International Research Journal of Applied and Basic Sciences

ISSN 2251-838X / Vol, 8 (9): 1276-1282
Science Explorer Publications

Fault-tolerant in wireless sensor networks using fuzzy logic

Sara Behzadi[1], Mohammad Azad[2]

1. Master student of Computer Software, Islamic Azad University, Science & Research Branch, saveh,
2. Faculty member, Islamic Azad University, Science & Research Branch, saveh,

Corresponding author email: srbehzadi@yahoo.com

ABSTRACT: A wireless sensor network with a large number of sensors to monitor the disposal of hazardous and inaccessible environments, placed. Sensors in wireless sensor networks due to energy depletion, hardware failure, software, and communication link errors, … may be damaged or fail. Thus, fault tolerance is one of the most important requirements for wireless sensor networks is considered. Fault tolerance means that In case of deterioration of sensors, network will continue to work correctly, without failure impact on network performance. In this paper, we propose algorithm for increasing fault tolerance Using fuzzy logic in wireless sensor networks. In the proposed algorithm, When the sensor is broken, The space covered by the sensor without cover remains and This space is lost due to sensor failure, by neighboring sensors faulty sensor are covered. the case that at each step of the algorithm, A neighbor of a faulty sensor that has a higher priority, to cover the lost space due to sensor failure is selected and it moves toward. To calculate prioritize neighbors, from fuzzy logic is used. Neighbor priority is based on the distance to the neighboring sensor faulty sensor, the distance to cluster heads, the amount of remaining energy and the amount overlapping sensing range neighbors sensors is determined. Then we compare the proposed algorithm with the algorithms FBFT, FTO, WCPZ. simulation results show that the proposed algorithm in terms of the motion sensors in the environment, fault-tolerant time, the amount of coverage has been better than the previous algorithm.
Keywords: wireless sensor networks, fuzzy logic, coverage, fault tolerance.

INTRODUCTION

Wireless sensor networks are a new technology of today's leading technologies. Recent developments have provided in electronics and wireless telecommunication, sensors design and construction of sensors with small size, reasonable price, low energy expenditure. The networks, Limitations, attributes and their own operational environment, which makes them different from the same samples. Wireless sensor network consists of many sensors, these sensors distributed in the environment and to pay environmental data collection. Information is collected by a sink and commands from the sink (node with a high energy level and equipment is required, the interface between the sensors and the end-user) is published; Sink connects with task manager by satellite link or Internet. Wireless sensor networks have many applications in field medical, military, environmental monitoring, prevention from disaster and … ; For this reason, It has been paid attention by many researchers in recent years [1, 2]. Due to limitations in sensor networks, hardware failure and other environmental factors … is possible some of the sensors are faulty; Failure of sensor nodes should not affect the network performance, This feature is considered as fault tolerance in the network; Currently faulty sensor detection mechanism and at the higher levels, fault

tolerance in sensor networks is considered as one of the important aspects of research. In this paper, we examined fault-tolerant from the viewpoint of coverage sensor network that Sensor failure have the least impact on the performance.

Then the paper is organized as follows: In part 2 we will review the work done in the field of fault-tolerant, in section 3 we explain the specifications of sensors, In Section 4 we describe the proposed algorithm, In section 5 we explain the simulation results and In section 7 we will raised the conclusions.

Literature review

Farzadnia and colleagues (2011) algorithm FTO[1] [3] offered. When a sensor is faulty, at each step of the algorithm execution, one of Neighbors faulty sensor for movement and cover the lost space due to sensor failure, is chosen. Neighboring sensor selection, based on neighbor distance of faulty sensor and overlapping sensing range each neighbor is doing with its neighbors; According to the contents explained, priority neighbors for selection according to equation (1) can be calculated.

$$priority(s_m) = \left(\sum_{i=1}^{n} overlap(s_m, s_i) \right) \Big/ d(s_m, s_f) \qquad \text{equation (1)}$$

In equation (1), neighbor sensor Priority (s_m) is calculated while it has n neighbors. sensor s_f is faulty, $d(s_m, s_f)$ shows the distance between faulty sensor and neighbor sensor, $\mathrm{overlap}(s_m, s_i)$ shows the amount overlapping sensing range neighbor sensor s_m and neighbor i.

When the sensor is faulty, the part of the area covered by the sensor without cover remains. The fault-tolerant algorithms in [4, 5, 6, 7] are, Redundant sensors are used to replace a faulty sensor. In this algorithms after replacing the redundant sensor to replace the faulty sensor, network coverage remains unchanged, In addition, more motion (movement) is imposed for replacement of a faulty sensor in to network.

