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A COMPARATIVE STUDY ON ALGORITHMS FOR MOBILITY IN WIRELESS SENSOR NETWORK

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ABSTRACT

The economical use of sensor network for its maximum coverage depended on the effective location of the sensors with respect to their desired locations. Normally adapted random deployment of the sensors would not result in achieving the objective. Some guided methodology should be incorporated to place the sensors at their intented locations. The algorithms namely Genetic Algorithm and Voronoi Vertex Averaging Algorithm for the above purpose were suggested by the authors which were, in this paper, being reviewed for the performance.

Keywords: *Sensor, Network, Deployment, Algorithm, Coverage*

1. INTRODUCTION

Wireless sensor network was being used extensively to monitor and control in remote and hostile faraway environment. Normally, the sensors were deployed randomly allowing the sensors to settle down at their destinations. This could quite often result in undesirable distribution of sensors – leaving some areas uncovered and crowding in other areas. That in turn affects the effectiveness and efficiency of networking. To overcome the problem the sensors were to be guided and directed to settle down as closely as possible near the predetermined location. That means the sensors should be made active and mobile by incorporating appropriate algorithms. The authors had researched and submitted two studies for publications based on Genetic Algorithm (GA) and Voronoi Vertex Averaging Algorithm (VVAA). There are more possibilities to improve the node deployment method in sensor network for its betterment. The unique feature of this research is that GA and VVAA were fast and efficient in redeploying the nodes. The fundamental need for this research was to better the distribution pattern of the nodes by redeployment of the same, thereby maximum coverage was achieved, as stated earlier. This study involved the use of Matlab for simulating the deployment strategies i.e., Random with GA and VVAA algorithms. The comparative study was to optimize the maximization of coverage of deployment.

The paper was further organized as follows. The literature review was presented in section 2. In section 3, the deployment algorithms which we took for comparison namely Random, Genetic Algorithm (GA) and Voronoi Vertex Averaging Algorithm (VVAA) were shortly narrated. Performance evaluation of the deployment strategies and the comparative analysis were presented in section 4. The conclusions and limitations were consolidated in section 5.The future works were suggested in section 6.

2. LITERATURE REVIEW

To throw some light on this subject, a few citation references were incorporated for better understanding and clarity.

Wireless Sensor networks consisted of tiny sensor nodes which were able to sense the event and process the data [1]. They also had wireless communication capabilities. Sensor deployment could not be performed manually in the areas which

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were not accessible by man. To get information about those areas, the nodes could be thrown out randomly as a mass through aircraft. After deployment, topology changes took place due to variations in sensor nodes' location, reachability and available energy. Also additional sensor nodes could be redeployed to replace the malfunctioning nodes. But the addition of new nodes required reorganization of the network. As a result, the sensor network topologies underwent frequent and continuous fluctuation after deployment [2]. Further it was required that the sensors should make decision based on the knowledge obtained from neighboring nodes [3]. Coverage was considered to be one of the basic and fundamental problems during the developments and manipulations of sensor network field [4 and 5]. Minimizing the battery consumption was the second objective. Maximizing the sensor network life was the third important objective in deployment. Various algorithms and protocols [6, 7, 8,9,10,11,12,13 and 14] had been proposed for deploying static sensors in the target field monitored. That required a large amount of redundant nodes in order to achieve a desired level of coverage and increased the cost of the network, In centralized deployment [15 and 16] , scalability was one of the main problems, since large number of sensors were used in the sensor networks. On account of several messages being reported by the centralized node, those algorithms led to single point collapse. Sensors were scattered by aircrafts or by flying robots in random deployment [17and 18]. But in random deployment the actual landing positions of the sensors were not sure due to the existence of wind and obstacles in the environment. The nodes took their own landing places. Also the density of the nodes was not uniform in the field [19]. In some of the areas the nodes were densely deployed and in some areas the nodes were sparsely deployed. There might be possibilities that the nodes could land in areas where no target was present [20]. Also some areas were left uncovered. Hence; the required coverage was not achieved. The proper deployment of sensors is important to acquire information about the target field [21]. Hence to overcome all those difficulties the distributed deployment algorithms [22, 23, 24 and 25] were used to move the sensors from one location to the other aspired location. The sensing devices were freely and easily being migrated from one place to another with the help of those algorithms to achieve balanced coverage.

