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INTNET OF THINGS

Optimizing Sink Position in a Wireless Sensor Network

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1 Optimizing Sink Position in a Wireless Sensor Network

Note: All numerical calculations in this section are detailed in the MATLAB file:chall1_4.m

1.1 Find the lifetime of the system when the sink is placed at the fixed position

Since the system lifetime is defined as the time until the first sensor's battery dies. When the sink node is located at a fixed point, the system lifetime can be calculated according to the following steps.

1) Calculate the distance (d) from each sensor to the sink:

$$d = \sqrt{(x - x_s)^2 + (y - y_s)^2}$$

For each sensor, calculate its distance to the sink.

2) Calculate the energy consumption for each sensor:

$$E_{total} = E_c \cdot b + E_{tx}(d) \cdot b$$

$$E_{tx}(d) = k \cdot d^2 \quad \text{where } k = 1nJ/bit/m^2$$

3) Calculate the lifetime of each sensor:

$$lifetime = \frac{E_b}{E_{total}}$$

The lifetime of each sensor is its initial energy divided by the energy consumption per transmission.

4) Calculate the system lifetime: The system lifetime is the shortest lifetime among all sensors.

The specific calculation process can be shown by code, see file :chall1_4.m, and the following results are obtained.

Sensor information:

Sensor ID	Position (x,y)	Distance(m)	Transmission energy (J)	Number of transmissions	Transmission time (hours)
1	(1, 2)	26.17	1.47E-03	3.40	0.57
2	(10, 3)	19.72	8.78E-04	5.69	0.95
3	(4, 8)	20	9.00E-04	5.56	0.93

4	(15, 7)	13.93	4.88E-04	10.20	1.71
5	(6, 1)	23.6	1.21E-03	4.12	0.69
6	(9, 12)	13.6	4.70E-04	10.60	1.77
7	(14, 4)	17.09	6.84E-04	7.31	1.22
8	(3, 10)	19.72	8.78E-04	5.69	0.95
9	(7, 7)	18.38	7.76E-04	6.44	1.07
10	(12, 14)	10	3.00E-04	16.70	2.78

System lifetime when Sink is at (20, 20): 3.40 cycles, corresponding time: 0.57 hours.

1.2 Find the optimal position of the sink

Goals:

Find the junction position (x_s, y_s) Maximizes system life, i.e. minimizes energy consumption for the worst sensors.

The simulated annealing algorithm is a systematic method to find the best position of the convergence point in the sensor network by simulating the physical annealing process, so as to optimize the overall performance of the network. The process involves the following key steps:

1) Problem initialization:

The parameters of the sensor network are defined and the parameters of the simulated annealing algorithm are set, such as the initial temperature and the maximum number of iterations. Stability of the algorithm controlled by the maximum number of iterations. Choose an initial junction location, which can usually be the geometric center of the sensor network or some other reasonable starting point.

1) Energy consumption calculation:

The energy consumption of each sensor is calculated for the current junction position. Energy consumption calculation includes transmission energy consumption and circuit energy consumption. Calculate the life expectancy of each sensor, that is, the number of transmissions each sensor is capable of making at the current junction position.

2) New and old location judgment:

Evaluate the current position and the optimal position lifetime, and decide whether to accept the new position according to the acceptance criteria of the simulated annealing algorithm.

3) Iterative process:

Repeat the above steps to continuously generate new junction locations and evaluate them based on energy consumption and lifetime. With the progress of iteration, the temperature is gradually lowered, making the algorithm more inclined to accept the solution with lower energy consumption, and gradually approaching the global optimal solution.

4) Achieve global optimization and determine the best position

Finally, the results are obtained by matlab：

Optimal Sink position: **(6.87, 7.65)**

System lifetime at the optimal position**: 21.43 cycles, corresponding time: 3.57 hours**

Comparison between fixed and dynamic sink positions:

System lifetime with fixed Sink position (20, 20): 3.40 cycles, corresponding time: 0.57 hours

System lifetime at the optimal dynamic Sink position: 21.43 cycles, corresponding time: 3.57 hours.

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>> chall1_4
Sensor information:
Sensor ID   Position (x,y)  Distance    Transmission energy (J)     Number of transmissions     Transmission time (hours)
1           (1, 2)          26.17       1.47e-03                    3.40e+00                    5.67e-01
2           (10, 3)         19.72       8.78e-04                    5.69e+00                    9.49e-01
3           (4, 8)          20.00       9.00e-04                    5.56e+00                    9.26e-01
4           (15, 7)         13.93       4.88e-04                    1.02e+01                    1.71e+00
5           (6, 1)          23.60       1.21e-03                    4.12e+00                    6.86e-01
6           (9, 12)         13.60       4.70e-04                    1.06e+01                    1.77e+00
7           (14, 4)         17.09       6.84e-04                    7.31e+00                    1.22e+00
8           (3, 10)         19.72       8.78e-04                    5.69e+00                    9.49e-01
9           (7, 7)          18.38       7.76e-04                    6.44e+00                    1.07e+00
10          (12, 14)            10.00       3.00e-04                    1.67e+01                    2.78e+00
System lifetime when Sink is at (20, 20): 3.40 cycles, corresponding time: 0.57 hours
Optimal Sink position: (6.87, 7.65)
System lifetime at the optimal position: 21.43 cycles, corresponding time: 3.57 hours

Comparison between fixed and dynamic sink positions:
System lifetime with fixed Sink position (20, 20): 3.40 cycles, corresponding time: 0.57 hours
System lifetime at the optimal dynamic Sink position: 21.43 cycles, corresponding time: 3.57 hours
fx >>
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1.3 Discuss the trade-offs involved in choosing a fixed sink position versus dynamically moving the sink

1) Advantages and disadvantages of a fixed Sink location:

The advantages are simple deployment and management, without the need for additional mobile control devices and complex algorithms. The disadvantage is that some sensors are far away from Sink and consume a lot of energy, resulting in system life limited by these sensors. For example, at the (20, 20) position, some sensors have high transmission energy consumption and quickly run out of energy.

2) Advantages and disadvantages of the dynamic Sink position:

The advantage is that it can be dynamically adjusted according to the position of the sensor, balancing the energy consumption of the sensor and extending the life of the system. The disadvantage is that it increases system complexity and cost, requires positioning devices and moving mechanisms, and consumes extra energy for moving Sink nodes.

3) Trade-off decision:

In the scenario that is sensitive to cost and does not require high system life, it is suitable to fix Sink

position; Dynamic Sink is more suitable in scenarios that require high system life and have sufficient resources.