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IOT Challenge 1 - Exercise 4

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1 | A: Find the lifetime of the system

When the sink node is placed at the fixed location $(x_s, y_s) = (20, 20)$ the energy consumption for each sensor $E_s(x, y)$ for one cycle is:

$$E_s(x,y) = b*(E_c + E_{tx}(d))[nJ] = b*(E_c + k*(\sqrt{(x-20)^2 + (y-20)^2})^2[nJ] \quad (1.1)$$

Computing the formula for each sensor we obtain the following energy consumption:

Sensor (x, y)	Distance from Sink Node	Energy Consumption (mJ)
(1, 2)	26,17	1,47
(10, 3)	19,72	0,88
(4, 8)	20,00	0,90
(15, 7)	13,93	0,49
(6, 1)	23,60	1,21
(9, 12)	13,60	0,47
(14, 4)	17,09	0,68
(3, 10)	19,72	0,88
(7, 7)	18,38	0,78
(12, 14)	10,00	0,30

The sensor with the highest energy consumption is the one located in $(1, 2)$, so it will be the first to run out of battery after $\frac{5mJ}{1{,}47mJ} = 3,4$ cycles, so the lifetime of the system is 3 cycles.

2 | B: Find the optimal position of the sink

2.1. Methodology

To determine the optimal sink node location, I evaluated all possible positions within the boundary formed by the given sensor coordinates. For each candidate position, I computed the maximum Euclidean distance to any sensor using:

$$d = \sqrt{(x_i - x_{sink})^2 + (y_i - y_{sink})^2} \tag{2.1}$$

where (x_i, y_i) represents the sensor coordinates and (x_{sink}, y_{sink}) is the candidate sink position.

The optimal sink node position is chosen to minimize the maximum distance between the sink and any sensor in the network. This is important because the sensor that is farthest from the sink determines how long will the system last. The farther a sensor is from the sink, the more energy it uses to transmit data. By minimizing the distance to the farthest sensor, the system lifetime increases since the maximum energy spent during a cycle by the sensors decreases.

The optimal sink node location wa computed as: $(x_{opt}, y_{opt}) = (6.9, 7.6)$

2.1.1. Code

I used the following python script to find the best location of the sink node:

```
import numpy as np
from itertools import product

def max_distance_for_sink(x_sink, y_sink, points):
    # computes the maximum distance from a possible sink node to any
        sensor
    return max(np.sqrt((x - x_sink) ** 2 + (y - y_sink) ** 2) for x, y
```

```
        in points)

def find_optimal_sink_position(points):
    # find the edges of the space where to search the sink in
    x_min = min(x for x, _ in points)
    x_max = max(x for x, _ in points)
    y_min = min(y for _, y in points)
    y_max = max(y for _, y in points)

    best_x, best_y, min_max_distance = None, None, float('inf')

    # perform a search over possible sink positions by generating all
    # combinations of x and y values within the bounds with steps of 0.1
    for x_sink, y_sink in product(np.arange(x_min, x_max + 0.1, 0.1),
                                  np.arange(y_min, y_max + 0.1, 0.1)):

        # for each possible sink compute the maximum distance to any of
            the sensors
        max_dist = max_distance_for_sink(x_sink, y_sink, points)
        # update the min max distance if a new optima is found
        if max_dist < min_max_distance:
            min_max_distance = max_dist
            best_x, best_y = x_sink, y_sink

    return best_x, best_y

if __name__ == "__main__":
    points = [
        (1, 2),
        (10, 3),
        (4, 8),
        (15, 7),
        (6, 1),
        (9, 12),
        (14, 4),
        (3, 10),
        (7, 7),
        (12, 14),
    ]

    best_x, best_y = find_optimal_sink_position(points)
    print(f"Optimal Sink Position: ({best_x:.2f}, {best_y:.2f})")
```

2.2. Result Evaluation

The energy consumption of each sensor using the new position of the sink node is the following:

Sensor (x, y)	Distance from Sink Node	Energy Consumption (mJ)
(1, 2)	8,13	0,23
(10, 3)	5,55	0,16
(4, 8)	2,93	0,12
(15, 7)	8,12	0,23
(6, 1)	6,66	0,19
(9, 12)	4,88	0,15
(14, 4)	7,96	0,23
(3, 10)	4,58	0,14
(7, 7)	0,61	0,10
(12, 14)	8,18	0,23

The sensors with the highest energy consumption in this case are the one located in $(1, 2), (15, 7), (14, 4), (12, 14)$, so they will be the first to run out of battery after $\frac{5mJ}{0{,}23mJ} = 21,74$ cycles, so the lifetime of the system is 21 cycles.

3 | C: Discuss the trade-offs of a fixed sink versus a dynamically moving sink

Instead of using a fixed sink, implementing a dynamically moving sink comes with some drawbacks:

- The sink node is typically more powerful than the sensors and remains active to receive parking status updates at any time. To ensure continuous operation, it should ideally be always powered rather than battery-operated. A moving sink makes this difficult to achieve.
- A mobile sink requires an algorithm to dynamically optimize its position based on incoming messages. This involves computing the next best location and activating movement mechanisms, both of which consume significant energy.
- For a moving sink to extend system lifetime, sensors must transmit at different time intervals. If all sensors send messages simultaneously, the sink would need to stay in a single optimal position to minimize the maximum distance. This setup could only improve system longevity if a reliable method is found to prevent the sink's battery from draining while sensors are transmitting, adding another layer of complexity and potential point of failure.

A fixed sink position is preferable, as it simplifies system design and allows the sink node to remain continuously powered.