LEACH Correction Algorithm based on Node Distribution Density

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Abstract: For failure of transmitting information due to disadvantage of LEACH-V Protocol in a unit in Voronoi Diagram in case residual energy of all nodes is lower than average energy, and without consideration of discrepancy of wireless sensor network and other factors, the thesis proposes a differentiated LEACH routing algorithm- LDCR; different routing algorithms are performed through considering residual energy, location factor and controlling size of communication radius when selecting cluster head through sensor node, and distinguishing hotspot and non-hotspot, so as to achieve improvement plan. It can be proved through LEACH Protocol and LDCR simulation that improved routing algorithm can reduce energy consumption and prolong network lifetime.

Keywords: Wireless sensor network; LEACH, Correcting algorithm; Node density; Protocol

1. Introduction

Wireless Sensor Network (hereinafter referred to as WSN) integrates computer, wireless communication, micro-sensor and other technologies, and it can monitor various environmental data and has been successfully applied to agriculture, health, chemistry, biology and other fields [1,8-10]. Sensor node is generally powered by battery and the battery cannot be replaced. How to effectively use energy is one of the major challenges of sensor networks [2]. Clustering routing protocol is a kind of routing protocol with efficient energy in wireless sensor networks at present. LEACH(Low Energy Adaptive Clustering Hierarchy) algorithm proposed in Literature [3,11] selects cluster head node at random in circular and equally distributes energy load of the entire network to each sensor node, so as to reduce energy consumption of network and improve overall lifetime of network. HEED algorithm (hybrid energy-efficient distributed clustering) proposed in Literature [4] improves heterogeneous distribution of generating cluster head of LEACH algorithm. Algorithm in Literature [5] is realized through cluster with different scale to balance energy consumption of node; the algorithm only applies for intensive sensor network. Algorithm in Literature [6,7] balances energy consumption in network, improves utilization ratio of network energy and prolongs network lifetime through calculating optimal cluster head and controlling members in clusters. LEACH-V proposed in Literature [12] selects cluster head through unit of Voronoi Diagram to make cluster uniformly distribute, and introduces residual energy and network average energy; if current energy is lower than average energy, the node cannot become candidate cluster head. However, the condition that information cannot be transmitted because current energy of all nodes is lower than average energy in a unit of Voronoi Diagram is left out of consideration. In practical application, there are differences in a certain sensor network, “hotspot region” with more interesting data and “non-hotspot region” with less interesting data. Main task of hotspot region is to promptly transmit monitoring objective, and main task of non-hotspot region is to monitor. Improved LEACH protocol- LDCR has been proposed aiming at disadvantage of LEACH-V and considering discrepancy of sensor network to reasonably select cluster head in line with residual energy under the circumstance of uniform distribution of cluster head, and adopt routing algorithm applied to regional characteristics, so as to prolong sensor network lifetime.

2. LEACH Clustering Routing Algorithm with Differentiation

2.1. System Model

2.2. LEACH Algorithm Analysis with Differentiation

LDCR is still divided into multi-cycle; cluster head node collects information gathered by node, and integrates and removes redundant information; single hop method is used for communication when distance between cluster head and base station is closer; multi-hop method is adopted when distance between cluster head and base station is farther. However, more factors have been considered in LDCR, such as discrepancy of different regions, uniformity of corresponding region on selection of cluster head, soundness of energy consumption.

2.2.1 Discrepancy of Regions: In practical application, if there are hotspot and non-hotspot regions in sensor network, different region should be differentiated to some extent on routing protocol.

Sensor node in hotspot region needs to receive/forward more interesting data, and transmission pressure on node is very heavy, which is easy to become bottleneck for extending network lifetime. To save network energy loss, smaller cluster should be adopted when monitoring energy loss is obviously lower than transmission energy loss, namely communication radius of the above region should be smaller. Sensor node in non-hotspot region needs to receive/forward less interesting data and transmission pressure on node in non-hotspot region is less; larger cluster should be adopted when transmission energy loss is obviously lower than monitoring energy loss, namely communication radius of the above region should be larger. Communication radius of cluster size in different regions is shown in Fig. 1.

![Figure 1. Communication Radius of Cluster Size in Different Regions](image)
2.2. Uniformity on Selection of Cluster Head: Selection strategy of cluster head is an important issue for clustering routing; space uniform distribution of cluster head node in different regions has been fully considered in LDCR from two aspects, mainly including: increasing threshold value and adjusting corresponding communication radius.

