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Increasing Reliability in Wireless Sensor Networks by Recovering Nodes in Faulty Clusters

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Abstract: Distributed sensor networks have received significant attention in military and civil application. Sensors have on-board energy supply. Efficient management of the network is an important. Thus issue for the life time of the system. Because of resource limitation in sensor nodes and using them in unavailable and harsh environments, any fault occurrence is common. Since fault in cluster-heads cause disorder in leading the packages and the nodes belonging to that cluster head become unavailable and re-clustering must done to solve this problem, which wastes the energy. In this paper, we present a method for recovery the nodes of faulty cluster-head. Simulation results show that our method has better performance than previous methods of re-clustering.

Key words: Wireless Sensor Network, Reliability, Cluster-Head, Recovery, Clustering.

INTRODUCTION

Wireless sensor network includes a lot of sensor nodes that spread in a defined limit for supervising environment events and sense the environment. For economizing the consumed energy, clustering is done. Clustering is one of the routing techniques in these networks that prevent the repetitious transmission of data by dividing nodes to various clusters and by choosing one cluster-head for each cluster, and decreases the energy consumption of nodes. Nodes of each cluster send their data to cluster-head and cluster-heads send data after aggregating them to base station that is called sink (Akyildiz, 2002).

Most important the applications of wireless sensor network are military, civil projects, border guarding, settlement and etc. (Xia, 2008; Karaki, 50011). Basically each node includes one sensor unit, communication unit, processing and energy unit and can consist of other elements like energy generator and position finding system (Karaki). Energy consumption, coverage, deployment, security, reliability, fault-tolerance, routing, etc. are discussed in wireless sensor networks (Mainwaring, 2002). One of the important issues in wireless sensor network is energy consumption that uses clustering for decreasing the energy consumption and increasing the life time and simplifying the routing (Heinzelman, 2000; Younis, 2004; Smaragdakis, 2004).

Though clustering has many advantages, existence of only one cluster-head cause bottle neck problem, that is, any fault in cluster-head cause unavailability in cluster nodes. To solve this problem, re-clustering must be done that wastes the energy and time in network. As another solution we can place redundant cluster-heads in the system, so we can replace the cluster-heads when a fault occurs. In this paper, we investigate the dependability of wireless sensor networks in the cluster-heads. The rest of the paper organized as follows: in section 2, we discuss about clustering and faults in cluster-heads. Section 3, describes the new method, and the evaluation of proposed method is shown in section
4. Conclusion is presented in section 5.

2. Related Works:

Our work has been influenced by several researches in sensor network domain. Projects such as Smartdust (Golsorkhtabar, 2010) WINS (Kahn, 1999), PicoRadio (Burnstein, 1996) have given different views to the abilities of sensors. Since sensor nodes are constrained in energy supply and bandwidth, a lot of research groups have concentrated on points such as energy aware routing (Burnstein, 1996) and energy consumption (Cerpa, 2002; Chen, *et al.* 2001).

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Various clustering methods have been presented for effective selection of a cluster-head like random method (Rabiner Heinzelman, 2000) or highest degree of connection (Parekh, 1994; Dugan, 1989).

Also, these methods do not concentrate on reliability and fault-tolerance of the network. When a fault occurrence in a cluster-head either the role is assigned to another node that needs re-configuration of the network or redundant hardware is used as replacement.

In clustering method, nodes are divided into groups that are called cluster. A node is considered as cluster-head for each cluster that other nodes send the sensed data to cluster-head and cluster-head sends data to base station after aggregating them. Any failure or fault in the cluster-head become unavailable the cluster nodes and re-clustering must be done that it is not efficient (Estrin, 1999). To solve this problem, a recovery mechanism can be used, that is, spread the nodes of the faulty cluster among neighbor clusters (Gupta, 2003). To assign a node to neighbor cluster-head, its distance with neighbor cluster-heads are computed and any node is assigned to nearest cluster-head.

To place a node like S_j in a cluster-head, the following equation is used:

$$s_j \; \varepsilon \; RSet_{Gi} \leftrightarrow [(R_{Gi} > d_{sj-Gi}) \, \Lambda \, (R_{sj,\max} > d_{sj-Gi})] \tag{1}$$

Where, S_j is a node must be recovered, R_{Gi} is the communication range of cluster-head G_i, $R_{sj,max}$ is the maximum range of node s_j and d_{sj-Gi} is the distance between node s_j and cluster-head G_i. Also in this paper, we assume that cluster-heads are connected and can interchange data. In distinct time intervals cluster-heads broadcast messages which show that each cluster-head is alive. As showed in Fig. 1, all of the cluster-heads are in direct connection with each other and broadcast their status. Since all cluster-heads are in direct connection, each cluster-head will receive the status and know that none of the cluster-heads are destructed.

Each cluster-head receives a status data from other cluster heads and stores 1 in the related part of a table. For example, for Fig. 1 the related table is showed as table 1.

If the cluster head doesn't receive a message, put number zero in the table. If all of the cells of a cluster head are zero, shows that cluster-head is destructed and the recovery that explained above must be done. For example, assume the cluster-head G4 as showed in Fig. 2, has been destructed and connection links between cluster-heads have been removed, so the table changes as table 2.

For example: G1, G4 cell in table2 is 0 that means there is no link between them.

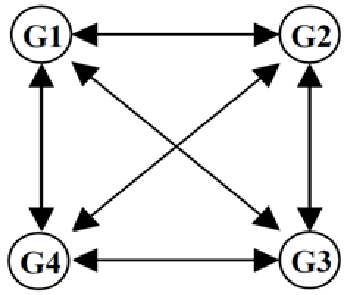

Fig. 1: Connection of cluster-heads (Gupta, 2003).

