MISR: Multiple Inheritor Selection for Recovery of Nodes in Faulty Cluster in Wireless Sensor Networks

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Abstract

A wireless sensor network composed of many sensor nodes which are used to monitor unavailable and harsh environments. Because these nodes are too small and battery operated which have limited energy, faults may occur. Fault tolerance is one of the most important issues in wireless sensor networks and must be increased as much as possible to avoid faults. In wireless sensor networks which use clustering architecture, the role of cluster head is very important and critical and fault tolerance in cluster head must be increased. Different approaches for increasing fault tolerance and fault management presented that have advantages and disadvantages. An approach for fault management in cluster head is to recover members of faulty cluster with specifying new cluster head for them. In this paper a new recovery algorithm based on inheritor selection is proposed. Previous algorithms do cluster head selection when each fault occurs but the proposed algorithm does this selection once and can select cluster head rapidly and without too much calculation. Simulations results show that the proposed algorithm has better performance in contrast to previous algorithms.

Keywords: *Sensor Networks, Clustering, Recovery, Fault Management*

1. Introduction

Recent advances in wireless communications and microelectro-mechanical systems have motivated the development of extremely small, low-cost sensors that possess sensing, signal processing and wireless communication capabilities. Wireless Sensor Networks (WSNs) have attracted a lot of recent research interest due to their applicability in security, monitoring, disaster relief and environmental applications [1] WSNs consist of a number of low-cost sensors scattered in a area of interest and connected by a wireless RF interface. To keep the cost and size of these sensors small, they are equipped with small batteries that can store at most 1 Joule [8]. Sensors gather information around themselves and the monitored area and send these information to an external node known as the base station [2]. Deployment of nodes can be done randomly or in a predetermined manner [3]. Also deployment process can be done with help of autonomous robots [4]. Clustering is a technique that divides nodes in groups called cluster and chooses one node as cluster head [5-7]. Nodes send collected data to cluster head and cluster head aggregates these data and send data to base station. Cluster heads may be homogenous or heterogeneous. Cluster head has a critical task and if it fails the nodes of corresponding cluster cannot send their data to base station.

Fault tolerance is the ability of a system to deliver a desired level of functionality in the presence of faults [8]. Since the sensor nodes are prone to failure, fault tolerance should be seriously considered in many sensor network applications. Actually, extensive work has been done on fault tolerance and it has been one of the most important topics in WSNs.

Five levels of fault tolerance were discussed in [9]. They are physical layer, hardware layer, system software layer, middleware layer, and application layer. First step in fault tolerance is fault detection. It is to detect that specific functionality is faulty, and to predict it will continue to function properly in the near future. After the system detects a fault, fault recovery is the second step to enable the system to recover from the faults. In this paper a new algorithm for recovery of nodes in faulty cluster with considering distance and residue energy.

The rest of this paper organized as follows: in section II others related works that exist in literature is discussed, section III explains the proposed algorithm, simulation and evaluation of proposed algorithm is presented in section IV and section V concludes the paper.

2. Related Works

In this section, we review the related works in the area of fault detection and recovery in wireless sensor networks. Many researchers studied fault management, fault detection and recovery [13-15]. In [16], a failure-detection algorithm that uses management architecture for WSNs called MANNA is proposed and evaluated. However, this approach requires an external manager to perform the centralized diagnosis and the communication between nodes and the manager is too expensive for WSNs. Some other algorithms employ mobile sensor nodes to replace the faulty sensors and heal coverage and connectivity holes. A method to use mobile robots to assist sensor replacements for the failed sensor nodes proposed in [17].

In [12] a method to detect energy failures in the nodes and reporting it to the respective members of the clusters reported. This detection is essential for the cluster members as they have to start the mechanism for the recovery of those failures. Every node has a record of its energy and the nodes in each cluster send their energy status as a part of the hello message, to their first hop members including their parent. The hello message consists of the coordinates, energy and node ID. This hello message illustrates the current energy status of the node. When the node is failing, it sends the failure report message to its parent and children. A node is termed as failing when its energy level drops below the threshold value.

