Journal of Theoretical and Applied Information Technology
15th December 2012. Vol. 46 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

A MULTI-HOP ROUTING SCHEME BASED ON DIFFERENT SPATIAL DENSITY OF NODES IN WSNS

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ABSTRACT

In this paper, the operating principle of SEP in wireless sensor networks (WSNs) is analyzed, and a multi-hop routing scheme (MH-SEP) is proposed based on different spatial density of nodes. The network is to be divided into different sizes of areas according to the multi-hop routing scheme, the cluster heads use multi-hop mode of communication to send their data to the base station considering the heterogeneous of networks. This paper mainly analysis the performance of scheme based on different spatial density of nodes. The simulation shows that the advantage of the new scheme. On the one hand, with the increase of the monitoring area, the space density decreases, the advantage of the MH-SEP is more and more obvious, comparing with SEP, on the other hand, greater size of surveillance area and smaller the density of the network is, the more obvious improvement is made from the new scheme.

Keywords: *Multi-hop, Routing Scheme, Spatial Density, Wireless Sensor Networks*

1. INTRODUCTION

Hierarchically Clustered topology schedule has such advantages: manage conveniently, use the energy efficiently, and fuse the data easily, etc. With good expansibility and robustness, it has become an important direction of topology study of wireless sensor networks (WSNs)[1].

Currently, a widely used routing protocols in WSNs is clustered routing protocol, it belongs to the hierarchical routing protocol. In clustered routing protocols, some of nodes in the networks are elected as cluster head (CH), then rest of the nodes are cluster members(CM),all the data collected by CMs would be sent to their nearest CHs. Data received by CHs is aggregated, packaged and sent to SINK, a cluster head and all its cluster members are known as a cluster.

LEACH(Low Energy Adaptive Clustering Hierarchy) was first proposed in literature [2] by Heinzelman. LEACH can prolong the network life period, because it reduces the number of nodes communicating with the station, and it can distribute the energy load to each node uniformly in every circle. Moreover, in recent years, algorithms for Clustered topology schedule, such as MPTC[3], AToM[4], GENSEN[5], have improved their performance from different aspects.

However all these studies aim at the homogeneous sensor networks (the nodes of the sensor network equipped with the same amount of energy). In fact, heterogeneous sensor networks are more similar to the reality, because the nodes with various functions lie in a lot of wireless sensor networks. Even for the wireless sensor networks composed by the same type of nodes, the new nodes are arranged on the basis of the old ones, in order to prolong the networks life. The nodes newly added have more energy than the old ones. On the other hand, it is impossible for every node to use its own energy uniformly, because of the failure of wireless link or other accidents.

It is necessary to design clustered topology suited to heterogeneous sensor networks, which is noticed by some study [6, 7, 8]. The way is put forward in [6] of electing cluster heads according to the residual energy of nodes. But it is hard to implement distributive because every node must know the total energy of the network. The heterogeneousness of the nodes is taken into account in SEP(Stable Election Protocol) in [8]. But it only fits the condition when the nodes having only two kinds of energy lie in the network. Practically the energy of the nodes distribute in the network randomly. In addition, redundancy of the nodes in the wireless sensor network is neglected in these literatures.

Clustered routing protocols with single topology structure such as: LEACH and SEP cannot provide effective measures to relief the large energy consumption for long-distance communications. The MH-SEP（Multi-Hops SEP）which is presented in this paper improved the SEP protocol by adding the multi-hop communication to the SEP protocol. So the communication of energy consumption can be reduced.

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With the advancement in networking and multimedia technologies enables the distribution and sharing of multimedia content widely. In the meantime, piracy becomes increasingly rampant as the customers can easily duplicate and redistribute the received multimedia content to a large audience. Insuring the copyrighted multimedia content is appropriately used has become increasingly critical.

Although encryption can provide multimedia content with the desired security during transmission, once a piece of digital content is decrypted, the dishonest customer can redistribute it arbitrarily[2, 3].

2. SYSTEM MODEL

Assume the case where N sensor nodes are distributed uniformly in square area $A = M´ M$. The network has characters as follows:

(1)WSNs are a static network with high density. It is impossible for deployed node to move to any other place, and the nodes are redundant for the WSNs.

