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Clustering and Routing Procedure for Indirect Transmission to improve the Lifetime of Wireless Sensor Network

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***Abstract*-** The electricity of sensor nodes in wireless sensor networks is very limited, Sensor nodes are often scattered outdoors and their energy consumption depends heavily on the area of coverage and network topology. In the related research, LEACH routing algorithm randomly selects cluster heads in each round to form a cluster network, which may cause additional power consumption and inability to maintain the optimal routes for data transmission. The cluster allocation and routing algorithm proposed in this study is based on the cluster architecture of LEACH, and the objective is to produce clusters with more sensor nodes to balance energy consumption of cluster head and routing prevents the cluster heads from exhausting electric power by forwarding data through detoured routes. The experimental results show that the proposed algorithm can efficiently increase the coverage ratio as well as lifetime of wireless sensor networks**.**

Index Terms- wireless sensor networks, routing algorithms, cluster networks, network lifetime

I. INTRODUCTION

The wireless sensor network (WSN) was initially a research project directed by UC Berkeley, where they used the micro-electro-mechanical technology to design wireless sensors about the size of a coin, also called smart dusts. A WSN consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, pollutants and motion to cooperatively pass their data through the network to the base station [1]. The WSN was first used to collect data in the battle fields. Due to its small size, low price and various functions, the WSN has now been used in daily applications, for example, taking care of elder people, vibration detection of bridge piers, detection of fire and CO_2 emission, and so on. When the sensor devices were first introduced, the major concerns were the cost, size, and energy consumption because of their limited computation speed, memory and power capabilities. Since the transmission distance also affects the energy consumption, it is another factor to be considered.

In the data transmission of WSN, the strength of signals is highly related to the distance, i.e., the longer the distance, the weaker the signal and the more energy consumed. When the distance is too long, it may cause the sensor nodes to exhaust energy quickly and thus affect the network lifetime. As a result, how to fully utilize the electric power of sensor nodes for continuous data transmission is an important topic of WSN research. Basically, the ways of data transmission for the WSN can be categorized as direct transmission and indirect transmission [2].

A. Direct Transmission

Each sensor nodes transmit the collected data to the base station directly. In this approach, the data rate is higher since there is no forwarding during transmission. Although the implementation for direction transmission is easier, the data may not be sent to the destination when the application area is very large, or the sensor nodes may die quickly due to high energy consumption. Therefore, this approach is suitable only for small-area applications.[10]

B Indirect Transmission

The sensor nodes send the collected data to the neighbor nodes, which will forward the data to the base station. This approach solves the problem of high energy consumption in long-distance transmission, but it may cause some nodes to consume more energy by forwarding data for the other nodes and thus affecting the network lifetime[10].

Usually, the deployment of a WSN is to scatter a large amount of sensor nodes over the application area randomly. Then, the sensor nodes start to collect and transmit data back to the base station via multi-hop forwarding. Since each node does not know the exact position of other nodes at the beginning, a self-organization protocol [3] is required to connect the sensor nodes to form a communication network for data transmission.

The main objective of a routing algorithm is to find a better way for data transmission to save electric power. Therefore, how to design an efficient routing algorithm to extend the lifetime of WSN has become a very important research topic.

The low-energy adaptive clustering hierarchy (LEACH) proposed by Heinzelman *et al.* [8] is a well-known hierarchical routing protocol applied in clustered wireless sensor networks because it can balance energy consumption within a cluster to extend the network lifetime. Its operation contains two stages, i.e., *initial stage* and *stable stage*. In the initial stage, the base station selects a few nodes as cluster heads based on random thresholds, and the other nodes join nearby clusters by sending out signals to discover the nearest cluster heads. When clusters are formed, the network enters a stable stage. Each node starts to sense and transmit data to its cluster head, which will then forward data to the base station along with its own data. Since the cluster head will consume more energy, it must be replaced regularly to prevent power exhaustion. Many routing algorithms were developed based on the same approach of LEACH in creating clusters, e.g., PAGASIS [5] and TEEM [6].