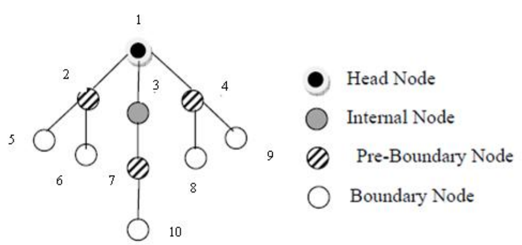

Fig. 1 Cluster Topology in Venkataraman

Consider example in Fig. 1 assume that node 7 is failing, and then it sends a fail report_msg to node 3, its parent and node 10 its child. In this work they deal with failures related to energy exhaustion, and therefore they assume that the failing node can send the failure report to its immediate hop members before it dies completely. This information of the failure report is an indication to start the failure recovery process. The children of the failing cluster-head exchange their energy status. The healthy child with the maximum residual energy is selected as the new cluster-head. After the new cluster-head is selected, the other children of the failing cluster-head are attached to this new cluster-head and the new cluster-head becomes the parent for these children.

In [10] Akbari et al. proposed a mechanism for recovery of nodes in faulty cluster that determines a node as secondary cluster head and if fault occurs in main cluster head, the secondary cluster head changes its role and acts and main cluster head and chooses another node as secondary cluster head. Every time a fault occurs this process repeats.

3. Proposed Algorithm

Most of previous works only determined distance for recovering nodes and it can affect energy consumption and death of cluster heads because it may happen that a node be recovered to a cluster head that has least distance to it but with low energy. Also in previous works each time a cluster head dies the inheritor selection is repeated. In this paper a new algorithm for selecting inheritors is proposed that determines energy and distance to recover nodes from faulty cluster. After clustering is done the cluster head queries information of nodes and each node calculates its rank according to equation 1 and sends it to cluster head.

$$\text{Rank}(i) = \frac{\left(A \times \frac{1}{(\text{distance}\ (i,ch))}\right) + (\text{residueE}\ (i))}{\sum_{j=1}^{n} \left(A \times \frac{1}{(\text{distance}\ (j,ch))}\right) + (\text{residueE}\ (j))} \qquad (1)$$

In equation 1, distance(I,ch) is the distance between node I and the cluster head, residueE(i) is the residue energy of node I and A is a constant to adjust impact of distance against energy.
Cluster head chooses his inheritors according to majority of ranks and broad cast inheritor list to all nodes. If cluster head dies all members of cluster know its inheritor and send their data to that node.

4. Simulations and Results

A 20m in 20m environment determined for simulation and 200 nodes with 0.5 joule initial energy scattered randomly in this environment. 20 cluster heads deployed in environment too. Simulation parameters are presented in table 1.

Table 1: Simulation Parameters

parameters	value
E_{TX}	50nj
E_{RX}	50nj
E_{fs}	10pj
E_{amp}	0.013pj
E_{DA}	5nj
Packet size	6400
Control Packet size	200
Sensing range	2m

After deployment of nodes, clustering is done with considering distance of nodes from cluster heads. For fault injection 3 faults occurs about time 2000, 4000, 6000. Fig. 2 shows the environment and faults. Nodes from faulty cluster heads specified with different colors.

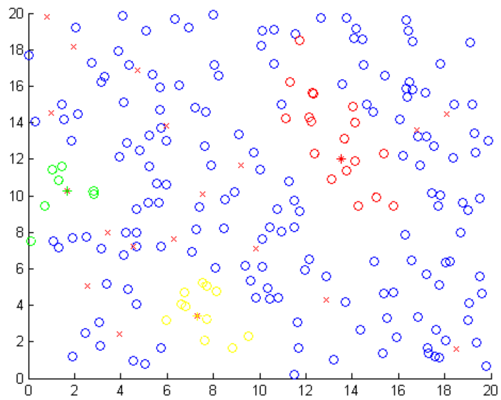

Fig. 2 Field and Fault Injection

Recovery of nodes done via proposed algorithm and each node assigned to inheritor of cluster heads. Fig. 3 shows this recovery.

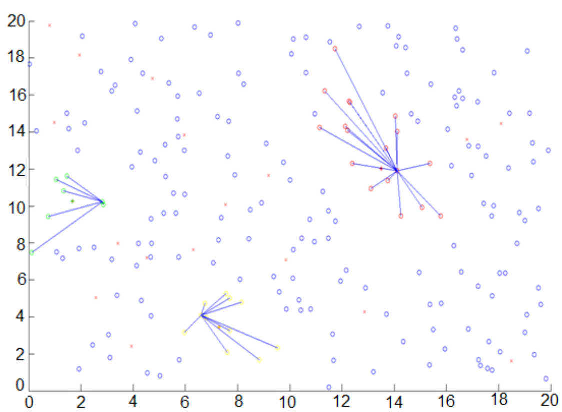

Fig. 3 Fault Recovery

To compare proposed algorithm to Akbari et al [10] each 500 seconds number of cluster heads recorded. Fig. 4 shows this comparison.

