Solving Connectivity Issues in Wireless Sensor Networks using Anchor Nodes

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Abstract - Wireless sensor network consists of battery powered nodes with fixed amount of energy that are randomly deployed in an area to gather data from its surroundings and send the collected data to the sink. The routing in the network is done by finding the lowest cost path. In case of failure of a neighbor node, routing is done via alternate path. In this paper, we propose a route recovery scheme considering the possibility of failure of all the neighbor nodes in the system. Route recovery scheme can be extended to multiple failures until there is at least one neighbor available for routing. The entire area is divided into grids where each grid consists of S number of nodes. We bring a new mobile node (anchor node) and position it at the center of the grid which contains the failed nodes. ICCA map is performed to find the relative coordinates of all the nodes in the grid. The position of the mobile node is altered to bring in the node without any neighbor within its coverage range and it is anchored at that position. Thus, an alternative routing path is established

Index Terms— Fault location, Anchor Nodes, Disjoint Network, Failure recovery, Wireless Sensor Networks.

I. Introduction

Wireless Sensor Networks (WSNs) use a large quantity of sensors in a target area for performing surveillance tasks such as environmental monitoring, military surveillance, animal tracking, and home applications. Each sensor collects information by sensing its surrounding region and transfers the information to a sink (also called a data center) via wireless transmission. Because of the features of sensors, WSNs have been implemented in harsh environments such as in the deep sea, arctic areas, and hazardous war zones. Different from other battery-powered apparatuses, recharging a sensor's battery is generally impossible. Although solar and wind energy can be used, such energy supplies are not reliable. Equipped with limited energy supplies, WSNs are much more demanding on energy conservation than the other kinds of networks. How to maximize the network's lifetime is a critical research topic in WSNs.

Various methods have been proposed in the literature for organizing energy efficient WSNs, in which sensing the coverage and network connectivity are two fundamental issues. Most of the controlled deployment methods aim at assigning the smallest number of sensors under the cost limitation in an area.

Sensors are battery powered stationary nodes which are distributed randomly in a target area. The information is transmitted from one node to another using low cost routing (LCR). LCR is the process of finding the most inexpensive and the most efficient path between the nodes to route the information from the source to the sink.

II. Literature Survey

The WSN may be of any area and is theoretically considered to be a square or a rectangle. The main aim is to deploy minimum number of sensors and yet establish a proper coverage [1]. The nodes deployed may be static or mobile. The failure may occur due to various reasons and the failure recovery has impacts of features life the network lifetime, quality of the information transmitted, efficiency and performance of the network. To simplify the fault recovery we divide the entire area into series of grids as in [2]. Previous proposals for fault recovery concentrate on reestablishing a working path again from source to destination. For example in [3] the failed nodes are identified and already existing sensor nodes are moved to reestablish the route. In [4] "RIM" is used to handle more than one node failure and the neighbors of the failed node are relocated establish connection. In [5] of nodes relocated are no path between any pair of nodes is extended. But the main disadvantage of these approaches is that they may introduce new failures or holes in the network, more energy can be wasted in moving the nodes over a distance. Also there exist constraints in the number of nodes that can be moved.

In [6], DARA, Distributed Actor Recovery Algorithm, is used to restore the connectivity of a network in a pre-node failure level. It has two variants namely, DARA-1C and DARA-2C. DARA-1C picks up and replaces one of the neighbors of a failed node and aims in minimizing the total distance travelled. DARA-2C strives to restore the bi-connectivity. In [7] single route or multiple path failure is handled. Self-Healing algorithm is used in order to overcome single route failure where each node checks for a shortest distance neighbor having the highest energy of all to transfer the control. In multiple path failure transmission Range increased, but the main disadvantage is that it reduces the life time of the network and may be used only when there is an emergency message to communicate, say for example the fact that the node's neighbours have failed can be informed to the sink. When all the above methods may prove to be un- useful we search for a method that does not introduce new failures or holes in the network, and there must be no constraint in the number of nodes that can be introduced or moved. For this purpose we introduce anchor nodes in the network .In [8] a path planning scheme for the mobile node is proposed to with the aim of minimizing the localization error the entire mobile node must be able to determine their locations. In [9] the localization protocols are proposed to without using hardware such as GPS receivers, which increases node costs. Here Curvilinear Component Analysis (CCA-MAP) protocol is used that uses a technique of patching together relative-coordinate, local maps into a global-coordinate map. Thus uses minimum number of anchor node to give the exact location of the node in the network. This CCA-MAP can be performed only once to find the location and for the optimal position finding we may move the anchor node and check for coverage for that we use an improvised version of CCA-MAP algorithm called iCCA-MAP [10] that does the procedures of CCA-MAP algorithm iteratively until the node is placed optimally. Though the results of every level of both if the algorithms are same the main advantage is that the computational time required for obtaining location estimates using iCCA-MAP is far smaller than the original CCA-MAP. The main aim is to use minimum number of anchor nodes and efficiently find their positions and reestablish the lost connectivity in the network.

