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Data Aggregation and Distance Based Approach to Boost Life Span of WSN

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Abstract: Wireless Sensor Networks (WSNs) are indispensable part of today's life. They're everywhere- civil surveillance, military operations, health industry, even common devices like a TV remote. These networks are capable of collecting data from the surroundings and be a consistent medium of information in a variety of applications which includes close scrutiny, node failure diagnosis, and biological disorder detection. Well, they consume energy and have a finite operational life. And hence, it brings us to think about energy efficiency. Due to finite and exhaustible source of energy, it is vital to design a network in which all nodes function for time as long as possible. A sensor node performs various tasks such as monitoring, processing and transmission of the processed data to the base station (BS).

In this paper, I propose a protocol based on the aggregation head selection method to enhance network's life span. This proposed protocol consists of three phases- Event detection, Aggregation Head selection and Data collection followed by transmission of data after the aggregation. This method selects an Aggregation Head in an energy efficient manner. The selection of Aggregation Head in a network occurs based on its residual energy and energy required to send the data to sink. It has proved to make the network life longer by virtue of taking into account the distance from other sensor nodes and distance from base station as essential aspects.

1) Introduction:

In today's modern era, the whole world is electronic. Wireless sensor networks are a part of this electronic world with blend of MEMS infiltrating more and more in our daily lives. With advancements in MEMS technology, the cost of the intelligent sensor nodes has been reduced. They make part of various applications such as: tracking and control in military, monitoring, medical, environmental and several other arenas. Therefore, it is quite frequent to witness introduction of new approaches and protocols in order to optimize the performance of Wireless Sensor Networks and to extend the reliability. While taking into account the challenges of Wireless Sensor Networks, these new approaches also have some built up key influences to achieve their objectives.

The objective of this paper is to study the factors that may have an effect on the desired performance of Wireless Sensor Networks. The wireless sensor nodes are characterized particularly by their limited non-rechargeable energy resources. If the residual energy of a sensor node, as an aggregation head, is limited, it'll affect the reliability of network. The residual energy of sensor node is also a very important characteristic as it determines the network lifetime of Wireless Sensor Network. My approach is to estimate the relevance of residual energy for a wireless sensor node and determine its participation in data aggregation so that network lifetime is maximized without connectivity and coverage loss.

2) Related Work:

Past few years have seen many research projects exploring data aggregation in Wireless Sensor Network from different standpoints. Data aggregation algorithm [1], provides an algorithm for unstructured sensor network to aggregate the data and send to the sink. An aggregation head is selected in this algorithm to collect the data from the nodes, aggregate the data and send it to the sink.

Data aggregation algorithm [2], provides an algorithm for structured sensor network to aggregate the data and send to the sink. A cluster head is selected to collect the data from the nodes, aggregate the data and send it to the sink in a hierarchical manner. It also calculates the energy consumption in CH rotation. It provides optimal number of tiers in the network and number of nodes in the tier.

LEACH [3], is the first clustering algorithm that was proposed for reducing power consumption. In LEACH, the clustering task is rotated among the nodes, based on duration. It uses direct communication algorithm by each Cluster Head to forward the data to the base station (BS). This algorithm provides a probabilistic approach for the cluster head selection and thereafter it provides a multi hop data transmission process to transfer data to the base station.

M-LEACH [4] introduced the distance concept between cluster head and sink to see if it is far or near, in LEACH protocol. Before this protocol, each cluster head directly communicated with sink. Higher distance consumes more energy. This protocol modified the LEACH protocol and it selects an optimal path having least distance to the sink and uses a multihop transmission between cluster head and sink. Data is transmitted through Multi-hop communication to the cluster heads. Then, the cluster head sends the data to the other cluster head using the optimal path. At the end, the nearest cluster head sends data to sink.

HEED [5] enhances the LEACH protocol and uses the metric of residual energy and node degree or density for selecting the cluster head. This protocol also works on multi hop concept, like M-LEACH. It uses an adaptive transmission power in inter clustering communication. It is a fully-distributed protocol. This protocol terminates in constant number of iterations and helps in obtaining low message overhead for the nodes and network. This algorithm enhanced the lifetime of the network but doesn't support the entire need of Wireless Sensor Network.

Energy-LEACH [6] makes the decision of selecting the cluster head based on the residual energy and makes node with higher residual energy node as a cluster head. At start, each node has equal energy, so a random node is selected as a cluster head and then the node with higher residual energy is selected as a cluster head for the next round. This process continues till the network becomes dead.

[7] and [8] show different type of applications of Wireless Sensor Network. These applications are the practical implementation of wireless sensor networks. This helps in harnessing the actual potential of Wireless Sensor Network which leads to new ways of doing things. New challenges occur during the implementation and its solution provides new applications of Wireless Sensor Network.