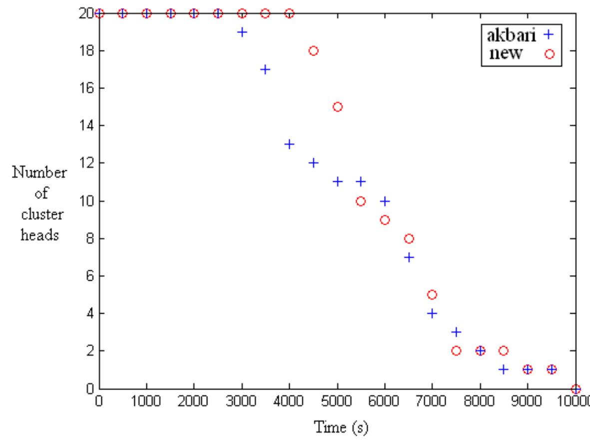

Fig. 4 Comparison of Alive Cluster Heads

Also the average energy of nodes calculated and graphed in fig. 5 for proposed algorithm and Akbari et al [10]. As can be seen in fig. 5 proposed algorithm has better energy consumption and it can balance energy consumption due to better recovery.

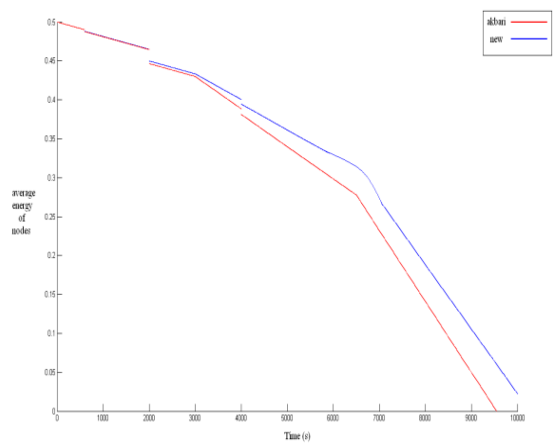

Fig. 5 Comparison of Energy Consumption

In second experiment a larger environment determined and a 50m in 50m field used to study the performance of proposed algorithm. Here because the distance of nodes are more than previous experiment we used a=10 to increase the effect of distance against energy. Fig. 7 shows this experiment and mean energy of nodes in contrast to Akbari et al [10]. Fig. 6 shows comparison of energy needed for recovery.

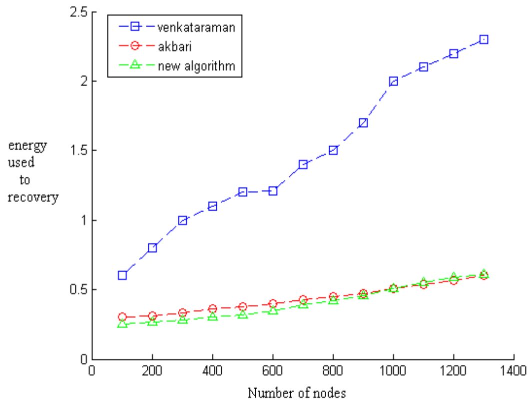

Fig. 6 Comparison of Energy Used to Recovery

Simulation result shows that before occurring faults and recovery of nodes, both algorithms have same energy consumption but after recovery due to better assign of inheritor and less calculation for selection proposed algorithm has better performance as energy balancing and life time prolonging.

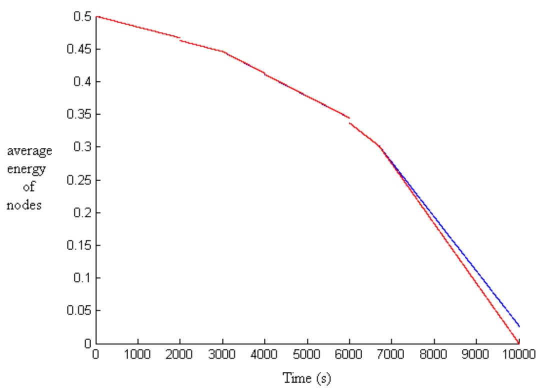

Fig. 7 Comparison of Energy Consumption in a Larger Area

5. Conclusions

In this paper a new algorithm for recovery of nodes from faulty cluster with considering energy and distance proposed. Evaluation of proposed algorithm done via simulation and simulation results show that proposed algorithm has better performance as fault tolerance and prolonging network life time when faults occur. As future work considering more parameters can be used.

