Data Multi-hop Algorithm for Wireless Sensor Networks based on LEACH Protocol

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Abstract. Nowadays, the LEACH algorithm which is commonly used in many protocols of WSN is a popular thing in the research fields. This paper proposes LEACH-ICM (LEACH-Inter Cluster Multi-hop) algorithm based on LEACH-ICE algorithm. The cluster head shall transfer data to the node which is closest to base-station and whose resident energy is available when its' resident energy is higher than limit energy. If all the nodes fail to accord with conditions, this cluster architecture will select new cluster head internally. By using this new data transfer way, LEACH-ICM balances the energy of the whole networks. Simulation results show that the algorithm achieves saving energy and extending the service life of the WSN.

Introduction

As for a very popular research field about networks and communication, WSN (Wireless Sensor Networks) combines many technologies such as sensors, distributed information processing_and wireless communication, and has its huge potential in military, intelligent, medical, remote control, and so on [1,2]. A large number of low cost microsensor nodes which have functions of data acquisition, wireless communication and oligomeric auto-formation net compose the WSN [3,4]. These nodes transfer information that they monitored to base-station by mutual cooperation. According to differences of network management and nodes' function, the routing protocols of WSN were divided into planar routing protocol and cluster routing protocol [5,6]. Planar routing protocol cannot optimal management communication resources and reaction progresses very slowly. Comparing with planar routing protocol, cluster routing protocol makes the whole networks self-government and improves energy efficiency. In this kind of protocol, in order to implement network communication using cluster architecture, all the nodes are divided into cluster heads and intra-cluster nodes. From past to now, LEACH protocol is commonly used in cluster routing protocol [7,8].

This paper put forwards LEACH-ICM (LEACH-Inter Cluster Multi-hop) algorithm based on LEACH-ICE(LEACH Inner Cluster Election)algorithm [9] in order to improve LEACH protocol. By changing the way of transferring data in the protocol, LEACH-ICM achieves to balance the energy consumption and extend the networks' life. The algorithm regulates that the cluster head shall send the data to the node which is closest to base-station and whose resident energy is available when its resident energy is higher than limit energy. When there is no such a node eligible, this cluster architecture will select new cluster head which is closest to the original cluster head.

The introduction of LEACH algorithm and LEACH-ICE algorithm. For all cluster routing protocols, LEACH protocol is the most earliest to be put forward [4]. In this theory, once a node's random number is lower than $T_{(n)}$ which is a threshold value, it will be the cluster head. Than, other ordinary nodes chose the closest cluster head's architecture to join in. Unless the cluster head died because of it using up the energy, the whole networks will continue to communicate [10].

As we now, it's illegitimate for the way to select cluster head. So, LEACH-ICE algorithm use a new mechanism of cluster head election to improve the possibility that node with high energy becomes a cluster head. The calculation formula of threshold value $T_{(n)}$ is given below [11].

$$T_{(n)} = \frac{p}{1-p\left[\mathrm{r}\bmod(1/\mathrm{p})\right]} * \frac{E_{n\_resident}}{E_{n\_initial}} \quad , \qquad n \in G \tag{1}$$

where $E_{n\_resident}$ and $E_{n\_initial}$ are the resident energy and initial energy of nodes.

What's more, LEACH-ICE change the simple way that node chose the closest cluster head to join with to choosing base station as its cluster head when it is closer to base station.

These improvements are very efficient, so this paper will continue to use them. As for all the consumption of networks communication, we give the calculation formulas which LEACH-ICE algorithm use as below.

Every time sensor nodes send $k-bit$ data, $E_{send} = \begin{cases} k*E_{elec} + k*\xi_{fs}*d^2, & (d < d_0) \\ k*E_{elec} + k*\xi_{fs}*d^4, & (d \geq d_0) \end{cases}$ (2)

Every time sensor nodes receive $k-bit$ data, $E_{receive} = k*E_{elec}$ (3)

Every time sensor fuses $k-bit$ data, $E_{\text{fuse}} = k*E_{ebf}$ (4)

Where E_{elec} is energy consumption of wireless transceivers. ξ_{fs} is limiting value of sensor. d is the distance from node to cluster head. d_0 is multipath attenuation threshold value. E_{ebf} is the energy consumption of fusing bit data.