The data aggregation enhances the energy saving in wireless sensor networks as found in [9] [10] [11]. Data aggregation process help to avoid sending redundant data, and thus saves energy. A node responsible for aggregating the data and reducing redundant data is called aggregation head. The aggregation head should be chosen carefully because data aggregation process is energy intensive, which means the aggregation head consumes more energy than the other normal nodes.

An aggregation algorithm used a gossip approach for transmission of data by Fauji et al. [12]. Some selective messages are received by all the nodes. One can say that data aggregation approach is better than the pure gossip approach to transmit the data. Data redundancy should be reduced to enhance the lifetime of Wireless Sensor Network. Data aggregation is done through a routing tree by Villas et al. [13]. The intermediate nodes aggregate the data before it is sent so that the energy consumption is reduced by cutting down data redundancy and thus improving lifetime of Wireless Sensor Network. But the tree creation and updating it also consumes a lot of energy.

A cluster-based data aggregation routing protocol is given by Wen et al.[14]. This algorithm provides a way to reduce the total energy consumption during data transmission. The clustering is done in the network and data is sent in a multi hop data transmission method. All the normal sensor nodes send the data to the Cluster Head and the cluster head sends this data to the base station. In this process the energy at cluster head is consumed more than at the normal nodes. So there is an algorithm to select the cluster head more efficiently.

A structure-free and energy balanced data aggregation technique is given by Chih-Min et al. [15]. In this algorithm a table maintains the position of the nodes which means every node knows position of other nodes in the network. This algorithm completes in two phases. Firstly, the aggregation heads are selected and secondly, the aggregated data is sent to the sink. A partial data aggregation technique is presented in [16]. In this algorithm energy consumption takes more attention, transmission delay also considered as an important parameter with a simple model used in this algorithm. All the above algorithms try to enhance the lifetime of Wireless Sensor Network and to balance the load among the nodes. These algorithms use different metrics for selecting the cluster head.

The decision mechanism proposed in [17] [18], to let the nodes decide if they participate in the data aggregation session or not. This participation relevance matrix considers the residual energy, proximity, density at the node and the data importance factors for the decision making process and provides different weights to these factors and compare with

a threshold value and take the corresponding decision. I, in the next section, have proposed an aggregation head selection mechanism and have presented the implementation of the data aggregation mechanism to enhance the lifetime of Wireless Sensor Network. The participation in aggregation process is given by a participation variable that depends upon the residual energy of the node.

The paper [19] shows how the Physical Layer Parameters for Wireless Sensor Networks optimized to consider the distance parameter in energy model. If the distance is too high then there is an optimized distance to find, that is responsible for the modulation process. After determination of this distance the modulation process takes place. This approach helps in optimizing the energy required to send the data from one node to other

node and is more efficient when the distance is greater.

In this paper, the proposed algorithm is compared with the algorithm given in [1]. There are few disadvantages of old algorithm like: the old algorithm decides the aggregation head only on the basis of higher residual energy without looking at whether it is capable of collecting the data from other nodes and able to send it to the sink after aggregating the data. At this condition the network will not be able to send the data to the sink. Also, the algorithm didn't consider the distance parameter that is able to reduce the energy consumption in data aggregation process. The proposed solution is provided to overcome these problems.

3) Proposed Algorithm:

Participation Variable R:

In this thesis, I've used the decision mechanism taken as a part from the idea proposed in [17] [18], to allow nodes to decide if they participate in the data aggregation process or not. I propose an algorithm of aggregation head selection and present an implementation of the data aggregation process.

We assumed that the residual energy affects the decision making process for the participation in data aggregation process. It provides a weight to the residual energy and also check the lifetime of the network during the change in the weight provided to the residual energy. So the Participation Variable R is given as:

$$R = \alpha * Eres$$

Where α is the weighting factor,

Eres is the residual energy of node.

The value of the weighting factor α is different for different networks. Network lifetime depends on this value. An optimal value for α is needed to be found for the network.

4) Network Energy Model:

Mechanism starts when a node detects an event. The Aggregation Head selection process occurs. Let node i be the most probable aggregation head that detected the event, it broadcasts a data aggregation request (AgRq) to its neighbours N. The nodes calculate R and decide whether they will participate to data aggregation or not and send the response to the node i. The energy used by the aggregation is given by:

$$E^{i}_{A} = D * E_{AgRq} + N * E_{AgRqR} + \sum_{j=1}^{k}(d_j * E_{AgResp}) + k * E_{AgRespR}$$

Where

D is the maximum distance to other node in the network.

d_j is the distance between node j and the aggregation head.

