The Wireless Sensor Network Implementation of a Hybrid Fault-Tolerant Routing Based on the Gaussian Network

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ABSTRACT:

Throughout this publication, we develop a dynamic fault-tolerant routing as a solution to the problem of fault-tolerance in wireless sensor networks (WSNs) that are based on hierarchical topology. Clustering and the labelling of sensor nodes as Gaussian integers are also components of the hierarchical topology. As a result, the area of the network is segmented into smaller square grids, and the cluster head of each grid is denoted by an integer based on the Gaussian distribution. A Gaussian network has been created using these cluster heads by connecting them all together. In this paper, a hybrid fault-tolerant clustering routing protocol for wireless sensor networks based on the Gaussian network is proposed. This protocol makes use of node symmetry, the shortest distance in the Gaussian network, as well as the benefits of multi-path routing (FCGW). The goal of the Fault Tolerance, Increased Data Reliability, and Energy Consumption (FCGW) project is to make wireless sensor networks more resilient to failures, increase the reliability of their data, and The findings of the experiments that were conducted in order to test the suggested scheme demonstrate that the FCGW protocol has a high level of data dependability. Additionally, the FCGW protocol uses approximately 48% of the energy that is available in the network, whereas other protocols use approximately 70% more energy.

I INTRODUCTION:

In wireless sensor networks (WSN), the metrics such as data reliability, optimum power consumption, defined as repeated, and data latency are some of the significant issues in the efficient implementation of the network [1–3]. In particular, in WSN, incorrect connections are constantly caused by the limited number of sensor nodes, as well as by severe communication settings like as rain, wind, snow, and water. This can be seen in [4]. As a result, increasing the failover clustering of the networks will result in an improvement in the quality and services and dependability provided by the WSN. Since that time, resolving concerns with high availability has been an essential necessity for the design of WSNs.

As of right now, there are a few different fault-tolerant strategies that have been suggested as ways to make fault tolerance better. These fault-tolerant strategies will be organised into three primary categories: mechanisms that are based on redundancy, mechanisms that are based on clustering, and mechanisms that are based on deployment, as described in [5]. To be more specific, the following are some of the benefits and drawbacks associated with each mechanism:

- Mechanisms that are based on redundancy: The fault tolerance may be increased by including redundancy components into the system, such as duplicate routing pathways, redundant time, and data duplication [6]. Active replicating and passively replicating both play a role in this mechanism's primary method to fault recovery, which is numbered 7. In active replication, every request for fault recovery is handled by each and every replica in the system. On the other hand, while using passive replication, just one of the replicas will be responsible for processing any fault recovery requests. In the event that this replica is unsuccessful, we shall proceed with another replica. As a result, the capacity for data recovery and the dependability of the data are both increased by this process. On the other hand, the expense of deploying and maintaining the network is also significant.

- Mechanisms that are based on clustering: This technique will form tiny clusters, which will make it easier to maintain the network and extend it [8, 9]. As a result, this mechanism prevents the haphazard failure of nodes and, at the same time, increases the cluster head node's capacity for efficient use of energy (CH). The failure of a CH, on the other hand, will have an effect on its cluster. Therefore, it is very necessary to enhance the fault tolerance efficiency of CH. Several ways have been offered for CH fault tolerance, and each of these approaches, whether they rely on the redundancy of CH or the re-election of CH after a period of time, results in a greater consumption of energy and a continuous increase latency.

- Mechanisms that are dependent on deployment: Wireless sensor networks (WSNs) are self-organizing networks that may be pre-located or randomly installed. Therefore, it is vital to maintain a robust network topology in order to prevent connection failure [10], which is needed to maintain a robust network topology in order to avoid connection failure. When employing the connected dominant set (CDS), network architecture improvements based on virtual backbone are one example of how to prevent connection failure [11]. This approach prevents information interference, maximises the efficiency of data transmission over a virtual backbone, and cuts down on energy loss. Even if improving the network structure may provide a solution to NP-hard issues, doing so will make the solution far more complicated.