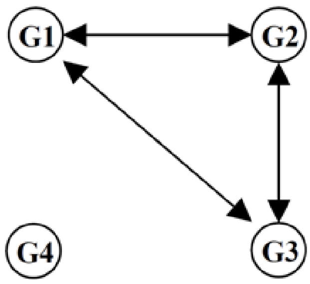

Fig. 2: Cluster-heads after destruction in cluster-head G4 (Gupta, 2003).

Table 1: Status of cluster-head (Gupta, 2003).

	G1	G2	G3	G4
G1	√	1	1	1
G2	1	√	1	1
G3	1	1	√	1
G4	1	1	1	√

Table 2: Status of cluster-heads save in table after occurrence of fault in cluster-head G4 (Gupta, 2003).

	G1	G2	G3	G4
G1	√	1	1	0
G2	1	√	1	0
G3	1	1	√	0
G4	0	0	0	0

3. Recovery with Assuming to Distance and Energy:

In section 2, the recovery method with assuming to distance of node and cluster-head is explained. The problem of this method is that in choosing the cluster-head, only its distance with specified node is considered, whereas remained energy of a cluster-head is an important parameter. If a node assigns to a cluster-head with low energy, possibly after short time, cluster-head's energy will finish and it will destruct and again we need recovery. For solving this problem, in choosing a cluster-head both distance from cluster-head, and remained energy of cluster-head must be considered. For a node to be a member of cluster-head, the nod should be satisfied in the following conditions.

$$R_{(Chi)} > d(S_j, ch_i) \Lambda (R_{(Sj)} > d(S_j, ch_i) \qquad (2)$$

For which $R_{(Chi)}$ is the range of cluster-head that recovered node connect to it, $d_{(Sj,chi)}$ is the distance of nod S_j and cluster-head ch_i and ch_i is *cluster-head*$_i$ that node S_j is added to it.

Among cluster-heads that satisfy in above conditions, a cluster-head is chosen that has the highest energy and the least distance.

$$\text{MAX } (E\ (ch_i) / d\ (s_j, ch_i) \qquad (3)$$

E (ch_i) is the energy of *cluster-head*$_i$

4. Experimental Results:

For evaluation of the presented method, some simulations are done in the MATLAB. As shown in Fig. 3, in first simulation we assumed a 10*10m environment and 100 nodes spread in environment randomly.

Each of them has the initial energy of one joule, also, 16 cluster-heads were assumed for this simulation that each has initial energy and connection range of 3 meters. Furthermore, each node as randomized give a data for sending and the cost of each send is assumed $1*10^{-3}$ joule. Then, during random intervals, fault occurs in the cluster-heads and because of this fault; re-clustering mechanism and recovery are done. As we expected, the simulated results shows in Fig. 3 that the presented method has better efficiency and less energy consumption than re-clustering method. Also, we repeated the experiment in 20*20m environment and with 250 nodes with 22 cluster-heads; also in this experiment, our method results showed better efficiency than re-clustering method. The results of this experiment are shown in Fig 4.

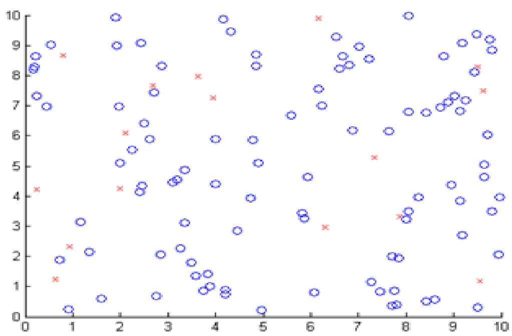

Fig. 3: Random deployment of nodes in 10*10 environment.

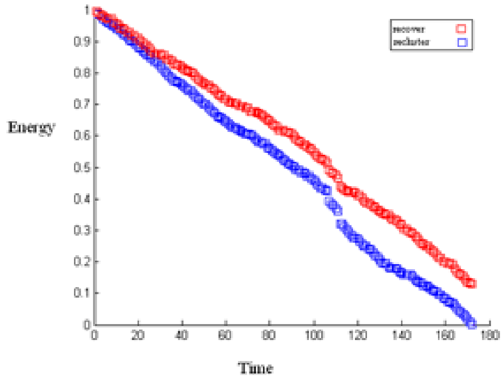

Fig. 4: Diagram of mean energy of nodes in 10*10 environment with 100 nodes and 16 cluster-heads.

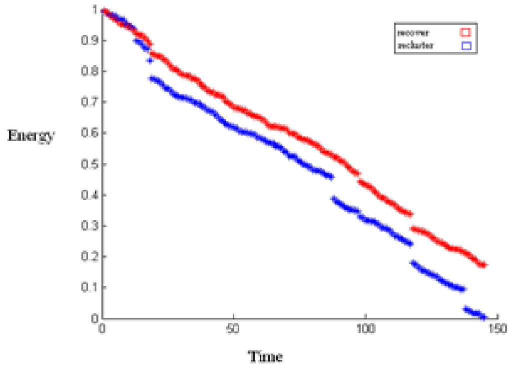

Fig. 5: Diagram of mean energy of nodes in 20*20 environment with 250 nodes and 22 cluster-heads.

Conclusion:

In this paper, we proposed a new recovery method for increasing the reliability in wireless sensor networks in which the criterion of recovering nodes was assumed as a function of distance and energy. The results of simulations show that the proposed method has better performance and less energy consumption than re-clustering method. Also, its efficiency is better than previous methods of re-clustering.

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