

LEACH Algorithm Based on Load Balancing

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Abstract

This paper discusses advantages of LEACH Algorithm and the existing improved model which takes the famous hierarchy clustering routing protocol LEACH Algorithm as researching object. Then the paper indicates the problem that in the algorithm capacity factor of cluster head node is not taken into account leading the structure of clusters to be not so reasonable. This research discusses an energy-uniform cluster and cluster head selecting mechanism in which "Pseudo cluster head" concept is introduced in order to coordinate with "Load Monitor" Mechanism and "Load Leisure" Mechanism to maintain load balancing of cluster head character and stability of network topology. On the basis of LEACH Protocol improving algorithm of LEACH-C, CEFL and DCHS. NS2 simulation instrument is applied to do simulation analysis on the improved algorithm. Simulation result shows that LEACH-P Protocol effectively increase energy utilization efficiency, lengthens network lifetime and balances network load.

Keywords: wireless sensor network, load balancing, load relief

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1. Introduction

Routing protocol is the supporting technology of WSN network layer. In order to lengthen network life cycle to capacity, favorable routing protocol is essential. As hierarchy clustering routing protocol can effectively lessen network energy consumption and enhance extensibility of network, it has been extensively researched. LEACH (low energy adaptive clustering hierarchy) is proposed earliest in WSN and is a mature hierarchy clustering routing protocol. Basic thought of LEACH is waiting for cluster head being selected randomly, balancing network energy consumption and further lengthening network life cycle. However, with technology developing and WSN applying scene constantly increasing, disadvantages of LEACH Algorithm also gradually come out. Therefore presentation of improved project is the key factor for LEACH Protocol research on the basis of keeping advantages of LEACH Protocol.

Among the present researches, most views are concentrated on studying reasonable and suitable clustering mechanism. While few study the kind of clustering mechanism when network runs for a while, cluster will dismiss and prepare to form together again. In LEACH Protocol, work burden of cluster head node is more than that of other nodes. When network operates for a period, energy consumption increases so that clusters will form again or base station suddenly assign a number of sensing tasks or local region increases a large number of sensing events. Under these circumstances, load of cluster head node will be overweight leading energy to rapidly consume even die [1, 2]. At this time, unstable state of network will lead cluster head role to be reassigned and make group dismiss which will consume a lot of network cost. Meanwhile by analyzing clustering pattern of LEACH, it is found that LEACH Protocol only takes communication cost between cluster head node and non-cluster head node into account but neglects factors like energy condition and location information of cluster head node itself. When clusters will form again or base station suddenly assign a number of sensing tasks or local region increases a large number of sensing events, work load of cluster head node will suddenly increase and energy of cluster head node will consume [3]. As alternating mechanism of cluster head role in LEACH Algorithm effects, alternating time for cluster head role will greatly shorten which easily make network topology change and present unstable phenomenon.

Aiming at disadvantages of LEACH Protocol, lots of improved models exist like the main ones EACH-C (LEACH-centralized) Protocol, LEACH-F (LEACH-Fixed) Protocol, CEFL Protocol and DCHS Protocol [4-9].

LEACH-C Protocol chooses suitable cluster head node according to the whole network information which can effectively solve the problem that too many or too little cluster head nodes appear in each LEACH cycle. This method helps find suitable number of cluster head node for the present network condition. In addition, LEACH-C can find appropriate cluster head node with fine communication location or enough electric power. Operating mechanism of LEACH-C is mainly based on “generalized energy information” meaning that all sensor nodes transfer information of present locations and energy consumptions to base station and base station calculates average electric power of the whole network according to information from all sensor nodes. When residual energy of one sensor node is lower than the whole average level, this node cannot be cluster head node. Then it will select nodes from remaining nodes to form cluster head node collection with suitable number, fine location and enough energy. Finally, base station broadcasts the cluster head node collection and the whole network structure to all nodes which will build reasonable WSN.

LEACH-F (LEACH-Fixed) Cluster Algorithm is similar to LEACH-C. Their difference is that base station generates cluster head order for each cluster to show cluster head role order of nodes. When LEACH-F Algorithm finishes clustering, network architecture of clusters will never change again in which member nodes act as their own cluster head roles according to cluster head order. Although this method can reduce cost of choosing cluster head node in each round, it can never solve the problem of increasing, decreasing and losing effect for sensor nodes.