Li and Santoto (2006) made presentations algorithm DSND[2] [6]. This means that each redundant sensor, selects the nearest active sensor as its representative; each redundant sensor has only one representative, a representative may be have several redundant sensors. Representative sensors record the location of the sensor redundant and together constitute a mesh of information on the web. As soon event a network failure, faulty sensor neighbors are found the nearest represent an redundant sensor using mesh information. After identifying the desired representation, the act of replacing the nearest sensor redundant with fault sensor will be performed. The algorithm, outset the shortest path between the sensor fault and the selected redundant sensor is determined and then transfer is done.

Wang and colleagues (2005) offered algorithm WCPZ[3] [7]; which network is composed of two types sensor, active sensors and sensor redundant. Outset network environment is divided into multiple rows and columns, then sensors network have been divided into subnets and each subnet is a set of cluster head. The cluster heads collect information for its members and also responsible for calculating redundant sensors around itself for Probable alternative coverage holes. Cluster head Sends redundant sensor information his all other cluster heads are in his column. When the sensor be diagnosed faulty, cluster head the sensor sends faulty sensor data to other cluster heads are located in their row. each of the cluster heads that have redundant sensor give its information to the cluster heads of the requesting for replace.

The main problem in the algorithms [6, 7] using redundant sensors, in these algorithms for every sensor is faulty should there be a sensor redundant to replacing the faulty sensor; That increase the more needs of redundantin sensor in network that economically not affordable, also, may distance Between redundant sensor and faulty sensor is far.

farzadnia and colleagues (2011) offered algorithm FBFT [3]. This means that when the sensor is faulty from neighboring sensors are used to cover the lost space and the sensor moves toward the faulty sensor that its distance to the faulty sensor is less and overlapping with its neighbors is more and into the lost space due to sensor failure are covered.

Sensors Properties

The proposed algorithm assumes that all network sensors are the same and randomly are dispersed in a two-dimensional rectangular environment and network is clusterd each of the sensors is a member of one cluster.

faulty sensor: The sensor is called the faulty sensor, if it is broken because of environmental factors (rain, snow, lightning, etc.), reduction or end of energy, collision to environment barriers and … . When a sensor is faulty, coverage network in sensing range the sensor disappears. The proposed algorithm is assumed the faulty sensors is specified.

sensor sensing range model: each sensor covers the circle with radius r_s that the sensor located in the center, to the surface, sensor sensing range is called.

sensor connection range model: sensor communication range will be the circle with radius rc that the sensor located in the center. Each sensor can communicate with sensors that are located at the distance of r_c,

[1] Fault tolerance overlapping

[2] Distance-Sensitive Node Discovery

[3] grid-quorum based relocation protocol (referred by Wang, Cao, Porta and Zhang=WCPZ)

(here it is assumed that $r_c=2r_s$). The two sensors are called neighbor that in communication range of each other. When two sensors are neighbors, their sensing range will overlape.
Movement Sensor: All network sensors have ability to move in different directions with base station orders.

Proposed algorithm

When the sensor is broken, part of the area is covered by the sensor without cover remains. In the proposed algorithm to cover the lost space due to sensor failures use from neighboring sensors faulty sensor, This means that neighboring sensors faulty sensors are ranked according to parameters until the sensor has a higher priority is selected in order to cover the miss area and move towards the faulty sensor.

In each stage from execution algorithm, this is done until compensate lost space due sensor failure. The proposed fault-tolerant algorithm, there are two basic issues: 1 - Choose sensor neighbor faulty sensor for motion. 2 - How to move the selected neighbor. Prioritize neighboring sensors faulty sensor is done using fuzzy logic, based on 4 parameters (distance from sensor neighbor to sensor faulty, distance to cluster heads, remaining energy, the amount overlapping sensing range) that these four parameters are the inputs of the fuzzy system and output is neighboring sensors prioritize and movement direction the selected sensor in a long with connected line selective sensor and faulty sensor, the amount half the distance to neighboring sensor and sensor faulty towards faulty sensor.

When sensors are distributed randomly in environment, is possible rang sensing some sensors are covered by other sensors completely (Figure 1). If such sensors are faulty, there is no surface without coverage, and it makes no problem for network coverage. In other words, if all of the sensor sensing rang is covered with their neighbors, in case of the failure of that sensor there is no need for running fuzzy fault tolerance method.

At each stage from running algorithm checked that sensing range the fault sensor is covered completely or not, If that sensing range the fault sensor is covered completely, the algorithm stops. Otherwise, as long as the total sensing range the fault sensors is covered completely, running algorithm continues. In figure 1 sensor (e) is fault tolerance, because if the sensor is damaged, lost space due to failure covered by its neighbors (a, b, c, d).

