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Energy Aware Fault Tolerant Clustering and Routing Mechanism for Wireless Sensor Networks

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Abstract

Objectives: The key constructions of Wireless Sensor Networks (WSN) are energy conservation and battery depletion of the sensor nodes which are restricted and irreplaceable. Designing an economical clustering and routing mechanism ought to incorporate these problems for large scale WSN. **Methods:** "Energy Aware Fault Tolerant Clustering and Routing Mechanism" is proposed in this work for efficient clustering and fault-tolerant routing. The main idea behind this mechanism is to spot a node which lies in next position to cluster head in terms of energy and configuring it to sleep mode. **Findings:** This is chiefly done to realize fault tolerance by activating the node in sleep mode during the failure of the cluster head. Intensive experiments were performed on this technique and the results are compared with the previous algorithms. **Applications/Improvements:** Energy-Aware Fault Tolerant techniques are effectively used in applications of WSN like army reconnaissance, environmental monitoring etc.

Keywords: Base Station (BS), Cluster Head (CH), Fault Tolerance, Wireless Sensor Networks (WSN)

1. Introduction

Nowadays wireless sensor networks are utilized in numerous styles of applications like environmental observance, military surveillance, health care and disaster management etc. In these applications failure of nodes led to numerous losses of time, money and human life[1]. The major components of WSN are sensing unit, power unit and communication unit. The most dependable challenge of WSN is energy dissipation because the energy depletion of the battery leads to losing of data and the procedure of transferring the detected data to the end user is discontinued[2]. WSN is commonly designed using cluster-based methods. Every cluster has one leader node referred to as Cluster Head (CH). In the cluster-based method, the network is created into clusters which are distinct teams of sensor nodes[3-5]. The clustering involves following advantages (i) redundant and the unrelated information is eliminated as clustering involves data aggregation. (ii) As each node maintain native route information, routing is made easy. (iii) The sensor nodes communicate solely with CH so communication bandwidth is preserved(9). The cluster Head is chosen such that it ought to be more powerful and possess a lot of energy than other sensor nodes. The CH is accountable for aggregating the data from the device nodes of its own cluster. The CH routes the accumulated value to other CH and this method lasts until the data reaches the Base Station (BS) that acts as the sink node. The routing method is done using "routing algorithms". There are many routing algorithms present for designing a WSN[6].

Since routing algorithms prefer low energy consumption to route the data from a sensor node to cluster head, energy conservation is that major part to be thought about because the discontinuance of data transfer cause network damage. Periodic checking of the energy of the sensor nodes will offer fault tolerance and stops the network from permanent harm. The periodic checking of the energy of the sensor node is done by deploying supervisor nodes in each cluster. The key disadvantage of this technique is the network lifetime is completely broken[7]. The CH is the node which is incredibly liable to failure.

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As the CH is liable for gathering data from all the nodes from its cluster, it performs more amount of when work compared with other nodes. So it dies easily. Though all the nodes are battery powered, coming up with energy efficient and energy aware mechanism can solely resolve this drawback[8]. Designing an energy aware mechanism is the way a lot of advantageous than other strategies. This technique conserves network lifetime in addition to energy. The sensor nodes present in the same cluster likely sense the similar quantity of data. The energy-aware mechanism is often brought into the data aggregation and data routing method by configuring a node within the cluster to sleep node that lies in next level to CH. This node can be used as CH in the case of the failure of the present CH. This technique improves network lifetime as well as the overhead of the communication throughout the network[9].

2. Related Works

In the paper[10] which consists of a divided graph for selecting sensor nodes and CH. The time complexity is incredibly high for large scale WSN. The proposed method overcomes the time complexity. This method also lacks in memory conservation. The method (11) consists of an algorithm of time complexity less than the previous one, however, lacks in specifying the energy conservation.

In the method of approach[11] load balancing of dissimilar clusters is considered as an important factor for clustering mechanisms. Network lifetime can be enhanced using this method. The CHs are replaced by gateways. Since the gateways are also battery powered devices they cannot provide improvements in energy conservation.

The paper[2] is the advancement of SPIN protocol which provides energy efficiency by designing a new protocol for cluster based methods. But these methods do not consider any fault tolerance mechanisms in the case of failure of CH.

