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Procedia Engineering 29 (2012) 1882 – 1888

Procedia Engineering

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2012 International Workshop on Information and Electronics Engineering (IWIEE)

A Energy-Efficient Clustering Routing Algorithm Based on Distance and Residual Energy for Wireless Sensor Networks

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Abstract

Aiming at the problem of limited energy of sensors in Wireless Sensor Network, based on the classic clustering routing algorithm LEACH, a distance-energy cluster structure algorithm considering both the distance and residual energy of nodes is presented in the dissertation, which improves the process of cluster head election and the process of data transmission. It reduces the adverse effect on the energy consumption of the cluster head, resulting from the non-uniform distribution of nodes in network and avoids the direct communication between the base station and cluster head, which may has low energy and far away from base station The results of simulation indicate that the improved algorithm effectively balances the energy consumption, prolongs 31% of the lifetime, reduces 40% of the energy consumption and has a better performance than the original LEACH protocol.

Keywords : Wireless Sensor Network; clustering algorithm; LEACH protocol; low energy consumption

1. Introduction

Wireless Sensor Network[1] is one of the three major high-tech industries in the future of the world which is consisted of a set of wireless sensor nodes according to a certain communications and topologies protocol. It has been widely utilized in the military, environmental monitoring, dysfunction diagnosis and the medical measurement[2]. As it's broad application prospects and great application values, it has become one of the hot research topics. Due to small size of a sensor node, sensor networks are constraint by limited power, limited communication capabilities, limited processing power and limited memory. Therefore, a more effective topology control protocol to prolong the lifetime, energy efficiency and to

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doi:10.1016/j.proeng.2012.01.231

improve coverage and the load balance is the key factor of WSN design[3].In the recently research, clustering is an important energy-saving method in WSN, and the good performance of WSN is highly dependent on energy-efficient clustering algorithm. LEACH[6] (Low Energy Adaptive Clustering Hierarchy） is one of the classic clustering protocols. Experiments show that the LEACH protocol can save more energy than the plane multi-hop routing protocols and the static network clustering algorithm. But the LEACH protocol does not take into account the location of nodes, which has induces a bad distribution uniformity of clusters. And it does not consider the residual energy of nodes, which leads to the early death of some nodes and the overall invalidity of the network. In addition, the algorithm is supposed the initial energy of all nodes are same, and the energy consumption of becoming cluster head node are basically the same in the first cluster head electing. Therefore, this protocol is not good for unbalanced-energy network. In this paper, we design a distance-energy cluster structure algorithm (DECSA). DECSA is based on the classic clustering routing algorithm LEACH, it considering both the distance and residual energy of nodes. It improves the process of cluster head selecting and the process of cluster forming. It reduces the adverse effect on the energy consumption of the cluster head, resulting from the non-uniform distribution of nodes in network and avoided the direct communication between the Base Sensor and cluster head, which has low energy and far away from Base Sensor. The results of simulation indicate that the improved algorithm effectively balances the energy consumption, prolongs 31% of the lifetime, reduces 40% of the energy consumption and has a better performance than the original LEACH protocol.

2. Energy and network model

In this section, we shall explain our assumed energy as well as network model, assumptions made here will be used in the performance evaluation section.

2.1 Energy model

In wireless transmission, attenuation of sending power decreased exponentially with the increasing transmission distance. Our energy model is same with that in Ref.[7]. Equation (1) represents the amount of energy consumed for transmitting l bits of data to d distance. Equation (2) represents the amount of energy consumed for receiving l bits of data which is caused only by circuit loss.

$$E_{TX}(l,d)=\begin{cases} l*E_{elec}+l*\varepsilon_{fs}*d^2, d \prec d_0 \\ l*E_{elec}+l*\varepsilon_{mp}*d^4, d \geq d_0 \end{cases} \quad (1)$$

$$E_{RX}(l,d)=l*E_{elec} \quad (2)$$

In which: E_{elec}: the energy consumption per bit in the transmitter and receiver circuitry; ε_{fs}: free space model's amplifier energy consumption; ε_{amp}: multiple attenuation model's amplifier energy consumption; d_0: a constant which relies on the application environment.

2.2 Network model

In this research, we assume that set of sensor nodes are randomly deployed in the square field to continuously monitor the phenomenon under inspection. We know that in LEACH algorithm, each node randomly decides to become a cluster head(CH).Once a node decides to become a cluster head ,it aggregates the data received from various nodes inside the cluster and send it to the base station. However,

completely independent random cluster head select can't guarantee the number and the distribution of cluster head in each round. It may selects a node which is far away from base station and has low residual energy to become the cluster head, which will cause the uneven energy loss of nodes in the network and form monitoring blind spot, even will influence the whole performance of the network. In order to improve this kind of situation, different from LEACH, in this paper, we will use a three level hierarchy structure network model, which divides the nodes into four categories: Base Station(BS) , Base Station Cluster head(BCH), ordinary cluster head node (CH), and common sensor node (SN). Following figure shows the network model of DECSA algorithm.