CEFL (Cluster-head Election using Fuzzy Logic) Protocol adopts Fuzzy Logical Algorithm to assign cluster head nodes on the basis of LEACH Protocol. Variable quantity to which CEFL Protocol clustering is according is the electric power, density and gravity degree of nodes. Node density means the whole number of nodes around the sensor. Node gravity degree is the degree to which sensor node is nearby the clustering center. CEFL fuzzily distinguishes each node according to “Center of Gravity” and selects one of representative accuracy from the fuzzy output results. Operation of the very fuzzy engine is set on base station. After operation is done, cluster heads are formed together and then clustering structure is broadcast to the whole network.

DCHS Algorithm (Deterministic Cluster-Head Selection) improves the cluster head selecting mechanism of LEACH Algorithm which adopts “energy comparing model” to choose cluster head node. In each cluster head election round, this algorithm comprehensively takes energy condition of nodes into account and selects the node with better energy condition to become cluster head role which leads the election of cluster head role to be more reasonable.

This research borrows “generalized energy model” of LEACH-C Algorithm in LEACH cluster head role alternation mechanism to solve the disadvantage of LEACH Algorithm in which cluster head is selected by single factor. Afterwards during concrete assigning process this research synthesizes the “center of gravity” [8] of CEFL Algorithm and “energy comparing model” [9] of DCHS Algorithm to discriminate and select better cluster head role from “generalized energy”. As work burden of cluster head than that of sensor node, its load condition needs monitoring during network operating process. This research adds Load Monitor Mechanism and Pseudo-Cluster Head (PCH) Mechanism to monitor load condition of cluster head node to promise the stability of cluster head node. When cluster head node energy is too low, pseudo cluster head node replaces the present cluster head node to prevent cluster head node from losing efficacy and dying and keep network normally operating. Moreover when base station suddenly assigns monitoring tasks or a large number of monitoring events come out in monitoring area, cluster head node load is too high to provide service. Also it quickly consumes a lot of energy. As cluster head role alternating mechanism in LEACH Algorithm affects, time of cluster head role alternation will greatly shorten which easily leads network topology structure to change and present unstable phenomenon. This research will add Load Relief Mechanism to make stability of cluster head role notably increase, keep network stability and lengthen network life cycle. The load balancing LEACH improved algorithm based on pseudo cluster head is called LEACH-P Algorithm (LEACH with Pseudo-Cluster Head, LEACH-P for short).

2. Research Hypotheses

During cluster head election process, this research borrows “Generalized Energy” Definition of LEACH-C Algorithm meaning that multiple factors of nodes influence such as

nodes' electric power residue, nodes' busy degree, nodes' communication bandwidth, clusters' center of gravity and whether nodes in clusters are nearby to better communication location. In order to simplify the research, it is supposed that each sensor node's busy degree and hardware configuration like communication bandwidth are available. Under this circumstance, sensor node cannot charge again after arranged and electric power resource consumes lower with wireless sensor network operating until none electric power is left. Beyond that, relative location between node and cluster center of gravity is taken into account. Therefore this research continues to use TDMA Scheduling project of LEACH Algorithm and edits an ID for each cluster in which each node also has one ID (eg. i , j). Otherwise new nodes would come into cluster because of mobility of sensor node or they may disappear in the former cluster for the reason that node leaves, mistakes or damages. This research supposes that network is a dynamic environment in which influence of node's moving speed will not be taken into account in order to simplify the problem.

This research defines sensor node in WSN as the following three roles. Sensor Node namely SN is member node in cluster managed by cluster head. Cluster Head Node namely CH mainly manage its SN. When CH moves, it will inform SNs to alternate their own roles. Pseudo-Cluster Head Node namely PCH is that when cluster head role comes into being, the best SN will be chosen to become alternative. PCH does not need to do anything apart from signing ID after it comes into being. When CH could not continue to manage its own cluster, PCH would replace it.

