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Energy Efficient Method in Fault Node Recovery for A Wireless Sensor Network

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***Abstract*— In Wireless Sensor Network, the sensor nodes forms a cluster and each cluster will have a cluster head. The cluster head is selected on the basis of battery level. The cluster head collect the data from the sensors and transmit the data to the sink node. Since the cluster head is transmitting more amount of data compare with other nodes, so it will drains the battery. Due to this the cluster head is losing the energy very fastly and shuts down. The battery drained cluster head is known as sensor fault. The sensor fault will leads to data loss. So, the sensor fault is re placed by using FNR algorithm. Even though, the sensor faults has been replaced; the cluster head have to transmit more data and loses its energy. To minimize the risk of sensor faults, an efficient method is used to compress the data.**

***Index Terms*— Grade Diffusion algorithm, Genetic Algorithm, Compact Sensing Theory, Wireless Sensor Network (WSN).**

INTRODUCTION

A wireless sensor network (WSN) is a wireless network consisting of geographically distributed self-governing devices called sensors, which senses the nearby information and transmits them to the sink node.Where the sink node is the centralised node which collects the data from the sensor nodes and each sensor nodes has limited wireless computational power to process and transfers the data to the sink node. Generally, these sensors are furnished with wireless interfaces with which they can communicate with one another to construct a network [7][8]. The sensor nodes are also called as source nodes where they contains the data which the sink node wants. The sensor node that has the data what the sink node wants will forwards the data through multiple sensor nodes.

Overall, the data that the sensor node has been collected is transmitted to the sink node under a routing protocol [8]. The routing techniques are basically of three categories: hierarchical and location-based routing,. And these protocols are further classified into query-based, multipath-based, QoS-based, coherent-based and negotiation-based depending on the protocol operation. The wireless sensor network has large number of sensor nodes and it is not much possible to build a global addressing scheme for the sensor nodes as the overhead of ID maintenance ishigh. So traditional IP-based protocols are not applicable for the WSNs.

Sensors are the device that contains limited battery power and memory [7]. A radio is used to transmit the data that the sensors have collected from the environment, and the battery in sensor node is defined as power source for individual sensor nodes in the network. The battery power may exhausts easily, so the power may be obtained by environment elements like solar panels.

Fault management protocol [9] [8] is having a equipment that can locate the failure easily and quickly, and also helps in analysing the reason for the occurrence of the failure, so the network maintenance will be efficient. Here, the node failure has been detected quickly and also recovers them with minimal costs, which also reduces the risk and impact of the failure that occurred in the network. Generally, the fault node occurrence will leads to energy drop in the network because the sensor faults are due to energy shutdown and the energy has to be improved by replacing the fault node with another node will leads to better transmission. The sensors in the networks will have their own degree of wireless computational power to process the data to be transmitted from sensor source to the sink node.Each of sensors are highly constrained in the energy resources [8] and also has limited processing power that leads to quick power loss and been a reason to the occurrence for the sensor faults. When the sink node wants a data which is holds by an distant sensor, then the sensor have to forwards the data through the intermediate sensor nodes which consumes minimal energy but in case of cluster head, the cluster head wants to transmit large amount of data comparing to other sensor nodes in the cluster so there may occurs the sensor fault quicker than all other nodes in the cluster.

RELATED WORKS

A. Directed Diffusion Algorithm

In the Directed Diffusion (DD) algorithm [1] [7], it consists of several elements: interest, data message, gradients. Interest is a query which holds that what the sink node wants, where in each interest there may be a description of sensing task that is supported by a sensor network for accessing data. The data is done by using the attribute-value pair; the sink node broadcast the interest throughout the wireless sensor network and performs an event of matching the data of the sensor nodes with the interest.

B. Grade Diffusion Algorithm

The Grade Diffusion (GD) [7] algorithm will provides grade for each sensor nodes in the WSN and the grades for each node is provided by depending upon the battery level of the sensor nodes. The GD algorithm broadcasts the grade and then proposes a routing algorithm to reduce the nodes load, which enhance the nodes lifetime. The GD algorithm will maintain the routing table that consisting of each sensor nodes and its neighbor nodes for better data transmission in WSNs.

C. Wireless Routing Protocol

The Wireless Routing Protocol (WRP) [8] is a table-based protocol with the goal of maintaining the routing information's of all nodes in the WSN. Each node in network maintains four tables: distance table, routing table, Message-Retransmission List (MRL) table and link-cost table. In MRL, a message has been sent among the neighbor which the holds the information about the change in the link between the nodes. When there occursa change in the link then the node will updates the distance table, link-cost table and routing table based on their new paths.

