans or conventions have been created in the course of recent decades that have filled the need. The examination field is as yet crude and more issues in WSNs are rising as it grows imaginatively.

The Wireless Sensors Network can be enhanced through various ways for the energy and path optimization, the improvement can be made with in a multi-bounce, staggered, various leveled WSN, regardless of whether it is an incorporated or a decentralized system with both of sound information hubs or the opposite, is one technique [4]. Different techniques are connected with the examination points of nodal situation issue, inclusion issue, sending approach type, adaptation to non-critical failure and traffic mindfulness, among numerous different measurements.

The most significant of the measurements in an improvement-based research with respect to a remote sensor arrange are Latency, Throughput, Energy utilization, Lifetime, Death and future, detecting capacities, organize overhead, etc[5].

A. *To Find the Shortest Communication Path*

Proficient information trade with minimal measure of energy loss is a significant prerequisite in the present territory of WSN technology [5][6]. A few advancements, that merit referencing. Djikstra's most brief way calculation has been the base of different late investigations in these research areas [7][8]. For example, in research [9], the algorithm estimates the base number of nodes between the source and goal node that could be utilized in the calculation of the path.

The work in [10] proposed a new method for the separation of the adjacent nodes in a system. The proposed work presents that if the two nodes in the network has same signal properties they will be terms as same nodes. In the brought together sort of systems, the plan for estimations of separations for the non-neighboring sensors must be unique in relation to the previously mentioned one. A few analysts are referenced in [11],[12],[13] and [14].

Amid the estimation of a separation between two hubs, if nature is loud, it takes various jumps for a similar data to reach with a specific precision to have the option to effectively help out there figuring [15]. Therefore, in specific situations, the mistake in counts about the separation increments relatively with the measure of engendering of blunders in estimations over the system. This makes its very own issue in a similarly disseminated WSN, which is intensified if the kind of system conveyance is non-reasonable for example at the point when the hubs are put arbitrarily [16][17].

B. *WSN Energy Optimization*

Various well- known journal publications are available that covered different networking setup and approaches for handling the energy streamlining issue in the Wireless Sensor Networks. It will be difficult here mentioning all the survey regarding the problems of the networks, but some of the issues that has to be explored in the survey are as followed through leading journal publications.

In the research work [18] a short diagram of the different sorts of sensors, internal design, kinds of working frameworks ready and distinctive correspondence related issues and difficulties. In this audit, in any case, the vitality issue has been talked about all around quickly.

The research study in [19] presents a top-down rundown of vitality streamlining calculations has been reviewed, in which the focal point of center has been the information total in WSNs. A few analysts reviewed vitality reaping systems for WSNs, that could demonstrate to be a superior answer for the sensors in [20] [21] [22].

C. *The research problem*

In the below shown WSN, let us characterize quantity of sensors introduced in a given region. Expect that every sensor can compute the separation to some other sensor utilizing the RSS or some other technique [23] [24]. In the event that there is a staggered, coherent progressive system with grouping and a conceivable multi-sink situation, in that case the standard parameters that will help in the streamlining of the sensor organize is the most limited way finding for the system. This ensures the sensor sending the information to a hub is utilizing as meager vitality as could reasonably be expected and that the information it means to deliver to the sink is achieving it in as meager jumps of sensors as could be allowed. Consequently, requiring the shortening of way for correspondence.

Another issue that emerges when getting ready for the way of correspondence is the measure of vitality accessibility. The accessible vitality may be displayed as a factor of nodes weight produced during networking of the hubs. Accordingly, when the ways are proposed to be made by the system, the heaviness of the sensor hub as a proportion of the accessible vitality in the hub is to be mulled over too. This makes the issue a blend of voyaging sales rep issue (SRI) and a specific improvement calculation. TSP guarantees that a determination of hubs from the system adds to the production of way to the sink. The determination of hubs in the WSN is made so that the contribution of the hubs in the way doesn't make them bite the dust very soon.

Steiner Tree is a seeking calculation in chart hypothesis, that are been utilized as of late in an application to WSNs for discovering the most limited conceivable way that a lot of hubs can be canvassed with so as to transmit information from a detecting hub to the sink. It has certain restriction of its own, for example it can't be connected to under three hubs at any given moment and this makes it in fact hard to apply to remote sensor hubs for most brief conceivable way creation. The Steiner calculation makes a virtual hub in the middle of the three hubs so that the way from any of the three hubs to some other hub is the briefest conceivable. Subsequently, the all-out separation between each pair of hubs in the set is by normal, the least conceivable.