PEGASIS works by connecting nodes in series, starting from the farthest node to the base station, to form a linked structure with its neighbor nodes. When all nodes are connected, the head of the linked structure will be selected. Then, every node combines both received data and its own data and sends them towards the head. When all data arrive at the head, it will be forwarded to the base station. Since the route is computed by the greedy algorithm, it is the shortest and consumes less energy than LEACH. However, the greedy algorithm is complicated and thus requires more energy in computation.

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) is also based on LEACH to transmit data to the base station periodically. It sets two threshold values, i.e.,hard threshold and soft threshold, to avoid the transmission of duplicated data. This approach can save some energy by reducing the amount of data, but it is not suitable for the applications requiring periodical data since the threshold values may not be met in occasion. Therefore, a revised version of TEEN was proposed [7] to remedy the drawback of reporting data periodically by reacting to sudden events in real time. Since both algorithms are based on LEACH, the amount of energy saved is still limited.

Before going to design good protocols let us first define impotent parameters i.e, what is coverage and lifetime.

A. Coverage Ratio

The coverage ratio of a WSN represents the percentage of area under monitoring, which is computed as the area covered by the working sensor nodes divided by the total application area (700m×700m =490000m2). The sensor nodes can function correctly only when they have enough electricity, so the electric power is the major factor affecting coverage ratio. A WSN cannot achieve its function when the coverage ratio is too low. Besides, sensor nodes have more feasible routes for selection to reduce energy consumption when the coverage ratio is high.

B. Network Lifetime

Network lifetime is the time span from the deployment to the instant when the network is considered nonfunctional. When a network should be considered nonfunctional is, however, application specific. It can be for example, the instant when the first sensor dies a percentage of sensor dies, the network partitions or the loss of coverage occurs [15].

These networks should function for as long as possible. It may be inconvenient or impossible to recharge node batteries. Therefore, all aspects of the node, from the hardware to the protocols, must be designed to be extremely energy efficient [14].

II. SYSTEM MODEL AND RELATED METHODS

The cluster allocation and routing algorithm proposed in this study is based on LEACH's clustered architecture. The difference is that the cluster allocation is done only once at the beginning and remains fixed for the rest of time, and the goal is to create clusters containing more sensor nodes to share the energy consumption of their cluster head in forwarding data to the base station.

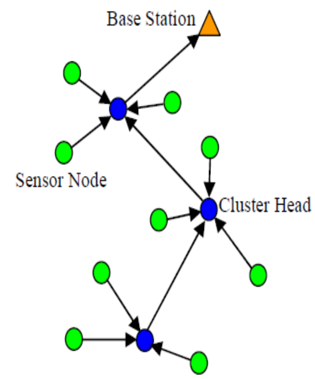

Figure1.Data transmission in a wireless sensor network

When the system starts its operation, regular nodes send out collected data to the cluster head, and then the cluster head forwards data to the base station through its neighbor cluster heads using the dynamic routing mechanism (Figure 1)[10].

This study achieves a higher coverage ratio and a longer lifetime as well. The methods of high-energy-first mechanism for determining the cluster heads, finding the forwarding node with the smallest angle [10],data compression [11] and sleep mode [12, 13] were also incorporated in the routing algorithm to further reduce the energy consumption and extend the lifetime of WSN. These methods are described in the following.

A. High-energy-first Method

In LEACH, a recently retired cluster head still has a chance to be selected again according to the probability function, which may lead to fast exhaustion of its electric power. Therefore, this study adopts the high-energy-first method to select cluster heads in each round to remedy this drawback. After collecting data, each sensor node has to send out data together with the information about its remaining electric power, and then the base station can decide which nodes are to be selected as cluster heads in the next round using broadcast messages.

