http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (21): 6463-6468, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.6463.6468

An Improved Farmland WSN Topology Based on YG and Clustering Algorithm

Feng Huang[1,2,3,4], Chunjiang Zhao[2,3,4], Feifei Li [2,3,4] and Huarui Wu[2,3,4]
[1]College of Computer Science, Beijing University of Technology, 100124, Beijing, China
[2]Beijing Research Center for Information Technology in Agriculture,
Beijing Academy of Agriculture and Forestry Sciences,
100097, Beijing, China
[3]National Engineering Research Center for Information Technology in Agriculture,
100097, Beijing, China
[4]Key Laboratories for Information Technology in Agriculture,
100097, Beijing, China

Abstract: The large scale farmland WSN monitoring has the characteristics of wide area and energy constraint. Nodes around sink node undertake lots of data transfer work, so these nodes have the problems of excessive energy consumption and some of them are inclined to early death. This study gives an improved a topology control algorithm for farmland wireless sensor networks based on Yao Graph topology and clustering algorithm. The improved algorithm is aimed to balance the nodes energy in the critical region and prolong the network lifetime by clustering and energy regulatory in the sink node communication range. The simulation results shows that this topology control algorithm is conductive to energy balance in the communication key areas-sink node communication range and at last prolong the nodes and the network life time.

Key words: WSN, large scale farmland, topology control, energy constraint, clustering, Yao graph

INTRODUCTION

Wireless sensor networks used in farmland environment can realize real time monitoring of farmland environment. It provides reliable farmland environmental data for farmland management and environment control. The farmland wireless sensor networks has characteristics which different from application in other areas.

The farmland environment monitoring lasts long time and the nodes are scattered in remote farmland environment and generally battery-powered. So it is necessary to have a energy efficient topology and routing.

The farmland has a vast area. It needs a large scale nodes layout to realize environment monitoring. Compared with small scale WSN with dozens of sensor nodes and tens or hundreds of meters coverage radius, the large scale wireless sensor networks have widely distributed nodes, large coverage area, complex data communication mechanism and higher requirements of global energy load balance requirements. (Han *et al.*, 2009), Since nodes near the sink node undertake a lot of data forwarding work from nodes far away from sink node, these nodes energy consumption is the largest in the whole network. The excessive energy consumption results in node death (Chen and Yuan, 2012). A large number of nodes dead in the same region will cause network coverage holes and the death of the nodes near sink node will cause interrupt transmission of information across the network. (Akyildiz *et al.*, 2002)

Therefore, how to balanced network node energy consumption and prolong the life cycle of the critical nodes and the wireless sensor networks is the key issue in the fields of large-scale sensor network applications. Topology Control is an effective way to solve this problem. Topology control scheme is to let each wireless node locally adjust its transmission power and select which neighbors to communicate according to certain strategy, while maintaining a structure that can support energy ef?cient routing and improve the overall network performance (Li *et al.*, 2006).

RELATED WORK AND PROBLEMS

Researchers have been doing a lot of work on topology control recent years. Currently the network topology control research focuses on two aspects: power control and clustered topology:

Corresponding Author: Chunjiang Zhao, Beijing Research Center for Information Technology in Agriculture,
Beijing Academy of Agriculture and Forestry Sciences,100097, Beijing, China

- **Power control:** By dynamically adjust or set the transmit power of nodes, the algorithm try to minimized the network nodes energy consumption
- **Sleep scheduling:** The hierarchical clustering topology control mechanism chooses some of the nodes as the cluster head nodes, the cluster head nodes formed the data forward backbone network, the non-backbone nodes can temporarily turn off communication modules into hibernation to save energy (Chen, 2011)

Yao, (1982) is the first partition-based topology control algorithm. Its basic idea is: use $_k$rays to divide the circle with center at node $_u$ into $_k$ conical areas. Then it leaves only the nearest one node to the node u within each cone. Typically k≥6 and the maximum node degree is smaller than k. Due to the network sparsity requirements, there are a few nodes connected to sink node. The nodes in the edge of the sink node communication area connect the sink nodes and the nodes out of the sink node communication area and undertake a lot of communication tasks so they consume more energy. After the energy of these edge nodes is depleted, the communication from the nodes out of the sink node communication area to the sink node is blocked. (Zhang *et al*., 2007)

Clustering algorithm makes some nodes as the cluster head nodes, the cluster head node form a data processing and forwarding backbone network, other non-backbone nodes can temporarily turn off communication modules into sleep state. This algorithm can extend the life of the node and it is very effective for node-intensive and event-driven network. But clustering algorithm is applicable to small size network. (Kang *et al*., 2010)

Using Yao Graph in large scale farmland WSN is incline to make nodes near sink node dead early because of large amounts of data transfer work. Use clustering algorithm can't meet the requirements of the large scale monitoring. This study combined the advantages of both Yao Graph and clustering algorithm, designed a wireless sensor network topology based on partitioning and energy.