(2)The node energy in WSNs is distributed uniformly in $[E_0,(1+ ¶_{max})E_0]$. E_0 is the least initial energy. $¶_{max}$ is coefficient for the node energy.

(3)It is finite for the node's detection ability with radius r_s, and the node is in the center of a circle.

(4)The sink is located in the center of the field A. The radio transmitting power of the sensor node could be controlled by itself.

In order to compare with other algorithm, let us assume the wireless communication model of the network using the model of [2]. In [2], to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting l bit message over a distance d, the energy expended by the radio is given by:

$$E_{T_x}(l,d) = E_{elec}(l) + E_{amp}(l,d)$$

$$= \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2 & d < d_0 \\ lE_{elec} + l\varepsilon_{mp}d^4 & d \geq d_0 \end{cases} \quad (1)$$

To receive l bit message the radio expends $E_{R_x}(l) = lE_{elec}$.

Where E_{elec} is the energy consumed per bit to run the transmitter or the receiver circuit, ε_{fs} and ε_{mp} depend on the transmit amplifier model we use, and d is the distance between the sender and the receiver. By equating the two expressions at $d = d_0$, $d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$ can be got.

the election probability of normal nodes and advanced nodes are:

$$p_{nrm} = \frac{p_{opt}}{1+\alpha \cdot m} \quad (2)$$

$$p_{adv} = \frac{p_{opt}}{1+\alpha \cdot m} \times (1+\alpha) \quad (3)$$

p_{opt} is the optimal clustering probability, which is decided by the number of nodes and the spatial distribution of density, Let m be the fraction of the total number of nodes n, which are equipped with α times more energy than the others. We refer to these powerful nodes as advanced nodes. In model, all nodes generate a random number between zero and one in firstly. If the random number is less than the threshold T(n), then the node becomes the cluster head and broadcasts the message.

There are different threshold for the normal nodes and the advanced nodes respectively, for the normal nodes, we have：

$$T(s_{nrm}) = \begin{cases} \dfrac{p_{nrm}}{1-p_{nrm}\left(r \cdot \mathrm{mod} \cdot \dfrac{1}{p_{nrm}}\right)} & if\ s_{nrm} \in G' \\ 0 & others \end{cases} \quad (4)$$

Where p is the cluster head in the percentage of all nodes, r is the running rounds, and G' is the set of nodes not selected as cluster head in the recent $\frac{1}{p_{nrm}}$ rounds.

For the advance nodes, we have：

$$T(s_{adv}) = \begin{cases} \dfrac{p_{adv}}{1-p_{adv}\left(r \cdot \mathrm{mod} \cdot \dfrac{1}{p_{adv}}\right)} & if\ s_{adv} \in G'' \\ 0 & others \end{cases} \quad (5)$$

G'' is the set of nodes not selected as cluster head in the recent $\frac{1}{p_{adv}}$ rounds.

At the establishment stage, cluster heads are elected according to the protocol; each cluster head

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creates a message of TDMA slot and sends the broadcast message to all nodes in the cluster region to establish a stable routing topology. After the establishment stage, each node begin to work, collecting data, and enter the stable stage. After a certain time, a new round begins, and so forth.

3. IMPROVED ALGORITHM OF MULTI-HOP COMMUNICATION BASED ON SEP PROTOCOL

3.1 Topological Defects Of SEP

Although SEP made some improvements according to the heterogeneous energy, but there is little of the inadequacies in the node topology. In SEP,SINK is assumed located in the center of the surveillance area, nodes are distributed in the area randomly, once a node becomes the cluster head, cluster heads of the network in any position have to communicate with the SINK directly. If the distance between the cluster head and the sink node is too long, then sending data needs the multipath fading channel model and consumes much energy. In this case, nodes would die at an early time, so SEP can't be applied to large-scaled wireless sensor networks.

SEP is a hierarchical routing protocol, cluster heads are used to communicate with SINK to avoid the energy consumption through long distance, so the multi-hop communication between the cluster heads also can achieve the same result, and this is also the starting point of this paper.