B. Determining Forwarding Node

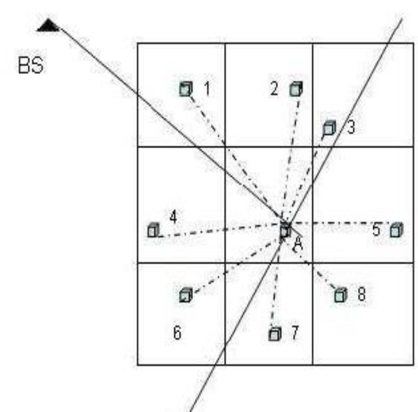

Figure 2.Determination of the forwarding node

In each round, a cluster head has to determine the forwarding node, which is also a cluster head in neighbor clusters. The most direct forwarding route is determined based on the angle between the directions of the base station and the candidate forwarding node. The neighbor cluster head with the smallest angle is chosen first as the forwarding node, and the goal is to use the shortest forwarding route to reduce energy consumption. For example, cluster head ***A*** in Figure 2 will select node 1 as the forwarding node, unless its remaining electric power is below the threshold. If node 1 is not available, node 4 will be selected next. This method can save energy by choosing the shortest route in forwarding data[10].

C. Data Compression

In WSN, the amount of data transmitted can also affect the energy consumption of sensor nodes. When a cluster head detects the same or similar data packets which are being transmitted, it can use the data compression method to filter out similar data packets. This method can reduce the amount of data and therefore save some energy.

D. Sleep Mode

When sensor nodes are scattered randomly during the deployment of a WSN, some nodes may be too close to each other and collect the same data. Therefore, using sleep mode can reduce the data amount and energy consumption. In this study, a grouping method is used to divide sensor nodes into a number of groups within a cluster. In each group, the node with more electric power is selected as the active node while the other nodes may enter sleep mode. The main objective of the grouping method is to evenly distribute active nodes in each cluster to reduce data similarity. Furthermore, the ratio of active nodes and the group size can be adjusted according to the requirement of data precision.

III. CLUSTER ALLOCATION AND ROUTING

This study adopted a fixed cluster allocation algorithm similar to the initial stage of LEACH. At first, the base station sends a threshold value to all sensor nodes for the selection of cluster heads. Then, this study used the cluster allocation algorithm to create clusters with more sensor nodes. After that, each sensor node sends the information back to the base station for later usage, including node number, cluster number, location and remaining electricity. As soon as the initialization stage is completed, the WSN begins its operation in each round to collect and transmit data by the routing algorithm.

A. Cluster allocation

The concept of set operation is used in dividing the sensor nodes in a WSN into a number of clusters. At the beginning, the initial stage of LEACH is used for selecting cluster heads, and then the cluster heads create their own clusters by communicating with the sensor nodes within the sensing area. For simplicity, the created clusters are defined as the allocated sets, while the sensor nodes not invited by any cluster heads are left in the unallocated set. Then, the allocated sets are sorted by the number of their sensor nodes, and those in the intersected sets are re-allocated to the set with more sensor nodes. The objective is to produce clusters with more sensor nodes such that they are more powerful in forwarding data for other nodes. After that, the sets with very few nodes will be deleted, and their nodes are put into the unallocated set.

When all sensor nodes in the intersected sets are reallocated, each sensor node belongs to a unique cluster. If there are still some sensor nodes in the unallocated set, the algorithm repeats the same process as described above until the remaining sensor nodes have been allocated to a certain cluster. The reason for re-allocating the sensor nodes in the intersected set is to produce clusters with more sensor nodes to compensate for the high energy consumption by cluster heads in forwarding data (Figure 3).

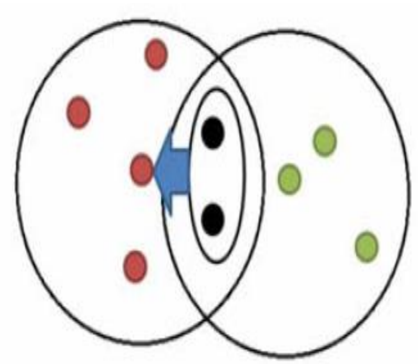

Figure 3.Allocating the intersected set to the set with more nodes

B. Routing

The routing algorithm operates by rounds. After sensor node deployment and cluster allocation, the routing algorithm uses high-energy-first method to select sensor nodes with more electric power as the cluster heads, and determines the forwarding nodes for data transmission. After that, all sensor nodes start to collect data, which are aggregated by the cluster heads and forwarded to the base station.

