Efficient time reducing and energy saving routing algorithm for wireless sensor network

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Abstract. The research article presents a novel energy saving routing algorithm for wireless sensor networks (WSNs) to meet the demand of present research trend. In contrast to conventional methods, a new concept of dominant node has been introduced in this paper. Unlike the conventional algorithms, the proposed method can be applied to both homogeneous and heterogeneous networks. The proposed method focuses on the proper energy distribution among the sensor nodes so that it can offer an energy efficient solution while maintaining improved network lifetime and throughput. The proposed idea has been validated through simulation results. Moreover, the supremacy of the proposed method has been established over existing ones.

1. Introduction

The WSN is a geographically deployed unattended tiny sensor nodes used to sense physical or ecological circumstances, and to co-operatively and efficiently transfer their information via the network to the Base Station (BS). The modern networks are bidirectional, and have control over activities of sensors. The improvement of wireless sensor networks was mainly influenced by military applications although today such networks are used in wildlife tracing, healthcare monitoring, search and rescue call and so on. The sensor nodes of the network located very densely. This WSN’s varies from the conventional Ad-Hoc networks with its constraint in coverage area, storage, power and computational capability and being cheap and massively distributed characteristic. To obtain minimization of energy, lots of research works have been carried out by the researchers to minimize the energy level of the sensor nodes.

In [1] Energy-Efficient Geographic Routing (EEGR) has been introduced. This algorithm contains each sensor nodes’ geographical information and then this information is used to save energy-utilization of the WNS.

In [2] A Distributed Degree based Energy Efficient Clustering (D2EEC) algorithm for WSN has been proposed. In this algorithm, based on node degree and energy, every sensor selects itself as a CH. It found that this algorithm stops in minimum rounds. It has also been established that this algorithm is efficient in increasing the network life period.

In [3] the authors illustrated an EEECARP-Efficient Energy and Event Clustering Adaptive Routing Procedure for Wireless Sensor Networks (EEECARP). Here a sensor with highest residual energy and nearer with the BS is selected as a CH. Most optimal multi-hop routing between the CHs is developed where every CH communicates with its nearest node and the CH nearest to the BS, which delivers
information to the BS. Hence, the algorithm reduces energy utilization among all nodes.

Another new Energy Efficient Dynamic Clustering Algorithm (EE-DCA) for WSN has been presented in [4]. This algorithm improves the energy utilization by varying the activity of wireless model of sensors. This algorithm helps to increase network life period. Under high density of nodes and high-traffic, EE-DCA observes superior than LEACH and BCDCP.

An Energy-Efficient Level based and Time-based Clustering algorithm (EELTC) for WSN has been proposed in [5]. This novel clustering hierarchical algorithm can form unequal clusters with less overhead. This algorithm, all sensors identify their levels on reception of a message-packet from the BS. Based on the received message, every sensor fixes time for advertising itself in the WSN to create clusters.

A new Clustering algorithm for WSN called ICR based Protocol Hierarchy to increase Lifetime of Wireless Sensor Networks [6] has been developed as a modification of the LEACH-TLCH (LEACH Method with Two Levels Group Head) algorithm. This novel clustering hierarchical algorithm can form unequal clusters with less overhead. In this algorithm, based on the received message, every sensor fixes time for advertising itself in the WSN to create clusters. On the basis of consumed energy, the cluster size increases in the next level including extra nodes. The results from simulation show that this clustering technique gives considerable improvements over the traditional EELTC in terms network life period.

To minimize Energy-Consumption due to CH formation, an energy-effective, weighted clustering protocol has been proposed in [7]. This algorithm is more efficient in the formation of cluster than LEACH [8] by considering saved Energy, mutual location, load balance and Medium Access Control (MAC) functioning. The outcomes indicate the proposed procedure better performs than the existing protocol.

The major problem in multi-hop wireless networks is energy-saving routing owed to the several power constraints of the sensors. An algorithm based on cycle-switching CH has been introduced in [9]. This article emphasizes the exertion and existing scenarios related to LEACH, significantly for energy of the node and the network life period, and improves energy of the node consumption and enhances the reliability of data transmission. To extend the network life period and minimize the energy-utilization, in [10] a novel energy-efficient protocol for wireless sensor networks (NEAW) has been proposed. Low Energy Adaptive Clustering Hierarchy with Deterministic Cluster-Head Selection (L-DCHS) is a distributed clustering procedure, which is well known. The NEAW is works on L-DCHS. Simulation results show that the NEAW can increase the network life period as well as energy-efficiency.

To solve real-life problems an improved clustering protocol Balanced and Energy-Efficient Clustering (BEEC) algorithm has been introduced in [11] for heterogeneous WSN. The BEEC optimizes the threshold for selecting CHs and then uses the coverage radius for balancing the distribution of CHs.

