Heuristic Solutions for the Lifetime Problem of Wireless Sensor Networks

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Abstract. In [5, 7, 8] an analytical model of the lifetime problem of wireless sensor networks is developed. The solution given by the model is not practical for WSNs. Each time, there is a change in a sensor network, the solution needs to be recalculated. Also, it is difficult to build ILP solvers inside the small sensors. Furthermore, when the number of sensor nodes and CHs increases, it quickly becomes infeasible to calculate an optimum solution. As the analytical model is not able to be used to solve complicated networks, heuristic solutions are then examined that can compute the solutions for large sensor networks. Finally, the simulation results of the heuristic solutions are presented and discussed.

Keywords: Base station location · Wireless sensor network · Routing · Non-linear programming

1 Introduction

It is important to design heuristic algorithms [6, 9, 10] to approximate the performance of the optimum solution. Heuristic algorithms are summarized below:

Heuristic solutions for the lifetime problem

LEACH:
In every round, select a sensor node as a CH randomly from all sensor nodes in sensor networks.

```
Given:
N : The number of sensor nodes indexed from 1 to N
s : The current CH solution
For every round of data transmission
                    s = Random[1...N]
Result: s is the CH solution for the round obtained from
the LEACH algorithm. (End of code)
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EEEAC (Avera):

In every round, select a sensor node to be a CH randomly from sensor nodes that have the energy level above the average energy of all nodes.

Given:
N : The number of sensor nodes indexed from 1 to N
s : The current CH solution
k : The number of sensor nodes that have energy above the average energy of all sensors
For every round of data transmission

$$s = Random[1...k]$$

Result: s is the CH solution for the round obtained from the Avera algorithm. (End of code)

LEACH_C:

In every round, select a sensor node, which has energy above the average energy of all nodes as a CH in order to minimize the total energy usage required to send traffic in that round to base station.

Given:
N : The number of sensor nodes indexed from 1 to N
s : The current solution
k : The number of sensor nodes that have energy above the average energy of all sensors
$f(s)$: The total energy consumption of all sensor nodes with solution s
s_0 : Best solution so far
Initialization: $s_0 \leftarrow \infty$
For (s from 1 to k)

$$\delta = f(s) - f(s_0)$$

If $\delta < 0$ **then** $s_0 = s$

Result: s_0 is the CH solution obtained from the LEACH_C algorithm. (End of code)

2 A New Heuristic Solution

RE:

In every round of data transmission to the base station, select a sensor node as a CH in order to maximize the minimum remaining energy of all sensor nodes.

Given:

N : The number of sensor nodes indexed from 1 to N

s : A current solution

$f(s)$: The minimum residual energy of all nodes with solution s

s_0 : Best solution so far

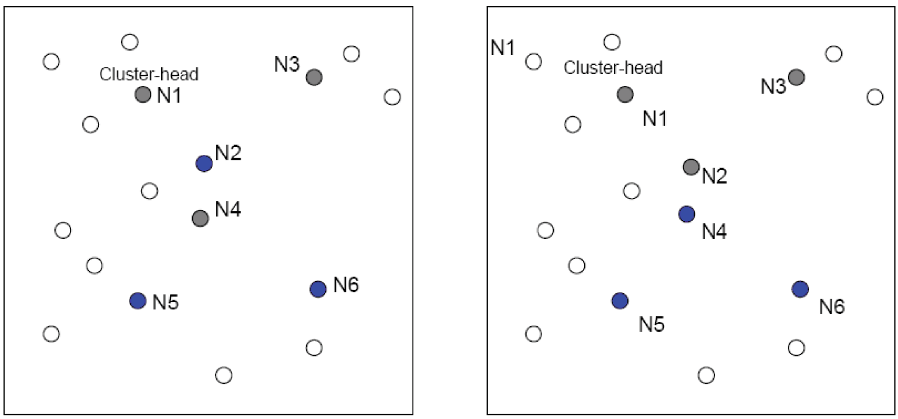
Initialization: $s_0 \leftarrow 0$

For (s from 1 to N)

$$\delta = f(s) - f(s_0)$$

If $\delta > 0$ **then** $s_0 = s$

Result: s_0 is the CH solution obtained from the RE algorithm. (End of code)



a) Full search b) Simple search

: Cluster-head for round i

: Cluster-head for round $i+k$

Search Method	Full search			Simple search		
Round i	N1	N3	N4	N1	N2	N3
Round $i+k$	N2	N5	N6	N4	N5	N6

Fig. 1. The order of cluster-head selection is not important (a) From a full search method, (b) From a simple search a method

3 Approximate Algorithm for RE

The authors in [1–4] mentioned that it is NP-hard to approximate Clustering Problem within a factor <2. Fortunately, the aim of the research is to extend the lifetime of sensor networks. To achieve this, CHs are reallocated in different rounds. We do not consider the cluster solution in each particular round, but the lifetime of the system (the total number of rounds) until the first sensor runs out of energy. As the CHs are reallocated from round to round, obtaining a poor solution of CHs in one round will not affect the whole performance in other rounds. In other words, a missed best solution of CHs can be revisited in other rounds. Therefore, a simple heuristic search scheme with a few hundred iterations could be enough to perform approximately as the full search. Figure 1 illustrates that a full search achieves different clustering solutions with a simple search in round i and round $i + k$. However, the simple search will achieve approximate lifetime performance of the full search, as the combination solution for the two rounds is the same (Node 1 to Node 6 are CHs).

The implementation of RE with a simple search is given below, in which the number of iterations, *iters* is set to a small number of about 100 in each round.

