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Energy Emphasis Fault Tolerance Routing Scheme for Wireless Sensor Network

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ABSTRACT

In wireless sensor networks (WSN), fault tolerance is one of the major challenges of deploying energy efficient WSN. In WSN fault can occur mainly due to two reasons link failures and node failures. In this paper, we propose a new "Energy Emphasis fault tolerance routing scheme (EFTR) for wireless sensor networks", in which we have reduced the problems of Distributed Multipath Fault Tolerance Routing Scheme (DFTR) and restructured the technique for fault tolerance. In our new scheme, we divide the whole WSN into clusters of efficient size using some parameters and for each cluster choose one cluster head. Then we propose two different fault tolerance routing schemes, one is intra fault tolerance routing within a cluster, between the source and cluster head and the second is inter fault tolerance routing between the different cluster heads to base station. These two fault tolerance routing will overcome the link failures and nodes failures problems efficiently within clusters and between the cluster heads to base station and reduce the energy consumption due to these faults. We also compare the performance of this new scheme with common fault tolerance scheme Distributed Multipath Fault Tolerance Routing and show its effectiveness through simulation.

Categories and Subject Descriptors

C.2.1 **[Network Architecture and Design]:** *Network communications, Network Topology, Wireless communication*

C.2.2 [**Network Protocols**]: *Routing protocols*

General Terms

Algorithms, Design, Measurement, Performance, Reliability, Experimentation.

Keywords: *Base Station, Cluster Head, Fault Tolerance, Intra and Inter Fault Tolerance Routing, Wireless Sensor Network (WSN)*

1. INTRODUCTION

With the emergence of sensor technology, a new type of wireless sensor network (WSN) comes into view. WSN is the collection of thousands of sensor nodes. These nodes are low cost and small sensor nodes. This WSN is used in many applications like battlefield surveillance, natural disaster monitoring, and for industrial process monitoring and control, where certain reliability should be ensured while providing robustness in presence of harsh surroundings [1]. In wireless sensor network the sensor nodes sense data from monitoring area and transmit to Base Station (BS). The BS is high battery powered device with high computational and memory capacity. Nodes communicate with BS by multi hop connection [2]. In WSN, fault occurrences are very high due to wireless communication, physical object of environment and different deployment policy. WSN faults are divided into two categories namely link fault and node fault [3]. In link failure data are unable to reach to destination and in node failure there is some hardware problem like sensor node damage, battery power etc. If battery power is discharged or damaged, it is very difficult to recharge or replace it due to remote deployment of nodes [4].

Multipath fault tolerance routing is a very popular fault tolerance mechanism in WSN. In this mechanism, nodes send multiple copies of similar data through multiple paths. Thus the high message overhead increases traffic congestion in the network and decreases the network life time [5]. Here we propose a new "Energy Emphasis Fault Tolerance Routing Scheme for Wireless Sensor Network" (EFTR) which removes the problem of distributed multipath fault tolerance routing scheme (DFTR) for fault tolerance in WSN. In this scheme, we divide the whole WSN into clusters of size which is efficient in such a way that the overall communication cost of the network will reduce. In each cluster, we create one cluster head (CH) using any efficient technique. We implemented the new fault tolerance routing algorithm. Within each cluster, we used another intra communication fault tolerance scheme. This scheme is used for reducing the energy consumption in the network. Here we did not send the multiple copies of data through multiple paths. We used only a single path for data transmission and the remaining path is used for fault tolerance only.

The rest of the paper is arranged as follows, section 2 describes the related work of fault tolerance routing. In section 3 we describe the whole process of the new fault tolerance routing scheme. In section 4, we describe the simulation result of this new routing scheme compared with another routing scheme, and section 5 we draw the conclusion of paper. One of the approaches to design the WSN is grid based approach which is helpful for creating the cluster according to grid information, so in this grid based clustering we have to create groups of sensor node which is known as a cluster. We get these cluster by creating grid , this grid creation can we do with the help of different parameter like based on sensing range [6], transmission range [1] etc. depending on the requirement. In this paper, we are proposing network design based on transmission range and sensing range. This design improves the network design and network life time.

2. RELATED WORK

In Multipath technique data is transferred from multiple paths at the time of routing [7]. But here we select a single shortest path from amongst multiple paths for data transmission from source to sink. If a fault occurs, then the current node chooses another path for data transmission from the remaining multiple paths.

