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Mobility Assisted Redeployments in Wireless Sensor Networks - A Study Based on the Density of Nodes

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ABSTRACT

Wireless Sensor Network (WSN) is widely used in data collection for the industrial administrative and research applications. The distribution / deployment of sensor nodes in the target field is of primary concern as it would greatly affect data acquisition and there by decision making. Random deployment is usually adopted when the environment is unapproachable by human which results in uneven distribution of sensors and poor network coverage. Mobility assisted deployments of sensors enhance the efficiency of such deployments by suitably moving the sensors for redeployment to optimal locations. To improve the sensor network coverage in random deployment, mobility assisted deployment algorithms such as Voronoi Vertex Averaging Algorithm (VVAA), Genetic Algorithm (GA) and V-GA (a combination of VVAA and GA) are used to redeploy the nodes. In this work, the sensors are redeployed using GA, VVAA and V-GA and the performance is analyzed in terms of coverage, coverage holes, node displacement, simulation time and energy for the deployment of 64 and 100 nodes. The results show that though the maximum coverage attained by the algorithms using 100 nodes were greater than that of 64 nodes, the improvement in coverage in redeployment from random deployment attained by the algorithms GA, VVAA and V-GA is better with 64 nodes than with 100 nodes. However, the coverage of 100 nodes with random deployment was the highest i.e., 86.65% which is 14.83% higher than with 64 nodes. This had prompted and mesmerized the scholar to go after the research study with nodes for all the algorithm i.e GA, VVAA and V-GA application, hoping to get even better results than that of 64 nodes. Nevertheless the improvements were in the decline trend when one moves from random to GA to VVAA to V-GA applications. This indicates that one could get contended with the use of 64nodes when algorithms are being applied for redeployment of the already deployed sensors by random deployment. It is a question of random deployment Vs algorithm redeployment that determines the improvement in coverage. Hence, the research study could be restricted to 64 sensor nodes if algorithms are to be adopted or extended to 100 nodes if only random deployment is to be adhered to. None the less, there is no bar in employing 100 nodes for all but for the cost and energy consumption constrained. The author chooses to study and suggest for 100 nodes if cost and energy consumption are not the constraints, since the coverage holes and distribution of nodes are better with 100 sensor nodes as sun in the respective figures.

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INTRODUCTION

WSN is a promising technology that is used in a wide range of applications such as environment monitoring, military operations, target tracking, surveillance system, vehicle motion control, earthquake detection and so on (Sai Prakash SKLV *et al*., 2014). WSN also plays a great role in data collection in the field of habitat monitoring, forest surveillance, battlefield surveillance, material management and healthcare (H.Zainol Abidin *et al*., 2014). The sensor network consists of several hundred sensor nodes, deployed closer to the phenomenon they are designed to observe (Manoj Rana *et al*., 2012). The effectiveness of the WSN depends on the coverage provided by the sensor deployment method. The coverage problem depends on a deployment of sensor node in WSN area (Mohammadjavad Abbasi *et al*., 2014). Deployment is positioning of the sensors to capture data and transmit them from a designated area depending on the target applications. There are different are deployment objectives and goals in different environments (Haitao Zhang *et al*., 2012). Coverage

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problem in WSN basically is caused by three main reasons: (i) not enough sensors to cover the entire area, (ii) limited sensing range and (iii) random deployment of sensors (Pallavi Sahu *et al*., 2012). The success of data acquisition in any network depends upon the sufficiency of coverage by the sensor nodes. The main problem in the wireless sensor network is deployment, coverage, and mobility strategy of sensor node. Maximizing the coverage with a given number of sensors is a fundamental issue in the design of sensor networks. As a standard practice, in the remote or hostile environment, the sensor nodes are being deployed randomly which may not cover maximum area and that too uniformly as required for the applications, since they could not follow logic. Hence, the randomly deployed sensors must be repositioned for increasing the coverage. The mobility is taken into consideration in redeployment of such sensors. The mobile sensor nodes are self organized and they will move from one place to other place in accordance with the direction which is achieved by appropriate algorithms (Sai Prakash SKLV *et al*., 2014).Mobility may be of two kinds i.e. active and passive. In active mobility the sensors are intelligent enough to find their path and move to the respective places whereas in passive mobility, the sensors are moved by human or environmental support (Mayur C *et al*., 2012). Normally, the mobile nodes would be initially distributed randomly and using algorithms those nodes would be moved or redeployed to the intented locations.

This work is focused on the comparative study of VVAA, GA and V-GA with 64 and 100 number of sensors. The experiment of reducing the sensors from 100 to 64 is carried out to confirm or deny any effect of reduction in sensors on the networking parameters. Following two scenarios are considered for comparison.

1. Sensor field with 64number of sensors (Initial field with more coverage holes)
2. Sensor field with 100number of sensors (Initial field with less coverage holes)

The algorithms were compared with respect to the coverage percentage, coverage holes, node displacement, and simulation time and energy consumption for node displacement.

After introduction, the paper has been organized as follows. Section 2 discusses about mobility assisted deployments proposed by various authors. In section 3, the present author's problem is described. In section 4, the results have been presented and analyzed. The conclusions are summarized in section 5.

2. Related Works:

To monitor the target area which is unreachable by human the sensors are randomly deployed resulting in uneven distribution of sensors and without achieving the desired coverage. After random deployment, the sensors are reorganized using various mobility assisted deployment algorithms proposed by different authors. In this section some of those algorithms are reviewed.

Virtual field based approaches, have been considered for sensor node deployment by various authors where the sensors are treated as particles having attractive and repulsive forces. Their movements depend on the neighbors and the distance between the sensor nodes. I. Larrabide *et al*., (2012) have presented self-deployment scheme to utilize the attractive forces generated from the centroid of a sensor's local Voronoi polygon, this simulation results show that their scheme could achieve a higher coverage, leading to less sensor movements in shorter time. The method is energy efficient. X. Yu *et al*., (2012) have proposed an approach, in which Delaunay triangulation is formed with these nodes, Force could only be exerted from those adjacent nodes within the communication range. Simulation results show that the approach has higher coverage rate and shorter convergence time than customary virtual force algorithm. Li *et al*., (2012) developed an extended virtual force-based approach to achieve the ideal deployment and the simulation results reveal that the virtual force approach could effectively reach ideal deployment in mobile sensor networks with different ratio of communication range to sensing range. It also achieves better performance in coverage rate, distance uniformity, and connectivity uniformity.

Sensor nodes are also deployed based on molecular theory. In molecular diffusion theory based approach the sensors follow the movement procedure of molecules i.e. the molecules diffused from higher density regions to the lower density regions. Rauy-Shiung Chang *et al*., (2008) used density controlled by each node to concurrently deploy sensor nodes in an environment particularly in an unknown expanse. Every sensor node calculates its local density and adjusts its location from higher density to lower density regions. The deployment is quick and able to cover as many areas as possible in a very short period. Muhammad Tariq *et al*., (2010) have presented an energy efficient distributed self-deployment algorithm based on diffusion of mobile sensors in the unstable network scenario. The method is based on the location information gathered from the neighbors. The molecular diffusion theory based approaches are useful in the in large scale networks.