3.2 Establishment Of Multi-Hop Communication Network

MH-SEP aims at the defect of single hop communication between cluster heads and SINK. Cluster heads are connected via multi-hop communication algorithm, just like the minimum spanning tree routing network [7] where SINK is the root, and cluster heads the branches and nodes the leaves.

The main idea of MH-SEP is cluster heads choose the cluster heads (or SINK) via which minimum expected communication energy consumption is caused as their parent nodes, and these cluster heads have already joined the communications link. And cluster members also choose the cluster head (or SINK) via which minimum expected communication energy consumption is caused as their parent nodes.

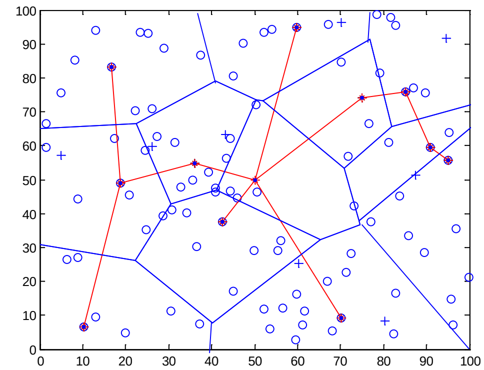

Figure 1: The Topology Of MH-SEP

In figure 1, we denote with ◦ a normal node, with + an advanced node, with red ∗ a cluster head, and with red ◦ the sink. Nodes in the same voronoi cell will report to the cluster head. From figure 1,we can see the difference between SEP and MH-SEP. In SEP, cluster heads of the network have to communicate with the SINK directly no matter how long is the distance between the cluster heads and SINK. While in MH-SEP, cluster heads will choose some cluster heads near the SINK as intermediary to communicate with SINK using multi-hop mode. Moreover, not all the cluster heads far from the SINK have to choose the cluster heads near the SINK as intermediaries unconditionally, this is because when the cluster head receives information, energy consumption will also be caused.

The main idea of MH-SEP is cluster heads choose the cluster heads (or SINK) via which minimum expected communication energy consumption is caused as their parent nodes, and these cluster heads have already joined the communications link. And cluster members also choose the cluster head (or SINK) via which minimum expected communication energy consumption is caused as their parent nodes.

With our study beforehand in heterogeneous WSNs, we could design the multi-hop communication judgment ([9],[10]).

4. SIMULATION RESULTS AND ANALYSIS

4.1 Simulation Parameters

In order to have an intuitive assessment of the MH-SEP, we must assume an appropriate analog space and energy model. Let us assume a heterogeneous sensor network in a 100m x100m sensor field. The sink node is in the center of the surveillance area, the number of nodes n=100. The maximum distance between nodes and SINK is

Journal of Theoretical and Applied Information Technology
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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

70m. In addition, in order to make the comparison, but also will have an area of 200m x 200m surveillance area to make comparative simulation. Our simulation energy model is as same as the classic model used in document [8].

The initial energy of each node in the LEACH algorithm is fixed, and E0 = 0.05j. Simulation of radio wave transmission characteristics are shown in Table 1. The size of information transmitted from cluster members to the cluster head and the size of information transmitted from cluster heads to the SINK are the same, the size is set to 4000 bits. The sink node is in the center of the surveillance area and is regarded as having infinite energy; the judgment standard of the multi-hop communication can be calculated in the simulation as:

$$d_1^2 - d_2^2 \geq \frac{E_{elec} + E_{DA}}{\varepsilon_{fs}} = 550 \quad (6)$$

In order to facilitate the establishment of multi-hop communication within a small range in the 100m x100m area. According to the energy model, in the simulation, the energy consumption of transmission/receiving information and data processing is reduced 10 times.

4.2 The Differences Caused By Sensor Network Space Density

In order to assess the sensitivity of the spatial distribution of density in MH-SEP, we chose the change of surveillance area as well as the change of the coverage density of the node to assess the network. We observe the change by changing the monitoring area and the number of nodes. In Figure 2, the surveillance area is 100m x 100m, the number of nodes n = 100; in Figure 3, the surveillance area is 150m x 150m, the number of nodes n = 100; in Figure 4, surveillance area is 200m x 200m, the number of nodes n = 100; in Figure 5, surveillance area is 150m x 150m, number of nodes n = 225.