3. DEPLOYMENT STRATEGIES UNDER COMPARISON

In this chapter, we shortly narrate the random deployment scheme as well as two mobility assisted deployment schemes using GA and VVAA.

3.1. Random Sensor Node Deployment

Random deployment was the primary deployment of the sensors. As stated earlier, that deployment might not cover the entire area leaving some uncovered areas. Hence, a mechanism to redeploy was the need of the situation.

3.2. Genetic Algorithm (GA) Based Sensor Node Deployment

GA was used to find as near perfect solutions for optimization problems. Techniques stimulated by evolutionary biotechnology - Genetic Engineering were used to redeploy the randomly placed sensors. The benefits of the application of GA were covered in later chapters.

3.3. Voronoi Vertex Averaging Algorithm (VVAA) Based Sensor Node Deployment

Having not fully satisfied with GA, the authors studied VVAA which resulted in better performance as detailed in subsequent paragraphs. The main difference in this algorithm was the use of Voronoi polygon and displacement based on the calculations of average of vertices of the Voronoi polygon. That had given an advantage of fastness and reduction in displacement; Resulting in considerable power saving.

4. COMPARATIVE ANALYSIS AND DISCUSSIONS

The Random, GA and VVAA based sensor network deployment scenarios were simulated using Matlab and the performance of deployment algorithms were analyzed and compared. The parameters particularly displacement of nodes, percentage of coverage, power consumption of nodes, network lifetime and simulation time were considered for comparison.

Common experimental parameters used for the simulation of GA and VVAA

The Sensor Network Size : 600m X 600m

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The Total Number of nodes	:	100nos
The Sensing Range of the Sensors	:	50m
The number of iterations	:	10

GA Parameters used (not applicable for VVAA)

The Total Population Size	:	100
The Total Number of Generations	:	10
The Mutation Level	:	0.20
The cross over Rate	:	0.20

Initially, the sensors were randomly dropped in the field of size 600mx600m as shown in Fig. 1a. The blue circles represent the dropped sensors and the green cricles represents the sensing range.The density of the sensore was not uniform in the targetted area. We found well covered uncovered areas in the target field. The coverage was only 86.38%. Hence to increase the coverage the sensor field was simulated using autonomous deployment algorithms namely GA and VVAA. After the tenth iteration of the GA and VVAA the sensors reached the locations as shown in Fig. 1b and Fig. 1c respectively. One could see that the sensors were moved from the densely deployed regions to the sparsely deployed regions. But we found that the VVAA based deployment moved the sensors to better locations than the GA based deployment.

