Topology Control Scheme for Fault Tolerance in Wireless Sensor Network

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Abstract— **The Wireless Sensor Network (WSN) consists of numerous sensor nodes deployed randomly. These sensors are having tendency to fail, due to restricted battery life. The lifetime of sensor nodes has a greater dependency on its battery, as a result of failure of nodes the network lifetime will be reduced. In this paper, we propose a scheme for fault tolerance in wireless sensor networks by controlling the topology. The algorithm first detects the faulty node in the computed shortest path by considering the parameters mobility and buffer size. If the fault node is found, then the alternative shortest path excluding faulty node is identified for successful transfer of data. From the simulation results, it is observed that the more number of nodes will fail as there is increase in the mobility.**

Keywords— Wireless Sensor Networks; Topology Control; Fault Tolerance

I. Introduction

WSN is constructed by distributing a lot of sensors in ad-hoc manner and consists of sensor nodes that are connected to each other by protocols and algorithms. The sensor node with the small size is characterized by the battery with a low capacity, the limited use of energy, the limited data processing capability. As the sensors which are used in sensor networks are mostly operated in the environments that human beings cannot access or reach, it is impossible to replace the battery of each sensor node once they are placed. Therefore, it is important for design requirements to be made so that WSNs uses energy proficiently and reduces the communication costs. In addition, the sensor network is used in various environments with the errors such as the noise of communication channels and hardware failures in transmitting and receiving data. Wireless sensor networks are beginning to become a reality, and therefore some of the long overlooked limitations have become an important area of research.

In WSN, some sensor nodes may fail or be blocked due to lack of power, or have physical damage or environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. This is the reliability or fault tolerance issue. Fault tolerance is the ability to sustain sensor network functionalities without any interruption due to sensor node failures [1][2]. Since the sensor networks are widely used in sensing the particular parameter from a restricted region and it has to transmit the same sensed parameter to the destination. If the sensor node is failed by short of storage capacity (buffer) or the high movement (mobility) of the sensor nodes, the data may not reach to the destination or if reaches it may not be accurate. Platforms such as surveillance and controlling applications, the low power sensor nodes are required with support of fault tolerant topology which increases the efficiency and accuracy of the network.

The objective of this paper is to create a wireless sensor network environment to calculate the shortest path from source to destination by considering the buffer size and mobility of the sensor nodes, to identify the fault nodes in the shortest path and to calculate the alternative path if the fault node found in the shortest path, so that there is no loss of data during the transmission from source and destination. A topology control scheme for wireless sensor network is also discussed in the paper. Proposed topology control scheme reduces node power consumption in order to extend lifetime of sensor network.

II. Related Works

Different fault detection techniques using different approaches are discussed in [3]. Two failure detection approaches such as centralized approaches and distributed approaches are explained. The topology control and different interference model in heterogeneous WSNs techniques are used to minimize the interference by topology control [4]. A localized fault detection algorithm to identify the faulty sensors and also tells about the implementation of proposed algorithm which has less complexity and high probability of correct diagnosis is presented in [5]. Agent based system and fault detection based on the reverse multicast tree to evaluate the probability of fault nodes is discussed in [6]. Supernodes consist of two transceivers, in that one is to connect to the WSN, and other connects to the supernode network. Supernode network will provide better QoS and the data packets are forwarded quickly to the end user. The principle of various phases composing fault detection is explained in [7]. It consists of establishing

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hypothesis test, generating the signal information, detecting the fault movement, estimating the fault amplitude and compensating the fault. Detailed diagrammatic representation of fault node recovery, redundancy analysis and distributed self organization scheme that ensures communication connectivity and sensing coverage when node fails either sequentially or simultaneously and it is necessary to extend the redundancy needed for fault tolerance [8].

In [9] [10], fault tolerant topology control scheme towards the minimization of the power consumption to provide connectivity between the vertices is explained. Algorithms used are mainly centralized, and proposes approximation algorithms for different topologies. An approximation algorithm [9] in which construction of nearest neighbor node and then extending the connectivity using minimum edge weight connected algorithm which is already exists. Cone-Based Topology Control (CBTC) algorithm for fault tolerance is presented in [10]. Authors in [11] describe a discrete topology control scheme which minimizes the transmission power of sensor nodes, so that it is possible to improve the reliability of network effectively. The network topologies which are derived from the algorithm may preserve at least two vertex disjoint paths between any pair of nodes. The results of the algorithm are compared with approaches to demonstrate the effectiveness of the methodology which is proposed. A cooperative, light-weight and fully distributed approach [12] with which the transmission power [13] of the sensor nodes can be tuned according to the local connectivity constraints [14].

III. PROPOSED WORK

In this section, network model considered for the proposed algorithm and topology control scheme for fault tolerance in WSNs are discussed.

