Optimizing Sink Position in a Wireless Sensor Network

Giuliano Crescimbeni, 10712403 - Arimondo Scrivano, 10712429

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Contents

1 Introduction

The goal of this challenge, divided into 3 subsections, is to calculate the energy consumption in a Wireless Sensor Network with a fixed position of the sink node. The challenge evolves with the calculation of the best Sink node position and the consequent Energy Evaluation of the system (the highest energy depending node is considered). The final section is a discussion of the Trade-off of a dynamic Sink position.

This document provides an in-depth technical description of the system implementation, including the code implemented, and energy estimation calculations.

2 Topology and node behavior

The system, depicted in the following image, is the 2-d representation of 10 nodes positions.

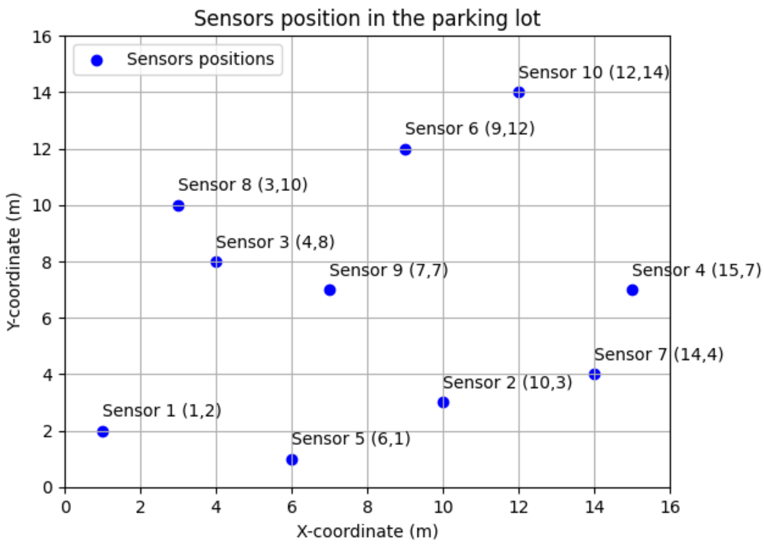


Figure 1: Topology of the system

Each node, every 10 min, has the task of transmitting a status update to the Sink node. The packet size is b = 2000 bit, and the initial energy per sensor is Eb=5 [mJ].

- Energy for the TX/RX circuitry: $E_c = 50$ [nJ/bit]
- Energy for transmission: $E_{tx}(d) = k \cdot d^2$ [nJ/bit], where d is the distance from the sensor to the sink, and $k = 1$ [nJ/bit/m^2].

3 System Lifetime with fixed Sink position

The goal of this task is to calculate de duration of the system, considering the most energy demanding node as reference, and the Sink in the fixed position (20,20).
Each node, for one transmission cycle has a power consumption expressed by the following formula:

$$E = \frac{\text{packet\_size} \cdot (E_{\text{TX}} + k \cdot d^2)}{10^6} \quad [\text{mJ}]$$

The distance is calculated as the distance in a 2-dimensional space between point A and point B:

$$d = \sqrt{(\mathrm{x}_A - \mathrm{x}_B)^2 + (\mathrm{y}_A - \mathrm{y}_B)^2} \quad [\text{m}]$$

The lifetime of the node is calculated as:

$$\text{Energy-consumptions-per-sec} = \frac{\text{E}}{600} \quad [\text{mJ/s}]$$

$$\text{Total lifetime} = \frac{\text{energy-base}}{\text{energy-consumptions-per-sec}} \quad [\text{s}]$$

As the final step, for each node, its lifetime is been calculated:

```
energy_consumptions = []
lifetimes = []

for sensor in sensors:
    energy_consumptions.append(calculate_energy_consumption(sensor,
        (20,20)))

for consumption in energy_consumptions:
    lifetimes.append(calculate_lifetime(consumption))
```

Point	**Value (s)**
1	2040.81
2	3416.85
3	3333.33
4	6147.54
5	2471.16
6	6382.97
7	4385.96
8	3416.85
9	3865.97
10	10000.0

Table 1: Lifetime of each sensor

The lifetime of the entire system, as the lifespan of the first node, is: 2040.81s (approximately 34 minutes)

This result indicates that the system can complete three full cycles and is interrupted during the fourth transmission. Consequently, the total operational lifetime is 30 minutes.

4 Best Sink node position for optimality

The objective, depicted in the following code snippet, is to find the optimal position for the sink node in the parking lot. The optimal position is the one that maximizes the minimum lifetime of all sensors in the network. To achieve this, for each potential position of the sink node, the energy consumption of all sensors is calculated, and the minimum lifetime across all sensors is determined. The position that results in the highest minimum lifetime is selected as the optimal sink position.

