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Proposing a Novel Algorithm for Fault-Tolerant Relay Node Placement in Wireless Sensor Networks

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Abstract

Wireless sensor networks are composed of hundreds or thousands of small nodes called sensor that work together and are associated with a specific task or tasks to do. Each of these nodes includes sensor, processor, communication components, a small memory and a source of energy. It is expected that wireless sensor networks will be used widely in many applications in near future. Scalability and lifetime extension in wireless sensor networks are critical issues in designing and implementing a wireless Sensor Network (WSN).Relay Nodes (RNs) in WSN are nodes with higher useful power and radius, which considered as head of network. RNs are able to disseminate data in a higher level, network clusters, and network regions. In this paper, a novel algorithm is proposed to cover all sensor nodes with the least possible RNs. The number of RNs can be calculated through a proposed mathematical function which has the maximum rate of detection. The proposed approach shows high capability for fault tolerance in WSN when compared to other algorithms.

Keywords: *Relay Node, Clustering, Fault Tolerance, Wireless Sensor Networks*

1. Introduction

In network clustering, network sensors which have been introduced as neighbors are placed in a network cluster based on a specific algorithm. This cluster is an intermediate between cluster nodes and sink. The network data directly send to head of cluster or indirectly through other nodes. Each of these network activities in itself consumes specific time and energy. The important issue is that what method should be selected to send data based on lowest time and energy. Although, a series of nodes with higher range and consumption power should be used for this process, the energy consumption in sensor nodes is economized, which resulted in processing load of calculations in sink becomes less. In order to collect optimum data, this paper uses sensor nodes and a series of nodes named relay node. To distribute the data to sink, these nodes placed into a region, which resulted in covering all sensor nodes. One of the important things that should be considered is to use the least number of RNs. Different approaches have been proposed for optimum data dissemination. Each of these approaches covers the region in a manner. Nodes can be expanded in different manners using different algorithm1. This paper aims to present a novel and smart algorithm to cover all sensor nodes with the least number of RNs.

The rest of paper is organized as follows: related work presents in Section 2. Section 3 presents data collection method and its criteria. The proposed algorithm discusses in Section 4. Obtained results, discussion, and comparison of the results presented in Section 5. Section 6 concludes this paper.

2. Related Work

Guowei et al. deal with designing and examination of an algorithm which can select the optimum head of nodes. In case of any error in network clusters, if the error is corrected, the position of cluster-head will be changed. This causes an improvement in the position at the time of creating an error. However, in large scale networks, because of the high possibility of occurring errors in nodes, and as a result, change of head-clusters, too much time and energy are dissipated. Gandhi and Narayanasamy[2] introduced an efficient algorithm to cluster nodes in large scale networks. The performance of this algorithm is based on the region classification into equal parts. Assume that N is the maximum number of nodes in a cluster, the algorithm of the region is as follows:

Step 1: If the no of sensor nodes in the cluster is greater
Than 'N' then partition the rectangular region into four equal quadrants or sub-clusters.
Step 2: For each sub-cluster obtained from the earlier step,
(i) Depth of this cluster is equal to one more than the depth of its super-cluster.
(ii) Repeat Step 1 for this sub-cluster.

This algorithm is an optimum approach to categorize rapidly and fairly, but sending by many intermediators through sensors causes energy dissipation and also in high density it leads to many classifications. Tang et al. [3] proposed a series of nodes called RN in order to have connection with sink. These nodes are disseminated in the network region with a calculated order, so that all network nodes are available in order to connect with RNs, however presence of RNs is the same in crowded and un-crowded areas. Sometimes, RN is considered for nodes which by themselves can be under the cover of adjacent RNs. Heinzelman et al [4] proposed an algorithm, which all nodes were placed in one cluster and data were sent to base station (BS). In Lindsey et al.[5] algorithm, nodes were put in the form of a chain, and each node takes a turn from BS. Some criteria such as density and number of sensor nodes, for dissemination of RN, were explored by Pan et al. [6] and Zhang et al [7] to optimize the cases such as number of RNs and fault tolerance. Misra et al. [8] and Yang et al.[9] examined the definition of some locations as candidate locations and selecting the best location for RN placement.