In "Neighbor Disjoint Multipath Scheme for fault Tolerant WSN" two problems are avoided, isolated node failure and co-located/localized node failure. It uses two performance metrics, first is Resilience and second is Excess energy expenditure factor to improve the WSN performance. According to this scheme, firstly select the shortest primary path for data transmission then select all alternate backup paths for fault tolerance. For selecting the backup path we use the two disjoint properties, first is when there are n paths between source and sink then no set of n node failures can result in total communication break between them, and second is that (n-1) backup paths with respect to primary path, reduces the probability of failure of primary path and backup path in case of link or node failure. This algorithm tries to minimize the impact of link or node failure in WSN and gives better result as compare to node-disjoint multipath technique and edge-disjoint multipath technique [6].

"Distributed Multipath Fault Tolerance Routing Scheme for wireless sensor networks" removes the problems of multipath fault tolerance routing scheme [8]. Mainly this scheme focuses on two problems, first one is traffic overhead, which is introduced when data is transmitted individually by the large number of paths and second one is energy hole, which decreases network life time. This scheme removes these problems by dividing the whole WSN into clusters of efficient size and in each cluster uses the level based multipath tree for data transmission to cluster head. The main focus of this scheme is on 100 percent data delivery and reduction of the delay for packet delivery to sink. The DMFTR technique work in two phases: first is Level detection and efficient cluster size formation and second phase is Fault tolerance data routing between the cluster head and nodes.

The "Maximally Radio-Disjoint Multipath Routing for Wireless Multimedia Sensor Networks" (MR2) overcomes the bandwidth issue in wireless multimedia sensor network [9]. It mainly focuses on the interfering path problems in WSN. This scheme solves the intra-session and inter-session interferences. MR2 scheme using the incremental scheme, initially builds only one path. When congestion occurs or BW is required, then it builds alternate path as the primary path. Here interference awareness and energy saving are achieved by putting subset of sensor nodes in passive state, which are not taking part in routing. This scheme increases the routing overhead but also increases the overall throughput.

The main reason for this is that a small number of non-interfering paths allow better performance than a large number of interfering ones.

3. FAULT TOLERANCE ROUTING SCHEME

In Wireless Sensor Network we perform two types of routing, first is Intra fault tolerance for cluster and second one is Inter fault tolerance routing between all cluster heads and base station. Before this we divide the whole WSN into different clusters of same size and implement topology for each cluster. Then choose the cluster head for each cluster in given steps we perform the energy efficient fault tolerance routing for WSN.

3.1. Create Topology

We divide the whole wireless sensor network into different clusters of same size and each cluster has a specific topology. In this topology every node should be connected through at least four nodes. Boundary nodes may not be satisfying this condition. Fig.1 show the example of this topology in which each node has at least four links except boundary nodes. In this topology we choose center nodes as a cluster head. These four links are considered as two incoming and two outgoing links for calculating the multiple paths between nodes and cluster head. By using this topology we get more paths for sending the data to cluster head which increases fault tolerance. Each node contains node level information and cluster level information. Node level is a level according to cluster head and cluster level is a level according to base station in WSN. Fig 2 shows the Cluster level. In DFTR each node connected with exact by four links. So DFTR will give less number of paths as compare to EFTR. The topology of DFTR is like a tree type [8].

Here we set the cluster size according to the number of levels of clustering. If number of levels in WSN for a cluster is decided as N then it is necessary that initially within a cluster the maximum number of levels with Cluster Head should also be N.

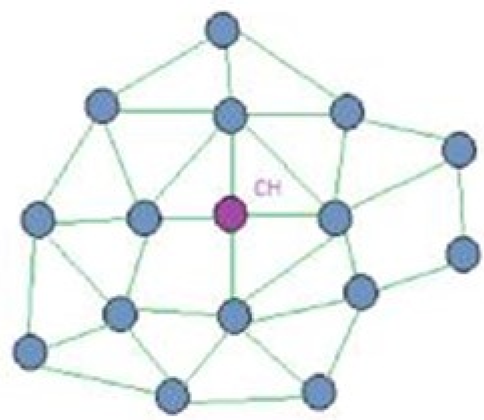


Figure 1: Topology within a cluster

3.2. Select Cluster Head

Cluster Head for a cluster can be selected in two different ways in EFTR. First at initial time and second after cluster head failure. Initially Calculate Cluster Head:

$$CHX = (X1 + X2 + X3 + \ldots\ldots\ldots + Xn) / n$$

$$CHY = (Y1 + Y2 + Y3 + \ldots\ldots\ldots + Yn) / n$$

Find the Euclidian Distance between (CHX, CHY) and each Sensor Node (Xi, Yi). Check which sensor node has minimum distance from (CHX, CHY), and that will be initial cluster head of Cluster.