Evolutionary algorithms inspired from natural evaluation help to find optimum strategy for solving node deployment problem. In the literature (S. Zeng,Z *et al*., 2012 and M. P. Poland, *et al* 2012 J.Mu˜nuzuri, 2012) some basic concepts of genetic algorithm application that will be applied in bioinspired computation are presented. Author (X.Wang *et al*., 2006) have proposed parallel particle swarm optimization (PPSO) to enhance the coverage for large area. The mobile node will use PPSO to relocate them to find optimal deployment in large area for various coverage optimizations. Several parallelization methods have been introduced to speed up the genetic and simulated annealing heuristics which are used for the deployment of sensing devices on a field with degree of difference security requirements (Rabie ramandan *et al*.,). Different parameters of sensing devices such as lifespan, number of state-switching allowed, number of moves, movement cost, and reliability are considered, Sensors with all of these parameters are adopted to be deployed on a field for a certain period of time (horizon). The resulting deployment schemes aim to achieve maximum coverage, better field security, and best usage of sensor capabilities. The authors have presented a genetic algorithm which searches for an optimal solution to the coverage holes problem in hybrid sensor network. The network in this study consists of both static and mobile nodes (Omar Banimelhem *et al*., 2013). Stationary nodes are initially deployed and mobile sensor nodes are added to overcome the coverage holes problems. The algorithm optimizes the network coverage in terms of the overall coverage ratio and the number of additional mobile nodes using different numbers of stationary nodes and various sensing ranges. The purpose of this study (Fozia Hanif Khan *et al*., 2012) is to develop a Genetic algorithm that improve the transmission of signals and the field coverage.

Computational geometrical approaches have been proposed by various authors in which the areas are represented by a set grids or polygons. The grids and polygons are changed when the sensor nodes are moved. Voronoi diagrams are useful to solve the coverage problem of wireless sensor networks. If each sensor could cover its own Voronoi subarea, then the total sensing field could be covered. Guiling Wang *et al*., (2006) have used Voronoi diagram to improve the coverage area within short time. Two sets of algorithms namely farthest point boundary and min-max point algorithms are proposed. Pillwon Park *et al*., (2010) proposed a scheme to cover the whole area and reduce the coverage expansion time. The average moving distance of the sensors is also diminished. Li, *et al*., (2009) used Voronoi diagram to assist in reducing the number of sensors needed to cover the maximum area for directional sensors.

V.Violetjuli *et al*., (2012, 2013and 2014) have presented three algorithms VVAA, GA and V-GA. Though all the algorithms improve the network coverage, VVAA improves the coverage better compared to GA and V-GA that too in initial iterations. In higher iterations, the marginal improvement in coverage is less. GA provided gradual improvement in coverage and the coverage is less than VVAA. GA also consumes more time compared to VVAA and the displacement of nodes is greater than VVAA. Hence, a combination of VVAA and GA in tandem application called V-GA is attempted to, to further improve the network performance. V-GA is two step algorithm in which VVAA is first applied to improve the network coverage. Then GA is applied to further the coverage. Three combinations are taken for the implementation of V-GA. Those studies are based on the distribution of 100 nodes in the sensor field. VVAA improves the coverage much better than GA. Compared to GA, the node displacement and simulation time in VVAA is very less. There is a marginal difference between the performance of VVAA and V-GA.

3. Problem Description:

The accuracy and the adequacy of data collection depend on the effective and efficient coverage of the area under study by the sensing nodes. Random deployment of sensrs has its own limitations both in coverage and dispersion, which are not satisfactory all the time.

Hence, to improve the coverage area and to achieve better results the dispersion which would enhance the effictiveness of networking, the sensors that are already deployed have to be redeployed by making use of many algorithms, independently as stand alone or in combination. Three algorithms GA, VVAA and V-GA (Tandem application) are used for this research study to optimize the sensors and the network parameters. The algorithms are analyzed in terms of coverage, coverage holes, displacement, simulation time and implicit energy consumption. The comparison is made between the performance by deployment of 64 and 100 nodes. The experimental parameters used for the simulation are

The sensor network size : 600 meter X 600meter
Total number of nodes : 64 and 100
Sensing range of the sensors : 50 meter
The number of iterations : 10
Parameters used for GA
Total population size : 200
The total number of generations : 10 (iterations)
The mutation Level : 0.20
The cross over Rate : 0.20.

The process flow chart of this study is shown in Fig 1.

The experimental sequence is as follows.

1. Sensors are distributed randomly (first field with 64 nodes and the second with 100 nodes)
2. Nodes are redistributed by GA, VVAA and V-GA algorithms
3. Performance of the algorithms are compared interms of coverage, coverage holes, displacement, and simulation time and energy consumption.

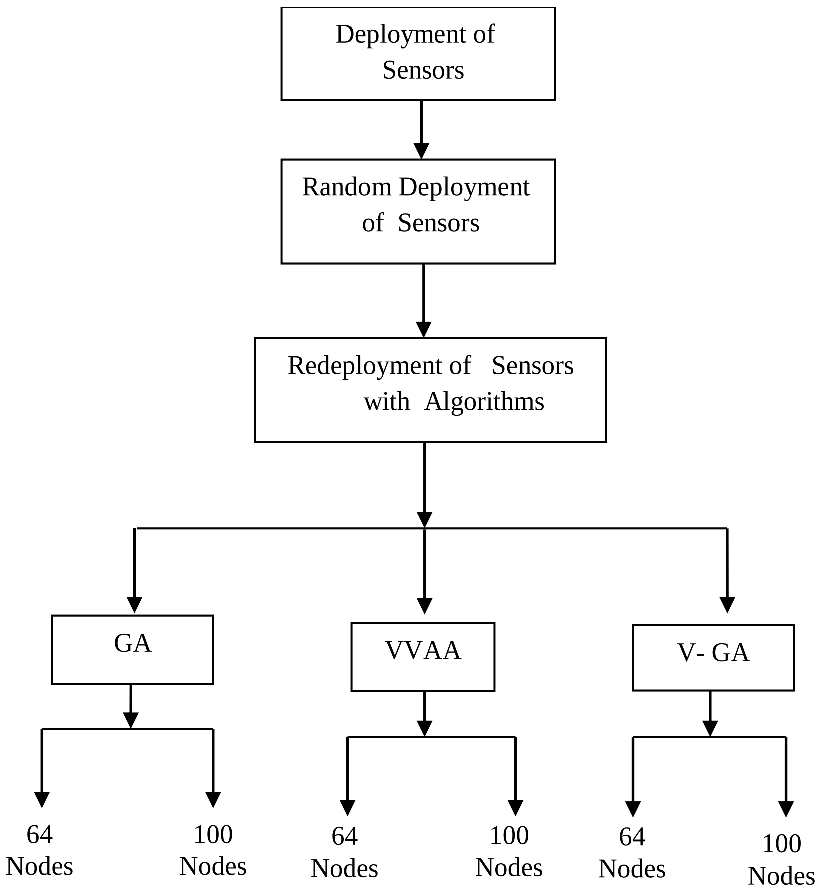

Fig. 1: Illustration of this study.

4. Simulation Results, Analysis and Discussions:

Initially 64 sensor nodes are distributed randomly. The algorithms GA, VVAA and V-GA are applied to redistribute the sensors. Then the above said procedure is repeated with 100 numbers of sensors. The simulations are performed using Matlab.

