Autonomous Deployment of Mobile Sensors Network in an Unknown Indoor Environment with Obstacles

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ABSTRACT

We developed a Voronoi-based algorithm, called Bio-Inspired Self Organizing Network (BISON), designed to provide a successful deployment of wireless sensor network (WSN) following fast, cost-efficient and self-organizing process, autonomously adapting to the unknown topology of the target environment, and avoiding obstacles discovered in real-time. To limit the power consumed during the deployment, BISON restricts each node to use only locally sensed information to adapt to live-discovered topology while avoiding obstacles and connecting with neighboring nodes. The algorithm is evaluated with respect to several metrics, and simulation results showed faster convergence to a fully connected network with lower deployment costs compared to similar algorithms reported in the literature.

CCS CONCEPTS

• **Computer systems organization** → **Self-organizing autonomic computing**; • **Computing methodologies** → *Generative and developmental approaches*;

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1 INTRODUCTION

By the time mobile sensor nodes are involved in several applications, it becomes difficult to manually allocate them in the area of interest, specifically in unknown environments, such as disaster areas, toxic regions, and generally, obstacle-rich environments [1–3]. Under such limitations, challenges arise in establishing self-deployment algorithms for WSN to autonomously re-allocate nodes and avoidance obstacles, allowing them to achieve optimum solutions with minimal costs [4]. Several optimization techniques proposed for solving related problems [5, 6], including potential fields, virtual forces between the sensor nodes [4, 7, 8], and bio-inspired techniques that optimize the performance of WSN [9–11]. Although these algorithms contribute to real applications constraints, they require knowledge of the surrounding environment, and assume continuous connectivity of the network throughout the process, unlike the approach in this report.

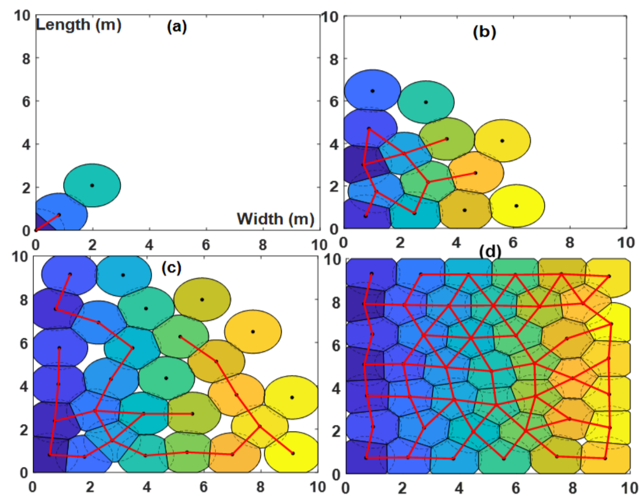

Figure 1: Snapshots of the distribution of nodes throughout the simulation. (a) The first nodes entering the area of interest (b) start forming the Voronoi boundaries (c) the distribution of nodes during intermediate stage, (d) the final distribution of nodes. The red lines represent the communication link between nodes.

2 BISON ALGORITHM

In this report, we demonstrate a specific variant of the Voronoi-based coverage algorithm termed BISON for Bio-Inspired Self-Organizing Network, which achieves optimum coverage in an unknown environment with obstacles, while ensuring full connectivity of the network (such that every sensor nodes is reachable), using centroid Voronoi tessellation mechanism. The number of

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nodes involved in the deployment process is unknown at the start. They enter the area one at a time based on gradual, conflict–free requirements to achieve full coverage and connectivity. Voronoi diagrams are re-calculated every time a new sensor node enters the area of interest, and the new allocation of nodes is guided towards the center of their Voronoi cells. Fig. 1 shows snapshots of BISON algorithm at different stages. If an obstacle exists within the node sensing range, the new Voronoi region will be limited by the obstacle's boundaries, the sensing range, and the neighboring bisectors, as shown in Fig. 2. The condition for which sensor nodes move toward their Voronoi centroid is limited by the summation of all the shifts happening in the system, rather than being limited by a certain threshold value. The communication range (R_C) and sensing range (R_S) are not identical, but follow the following prescribed relationship $R_C = \sqrt{3}R_S$.

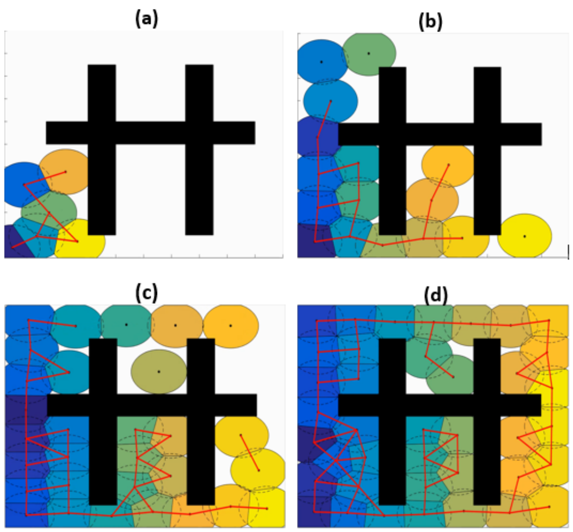

Figure 2: Snapshots of one of the simulations generated for BISON algorithm in an environment with obstacles.

3 SIMULATION ANALYSIS

We developed BISON simulations using MATLAB. The assigned parameters are sensing range $R_S = 1m$, area of $10 \times 10\ m^2$, and an average shifting threshold of $R_S/100$. The metrics of evaluation computed to evaluate the system is Percentage Area Coverage (PAC) [12].

Different obstacle shapes are studied in this Report. Fig. 3 represent the results of PAC for 4 different shapes and includes raw data map output for H and 2-rooms shapes commonly seen in offices/factories area. It is observed that BISON algorithm provides almost full coverage for all different shapes with percentage coverage between 81% (for T shape environment) and 91% (for C shape environment).

4 CONCLUSION

In summary, we developed a new strategy for self-deployment and re-allocation of mobile sensor nodes to establish blanket coverage in an unknown, obstacle rich area based on centroid Voronoi tessellation motivated algorithm. The Voronoi boundaries are generated

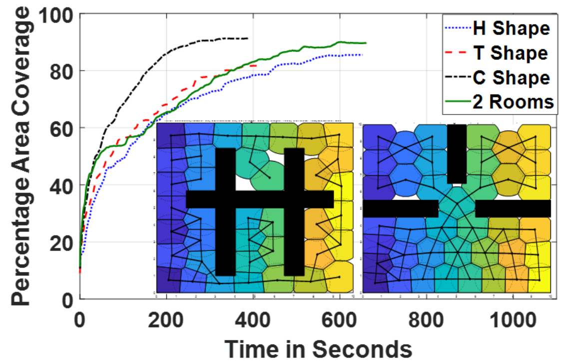

Figure 3: Percentage Area Coverage results for different obstacles shapes. The color maps represent raw data map output from the code for H and 2-rooms obstacles, respectively.

from the intersection between each node's bisectors with the neighbor nodes, its sensing range, and obstacles boundaries if they exist within the nodes sensing range. We demonstrated different obstacles shapes, and the simulation results revealed the applicability of the algorithm in several applications. Future work will consider analysis of different scattering obstacles as well as different spacing among obstacles to be more compatible with real implementations.

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