The[12] is an improved in both time and energy when put next with the previous methods. As this approach could be a centralized one they recovery mechanisms are very robust and re-clustering is made necessary whenever there is a CH failure that could be a troublesome one.

The[13] is the preferred procedure in which network is formed into clusters by employing a disseminated algorithm. This method is incredibly helpful for load matching. The shortcoming of the technique is the node with less energy could also be nominated as CH which may expire easily and communication via BS and CH ought to contain just one hop.

The system[14] is to stabilize the energy utilization of the network. The most drawback of this technique is that for adjusting energy utilization it ought to pick a next-hop node which can't have some other next-hop node within its communication range. This disposes of the spreading of some valuable data to the BS. Furthermore, none of the processes have thought about fault tolerance issues.

As the[15] is a preferred routing protocol based on a multipath which supports on request based data delivery. Multiple split paths are created between source nodes and the BS. If any one of the ways gets failed due to intermediary node failure, then alternate path is chosen to communicate the data. Thus, consistency in data delivery is increased. DD is not appropriate for the applications that need constant information delivery.

3. The Energy Aware Fault Tolerance Mechanism

To boost the consistency and throughput of the system performance are the most focus of fault tolerance mechanism. Also, the fault tolerance mechanisms boost the energy of the entire network.

The proposed system of this paper deals with "Energy Aware Fault Tolerant Clustering and Routing Mechanism" which is a reliable fault tolerance mechanism which takes care of the cluster which experiences sudden failure of cluster head (CH). The mechanism is explained as follows.

The proposed method consists of four modules namely,

1) Cluster Construction,
2) Data Routing,
3) Fault Detection and
4) Fault Recovery.

3.1 Cluster Construction

In the cluster construction phase, the network is formed in several clusters. One main node is considered as a sink node which can also be termed as Base Station (BS) which will not be the member of any cluster. The major work of the BS is to initiate the transmission through sensing process. Sensing is the process of knowing the presence of sensor node in the communication series of the sensing node. And it is also done for checking whether the node is capable of transmitting data. Initially, BS senses the nodes within its communication range (i.e.) (the nodes lying one hop neighbor to

BS) by directing a message to its neighbors. The nodes receive the message and respond to BS. During sensing and transmission nodes lose some amount of energy. After sensing the energy of the nodes are calculated and compared. As a result, a node with the highest energy among the other nodes is chosen as CH and the node with energy next to CH is chosen as the node which is to be configured to "sleep mode".

The node which is configured to sleep mode will not participate in any of the process occurring in the cluster. It is configured such that it should be invoked readily at the instance of failure of CH. This process continues until all the nodes are sensed. Each node in the cluster can sense its one-hop neighbor but the CH is responsible for choosing the CH of another cluster. At the end of cluster construction module, the network is formed into various clusters and the CH and sleep nodes are identified in each cluster.

3.2 Data Routing

In the data routing phase, three source nodes are deployed which are already the member of the network and do not belong to the same cluster. The source nodes are responsible for the creation of sensed data which is to be routed across the CHs and reach the destination which is the BS. The source node can send its data directly to CH and even it can route via the neighbor sensor nodes while the CH lies little far away from the source.

3.3 Fault Detection

The next phase is fault detection phase. The fault is detected through the acknowledgment messages. The source node expects an acknowledgment from the CH whether it took the data properly and reached the BS. The fault is detected whenever there is no acknowledgment from the CHs that means it is due to the CH failure.

3.4 Fault Recovery

This paper proposes a fault recovery mechanism which does not allow the data to be discarded. The system is designed such that at the time of CH failure the node which is in sleep mode is invoked immediately. The source node doesn't receive an acknowledgment from the existing CH but it receives an acknowledgment from the new CH that it has been invoked by replacing the old one. At that point, the source node begins sending information to new CH.

4. Simulation Results and Discussion

The network is constructed with 100 nodes in the area of X and Y coordinates 1200*760, which is evaluated using NS2 Simulator. The BS is positioned in the range 1540*613. The proposed mechanism is compared with "Distributed Fault Tolerant Clustering and Routing Algorithm" which is termed as DFCR. The initial energy of the nodes is given as 0.5J and it varies after sensing process. The nodes lose 0.000175J of energy during sensing and 0.175J of energy during transmitting and receiving of messages.

