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Detection of Energy Hole in Wireless Sensor Networks

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Abstract—Wireless sensor network consists of multiple numbers of sensor nodes which are densely deployed in an unattended environment with the capabilities of sensing, wireless communications, and computations. Due to various factors, several deviations can occur in wireless sensor networks that may lead into energy holes. If holes are not detected at early stage, coverage hole size will increase rapidly. This paper proposes a topology based hole detection algorithm. The spiral algorithm focuses on efficient routing protocol for longevity of WSNs.

Keywords—WSNs; Energy hole; Hole detection; Minimizing hole; Routing protocols; Cluster head.

I. INTRODUCTION

"A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations."

Wireless Sensor Network consists of base stations and a number of wireless sensors (nodes). Usually it consists of tens to thousands of such nodes that communicate through wireless channels for information sharing and cooperative processing. These nodes are highly constrained in terms of physical size, CPU power, memory, and bandwidth[10]. Small size implies nodes with smaller batteries. As nodes are battery powered, energy efficiency is paramount. Ad-hoc deployment implies no maintenance or battery replacement. Batteries might have to last for years.

Generally these nodes operate in challenging physical environment (heat, dust, moisture, pressure). In such conditions, various factors can affect the node's performance and can even destroy it. Network hole appears in the network due to the destruction of group of nodes[7][9].

An area where a group of sensor nodes stops working and does not take part in data sensing and communication is termed as a hole in the network. Holes are the barriers for communication. Holes have a huge impact on the performance of the network. Holes affect the network capacity and perceptual coverage of the network. Due to limited battery the nodes may die with passage of time. In case of random deployment, there is a huge possibility that all areas of target region are not covered properly leading to formation of holes. Hole detection[1][2] identifies damaged, attacked, or inaccessible nodes. If there is a hole in the network then data will be routed along the hole boundary nodes again and again which will lead to premature exhaustion of energy present at these nodes. This will ultimately increase the size of hole in the network. Detection of holes avoids the additional energy consumption around holes because of congestion. It assures long network life and efficient use of nodes.

Wireless sensor networks consist of protocols and algorithms with self-organizing capabilities[8]. In this paper we have compared different existing routing protocols with their efficiency to detect and minimize energy holes. An hole detection and minimization algorithm proposed which is based purely on the topology of the nodes[6].

This paper is organized into sections. The remainder of the paper is organized as follow. Section II includes various related works and a brief comparison of existing routing protocols. Section III deals with the proposed algorithm. The conclusion is stipulated in Section IV.

II. RELATED WORKS

Various routing protocols have been proposed to address the efficient usage of energy in wireless sensor network such as LEACH, PEGASIS and TREEPSI[3][11]. Here we briefly summarize some of existing protocols.

2.1. LEACH

LEACH protocol is a hierarchical protocol which consists of many sensor nodes, some cluster head and a base station. Many sensor nodes of a cluster are connected to a cluster head. Many cluster heads are connected to a base station. Overhead usage of each node in LEACH is comparatively higher and power consumption is too fast. So, sensor node death is higher in case of LEACH[6].

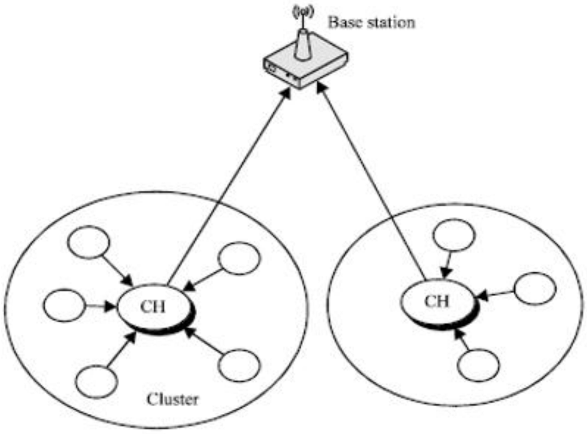

Figure 1. LEACH Protocol

2.2. PEGASIS

Power Efficient Gathering in Sensor Information System (PEGASIS) is a chain based protocol. PEGASIS consists of number of nodes connected in chain structure. In the chain structure, a head node is chosen as leader which receives data from the chain and transmits it to base station. Overhead usage of each node is comparatively lesser than LEACH. So, sensor node death is relatively lower in case of PEGASIS[4].

