An Improved Cluster Head Selection Approach for Energy Efficiency in Wireless Sensor Networks: A Review

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***ABSTRACT*—In this paper, we analyze various energy efficient routing protocols to improve the lifetime of wireless sensor networks. WSNs are composed of a large number of sensor nodes which have limited energy. Energy conservation is a very critical issue to design energy efficient routing techniques in wireless sensor networks. The paper reviews the traditional energy efficient protocols to improve cluster head selection approach. The proposed algorithm considers the sensor nodes residual energy to select optimal cluster head for next round of cluster head selection algorithm. The algorithm guarantees the entire network stays alive for longer time than the other existing energy efficient techniques. The proposed technique thus improves the overall performance of wireless sensor networks in terms of increasing the lifetime of sensor nodes, reducing the bandwidth consumption and latency of WSNs. Also balancing energy distribution among all nodes of the network increases the round number at which the first node dies which reduces the energy holes in WSNs.**

Keywords—Cluster Head Selection, Energy Efficiency, LEACH, Network Lifetime, Wireless Sensor Networks

I.INTRODUCTION

Wireless Sensor Network (WSN), a distributed system consisting of a Base Station and large number of Sensor Nodes (SN) that integrate micro sensing, computing and wireless communication capabilities, which are capable of detecting various events related to its surrounding environment such as speed, temperature, pressure, difference in displacement, light, etc. [1] . These nodes operate in ad-hoc manner and have limited hardware and energy recourses due to its small size. The data sensed by the sensor node in the network gather data in form of electrical signals that are further converted to digital form and wirelessly transmitted to BS where the information can be accessed. As a new technology for information collecting and processing, there are wide range of applications of WSNs in military, health, commercial applications and so on.

The energy source of sensor nodes in WSNs is usually powered by battery, which is undesirable, even impossible to be recharged or replaced. Therefore, improving the energy efficiency and maximizing the lifetime of network are the major challenges in sensor networks [2].

A WSN can be reactive or proactive. In proactive case, nodes send their data to the Base Station (BS) or Cluster Head (CH) only when they detect an event and keep transmitter off when they do not detect any change in the environment. While in reactive protocol, nodes keep sending the data to the BS all the time. So they quickly consume their energy as compared to the proactive protocols.

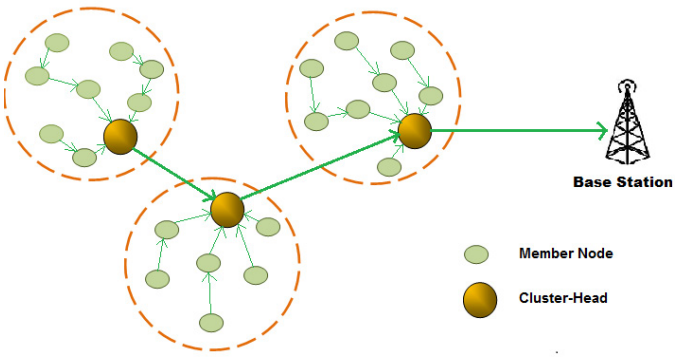

Fig. 1: Clustering Scenario in Wireless Sensor Networks

LEACH (Low Energy Adaptive Clustering Hierarchy) is a clustering algorithm which allows dynamic selection of cluster heads for energy utilization among all of the sensor nodes in WSNs. LEACH is divided into number of rounds for selecting cluster heads. LEACH uses one hop inter-clustering to reach the faraway BS which misses the cooperation among cluster heads which is a major drawback of LEACH as more energy is consumed by the sensor nodes that are far away from the BS. Multi-hop inter-clustering algorithm leads to better performance in terms of energy conservation that leads to increase in lifetime of WSNs.

Dynamic CHs selection routing protocols are the most suitable way to overcome conventional protocols

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deficiencies which achieve well-organized topology and simple data fusion with lower overhead traffic, less energy consumption, and as a result , longer network lifetime.

At the beginning of each round of CH selection normal node chooses a random number x between 0 to 1 and checks if it is less than a certain threshold value T (n)[20],then it is converted from normal node to CH node, where the threshold function is defined as follows:

$$T(n) = \begin{cases} \dfrac{P}{1 - P * \left(r \bmod \left(\frac{1}{p}\right)\right)}, & n \epsilon G \\ 0, & otherwise \end{cases} \quad (1)$$

where P is the desired percentage of CH which is a predefined value (e.g. P=0.01), r is the current round number, and G is the set of nodes that have not been selected as CHs in the last 1/p rounds.