(1) Increasing threshold value
Two kinds of cluster heads in LDCR: candidate cluster head and formal cluster head. Increase probability of normal node selected as candidate cluster head node; make candidate cluster head be $2^k$ for each round; maximum number of selected cluster head in LEACH protocol is $k$. Calculation formula of threshold value $P(t)$ is as follows:

$$
P(t) = \begin{cases} 
\frac{2k}{N-2k*(r \mod \frac{N}{2^k})} & C_i(t) = 1 \\
0 & C_i(t) = 0
\end{cases}
$$

(2.1) where $N$ refers to total amounts of nodes, excepting base station; $k$ refers to the best clustering numbers of LEACH protocol; $t$ refers to number of round; order $C_i(t)$ refers to node; whether $i$ is selected as cluster head in recent round of $(r \mod \frac{N}{k})$.

In consideration of uniform distribution of cluster head in the whole region, more candidate cluster head nodes can be obtained in each round through increasing probability of election, and formal cluster head with more reasonable energy and location can be selected from these candidate cluster head nodes.

(2) Adjusting corresponding communication radius
When normal node elected candidate cluster head node broadcasts around to compete for formal cluster head, the scope of broadcast should take itself as center and radius as $R_i$ (in hotspot region, and $R_i$ in non-hotspot region). Within adjusting radius, all candidate cluster head nodes compete in their own region; communication radius is $R_i$ in non-hotspot region, and $R_i/2$ in hotspot region; adjusting radius decides distance of two formal cluster heads in corresponding region, so formal cluster head in the same region cannot be too concentrated, so as to make formal cluster head uniformly distribute.

2.2.3. Soundness of Energy Consumption: LEACH-V can make cluster uniformly distribute, but the condition that current energy of all nodes is lower than average energy in a unit of Voronoi Diagram is left out of consideration. Uniform distribution of cluster head has been considered in LDCR, meanwhile, it is considered in LDCR that node with more node energy will be selected cluster head when residual energy of all nodes within communication radius is not enough, so as to reasonably use energy.

Different routing strategies should be selected according to different regions in the process of implementation of LDCR. Smaller cluster should be adopted when data traffic in hotspot region is large, so as to shorten communication distance and reduce energy consumption.

2.3. LEACH routing Algorithm with Differentiation

2.3.1. Description of Pseudo-code: Assume that threshold value of cluster head of system is $P(t)$; communication radius of node I is $R_i$; residual energy is $E_i$.

Node state set: $NS= \{\text{normal, candidate, cluster head, havebeen head}\}$ respectively mark the node as normal node, candidate cluster head node, cluster head node and normal node served as cluster head.

Set of candidate cluster head node: $ML= \{C_1, C_2, \ldots, C_K\}$

Set of final cluster head node: $CHML= \{CH_1, CH_2, \ldots, CH_L\}$ ($0 \leq L \leq K$)

Perform the following algorithm for any sensor node $i$:

The first stage: elect candidate cluster head node
if node I is in hotspot region
$R_i = R_i/2$; //adjust its communication radius
end if
Generate a random number between 0-1;
Mark state of node as normal;
if random $< P(t)$ and havebeenhead=0
Set state if node i as candidate

Figure 2. LDCR Clustering Graph
Broadcast message of candidate cluster head; // participate in competition of cluster head
end if

The second stage: select cluster head node
if node state is cadidating message
Receive all candidate message and store in ML list;
// decide whether it is the maximum energy in neighbourhood
head = true
while head and (not ML is empty) do
Select a candidate cluster head Mj from ML list, and its residual energy refers to Ei;
if Ei>Ej
head=false
end if
end while
If head
Broadcast message of cluster head; mark node state as cluster head;
Havebeenhead = 1;
Else
Convert node state back into normal;
End if

The third stage: add cluster into normal node
If node state is in normal
Receive all cluster head message and store in CHML list;
// select candidate cluster head with the maximum energy
E=0; M=0;
while not CHML is empty do
Select a cluster head Mj from CHML list; and its residual energy refers to Ej
if E>Ej
E=Ej;
M=Mj;
end if
end while
Send/add message of cluster to latest cluster head or cluster head with the maximum energy;
End if

The fourth stage: confirm cluster head node
If node state shows as cluster head
Receive all adding message and include them into member of cluster;
Send confirmation message for each member;
End if

2.3.2. Node State Transition: Node in network is divided in normal node, candidate cluster head node, cluster head node and normal node served as cluster head. Forming process of cluster is divided into election stage of candidate cluster head node, selection stage of cluster head node and the stage adding cluster into normal node.