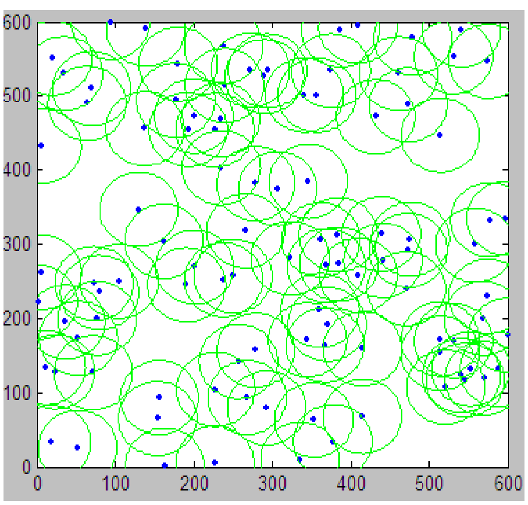

Fig.1a Random Deployment

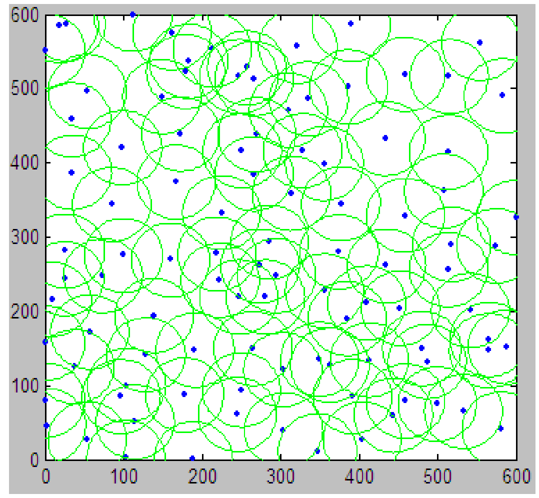

Fig.1b GA based Node Deployment

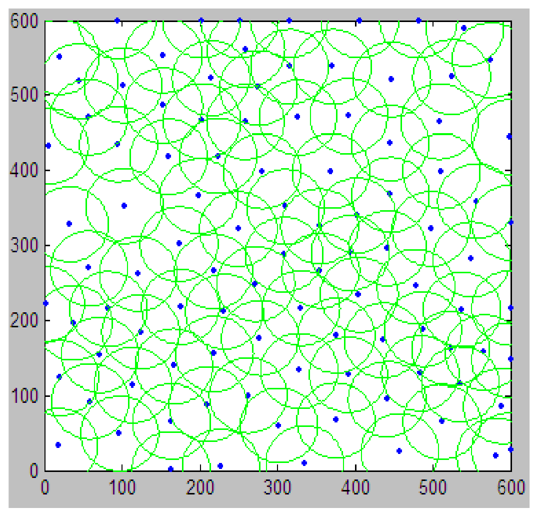

Fig.1c VVAA based Node Deployment

During each iteration of GA and VVAA based deployments, the system was programmed to discover better locations and the sensors were moved to those locations. So, the coverage was improved iteration by iteration as shown in Table1 and Fig.2.

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Table 1: Percentage of covered area using GA and VVAA based sensor deployments

- *The coverage by Random deployment was 86.38%*

Iteration Number	Coverage in Percentage	
	GA	VVAA
1	87.91	94.7
2	89.40	96.5
3	90.97	97.3
4	91.87	97.8
5	92.51	97.8
6	93.13	98.2
7	93.96	98.5
8	94.58	98.5
9	95.67	98.5
10	95.79	98.9
Average	92.579	97.67

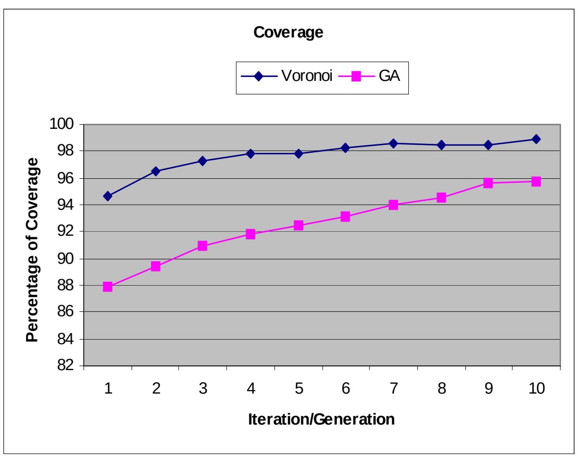

Fig. 2 .Iteration Vs Percentage of Coverage

The sensor filed with the covered (green) and uncovered (grey) regions using Random, GA and VVAA based deployments were shown in Fig 3a., Fig.3b and Fig 3c respectively. One could see that the Random deployment left more uncovered regions and were reduced by the GA and VVAA based deployments. In VVAA deployment only a small area was left uncovered than the GA based deployment.