Even though LEACH-ICE algorithm has improved some defects of cluster mechanism in LEACH protocol, there still exits deficiency in stable communication stage. Thus, this paper propose new way of transfer data to balance the energy consumption in every area of the whole process.

Data multi-hop and fusion mechanism

Based on LEACH protocol, LEACH-ICM algorithm references the cluster mechanism from LEACH-ICE algorithm and improves its' deficiency. In the stage of stable communication, the algorithm regulates that the cluster head shall fuse the data it monitored and send them to the node which is closest to base-station and whose resident energy is available if its' resident energy is higher than limit energy. When there is no such a node eligible, this cluster architecture will select a new cluster head which is closest to the original cluster head. The way of transferring data is shown in Fig. 1.

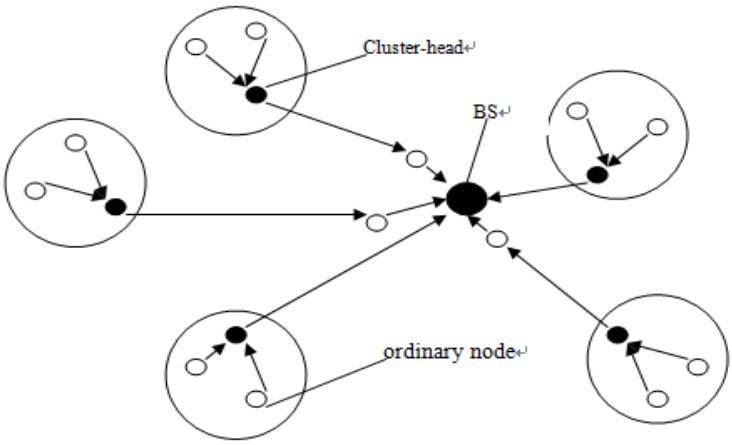

Fig. 1 data multi-hop

Because the essence of the LEACH protocol is selecting cluster head in cycle, it really increases unnecessary energy and time consumption that the whole networks begin a new round clustering once a cluster head is died. Considering the long time communication of the networks, this paper improves new data transferring mechanism in the stage of stable communication. When the resident energy of some cluster head is lower than limit energy ∂_1 E_{send} which means this cluster head cannot send

$k-bit$ data within ∂_1 times, it will send all the messages it received in this round to the node which is closest to base-station and whose resident energy is available if its resident energy is higher than $\partial_2 E_{send}$. When the selected node receives the message, it should fuse them with the data monitored by itself and send them together to its cluster head. According to the deficiency in LEACH-ICE algorithm, we know that the biggest energy consumption in the whole networks is the cluster which is furthermost from the base station. Some nodes which is closer to the base station even can communicate with the base station directly that means they chose the base station as their cluster head. So, in the communication process, nodes which satisfy data multi-hop condition will change sending data to the base station to communicating with their cluster head. In the way, these nodes will become closer by degrees to the cluster head which sends data to them. Until the resident energy of all nodes in the networks is lower than $\partial_2 E_{send}$, data multi-hop is failed. In this condition, the cluster head will notice other nodes in this cluster and choose the closest node as the new cluster head. Other clusters will continue to communicate. And the distribution of whole cluster architecture is not changed until all the cluster members died. The key steps of the algorithm are given below.

Step. 1 if(node.resident_energy>= $\partial_1 E_{send}$){node.resient_energy- = E_{send} ;}

Step. 2 if（node.resident_energy >= $\partial_2 E_{send}$ && node.resident_energy <= $\partial_1 E_{send}$ ）

{

for(all nodes){select the closest node[j] to BS whose resident_energy> $\partial_2 E_{send}$;}

d=from node to node[j];

node.resident_energy - = $\dot{E}_{send}$;

node[j].resident_energy - = $\dot{E}_{\text{fuse}} + \dot{E}_{receive}$;

}

Step.3 if(node.resident_energy >= E_{send} && node.resident_energy <= $\partial_2 E_{send}$)

{

for(all the cluster member){ select the closest node[k] to luster-head;}

for(all the cluster head){ change the number of cluster to the node[k];}

node[k] becomes cluster head;

for(all the cluster member){ chooses node[k] to join in the cluster;}

node.resient_energy - =ordinary_node. E_{send} ;

}

Step.4 if ((node.resident_energy< E_{send}){ the node is dead};

where $\dot{E}_{send}$, $\dot{E}_{\text{fuse}}$ and $\dot{E}_{receive}$ are the energy consumption between the node and node[j].