Hence, the WSN comprises of wireless nodes called as sensors with low power batteries and less computational and communicational capacity. Therefore, communication between sensor nodes on WSN with efficient energy mechanism is very vital. Thus, our main intention is to decrease the energy consumption of each node so that wireless sensor networks can work for long time without any power distraction.

2. Network simulation model
For our network simulation, we assumed that S sensors that are distributed randomly in M×M area with the properties:
• All Sensors are deployed randomly in the sensor field.
• All sensors are stationary after they are deployed.
• All sensors have different energy levels. The energy of each node is chosen randomly between 0 and 2 joules.
• All sensors are homogeneous and power constrained, with unique Id, which will be discussed later.
• A fixed BS is positioned away from the sensors where each data have to be transmitted.
• Every sensor can transmit data to other sensor or to BS directly by energy control.
The communication link is symmetrical. The energy required to transmit data from node A to node B is the same as the energy required to transmit data from node B to node A.

Every node can estimate the distance between the nearest node and itself using certain techniques and can respond with its identification number. We assumed a radio energy dissipation model as that was used in [8]. In WSN, the data aggregation parameter is set as EDA. When a sensor node transmits data to another sensor-node, radio dissipates $\varepsilon_{\text{elec}} \times d^2 p[/bit]$ [13] for data to be transmitted, the distance between the two nodes is ‘d’. The receiving energy is independent of the distance and is assumed to be $\varepsilon_{\text{elec}} \times d[/bit]$. Also, there is a free space loss or path loss [12] associated with every transmission proportional to the square of distance.

Keeping all the parameters in mind, we tried to develop a new algorithm so that to transmit a data packet to the BS from any sensor node the energy consumption as well as the time consumed will be minimum. The algorithms have been described step by step in the next section.

3. Algorithms

The total procedure of transferring data from any sensor node to the BS can be divided into a few number of modules and those have been described below step by step:

3.1 Dominant Node (DN) Selection Stage

Every node in this network model can be characterized by four parameters. The first parameter is the node status (S) which indicates whether it is a normal or dominant node. The second one is the distance from nearest dominant node (D). The third parameter includes the number of hops required to reach the BS (R), and the last one is the decision status (Y). So every node in the network will be represented by N(S, D, R, Y).

Instead of going for conventional cluster formation and CH selection, we are introducing a new concept of what can be called dominant node or DN. A DN is a node which can communicate with another DN or directly with the BS. Every node which has a status ‘N’ will send data to its nearest DN. Every node calculates the minimum energy required to transmit data directly to the BS. This minimum energy is given by

$$E_{\text{min}} = E_{\text{elec}} \times k + \varepsilon_{\text{elec}} \times k \times d^2 + \text{FSPL}(d)$$

Where ‘k’ is the size of the data packet and FSPL is the free space path loss which is dependent on the distance. As the value of ‘d’ (which is the distance between the sensor node and the BS) is different for different sensor nodes, the value of $E_{\text{min}}$ is also different for different sensor nodes and it is constant as the nodes are stationary. If the power of a sensor is at least ‘$\alpha$’ times its corresponding $E_{\text{min}}$, the status of the node will be ‘D’, where ‘$\alpha$’ can have any value between 5 and 10.

Actually it is found that if the value of $\alpha$ is too high, the number of dominant nodes will be very less. And as their number is already very few, the pressure on them will be high and they will die at a rapid rate and overall network lifetime will decrease. If $\alpha$ is very low, the number of dominant nodes will increase significantly, the energy difference between a dominant node and a normal node will be much less, the rate of conversion from dominant node to normal node will be high once the operation starts and throughput will decrease. So, we have to choose some moderate value of $\alpha$ to balance both sides.
In the above Figure 1, network lifetime and throughput both have been plotted against α. As we see, we get the optimum value for α within the specified range.

3.2 ‘D’ Value selection
Before the routing operation starts actually, the value of the parameter ‘D’ gets updated. In case of a dominant node, ‘D’ indicates the value of the distance of that node from the BS in the shortest possible way via other dominant nodes. This can be understood clearly from Figure 3.

At first the BS checks for its nearest dominant nodes and which are nearest to it, they update their ‘D’ values to be their respective distances from the BS. Then in the second stage, the other dominant nodes which are nearest to those dominant nodes, they add their respective distances with those ‘D’ values and update their own ‘D’ values. This follows a simple algorithm. This program has to be run a finite number of times before we get the ‘D’ values of all the sensor nodes.
Algorithm 1: Procedure of updating ‘D’ values of the dominant nodes

**Input:** ‘D’ value of its nearest dominant node (D₀) and distance from the nearest dominant node (D₁=d₁ (say)).

**Output:** ‘D’ value of its own.

**Algorithm:**

```
D_initial := NULL;
If (D₀ == d)
    { D = d + d₁; }
else
    { D = NULL; }
```

3.3 ‘R’ Value Selection
Following the algorithm portray in the earlier section, we get the ‘R’ values of all the sensor-nodes. For a dominant node, the value of ‘R’ is the number of hops required to reach the BS, whereas for a normal node the value of ‘R’ marks the number of hops required to reach the nearest dominant node. For the nodes nearest to the BS, the value of ‘R’ will be 1, and rest all will update their values in the aforementioned way.