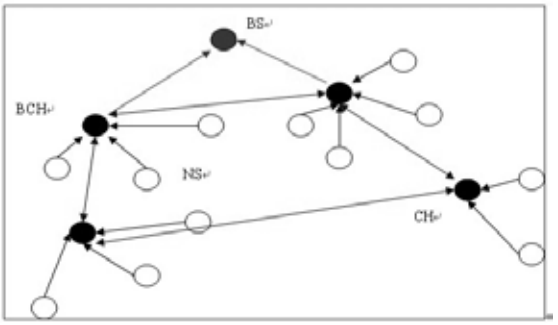

Figure1. Three level hierarchy structure network model of DECSA

3. DECSA Algorithm

In this section, we describe our proposed clustering algorithm DECSA(Distance-Energy Cluster Structure Algorithm). DECSA is a distributed competitive unequal clustering algorithm, it considers both the distance and residual energy information of nodes. Similar to that of LEACH, DECSA protocol continues by round and each round can be divided into initialization stage and stable working stage. In order to minimize energy consumption, the stable working stage should be greatly longer than the initialization stage.

3. 1. Initialization stage

In the initialization stage, cluster head is elected and TDMA time slots are distributed to ordinary member nodes by the cluster head. Within a given time slot, ordinary member nodes are joined an appropriate cluster. The process of cluster head select consists of following 2 parts: election of ordinary cluster head node (CH) and election of Base Station Cluster head (BCH).In the part of election CH, the main difference between LEACH and DECAS in this part is DECSA employs both residual energy and distance parameter. First, each sensor node generates a random number between 0 and 1.If the random number for a particular node is smaller than the predefined threshold T, then that sensor node becomes the first round cluster-head, we call it false-cluster-head there. And then all the nodes in the cluster are respectively calculate their k(i), and compared it with their current false-cluster-head. If it is greater than the false-cluster-head's k(i), then announced that he become the CH of this cluster. If it is smaller, then the false –cluster- head become the CH. Thus, the election of cluster head considers both the nodes' energy consumption and the communication between the network, comparing the difference of k(i), let the high residual energy, high efficiency of communication node has the bigger probability to be elected as CH, it will prolong the lifetime of the network.

$$k(i) = E_n(i) \div d_0(i) \quad (3)$$

Where k(i)is the threshold of elect CH , En(i) is the residual energy of node i, d0(i) is the average distance between node i with all other nodes in the same cluster.

After the election of cluster-head, in the part of election base-station-cluster-head, we use threshold TBCH to select which CH will become the BCH. We select those CH whose TBCH(i) are larger than the predefined threshold TBCH0 as the base-station cluster-head(BCH). The rest of the cluster heads as ordinary cluster head nodes CH. We define TBCH(i) as follow:

$$T_{BCH}(i) = \left(E_n(i) \div E_0\right) + \left(E_n(i) \div d(i)\right) \quad (4)$$

where En(i) is the current residual energy of node i, E0 is the initial energy of node in the network, d(i) is the distance between node i with base station.

3.2. Stable working stage

In the stable working stage, base station broadcasts the message to the entire network. After received the messages, according to the different value of TBCH(i) , base-station-cluster-head select the maximum TBCH cluster-head as its next hop ,and the rest hop can be selected in the same manner until all of the cluster head nodes are connected ,forming a complete communication path. In order to reduce the direct communication between the base station and the cluster-head which is far away from the base station and has low residual energy. Common nodes (SN) in the cluster will transmit data packet to their closest cluster-head, then cluster-head will collect and fusion those data and transmit them to the base-station-cluster-head, rather than transmit them to the base station directly. And then, base-station-cluster-head will communicate with the base station. Avoiding the narrowness of the election of base-station-cluster-head, balance the consumption of energy and data transmission, the value of threshold TBCH0 should be dynamic changed according to the real-time network's state, thus could guarantee the base-station-cluster-head of the whole network be elected is the most appropriate. The value of TBCH0 should between the average TBCH and the maximum TBCH in network .Of course, the difference of the TBCH0 threshold will cause different influence the performance of the network directly. The simulation experiments show that when TBCH0 takes 75% of the maximum TBCH, the network will have its best performance.

4. Evaluation

In this section, we present the results of the experiments that we have done to evaluate our algorithm. DECSA and LEACH algorithms are simulated, analyzed and compared using MATLAB software. Parameters in the simulation are shown in Table 1.