A. Network Model

WSNs consist of several sensor nodes which are randomly deployed in some area as shown in fig.1.The transmission range of each node is restricted to some distance which reduces the direct communication with the other nodes in the sensor network. Hence, it requires intermediate nodes/access points for communication with others nodes. The neighboring nodes are defined as the nodes which come within the transmission range of that particular node, so that it can communicate directly without any intermediate node.

B. Proposed Scheme

Initially the shortest path is computed from source to destination by considering the node parameters buffer size and mobility.

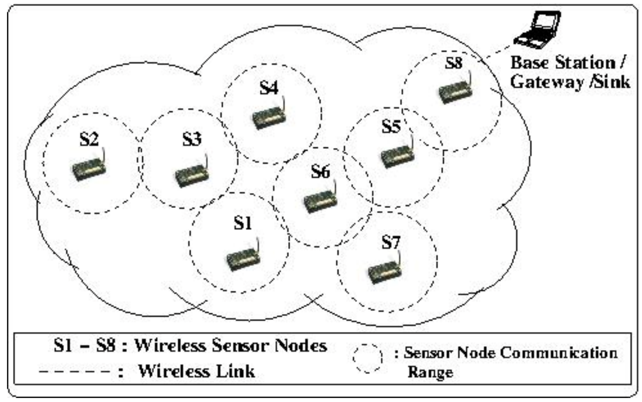

Fig.1 Network Model

After calculating shortest path, fault identification factor is calculated and compared with the randomly assigned threshold value. If the fault identification factor of a node is less than the threshold value, then that node is considered as the fault node and the alternative shortest path is rerouted from source to destination excluding the fault node.

The proposed scheme operates in the following phases: (i) formation of clusters, (ii) computation of shortest path, (iii) identification of fault node and (iv) path rerouting.

1) Formation of clusters: The nodes considered for the creation of the wireless sensor network which are randomly distributed. And the nodes considered for the sensor network are divided equally into `n' number of clusters. Then network is created such that each node is connected to each other node, and there exists cluster to cluster connection considering the shortest path.

2) Computation of shortest path: Randomly source and destination nodes are selected and shortest path is computed from source to destination on the basis of mobility and buffer size of sensor nodes. Each sensor node has connection with every other sensor nodes and the algorithm considers the next node which has the less mobility and sufficient buffer. This process continues till it reaches the destination and a shortest path with low traffic is identified from source to destination.

3) Identification of fault node: The shortest path computed from source to destination has many numbers of intermediate nodes. Out of the available intermediate nodes, fault node is identified based on the fault node identification factor.

Let, F = is the fault node identification factor.
B = is the buffer size of a sensor node.
M = is the mobility of a sensor node

A sensor node can be considered as a good node if it has high buffer size `B'; therefore `F' is directly proportional to the buffer size which is shown in Equation (1)

$$F \propto B \qquad (1)$$

Similarly a non fault sensor node can be considered if it has low mobility, therefore `F' is inversely proportional to the mobility which is given by Eequation (2) .

$$F \ \alpha \ 1 / M \qquad (2)$$

Therefore

$$F \ \alpha \ B / M$$
$$F = K (B / M) \qquad (3)$$

Where `K' represents the weighing function and lies between 0 and 1.

4) Path rerouting: According to the threshold value Set `T', there may be more than one node may have the `F' value less than the threshold. Among those lowest `F' valued node is considered as the fault node. After identifying the fault node, algorithm excludes or removes that identified node from the shortest path and reroutes the path again from source to destination which has low traffic.

C. Algorithim

Proposed topology control scheme for fault tolerance in WSNs is depicted in the below mentioned algorithm.

Begin

- Random deployment of nodes: Nodes are deployed in a area of `A' sqm in a random manner using Euclidian Distance Formula =

  $$Dij = \sqrt{(mi - nj)^2 + (pi - qj)^2}$$

  Where mi & nj are current position of nodes and pi & qj are position of nodes from where the distance is to be calculated. Assume Dij>0 i.e. no two nodes cannot be at the same location.
- Exchange of control packets among sensor nodes consists of <*Node id, Position, Buffer, Mobility*>.
- Cluster Formation: The nodes which are present within certain region of event detection involves in cluster formation process.
- Identifying the route from source to sink: Data is transmitted from source to sink node through intermediate cluster heads (CHs) and nodes which are having maximum buffer size and minimum mobility.
- Identifying the fault node: Depend upon the mobility and buffer size of the sensor node, the fault identification factor is computed using eqn (3).
- Identifying alternative path and rerouting the data packets using alternative routes excluding fault node.

End

IV. SIMULATION

The simulation of the proposed model is done using C in Dev C++ tool as discrete event simulator. In this section, we discuss simulation model, simulation inputs, simulation procedure and performance metrics.