WIRELESS SENSOR NETWORK MODELS

For ease of description and analysis, make the following assumptions:

- The network is a static network, where all nodes are fixed
- Sink node can get a continuous supply of energy and its node communication radius is $rmax_{sink}$
- All the nodes except sink node are isomorphic nodes and the communication radius is rmax
- Each node can obtain its remaining energy and has some storage space to store the neighbor point information

ALGORITHM DESCRIPTION

This study use Yao Graph to contribute the topology graph in the area far away from the sink node and use leach clustering algorithm in the area around sink node. Use clustering algorithm in the area around sink node so that the nodes in the edge of the sink nodes communication area can do short range data forwarding. Cluster head rotation mechanism can balance the nodes energy consumption, improve energy efficiency and prolong the network lifetime.

Partition: This algorithm first does area partition in the entire network area. The entire network is divided into two parts:

- **Clustering area:** A circular area with sink node as the center and the sink node communication radius as the radius
- **YG topology area:** The area out of the clustering area Fig. 1

Contribute the topology graph in the YG area: To get the YG topology graph in the YG area we first generate global original topology graph. All the nodes transmit signals with the maximum power and generate the original topology graph Fig. 2a.

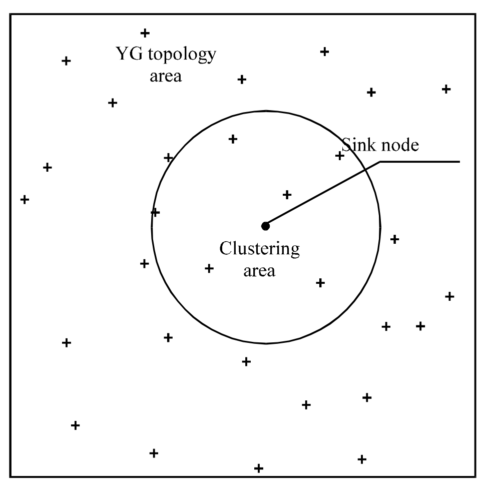

Fig. 1: Partition diagram

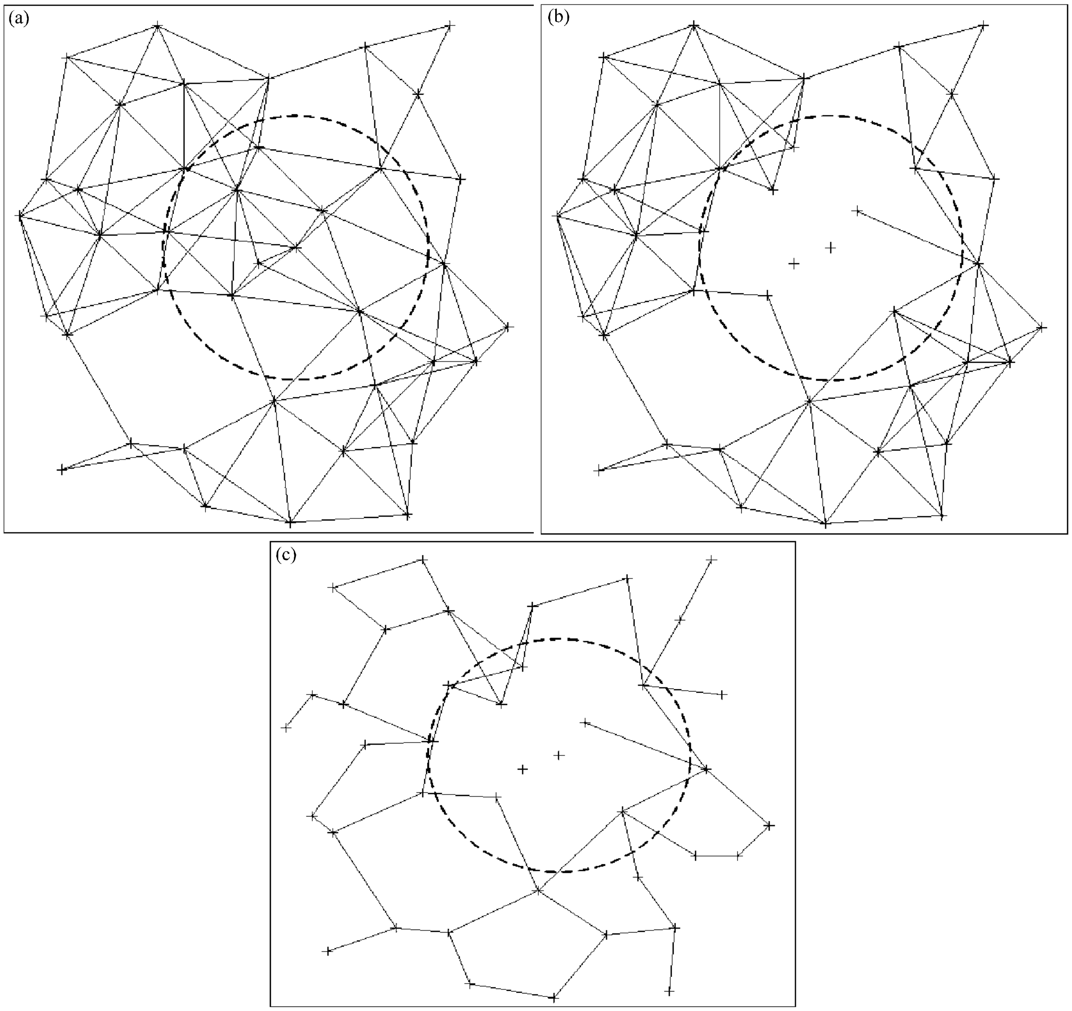

Fig. 2(a-c): YG topology area topology contribution diagram, (a)The origin topology graph, (b) Delete links in clustering area, (c) YG topology generation in YG topology area

After the contribution of the original topology, we judge each of the original topology links: If both the link terminals are in the clustering area, delete this link. We delete all the links in the clustering area to facilitate the clustering work. Figure 2b. If one link terminal is in the clustering area and the other is in YG area, we keep this link. If both the link terminals are in the YG area, we use YG topology algorithm to decide if we can keep this link Fig. 2c.