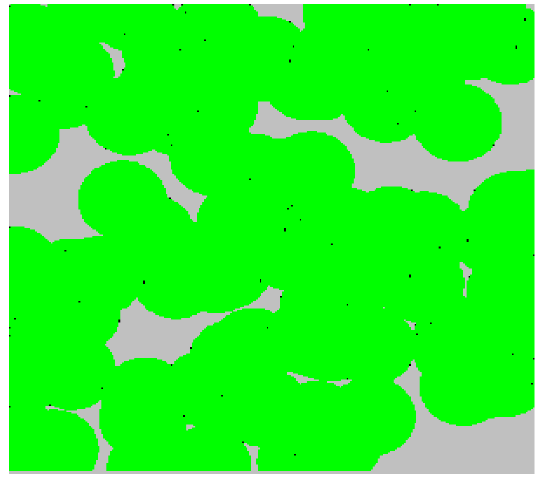

Fig.3a Random Deployment

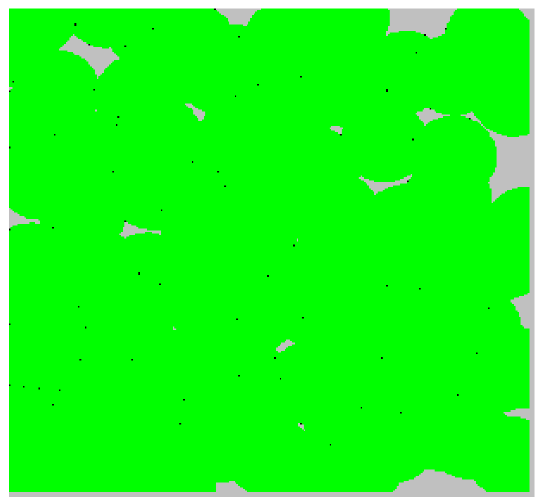

Fig.3b GA based Node Deployment

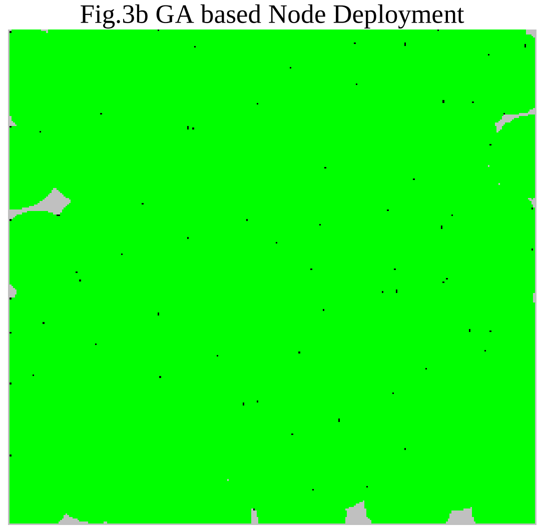

Fig.3c VVAA based Node Deployment

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The displacement of nodes and cumulative displacement of nodes in each iteration of GA and VVAA based deployments were tabulated in Table 2. Fig.4 shows the total node displacement and Fig.5 shows the cumulative sum of total node displacements of nodes during the deployment process. In random deployment there was no node movement. In both GA and VVAA based methods when the iteration was increased the node movement was reduced. In VVAA method the displacement was lesser than the GA based method.

Table 2: Displacement of nodes in GA and VVAA based deployments.

- *There was no displacement of nodes in Random deployment*

Iteration Number	Displacement in Meters		Cumulative Displacement in Meters	
	GA	VVAA	GA	VVAA
1	2669	2389.5	2669	2389.5
2	2253	1162.9	4922	3552.4
3	1961	818.6	6883	4371.1
4	1691	510.8	8574	4881.9
5	1628	340.0	10202	5221.9
6	1558	251.7	11760	5473.6
7	1563	282.9	13323	5756.5
8	1446	248.7	14769	6005.2
9	1434	196.7	16203	6201.9
10	1461	263.8	17664	6465.7
Average	1766.4	646.57		

Fig.4 Iteration Vs Displacement

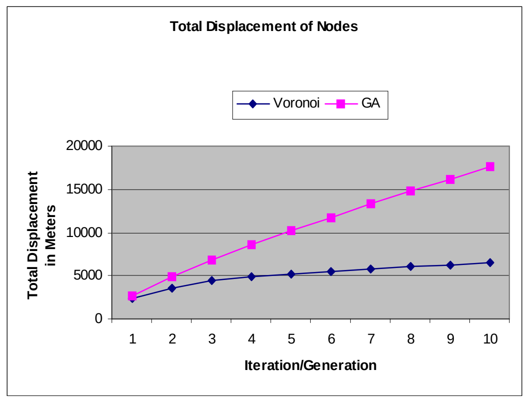

Fig.5 Iteration Vs Cumulative Displacement

While implementing the VVAA based deployment we also compared the Voronoi regions of the sensors. Voronoi regions of the sensors in random deployment and after optimization using VVAA based deployment were shown in Fig.6a.and Fig.6b respectively. In the Inner regions of the sensor field VVAA was better when compared to random but it would not improve the coverage at edges of the sensor field. Because the calculation of Voronoi polygon became inaccurate due to absence of nodes in the corners of the field.

