Energy efficient sensor nodes placement using Territorial Predator Scent Marking Algorithm (TPSMA)

H Z Abidin\textsuperscript{1} and N M Din\textsuperscript{2}
\textsuperscript{1}Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
\textsuperscript{2}College of Engineering, Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, 43000 Kajang, Selangor, Malaysia

E-mail: husnaza@salam.uitm.edu.my

Abstract. The positions of sensor nodes in a Wireless Sensor Network (WSN) must be able to provide maximum coverage with a longer lifetime. This paper proposed a sensor node placement technique that utilizes a new biologically inspired optimization technique that imitates the behavior of territorial predators in marking their territories with their odors known as Territorial Predator Scent Marking Algorithm (TPSMA). The TPSMA deployed in this paper uses the maximum coverage ratio as the objective function. The performance of the proposed technique is then compared with other schemes in terms of uniformity and average energy consumption. Simulation results show that the WSN deployed with the proposed sensor node placement scheme consumes lower energy compared to the other two schemes and is expected to provide longer lifetime.

1. Introduction
An energy efficient Wireless Sensor Network (WSN) with maximum coverage can be achieved through a cost effective deployment mechanism. This can be done by utilizing an effective planning mechanism in arranging the limited number of sensor nodes. Romoozi [1] stated that there is a tradeoff between energy consumption of sensor nodes and network coverage. Closer sensor nodes will reduce the energy usage but the network coverage will become smaller.

A sensor node placement scheme that utilizes a new biologically inspired optimization technique known as Territorial Predator Scent Marking Algorithm (TPSMA) is introduced in this paper. This is to ensure that WSN deployed with this scheme would be able to reduce the energy usage without jeopardizing the required coverage level. TPSMA imitates the behavior of territorial predators in marking its territories with their odors and in this paper, the sensor nodes placement scheme would mark the area that the sensor nodes would give the maximum coverage ratio. Sensor nodes will then be placed according to the marked area.

The rest of the paper is organized as follows. Section 2 will outline our methodology followed by our simulation model in section 3. Section 4 deals with simulation results and finally section 5 concludes the paper.
2. **WSN Sensor Node Placement based on TPSMA**

Territorial predator such as tigers and bears can be defined as predators that consistently defend a specific area against animals from other species. The territory is chosen based on certain factors such as food resources. Most territorial predators use scent marking to indicate the boundaries of their territories which are also playing a role in territorial maintenance and as information sites for other members of the population [2]. Scent matching allows a resident animal to distinguish other residents from intruders by recognizing their scent, thereby reducing the need for territorial encounters [3]. The marks may be deposited by urination, defecation, rubbing parts of bodies such as chin and foot, scratching, using glands and vegetation flattening [2].

Territorial predator scent marking behaviour can be adopted in designing the sensor node placement technique where the territory of a sensor node can be scent marked based on the design objectives such as maximum coverage, minimum uniformity, minimum energy consumption and maximum connectivity. This is done based on the scent marking behaviour where normally predator will scent mark the area due to certain factors such as food resources. Sensor node will identify its monitored location based on their marked territories that imitates the scent matching behaviour.

### 2.1. Assumptions

- Sensor nodes are homogeneous static nodes and must not exceed the number of potential sensor node locations.
- Number of monitored locations are equal to the number of potential sensor node locations.
- Monitoring area is a 2-dimensional area that is broken up into several monitored locations.
- The center of each monitored location is considered as monitored point.
- Each monitored location can only be equipped with 1 sensor node and may be monitored by more than 1 sensor node.
- At least one path must be there between each sensor node and the base station.

### 2.2. Sensing Model and Objective Function

Binary Sensing Model (BSM) is adopted in this study. The covering area of sensor nodes is assumed to be a circular area with a radius of $R_i$ that represents the sensing range. The probability of node $s_j(x_{sj}, y_{sj})$ detects an event occurs on $i(x_i, y_i)$ is [4]:

$$
P_{cov}(s_j, i) = \begin{cases} 
1 & d(s_j, i) \leq R_i \\
0 & \text{otherwise} 
\end{cases}$$

(1)

where $d(s_j, i)$ is the Euclidean distance between point $i(x_i, y_i)$ and $s_j(x_{sj}, y_{sj})$

$i$ can be considered effectively covered if $P_{cov} > C_{th}$ where $C_{th}$ is the coverage threshold [5]. The objective function is determined by using the following equation which was presented in [5]:

$$
Objective Function, f(x) = \frac{N_{effective}}{N_{all}}
$$

(2)

where $N_{effective}$ is the number of locations that are effectively covered and $N_{all}$ is the total number of locations. The following pseudocode describes the proposed TPSMA scheme.
3. Network Model
Simulation parameters are tabulated in Table 1 and results are then compared with works done by Deyab et al. [6] and Chakrabarty et al. [7] who utilized Integer Linear Programming (ILP). Deyab proposed an algorithm where a monitoring area is divided into few grids and each grid is represented by a critical point. The technique proposed by Deyab specified that sensor nodes and relay nodes could not be placed on the critical point itself. Only specific area is fully covered because the aim of this technique is to reduce the deployment cost. Chakrabarty proposed a sensor node placement technique that uses different costs of sensor nodes. The sensor nodes also have different detection range.

| Parameter                  | Value       |
|----------------------------|-------------|
| Number of sensor nodes     | 10 to 16    |
| Monitoring Area            | 100m x 100m |
| Sensing Range, $R_s$       | 20m         |
| Number of monitored locations | 16         |
| Coverage Threshold, $C_{th}$ | 0.9        |

4. Simulation Results
WSN with smaller uniformity is considered more evenly distributed in the monitoring area hence is expected to have a longer lifetime. Figure 2 shows that the uniformity value reduces as the number of sensor nodes increases because uniformity metric is determined by the communication range and density of sensor nodes [8]. As compared to works proposed by Deyab and Chakrabarty, TPSMA gives the lowest uniformity. Uniformity given by TPSMA is nearly 70% lower than uniformity given by Deyab when the WSN is deployed with 10 sensor nodes and approximately around 77% when it is deployed with Chakrabarty scheme. From this observation, it can be said that, sensor node placement with the proposed TPSMA scheme is expected to provide longer lifetime compared to the other two schemes.

As shown in figure 3, TPSMA has the lowest energy usage while the technique proposed by Deyab consumes the highest energy. The average energy consumption reduced by approximately 12 Joules and 66 Joules compared to techniques proposed by Chakrabarty and Deyab respectively. This graph conforms with the uniformity graph shown in figure 2 where WSN deployed with TPSMA is expected to have the longest lifetime followed by Chakrabarty and Deyab respectively.
5. Conclusions and Future Work
A sensor node placement scheme based on TPSMA has been proposed in order to ensure a cost effective WSN deployment with minimum energy consumption. Based on the simulation results obtained, it can be concluded that WSN deployed with maximum coverage TPSMA sensor nodes placement scheme is an energy efficient technique that offers considerably lower energy consumption and lower uniformity value compared to the works done by Deyab et al. and Chakrabarty et al. This result implies that, WSN deployed with proposed scheme is expected to be more energy efficient with longer lifetimes. Further work would focus on developing a multi objective TPSMA sensor node placement scheme.

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