```
Given:
    N : The number of sensor nodes indexed from 1 to N
    k : Number of CHs
    s : A current solution
    f(s): The minimum residual energy of all nodes with solution s
    iter : Number of searches in a round
  Niter : Iteration counter
  s_0 : Best solution so far
Initialization: s_0 ← 0 , iter ← 100 and Niter ← 0
While ( Niter < iter )
        Num_cluster=0;
        While (Num_cluster<k)

            new_node= Random[1...N]
            Num_cluster++;
        δ = f(s) − f(s_0)
        If δ > 0 then s_0 = s
        Niter ++
End While
Result: s_0 is the solution for RE in a round with iter
number of iterations. (End of code)
```

4 Simulation Results

In order to compare the performance of the simple method with the solution of a full search, 50 random 50-node sensor networks are generated. Each node begins with 250,000 units of energy. The energy provides a system lifetime about 100 to 150 rounds. The number of CHs is set to 3. A full-search method requires 50^3 numbers of searches in each round. In each topology, RE with 100 searches in each round and the full search are run and their performances are compared. The network parameters are given below:

Network size $(100m \times 100m)$	
Base station $(50m, 175m)$	
Number of sensor nodes	50 nodes
Position of sensor nodes: Uniform placed in the area	
Energy model: $E_t = \alpha d^2$, where α is set to 1	

The position of sensors on the network is defined in Fig. 2.

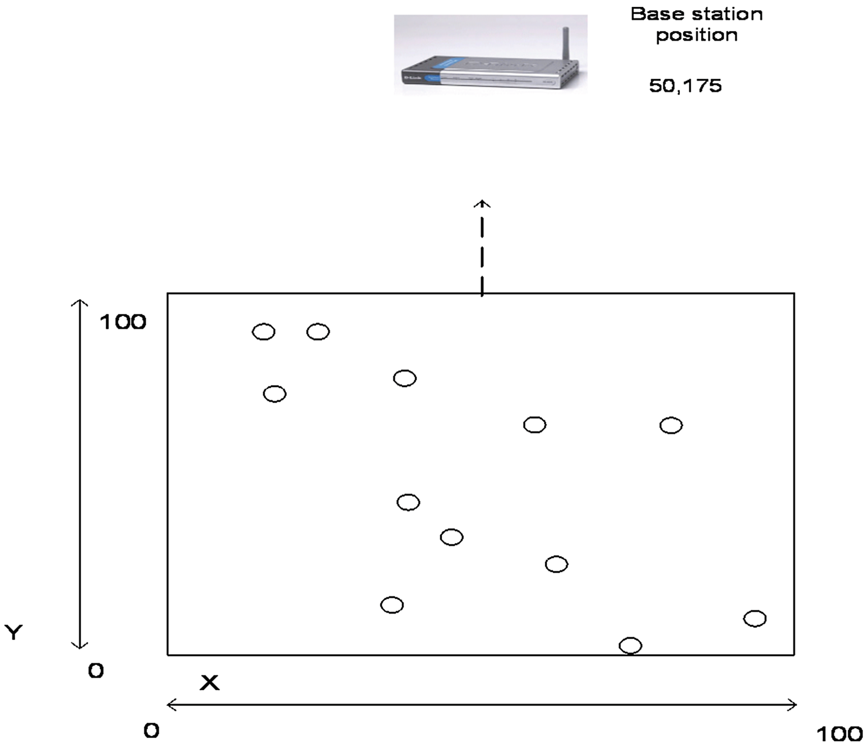


Fig. 2. Definition of sensor positions and base station position in this thesis

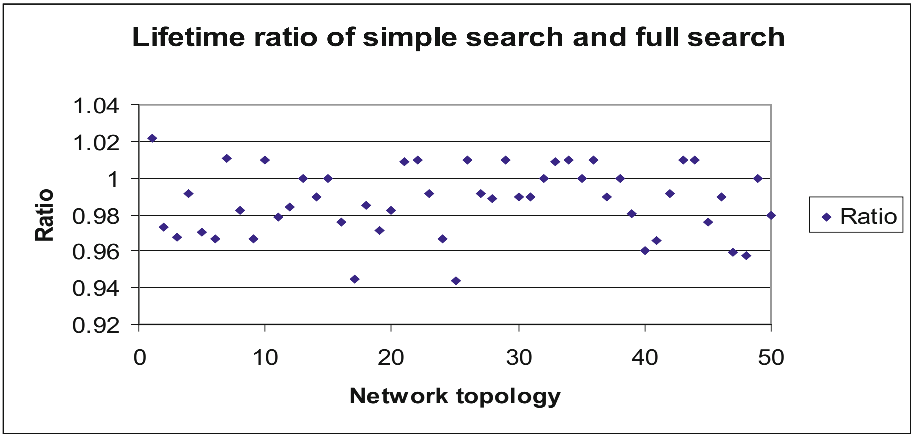


Fig. 3. Ratio of number of rounds between a simple search and a full search

Figure 3 plots the ratio of the lifetime (number of rounds) of RE method and the full search method on the same 100 network topologies. This can be seen from Fig. 4.10 that after from 100 to 150 rounds, the RE method provides almost the same lifetime as the full search method (Table 1).

Table 1. Results for Fig. 3

Mean	0.987
Variance	0.019
90 % confidence interval of the sample mean	(0.983, 0.991)

5 Conclusions

To exploit the function of the sensor networks, sensor nodes are grouped into small clusters so that CH nodes can collect the data of all nodes in their cluster and perform aggregation into a single message before send the message to the base station. Since all sensor nodes are energy-limited, CH positions need to be reallocated among all nodes in the network to extend the network lifetime. Therefore, heuristic algorithms are needed to solve the problem. Heuristic