Minimal Node Deployment in Wireless Sensor Networks Under Coverage and Connectivity Constraints

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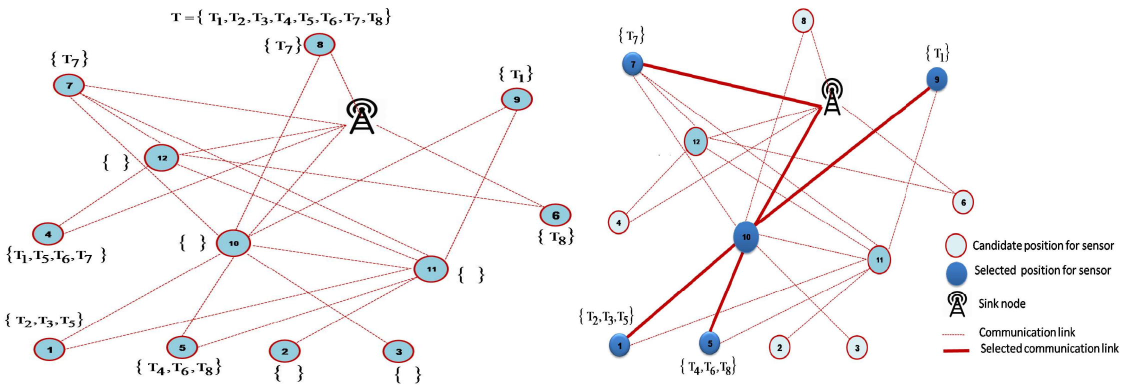
1 Introduction

One of the most interesting IoT applications is Smart Car Parks (SCPs) based on Wireless Sensor Networks (WSNs). This type of networks which constitute a particular class of Ad hoc networks have become a very attractive field of research. In fact, they have received the attention of many researchers who have been interested in issues raised by these networks, such as energy consumption [1], cost deployment [5], coverage and connectivity [5]. In this paper, we address the problem of deterministic sensor nodes deployment in WSN dedicated to fire surveillance in SCPs. More precisely, We will use a multi-objective optimization approach to propose a solution based on a recent meta-heuristic called Whale Optimization Algorithm (WOA) [2] to solve the WSN deployment problem by minimizing network cost (number of deployed sensor nodes) while fulfilling the constraints of targets coverage (all car spot must be covered by at least one sensor node) and network connectivity. On the other side, since alerts generated by sensor nodes must be received by the sink node with minimal end-to-end delay, we have considered a second objective which consists of minimizing the hop-count from each sensor node to the sink.

The problem described above is represented as a graph $G(N \cup \{sink\}, E, T)$, where N is the set of candidate positions for sensor nodes, E is the set of edges, representing the communication between sensor nodes, and T is the set of targets to be covered and each sensor node has a list of target T_i that can cover them (see Figure 1a). Figure 1b, shows the minimal sensor nodes N^{OPT} to be deployed.



(a) Input graph

(b) Induced sub-graph

FIG. 1 – Graph representation of the node deployment problem.

2 Problem Formulation

The input graph is represented using a vector X with a fixed size (representing the candidate positions of sensor nodes. To indicate that a candidate position has been selected to deploy a sensor node, every vector element is set to either 1 or 0. On the other side, each solution is evaluated using the following objective function.

$$F1 = \min \sum_{i \in N} X_i \qquad F2 = \min\{ \max_{i \in N^{OPT}} (distance_{(sink,i)})$$

To solve this problem, we transform it into a mono-objective problem F using the weighted sum approach [4] :

$$F = \min\{\alpha \times F1 + \beta \times F2\}$$

where : $\alpha, \beta \in [0, 1]$, and $\alpha + \beta = 1$

Under constraints :

$$\bigcup T_i = T, \forall i \in N^{OPT}$$

$$\forall i \in N^{OPT}, \exists Path_{(sink,i)}$$

3 Methodology

Linear programming modeling has been proposed to solve small instances generated for this problem [3]. Since this problem has been shown to be NP-hard [1], we have adopted the Whale Optimization Algorithm (WOA) in order to resolve larger instances in an acceptable time. Figure 2 summarizes our workflow.

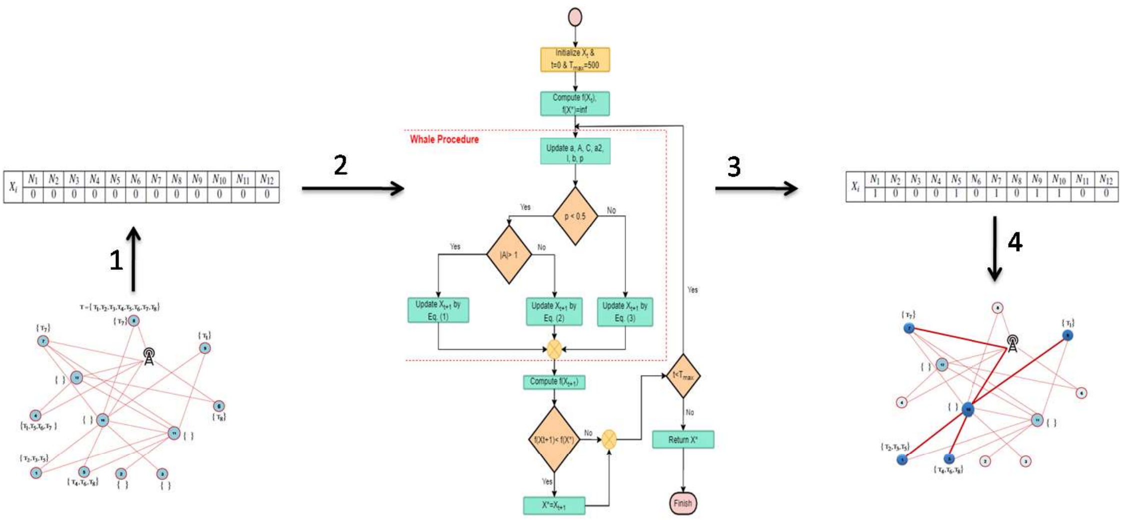


FIG. 2 – Workflow

References

[1] Cardei, Mihaela, et al. *"Energy-efficient target coverage in wireless sensor networks." Proceedings IEEE 24th Annual Joint Conference of the IEEE Computer and Communications Societies, Vol. 3. IEEE, 2005.*

[2] Mirjalili, Seyedali, and Andrew Lewis *"The whale optimization algorithm."Advances in engineering software, 2016.*

[3] S. C. Benghelima, et al. *"Multi-objective Optimisation of Wireless Sensor Networks Deployment : Application to fire surveillance in smart car parks," 2021 International Wireless Communications and Mobile Computing (IWCMC), 2021.*

[4] Marler, Rn et al. *"The weighted sum method for multi-objective optimization : new insights." Structural and multidisciplinary optimization, 2010.*

[5] Benatia, Mohamed Amin, et al. *"Multi-objective WSN deployment using genetic algorithms under cost, coverage, and connectivity constraints." Wireless Personal Communications, 2017.*