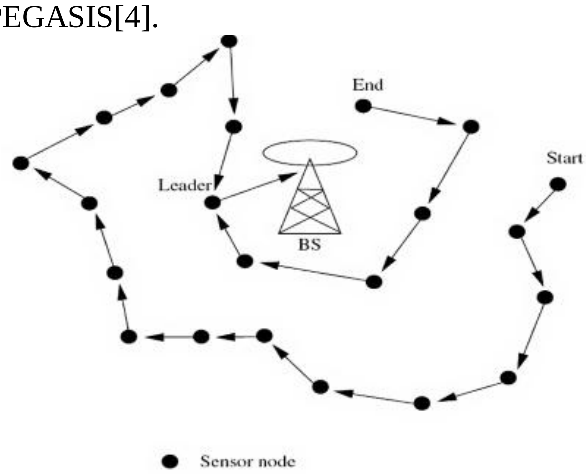

Figure 2. DPEGASIS Protocol

2.3. TREEPSI

TREEPSI[3] is tree based routing protocol which combines the features of LEACH and PEGASIS. It follows a multiple chain hierarchical approach. Here leaf nodes are connected to a sub root node. These sub root node are connected to higher level sub root nodes. Finally, sub root node is connected to a base node which communicates with base station. Overhead usage of each node varies from nil to high. So, here death of sensor node varies from root node to leaf node.

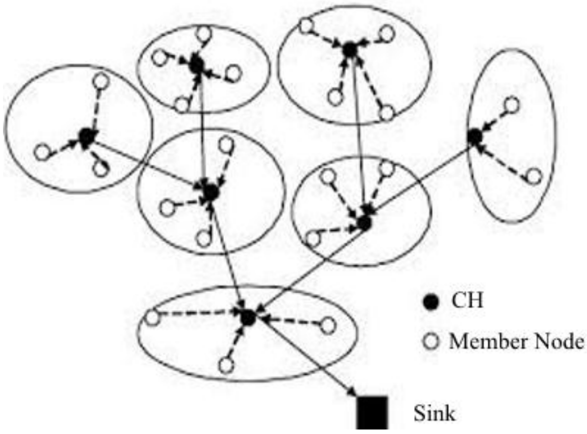

Figure 3. TREEPSI Protocol

Every routing protocol has some limitations. In LEACH, death rate of nodes is higher. In PEGASIS and TREEPSI, head node energy consumption is higher which can lead to uneven death of node in protocols.

III. PROPOSED WORK

We have analyzed some routing protocols with their limitations. So, in our designed spiral routing protocol, nodes are deployed and connected in a spiral overview which ensures the efficient use of energy in WSNs.

3.1. Spiral Routing Protocol

Nodes are deployed in a spiral structure as to consume more area coverage per unit node. Initially every node energy level is equal. There is a cluster head which controls data transmission to base station. Cluster head node's function is dynamic[10]. Every node can become cluster head one at a time. The following diagram shows the spiral routing protocol.

The movement of cluster head is in the direction of the spiral. Initially the center node is cluster head. After first interval, the next node according to spiral, becomes cluster head. This process continues till the last node when each and every node have used theoretically same amount of energy.

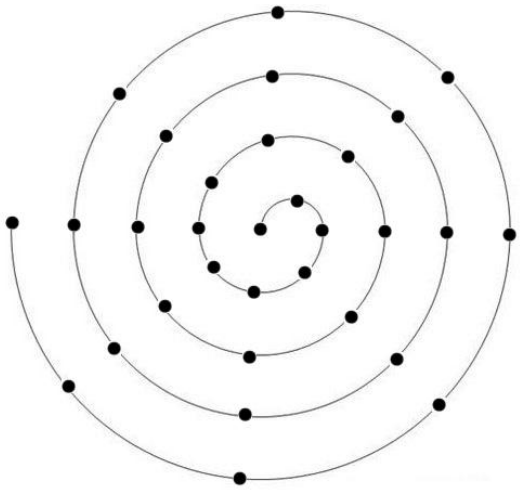

Figure 4. Spiral Routing Protocol

To implement the spiral routing protocol we have to assume that initially every node have equal amount of energy. Energy of any node can be determined dynamically. Each node has a capacity to enhance its coverage area. If the energy level of a node is zero then the node is either damaged or used completely. Spiral structure is formed after the random deployment of the nodes.

3.2. Deployment of nodes

Nodes can be deployed in any random sequence such that it can cover maximum amount of coverage area with minimal overlap. But after deployment we have to arrange the connection of nodes in such a way that it forms a spiral structure. The following diagram shows the spiral formation.