3. Algorithm Statements

This research divides LEACH-P Algorithm into three stages namely Initial Phase, Active Phase and Inactive Phase. During Initial Phase, some node energy has been consumed in network and the former topology structure reorganizes cluster after dismissing. At this moment, "center of gravity" and "energy comparing model" will be used to build hierarchy cluster structure. Active Phase is the stage collecting perception information when new network topology has finished clustering and begins to perform tasks again. It is similar to Steady Phase of LEACH. Inactive Phase is network unstable stage when CH will lose effect. During Inactive Phase, this research will lead PCH to replace CH to prevent from influencing the cluster's operation even stability of the whole network. Through such mechanism, clusters' dismiss and network instability resulting from reselecting CH will be avoided. After one round, new CH will assign new PCH.

3.1. Initial Phase

By description of LEACH cycling initial phase, it is seen that the existing cluster head role alternating mechanism of clustering algorithm leads the number of broadcast information and repeating perception information in LEACH network to be too much so that "Broadcast Storm" and "Information Collision" easily come into being. Therefore after large-scale network operating for a while, the former network topology structure becomes unstable and needs to afresh cluster. This time the way of broadcasting large number of information in LEACH Algorithm will not be used but it will be "Reciprocal Mechanism" [10, 11]. When Initial Phase using LEACH-P Protocol to cluster begins, each SN of network will produce a random number which inverses until random number of SN is 0. Then it will propose to compare energy condition with neighbor nodes (more than one at least). Energy of SN contains nodes' electric power residue, nodes' busy degree, nodes' communication bandwidth, clusters' center of gravity and whether nodes in clusters are nearby to better communication location. When all SN propose energy comparing request at the same time ("Broadcast Storm" in LEACH Algorithm comes into being because of this), "Reciprocal Mechanism" can help disperse lots of communication traffic.

Center of gravity theory in LEACH-P Protocol is similar to "Center of Gravity" of CEFL [8] improved algorithm. Cluster areal coordinate lies in areal coordinate X of Number j Cluster. It is CX_j that sum of X divided by number of nodes i . Shown in Formula 1.

$$CX_j = \frac{\sum_i X_{ji}}{i} \quad (1)$$

Cluster areal coordinate lies in areal coordinate Y of Number j Cluster. It is CY_{ji} that sum of Y divided by number of nodes i. Shown in Formula 2.

$$CY_{ji} = \frac{\sum_i Y_{ji}}{i} \quad (2)$$

Suppose that SN coordinate is (X_{ji}, Y_{ji}) . d_{ji} is the distance which ith SN in Number j Cluster is apart from center of gravity. As is shown in Formula 3, the closer SN is to center of gravity, the better communication effect it is in the cluster.

$$d_{ji} = \sqrt{(X_{ji} - CX_{ji})^2 + (Y_{ji} - CY_{ji})^2} \quad (3)$$

Energy of SN is calculated by dump energy (e), busy degree (b), node communication bandwidth (c) and distance between SN and center of gravity (d). According to the four factors' different importance, different weight values (W_i) will be arranged to calculate each energy value E_{current} on SN of the four factors. It is shown in Formula 4.

$$E_{\text{current}} = e * W_1 + \frac{1}{b} * W_2 + c * W_3 + \frac{1}{d} * W_4, \sum_1^4 W_i = 1 \quad (4)$$

We borrow energy value comparing thought [9] of DCHS Algorithm. Suppose that i of SN is the number whose random number inverses to 0 at first in Number j Cluster. Its nearby SN is k. If $E_{i\text{-current}} > E_{k\text{-current}}$, SN i is selected to be CH.

When Initial Phase begins, each SN in network produces a random number which constantly inverses. The first random number which inverses to 0 will propose energy comparing request to nearby nodes (more than one at least) in advance.

When there are more than two clusters nearby the SN which finished inversing, distance between CH of these clusters and SN will be the selecting principle to join in the cluster. If distances are the same, one of them will be randomly chosen.

If there is SN which has finished clustering or has not joined in clusters, the SN which finished inversing will choose the latter to do energy comparison in order to accelerate convergence rate.