As can be seen from Fig. 2: The nodes far away from the sink node and have no links with the clustering area nodes have a low node degree; the nodes near the clustering area have a high node degree because they keep all the links with the clustering area nodes.

The related symbols and definitions used in the algorithms:

- No. of the nodes in graph G
- **$|M_i|$:** The number of node $_i$'s one hop neighbor nodes in graph G
- **K:** Partition number for each node
- **Eu:** The set of the wireless sensor network link between node $_u$ and its one hop neighbor node
- E_{uv}: The link between node u and node v

The algorithm pseudo-code is as follows:

```
For i=1 to N do
  For k = 1to K do // K cones
    Compute all angel region of every cone,
denote as Cik
    End for
//compute the angle of node i's one hop
neighbors
  For j = 1 to|Mi| do
//determine which conical areas is each one
hop neighbor nodes in
      Compute all angle of every edge, denote
as Dirij
      Computer in which cone are Eij in;
// Edge retention and deletion
       if (i in the clustering area && j in the
clustering area)
//both terminate nodes are in clustering area,
delete the link
         Ei = Ei -Eij
     Else if (i in clustering area |j| in
clustering area)
// only one terminate node is in clustering
area, keep the link
        Ei = Ei
         Else
// both terminate nodes are in clustering area
          If (Eik is the shortest edge in this
cone)
        Ei = Ei
      Else
          Ei = Ei-Eij
           End if
     End if
  End for
End for
```

Select the cluster head: In the clustering area, the cluster head undertake a lot of data forwarding work, so they have large energy consumption. The nodes in the edge of clustering area have direct link with nodes out of the clustering area, so they are key nodes in the communication link. A longer life of these nodes is necessary because all the information from the YG area reach the sink nodes routing by these key nodes.