3. Data Collection Method

In order to collect optimum data from the sensor nodes and distribute them to sink a series of nodes called RN is applied. In this paper, these nodes placed in regions, so that they cover all sensor nodes. The important issue is to use the least number of RNs. Nodes can be expanded in different manners using different algorithm. Assume that each RN radius is two times larger than the sensor nodes, all RNs with this radius can be expanded in region, as shown in Figures 1, 2 and 3.

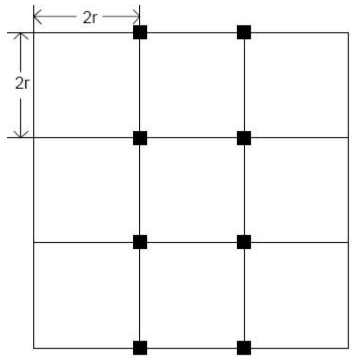

Figure 1. Placement using k=2, 1=1 values

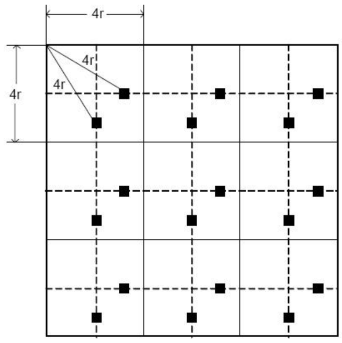

Figure 2. Placement using k=2, 1=2 values

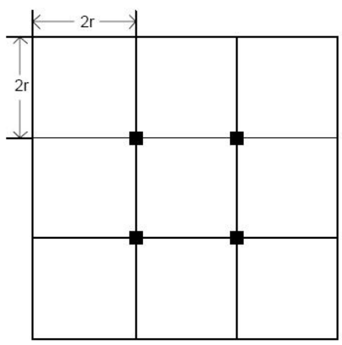

Figure 3. Placement using k=1, 1=1 values

For ignoring the sensor nodes placement in region, RNs can be disseminated this approach in the region. However, to consider the sensor nodes placement in the region, RNs can be disseminated.

As the main aim is to decrease the number of nodes, it may be possible to do not see any especial density of sensor nodes in an area of the region, however according to the proposed algorithm, RN exists in these areas. By considering more criterions, that is sensor nodes locations, the new and smart algorithm is proposed.

4. The Proposed Algorithm to Optimize the Number of RNs

The main aim of this study is to optimize the number of RNs using new criterion. This criterion is the manner of sensor nodes arrangement in regions.

Furthermore, unnecessary interactions between RNs are decreased using quad-tree approach to cluster. In the proposed algorithm, the work begins with placement of a RN in the middle of region. Then the region is divided into four equal parts by divide and conquest approach, while RN is in the center. Each of these four parts in itself is considered a separate region and at least one sensor node will repeat the same steps in that region. The proposed algorithm presented as follow:

```
Sub-region ALGORITHM(region){
int count:=0;
int threshold=N
if region is empty from sensor node then
        Do nothing;
else
        Divide region in four sub region;
For each (sub-region in region){
Count ++;
While (count <threshold )   {
        If (there is any sensor node in the region)
ALGORITHM(sub-region);
        Break;   }
Place a relay node in the center of sub-region
}
```

The main disadvantage of the algorithm presented in [3] is the impact of sensor nodes density on hops of division and as a result on the number of clusters, as the number of sensor nodes is the only criterion to make decision on moving to the next hop of division, and in case of facing a high density of nodes, many numbers of nodes are in the unit of area, many divisions are needed, which is a time-consuming process.

In the proposed algorithm, the presence of sensor nodes is a criterion, which causes high or low density has no effect on the hops of division. Hops are controlled by a threshold value. The threshold value does not allow excessive divisions in the hops, as shown in Figures 4 to 7.The threshold value has its own criteria, which depends on the size of region.