Original state of nodes are generally normal nodes; if random number of normal node is less than threshold value of cluster head in the election stage of candidate cluster head node, original state of node is candidate cluster head node; in the selection stage of cluster head node, there are two kinds of state transition for candidate cluster head node; if energy of candidate cluster head node is maximum within its communication radius, original state of node is cluster head node, otherwise normal node. After the first round, cluster head node is converted into normal node served as cluster head, and then the normal node served as cluster head cannot run for cluster head due to decrease in energy at the next round. Energy of most nodes is reduced through several rounds, and then normal node served as cluster head can run for cluster head as normal node again.

Transition of different node states is shown in Fig. 3:

3. Simulation Experiment

3.1. Experimental Program
Analog simulation is carried out for LDCR and LEACH-V protocol on NS2 platform from multiple aspects. It is assumed to use small-scale sensor network deployed randomly, and then sensor node can perceive geographical position, so as to adjusting corresponding communication radius.

It is assumed that nodes are randomly distributed in square region of \((x=0, y=0)\) and \((x=100, y=100)\), and base station is located in the position of \((x=50, y=50)\). Bandwidth of channel is 1Mbps, and capacity of data package is 500bit. Energy model the same with LEACH-V protocol is adopted: initial energy of node is 2J; transmitted energy: \(E_{ele}=50nJ/\text{bit},\ xele=10pJ/\text{bit/m}^2,\ emp=0.0013pJ/\text{bit/m}^4\); energy consumed in data fusion: \(E_{PA}=5nJ/\text{bit/signal}\).

Without loss of generality, it is assumed that distribution of hotspot and non-hotspot regions takes straight line of \(y=ax+b\) as boundary. Non-hotspot region is on the upper side of curve, and hotspot region on the lower side curve.

3.2. Analysis of Results of Simulation Experiment

(1) Contrast of average residual energy: contrast of average residual energy of LDCR hotspot and non-hotspot region shown in Fig. 4. There are two parts of energy consumption of cluster head; one is that energy consumption is to collect information of node and fuse the information; another is energy consumed in the process of transmitting information. The information collected in hotspot region is more, and the transmission distance is short; the information collected in non-hotspot region is less, and the transmission distance is long. It can be seen from Fig.4 that energy consumption in hotspot region is more than that in non-hotspot region, but the discrepancy is less. Therefore, a part of nodes cannot die so earlier, so as to balance network energy consumption.

![Figure 4. Contrast of Average Residual Energy in Hotspot and Non-hotspot Region](image)

Average residual energy of LDCR and LEACH-V protocols in the operational process is shown in Fig. 5. Average residual energy of LDCR protocol is more than that of LEACH-V protocol, namely LDCR can reduce energy consumption of network and prolong network lifetime from the aspect of energy consumption.

![Figure 5. Contrast of Average Residual Energy](image)

(2) Contrast of average number of cluster head under different density: average number of cluster head of LDCR and LEACH-V protocols under different density is shown in Fig. 6. It can be seen from Fig. 6 that average number of cluster head of LDCR protocol is weaker than that of LEACH-V protocol in the beginning, but average number of cluster head of LDCR protocol is more optimal than that of LEACH-V protocol at the 200 nodes. When nodes reach 400, average number of cluster head of LEACH-V protocol is about 18, and average number of cluster head of LDCR protocol is about 25. Average number of cluster head of LDCR protocol tends to be more idealistic number of cluster head (optimum number of cluster head is stipulated as probability of node for each round to be cluster head × number of node; probability of node for each round to be cluster head is set as 0.12 in the thesis); it can be seen from the figure that the greater the density is, the more idealized the number of cluster head of LDCR is.
Figure 6. Contrast of Average Number of Cluster Head under Different Density

(3) Contrast of death round of node under different density: death round of node of LDCR and LEACH-V protocols under different density is shown in Fig. 7. It can be seen from Fig. 6 that death round of the last node of LEACH-V protocol is about 6500 and that of LDCR protocol is about 8200 when number of node is 300. Death round of the last node of LDCR protocol is higher than that of LEACH-V protocol. It can be seen that LDCR prolongs network lifetime.

Figure 7. Contrast of Death Round of Node under Different Density

4. Conclusion

It is assumed that wireless sensor network node is randomly deployed in square region, and node can perceive geographical location, probability of getting monitoring objective in deployment area of sensor node is different, hence the area with higher probability of getting monitoring objective is set as hotspot region. More detailed clustering area is adopted for hotspot region to accurately monitor subjective. Through LEACH protocol and LDCR simulation, it can be proved that improved routing algorithm can reduce energy consumption and prolong network lifetime.

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References