It can be seen from Figure 2-5, with the increase of the monitoring area, the space density decreases, the role of the MH-SEP is more and more obvious, in contrast of SEP, normal rate is getting higher and higher. From about 15% of Figure 2, to Figure 3, approximately 27%, then about 50% in Figure 4. Moreover, with the same density, the greater the detection area is, more obvious the result is, but obviously not as good as density decreases, we compare Figure 3 with Figure 5, the improvement is only from 27% to 27.5%, the change is not very significant.

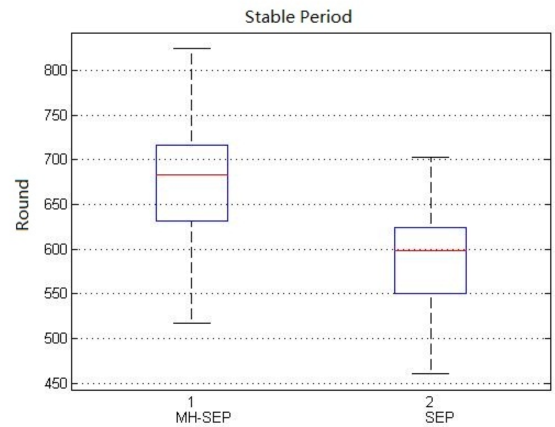

Figure 2: Statistical Box Diagram Of Different Stable Regions With100m X 100m Area, N=100

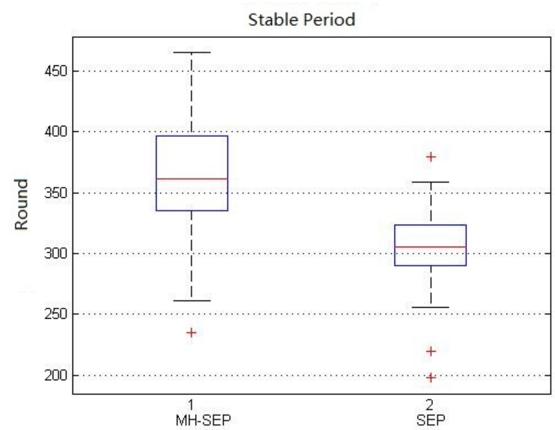

Figure 3: Statistical Box Diagram Of Different Stable Regions With150m X 150m Area, N=100

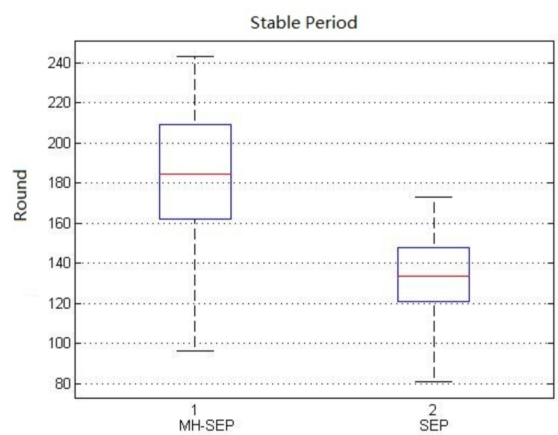

Figure 4: Statistical Box Diagram Of Different Stable Regions With200m X 200m Area, N=100

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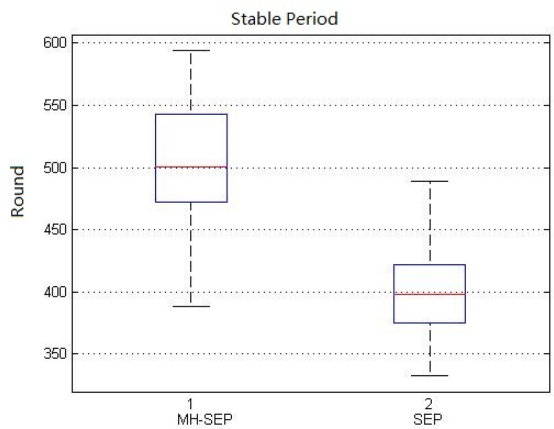

Figure 5: Statistical Box Diagram Of Different Stable Regions With150m X 150m Area, N=225

4.3 Heterogeneous Degree Impact To The Algorithm

The heterogeneous network is extent network, mainly due to the presence of advanced nodes which have more initial energy than normal nodes. The additional energy ratio of these advanced nodes, α×m, is the standard we identified a heterogeneous degree. Through changing the heterogeneous extent, we record the stable region of MH-SEP and SEP and make comparisons, so we can analyze the heterogeneous degree impact to the algorithms.