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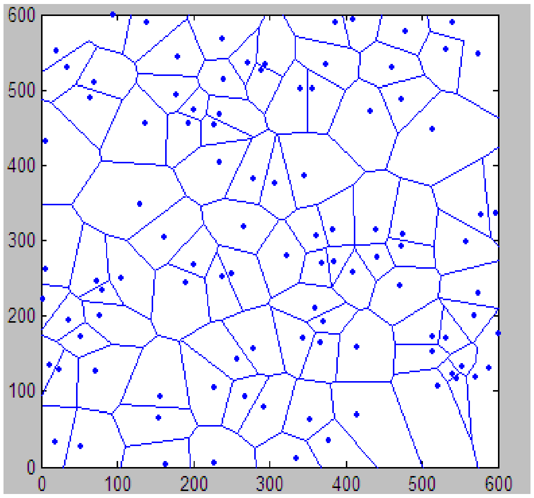

Fig. 6a Voronoi Regions of Random Deployment

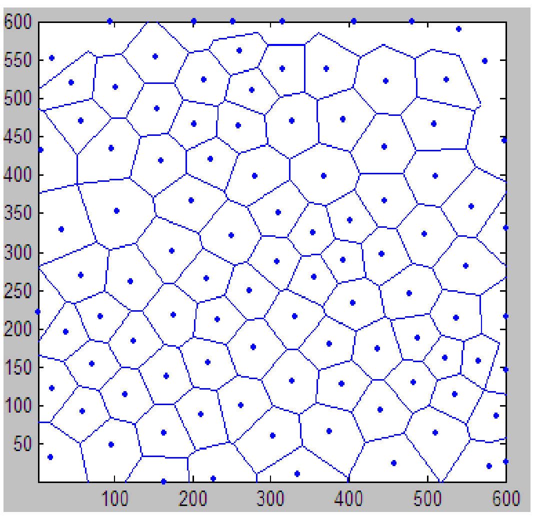

Fig. 6b Voronoi Regions of VVAA based Deployment

In random deployment the nodes remain in the same locations where they were deployed. The total and average distance of displacement of nodes at the end of the ten iterations is shown as bar charts in Fig.7 and Fig.8. As shown in these bar charts the displacement of nodes is less in VVAA based deployment than GA based deployment. In practical deployments, huge amount of power would be wasted to move the sensor to optimum locations. Since the VVAA based method is finding the optimum locations with minimum displacement, it would save huge amount of energy and hence enhance the life of the sensor node. The diplacement of the node is directly proportional to the power needed to move the node. Hence, we may consider these graphs as energy graphs also. So, obiously the VVAA based sensor node deployment would need less egergy to move the sensors to achieve optimum locations.