IV. SIMULATION RESULTS

This study conducted several simulation experiments to analyze if the proposed algorithm could extend the lifetime of WSN. The results were compared with those of LEACH algorithm under the same conditions.

Before the simulation experiments, this study provides the following analysis about the power consumption by sensor nodes. Basically, the energy required for transmitting a signal is highly related to the distance [14]. The following equation shows the energy consumed when sending a signal to a distance d by an amplifier.

$$\text{Energy consumption} = \begin{cases} \varepsilon_{fs} \times d^2, \text{if } d \le d_0 \\ \varepsilon_{tr} \times d^4, \text{if } d > d_0 \end{cases}$$

Using d_0 as a threshold, if the transmission distance is shorter than d_0, *a* free-space propagation model is used to calculate the consumed energy, which is proportional to the square of distance. If transmission distance is longer than d_0, the two-ray ground propagation model is used for calculation and the consumed energy is proportional to the fourth power of distance. In that case, the consumed energy has a great influence on the wireless communication system. In the above equation, ε_{fs} and ε_{tr} are the parameters for the free-space propagation model and two ray ground propagation model with their values equal to 10 pJ/bit/m^2 and 0.0013 pJ/bit/m^4, respectively; Here, d_0 is defined as $\sqrt{\varepsilon_{fs}/\varepsilon_{tr}}$ which is the threshold of transmission distance and its value is about 87.7. To simplify the computation, it is assumed that d_0=100m.

For most sensor nodes in WSN, the consumed energy is proportional to the square of distance when collecting and sending data to their cluster head. The cluster allocation algorithm can increase the node density in a cluster and thus reduce the distance and consumed energy in transmitting data. As the operation continues, the sensor nodes near the base station may exhaust their electricity and thus cannot forward data for the outer sensor nodes. Consequently, the outer sensor nodes may need to transmit data directly to the base station at a longer distance, so the energy consumed is proportional to the fourth power of distance.

The parameters for the experiments are described in the following. The size of the application area is 700m×700m and there are 100 sensor nodes deployed. The longest transmission distance for a senor node is 200m. The initial energy in each sensor node equals 1J, and the energy for sending and receiving data are the same, 50nJ/bit. Each data aggregation takes 5nJ/bit with the compression rate =70%. The amplifier parameters for the two models are ε_{fs}=10pJ/bit/m^2 and ε_{tr} =0.0013pJ/bit/m^4, respectively.

Table 1.Simulation parameters

Parameter name	Value
Application area	700m×700m
Initial energy of node	1J
d_0	100m
Number of nodes	40,60,80,100
Data rate	10,12,14,16,18,20 bit/sec

Figure 4 shows the lifetime for leach and proposed algorithm, while keeping number of nodes and simulation time constant. It shows that the lifetime of proposed algorithm is greater than LEACH.