Figure 2 shows the routing topology structures of wireless sensor network in different rounds.The communication relationship in nodes charges with the round increase. In figure 2, red + represent the cluster head, blue o represent the ordinary sensor node, green * represent the death node, red triangle represent the base station. Red-dot lines represent the communication between base-station-cluster-head and base station. Green dashed lines represent the communication between the cluster-head nodes. Blue-solid lines represent the communication between the common sensor node and its cluster-head.

In figure 3, when r=1400, the whole nodes of the network are all dead, then the communication is over.

Table 1. Experimental simulation parameters

Parameter	value
Area of network	200m*250m
Number of nodes	100
Sink coordination	(100,250)
E_0	1J
$E_{TX}= E_{RX}$	50nj/bit/m
E_{DA}	5nJ
ε_{fs}	10pJ/bit/m^2
ε_{amp}	0.0013 pJ/bit/m^4
packetLength	5000bytes
Rmax	1800

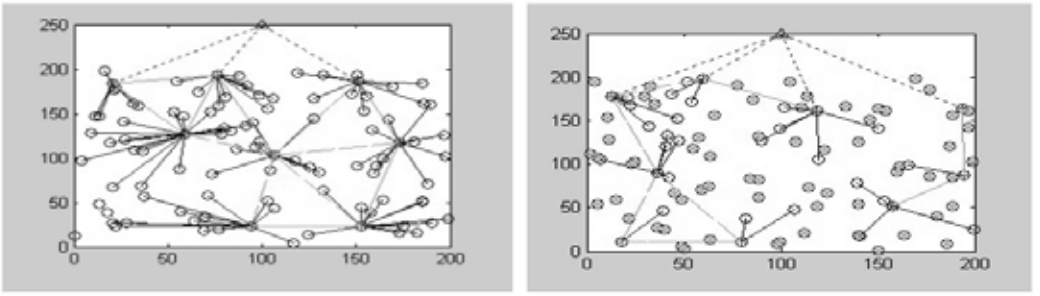

Figure2. Routing topology structure of network in different round,(a)r=100;(b)r=1000.

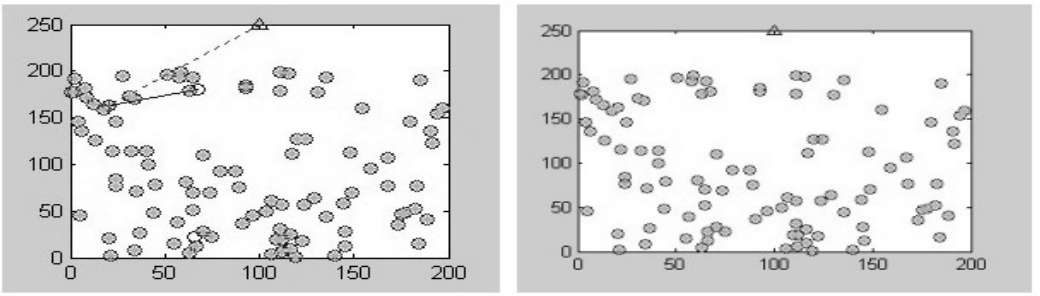

Figure3. Communication structure of network (a) r=1300;(b) r=1400

Figure 4 is a comparison of the number of nodes that remain alive over the simulation time between LEACH algorithm and DECSA algorithm. It is clear that numbers of nodes alive in DECSA are more than LEACH algorithm at the same round. As is show in the figure 4, if apply the LEACH algorithm, system nodes begin to die respectively after about 800 round, while if we apply the DECSA algorithm, it can sustain until the 1150.Moreover, compared with the LEACH and DECSA algorithm, the valid lifetime is prolonged by 31%.Part1 is only improved the process of cluster head selection in the initialization stage of DECSA. Part2 is only improved the process of data transmission in the stable

working stage of DECSA. If we apply the part1 of DECSA algorithm, system nodes begin to die after about 1050 rounds, and it prolongs about 21.4% lifetime of the network. For part2, system nodes begin to die after about 1000 round, and it prolongs about 16.3% lifetime than LEACH.

