Secure and Fault Tolerant Dynamic Cluster Head Selection Method for Wireless Sensor Networks

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Abstract

In this paper we propose a dynamic cluster head selection technique, Secure and Fault Tolerant Dynamic Cluster Head (SFDCH) Selection algorithm. The proposed algorithm selects the nodes having the threshold value above the average. From the selected nodes, the node with maximum available energy, at a minimum distance and having maximum throughput is selected as the cluster head. The proposed method is dynamic in nature as selection process is refreshed periodically. The Proposed SFDCH is compared with existing K-means and K-sep methods using netsim simulator. The results prove the efficiency of our SFDCH in terms of accuracy, energy efficiency and enhancement of network lifetime over the existing methods.

Keywords: Cluster Head; Dynamic; Fault Tolerant; Energy Efficient; Network lifetime; Throughput; Threshold value.

1. Introduction

With the increase in the amount of data generated by the different needs of the humans as well as the physical and environmental conditions, a new class of networks has evolved which is known as Wireless Sensor Networks or the WSN’s. These networks are composed of large number of tiny sensor nodes which are battery driven and are a subtype of distributed systems. They are employed in the system without any infrastructure mainly with a view to keep
an eye on the environmental and physical conditions and collectively pass all the collected data through the network
to the main locations called the sink nodes.

Battery life of these sensor nodes is limited and is impossible to recharge as compared to the sink nodes whose
batteries are rechargeable and there is no energy constraints. Sensor nodes can communicate with the sink nodes
directly or through various multi-hop transmissions. As it is impossible to recharge the batteries once they have been
placed therefore protocols for such networks should be designed to maximize the network lifetime.

Sensing, Processing and Communicating are the three main tasks of the sensor nodes. However most of the
energy is consumed in communicating the sensed data to the sink nodes. Energy consumed is directly proportional
to the distance of the communicating node to the sink node therefore more the distance, more is the energy
consumed. Thus to prolong the network lifetime various energy efficient protocols have been devised. Amongst all,
Cluster based protocols which work on the Euclidian distance phenomena, have proved to be very efficient wherein
the sensors are organized into clusters. Each cluster has a chosen cluster head which is responsible for aggregating
the data collected by its cluster members and disseminating the same to the sink node. Energy, battery life and
distance of the node from the sink node are the key factors which are taken into consideration while electing the
cluster head.

2. Background work

A lot of work has been done in the field of wireless sensor networks. Authors have proposed different methods
for categorizing the documents.

2.1 Low-Energy Adaptive Clustering Hierarchy (LEACH)

In LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol the data is sent to the cluster heads who in
turns forward the same to the sink node after aggregating. The rounds in the LEACH operation are divided into two
namely - a set-up phase and a steady-state phase. Organization of the clusters is done in the set-up phase and the
data is sent to their cluster heads in the steady-state phase. Cluster Heads repeat after every P rounds, where P is the
percentage of the cluster heads. Therefore each round has 1/P probability of becoming a cluster head in each round.

A node that is not a cluster head selects a new cluster head that is closest to it at the end of each round and joins
that cluster head. Head than creates a schedule for each node to transmit the data.

2.2 Power Efficient Gathering in Sensor Information Systems (PEGASIS)

PEGASIS is a chain-based protocol and an improvement over LEACH protocol. In PEGASIS, each node
communicates with its immediate neighbour and finally transmits to the base station turn by turn. Greedy
algorithm or the phenomena of sending the chains by the sink nodes to the sensor nodes can be applied in organizing
the sensors into chain. Only one node is allowed to aggregate the data and send it to sink. However this protocol
needs a wider knowledge of the complete topology of the network whereby increasing the complexity of the
protocol. Since there is only a fixed data path followed by every node, so in case of node failures discovering a new
path is often difficult .This protocol helps in conserving energy but it does not focus much on the quality of service
issue.