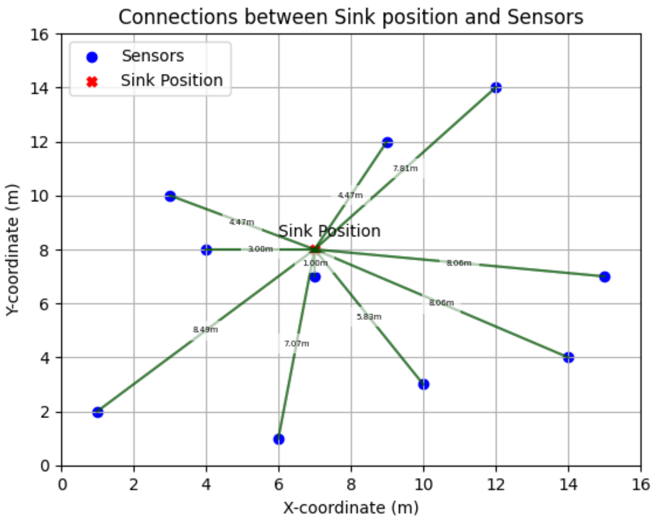
```python
def find_best_sink_position(grid_size=21):
    best_position = (0, 0)
    max_min_lifetime = 0

    for x in range(grid_size):
        for y in range(grid_size):
            sink_position = (x, y)
            lifetimes = []
            for sensor in sensors:
                energy_consumption = calculate_energy_consumption(sensor,
                     sink_position)
                lifetimes.append(calculate_lifetime(energy_consumption))
            min_lifetime = min(lifetimes)

            if min_lifetime > max_min_lifetime:
                max_min_lifetime = min_lifetime
                best_position = sink_position

    return best_position, max_min_lifetime
```

The results are:



The best sink position is:
(x = 7, y = 8)

Life time of the system:
12295.08s

Figure 2: Topology of the system

5 Trade-offs discussion in choosing a fixed sink position versus dynamically moving the sink

5.1 Fixed Position Sink

A fixed position sink is placed at a predetermined location within the network, and sensor nodes transmit their data to it periodically. In our scenario, the sink is positioned in (7,8) in ord er to have minimal energy consumption. The main advantages and disadvantages of using a fixed position sink are as follows:

5.1.1 Pros

- **Simplicity:** The fixed sink simplifies network design since its position is known and does not change.
- **Energy-efficient for sensors closer to the sink:** For sensor nodes located near the sink, energy consumption is minimized due to shorter transmission distances.
- **Stable Communication:** With a fixed sink, the communication path is stable, avoiding issues related to dynamic movement and changes in routing.

5.1.2 Cons

- **Energy depletion for distant sensors:** Sensor nodes located farther from the fixed sink must expend more energy to transmit data, which reduces the overall lifetime of the network.

5.2 Dynamic Position Sink

A dynamic position sink, on the other hand, can move within the network to optimize energy consumption. The advantages and disadvantages of using a dynamic sink are as follows:

5.2.1 Pros

- **Energy optimization:** A dynamic sink can move closer to sensors that have low battery levels, reducing the energy spent on transmission and extending the lifetime of the network.
- **Distributed energy consumption:** With the sink moving throughout the network, the energy consumption is more evenly distributed across all nodes.

5.2.2 Cons

- **Increased complexity:** The dynamic sink requires sophisticated algorithms for movement and routing, adding complexity to the network's design and management.
- **Energy cost of movement:** The movement of the sink itself consumes energy, which may decrease the overall network lifetime.
- **Unpredictable communication paths:** The dynamic movement of the sink can lead to fluctuating communication paths, which may cause instability in data transmission.

The image below illustrates a possible movement path for the sink, designed to optimize energy consumption between **Sensor 1** and **Sensor 10**, which are the farthest sensors from the optimal position (7,8).

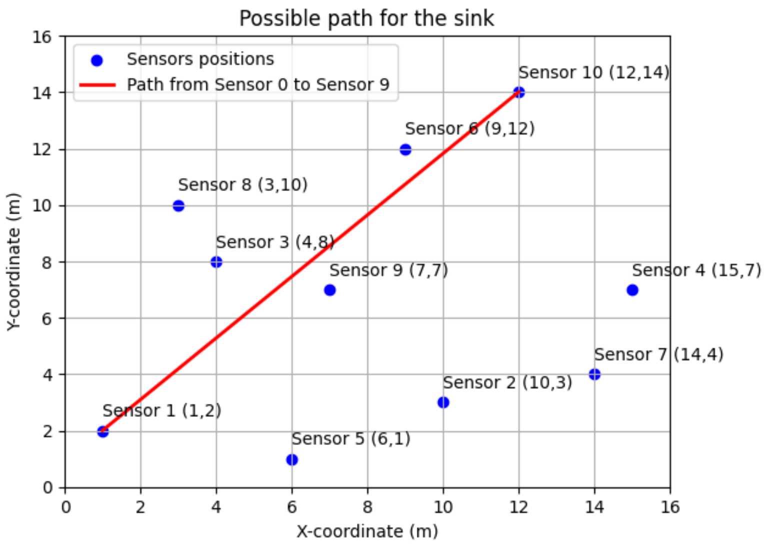


Figure 3: Moving path of the sink

5.3 Conclusion

The choice between a fixed and dynamic position sink depends on the specific needs and constraints of the wireless sensor network. While a fixed sink offers simplicity and stable communication, a dynamic sink provides better energy efficiency by adapting to the network's changing conditions, though at the cost of increased complexity and potential energy consumption for movement. The optimal choice will depend on the mutability of the network and its topology