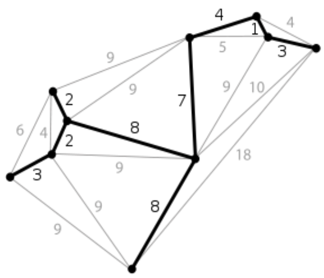

Figure 3. Minimum Spanning Tree

II. MATERIALS AND METHOD

A. *Graphs and Trees*

A scientific set that contains collection of edges and vertices is known as Graph. For example, in a real time environment, a lot of towns go about as hubs and the streets joining them go about as edges. Correspondingly, a system with sensor hubs and the interfacing pathways go about as hubs and edges separately. As per directionality, charts are defined in two types, coordinated and undirected diagrams. The coordinated diagrams have additional element to bear reliance for the ways, for example certain ways are enabled uniquely from one course to the next, and not a different way. A run of the mill diagram comprising of eight edges and six vertices is demonstrated as follows:

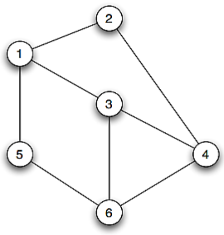

Figure 4. A simple undirected graph example

Definition: The graph is shown as a couple of (V, E), where V is a limited arrangement of qualities representing the chart's edges, while E has a lot of limited edges. E is encompassed in VxV and G denotes the diagram. G is a coordinated diagram if E has a lot of requested combines and is undirected if the arrangement of edges is unordered sets.

The Vertices, V= {1,2,3,4,5,6} and the Edges, E= {(1,2), (1,3), (1,5), (2,4), (3,4), (3,6), (4,6), (5,6)}

Definition: A way is along these lines, characterized in a graph as a succession of vertices associated by the edges, in which the vertices don't happen on numerous occasions. This is represented by P. For example, for the precedent diagram appeared, the path is like {6, 5, 1, 2}.

In light of the paths and their availability, there are two kinds of charts, one is the connected and the other one is non-connected. In the connected graph each pair of vertices is associated, for example there is a way for each pair of particular vertices. In the detached or non-connected graph there is in any event one sets of detached vertices, between which, a way can't exist.

Definition: A cycle is an exceptional way in which the start and end vertices are equivalent.

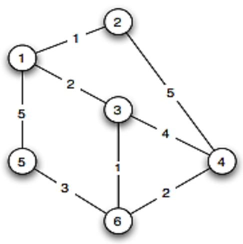

Figure 5. Example of a Weighted Graph

B. Dijkstra's algorithm

Djikstra's - a Dutch researcher, who introduced an instinctive method to discover the briefest route in a chart between the two vertices of any associated chart. In a given chart G= (V,E,w) with identified loads w, where w is a capacity that maps positive whole numbers to the area of the edges, for each edge in the diagram spoken to by an arranged pair of c and y organizes for example e=(x,y) ϵ E, the load is then denoted by w(e) and w(x,y) denotes the separation in between the vertices of the system. Thus, w shows the system's nodes separation, for example the chart's vertices.

The path is shown mathematically as $\pi = v_1 v_2 v_3 \dots v_n$ with n vertices. v_1 to vertex v_n can be denoted arithmetically by $w(\pi) = w(v_1, v_2) + w(v_2, v_3) + \cdots w(v_{n-1}, v_n)$.

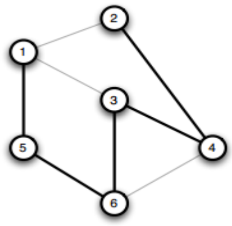

Figure 6. A spanning tree of graph in figure.[4]

On the off chance that for a similar chart or system, no other path with w(π) not as much as this esteem exists, at that point the path is considered shortest between vertex v_1 and v_n. Give us a chance to signify the separation between two vertices of chart by d(a,b), at that point if the hubs are associated, this separation d is limited, and vast generally.

Problem: The issue is characterized in scientific terms as pursues. Given a weighted diagram with associated vertices, represented by G=(V,E,w), as clarified in advance of, and an essential vertex s and auxiliary vertices v, it is wanted to locate the briefest route from the source vertex s to every one of the vertices v. Dijkstra's calculation discovers the briefest route issue's answer by utilizing an insatiable way to deal with the inquiry of the paths.