III. Problems and Assumptions

Problem

Every node in the WSN transfers data to the destination in a single-hop or multi-hop fashion. In the multi-hop routing the connection between a node and its neighbor is very essential. The failure of a node may cause disconnection in the network. A node can fail for any of a variety of reasons, e.g., broken node hardware, a broken network, software bugs, or inadequate hardware resources.

If the neighbor of a low cost fails, the node selects alternate route in the following way

```
If
        The failure in node has been found then
Repeat
        //Whether there is path to next hop neighbor
      //Whether there is reply for "NEW PATH" Message
  Until (A neighbor for transmission has been found)
End if
```

Similarly if this node also fails the next best route selection in this process is possible until the node has at least one neighbor node, if all the neighbors fail the node becomes disjoint as in Fig 1.

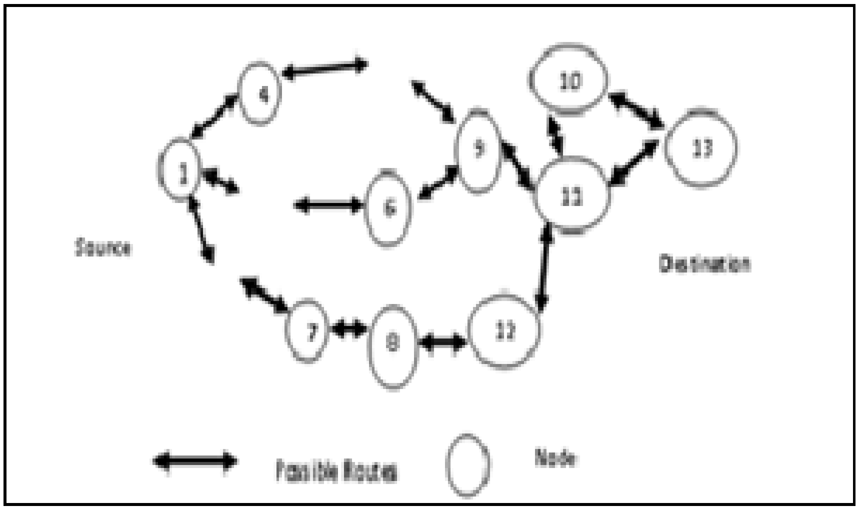

Figure 1 Disjoint Network

Thus, to establish reconnection in the network, some means has to be carried out. In this paper we propose the usage of mobile nodes that we call anchor nodes. These anchor nodes are mobile nodes until they are anchored to their positions. The anchor nodes are moved from the sink to the location where the connectivity is needed.

Assumptions

The following assumptions were made.

- The mobile node's identity is known as a result of the application context. If the application context is such that it does not provide the mobile node's identity, we would at best be able to determine relative mobility by detecting neighborhood changes through periodic Hello messages.
- All nodes have the same transmission range, which is assumed to be a perfect circle.
- All messages are sent and received without error and/or collision
- All nodes have the same computational power and memory capacity.
- Anchor nodes have exact information regarding their location. This is a realistic assumption since anchors nodes could be mounted with a GPS module which obtains the global position of the node.

Other techniques are also possible, such as manually placing the anchor nodes and keeping track of their location either by using GPS or an arbitrary user-defined positioning system.

We take

a_i = current position (coordinates) of the anchor nodes
N_i = position of the nodes without any neighbors in every grid(it may be N_1, N_2, N_3, N_4 etc)
R_{sen} =sensing radius of the anchor node.

IV. Recovery from Failure

The area under consideration (the area deployed with WSNs) is divided into grids as in Fig 2.

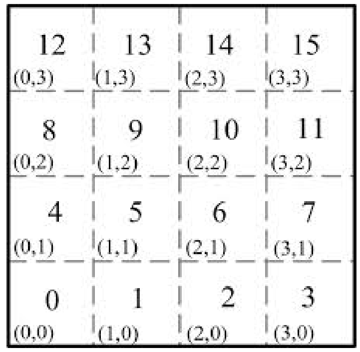

Figure 2 Area under consideration

Each and every node in all the grids is checked. If any node has no neighbors at all, that is, if every possible neighbor of the node had failed, then it is considered as a lone node.