A. Simulation Model

In the simulation consider 'N' number of nodes for the creation of network, let 'B' be the size of buffer and 'M' be the mobility of the node defined by the random function. The path creation takes place by considering parameters of a node with less mobility and higher buffer size for the better performance of the network. The direction of node movement is assumed to be fixed during the simulation. The network for the detection of fault node, it compares each node in the computed path with the threshold value 'F', of any node below the threshold value it assigns as a faulty node. After that alternative path is identified by considering the buffer and mobility parameter and rerouted by discarding the identified faulty node, so that data transmitted successively from source to destination. We also calculated time to compute the shortest path and rerouted path by varying the total number of nodes.

B. Simulation Inputs

Proposed scheme results are illustrated by choosing the input parameters as follows: N = 10 to 50, M=20 Km/hr to 60Km/hr, B=100Mb to 200Mb and T is determined by the network administrator. The above parameters are checked every time for different values of N and the performance of the proposed scheme is observed. Also the different values of M and B are considered, each time the number of fault nodes or the percentage of fault nodes is analyzed.

C. Simulation Procedure

Simulation procedure steps are as follows:

Begin

Step1. Create the network topology for given number of nodes.

Step2. Calculate the shortest path for entered source and destination node.

Step3. Detection of fault node in the path.

Step4. Identifying the alternative path.

Step5. If alternative path exists, reroute the path.

End

D. Performance Metrics

To test the performance effectiveness of the proposed scheme, some of the performance metrics analyzed are as follows:

- Mobility: It is the phenomenon of movement of sensor nodes freely in wireless sensor network. It is expressed in terms of Kmph.

- Buffer Size: It is the amount of memory for the storage of the data in sensor node. It is expressed in terms of Mb.
- Path Duration: The amount of time for the gathering of the information of sensor node in the computed path. It is expressed in terms of milli seconds.

V. RESULT ANALYSIS

In this section, as a measure of performance, we analyze the simulation results of our proposed scheme to demonstrate the effectiveness. We run the code for several times for different sets of parameters and obtained the results as shown in the following sections.

The Fig.2 shows the number of nodes versus percentage of fault node by keeping the buffer size constant to 100Mb. Generally the percentage of fault node increases as with the increase in the number of nodes. Percentage of fault node also increases with increase in mobility values of sensor nodes. For different mobility values it is clear that better performance of the network can be achieved by keeping the mobility minimum.

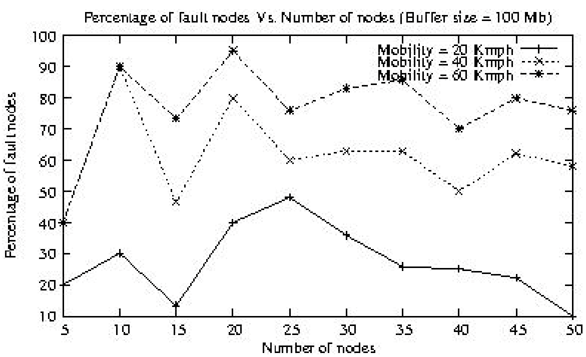

Fig. 2 Percentage of fault nodes Vs. Number of nodes (Buffer size= 100 Mb)

In Fig.3, the percentage of fault nodes versus number of sensor nodes under constant mobility of 20kmph is analyzed. Percentage of fault node is decreased as there is increase in the buffer size. With varying buffer size the percentage of fault node is also varied, but the overall fault percentage is less since the mobility is kept constant to lesser value.

Percentage of fault nodes versus number of nodes under mobility value of 40kmph is shown in fig.4. We can observe that the percentage of fault node increases as compared with mobility equal to 40kmph. Percentage of fault nodes is also high for lesser value of buffer size as it is high for 100Mb of buffer size compared 150Mb and 200Mb.

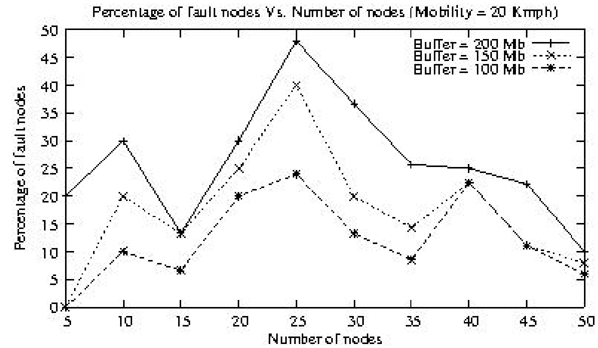

Fig.3 Percentage of fault nodes Vs. Number of nodes (Mobility 20= Kmph)