The major factors like Network Lifetime, Throughput Ratio and Average End-to-End delay are considered and compared with existing system

The figures 1, 2, 3 present a comparison graph of EAFTM and DFCR. The graphs present "Throughput Ratio", "Average end-to-end Delay and "Network Lifetime". EATFM overcomes all the disadvantages of the DFCR method and lies in the higher position of all the performance.

The figures 4 and 5 explain about the hardware experimental setup of this method which comprises of three nodes, the master node, and other two nodes. The master node acts as the sink node and among other tow

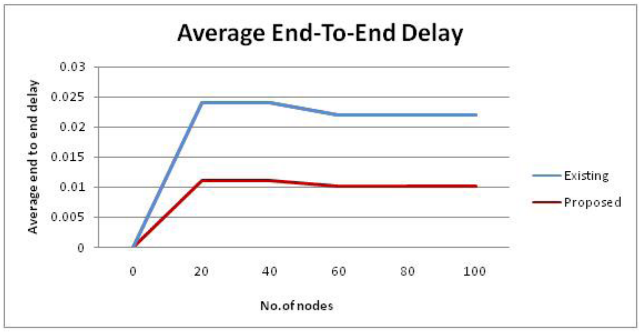

Figure 1. Average End to End Delay.

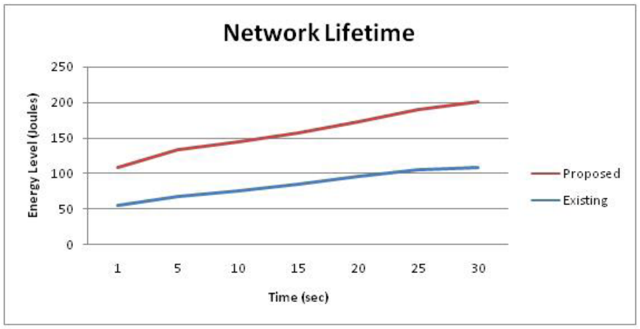

Figure 2. Network Lifetime.

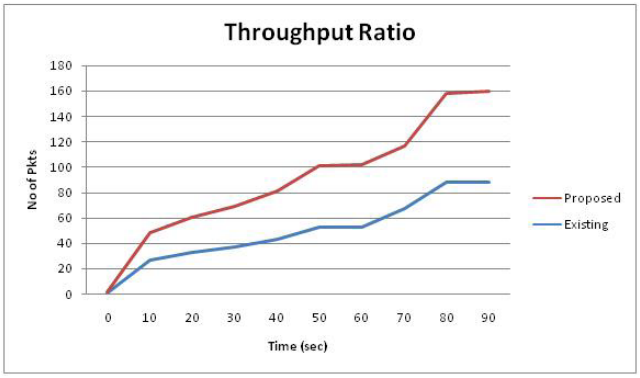

Figure 3. Throughput Ratio.

Figure 4. Hardware Setup.

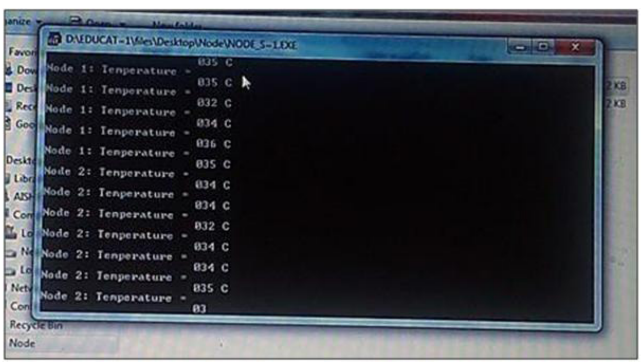

Figure 5. Achievement of Fault Tolerance

nodes, one act as the Cluster Head (CH) and other acts as sleep node. The laptop is used for viewing the status of these three nodes. The CH continuously transmits the temperature values to sink node which is monitored in the laptop. When the CH fails the sleep node is invoked and it is considered as a new CH and it continues the transmission. From this fault tolerance is achieved.

5. Conclusion

In this paper, the energy-aware fault tolerant clustering and routing mechanism for WSN are proposed which is the reliable mechanism for efficient data transfer which prevents network damage and loss of data. The results are compared with the existing mechanism DFCR and enhancements of the proposed fault tolerance mechanism are analyzed. This method can be further enhanced with the redeployment of the failed CH immediately without leaving it lie redundant in the network and making it as the member of the same cluster.

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