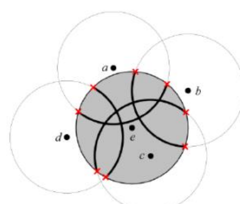

Figure 1. fault tolerance sensor

Inputs fuzzy system for selecting neighbor in the proposed algorithm

In the proposed algorithm, we considered four parameters to prioritize neighboring sensors, These parameters are distance from sensor neighbor to sensor faulty, distance to cluster heads, remaining energy, the amount overlapping sensing range, That in the following we describe these parameters. For each neighbor, these parameters are given as inputs to the fuzzy system, at each step of the algorithm implementation neighboring sensors of the faulty sensor are prioritized based on a fuzzy system and sensor is selected that have the highest priority for move.

The first parameter for prioritize neighbors is the amount overlapping sensing range of neighboring sensor that ratio overlapping every neighbor, equal to ratio its amount overlapping sensing range with neighbors on amount total overlapping all the neighboring sensors. So amount overlapping each neighbor sensor is relative amount. The second

parameter that we have considered for neighbors prioritize is distance between neighbor sensor to faulty sensor that In this case euclidean distance between neighbor sensor and faulty sensor is calculated. The third parameter is remaining energy neighbor sensor. Energy stored in each sensor is measured by joule and this amount is low based on the motion sensor. The fourth parameter that is used is the distance to cluster heads, distance to the cluster heads is distance between considered sensor to main sensor (cluster head);

If the distance from the cluster heads is more then number of sensors that are placed after the considered sensor is less to through considered sensor transmit their information the cluster heads. Therefore if considered sensor move then network has less risk.

After the input parameters of the fuzzy system determined, the neighbor sensor to move chosen that have higher priority. for example, one of fuzzy rules can be stated as follows: If distance between neighbor sensor to the faulty sensor is far, the amount overlapping with its neighbors is very high, amount remaining energy is high and the distance cluster head is medium, Its priorities selection will be high for moving. Figures 2 to 6, Input and output membership functions of the fuzzy system are shown.

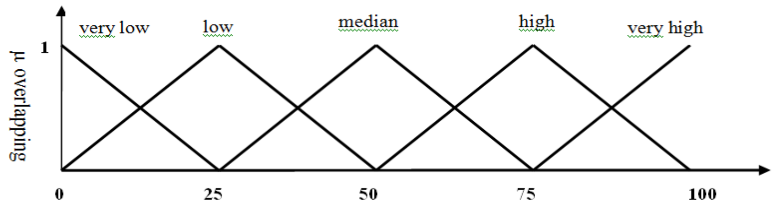

Figure 2. membership functions amount overlapping sensor neighbor

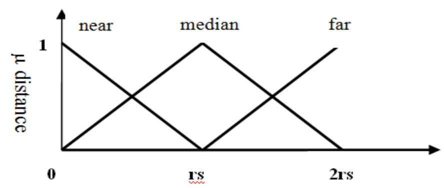

Figure 3. membership functions distance between neighbor sensor to faulty sensor

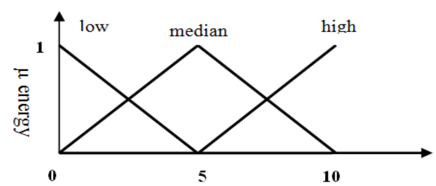

Figure 4. membership functions remaining energy of neighbor sensor

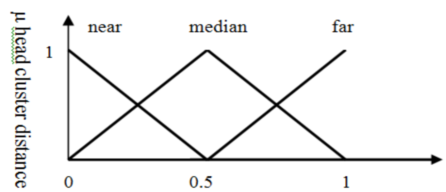

Figure 5. membership functions distance to cluster heads

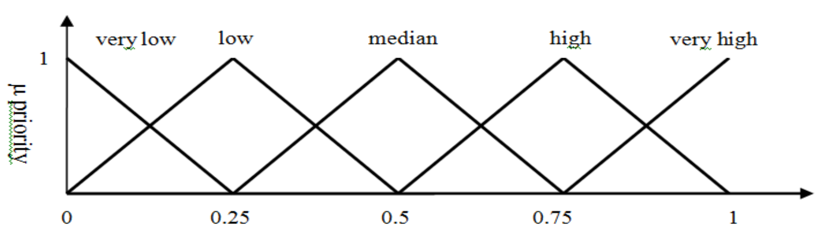

Figure 6. membership functions priority neighbors

designed fuzzy system rules to select neighboring summarized in Table 1 is obtained.