The limited multiple ∂_1 and ∂_2 is very important to the algorithm, because they decide when the cluster heads change the way to transfer data and when to select new cluster head. Many simulation results show that this part of new data transferring improves networks' communication quality and avoids redundant clustering. The algorithm balances energy consumption between different levels on intra-region and extends the whole networks' life in a great extent.

Results and discussion

The simulation in this paper determinates the life time and average energy consumption in every round of 100 nodes which random distribution in the area of (100,100). The algorithm regulates the initial energy of all nodes is 2J. A node is died when its resident energy is lower than 0.02J. The probability p of a node achieves to be a cluster head in the stage of clustering for every round is 0.05. The multipath attenuation threshold value d_0 in the stage of stable communication is 75. We regulates the coordinate of the base station is (50, 175) which means the base station is out of the whole networks.

By contrast many simulation results, we found that equilibrium degree of energy consumption on intra-region along with the increase of ∂_1 and ∂_2 trend to be a parabola function. The most communication rounds appear when ∂_1 is 75.2 and ∂_2 is 31.5. Thus, we use these parameters in the simulation as given blow.

The average energy consumption of nodes. The simulation chose 10 rounds randomly to compare average energy consumption after three algorithms executing. The result is shown in Fig. 2. Calculation shows that LEACH-ICM algorithm saves energy in every round for about 29.61% and 47.02% compared with LEACH-ICE and LEACH algorithm. The algorithm balances energy consumption on intra-region because it regulates nodes which are closer to the base station bear more energy consumption by using new data transferring way early in the stage of stable communication.

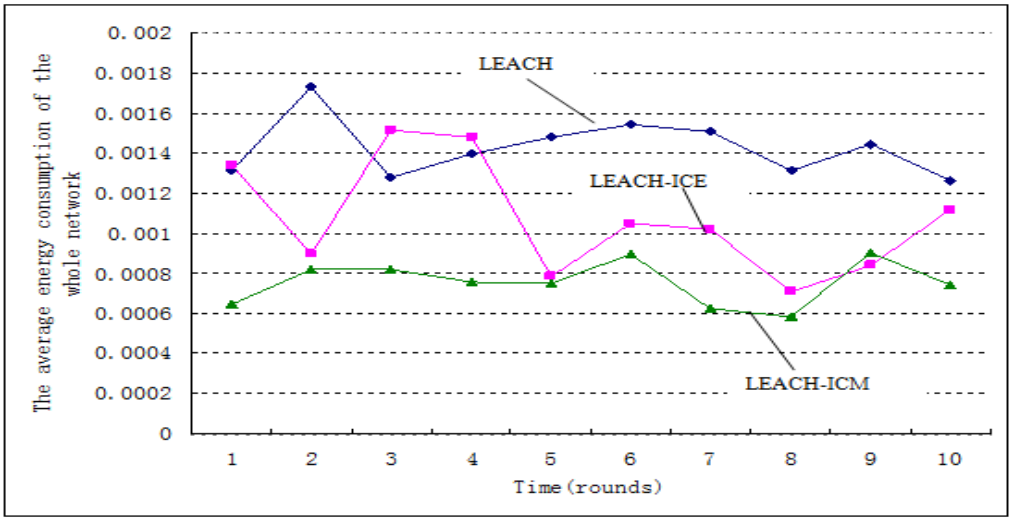

Fig. 2 average energy consumption of networks in the same time

The life of nodes and networks. This paper uses the standard of FND (First Node Dies), HNA (Half Node Alive) and LND (Last Node Die) to metric the life of nodes and networks [12]. We statistical and compare the networks life of three algorithms which means the rounds of 100 nodes alive as shown in Fig. 3 and compare the communication rounds in the time of FND, HNA and LND after three algorithms executing as shown in Fig. 4. As you can see, LEACH-ICM algorithm makes great improvement in extending the life of networks compared with LEACH-ICE and LEACH algorithm. After calculating, we found that the communication rounds extends about 37.46% and 64.76% for FND, about 13.02% and 59.45% for HNA, and about 13% and 45.91% for LND. For the whole communication process, LEACH-ICM run 2174 rounds when LEACH-ICE runs 1924 rounds and LEACH only runs 1490 runs.