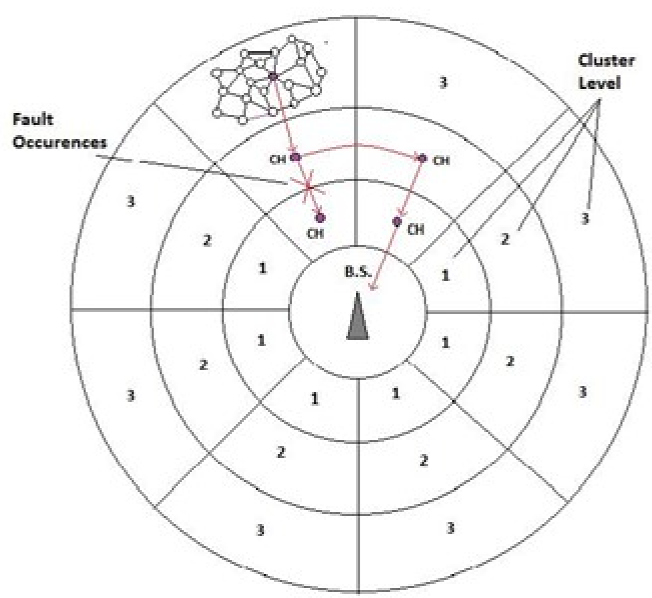


Figure 2: Wireless Sensor Network

After Cluster Head failure:

After initializing the Cluster head, if this Cluster head fails then who will be next Cluster head? For this we calculate the new Cluster head again. Firstly we find out the center of all nodes using K-means algorithm. If n1, n2, n3 . . . . nn are the number of nodes currently available in the cluster, then we calculate the mid of all nodes using the following method:

$CHX = (X1 + X2 + X3 + \ldots\ldots\ldots + Xn) / n$

$CHY = (Y1 + Y2 + Y3 + \ldots\ldots\ldots + Yn) / n$

Then we calculate the distance between this center (CHX , CHY) and all nodes of cluster and arrange the nodes in ascending order. For example:

n3 <n2 <n5 <n1 <n4

Here total number of nodes is assumed to be five. Now n3 has minimum distance from center and n4 has maximum distance. We select the 25% initial nodes for choosing a new cluster head. Now select the maximum energy level node for new cluster head from initial nodes. This will give the nearly center cluster head with maximum energy level. In DFTR choose cluster head near to the base station, then it may be having low energy level, causing it do go down after some time and they would have to calculate cluster head again [8]. This will consume the energy rapidly.

3.3 Update Route Table of all nodes in Cluster

Route Table of node contains the information of all neighbors' nodes along with their level according to the Cluster Head in EFTR. To update route table of all nodes we use a modified broadcast technique to minimize the number of packets broadcasted. Firstly apply the breadth first search technique from Cluster head and find out all paths to all nodes. Starting from the cluster head, discovery packets are broadcast to immediate neighbors. When the discovery packet is received by a node it updates it's route table with level information. Each of these neighboring nodes forward these packets to their immediate neighbors. When a node receives a packet from a node having a higher level then it discards this packet if it has already received a packet from a lower level node. In DFTR there is no need to update routing table. Because in DFTR each node forward copy of each data packets to upper two nodes. So no need to contain the any level information in route table.

After updating their route table each cluster head keeps the information of it's neighboring cluster heads with their cluster level with respect to the base station. Cluster heads nearest to base station have level 1, the cluster heads nearest to level 1 cluster heads have level 2 and so on. It is updated by the base station using broadcast technique in which each node keeps the information of its cluster level. Hence each cluster head keeps the neighboring cluster head information along with their level.

3.4.Calculate all Paths between Source and Cluster Head

Inside the cluster if any node detects any information and wants to send this information to the cluster head, then first, it calculates all shortest paths between source node and cluster head and chooses the minimum delay path for forwarding the packets. Algorithm given below shows how to calculate all paths between source node and cluster head.

Path_Calculation (source, ClusterHead)

Start:

path_delay = 0, path = source;

[1] Choose atleast one or two same minimum level nodes link from Route Table.

[2] Forward route discovery packets to next one or two nodes and set path matrix.

path = path + current_node;

[3] At current node set the path delay.

path_delay = path_delay + (receiving_time – sending_time);

[4] if (current_node_level != 0 and outgoing_links != 0)

Path_Calculation(current_node, ClusterHead);

else

if (outgoing_links == 0 and current_node_level != 0) send negative acknowledgement to previous node. path = path – previous_node.

path_delay = path_delay – (current.receiving_time

– previous.receiving_time);

update route table of current node by deleting *previous node entry.*

Path_Calculation(current_node, ClusterHead);

[1] if(current_node_level == 0 and outgoing_links != 0)

send positive acknowledgement to source using path matrix.

end total delay with positive acknowledgement.