E_{AgRq} is the energy consumed in broadcasting the message to one unit distance by node i.

E_{AgRqR} is energy consumed in receiving the aggregation request message sent by i.

E_{AgResp} is the energy consumed by the transmission of each aggregation response message to 1 unit distance.

$E_{AgRespR}$ is the energy consumed by the node i, when it receives a data aggregation response message.

k is the number of nodes participating in the aggregation process.

The energy used to transmit the mean of messages to the base station E_{TT} is –

$$E_{TT} = distance * E_T + E_R$$

Where

distance is the distance between sink and aggregation head.

E_T is the energy needed to transmit a message by a node to the sink.

E_R is the energy needed to receive a message by sink.

The total energy consumption E using the aggregation mechanism is given by-

$$E=E_{TT} + E^i_A$$

Energy Consumption at Node:

Node i that detects the events, sends the aggregation request, receives the aggregation responses and transmits the mean of messages. Thus node i consumes:-

$$D * E_{AgRq} + k * E_{AgRespR} + distance * E_T$$

Aggregation Head Selection Algorithm:

The AgHd consumes higher energy than the other common nodes participating in the aggregation process, it should be picked with care to maximize the lifetime of the network. There are following things that are used in selecting the AgHd-

a. Its residual energy Eres.

b. Its proximity to the base station: distance, between the node i and the base station.

c. Its identifier id.

The aggregation head is selected by the following algorithm:

1. Let node i detects an event, check if (Eres > Emin)

2.1. If (yes) then i make itself the cluster head (AgHd = true) and sends an aggregation request packet (AgRq) to its neighbours (N). The AgRq message contains the residual energy 'Eres', the distance to the sink (base station) 'distance' and the id of the node 'id'.

2.2. When an AgRq message is received from a node j, the node i checks for its detected events whether if it has detected the same event (AgHd = true). Then the decision of aggregation head is carried out by comparing the residual energy and E_min (of that node) first, then the distance between the node and the sink (base station) and finally if both are same then decided by the identifiers means Identifiers is mainly used when two or more nodes contains the same residual energy and are at same distance from the sink.

3. If (no) then i sends an event detection message and the sensors that receive that message, follows all the above steps again.

Pseudocode for algorithm:

```
1: Do while true
2: AgHd← false
3: if an event is detected then
4: while (E^i_res < E_min)
5: broadcast a event detecting message
6: end while
```

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AgHd ← true
send Aggregation Request AgReq (E^i_{res}, N^i_{hop}, id^i)
initiate (time out)
end if
if node j (receive (AgReq (E^i_{res}, N^i_{hop}, id^i))) then
if AgHd = true then
if ($E^i_{res} > E^j_{res}$) or ($E^j_{res} < E_{min}$) then
AgHd ← false
else if ($E^i_{res} = E^j_{res}$) and ($N^j_{hop} > N^i_{hop}$) then
AgHd ← false
else if ($N^j_{hop} = N^i_{hop}$) and ($id^i < id^j$) then
AgHd ← false
end if
end if
end if
if (AgHd ← false) then
calculate partition variable R
if R > threshold value then
send AgResp
end if
end if
end if
if node i receive AgResp then
Collect the data from AgResp and Aggregate it (mean)
end if
if (timeout = 0) then
send aggregated data
end if
end while

Message sending Algorithm:

If the node is not an aggregation head (AgHd) then the node calculates R. If R > Threshold, then it sends the data to AgHd else do nothing. When the timeout occurs then AgHd aggregates the received data and sends it to the sink.

So, in this proposed algorithm the aggregation head is selected not only on the basis of higher residual energy but also on the basis of least energy consumption in data aggregation process. The node that wants to be an aggregation head, should also have the energy greater than or equal to the minimum energy required in data aggregation process. The proposed algorithm also includes a distance parameter that reduces the energy consumption in the data aggregation process. These modifications result the higher lifetime of the wireless sensor network.

4) Simulation Result:

Simulation Parameters:

Simulation is performed for different simulation time with 100 randomly deployed sensor nodes over 100*100 m^2 dimension sized network. Figure 5 shows how sensor nodes are randomly deployed.

Lifetime Comparison:

The comparison is done with the algorithm given in [1]. This paper also provides a data aggregation algorithm and an improved aggregation head selection algorithm for data aggregation in wireless sensor network.