4.1. Coverage Performance of GA, VVAA and V-GA for 64 and 100 nodes:

For each case of 64 and 100 nodes, 10 experiments are performed. The coverage achieved by Random deployment of 64 and 100 sensors are recorded. To enhance the coverage attained by random deployment of 64 nodes, the movement assisted deployment algorithms namely GA, VVAA and V-GA are applied to redistribute the sensors to iteratively identified locations aiming towards maximum coverage. The number of iterations for simulating those algorithms is 10.

The senor fields with randomly distributed 64 numbers of sensors is shown in Fig 2(a) The field with 100 sensors is shown in Fig 3(a). From 2(a) and 3(a), it is seen there are more coverage holes left in the sensor field with 64 numbers of nodes than 100 nodes. The nodes are represented in blue colour points and the sensing range of the sensors is represented as green colour circles. The coverage holes are the areas filled with black colour. The sensor fields after applying the algorithms are shown in Figs 2(b) to 2(d) for 64 nodes with GA,VVAA and tandem V-GA algorithms respectively. For performance comparison the procedures are repeated with 100 nodes and the sensor fields are shown in Figs 3(b) to 3(d).

With the application of GA, VVAA and V-GA the coverage holes are reduced. The nodes are well distributed. In spite of improvement in network coverage by the algorithms, the field with 64 nodes is left with more coverage holes than that with 100 nodes at the end of application of all the algorithms. The iteration wise coverage achieved by the algorithms for 64 nodes are compared and shown in Figs from 4a to 4j and for 100 nodes in Figs from 5a to 5j.

From the Fig. 4a to 4j and 5a to 5j it is seen that VVAA improved the coverage initially and later the improvement is marginal. It is the same for the field with 64 and 100 nodes. With GA, though the improvement is gradual but less compared to VVAA and V-GA. V-GA followed the same characteristics as that of VVAA till 5 iterations and there after the improvement is marginal between 6 to 10 iterations. The coverage achieved by Random and average coverage reached by after 10 iterations of GA, VVAA and V-GA are given in table 1. It is found as obviously expected, that less number of sensors would result in less network coverage. With random

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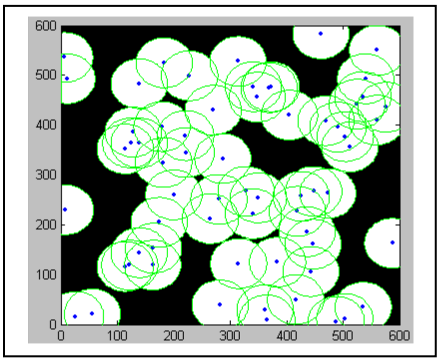
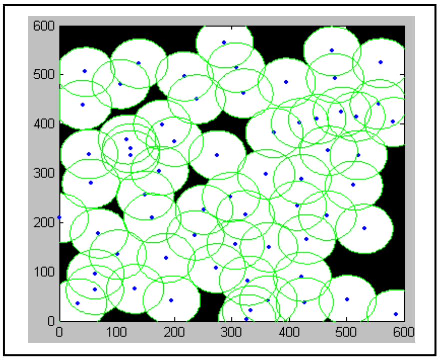
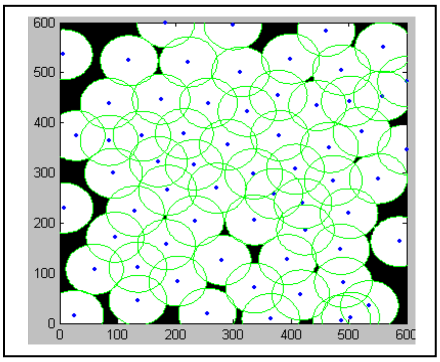
deployment, increase of number of sensors from 64 to 100 enhance the coverage area substantially about 14.83% since more sensors cover wide areas.



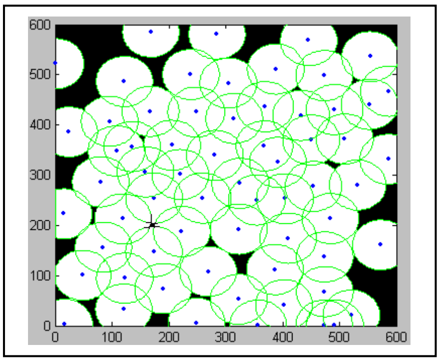
2a. Random (64 Nodes)



2b. GA (64 Nodes)

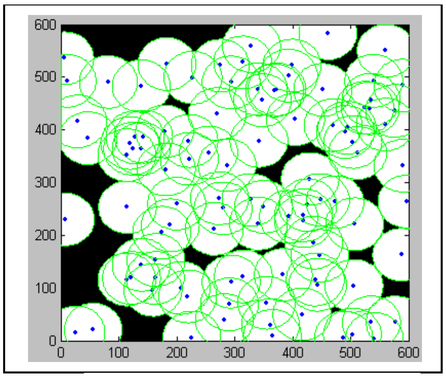


2c. VVAA (64 Nodes)

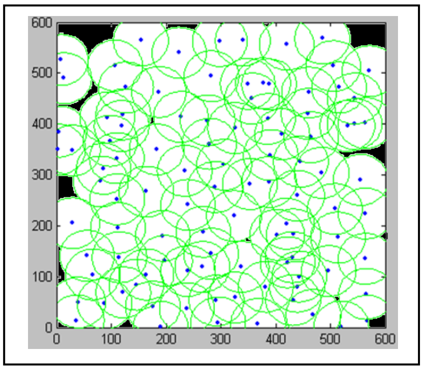


2d. V-GA (64 Nodes)

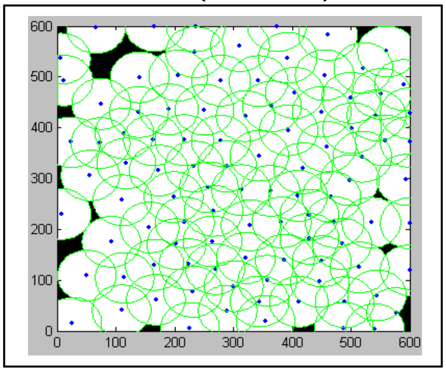
Fig. 2: 64 Nodes Distributed Randomly.



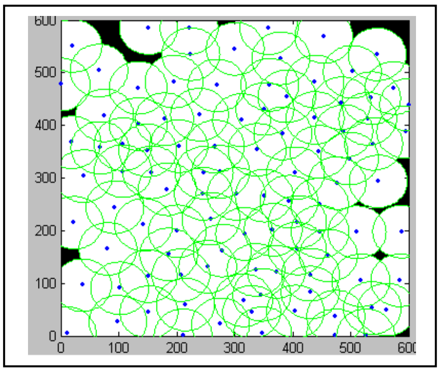
3a. Random (100 Nodes)



3b. GA (100 Nodes)



3c. VVAA (100 Nodes)



3d. V-GA (100 Nodes)

Fig. 3: 100 Nodes Distributed Randomly.