D. Cluster-head Gateway Switch Routing

The CGSR [8] [12] is a clustered multi-hop wireless network, in which each cluster has a cluster head. A cluster-head selection algorithm is used to elect a node as the cluster head within the cluster. Generally, the cluster-head is having a disadvantage of frequent cluster head change that affects routing protocol performance.

E. Dynamic Source Routing

The DSR [8] maintains a route cache that contains the route information and when a node wants to send a data, it will consult with the route cache whether the node already has a route to the destination. If not, then the node requests the Route discovery to connect the node with destination.

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The Enhanced Error Node Recovery algorithm is the combination of Fault Node Recovery algorithm and the Compact Sensing Theory. The Fault Node Recovery algorithm replaces the sensor fault with minimum cost and the Compact Sensing Theory compresses the data from the sensors and forwards to the cluster head to reduces the future energy loss in transmitting the data from sensors to the sink node as shown n the Fig. 1

A. Fault Node Recovery algorithm

The Fault Node Recovery algorithm [7] [11] is based on the Genetic Algorithm, which holds the entire information about each sensor nodes in the WSNs. The Genetic Algorithm consisting of five steps: initialization, evaluation, selection, crossover and mutation. The FNR algorithm calculates A_{th}value in equation (1)

$$A_{th} = \sum_{i=1}^{\max\{Grade\}} T_i$$

$$T_i = \begin{cases} 1, & \frac{N_i^{now}}{N_i^{original}} < \beta \\ 0, & otherwise \end{cases} \quad (1)$$

Where,

N_i^{now} -the number of sensor nodes still functioning at the current time with grade value *i.*

$N_i^{original}$ -the number of sensor nodes with the grade value *i*

β -parameter that has been set by the user and must be between 0 to 1.

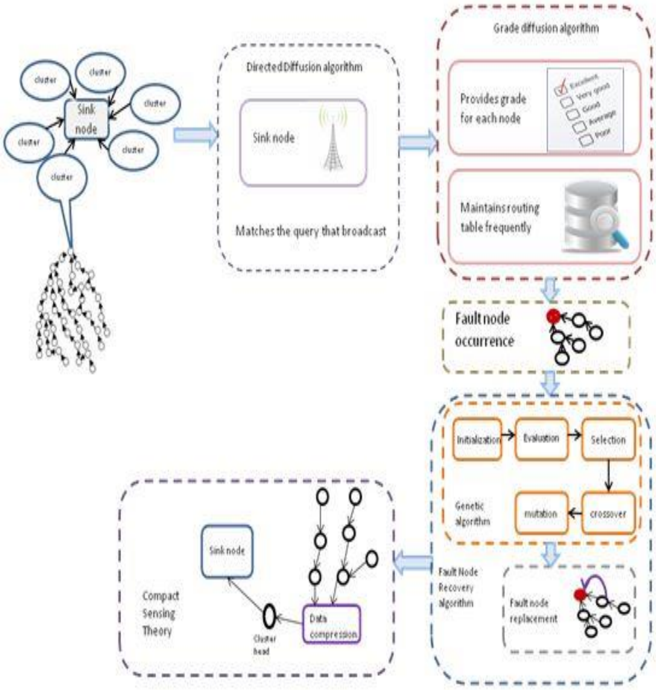

Fig. 1. Enhanced Error Node Recovery Algorithm Architecture

i. Initialization

In Initialization ste[11]p, the genetic algorithm generates the chromosomes, and the number of chromosomes is determined by considering the population size. The chromosome is a group of genes, where the elements of genes are either 0 or 1. If the element of the gene is 1 then the node is to be replaced and if the element of gene is 0 then the node is functioning node as shown in Fig. 2.

9	7	10	81	23	57	34	46	66	70
1	1	0	0	1	1	0	0	1	0

Fig. 2. Chromosomes with genes

ii. Evaluation

In Evaluation step, the fitness value is calculated by considering the grades of the sensor nodes as its parameter. The genes cannot be used directly into the fitness function because the genes are used to represent only the node is a functioning node or non-functioning node. Hence, the number of routing paths available if some non-functioning sensor nodes are replaced is calculated, and the fitness function is defined as equation (2)

$$f_n = \sum_{i=1}^{\max(Grade)} \frac{P_i \times TP^{-1}}{N_i \times TN^{-1}} \times i^{-1} \quad (2)$$

Where,

N_i –the number of replaced sensor nodes and their grade value at i.

P_i – the number of re-usable routing paths from sensor nodes with their grade value at i.

TN –total number of sensor nodes in the original WSN.