End:

In this algorithm, we have to pass source node and cluster head and it returns the multiple paths between them. It also returns the delay of each path which shows the delay between source node and cluster head if we choose that path.

For example it returns the n number of paths and the corresponding delay information of each path .

P = (p1, p2, p3, ...,pn) D = (d1, d2, d3, ...,dn)

3.5. Perform Intra Fault Tolerance Routing between Source Node and Cluster Head

If a node detects an event then the path through which data has to be sent is decided by the routing technique. If any link or node failure occurs, then to handle this fault the following algorithm is used. In this algorithm, we use the concept similar to sliding window routing protocol for detecting the fault at current data sending time [10]. Here each node have same n size buffer which contain the copy of each forwarded data packets. When receiver buffer is full then it send one acknowledgement to previous source node for giving its living information. If source node is not getting acknowledgment after sending n data packets, it means link or node is failed and then it select the new path from path matrix and again send the copy of all previous sending data. In increase the delay in EFTR but overall delay performance is nearly equal to the DFTR. Because in DFTR they send the many copies of same data in every nodes irrespective of whether that node exists or not. The algorithm is:

IntraFaultToleranceRouting(source, ClusterHead)

Start:

1. Calculate all paths between source and destination.

2. PathCalculate(source, ClusterHead)

3. This will return the total number of paths and corresponding delay.

P = (p1 , p2 , p3 , ..., pn) D = (d1 , d2 , d3 , ..., dn)

4. Choose one path which has minimum delay. Let if Pi is a path which has minimum delay di then:

di = min(d1 , d2 , d3 , ..., dn)

5. Now forward the packets through this path using a technique like selective repeat.

6. If fault occur then again calculate the new paths from current node to cluster head.

a. PathCalculate(CurrentNode, ClusterHead)

b. Go to step 3.

End:

3.6. Perform Inter Fault Tolerance Routing between Cluster Heads and Base station

If a node of any cluster senses any information, this node uses Intra fault tolerance routing for forwarding the information to their cluster head in the respective cluster. After that this cluster head forwards the data packets to another cluster head of another cluster which is near to the base station. This process continues until all the packets reach successfully at base station. The selection of the next cluster depends on the level number of that cluster which is stored in route table of that cluster. This cluster level information is updated at the time of route table updating. Given algorithm show how to handle fault of cluster heads in this routing.

InterFaultToleranceRouting(Current_CH)

Start:

1. CH_Path = Current_CH, next_CH = Current_CH;

2. While (next_CH != BaseStation)

Choose the one next CH with lower level from Route table of Current_CH.

If(next_CH.level<= Current_CH.level)

CH_Path = CH_Path + next_CH;

3. Next_node = CH_Path.next_CH;

4. While (! full data receive at BaseStation) If (Next_node is exist)

Forward data packets to Next_node; Next_node = CH_Path.next_CH;

else

Stop data transmission.

CH_Path = CH_Path – (Next_node to BaseStation).

InterFaultToleranceRouting(Current_CH.pat hNode);

End:

Here CH_Path shows the path from current cluster head to base station. If any node or link fails then it is detected by acknowledgement technique [10] same as the intra fault tolerance routing and again the path from failure node to base station is calculated.

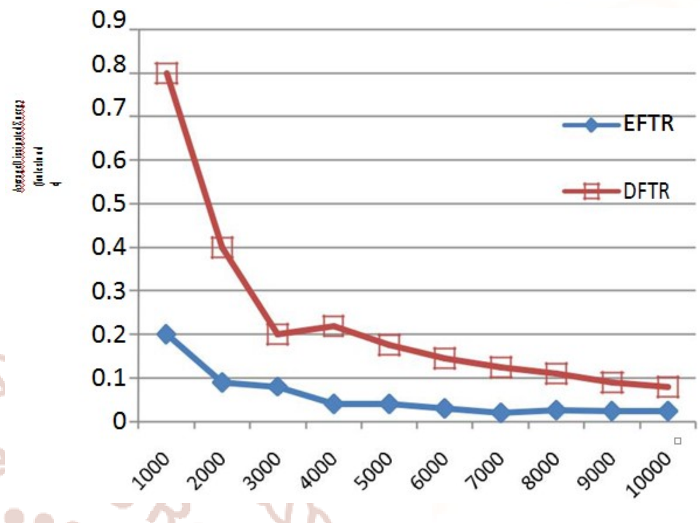
5. SIMULATION RESULTS

Here we evaluate the performance of this new technique. For this technique we perform the simulation for Wireless Sensor Network deployed in 600 × 600 m^2 area. In this area we distribute all nodes randomly which initially contain 1.0 Joule energy. Table 1 shows the simulation parameters.