Energy consumption model: Nodes energy consumption model to send r bit data:

$$p\ (r, d) = r\ (\alpha_1+\alpha_2 d^m) \tag{1}$$

where, d is the distance between the transmitting and receiving nodes; α_1 is the parameter independent of the distance, including energy consumption of transmitting circuits; α_2 is related to the distance; m is the path loss exponent and usually between 2 and 4.

The parameter m is set to be 2 in this study. So, the when the communication data amount is determined, the data forwarding energy has an exponential relationship with the distance.

Cluster head weight: In this study, we calculate the cluster head weight w consider node degree, node remaining energy and the distance to the other nodes in the clustering area. We choose nodes with higher node cluster head weigh as cluster head. To calculate the cluster head weight of node u in the clustering area:

- Calculate the node degree of node u, denoted as m_u
- Calculate the remaining energy of node u, denoted as E_u
- Calculate the nearest distance from the node u to the other nodes in the clustering area, denoted as α_u; calculate the distance from the node u to the sink node, denoted as b_u

Considering the three factors above, then the weight of each node is expressed as:

$$w = \alpha_1 \frac{m_u}{m} + \alpha_2 \frac{E_u}{E_0} + \alpha_3 \frac{r_{max\_sink} - b_u}{r_{max\_sink}} + \alpha_4 \frac{a_u}{b_u} \tag{2}$$

where, α_1, α_2, α_3, α_4 are the node degree, the node remaining energy, the distance to the sink node, the ratio of the distance to the clustering area node and the distance to the sink node parameters, respectively. m is the number of the nodes in the clustering area. E_0 is the initial network node average energy; $E_u$is the energy of node u. As can be seen from the Eq. 2, the larger the node degree of node u, the lager the cluster head weight; the larger there maining energy of node u, the larger the cluster head weight; the larger the distance to the sink node, the larger the cluster head weight; the larger the ratio of the distance to the clustering area node and the distance to the sink node, the larger the cluster head weight.

CLUSTERING

After the cluster head nodes have been determined, each none cluster head nodes in the cluster area choose a nearest head node as its cluster node or communicate directly with the sink node. If the distance from the none cluster head node v to the nearest cluster head node is longer than the distance to the sink nodes, then the node clustering; if the distance from the none cluster head node to the nearest cluster head node is shorter than the distance to the sink nodes, then the node communicate directly with the sink node.

Figure 3 is the final network topology combined with YG and clustering topology algorithm.

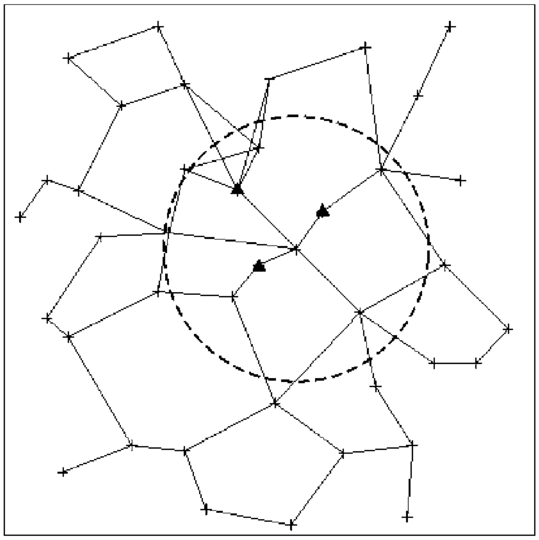

Fig. 3: Improved topology graph

SIMULATION RESULTS

This study use Matlab simulation software to do simulation comparative experiments between this improved topology construction algorithm and YG algorithm.

The area of the simulation scene is set to be 1000×1000m, the simulation compared the average node degree of network with different number of nodes: 200, 400, 600, 800, 1000 nodes. All nodes are isomorphic nodes with the same initial energy and maximum communication radius. The YG topology conical partition number is 6. Simulation parameters are shown in Table 1.

Compared with YG Topology algorithm, the average node degree of this improved algorithm increases. The reason is that the node degrees of nodes in the two partition junction area are higher. And the higher the density of nodes, the more the average node degree increases.

We analysis the scene 100×100 meters with 200 nodes scattered randomly. In the simulation process, there are 22 nodes in the clustering areas. Figure 4 shows the average energy consumption and the survival node number in the clustering area.