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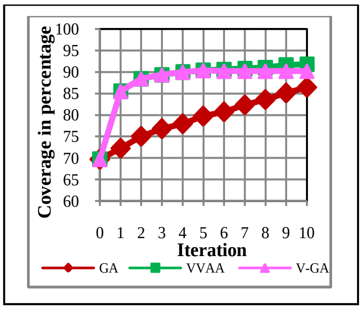

Fig.4a Coverage vs. Iteration
Experiment 1 (64 Nodes)

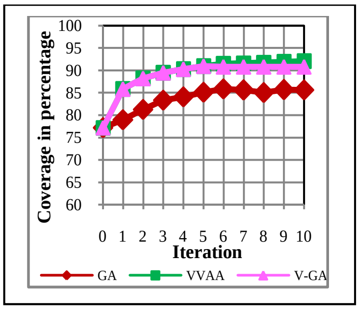

Fig.4b Coverage vs. Iteration
Experiment 2 (64 Nodes)

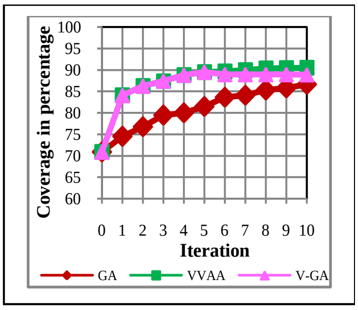

Fig.4c Coverage vs. Iteration
Experiment 3 (64 Nodes)

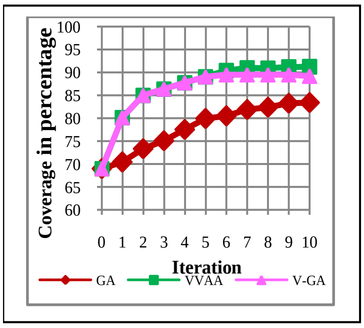

Fig.4d Coverage vs. Iteration
Experiment 4 (64 Nodes)

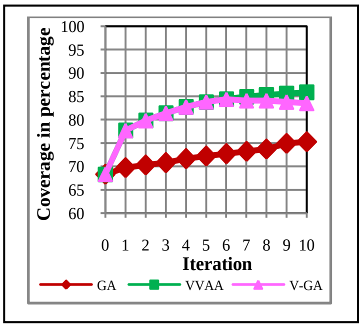

Fig.4e Coverage vs. Iteration
Experiment 5 (64 Nodes)

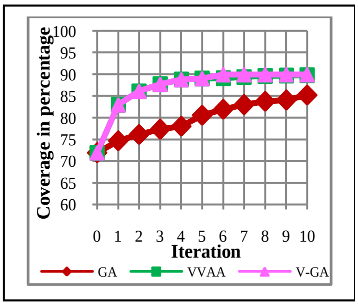

Fig.4f Coverage vs. Iteration
Experiment 6 (64 Nodes)

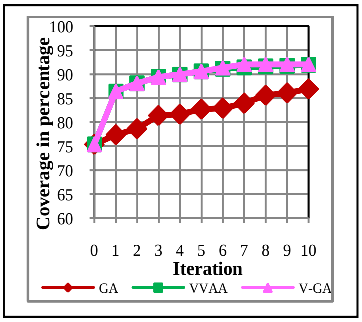

Fig.4g Coverage vs. Iteration
Experiment 7 (64 Nodes)

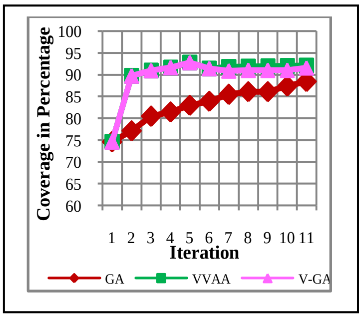

Fig.4h Coverage vs. Iteration
Experiment 8 (64 Nodes)

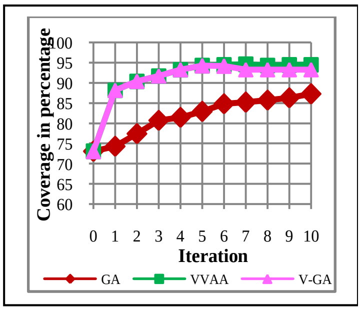

Fig.4i Coverage vs. Iteration
Experiment 9 (64 Nodes)

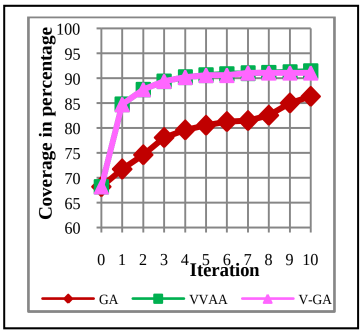

Fig.4j Coverage vs. Iteration
Experiment 10 (64 Nodes)

Fig. 4: Coverage vs Iterations for 64 Nodes.

The average coverage achieved by the individual algorithms for redeployment are compared for 64 and 100 nodes as shown bar charts in Fig 6. It is revealed that the coverage is better with random and the use of GA when the nodes are increased from 64 to 100 nodes. VVAA and V-GA provided better coverage with 64 nodes itself and further enhanced with 100 nodes is to the tune of 7% only.

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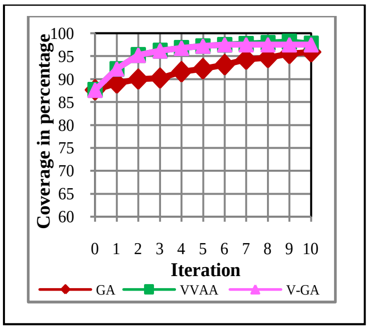

Fig.5a Coverage vs. Iteration
Experiment 1 (100 Nodes)

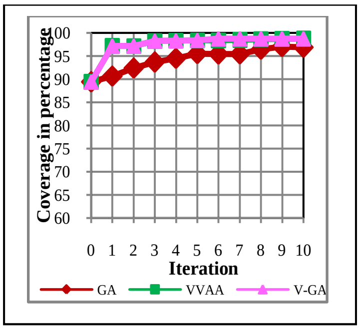

Fig.5b Coverage vs. Iteration
Experiment 2 (100 Nodes)

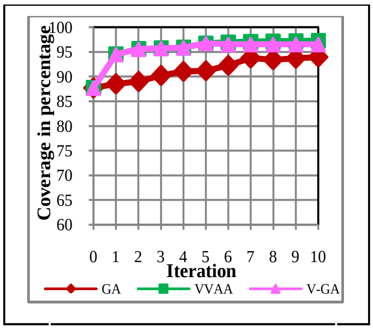

Fig.5c Coverage vs. Iteration
Experiment 3 (100 Nodes)

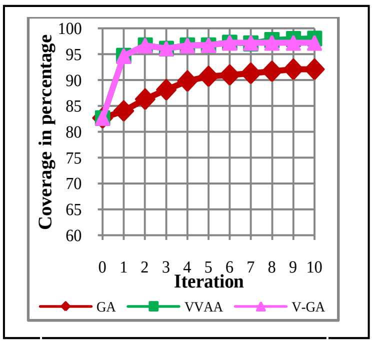

Fig.5d Coverage vs. Iteration
Experiment 4 (100 Nodes)

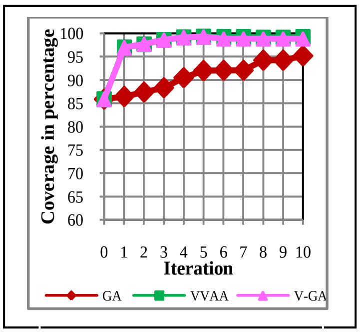

Fig.5e Coverage vs. Iteration
Experiment 5 (100 Nodes)