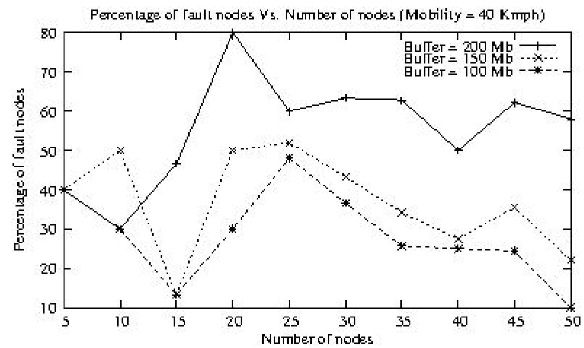

Fig.4 Percentage of fault nodes Vs. Number of nodes (Mobility= 40 Kmph)

The Fig.5 shows the graph for percentage of fault node versus number of nodes keeping mobility constant to 60kmph. We can observe that the fault nodes will decrease as the number of nodes as the buffer size decreases. Since the mobility is kept high, the fault node percentage is more as compared with the previous results where mobility is 20kmph and 40kmph. Also there is variation in fault node percentage with varying mobility.

From above results it is clear that, the number of fault nodes i.e., percentage of fault nodes will increase as there is increase in the mobility of the sensor node and decrease in the buffer size. So for the fault tolerant network always, the mobility should not be too high and buffer size should not be too less, there should a compromise between these two parameters.

The fig.6 shows routing delay versus total number of nodes by varying the mobility. Since more time is required to collect the parameter values of the each node and to compute the shortest path by considering the buffer size and mobility, if the number of nodes is more.

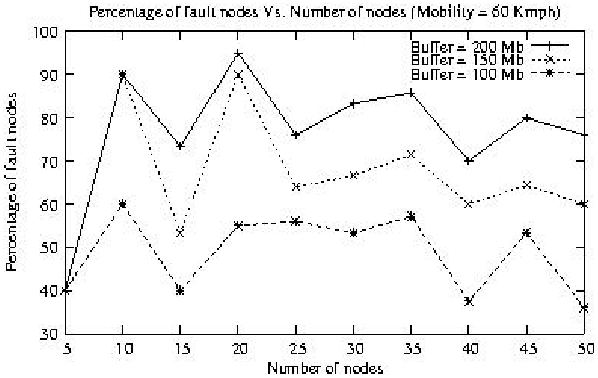

Fig.5 Percentage of fault nodes Vs. Number of nodes (Mobility= 60 Kmph)

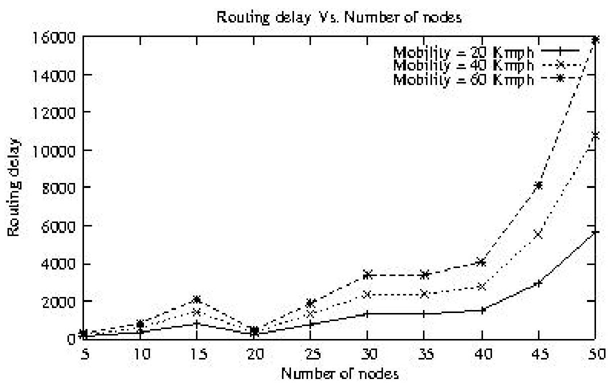

Fig.6 Routing delay Vs. Number of nodes

So the path computation time increases with increase in the total number of nodes. From the result it is clear that, the path computation time increases as there is increase in the total number of nodes in the network.

Reroute path computation time increases as there is increase in the total number of nodes (as shown in fig. 7). This is because it takes more time in collecting the information of nodes and recomputation of the path as compared to shortest path.

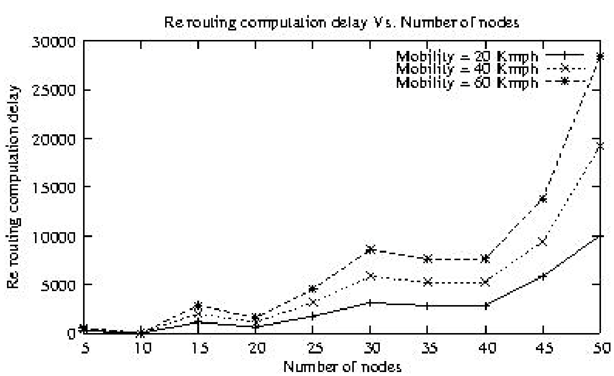

Fig.7 Rerouting Computation delay Vs. Number of nodes

VI. CONCLUSION

In this paper a method for detection of fault node in the sensor network using fault tolerant topology control scheme is discussed. The fault in a sensor network occurs because of the sensor node failure. As it is considered, in this work the sensor nodes fails due to the less buffer size and the high mobility of the sensor nodes. The fault sensor nodes can be identified and eliminated efficiently, and alternate path is computed with the proposed approach. In the proposed scheme a single fault sensor node is identified. Further the work can be extended by considering multiple fault sensor nodes along with alternate path identification.

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