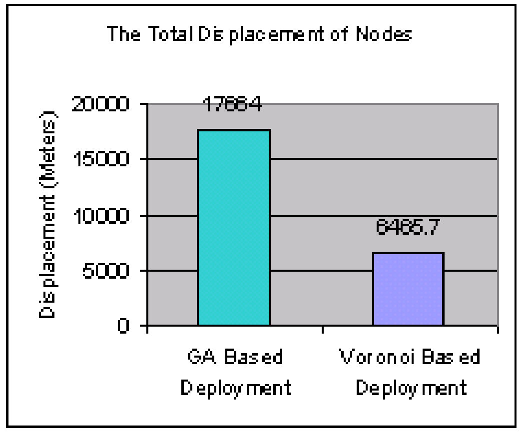

Fig. 7 Comparison of Total Displacement

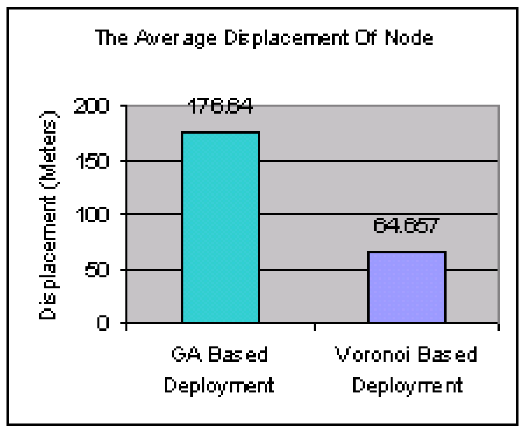

Fig. 8 Comparison of Average Displacement per Iteration/Generation

Table 1: CPU Time

Method	Time Taken (sec)
GA Based Deployment	30.25
Voronoi Based Deployment	3.38

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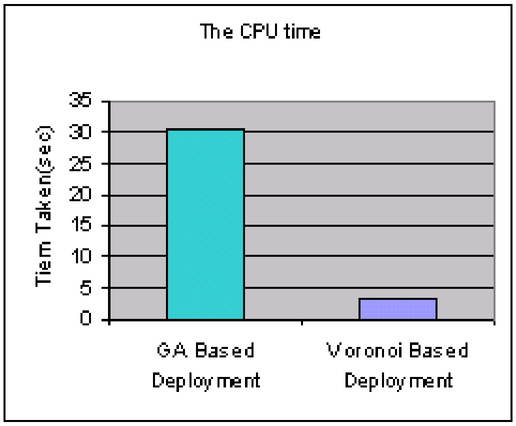

Fig. 9 Performance in terms of Time

The time taken for running the algorithms for ten numbers of iterations were shown Fig.9 and given in table3.That time was consumed to display the corresponding step by step results (including the graphics showing the sensor nodes, Voronoi regions of the network and coverage map). In VVAA based method less time was consumed for the above operations.

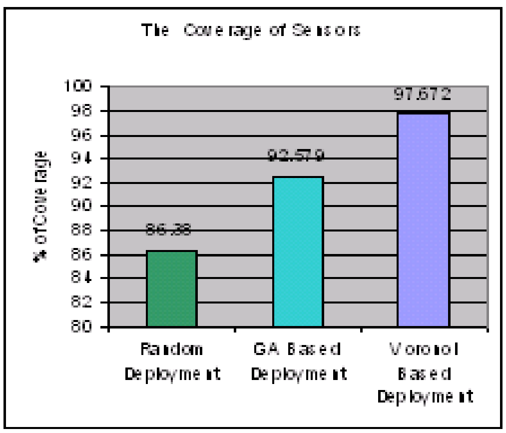

Fig.10 Average Coverage achieved by Different Methods

The average coverage achieved by random, GA and VVAA based deployments were shown and compared in Fig.10. The GA and VVAA based methods improved coverage. But, VVAA based deployment provided better coverage than the other two deployment methods.

5. CONCLUSION AND LIMITATIONS - CONSOLIDATED

The results of the comprehensive review of GA and VVAA algorithms could be summarized as follows.

1. The use of GA increased the coverage to 92.6 % compared to 86.4 % coverage in random deployment.
   Whereas the % coverage with VVAA had increased to 97.7 %. (An increase of 5 % over GA usage).
2. The displacement of nodes comes down from 17664 for GA to 6467 for VVAA adaption.
3. Since the coverage was higher, with reduced displacement of nodes the VVAA system would consume less power compared to GA system. (The research study on numerical values has not been carried).
   That would in turn prolong the life of the battery and consequently enhance the life of the network.
4. VVAA was faster than GA since the optimum coverage was achieved with less number of calculations. It was reduced from 30.25 seconds to 3.38 seconds.

5. Limitations:
   - The entire research was based on simulation techniques rather than an experimental one.
   - The actual power consumption, power saving and lifetime were not determined but were logically summarized, since the distance moved by the nodes were reduced.

6. FUTURE WORKS

The following topics which could not be addressed to in the present research due to limitations and constraints might be taken up for future study.

1. Power consumption and saving calculations could be attempted to.
2. The study could be carried out with less or more number of nodes than the ones covered in this study.
3. Similarly, the study could be carried out with different iteration levels.

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4. Other optimization techniques such as TSP and PSO could be tried.
5. With the same algorithms (GA and VVAA) other simulation techniques such as Ns2 and OMNeT ++ could be adapted.

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