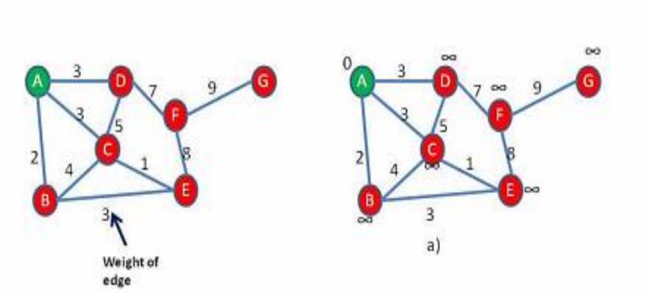

Figure 7. Dijkstra algorithm greedy method described with a graph

It begins off by discovering every conceivable route from a solitary vertex to other vertex by picking just vertices those are nearest to the past vertex. It basically implies the tree that is made by the Dijikstra's calculation is the base weighted tree.

This tree is called as the shortest path tree (SPT). Most significant point to be recollected here is that the SPT shouldn't be an extraordinary arrangement of the chart. There can be numerous SPT in a solitary chart, and this is entirely distinctive from the minimum tree spanning (MST) as follow.

Minimum Spanning Tree

In an allied chart G with E edges, w loads and V vertices G=(V,E,w), a Minimum Spanning Tree (MST) is can be defined as an intersecting tree for the said diagram to such a degree that the comprehensive load of the tree is least.

It infers that of the different possible results of the SPT, just a single hopefully fits for the MST of the chart. For our model network, the example of SPT and MST are ensued as:

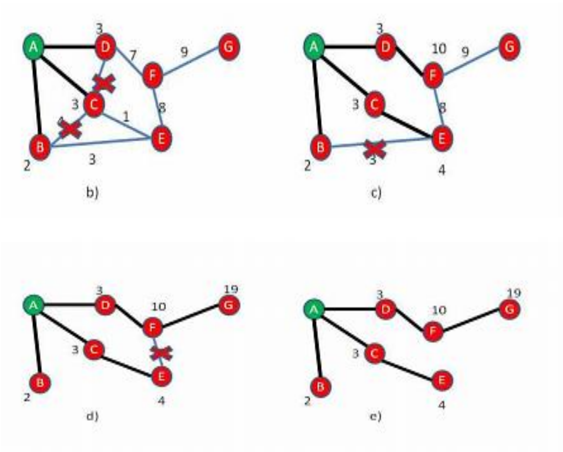

Figure 8. Dijkstra's algorithm explained graphically

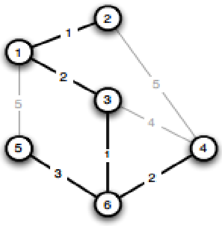

Figure 9. MST of the example graph

- *SPT and MST appliance to WSNs*

While the appliance and preparation of these SPT and MST calculations to the WSN situation, the weighted diagram idea need to be slightly elucidated. The loads in the chart proposes as referenced before signifies the parting of the hubs from one another, yet it may communicate to some other model parameter of WSN. Give us an option to indicate the weight "w" as the separation between any two sensors of the system.

- *The issue in MST*

The concern in the minimum spanning tree associated with wireless sensor systems is that the disconnections between the sensors isn't the main standards that can handle the issue of energy prolific information transmission in WSN. Be that as it may, there is likewise another parameter of the system, specifically, the rest of the energy in the node of the system.

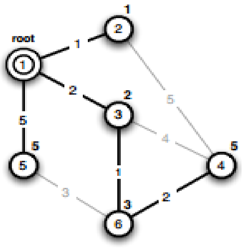

Figure 1. SPT of the graph with root vertex 1

The rest of the energy perhaps won't be enough in a state that may necessitate minor separation to transmit information efficiently, yet because of the insignificant amount of residual energy in a sensor, the assignment probably won't be accessible. From a node that is left with an insignificant measure of vitality may prompt its initial failure during transmission of information and may break the MST path generated to transmit the data.

III. Simulation And Results

The simulations start by mounting fifty sensors in a 100×100 meters region. The total 1225 possible routes developed in between fifty sensors are stated by blend calculation without redundancy. All routes are properly examined for the loads categorized by separation and remaining vitality. The loads represent a plotted arithmetical incentive for the separation between two sensors just as the vitality utilized while their talking with the route.

In each cycle of the process, the system is counted to have transmitted and received fifty signals, every last one of the sensors has used a portion of their energy and in this manner, and the estimation of remaining vitality has reduced. The fundamental phase of the system can appear with every single probable route in between nodes.