It has been shown via the overview that was provided above that increasing the efficiency of clustering and improving the network architecture both have greater benefits for single point of failure in wireless sensor networks. In addition, throughout our prior studies [12], we proposed a modelling of WSN based on a Probability distribution network in order to improve energy consumption by the fastest distance multicast routing and optimise the management of network topology. This was accomplished by optimising the management of the network's topology.

Therefore, in order to continue expanding on prior research, the purpose of this study is to present a solution making use of the Gaussian network model to address the problem of fault tolerance in WSN. The most important notion for fault tolerance in this approach is to take use of the effectiveness of clustering routing and the symmetry of Gaussian networks that are based on multipath routing.

The following is a list of our primary contributions:

• The geographic adaptive fidelity (GAF) algorithm will be used to cluster the random sensors after which they will be broken up into virtual grids. • Each CH node will be defined as a Gaussian integer and connected together to form a Gaussian network, which will allow WSN-management to be optimised as a Gaussian network. • In order to improve consumption energy efficiency and prolong network lifetime, each cluster will choose one active node at a time to serve as a CH node. In this research, a fault-tolerance method for CH nodes is presented as a possible solution. Because the Gaussian network utilises symmetric links, in the event that the primary routing path experiences a failure, it can be easily replaced by the superfluous routing paths. This results in an increase in the data's reliability as well as an optimization of the network's power consumption.

II RELATED WORK:

A. Have an understanding of the fault tolerance

Wireless sensor networks are distinguished by a number of key qualities, one of which is fault tolerance. As a result, network connectivity is strengthened in order to guarantee the dependability and accessibility of something like the network despite the challenging surroundings and the restricted capacity of the node.

For this reason, in order to categorise fault tolerance methods and get an understanding of how they work, many related theories have been developed in the prior literature [4, 7], [14, 15], and [16], as follows:

• A Fault: A problem may be defined as any unanticipated change or aberrant state that occurs inside a system. An error may be caused by a variety of different types of flaws. A malfunction in any one of a system's components may bring to the breakdown of the whole system.

• Fault detection: In order for a system to take any kind of preventative action, the very first thing it has to do is identify which particular problems have arisen inside the network.

• Fault diagnosis is the process of establishing the variables that impact faults and diagnosing the sorts of reasons that result in faults. • Faults may be caused by a variety of circumstances, therefore it's important to be able to differentiate between them.

• Defect recovery: Once a fault has been identified by the system, the next step is to either stop any more faults from occurring or recover from the fault that has already occurred. The most important strategy for accomplishing this objective is to reproduce components whenever there is an error in the system.

The malfunction in a WSN may be brought on by a wide range of factors, including the network's equipment, software, nature of communication, power restriction, timeout, rogue nodes, and so on. On the other hand, depending on techniques to fault identification and troubleshooting [15], [17], the approaches to fault tolerance will be split into three categories as follows:

• The centralised strategy is one that primarily relies on the use of a single centralised node in order to carry out fault management. This centralised intermediate node will be responsible for determining the state of all other nodes in the network by collecting and processing input from all other nodes. As a result, the centralised technique is inefficient in wide-area wireless sensor networks (WSNs).

As a result, the amount of energy that is used for network management and data transmission is enormous, and the amount of data delay is also increasing; all of these factors have a significant impact on the effectiveness of failure detection including fault recovery in WSNs.

• The distributed approach: With this method, the state of each node in the network will be determined by gathering and analysing information from other nodes in the network's immediate vicinity. The dispersed method will cut down on the amount of data that is sent to the main node, which will in turn help to cut down on the amount of energy used, increase the lifespan of the components, and cut down on the amount of data that is delayed. Therefore, this strategy is capable of being used successfully to wide-area wireless sensor networks (WSNs).

However, the success of this strategy is greatly related to the concentration of the nodes in the surrounding area. Because the number of nodes in a network naturally declines with time, this always has a detrimental impact on the fault detection accuracy.

• The hybrid method relies not only on the centralised node to gather information but also on the neighbour nodes to exchange information in order to ascertain the status of the nodes. The key concept behind this strategy is to depend on both the centralised node and the neighbour nodes. The large-scale network issue of centralised techniques and the node density problem of distributed approaches are both addressed by the hybrid strategy, which involves the installation of extra hardware (super nodes, mobile sink). Nevertheless, the installation of new hardware will result in a rise in expenses and would make it more difficult to create genuine networks.