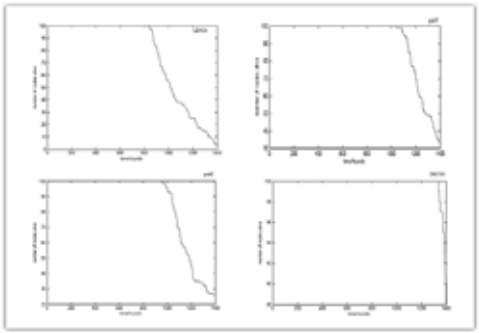

Figure 4 Lifetime of network between DECSA and LEACH

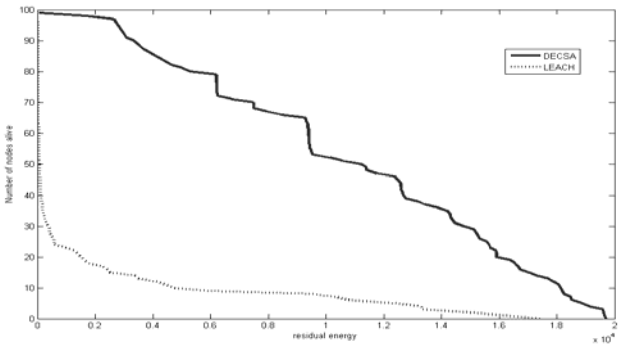

Figure 5 Residual energy relationship of nodes between DECSA and LEACH

Figure 5 shows the residual energy consumption of nodes between DECSA and LEACH. It clearly depicts that DECSA has a better performance than LEACH in terms of energy consumption. reduces In the condition of the same energy consumption, the number of remain alive node in LEACH algorithm is far more less than the number in DECSA algorithm, it reduces about 40% of the energy consumption.

5. Conclusions

In this paper, we proposed a cluster routing algorithm DECSA considering both the distance and residual energy of nodes, improved the process of cluster head election and the process of data transmission of network. This makes the node with more residual energy and has high polymerization degree in the network has greater probability to become cluster heads. In the stable working stage, it reduces the adverse effect on the energy consumption of the cluster head, resulting from the non-uniform distribution of nodes in network and avoids the direct communication between the base station and the cluster head, which may has low energy and far away from base station. The results of simulation indicate that the improved algorithm effectively balances the energy consumption, prolongs 31% of the lifetime, reduces 40% of the energy consumption and has a better performance than the original LEACH protocol.

Acknowledgements

I owe profound debt of gratitude to many people who have greatly contributed to have helped with the development of this paper in their special ways .Especially grateful to our supervisor, Professor Dingqun, for her sense of responsibility, enlightening guidance. We would also express our heartfelt gratefulness to my college Heilongjiang University.

References

[1] AKYILDIZ I F,SU W,SANKARASUBRAMANIAN Y.Wireless Sensor Networks:a survey.Computer Networks Journal,2002,38(4):393-422.

[2] ZuChang Ma,YiLing Zhang,Tao Mei.Survey on wireless sensors network . Journal on Communications,2004,25(4):114-124.(in Chinese).

[3]Peng Jing, Liu Guanghu,Xie Shihuan. Routing Protocols in Wireless Sensor Network Presents and Future Trends. Application Research of Computers.2007()2:4-9.

[4] Stojmenovic I, Lin X. Power-aware localized routing in wireless networks .IEEE Transactions on Parallel and Distributed Systems, 2001,12(11): 1122 - 1133.

[5] Zhou Z,Zhou S,Cui S,etal.Energy-efficient cooperative communication in a clustered wireless sensor network.IEEE Transactions on Vehicular Technology,2008,57(6):3618-3628.

[6]Hu Gang, Xie Dongmei, Wu Yuanzhong.Research and Improvement of LEACH for Wireless Sensor Networks.Chinese Journal of Sensors and Actuators. 2007,20(6):1 391-1 396.

[7] Heinzelman W,Chandrakasan A,Balakrishnan H. Energy-efficient Communication Protocol for Wireless Sensor Networks[C]//Proceeding of the Hawaii International Conference System Sciences,Hawaii,January 2000.

[8] E.shih.S.Cho.N.Ickes.R.Min， A.Wang,A.Chandrakasan， Physical Layer Driven Protocol and Algorithm Design for Energy-Efficient Wireless Sensor Networks.Proc.ACM MobiCom’01，Rome，Italy，pp.272-286，July2001.

[9] National Semiconductor Corporation，LMX3162 Single Chip Radio Transceiver Evaluation Notes and Datasheet，March 2000.

[10] G. .Pottie.W.Kaiser “Wireless integrated newtokr sensors，”Communication of the ACM，vol.43，pp.51-58，May 2000

[11] Heinzelman W, Chandrakasan A,Balakrishnan H.An Application specific Protocol Architecture for Wireless Microsensor Networks.IEEE Trans.on Wireless Communica-tions,2002,10:660-670.

[12] Xie Q L,Lea C T,Golin M J,et al.Maximum residual energy routing with reverse energy cost[C]//IEEE.Proc Globecom IEEE Globecom Conference. SanFrancisco: IEEE Press,2003:564-569