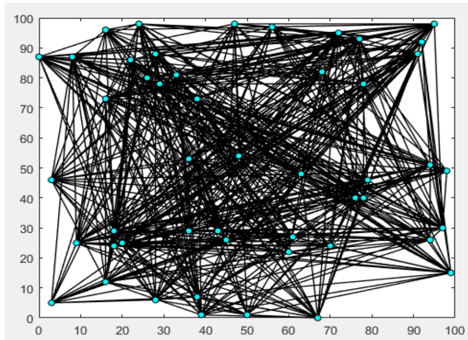

Figure 11. Initialization of the network

After executing the algorithm, when it kept running for 1000 cycles, the energy and the path that optimized can be viewed distinctly. The results of the work have shown in the associated images. The following chart has the minimum spanning tree of the system came about and improved by PSO computation.

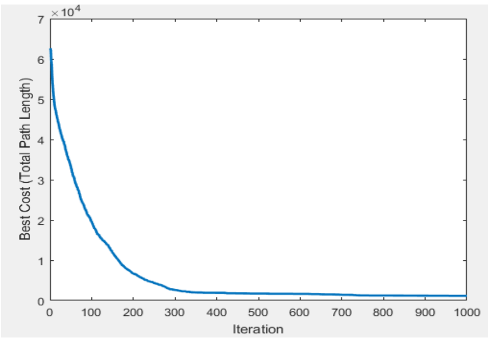

Figure 12. Progression, Minimalization of each sensor's cost

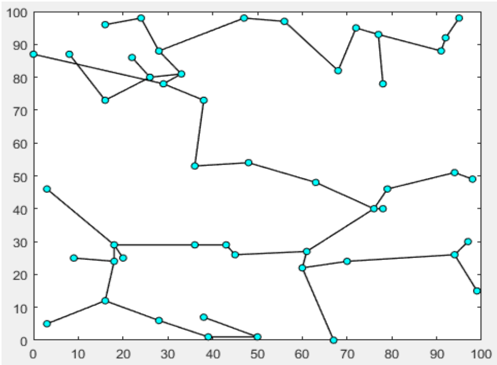

Figure13. MST of the particular network

The X and Y directions of the existent testing system's conveyed sensors are listed in table III given below. The total energy usage of the system in one cycle is 2.91172E-05. In the event that the total energy of the system is counted as 250J, at that point the system will survive about 9 Million cycles taking into consideration the largest quantity of energy per cycle as 5.24023E-07J. Suppose each sensor takes 1ms to receive, process, decide and then transmit data in an information flooding scenario, and that RF waves travel at 87% of speed of light in air, the trip time of a sensor at the far end of a network from where data will reach the other far end in a 100m distance in 0.00707 seconds or 7.0 ms.

Thus, the latency of a single transmission reception data exchange will be 14ms. For 9 million iteration life time, the real life of the network becomes 9000000*14ms= 33 to 35 Hours (2.91E-05 to 5.2E-07 energy usage per iteration) of Peak Connectivity Lifetime with no delays, no sleep state, no data retransmissions, and no idle state of the sensor. These values are exaggerated. The actual life time will account to many days depending on sensors type and usage frequency. As conferred previously, the sleep mode is 1/10th in energy consumption than the active state, so a normal working of the sensors would be 350 Hours, or at least 14.5 days, which is a substantial enhancement.

TABLE I. WIRELESS SENSOR NETWORK PARAMETERS

Parameter Name	Value / Property
Total Nodes	50
Area Dimensions	100x100 meters
Initial Energy of sensor	Considered any large value
Data aggregation energy	05 nJ
Maximum Cycles	1000
Free Space Loss Energy	10 pJ
Multipath Loss	1.2 Fj
Transmit Amplifier	50 nJ
Receive Amplifier	50 nJ

TABLE II. ALGORITHM RELATED PARAMETERS

Name of parameter	Value/Property
Maximum coding iterations $iter$	1000
Population of particles n	250
Weight constant of inertia, ω	0.2
Inertia weight damping ratio w	1-yes
Learning Coefficients for w_{damp}	0.2
Personal Learning Coefficient c_1	0.7
Global Learning Coefficient c_2	1.0