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References

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam & E. A. Cayirci, survey on sensor networks: *IEEE Communications Magazine*, 2002, pp. 102–114.

[2] A. Bharathidasas & V. Anand, Sensor networks: An overview, *Technical report, Dept. of Computer Science*, University of California at Davis, 2002.

[3] K. Sohraby, D. Minoli & T. Znati, Wireless Sensor Networks Technology Protocols and Applications, 2007.

[4] F. Nematy, A. M. Rahmani, M. Teshnelab & N. Rahmani, "Ant Colony Based Node Deployment and Search in Wireless Sensor Networks", International Conference on Computational Intelligence and Communication Networks (CICN), 2010, pp. 363 – 366.

[5] S. Rasouli Heikalabad, A. Habibizad Navin, M. K. Mirnia, S. Ebadi & M. Golesorkhtabar, "EBDHR: Energy Balancing and Dynamic Hierarchical Routing algorithm for wireless sensor networks", IEICE Electron. Express, Vol. 7, No. 15, 2010, pp.1112-1118.

[6] W.R. Heinzelman, A.P. Chandrakasan & H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks", IEEE Transactions on Wireless Communications 1(4) 2002, pp. 660–670.

[7] M. Golsorkhtabar, M. Hosinzadeh, M. J. Heydari & S. Rasouli, "New Power Aware Energy Adaptive protocol with Hierarchical Clustering for WSN", International Journal of Computer and Network Security, Vol. 2, No. 4, 2010, pp.38-40.

[8] J. M. Kahn, R. H. Katz & K. S. J. Pister, "Next Century Challenges: Mobile Networking for Smart Dust", in the Proceedings of 5th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom 99), Aug. 1999, pp. 271-278.

[9] F. Koushanfar, M. Potkonjak,& A. Sangiovanni-Vincentelli, "Fault Tolerance in Wireless Sensor Networks," in Handbook of Sensor Networks, I. Mahgoub and M. Ilyas (eds.), CRC press, Section VIII, no. 36, 2004.

[10] A. Akbari, A. Panah, O. Panah, & N. BeikMahdavi, Self healing by clustered in wireless sensor networks, *World applied sciences journal 13(4)*, 2011, pp. 909-915.

[11] K. L. Man, C. Chen, & D. Hughes, Decentralized Fault Detection and Management for Wireless Sensor Networks, *Future information technology*, 2010, pp. 1-6.

[12] G. Venkataraman, S. Emmanuel, S. Thambipillai 'DASCA: a degree and size based clustering approach for wireless sensor networks'. Proc. IEEE, Int. Symp. Wireless Communication Systems, Siena, Italy, September 2005, pp. 508–512.

[13] Z. ZHOU, S. DAS, H. GUPTA, 'Fault tolerant connected sensor cover with variable sensing and transmission ranges'. Proc. IEEE Sensor and Ad Hoc Communications and Networks, Santa Clara,USA, September 2005, pp. 594-604.

[14] M. DING, D. CHEN, K. XING, X. CHENG, 'Localized fault-tolerant event boundary detection in sensor networks'. Proc.

[15] MENG x., NANDAGOPAL T., LI E., LU S. 'Contour maps: monitoring and diagnosis in sensor networks', Proc. In!. J. Comput. Telecommun. Netw, 2006, 50, (15), pp. 2820-2838.

[15] X. MENG, T. NANDAGOPAL, E. LI, S. LU, 'Contour maps: monitoring and diagnosis in sensor networks', Proc. In!. J. Comput. Telecommun. Netw, 2006, 50, (15), pp. 2820-2838.

[16] L. B. RUIZ, I. G. SIQUEIRA, L. B. OLIVEIRA, H. C. WONG, J. M. S. NOGUEIRA, A. A. F LOUREIRO, 'Fault management in event-driven wireless sensor networks'. Proc. 7th ACM Int. Symp. Modeling, Analysis and Simulation of Wireless and Mobile Systems, Venice, Italy, October 2004, pp. 149-156.

[17] Y. Mel, C. XIAN, S. DAS, YC. HU, Y. H. LU, 'Repairing sensor networks using mobile robots'. Proc. ICDCS In!. Workshop on Wireless Ad Hoc and Sensor Networks, Lisboa, Portugal, July 2006.