From figure 6, we can clearly see that: because of the increase of the heterogeneous degree, the initial total energy of the entire wireless sensor networks increase correspondingly, the length of the stable region increases gradually. At the same time, we can easily see the difference between the MH-SEP and SEP stable period length did not show significant trends with heterogeneous degree of change. Figure 7 shows how the difference between stable region length of MH-SEP and SEP changes. We can see that the difference is 55-70, which has no significant relationship with heterogeneous degree. It also confirms the consistency between the MH-SEP and SEP for heterogeneous clustering. After all, in MH-SEP, clustering probability of SEP is not changed, but to some extent the communication consumption of each round is reduced. This is consistent with the data curve growth of the two algorithms.

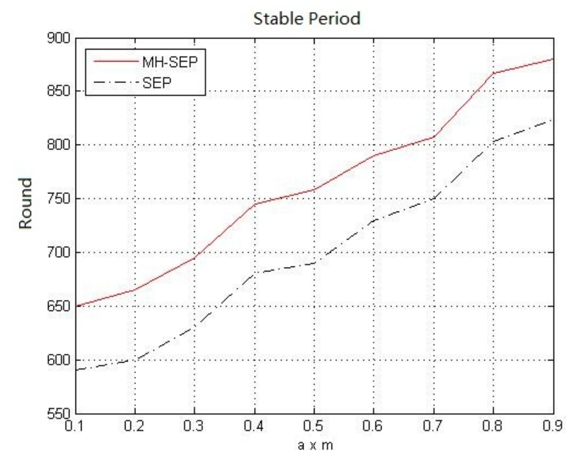

Figure 6: Stable Region Comparison With SEP And MH-SEP

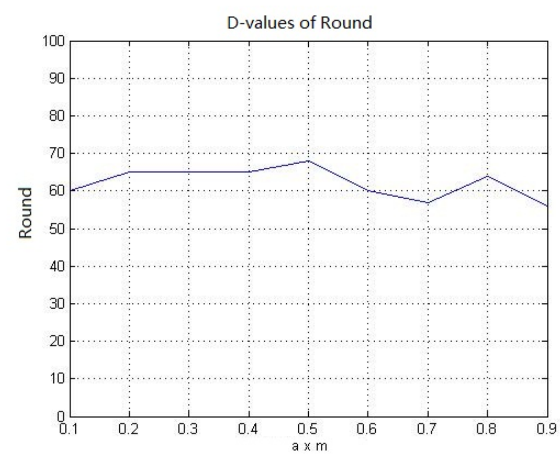

Figure 7: The D-Values Of Round Between SEP And MH-SEP

5. CONCLUSION

With the increase of the monitoring area, the space density decreases, the role of the MH-SEP is more and more obvious, in contrast of SEP, normal rate is getting higher and higher. Via simulation, the MH-SEP and SEP were compared, these are the conclusions:

- Under the conditions of meeting the distance requirements, in MH-SEP, the length of the stable region is longer;
- MH-SEP has the longer stable region, at the same time, without sacrificing the function of the nodes, the throughput of MH-SEP is almost the same with that of SEP ,or even larger;
- Due to the improvements of MH-SEP is based on the long-distance communications, it is subject to the size of surveillance area and the density of nodes. Greater size of surveillance area and smaller

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

the density of the network is, the more obviously the improvement makes from MH-SEP;

• Under the same spread density, MH-SEP is more responsive to the large area of monitoring tasks than SEP.

• Due to the optimum clustering and the cluster head election in both MH-SEP and SEP is the same, the heterogeneous degree of impact is the same in terms of both.

ACKNOWLEDGEMENTS

This work was supported by the National Key Technology R&D Program (2012BAK17B02), as well as Science and Technology Development of Jiangxi (20112BBE50021, 20112BBE51018)

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