The number of lone nodes is counted. If any grid has 1 or more lone nodes, then the grid is said to be suffering from multiple node failure.

The number of grids containing multiple node failures is found out. The same number of mobile nodes is taken. One anchor node is allotted for every grid with failures

The following steps are done only for the grids with failure simultaneously.

A. Placing the anchor nodes
B. The iCCA-MAP Algorithm
C. Checking coverage.

A. Placing the Anchor Nodes

The anchors are placed at the center of the rectangular grid. The point of intersection of the2 diagonal of the rectangle is considered to be the center of the rectangular grid.

B. The ICCA-Map Algorithm

The iCCA-MAP algorithm computes a single local map for the mobile node rather than computing the local map of every node in the network as is performed in CCA-MAP.
In iterative Curvilinear Component Analysis- Mobile Anchor Point (iCCA-MAP) algorithm, a local map is built for every mobile node in the network. This is usually done in a range-based scheme where the local distance between mobile node and all the stationary nodes is measured and used as input in the form of local distance matrix. The local distance matrix of the local map is computed and used as the approximate distance matrix. Each mobile node then applies the CCA algorithm generating the relative coordinates for every node in its local map by giving the local distance matrix as the input. The local maps are generated iteratively. A linear transformation is applied for merging a new local map into the current map. Using the anchor nodes the relative local map can be translated to an absolute local map, where coordinates reflect the node positions based on the coordinates used to localize the anchor nodes.

C. Checking Coverage

After finding the coordinates of all the nods in the grid, an inspection is performed to check whether all the lone nodes in the grid come within the sensing radius of the anchor node. It's done by checking whether he

distance between the anchor node and the lone node is less than the sensing radius. If it is within the range the connection is established and the routing can be performed via the anchor node. Otherwise if any of the lone nodes are not covered by the newly anchor fixed anchor node then the anchor node is moved for a random distance along the diagonal near the coordinates of the lone node. Again the iCCA-MAP algorithm is performed and again the coverage is checked. These steps are repeated until all the lone nodes in the particular grid come under the coverage of the anchor node. Thus a new routing path is established.
The recovery from failure can be summarized in the form of algorithm

```
Start
Divide the total area into rectangular grids
For all grids
Do
For all nodes in the grid
Do
    If (no of neighbors of any node=0)
        Ni=node having no neighbors
        i++
    Else
        No problem in the grid
    End if
End
    If i>0
        The grid has multiple node failure
        n=no. of grids with multiple node failure
        No. of anchor nodes needed=n
        For (j=0; j<=n; j++)
        1. P=the point to intersection of the diagonals
           of the rectangular grid
        2. Move the anchor node and place it at point p
        //performing ICCA-MAP
        3. Use CCA-MAP to estimate the location of all
           nodes in the grid
        4. Construct the local map of the grid using the
           anchor node as reference
        5. Compute the shortest distance matrix of the
           anchor node and use it as the approximate
           distance matrix.
        6. Apply the CCA algorithm on the anchor node
        7. Input the local distance matrix and Generate
        the relative coordinates of neighbor node of the
         anchor node.
        8. Merge the local map of the anchor node with
           the original relative local map.
        9. Transform the relative map to an absolute map
        10. for all nodes without neighbors
                If distance (an, Ni) < Rsen
                 Alternate route established
                 Else
                 Until distance (an, Ni) < Rsen
                Move the anchor node along the diagonal near the coordinate of Ni
                End if
            Repeat steps 3 to 8
            Establish the alternate route
```

```
            End
        End if
End
End
```

V. Lifetime Estimation in the Failure Recovery Process

The initial lifetime of the network as given in [11]

$$EN_0 = \frac{E0 - Eidle}{p + r * Etrans} \qquad (1)$$

Here E0 is the initial energy of the network. Eidle is the energy wasted while the nodes are being idle p is the total power consumed by the network. R is the rate of transmission of date from one node to the other and Etrans is the energy spent in that transmission. This lifetime is applicable when all the nodes in the grid and subsequently all the grids and ultimately the entire network is properly working without any failure.

When nodes start failing the energy of the system decreases and in turn the total life time decreases.