3.2. Active Phase

When network forms clusters again, overload phenomenon for CH will come into being during a short time if base station suddenly assign a lot of monitoring tasks or lots of monitoring events come out in monitor area. This kind of condition leads CH to rapidly consume electric power. Aiming at this, this research adds Load Monitor Mechanism into topology structure to assess the present load capacity value of CH and applies "Slow Start" [12, 13] Concept to lengthen CH alternating time and to keep it effectively operating namely Load Relief Mechanism.

Load Monitor Mechanism means that after network forms clusters again, the present load condition of CH will be assessed by using load capacity function to calculate its load capacity value and set its load capacity threshold value. Capacity value calculating function is shown as Formula 4. However, there is not direct relationship between load capacity of CH and distance between node and center of gravity. Therefore Formula 4 needs correcting which is that dump energy(e), processing unit busy degree(b) and node communication bandwidth(c) will be independent to be L Function namely load capacity function shown in Formula 5. L value can help assess whether the present work load of CH is ideal.

$$E_{\text{current}} = L + \frac{1}{d} * W_4, \sum_1^4 W_i = 1; L = e * W_1 + \frac{1}{b} * W_2 + c * W_3, \sum_1^3 W_i \leq 1 \quad (5)$$

After calculating load capacity value L of CH according to Formula 5, load capacity threshold value L_t needs setting to estimate load capacity. Therefore corresponding threshold weight value t_1, t_2, t_3 must be set in allusion to each weight in capacity function so that load capacity threshold value L_t will be got as is shown in Formula 6.

$$L_t = e * t_1 + \frac{1}{b} * t_2 + c * t_3, \sum_1^3 t_i \leq \sum_1^3 W_i \leq 1 \quad (6)$$

It is known that whether cluster head role needs alternating is decided by load capacity value of CH through calculation of L and L_t . When $L < L_t$, PCH will replace CH to reduce network cost for passively alternating cluster head roles. However, if low capacity phenomenon of network is from short-time busy condition, energy of its processor unit and communication bandwidth will recover because of event finishing or load relief. The way PCH replacing CH is practicable. However, frequent replacing of CH increases maintenance cost of clusters. We then bring out Load Relief Mechanism to solve the problem of misjudgments and lengthen alternating time of CH.

Slow Start Concept [12, 13] proposed by Shah, R.C. helps better lengthen alternating time of CH and leads PCH to work effectively namely Load Relief.

When capacity value L of CH is lower than threshold value L_t , PCH can receive permission of perception information transmission and information integration. In order to keep the consistency of information and prevent the former transmission and integration work from suspending, CH will continue to finish it. Through Load Relief Mechanism, load capacity of CH gradually returns to the normal condition by the share of PCH. At this time, it is necessary to take back part of work by PCH one by one. When capacity value of CH gradually becomes higher than threshold value, information "I am ready" will be broadcast to each node in clusters. Then SN with data transmission request directly communicates with CH. Meanwhile PCH transmits the well-done information integration to CH. When CH is done Load Relief Mechanism, CH issues "I am busy" to all SN including PCH which means CH is busy. After PCH receives information, it also receives permission of perception information transmission and information integration.

Through Load Relief Mechanism, load capacity value of CH gradually becomes normal under the help of PCH. Therefore load capacity function value L will be higher than L_t again. When CH normally works, work permission of PCH will be withdrawn. If load condition may not be effectively solved or electric power is so low that it cannot normally work, CH itself will start CH role alternation and meanwhile PCH replaces managing role. When PCH becomes formal cluster head role, it will also assess its own capacity as it is the node keeping better capacity value. When load capacity of PCH is not fine, clusters will be dismissed and formed again in order to prevent this cluster from loading too much and keep some SN from dying.

3.3. Active Phase Inactive Phase

When CH cannot communicate with SN because of insufficient electric power, not being into communication area, damaging or other factors, the present clustering stage is inactive phase. In the past researches, if CH loses effect before this round ends, SN would directly communicate with base station until the next round begins. However, this kind of mechanism will lead network to load too much and become unstable. In order to prevent this condition, this research proposes that PCH can be used to maintain cluster head role operation. This type of role alternation is divided into initiative replace and passive replace.