2.3 K-Means

Clustering allows for unsupervised learning wherein the software or the machine learns on its own about the
using of learning sets or the data and puts the data into desired class. K means is a simplest algorithm used to give a
solution for the clustering problems. Based on some of the similar properties like the Euclidean distance measure;
each data is assigned to the nearest partition. We choose the random centroid which is mean of all the points in the
cluster. These centroid moves at each iteration. Correlation, Cosine similarity, Euclidean distance are the
mechanisms used for the calculation of the nodes which will be in one cluster. The result of the clustering depends
on the initially selected centroid and only the numeric data values can be clustered accurately. The main objective of
the K-means is the minimization of the objective function that determines the closeness between the data and the
cluster centres.

2.4 K-Stability Election Protocol (K-SEP)

K-SEP is a heterogeneous-aware protocol that is used to increase the time interval before the death of the first node. It is basically used in the scenario where the feedback from the sensor nodes is reliable. In order to become a cluster head the remaining energy in each node is considered. Total energy is increased by \( (1 + \beta x) \) times where \( x \) is the fraction of advanced nodes and \( \beta \) is the additional energy factor. The advanced nodes become cluster heads more often than the other normal nodes as they have additional energies associated with them. The probability of becoming a cluster head is \( P_{\text{optimal}} \) for each cluster head.

For a two level heterogeneous network \( p \) is defined as

\[
P_{\text{normal}} = \frac{P_{\text{optimal}}}{(1 + \beta x)} \quad \text{(For normal node)}
\]

And

\[
P_{\text{advance}} = \frac{P_{\text{optimal}}}{(1 + \beta x)} \times (1 + \beta) \quad \text{(For advanced node)}
\]

3. Proposed Algorithm : Secure and Fault Tolerant Dynamic Cluster Head Selection Algorithm (SFDCH)

Selection of the Cluster Head is a tedious job in wireless networks, so in this paper we propose a secure and fault tolerant dynamic cluster head selection algorithm. The proposed method selects the most eligible node as cluster head, where the eligibility criteria for cluster head is as follows. The eligible node for the CH should have

1. Threshold value above average of all the participating nodes.
2. Highest energy available.
3. Highest throughput.
4. Minimum distance from the sink node.
5. It should not have failed in the last \( N \) transactions.

3.1 Secure and Fault Tolerant Dynamic Cluster Head Selection Algorithm

Input:
Nodes = \{N1, N2, N3, ..., Nn\}
Clusters = \{C1, C2, C3, ..., Cn\}

Output:
A Cluster Head CH in each cluster with Threshold \( Th \) above Average Threshold (\( Th_{\text{avg}} \)), Highest Available Energy \( E_{\text{avail}} \), Minimum distance from the SINK MinDistNode and High Throughput (TP).

CH: Cluster Head

If for a node \( Th \geq (Th_{\text{avg}}) \) \&\& \( E_{\text{avail}} \) is maximum \&\& Distance is Low \&\& TP is High.
then node = CH

STEPS of proposed algorithm
Phase 1: Determine the eligible nodes by using step 1.
Phase 2: Determine the Threshold energy of the nodes by using step 2.
Phase 3: Determine the Available Energy in the node using step 3.
Phase 4: Calculate the Minimum Distance and Throughput using step 4.
Step 1: Finding the eligible nodes

For finding the eligible nodes we focus on the nodes past record of not being a cluster head already and not failed for the last n operations.

for all the nodes in a cluster
if node = already (CH)
go to next node
check the node status in memory table
if nodestatus = fail (trans id)
then go next node
else node can be selected
move to step 3
refresh
check for node availability for n sec
if Node Available
Continue
else select the next Cluster Head

Step 2: Calculating the Average Threshold ($Th_{avg}$) of the network

Threshold value is the value for which the node will survive in the network. Before electing any node as a CH we take into account its threshold value. If this value is above the average that is set for the network, only then the node participates in the next race.

for each node in cluster C1,...,CN
calculate threshold

$$Th(n) = Prob1 - Prob\left( rmod \frac{1}{Prob} \right)$$

if nbelong to $G$

$$Th(n) = 0$$

if ndoesnotbelongto$G$

select all the nodes having the values above the threshold value by calculating the average threshold

$$Th(avg) = \frac{\sum \overline{Th(n)}}{n}$$

if $Th(n) \geq Th(avg)$
put in (ListHigh)
else Put in (ListLow)

Step 3: Calculating the Available Energy

In this step we have calculated the energy available with a node. Node with the highest energy available amongst all is eligible for consideration of the CH.
for all the nodes in the ListHigh
   Energy = Power * Time

calculate the available energy of each node
   \( E_{avail} = \frac{Current\ Energy}{Maximum\ Energy} \)  

create a List \( E_{avail} \)sort in descending order.