Consider a network that is divided into N number of grids. Each grid contains S number of nodes and S is a variable. When failure occurs the number of nodes decreases. Let us assume that the number of nodes failed in a grid to be n. and the number of grids without any failure to be X.
The lifetime of the network after some data transactions is

$$Eg = \frac{Epres_j - Eidle_j}{p + r * Etrans_j}. \text{ Here } Epres = E0 - \sum_{j=1}^{N-x}(t * r * Etrans) \qquad (2)$$

is the present energy of the grids and is obtained by subtracting the total energy spent in data transmission from the initial network energy.

This equation is summed from 1 to the maximum number of grids having failure that is got by subtracting the number of properly working grids from the total number of grids. The life time of every single grid with failure is obtained by $\frac{Eg}{N}$. The life time of every single node in grid is obtained by $\frac{Eg}{N*S}$ and is summed over a limit of 1 to the number of failed nodes (n) to get the total lifetime of the failed nodes. Using these equations, the equation for the lifetime of entire grids with failure is obtained by subtracting the total lifetime of all the failed nodes in the grids from the total life time of the grids suffering from failure
Thus the life time of grids with failure is equal to

$$\sum_{j=1}^{N-X}\frac{Eg}{N} - \sum_{j=1}^{N-X}\sum_{i=1}^{n}\frac{Eg_{ji}}{N*S} \qquad (3)$$

To cope up with the failure methods like redefining the nodes and increasing the transmission power etc., are used until there is at least one neighbor node to do the transmission. When all those means cannot be implemented then a mobile node (anchor node) is introduced.

The lifetime of the mobile node is Emob it is the total of energy needed to move and fix the anchor node in the middle of the grid (Efix) and the energy required to move it along the diagonal and fix it at the correct location to establish coverage using iCCA-MAP algorithm (Map). It is summed over the limit of 1 to the total number of anchor nodes in the network. That is represented by

$$\sum_{j=1}^{N-X}\sum_{k=1}^{m} Emob_{jk} \qquad (4)$$

The life time of the network after introducing the anchor nodes in increased and is represented as

$$Eam = \frac{Epresm_a - Eidle_a}{p+r*Etrans_a} \quad (5)$$

Here Epresm=E0-$\sum_{j=1}^{N-x}(t * r * \text{Etrans})+\sum_{k=1}^{m} \text{Eom}_k$ is the present energy of the grids after introducing the anchor node and is obtained by subtracting the total energy spent in data transmission from the initial network energy and the initial energy of the mobile node is added to it.

The equation is summed over a limit of 1 to the sum of number of properly working node in the network to the number of mobile nodes in it (S-n+m). It is represented by

$$\sum_{j=1}^{N-X}\sum_{a=1}^{S-n+m} \text{Eam}_{ja} \quad (6)$$

The total life time of the grids without any failure is got by summing Eg over a limit of 1 to the total number of properly working grids in the network it's represented as

$$\sum_{l=1}^{X} \text{Eg}_l \quad (7)$$

The network lifetime is defined as the amount of time until any sensor runs out of energy [8], thus in our problem the total life time of the network EL is the sum of the initial lifetime of the network, the life time of grids with failure, lifetime of the mobile node, The life time of the network after introducing the anchor nodes, life time of the grids without any failure(adding -(1) ,(3) ,(5) ,(6) ,(7)). Thus

$$EL = EN_0 + \sum_{j=1}^{N-X}\frac{Egj}{N} - \sum_{j=1}^{N-X}\sum_{i=1}^{n}\frac{Eg_{ji}}{N*S} + \sum_{j=1}^{N-X}\sum_{k=1}^{m} \text{Emob}_{jk} + \sum_{j=1}^{N-X}\sum_{a=1}^{S-n+m} \text{Eam}_{ja} + \sum_{l=1}^{X} \text{Eg}_l \quad (8)$$

Thus from the equation (8) the total life time of the network until the entire energy drains out is given by

$$EL=EN_0 + \sum_{j=1}^{N-X}\left(\left(\frac{Egj}{N} - \sum_{i=1}^{n}\frac{Eg_{ji}}{N*S}\right) + \sum_{k=1}^{m} \text{Emob}_{jk} + \sum_{a=1}^{S-n+m} \text{Eam}_{ja}\right) + \sum_{l=1}^{X} \text{Eg}_l \quad (9)$$

VI. Conclusion

In this paper, we have introduced a route recovery scheme for multiple route failures that happens as the result of an energy loss and there is no possibility to transfer the data. When there is no way of transmitting the data new node is introduced in the place of failures by means of localization algorithm and A model has been created for network lifetime with which it can be proven that there will be increase in lifetime.

VII. References

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