TP –total number of routing paths in the original WSN.

iii. Selection

In selection step, the chromosomes with the lowest fitness values are rejected and retain the rest. It almost consists with better fitness value and puts them in mating pool. The worse chromosomes will be deleted and new chromosomes are produced by considering the chromosomes in the mating pool. The selection step is shown in Fig.2.

iv. Crossover

The crossover step is used to change the individual chromosome, the one-point crossover strategy is used to create new chromosomes. Two chromosomes are chosen from the mating pool where the selected chromosomes are gathered, to produce two new offspring chromosomes as shown in Fig.3. Generally, the chromosome point is chooses between the first and last genes of the parent chromosome. Then the fraction of each chromosome on either side of the crossover point is exchanged and fused. The rate of choice is made according to roulette-wheel selection and the fitness value.

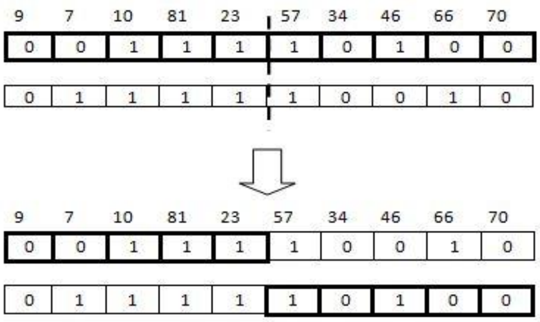

Fig.3. Crossover step

v. Mutation

The mutation step will introduces a traits not found in the original chromosome and prevents the GA from converging too fast. It may flip a gene randomly in the chromosome that has been performed by crossover as shown in Fig.4. The chromosome with the best fitness value is the solution after the selection step. The FNR algorithm will replace the sensor nodes in the chromosome with genes of 1 to extend the WSN lifetime.

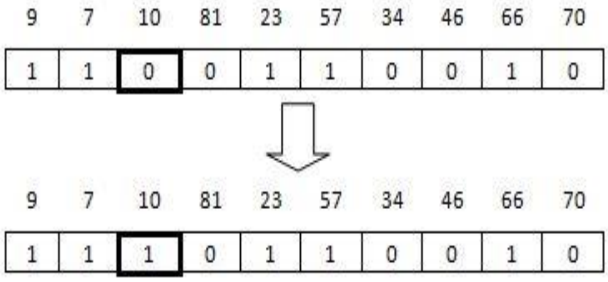

Fig.4. Mutation step

B. Compact Sensing Theory

In signal processing [15] [14] [13], the sensor needs the signal at least in Nyquist rate [3] for reconstruction of signal. Here, the needed signal is a one dimensional vector x P^M can be explained as Equation (3)

$$X = \sum_{i=1}^{M} s_i \psi_i x = \psi s \qquad (3)$$

Where,

ψ -the matrix with i_{th} column ψ_i.

x -signal that called L-sparse.

Where the compressibility of the signals is called transform coding, which obtains full signal x P^M and the transform coefficients are calculated by $= \psi^T$x. The Compact Sensing Theory will locate the largest L-coefficients and the remaining are deleted, at last the located L-coefficients will be encoded and forwarded. Thus the amount of data has been minimized by decreasing the transform coding.

The compressive sensing [3] [2] [6] [13] [14] will be done in the cluster head because the cluster head have to transmit large amount of data comparing to other node in the network, so the data has to be minimized.

Due to large amount of data in the cluster head, the energy loss will occurs in the cluster head, so the data has been collected in a data centre and compressed and then transfers to the cluster head which minimizes the energy consumption in cluster head [8] to compress the data. Where there may occurs the repetition of same data so the data centre will also performs the averaging of the data collected and reduces the energy consumption in cluster head to send the repeated data. Hence, the Compact Sensing Theory [2] [5] [4] helps in minimizing the unwanted energy consumption to transfer the data to the sink node by introducing the data centre for compressing and averaging the data that has been collected from the sensor nodes in the network.

CONCLUSION

In WSN, the sensor node utilizes the energy resources called battery power and in addition to the routing, the trivial solution of the sensor faults and its replacement is important.

The Enhanced Error Node Recovery algorithm is the combination of Fault Node Recovery algorithm and the Compact Sensing Theory which helps in decreasing the energy consumption of sensor nodes by compressing the data where the compressed data will consumes lesser energy comparing to the live data. And the fault node is identified by the Fault Node Recovery algorithm and also recovered them with minimal cost. Hence, the Enhanced Error Node Recovery will reduce the risk of future sensor fault occurrence.

Further the lifetime of the mobile sensor nodes can be improved by providing some low energy nodes into sleep states and forwards through other nodes in the wireless sensor network and the performance of the Enhanced Error Node Recovery algorithm will be deducted using NS2.

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