After CH is done load relief and its capacity threshold value is moderately adjusted, PCH will initiatively replace CH if load capacity of CH is still too low. The advantage for this is that PCH receives relative information transmission work before CH loses effect so that communication cost is lower. Also this prevents clusters from being unstable because of services or links are suspended. Passive replace is that SN passively communicates with PCH and PCH manages the whole cluster when CH has lost effect and SN still cannot communicate with CH after several times. When PCH becomes new CH, it will choose SN with better capacity value to be PCH. On the contrary, if SN cannot communicate with PCH after several wrong

tries, this cluster will dismiss and each node returns to the initial phase to form clusters and choose CH and PCH.

4. Simulations and Analyses

4.1. Comparison of Cluster Head Electric Power Consumption

Simulation parameter: Network scope is $100 \times 100 m^2$; Base station location is (0, 0); Initial electric power is 0J; Cluster scope is 30m. In order to test and verify that Load Relief Mechanism of LEACH-P Protocol can balance work load of cluster head and reduce electric power consumption, 50 nodes are chosen in experiment scene among which 30 times' results are averaged. In the experiment, we will calculate the average residual electric power of CH both in LEACH Algorithm and LEACH-P Algorithm of each unit time of the whole network. Figure 1 is average residual electric power of CH and PCH under environment of 50 nodes from which it is seen that after network operating for a while, nodes consume some electric power especially that of CH. If LEACH Protocol is still be used to form network, its energy consumption will constantly decrease until electric power is used up as no other nodes can afford the load of CH. However in LEACH-P, PCH can initiatively share part of work of CH and lead electric consumption of CH to become slower when the load of CH is too high. As is shown in Fig.1, electric consumption of CH in LEACH-P greatly reduces in about 0-60 unit times. However, electric consumption of CH at the 60th and 755th turning points becomes gently fall with the help of PCH.

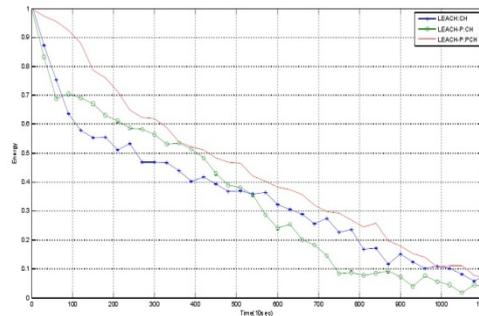


Figure 1. Average Residual Electric Power of CH and PCH under Environment of 50 Nodes

4.2. Comparison of Network Survival Time

In order to test and verify that cluster alternating mechanism of LEACH-P can increase stability of network, we use LEACH-P Algorithm, LEACH Algorithm and LEACH-C Algorithm to check the survival time of the whole network in experiment whose simulation result is shown in Figure 2. Figure 2 is the average results in which 50 sensor nodes separately perform 3 protocols 30 times. Among this, y axle is the whole number of survival node; x axle is unit time and each unit time is 10 seconds. It is known from Figure 2 that network survival time of LEACH-P Protocol is greatly longer than that of LEACH and LEACH-C Protocol.

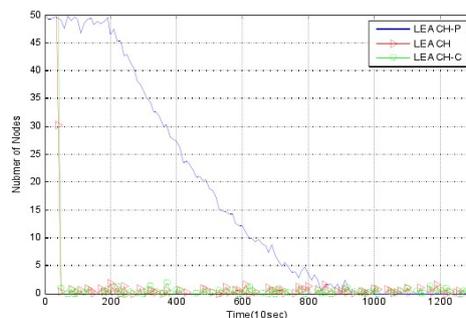


Figure 2. Number of Residual Survival Node in Each Unit Time under 50 Nodes Environment

5. Conclusion

It is seen from simulation result that in terms of LEACH-P, "center of gravity" leads cluster head location to be more reasonable. Also the collocation of PCH Mechanism and Load Monitor Mechanism makes energy consumption of CH not rapidly worsen because of lots of events. As PCH Mechanism of LEACH-P works, cluster head load condition of network still becomes fine. LEACH-P shows its excellent performance under the condition of large number of events and sensor nodes because when load capacity of CH is low, LEACH-P Protocol will start Load Relief Mechanism to balance load. Therefore LEACH-P Protocol can enhance efficiency of energy utilization, increase balance of energy consumption, keep stability of network topology and lengthen network cycling lifetime.

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