TABLE III. DISTANCE AND ENERGY UTILIZATION

From	To	Distance (m)	Energy (J)	From	To	Distance (m)	Energy (J)
7	1	79.1	3.96E-07	27	26	5.1	2.55E-08
7	2	79.1	3.96E-07	50	26	83.7	4.18E-07
38	2	75.7	3.78E-07	26	27	5.1	2.55E-08
32	3	23.3	1.16E-07	42	27	63.5	3.18E-07
19	4	25.5	1.27E-07	45	28	71.6	3.58E-07
29	4	35.7	1.79E-07	4	29	35.7	1.79E-07
43	4	89.7	4.49E-07	12	29	71.6	3.58E-07
49	4	96.2	4.81E-07	21	30	42.8	2.14E-07
18	5	73.6	3.68E-07	35	31	87	4.35E-07
9	6	58.1	2.90E-07	38	31	49.3	2.46E-07
1	7	79.1	3.96E-07	3	32	23.3	1.16E-07
2	7	79.1	3.96E-07	44	32	83.2	4.16E-07
18	8	80.5	4.02E-07	11	33	34	1.70E-07
6	9	58.1	2.90E-07	14	33	104.7	5.24E-07
23	9	58.1	2.90E-07	20	33	39.6	1.98E-07
34	9	24.1	1.20E-07	9	34	24.1	1.20E-07
17	10	48.4	2.42E-07	40	34	55.3	2.77E-07
47	10	27.7	1.38E-07	31	35	87	4.35E-07
15	11	72.4	3.62E-07	39	35	67	3.35E-07
33	11	34	1.70E-07	38	36	90.6	4.53E-07
38	11	80.1	4.01E-07	16	37	67.4	3.37E-07
15	12	57.8	2.89E-07	22	37	15.5	7.76E-08

From	To	Distance (m)	Energy (J)	From	To	Distance (m)	Energy (J)
29	12	71.6	3.58E-07	48	37	73	3.65E-07
39	13	104.8	**5.24E-07**	2	38	75.7	3.78E-07
45	13	100.4	5.02E-07	11	38	80.1	4.01E-07
33	14	104.7	5.24E-07	31	38	49.3	2.46E-07
11	15	72.4	3.62E-07	36	38	90.6	4.53E-07
12	15	57.8	2.89E-07	13	39	104.8	5.24E-07
37	16	67.4	3.37E-07	35	39	67	3.35E-07
10	17	48.4	2.42E-07	34	40	55.3	2.77E-07
42	17	48.4	2.42E-07	48	41	99.5	4.98E-07
5	18	73.6	3.68E-07	17	42	48.4	2.42E-07
8	18	80.5	4.02E-07	25	42	3.6	1.80E-08
20	18	75.1	3.76E-07	27	42	63.5	3.18E-07
4	19	25.5	1.27E-07	4	43	89.7	4.49E-07
18	20	75.1	3.76E-07	48	43	49.3	2.46E-07
33	20	39.6	1.98E-07	22	44	54.4	2.72E-07
24	21	42.1	2.10E-07	32	44	83.2	4.16E-07
30	21	42.8	2.14E-07	13	45	100.4	5.02E-07
37	22	15.5	7.76E-08	23	45	70	3.50E-07
44	22	54.4	2.72E-07	28	45	71.6	3.58E-07
9	23	58.1	2.90E-07	24	46	28.2	1.41E-07
24	23	24	0.00000012	47	46	22	**1.10E-07**
45	23	70	3.50E-07	10	47	27.7	1.38E-07
21	24	42.1	2.10E-07	46	47	22	1.10E-07
23	24	24	0.00000012	37	48	73	3.65E-07
46	24	28.2	1.41E-07	41	48	99.5	4.98E-07
42	25	3.6	1.80E-08	43	48	49.3	2.46E-07
26	50	83.7	4.18E-07	4	49	96.2	4.81E-07
26	50	83.7	4.18E-07	4	49	96.2	4.81E-07

The coordinates of the nodes in the network are shown below:

TABLE IV. COORDINATES OF THE NODES OF THE NETWORK

Node	X Coord	Y Coord	Node	X Coord	Y Coord
1	98	49	26	92	92
2	79	46	27	91	88
3	38	7	28	0	87
4	18	29	29	36	29
5	97	30	30	16	96
6	22	86	31	63	48
7	94	51	32	50	1
8	99	15	33	60	22
9	26	80	34	16	73
10	68	82	35	48	54
11	61	27	36	78	40
12	43	29	37	16	12
13	38	73	38	76	40
14	67	0	39	36	53
15	45	26	40	8	87
16	3	5	41	9	25
17	72	95	42	77	93
18	94	26	43	18	29
19	3	46	44	39	1
20	70	24	45	29	78
21	24	98	46	47	98
22	28	6	47	56	97
23	33	81	48	18	24
24	28	88	49	20	25
25	78	78	50	95	98

The average separation of these inter-nodal paths is 59.422 meters.

CONCLUSIONS

This research is a combination of MST and PSO algorithms exercised together to optimize the path and energy of fifty nodes network distributed casually on a 100x100 meters region. This study is a complete demonstration of the sensor network to the particular coordinates so that a scholar in coming time may enhance and refer to it. However, the unavailability of existing researches published codes form and comprehensive facts, have hindered to perform the comparison course of this work.

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