methods consider the lifetime of networks as a number of rounds. Each round is a duration of time to send a unit of data and the CHs are reallocated among all sensor nodes from round to round. First, previous heuristic methods are implemented. Simulation results show that these methods perform quite far from the optimum solution as they do not directly work on the remaining energy of all sensor nodes. A new heuristic method (RE) is then proposed. 100 random 50-node networks are used to evaluate the performance of the methods. Simulations show that RE provides performance very close to the optimum solutions and outperforms previous heuristic methods.

References

1. Nash, S.G., Sofer, A.: Linear and Nonlinear Programming. McGraw-Hill, New York (1996)
2. Kanungo, T., et al.: A local search approximation algorithm for *k*-means clustering. In: Proceedings of the Eighteenth Annual Symposium on Computational Geometry (2002)
3. Arora, S., Raghavan, P., Rao, S.: Approximation schemes for Euclidean k-median and related problems. In: Proceedings of the Thirtieth Annual ACM Symposium on Theory of Computing, Dallas, TX, pp. 106–113, May 1998
4. Kolliopoulos, S.G., Rao, S.: A nearly linear-time approximation scheme for the Euclidean k-median problem. In: Nešetřil, J. (ed.) ESA 1999. LNCS, vol. 1643, pp. 378–389. Springer, Heidelberg (1999)
5. Tung, N.T., Binh, H.T.T.: Base station location - aware optimization model of the lifetime of wireless sensor networks. In: Mobile Networks and Applications (MONET), May 2015. doi:10.1007/s11036-015-0614-3. (SCIE IF 2013 1.496)
6. Tung, N.T.: Energy-aware optimization model in chain-based routing. ACM/Springer Mobile Netw. Appl. (MONET) J. **19**(2), 249–257 (2014). (SCIE IF 2013 1.496)
7. Tung, N.T., Van Duc, N.: Optimizing the operating time of wireless sensor network. EURASIP J. Wirel. Commun. Netw. (2012). doi:10.1186/1687-1499-2012-348. (SCIE IF 2013 0.8), ISSN: 1687-1499
8. Tung, N.T., Ly, D.H., Binh, H.T.T.: Maximizing the lifetime of wireless sensor networks with the base station location. In: Vinh, P.C., Vassev, E., Hinchey, M. (eds.) ICTCC 2014. LNICST, vol. 144, pp. 108–116. Springer, Heidelberg (2015)
9. Tung, N.T., Vinh, P.C.: The energy-aware operational time of wireless ad-hoc sensor networks. ACM/Springer Mobile Netw. Appl. (MONET) J. **18**(3), 454–463 (2013). (SCIE IF 2013 1.496)
10. Tung, N.T., Minh, N.S.: Power-aware routing for underwater wireless sensor network. In: Vinh, P.C., Alagar, V., Vassev, E., Khare, A. (eds.) ICCASA 2013. LNICST, vol. 128, pp. 97–101. Springer, Heidelberg (2014)