Table 1: Simulation Parameters

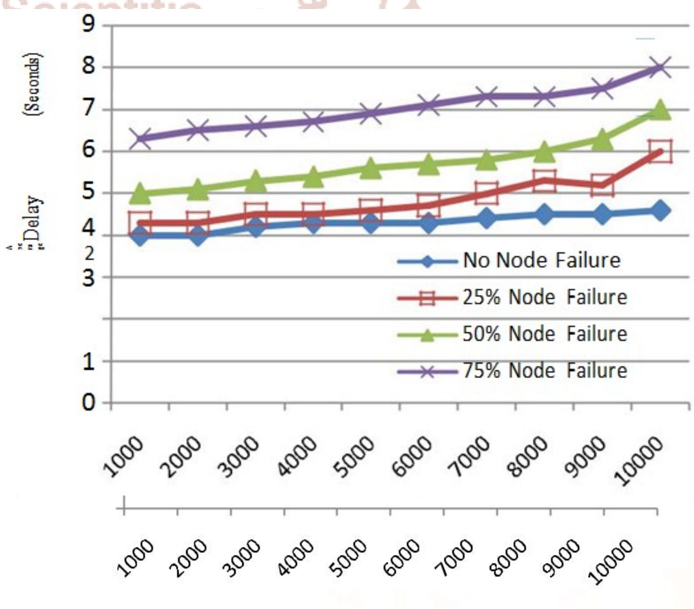
Wireless Sensor Network Area	600 × 600 m^2
Total number of nodes in Network	8000 to 11000
Size of Data	500 bit per packet
Initial Energy of each Nodes	1.0 Joule
Energy loss by trasmitter	50 nJ/bit
Energy loss by receiver circuit	10 nJ/bit

Using these parameters we perform the simulation of this routing technique and for the same parameters we perform the routing according to DFTR (Distributed Multipath Fault Tolerance Routing Scheme for Wireless Sensor Network [8]).We compare both the routing technique in terms of the energy consumption for different number of nodes in network. We can see that according to the given simulation result the energy consumption is more in DFTR as compared to that in our technique. In our technique, if we increase the fault tolerance, then it increases some delay but reduces the energy consumption. In DFTR delay does not increase but the energy consumption increases.



Network Size (Nodes)

Hence the results show that, if fault tolerance is increased then in DFTR network life time is decreased but in our technique (Energy Efficient Fault Tolerance Routing or EFTR) network lifetime will increase.



Network Size (Nodes)

In EFTR we calculate the average delay for different network size with different rate of node failure. Graph show the result of average delay of EFTR which is give the much similar performance with DFTR average delay performance [8]. It is give 2 to 4 seconds difference compare to DFTR. So for better efficient throughput in terms of energy we can avoid this difference. So in our EFTR scheme we increase some overhead for avoid duplication of data packets forwarding which will increase some delay but it will be not too much. So after increasing delay with respect to DFTR, throughput of EFTR will be much better.

5. CONCLUSION

There are many fault tolerance routing algorithms like DFTR, neighbor disjoint fault tolerance routing etc. which give better performance in terms of delay but consume a lot of energy for fault tolerance. Therefore overall throughput decreases. In this work we implement a new Energy Emphasis Fault tolerance routing (EFTR) for wireless sensor networks, in which we reduce the problems of link failure and node failure. In our new scheme we divided the whole WSN into clusters of efficient size using some parameters and for each cluster choose one central cluster head. Then we introduced the two different fault tolerance routing schemes, one is intra fault tolerance routing for within a cluster between the source and cluster head and second one is inter fault tolerance routing between the different cluster heads to base station. We calculated the n number of paths from source to sink. Then we chose one path for data transmission and remain n-1 paths are used in case of link or node failure. These n-1 paths reduce the probability of primary path failure. This new routing increases routing overhead but also increases the overall throughput. It also reduce traffic overhead problem when data is transmitted by the large number of paths individually. We compared the performance of this new EFTR technique in terms of energy with Distributed Multipath Fault Tolerance Routing. It is found to give better performance and lower energy consumption and increased network life time.

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