Step 4: Calculating Minimum Distance and Throughput

For the node with the highest energy, calculate its minimum distance and throughput value. If two nodes have same energy, node with the minimum distance is taken as the CH and if two nodes have same energy and same distance then the node with high throughput \(^6\) is selected as a CH. The proposed concept is explained by Fig. 1.

for the first node in \( E_{avail} \)sort
   calculate minimum distance using LEACH-MP
   \[ \text{Throughput} \ (TP) = \frac{\text{Size of the Packet}}{\text{transmissiontime}} \]  
   node=CH

if 2 nodes have same energy
   Node with min dist = CH

if 2 nodes have same energy and same minimum distance
   Node with max throughput=CH

3.2 Diagrammatic view of the proposed concept

In the Fig. 1. below, the given network is divided into different clusters based upon the similar properties and Euclidean Distances. Every cluster chooses its CH which communicates with the sink node. A node is eligible to become a cluster head (CH) if its threshold value is greater than or equal to the average threshold and it has the highest available energy, minimum distance from the sink node and high throughput value as depicted in the diagram.

4. Flowchart

After checking the node for its past record of being a CH already and its failures, it is checked future for its eligibility to become a CH. Nodes are put in a high threshold list if its value is above the average threshold value and those with the less value are kept in the low threshold value list which can be later used for other purposes. Nodes are then compared for their highest available energy, minimum distance and high throughput. If two nodes have same energy, minimum distance is taken as the deciding factor and if energy and distance are both same, threshold is taken as the deciding factor. The flowchart of the proposed scheme is as follows:
5. Results

The proposed algorithm SFDCH is compared with existing K-Sep and K-Means cluster head selection methods. All the simulations are done with netsim simulator with simulation parameters given below.
Table 1. Simulation Parameter Table.

| Parameter                  | Value                  |
|----------------------------|------------------------|
| Simulation Area            | 1000x1000              |
| No of Nodes                | 100                    |
| Radio Propagation Model    | Two ray Ground         |
| Channel Type               | Channel/Wireless Channel |
| Antenna Model              | Antenna/Omni antenna   |
| Interface Queue Type       | Queue/Drop Tail/PriQueue |
| Energy Model               | Battery                |
| Min Packets in fig         | 40                     |
| Initial Energy Available   | 65 JPs                 |

Simulation results show that proposed SFDCH method for cluster head selection is better in terms of Accuracy as cluster head selection process is dynamic in nature so best possible scenario is taken, see Fig. 3. Proposed method is saving more energy than existing methods because maximum energy available node is selected as cluster head, see Fig. 4. Due to dynamic nature, using maximum throughput and conserving energy the proposed SFDCH is extending the Network lifetime as in Fig. 6. But delay of our algorithm is more as we are first calculating energy, then distance and then throughput which change the initial setup but at last gives the best results, see Fig. 5. Thus our proposed scheme works successfully in selecting the best available cluster head in the entire cluster set.

6. Conclusion

In this paper we have proposed a new secure dynamic cluster head selection method. Our proposed SFDCH algorithm works on dynamic nature of sensor networks, the complete process of selection is refreshed after every second to finalize the cluster head. In the proposed method first of all the nodes having threshold value above the average network threshold value for of the network are termed as eligible for the cluster head. From these eligible
nodes the node having maximum energy available, node at a minimum distance from sink and having maximum throughput is selected as cluster head node. The proposed SFDCH is evaluated and compared with existing K-means and K-sep methods using netsim simulator. The simulation results prove that our proposed SFDCH is more 44% accurate than existing methods, as well as our proposed algorithm is more energy efficient and enhancing the network lifetime.

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