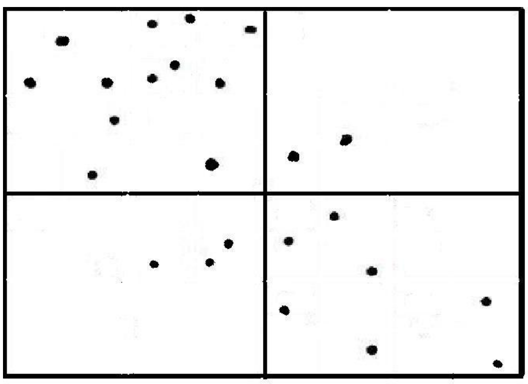

Figure 4. First hop of algorithm

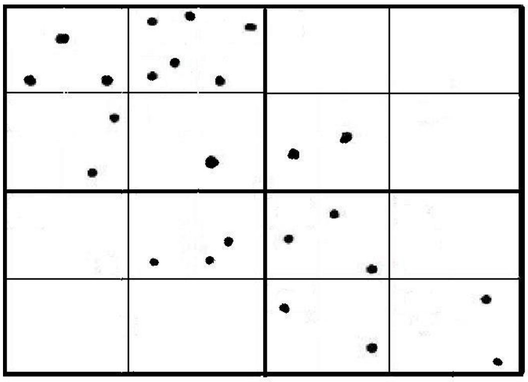

Figure 5. Second hop of algorithm

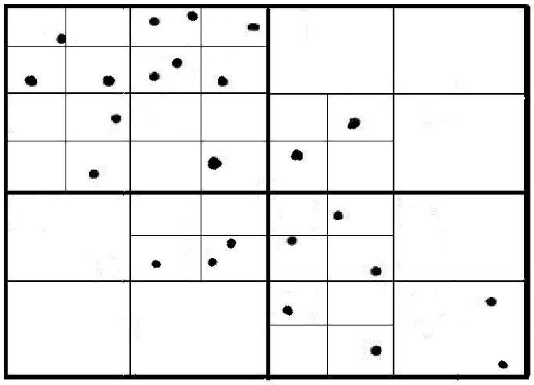

Figure 6. Third hop of algorithm

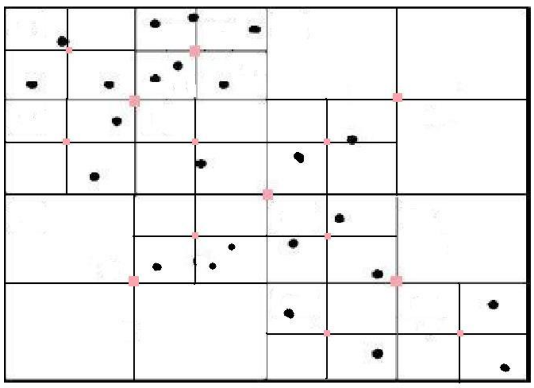

Figure 7. Forth hop of algorithm

During dividing the region into the equal parts, the path should be defined with high precision. If the threshold value is low, it is possible the sensor nodes not covered. Also, if the threshold is very high because of conflict between RNs, it is possible that one or more RNs are placed, while the most part of area are covered by other RNs that have no regions. In order to avoid such problems, threshold value will be used. Threshold value depends on RN radius and the region size, which calculated by the following algorithm.
Assumptions:

r: RN Radius
D: size of the region side

Algorithm:

```
intThreshold_Value () {
q=r * 2;
While (d>=q)
{
d=d / 2;
threshold + +;
}
Return threshold;
}
```

5. Results and Discussion

In order to evaluate the proposed algorithm, data were collected, the number of RNs in different size of regions was calculated, and the amount of necessary RNs in proposed algorithm in the worst case was determined. Also, the number of RNs was calculated by defined function in Equation 1. This function can be used to determine the number of RNs.

$$\begin{cases} t_n = 1 & \lceil \log_2^n \rceil \le 2 \\ t_n = t_{n-1} & \lceil \log_2^n \rceil = \lceil \log_2^{n-1} \rceil \\ t_n = 4t_{n-1} + 1 & \lceil \log_2^n \rceil > \lceil \log_2^{n-1} \rceil \end{cases} \quad (1)$$

The obtained results from proposed algorithm are compared with other algorithms as shown in Figures 8 to 10.