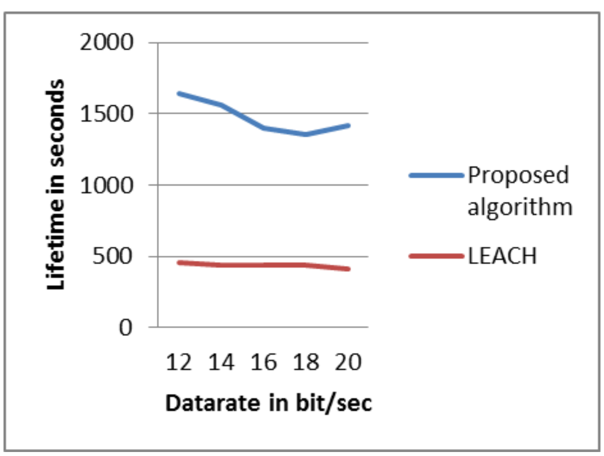

Figure 4.Comparing the lifetime of LEACH and proposed algorithm

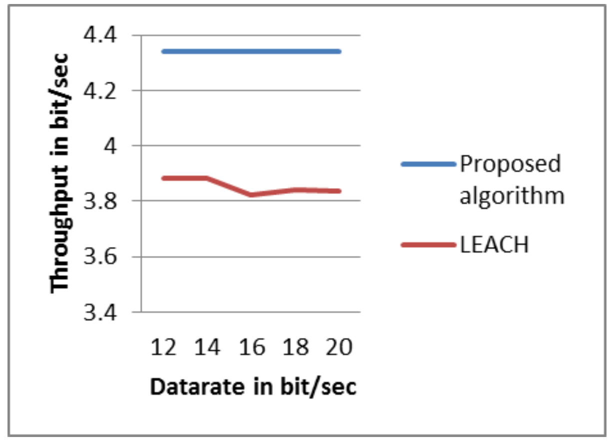

Figure 5.Comparing the throughput of LEACH and proposed algorithm

Similarly Figure 5 shows the comparison of throughput, Figure 6 shows the comparison of latency and Figure 7 shows the comparison of packet delivery ratio for both proposed algorithm and LEACH. And in all these cases number of nodes and simulation time kept constant for both models.

Figure 8, shows the coverage ratio of both proposed algorithm and LEACH.As shown in the graph the coverage ratio increase as the number of nodes increasing, but the coverage ratio of proposed algorithm in high compared to the LEACH. In this case the application area, data rate and simulation time kept constant for both model.