Table 1. fuzzy rules to prioritize the neighboring sensors

Distance fault sensor	overlapping	remaining energy	Distance cluster head	Priority neighbors
low	very low	low	low	very low
low	very low	low	far	low
low	very low	median	far	median
low	low	low	low	low
low	median	median	far	high
median	low	median	low	low
median	very high	high	median	high
median	very high	high	far	high very
far	very low	low	low	low very
far	very high	median	far	high
far	very high	high	low	median
far	very high	high	median	high
far	very high	high	far	high

SIMULATION RESULTS

In the proposed method, it is assumed that all sensor are the same, and disperse randomly in the area. The observing range of each sensor is considered as 5 meter, and its communicating range is regarded as 10 meter. Sensors which distance are less than 10 meter are considered as neighbors. In the simulations, it is assumed that some of these sensors are randomly broken. In this paper, the proposed model in implemented using MATLAB software. The proposed method is compared with WCPZ, FTO, FBFT algorithms considering the following factors: the total movements of replacement sensor, the total overlapping of all sensors' observing area, and the time consuming for fault tolerance. The comparison is done on the very same network (in terms of the number of sensors, their location). Figure 7 shows the results of running the algorithm on a network with 100 sensors in a 50m × 50m. The proposed method is compared with WCPZ, FTO, FBFT algorithms while the number of sensors failures are varied. Figure 7 also shows the results of total sensors movements for covering the miss area after running the algorithm. The results of the simulation shows that the amount of sensors movements for covering the miss area in WCPZ is higher than

the proposed algorithm. That happens due to the using redundancy sensors in WCPZ algorithm for broken sensors. The redundancy sensors may located in each part of the network. The replacements of these sensors causes a large amount of movements in the network while in the proposed method the amount of movement is less because the neighbors sensors are used to cover the miss area. In this case, the number of neighboring sensors are more and less movements are necessary to cover the miss area. when the density of sensors increases, the overlapping of sensors increases; in this case, the total movement of all sensors tends to zeros for covering the miss area in the proposed method. That occurs because of the more number of fault tolerance sensors in the dense area. There are some sensors which observing area is completely covered by their neighbors; when they are broken, their observing area have still under the cover. However, in WCPZ algorithm, increasing the density of the sensors has no effects of the covering the miss area when the sensor is broken. In this algorithm, the redundancy sensor is used for replacing the broken sensor, so more movement is imposed into the network. the result of FTO and FBFT algorithms are almost the same, because both algorithms use two parameters (the overall overlapping of observing area and the distance to the faulty sensor) to prioritize their neighboring sensors. The results of simulation shows that in FTO and FBFT algorithms, the amount of sensors movements for covering the miss area is more than the proposed method, and less than the WCPZ algorithm when the sensor in broken.

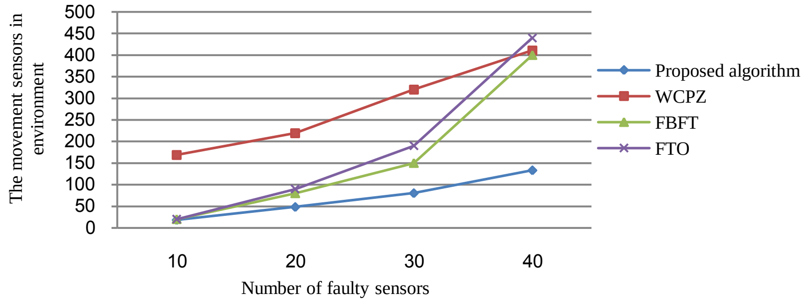

Figure 7. sensors movement

Figure 8 represents the results of overlapping the sensor observing area obtained after running the algorithms. When sensors are distributed in the area, some of the sensors observing ranges overlap with each others. If the overlapping of the sensors observing ranges is more, it shows the covering the same area by sensor is more. In the proposed method, the goal is the neighbor sensors decrease the amount of overlapping sensors observation ranges with their neighbors in order to cover the faulty sensors more. Therefore, after running the algorithm, the less the overall of the overlapping sensors observation ranges, the more the miss area is retrieved, so the best covering is obtained with the least number of the sensors (without using the redundancy sensors). The overlapping observation ranges in the proposed method is less than the WCPZ algorithm, because, in the proposed method, each sensor decreases its overlapping with its neighbors when it moves toward to the faulty sensor for covering the miss area. However, in the WCPZ algorithm, the overlapping does not change with different number of faulty sensors. That happens because the redundancy sensors are used for replacing the faulty sensor. The redundancy sensor is exactly replaced with the faulty sensor, so the overall overlapping and the network coverage do not change. FTO and FBFT algorithm act the same in the terms of overall overlapping. Like the proposed method, in these two algorithms, the overlapping of the sensor observing ranges decreases with the increasing the number of faulty sensors. Nonetheless, in the proposed method, the network coverage is better, since the selection of sensor neighboring is done carefully. In the proposed method, the ratio of overlapping the observing area is less when the sensor is broken.