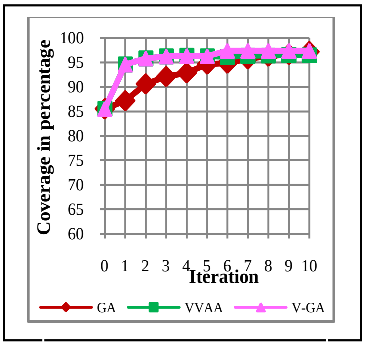

Fig.5f Coverage vs. Iteration
Experiment 6 (100 Nodes)

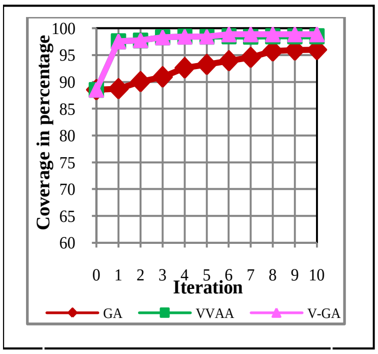

Fig.5g Coverage vs. Iteration
Experiment 7 (100 Nodes)

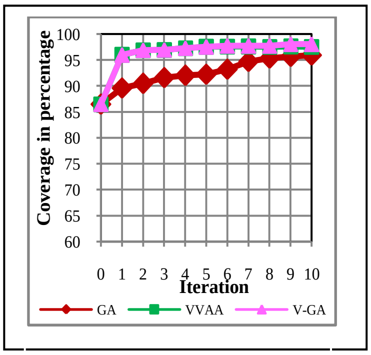

Fig.5h Coverage vs. Iteration
Experiment 8 (100 Nodes)

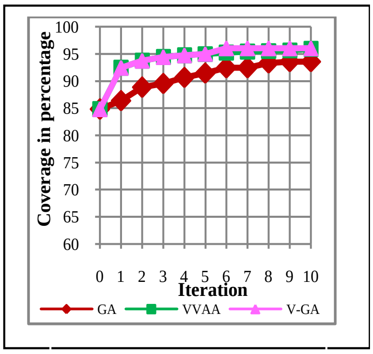

Fig.5i Coverage vs. Iteration
Experiment 9 (100 Nodes)

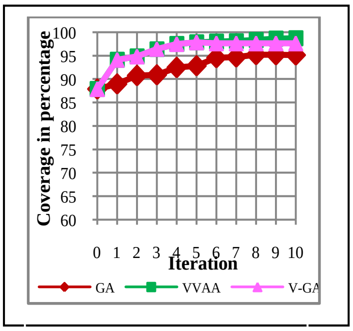

Fig.5j Coverage vs. Iteration
Experiment 10 (100 Nodes)

Fig. 5: Coverage vs Iterations for 100 Nodes.

Table 1: Coverage percentage by GA, VVAA and V-GA (64 and 100 nodes).

Exp.No.	Random		GA		VVAA		V-GA	
	64 Nodes	100 Nodes	64 Nodes	100 Nodes	64 Nodes	100 Nodes	64 Nodes	100 Nodes
1	69.69	87.64	86.44	95.91	91.85	97.73	90.18	97.54
2	77.19	89.42	85.64	96.9	92.03	98.77	90.8	98.78

3	70.86	87.71	86.63	93.99	90.48	97.33	88.89	96.55
4	69.01	82.69	83.4	92.07	91.22	98.08	89.16	97.2
5	68.31	85.88	75.27	95.16	85.84	99.21	83.46	98.88
6	71.95	85.47	85.23	97.14	89.80	96.5	89.96	97.37
7	75.37	88.55	86.93	96.02	91.95	98.51	92.07	98.87
8	74.59	86.49	88.41	95.93	92.05	97.57	91.58	98.05
9	73.07	84.79	87.28	93.56	94.57	95.87	93.32	95.99
10	68.22	87.91	86.35	95.14	91.39	98.73	91.11	97.62
Average	71.82	86.65	85.16	95.18	91.12	97.83	90.05	97.68

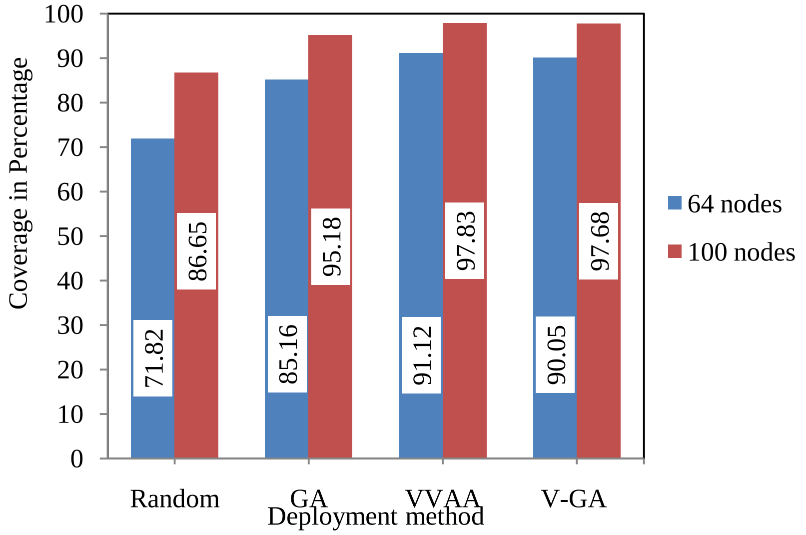

Fig. 6: Comparison of average coverage for 10 experiments.

The average coverage holes in the field left using 64 and 100 nodes are compared in figure 7. It is observed that the use of VVAA and V-GA provided only about 7% reduction in percentage of coverage holes when the nodes are reduced from 100 to 64.In brief, when the sensors are increased from 64 to 100 the VVAA benefit is only 6.71% whereas benefit using GA is 9.99%. The benefit with V-GA is 7.6% whereas the same benefit with Random distribution is 14.83%.

Finally the improvement in coverage (from Random deployment) with 64 and 100 nodes using the mobility assisted deployments GA, VVAA and V-GA are compared in figure 8. It is understood that the marginal improvement in network coverage after initial Random distribution is better with 64 nodes than that of 100 nodes.

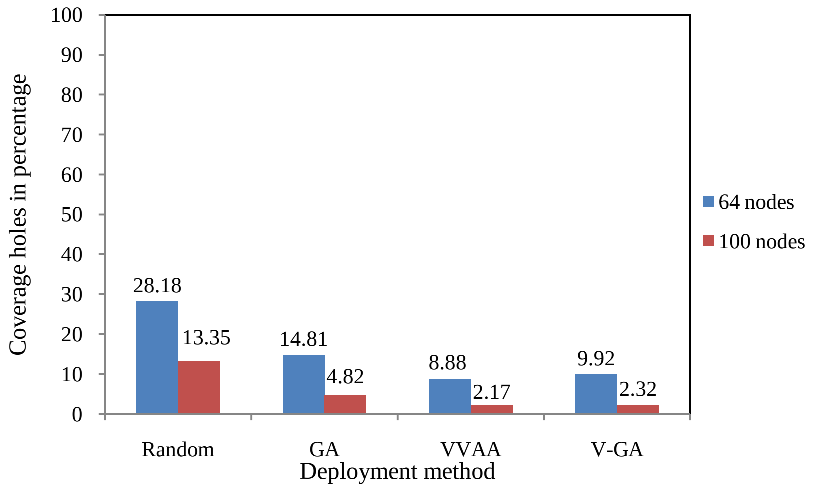

Fig. 7: Comparison of average percentage of coverage holes for 10 experiments.