As can be seen from the figure, the overall energy consumption of the improved algorithm is higher than the YG Topology, but the improved algorithm has a longer network life time. The improved algorithm in this study has more survived node compared with that of YG algorithm after 50 sec. For the YG algorithm, the number of the survived nodes and the average remaining energy keep stable; for the improved algorithm, the number of the survived nodes and the average remaining energy keep decreasing, after 350 sec. That means after 350 sec, the improved algorithm keeps working but the YG network data transfer is limited.

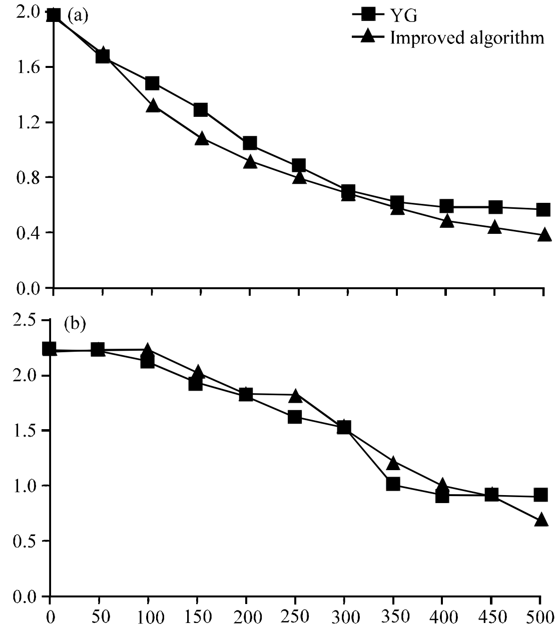

Fig. 4(a-b): Simulation results, (a) Over all remaining energy of nodes in clustering area, (b) No. of surviving nodes in clustering area

Table 1: Simulation parameters

Parameters	Values
Node initial energy	2 J
YG topology conical partitions	6
Channel bandwidth	1 Mbps
Node transmission radius	20 m

CONCLUSION

Aims at the large scale farmland wireless sensor network and the characteristic of energy constraint, this study improved a topology algorithm based on cluster algorithm and Yao Graph Topology algorithm to prolong the nodes life in the critical area and at last prolong the network life.

The simulation results show that the improved topology has a higher node degree and the average energy consumption compared to the YG algorithm in the simulation process, but the data is very close. And the advantage of this algorithm is that the life time of the improved algorithm is longer than the YG topology algorithm. That is because the improved algorithm considered the energy balance in the critical area in the topology contribution. Try to extend the life time of the nodes around sink node can conductive to the long distance data transfer from remote nodes

ACKNOWLEDGMENTS

This study was supported by Natural Science Foundation of China (61271257); Beijing Municipal Natural Science Foundation (4122034); National Technology R and D Program (2012BAD52G01).

REFERENCES

Akyildiz, I.F., W. Su, Y. Sankarasubramaniam and E. Cayirci, 2002. A survey on sensor networks. IEEE Commun. Mag, 40: 102-114.

Chen, L., 2011. Research on algorithms for topology control in heterogeneous wireless sensor networks. Soochou University, Suzhou, China.

Chen, Y.J. and S.F. Yuan, 2012. Minimum energy consumption topology control for wireless sensor networks. J. Univ. Electron. Sci. Technol. China, 21: 568-573.

Han, S.X., Y.M. Fan, L. Zhang and F.R. Luo, 2009. Three-layer topology architecture and topology control algorithm for large-scale wireless sensor network. J. Comput. Appl., 29: 1523-1526.

Kang, Y.M., Z.J. Li, J. Hu and C. Ji, 2010. A low-power hierarchical wireless sensor network topology control algorithm. Acta Automat. Sinica, 36: 543-549.

Li, X.Y., W.Z. Song and Y. Wang, 2006. Localized topology control for heterogeneous wireless ad-hoc networks. ACM Trans. Sensor Networks, 2: 129-153.

Yao, A.C., 1982. On constructing minimum spanning trees in k-dimensional spaces and related problems. SIAM J. Comput., 11: 721-736.

Zhang, X., L.U. Sang-Lu and G.H. Chen, 2007. Topology control for wireless sensor networks. J. Software, 18: 943-954.