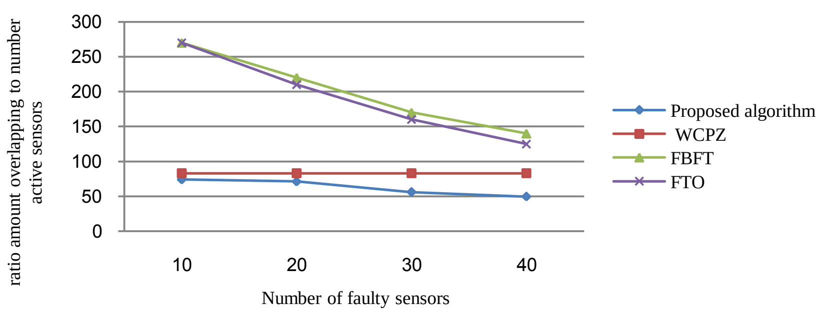

Figure 8. ratio amount overlapping to number active sensors

Figure 9 shows the results of the time consuming for fault tolerance after the running the algorithm. The results show that in the proposed method, the time needed for tolerating the faulty sensor is less than the other algorithms. In this case, the network will be normal in the shorter time.

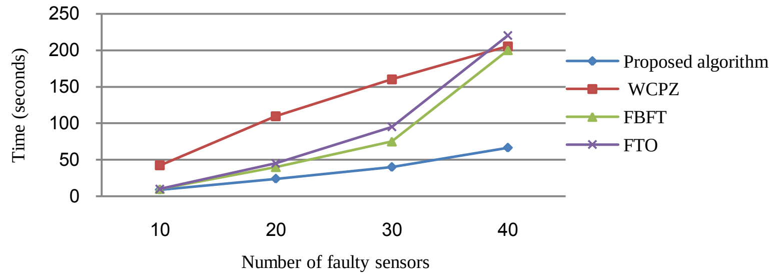

Figure 9. time of Fault Tolerance

CONCLUSION

In this paper, we proposed a novel algorithm for increasing the fault tolerance in wireless network using fuzzy logic. the objective of the paper is that, if there are some faulty sensors in the network, the network works correctly without being affected by the faulty sensors. Unlike [6, 7], in the proposed algorithm, the neighboring sensors are used to cover the miss area due to the faulty sensor. So, there is no need for redundancy sensor. In this case, the network is economically more affordable. In the proposed method, reducing the overall overlapping observing area leads to not only more fault tolerating but also better area coverage. On the other hand, in the proposed method, the total movements of sensor for covering the miss area and the total time consuming for fault tolerance are less than the other WCPZ, FTO and FBFT algorithms. As a result, less energy is consumed in the proposed method, and the network lifetime increase.

REFERENCES

Farzadnia A, Harounabadi A, Lotfinejad M. 2012. A Fuzzy Method for Fault Tolerance in Mobile Sensor Network, Journal of Academic and Applied Studies, 2(12):52- 62.

Lai Y, Chen H. 2007. Energy-Efficient Fault-Tolerant Mechanism for Clustered Wireless Sensor Networks, Proceedings of 16th International Conference on Computer Communications and Networks, 272-277.

Li X, Santoto N.2006. ZONER: A ZONE-based sensor Relocation Protocol for Mobile Sensor Networks, Proceedings of IEEE in 6th International Wireless Local Networks(WLN), 923-930.

Li Z, Santoro N, Stojmenovic I. 2007. Mesh – based Sensor Relocation for Coverage Maintenance in Mobile Sensor Networks, Proceedings of LNCS in 4 th International Conference on Ubiquitous Intelligence and Computing (UIC), 696 – 708.

Liu D, Stojmenovic I, Jia X.2008. A scalable quorum based location service in ad hoc and sensor networks, Proceedings of ACM in International of Communication Networks and Distributed Systems, 1(1):71 – 94.

Wang G, Cao G, Porta T, Zhang W.2005. Sensor Relocation in Mobile Sensor Networks, Proceedings of IEEE 24th Annual Joint Conference of the Computer and Communications Societies (INFOCOM'05), 733-741.

Zorbasa D, Glynosa D, Kotzanikolaou P, Douligerisa C. 2010. Wireless Sensor Networks using Cover Sets, AdHoc Networks, 8(4):400-415.