3.4 ‘Y’ Value Selection
This value acts as a flag status for the sensor nodes. It can have only one of the two values-0 and 1. As soon as the sensors are installed in the region, all the dominant sensors get their ‘R’ and ‘D’ values as said in the last section. Every dominant node also calculates the energy needed to directly communicate with the BS using equation (1). Now, it calculates the average energy consumed (E_avg) via the other path by calculating total energy dissipated in that path (using equation (1) with d=“D”) divided by total number of nodes associated with it (got by ‘R’ value).

If \( E_{avg} > E_{min} \), it directly communicates with the BS, the value of ‘Y’ is set 1 and vice versa. In other words, the communication is always done in a path where average energy consumption per node is less. For a normal node, the steps are exactly same, only in this case the nearest dominant node performs the duty which the BS does in case of a dominant node.

3.5 Working Procedure
When the sensor nodes start working in the network, after every round every node checks the status of ‘S’ value. If any dominant node is relegated to normal node, a new link is formed or path is redesigned as shown in Figure. 3. Same thing happens when any normal node dies.
4. Simulation results and analysis
Within the work, a Novel Energy-Efficient Time Reducing Routing Algorithm for WSN has been presented. Assuming collisions, data loss, and errors are handled at lower layers of the protocol stack, this work is carried out on simulation, and comparing the results of various parameters with those of already, existing energy efficient protocols like LEACH-M [14], EEDMC [3], PEGASIS [14] and EECHS-MWSN [13]. The mathematical analysis, simulation setup and results are given in next sections.

4.1 Analysis of Performance
To analyze the performance of our protocol with respect to its efficiency, we used various parameters in this article such as the throughput, average energy-consumption, and network life-period.

4.1.1 Average Energy-Consumption [13] - The Average Energy-Consumption\([j]\) is computed as Total consumed Energy for total receiving packets.

4.1.2 Network Life-period [13] - This is defined as time span between beginning of operation of WSN until the last the dies.

4.1.3 Throughput [Max. Output] [13]: It is the product of number of packets delivered and packet size in bits per the time taken for Simulation.

4.2 Simulation Setup
In our simulation, we used 100m×100m field of 100 sensor nodes distributed randomly in the sensor field. We assumed the location of BS to be (90,170).

4.3 Results
The performance and evaluation of our new protocol is done and correlated with other existing protocols mentioned above. The important results we got after simulation the results have been represented graphically for each of the parameters as shown below.
From Figure 4, it is seen that energy-utilization of the proposed algorithm is almost equal to that of EEDMC [3] and EECHSMWSN [13]. However, the proposed method shows considerable improvement over LEACH-M and PEGASIS [14]. Moreover, as the algorithm emphasizes on energy distribution among nodes, after every round of transmission of data packets, total energy loss i.e. summation of energy loss of all nodes, will be minimized [15, 16].

The performance of the proposed algorithm has also been evaluated in terms of number of alive nodes with number of elapsed sensor-nodes as shown in Figure 5. It is clear that the proposed protocol is able to maintain 100 alive nodes till 5500 rounds approximately after which the nodes start dying out at a slow rate and finally gets exhausted after 9000 rounds. However in EEDMC the nodes die in a much faster rate. As far as other existing protocols i.e. EECHS-MWSN, LEACH-M and PEGASIS are concerned, they exhibit much inferior performance to the proposed one.

This happens because of the fact that routing path selection in the proposed protocol is based on average energy dissipation of the nodes and total energy consumed is distributed among as many nodes as possible. The variation of throughput with number of sensor-nodes of the proposed and other existing algorithms have been presented in Figure 4.3.
For our protocol the path of routing of packets generated at any point is predetermined as discussed and for this reason we get a higher throughput using this protocol than the others. We know that as network size increase, the throughput also increases. Another observation is that at lower levels throughput increases significantly with increases in number of nodes, and in later stage this rate of increase decreases and the value tends to a constant value.

5. Conclusion
We have seen that we got significant improvement almost in all the fields. The main advantage of this protocol is that it can be applied to both homogeneous and heterogeneous WSN. Although this protocol can be applied to both stationary and mobile WSN, the throughput decreases drastically when this protocol is applied to a mobile WSN. Future work could be extended in this direction.

6. References

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