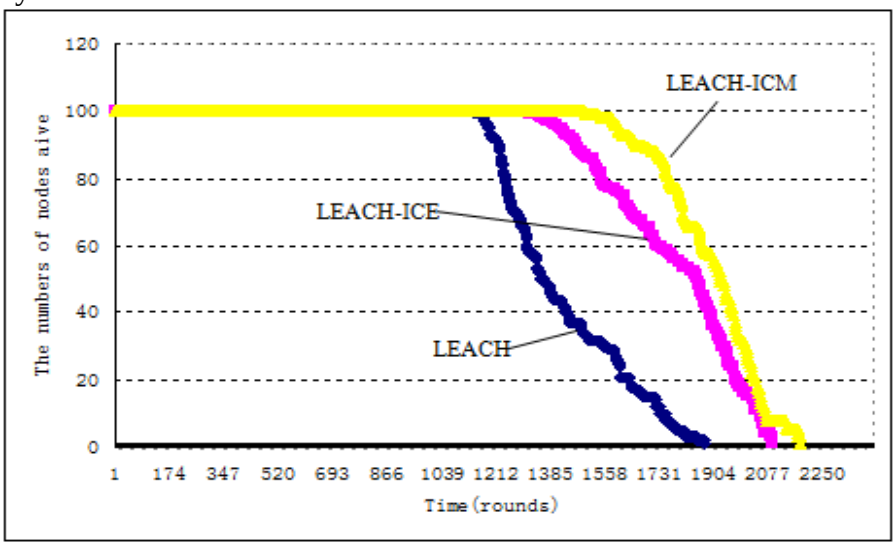

Fig. 3 the numbers of nodes alive in the same time

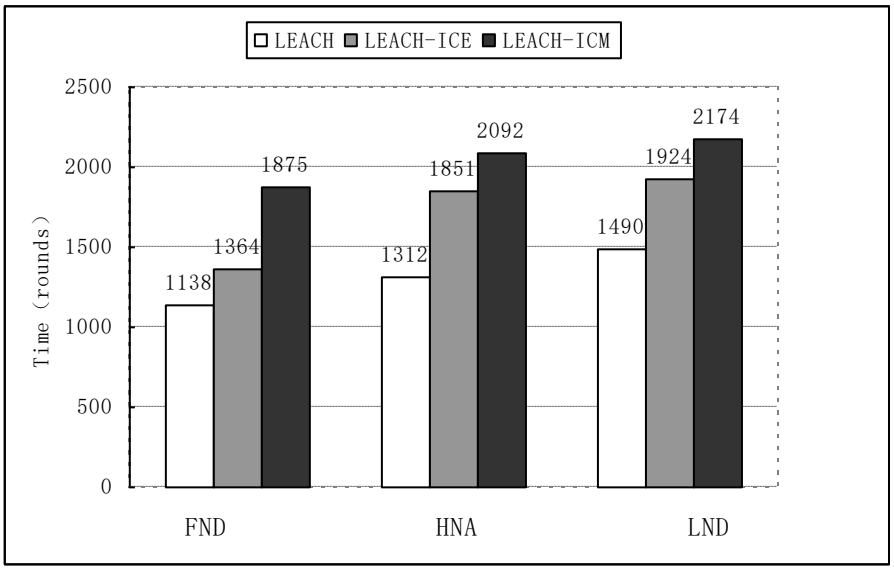

Fig. 4 communication rounds for FND, HNA and LND

Summary

This paper proposes the LEACH-ICM algorithm for WSN based on the LEACH-ICE algorithm. The algorithm changes the way to transfer data in the stage of stable communication by regulating that the cluster head shall fuse the data it monitored and send them to the node which is closest to base-station and whose resident energy is available if its' resident energy is higher than limit energy. When there is no such a node eligible, this cluster architecture will select a new cluster head which is closest to the original cluster head. The simulation result shows that LEACH-ICM algorithm balances the average energy consumption of nodes on intra-region and extends the life of nodes and networks efficiently.

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