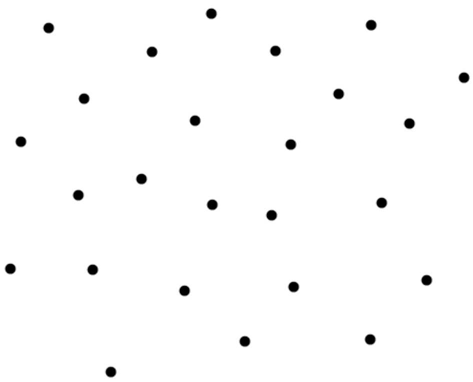

Figure 5. Deployment of nodes

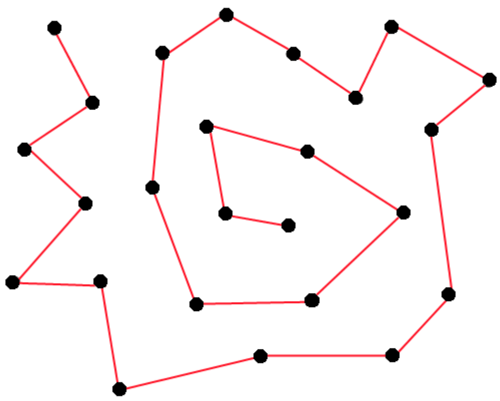

Figure 6. Spiral structure formation of nodes

3.3. Spiral Routing Algorithm

Initially every node is initialized with maximum energy level. When the cluster head node's energy level is decreased by 10 percent of maximum energy level, cluster head node changes and all the nodes are checked. This is one interval. This process continues till every node is decreased by 10% of maximum power. This completes one cycle. After first cycle, cluster head change back to center node and repeats the same interval process. This process continues till every node's energy level reaches to zero.

The following algorithm is implemented for spiral routing.

```
n = number of nodes
p[i] = energy level of node i.
mp = initial energy level of each node.
ap = interval energy level.

for i in range(1,n)
   p[i] = mp

ap = mp

while(ap > 0)
{
   ap = ap - (10  %  mp)
   i = 1

while(i <  n)
   {
         if(p[i] > ap)
```

```
            transmission()

        else if(p[i] = 0)
            energyhole()
            continue
        else
            continue
        i = i + 1
        checknode()
    }
}

checknode()
{
        for i in range(1,n)
            if(p[i] == 0)
                energyhole()
}
```

3.4. Cluster Head Movement

Cluster head remains cluster head until its energy level equals to the calculated interval energy level (ap). When energy level of cluster and interval become equal, the next node according to spiral becomes the cluster head.

```
transmission()
{
        k = p[i]

        for k in range(p[i], ap)
            i = cluster head

        if(k == ap)
            i + 1 = cluster head
            break
}
```

3.5. Energy Healing Algorithm

Whenever nodes with zero energy level are detected, it is considered as an energy hole. As soon as energy hole is detected, energy hole healing algorithm takes place. In this algorithm, energy hole is replaced by virtual interval energy level. This virtual interval energy level is generated by its nearby nodes. The nearby nodes increase its coverage area losing its own energy level to heal the energy hole. The coverage area of each nearby node is increased in an equal proportion and its sum is equal to interval energy level of other node.

```
energyhole()
{
        q = number of nodes connected to i
        m = ap / q
        for j in range(all the nodes connected to i)
            p[j] = p[j] -  m
```

}

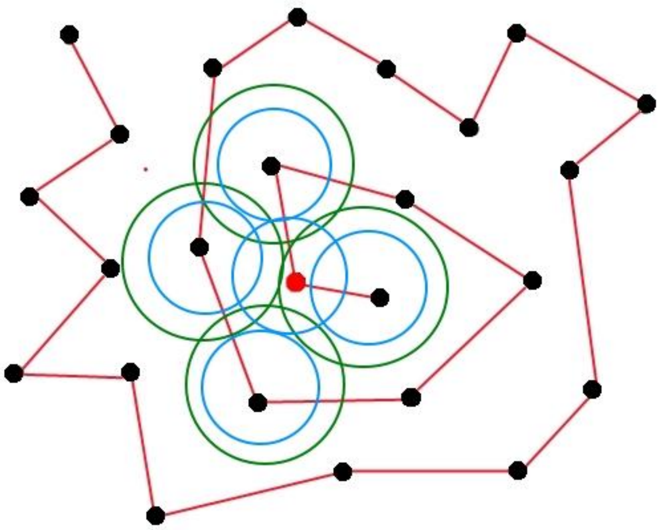

Figure 7. Energy hole healing

Energy hole.

Coverage area of nodes before energy hole.

Coverage area of nodes after energy hole.

IV. CONCLUSION

The identification of holes in a wireless sensor network is of primary interest since the breakdown of sensor nodes in a larger area often indicates one of the special events to be monitored by the network. This task of identifying holes is especially challenging since typical wireless sensor networks consist of lightweight, low-capability nodes that are unaware of their geographic location from base station. Relative distance of each node from other plays a vital role for routing data. PEGASIS protocol uses efficient routing protocol in this uncertain environment. The spiral algorithm is improved PEGASIS protocol with dynamic cluster head. This protocol eliminates the loss of uneven energy problems and balances the overall energy level of each node to an optimized level.

As the proposed algorithm is purely theoretical, practical simulation and implementation is the major future aspect. The proposed algorithm deals with healing the energy hole by increasing uniform amount of energy level but practically this method requires sensors which can increase their coverage area[5].

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