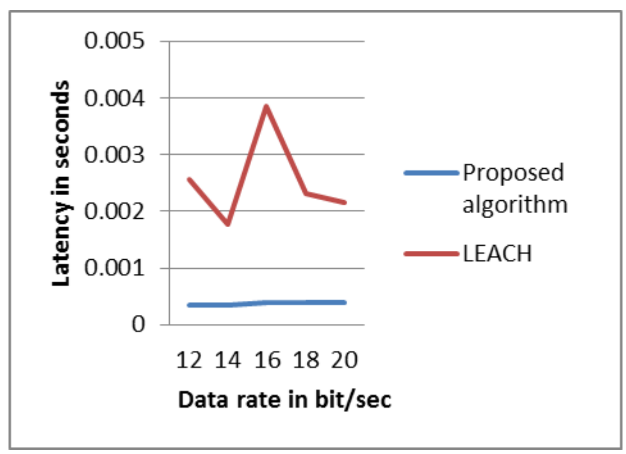

Figure 6.Comparing the latency of LEACH and proposed algorithm

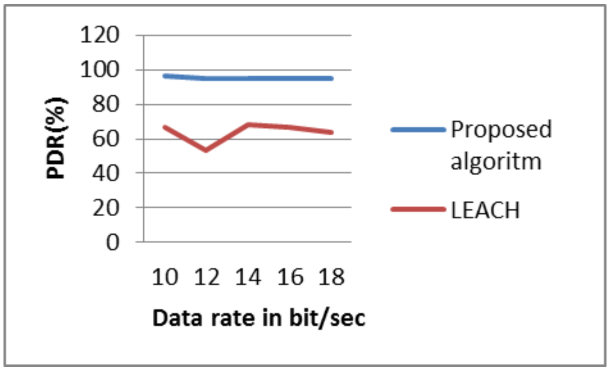

Figure 7.Comparing the PDR of LEACH and proposed algorithm

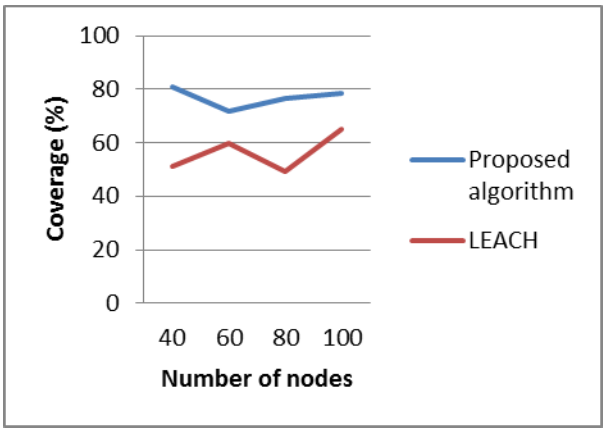

Figure 8.Comparing the coverage ratio of LEACH and proposed algorithm

V. CONCLUSION

For large-area applications, most routing algorithms adopt indirect transmission mode to solve the problem of high energy consumption due to long-distance transmission because it may cause the sensor nodes to exhaust electricity quickly. This study proposed a cluster allocation algorithm which forms clusters with more number of sensor nodes and routing algorithm which finds a better way for data transmission to save electric power, to remain a high coverage ratio and thus extend the lifetime of WSN. The simulation results show that the lifetime and coverage ratio for the proposed algorithm is higher than that of LEACH.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, Wireless Sensor Networks: a Survey, Computer Networks, vol. 38,no. 4, pp. 393-422, 2002.

[2] W. R. Heinzelman, A. Chandrakasan, and H.Balakrishnan, Energyefficient communication protocol for wireless microsensor networks, Proceedings of the 33rd Hawaii International Conference on System Sciences, vol. 8, pp. 8020, Jan. 4-7, 2000.

[3] K. Sohrabi, J. Gao, V. Ailawadhi, and G. J. Pottie, Protocols for selforganization of a wireless sensor network, IEEE PersonalCommunications, vol. 7, no. 5, pp. 16-27, 2000.

[4] M. J. Handy, M. Haase and D. Timmermann, LEACH-C□ Low energy adaptive clustering hierarchy with deterministic cluster-head selection, 4th IEEE International Conference on Mobile and Wireless Communication Network, pp. 368–372, Sep. 2002.

[5] S. Lindsey and C. S. Raghavendra, PEGASIS: Power efficient gathering in sensor information systems, Proceedings of the IEEE Aerospace Conference, vol. 3, pp. 1125-1130, 2002.

[6] A. Manjeshwar and D. P. Agrawal, TEEN: a routing protocol for enhanced efficiency in wireless sensor networks, Parallel and Distributed Processing Symposium, pp. 2009-2015, Apr. 2001.

[7] A. Manjeshwar and D. P. Agrawal, APTEEN: a hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks, Proceedings of the International Parallel and Distributed Processing Symposium, pp. 195-202, 2002.

[8] W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan, “Energy-efficient communication protocols for wireless microsensor networks,”Proceedings of the Hawaii International Conference on Systems Sciences, pp. 3005-3014, Maui, Hawaii, USA, January 2000.

[9] R. Ghrist and A. Muhammad, Coverage and hole-detection in sensor networks via homology, Proceedings of the 4th International Symposium on Information Processing in Sensor Networks, pp. 254- 260, Apr. 24-27, 2005.

[10] Wernhuar Tarng, Kuo-Liang Ou, Kun-Jie Huang, Li-Zhong Deng, Hao-Wei Lin, Chang Wu Yu, Kuen-Rong Hsieh and Mingteh Chen, Applying Cluster Merging and Dynamic Routing Mechanisms to Extend the Lifetime of Wireless Sensor Networks, International Journal of Communication Networks and Information Security, vol.3, no. 1, pp. 8-16, 2011.

[11] X. Tang and J. Xu, Extending network lifetime for precisionconstrained data aggregation in wireless sensor networks,Proceedings of IEEE INFOCOM, Apr. 2006.

[12] J. M. S. N., L. B. Ruiz and A. F. Loureiro, Manna: A management architecture for wireless sensor networks, IEEE Communication Magazine, vol. 41, pp. 116–125, 2003.

[13] V. Raghunathan, C. Schurgers, S. Park, and M. B. Srivastava, Energy-aware wireless micro sensor networks, IEEE Signal Processing Magazine, vol. 19, no. 2, pp. 40-50, 2002.

[14] W. B. Heinzelman, P. Chandrakasan, and H. Balakrishnan, An application-specific protocol architecture for wireless micro sensor networks, IEEE Transactions on Wireless Communications, vol. 1,no. 4, pp. 660-670, 2002.

[15] Yunxia chen,Qing Zhao,”On the Lifetime of Wireless Sensor Networks”,IEEE communications letters,vol.9,no.11,november 2005.

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