A number of other fault routing protocols, such as clustering-based protocols, multi-path-based protocols, and hybrid-based protocols, have been presented in accordance with these fault tolerance methodologies in order to obtain improved fault recovery efficiency.

In the next paragraph, the specifics of a typical attack detection routing will be dissected in further depth.

The Fault-Tolerant Forwarding in Different Literatures, Part B

Several protocols for fault-tolerant routing will be described in further depth in the next section. In addition to being included into our proposal, these routing protocols will also be used throughout the performance assessment procedure outlined.

1) Fault-tolerant Protocols for Clustering and Routing: According to [18], the clustering technique in WSN is one that has shown itself to be an energy-efficient procedure. In addition, clustering protocols considerably increase the fault tolerance. Some examples of clustering protocols are the routing protocols FT-LEACH [20], HEED [21], and FTS [22], amongst others.

• The FT-LEACH protocol is responsible for the decreased number of CH faults in LEACH [19]. This is accomplished by randomly picking the CH nodes and basing the selection on the amount of residual energy present in each node. The primary concept behind fault tolerance in FT-LEACH is that each common member (CM) node will only communicate data to CH when its value varies from the value it had at the value it had at the value it had the time before. The benefit of this idea is that it eliminates the need for CH nodes to process repetitious data and eliminates the risk of CH nodes malfunctioning as a result of an interruption in their supply of energy. The energy consumption criteria for the data interchange are not, however, explained in a clear and concise manner by the author.

• The HEED protocol makes periodic selections of CH nodes based on a hybrid of the residual energy of nodes and a secondary parameter such as node proxi or node degree. This hybrid is used to determine which nodes are selected. Each node will do a CHprob calculation, which stands for CH probability, using the remaining energy of the node to determine whether or not it should be elected as a CH node. The CHprob provides assistance to the HEED protocol so that it can prevent the election of low-energy nodes as CH, which would result in the network rapidly losing connectivity.

HEED, on the other hand, is dependent on the number of high-energy nodes that are present in the network; consequently, an increase in the number of fault nodes will result in a decrease in the fault tolerance performance of the system.

• The FTS protocol is proposed for fault diagnosis and fault recovery. In FTS, each cluster will choose a spare CH (SCH) node based on the remaining energy of nodes and its distance to the CH node in order to perform fault diagnostics on the CH node. This decision will be made in accordance with the FTS protocol.

This method is quite useful for fault tolerance and its effectiveness. However, since FTS is dependent on information being sent around between nodes, decreasing the node density would, in the long run, result in a reduction in the performance of the routing system.

2) Fault-tolerant Protocols for Routing Multiple Paths: An essential strategy worth pursuing is one that uses several routing paths to improve the fault tolerance of wireless sensor networks. The number of co routing will construct a few different routing pathways between the source node and the sink node. Following then, the data will be transferred by one of these pathways, which will ultimately lead to an improvement in the data's dependability. In the event that the main routing route is unable to complete the routing process, it may be substituted with another path [23]. A fault-tolerant strategy should look something like this. The literature [24] to [26] also mentions the advantages of multi-path routing in WSN, such as fault tolerance, load balancing, quality of service, and other similar benefits. [24] to [26]

According to [24], the fault tolerance that is based on multi-path routing may primarily be split up into three distinct types.

• Alternative path routing: for alternative route routing, a few different multi-path routings have been suggested, such as in the literature [27], etc. These protocols' goal is to guarantee that various pathways are redundant, which is their primary function. The sink node is responsible for constructing the various pathways in order to disseminate information to other nodes in the network. As a consequence, these protocols place a significant amount of reliance on sink nodes, which results in poor efficiency and the passive building of alternatives.

• Reliable transmission of data: the protocols have suggested to strengthen the dependability of the data by increasing the number of redundant packets that are created while the data is being sent, as shown in [28] and [29]. One of the benefits of using these protocols is that they do not need the maintenance of a routing table. To establish redundancy pathways in the event of a problem, however, would result in an increase in both the delay time and the expenses associated with routing.