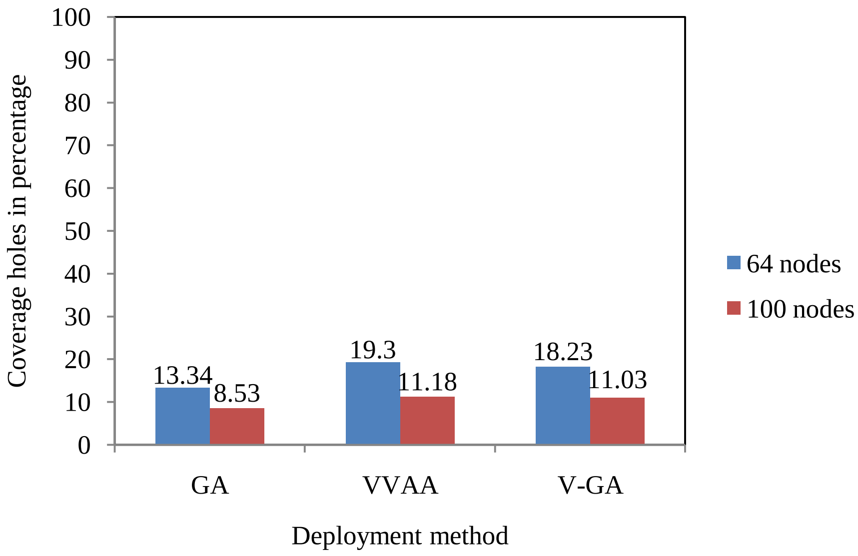

Fig. 8: Improvement in coverage after Random deployment.

4.2. Node displacement:

As described the Random deployment set the sensors at its own location randomly without following much of or any of logics. The locations-in most of the cases are not the desired ones. Yet, they would not move and adjust themselves without any external mechanism. In other words, there would not be any repositioning on its own after deployment in Random distribution.

To achieve the required coverage, the already displayed sensors have to be redeployed and displaced by moving them from the crowded area to lean area. These results in displacement of nodes over varying distances depending upon the algorithms adopted namely GA, VVAA and V-GA. The maximum distance travelled by the sensor nodes after 10 iterations are given in table 2. The displacements are tabulated for 10 experiments. From the table 2 it is observed that the distance travelled by 64 sensors would be less than that of 100 nodes since the number of sensors are less.

Table 2: Maximum displacement in meters for 10 experiments (64 and 100 nodes).

Exp. No.	GA 64 nodes	GA 100 nodes	VVAA 64nodes	VVAA 100 nodes	V-GA 64 nodes	V-GA 100nodes
1	11269	17593	3419	4700	4778	6748
2	10353	17883	3296	4653	4549	6865
3	11268	17370	3761	4793	5964	6794
4	11427	16268	4005	5600	5960	7295
5	11155	17989	3689	4807	8445	6748
6	11513	17891	4030	4236	5094	6529
7	11154	17636	3367	4839	6272	6349
8	11492	17476	4084	5054	7541	8596
9	11665	14493	4259	4385	6978	9038
10	11378	17747	3772	5826	7687	7343

The distance moved by the sensors in each iteration is calculated. The displacements are analyzed for 10 experiments .The displacements with 64 and 100 nodes are shown for different algorithm in figures from 9a to 9j and figures from 10a to 10j respectively . The displacement by 64 sensors is less than that of with 100 sensors because of less sensors. The energy consumption for node movement is proportional to the distance travelled by the sensors. Since the node movement is less with 64 nodes the energy consumption is also reduced consequently (an indirect derivative).

The maximum distances travelled by the sensor are averaged for 10 experiments and compared in figure 11. There is much reduction in distance travelled by the nodes in GA obviously when the nodes are reduced from 100 to 64 nodes. The reduction is less in VVAA and in V-GA there is marginal difference because of the improvement in coverage at the initial stages. The reduction in displacement is more in GA compared to VVAA and V-GA because of irregular movement of sensors due to continuous improvement coverage for every itration.

4.3 Simulation time:

For the implementation of the algorithms using Matlab, the time taken for running the algorithms and displaying the results are averaged for 64 and 100 nodes. The results are produced as graph in figure 12.

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VVAA consumes lesser time than GA and V-GA because of initial associated improvement that is substantial compared to later iteration and lesser computations. The difference in simulation time for 64 and 100 nodes are compared in figure16.The time difference with 64 and 100 nodes is less in VVAA and V-GA than in GA. This could be due to the longer distance travelled by the nodes for relocation and more computation (with GA).

4.4 Results -Consolidated:

The coverage percentage achieved by various deployments random, GA, VVAA and V-GA with 64 and 100 nodes are tabulated in table 3.The node displacement, simulation time and the indirect parameter energy consumption of different deployments are consolidated in the table 4.

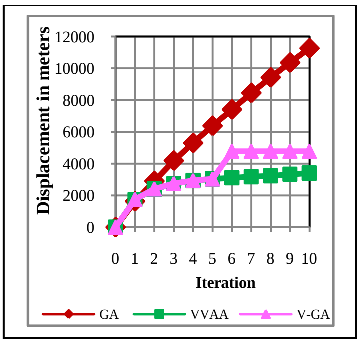

Fig.9a Displacement Vs Iteration Experiment 1(64 Nodes)

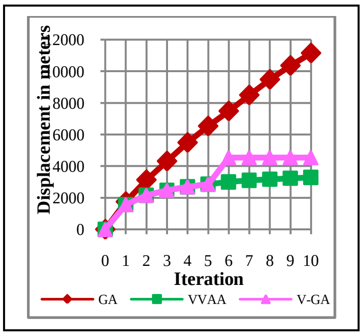

Fig.9b Displacement Vs Iteration Experiment 2 (64 Nodes)

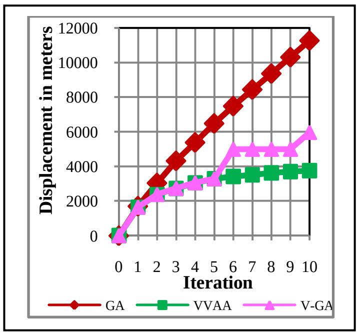

Fig. 9c Displacement Vs Iteration Experiment 3 (64 Nodes)

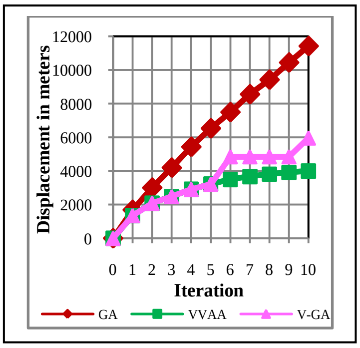

Fig. 9d Displacement Vs Iteration Experiment 4 (64 Nodes)