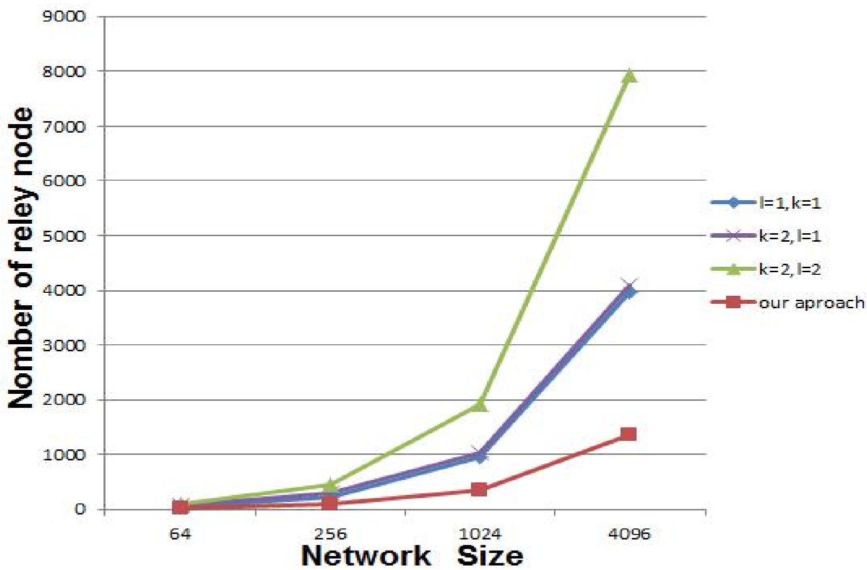

Figure 8. The graph related to the number of RNs in different sizes of region

The main idea in the proposed algorithm is to use divide and conquest approach and divide the problem into four parts, in order to decrease the calculation time in the algorithm. Compared with Figure4, the number of RNs has also been decreased.

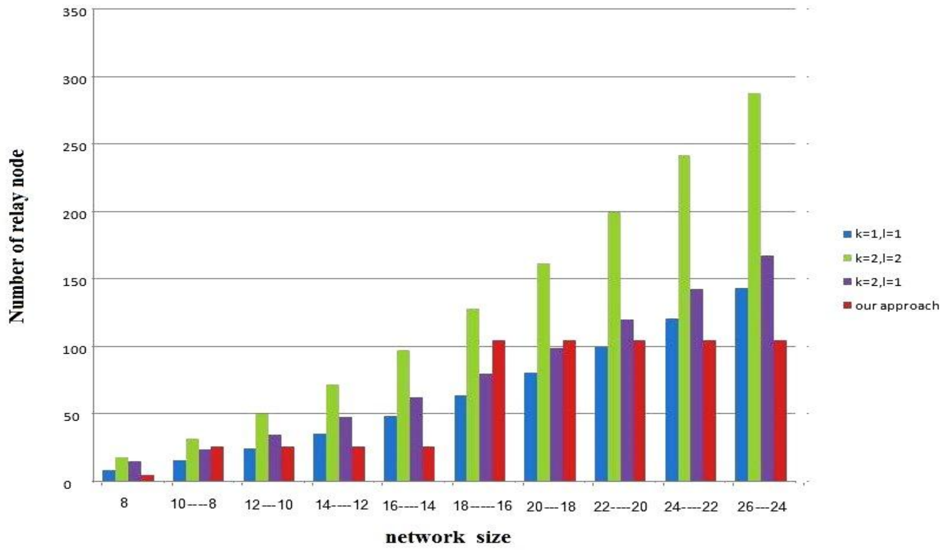

Figure 9. The comparison of the proposed algorithm with algorithm [3]

The proposed algorithm has more advantages when compared with algorithm in [2]. According to the obtained results, due to optimum decrease in the number of RNs, the proposed algorithm is significantly better than algorithm in [3].