• Effective usage of network resources: protocols such as HEED-FT [30], I2MR [31], and others have developed multi-path protocols in order to more effectively utilise network resources. In light of this, routing will sometimes keep certain redundant routing pathways in place in order to maintain a balance of efficiency and to restore the routing path in the event that the primary routing path becomes disconnected.

Hybrid fault-tolerant routing protocols are the third category. Clustering assures excellent energy efficiency and extends network life, while multi-path routing increases data dependability and optimises fault connections. Both of these features contribute to the life of the network. As a result, numerous fault-tolerant routing protocols based on a mix of multipath routing and cluster routing have been developed.

It has been discovered that the k-connectivity network may benefit from a technique known as resilient emission distributed clustering (REED) [32]. The advantage of using REED is that it locates and repairs the problematic connection in an easy and rapid manner. In order to ensure that it reduces the amount of money spent on repairing broken connections. However, this approach is only applicable to the CH node; the defect in the CM node has not been taken into consideration in this suggestion. In addition to this suggestion, it is contingent on the high cost of maintaining alternative routing channels in the network as well as the high density of nodes in the immediate vicinity.

Using HEED as the backbone, the authors of [30] introduced a fault-tolerant multipath routing protocol for WSN called HEEDFT. The purpose of the HEED-FT project is to improve data dependability and load balancing via the use of clustering and multiple routing paths.

In HEED-FT, each cluster will choose a deputy cluster head node (SCH) to increase fault tolerance based on the energy-weighted centre of parameters (EWNC, resource node centrality). As a consequence of this, the data will be transferred over either the SCH or CH route, both of which have been established. On the other hand, the maintenance of SCH nodes, together with extremely sophisticated algorithms, leads in a gradual decrease in the energy efficiency of the system.

III FAULTTOLERANCE MECHANISM

We present a hybrid responsibility to fix routing protocol that is based on a mix of clusters and number of co routing. This protocol is based on the hierarchy topology that is based on a Gaussian network of WSN. Our suggestion for a wireless sensor network protocol is referred to as fault tolerance clustering, and it is based on a Gaussian network (FCGW). The fault tolerance mechanism in FCGW is primarily concerned with fault detection and fault recovery for CH nodes. As a result, our system for fault tolerance is comprised of two phases: the damage detection period and indeed the fault recovery phase. As a consequence of this, the process of fault recovery will be optimised as multiple route routing. This optimization will be based on the symmetric connections of the Gaussian network as well as the shortest path routing as described in formula (5). A. The Phase of Fault Detection There are many different things that may go wrong in wireless sensor networks, including programming errors, equipment malfunction, natural variables, and an overly demanding deployment environment for the devices, all of which can lead to connection failures in the network. In this research, we provide a proposal for a defect detection technique for CH nodes that is based on cluster and consciousness by tracking the information transferred between neighbouring CH nodes. Therefore, after the selection of CHs, the CHs periodically broadcast the grid-ID (the grid index) and the CH-ID (the CH index) for the CHs in the four clusters that are near to one another. As a result, each CH node would update a CH neighbour table known as Negatable. This table will include the adjacent grid-ID, CH-ID, and CH statuses of clusters that are neighbouring each other (Fig. 4). If a CH does not receive any communication from the CHs that are next to it during the information sharing time TheathCH (TheathCH Ta), then the CH will mark the status of the relevant CH in the CH neighbour table as "false." This will cause the CH to become disconnected from its neighbours. Our approach will determine whether or not there is a problem in the CH node based on the state of the CH in the CH neighbour table. B. The Phase of Fault Recovery Our model of the network predicts that failures might take place at either the CH nodes or the CM nodes, which would result in the disconnection of the link between the CH nodes (referred to as extra-connections) either between CH and CMs (referred to as intra-connections).