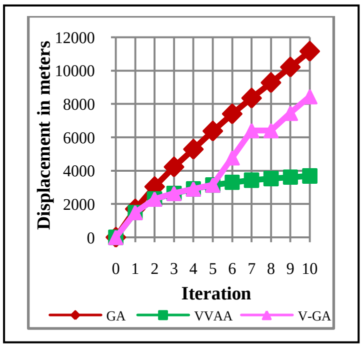

Fig. 9e Displacement Vs Iteration Experiment 5 (64 Nodes)

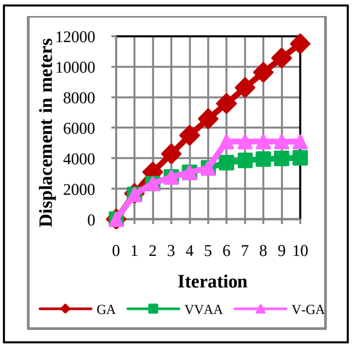

Fig. 9f Displacement Vs Iteration Experiment 6 (64 Nodes)

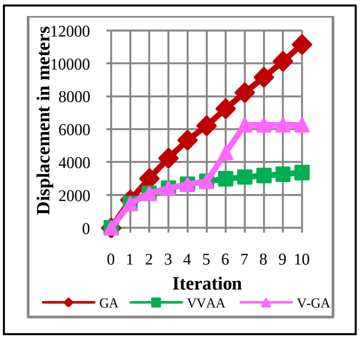

Fig.9g Displacement Vs Iteration Experiment 7 (64 Nodes)

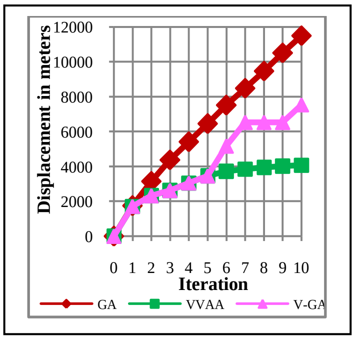

Fig. 9h Displacement Vs Iteration Experiment 8 (64 Nodes)

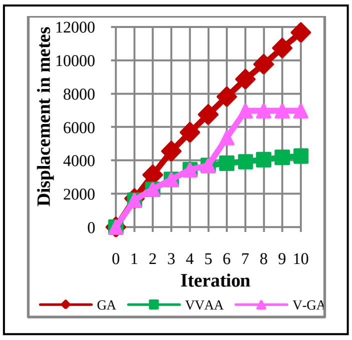

Fig. 9i Displacement Vs Iteration Experiment 9 (64 Nodes)

Fig. 9: Displacement vs Iterations for 64 Nodes.

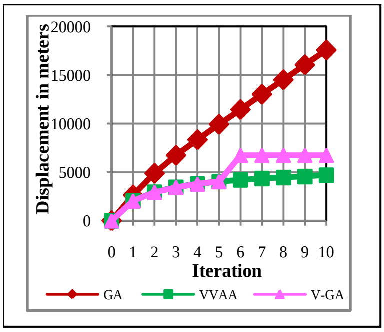

Fig. 10a Displacement Vs Iteration
Experiment 1 (100 Nodes)

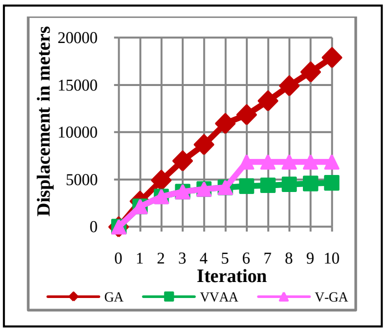

Fig. 10b Displacement Vs Iteration
Experiment 2 (100 Nodes)

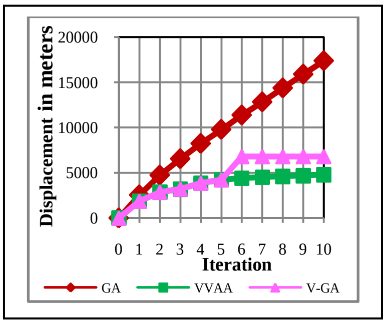

Fig. 10c Displacement Vs Iteration
Experiment 3 (100 Nodes)

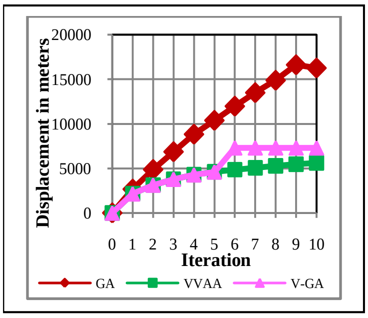

Fig. 10d Displacement Vs Iteration
Experiment 4 (100 Nodes)

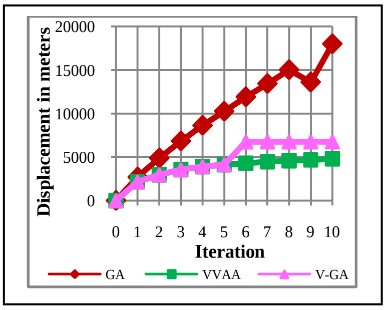

Fig. 10e Displacement Vs Iteration
Experiment 5 (100 Nodes)

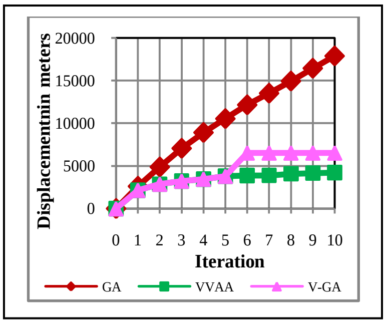

Fig. 10f Displacement Vs Iteration
Experiment 6 (100 Nodes)

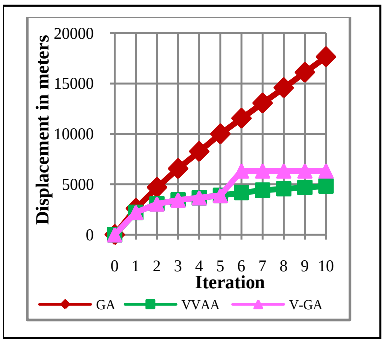

Fig. 10g Displacement Vs Iteration
Experiment 7 (100 Nodes)

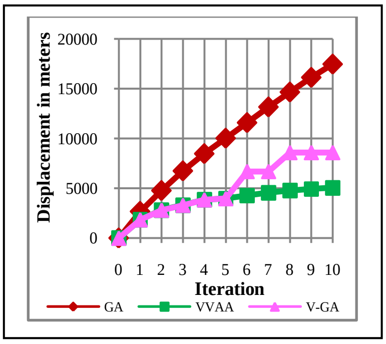

Fig. 10h Displacement Vs Iteration
Experiment 8 (100 Nodes)

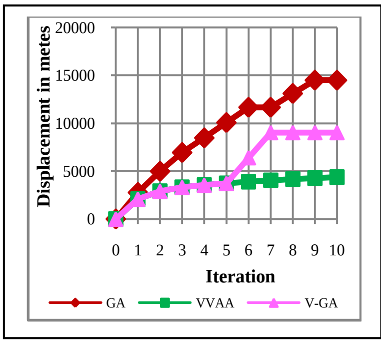

Fig. 10i Displacement Vs Iteration
Experiment 9 (100 Nodes)

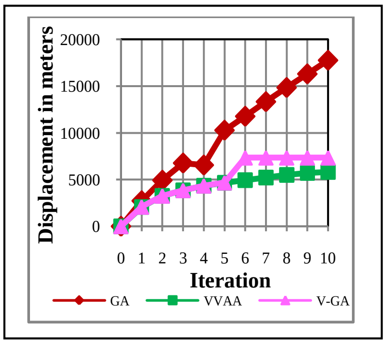

Fig. 10j Displacement Vs Iteration

Fig. 10: Displacement vs Iterations for 100 Nodes.