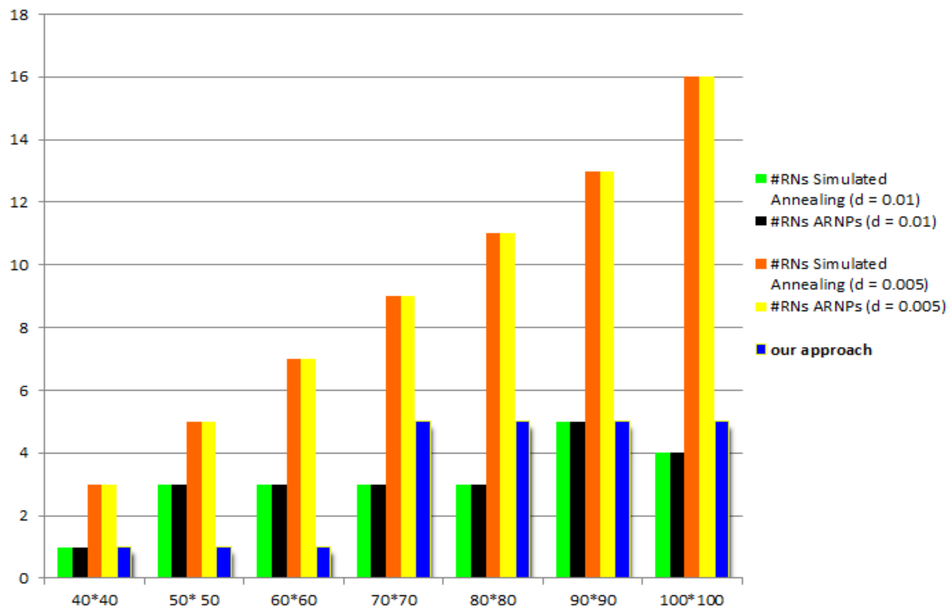

Figure 10. The comparison of the proposed algorithm with algorithm [9]

6. Conclusions

This paper aimed to present a novel and smart algorithm using more criteria to optimize the energy consumed by sensor nodes and also to decrease optimum data and the number of RNs, which communicate to sink. The first advantage of the proposed algorithm is that, in high density of sensor nodes, the performance of division algorithm depends on distance and not on the number of nodes, which leads to a significant increase in the number of RNs. The second advantage is that the proposed algorithm provides high level of fault tolerance, as sensor nodes are covered by RN, also in case of any problem for each of the nodes, no problem will be occurred in the nodes' communications. The proposed algorithm can decrease the number of RNs and increase fault tolerance in WSN, without any decreasing in the coverage area.

7. References

[1]. W. Guowei, L. Chi, Y. Lin, L. Bing. "A Cluster Based WSN Fault Tolerant Protocol", Journal of Electronics (China), Vol. 27, No. 1, 2010, pp.43-50

[2]. K. I. Gandhi, P. Narayanasamy. "A Cluster-Based Quad-Tree Partitioning for Scheduling the Mobile Element in Wireless Sensor Networks", International Journal of Wireless Information Networks, Vol. 18, No. 1, 2011, pp. 50-55.

[3] J. Tang, B. Hao, A. Sen. "Relay node placement in large scale wireless sensor networks", Computer Communications, Vol. 29, No. 4, 2005, pp. 490-501.

[4] W. R. Heinzelman, A. Chandrakasan, H. Balakrishnan." Energy Efficient Communication Protocols for Wireless Micro sensor Networks", Proceedings of the 33rd Hawaii International Conference on System Sciences, 2000.

[5] S. Lindsey, C. Raghavendra, M. Sivalingam. "Data Gathering Algorithms in Sensor Networks Using Energy Metrics", IEEE Transactions on Parallel and Distributed Systems, Vol. 13, NBo. 9, 2002, pp. 924-932.

[6]J. Pan, Y.T. Hou, L. Caiy, Y. Shiz, S.X. Sheny. "Topology Control for Wireless Sensor Networks", Mobicom'3, 2003, pp. 286-299.

[7] W. Zhang, G. Xue, S. Misra. "Fault-Tolerant Relay Node Placement in Wireless Sensor Networks": Problems and Algorithms, IEEE INFOCOM, 2007, pp. 1649-1657.

[8] S. Misra, S.D. Hong, G. Xue, J. Tang. "Constrained Relay Node Placement in Wireless Sensor Networks to Meet Connectivity and Survivability Requirements", IEEE INFOCOM 2008, the 27th Conference on Computer Communications, 2008, pp. 281-285.

[9] D. Yang, S. Misra, X. Fang, G. Xue, J. Zhang. "Two-Tiered Constrained Relay Node Placement in Wireless Sensor Networks": Efficient Approximations, IEEE SECON, 2010, pp. 323-331.