In the event that CM nodes experience a problem, they will be removed from the cluster automatically. In the event that CH nodes experience a fault, the fault recovery method will be carried out until another CH is re-selected inside the cluster. In the fault recovery method, one CH prior to delivering the packet, it will obtain the next CH state from the NeighTableCH. If

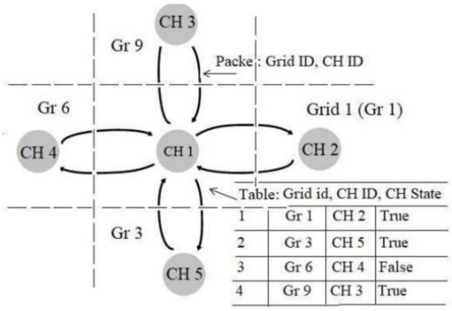

Figure 1 illustrates the definition of the CH neighbour table, also known as the NegTableCH, along with an example of the CH neighbour table for CH 1.

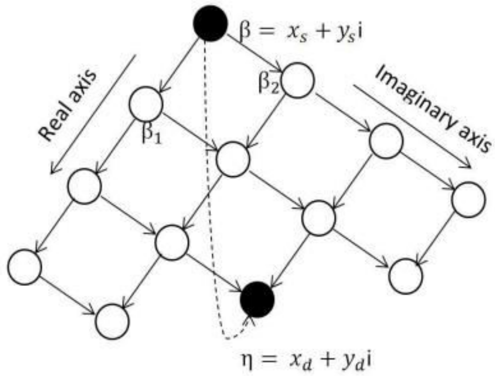

Fig. 2. Multi-path routing in fault-recovery; for instance, packets at node 0 might be sent to node 1 or node 2 respectively.

In the event that this subsequent CH fails, the packets will be automatically sent to other subsequent CH nodes in accordance.

Therefore, the routing pathways that packets take from the CH (=xs + ysi) node to the BS (= xd + ydi) node contain D(,) = |Xmin|+|Ymin| hops as part of their journey (1). This indicates that at node = xs + ysi, the packets may be transferred to following nodes 1 = (xs+1)+ysi or 2 = xs+(ys+1)i (Fig.2) as in method 2; alternatively, the packets can be transmitted in real dimension (real axis) or in imaginary dimension (imaginary axis). As a result, in our fault recovery method, the number of redundant routing pathways to transfer data from the source node to the destination node is Npath, where Npath is a 2-combination of a set D(,). This number can be found by using the formula (6). Consequently, in the course of the routing process, if the next CH fault on the real axis (1 is faulty), it will be replaced by the next CH node in the imaginary axis (2), and in the same way, if the CH fault on the imaginary axis (2 is faulty), it will be replaced by 1 as shown in the formula. In either case, the CH fault on the real axis will be replaced by the CH fault on the imaginary axi (7). In the third algorithm, we went into depth about the fault detection and fault recovery mechanism in the new WSN network architecture. This mechanism is straightforward and easy to put into practise.

$$N_{\text{path}} = \frac{D(\eta,\beta)!}{2!(D(\eta,\beta)-2)!} \quad (6)$$

$$P_{(\beta,\eta)} \rightarrow \begin{cases} formula(5), & \text{if there is no fault,} \\ \beta_{1(x_s\pm1,y_s)}, & \text{if fault in imaginary axis,} \\ \beta_{2(x_s,y_s\pm1)}, & \text{if fault in real axis} \end{cases} \quad (7)$$

IV CONCLUSION

Through using Gaussian network connection features and clustering routing, we have designed a hierarchical topology for a wireless sensor network in this research. Our methodology calls for the placement of the sensors in a haphazard fashion throughout a rectangle space, with each sensor being grouped into a separate square grid. Due to the fact that the CH nodes are linked together to create a Gaussian network, this strategy has better fault tolerance thanks to its use of symmetric connections and multi-path routing. Additionally, the CH nodes are represented in the routing protocol as Gaussian integers, which helps to minimise the complexity of the routing algorithms. This is accomplished by using the routing protocol. The conclusions drawn from the proposed plan result in a substantial reduction in the costs associated with routing and the maintenance with multi-path routing. Nevertheless, interconnecting lengthy sensor nodes as part of a Gaussian network in a distributed environment presents a significant problem that may lengthen the time it takes for packets to be delivered. Using the Gaussian network qualities and its Hamiltonian cycles, we would proceed in the present to solve broadcast concerns that arise in wireless sensors networks.

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