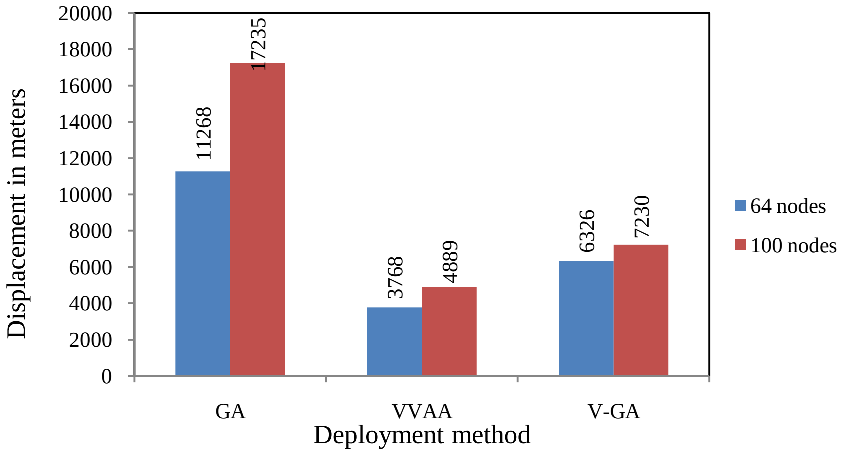

Fig. 11: Comparison of average distance travelled by sensor nodes (64 and 100 nodes).

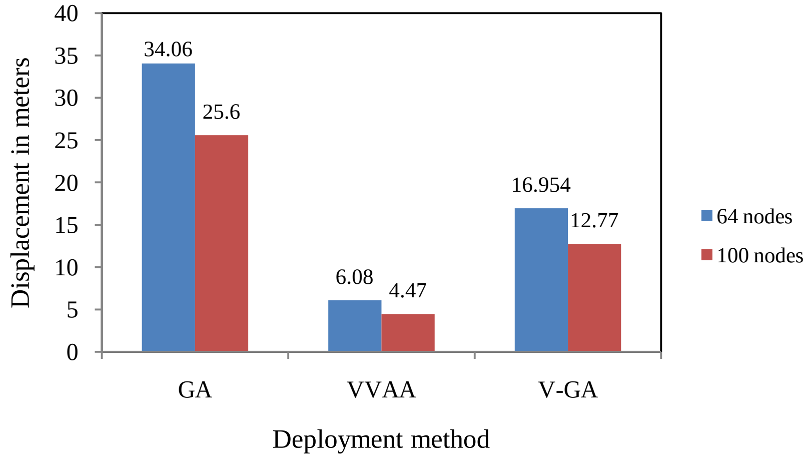

Fig. 12: Comparison of simulation time.

Table 3: Network Coverage Percentage.

S.No		Deployment and redeployment with algorithm	Network coverage % for		Marginal improvement in coverage for 100 nodes over 64 nodes C
			64 nodes A	100 nodes B	
1.		Random	71.82	86.65	14.83
2.	a.	GA	85.16	95.18	10.02
	b.	Marginal improvement in coverage over random deployment	14.34	8.53	
3.	a.	VVAA	91.12	97.83	6.71
	b.	Marginal improvement in coverage over random deployment	19.30	11.18	
4.	a.	V-GA	90.05	97.68	7.63
	b.	Marginal improvement in coverage over random deployment	18.23	11.03	

Table 4: Results – Displacement, simulation time and energy consumption.

S.No	Redeployment method	Node Displacement in meters		Simulation time in seconds		Energy Consumption	
		64 nodes	100 nodes	64 nodes	100 nodes	64 nodes	100 nodes
1	GA	11268	17235	25.6	34.06	High	High
2	VVAA	3768	4889	4.47	6.08	Low	Low
3	VGA	6326	7230	12.77	16.95	Medium	Medium

5. Conclusion:

The plethora of data obtained as results of the study had clearly directed the author to conclude and ascertain the following.

1. Obviously expected and predicted fact that more number of nodes would lead to better coverage is established; as seen in the table that of 64 nodes from random deployment with all algorithms (GA, VVAA and V-GA).Refer column A&B of table 3.
2. As seen in the table 3 column C, the marginal improvement of network coverage for random deployment was the highest (14.83%) since there is

no improvement of coverage after initial deployment. In other words algorithms and relocation is not being carried out and hence the marginal increase in coverage is the highest for the addition of 36 nodes (from 64 to 100) because marginal utility of each additional node is high; i.e more nodes more the coverage.

3. However, the marginal improvement in coverage for 100 nodes over that of 64 nodes kept on decreasing with the application of algorithms. This is due to two reasons. One being already achieved high percentage of network coverage with not much scope for further improvement. Second reason is the diminishing marginal utility of the additional nodes resulting in decreasing in the marginal improvement in coverage. Refer the column C of table 3, bs. The law of diminishing utility i.e the incremental improvement keep on decreasing with every addition.

4. Nevertheless, one important aspect is that with the application of algorithms GA,VVAA and V-GA is all the time positive irrespective of number of nodes over and above the percentage coverage of random display. Refer to as of column A&B of table 3. This is as assumed and presumed while taking up this research study.

5. It is simple arithmetic that more the number of sensors to be migrated and re-oriented by movement the overall distance they are travelled (moved) increases; as seen in the table 4. This is irrespective of the algorithms applied.

6. Consequent to the higher number of nodes movement as mentioned in point 5, the time taken for their settlement would the obviously higher. This is confirmed by the results depicted in table 4

7. However, the effectiveness and the efficiency with which the algorithms handle the nodes in redeploying reduce the distance travelled and subsequently times taken get reduced. Refer to table 4.

8. The energy consumption and the conservation of power is an implicit derivative to the number of nodes, distance travelled and the time taken for settlement. It is not an explicit and direct measurement; but an assumed value; based on general perceptions that larger distance with larger time for larger number of nodes results in higher power consumption.

9. Even though the results of VVAA and V-GA are closely or VVAA better than V-GA marginally the coverage uniformity and better/uniform distribution of nodes leading to uniform coverage holes as seen in fig 2d and 2c. This would result in improvement of coverage adequacy and accuracy of the data captured by the uniformly distributed nodes.

10. In short two conclusions could be arrived at and suggested for adoption.

a. If cost and power consumption are not critical V-GA-100 nodes could be used for such applications where accuracy, adequacy and preciseness are important like areas related to defence, war zone data, space and spy related ones.

b. For others where economy is the retrained then V-GA -64 nodes would be sufficient. Without compromising good and sufficiently reliable results could be achieved.

c. In both the cases VGA is recommended because of its uniform and equitable distribution of nodes and coverage holes that would improve the quality of the data it captures. Even though VVAA provides better coverage it is marginal and hence it could be compromised. This aspect could be further researched and studied as further works.

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