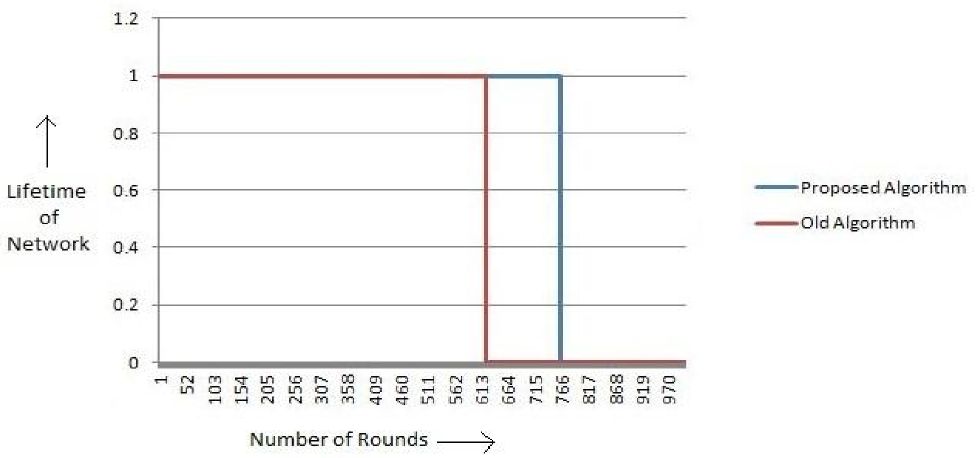

Figure (1)

The **figure(1)** shows that the proposed algorithm has more network lifetime than the old algorithm because in old algorithm the aggregation head is selected on the basis of it's residual energy only and it may occur that a node with highest energy isn't able to send the data to the sink due to the unknown distance from other nodes. The network becomes dead at this time because it will choose the node as an aggregation head which is unable to send the data to the sink.

Whether there can be a chance that the node with lower residual energy would be able to send data to the sink and this process increases the lifetime of the network. This process is used in the proposed algorithm which selects the aggregation head with possibly lower residual energy but with an ability to send data to the sink. It increase the total lifetime of a network.

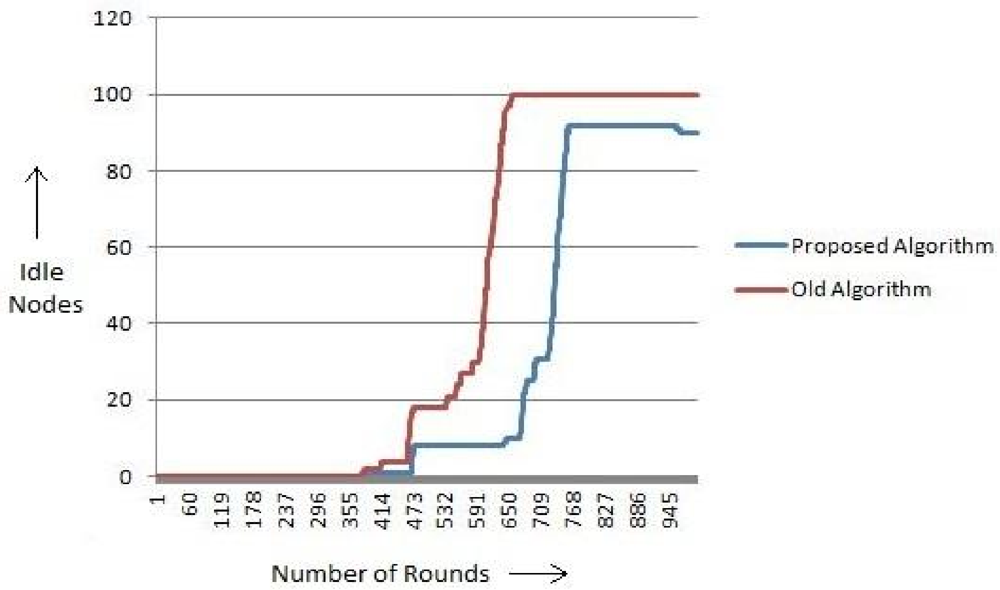

Figure (2)

The **figure(2)** shows that the number of idle nodes seen as incapable of becoming aggregation head are higher in old algorithm as compared to what is in proposed algorithm.

The simulation result shows that the proposed algorithm provides 5-9 % more lifetime than the old algorithm. The aggregation head selection algorithm and the data aggregation algorithm in the proposed algorithm are more efficient than the old algorithm.

5) Conclusion:

This paper presents an improved energy aware data collection, aggregation and transmission protocol based on the aggregation head selection algorithm in an unstructured network. It increases the lifetime of the network.

This protocol changes the method of aggregation head selection and derives an energy model for data transmission to the base station. It achieves the target of the improvement in energy conservation and prolong the lifetime of the network. Simulation is performed on Matlab and achieved better results in energy consumption by the network.

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