The main purpose to design and develop an energy efficient technique for WSNs is to improve the network lifetime and to increase the overall performance of network. In order to achieve this goal, there are number of energy efficient techniques available based on different parameters like, to improve CH selection approach, to reduce energy consumption of individual nodes, on improving inter cluster communication mechanism along with an optimal technique of cluster formation, residual energy based approach ,on calculating threshold value to select optimal set of CHs on considering various network topological parameters like average distance between sensor nodes and BS, area of the field and number of sensor nodes deployed over field.

LEACH is better than conventional routing protocols as the responsibility of CH is distributed around all the sensor nodes, and also data aggregation by CH from member nodes reduces energy dissipation of the network. But LEACH still ignores the residual energy at each node during the CH selection stage. In the next section, various ideas have been proposed to overcome the deficiencies of LEACH discussed in the earlier section.

II. LITERATURE REVIEW

Van-Trinh Hoang, Nathalie Julien, Pascal Berruet, in their work presents a novel CH selection approach to extend network lifetime and reliability in WSNs by taking obstacle aware criteria into consideration [2]. The approach allows selecting the most appropriate sensor nodes to become CH, reducing 93% the number of lost packets in the network, hence improving the network throughput up to 53% which extends the network lifetime up to 11%.

Osama Moh'd Alia, Zyad Shaaban, Ahmad Basheer, Alaa Al-Ajouri, and Ahmed Alsswey, proposed an energy efficient dynamic clustering algorithm for WSNs that automatically organizes the sensors into appropriate number of clusters in network to select best set of CHs [3]

Itika Gupta, A. K. Daniel, in their paper proposed an efficient clustering algorithm [4] with position based multi-hop approach to partition the network region into levels with increasing number of CHs at each level on considering the fact that, the CH which is closer to BS always have smaller in size because it forwards the data to BS using round robin technique to make the network more energy efficient to select the CH with minimum energy. The proposed protocol improves the performance in delay and energy consumption due to multi-hop utilization of network.

A.Haider, N. javaid, N. Amjad, A. A. Awan, A. Khan, N. Khan, proposed a protocol REECH-ME to improve WSNs lifetime and the stability period of the network [5]. In this protocol the node with the maximum energy in clusters becomes CH of that cluster for that particular round and the number of CHs in each round remains the same. REECH-ME uses the energy of all nodes is very efficiently utilized. Ideally, whenever the data is sent to the sink it reaches without any packet loss. But in real situation this ideal condition does not exist.

Sushant Miglani, Rajoo Pandey, proposed optimization of clustering probability of LEACH protocol for lifetime maximization of WSNs [6].In the proposed scheme, the optimum number of CHs is determined first by proposed formula for optimum clustering probability. This optimal clustering probability actually depends upon various network topological parameters like average distance between sensor nodes, and BS, area of the field and number of sensor nodes deployed over field.

M. Natranjan, R. Arthi, K. Murugan, in their work proposed energy aware algorithm to extend the lifetime of WSNs [7]. They provide a technique for the proper organization of nodes to expand the lifetime of the whole network through aggregating data at the CH. Cluster formation and CH selection technique are employed to achieve better operation and prolong the network lifetime by minimizing energy consumption. In their work, they applied LEACH and PSO (Particle Swarm Optimization), for producing energy aware clusters with optimal selection of CH.

Yiping Yang, Chuan Lai, Lin Wang, Lin Wang, presented in their work an Energy EfficientClustering Algorithm (EECA) adapted two steps CH selection mechanism for WSNs, where in first step the node with the highest residual energy is selected as anchor CH, and the candidate CHs are determined according to their residual energy as well as the distance from the anchor CH. In second, the candidate CHs compete to be the CHs via a delayed broadcast mechanism.

Qingwei Liu, Jin Li and Mandan Liu, in their paper introduce a clustering algorithm based on Local Competition and Double Weigh Communication Energy Consumption (LCDWCEC) for WSNs [9]. In the CH selection phase of the proposed work, uses a strategy based on energy and ID which is called local competitive, then in the cluster formation phase, uses a strategy based on taking into account of plain nodes and CH node communication consumption.

Lu Gao, Zhongmin Li, in their proposed a LEACH-based protocol, Dynamic Cluster LEACH (DCL) in which all the nodes are grouped based on location and a CH is elected in every group, which ensures CHs even distribution in the network area which leads to increase the energy efficiency and prolong the network lifetime.DCL takes into account node energy and CH distribution. [10].

Ashfaq Ahmad, Nadeem Javaid, Zahoor Ali Khan, Umar Qasim, Turki Ali Alghamdi , presents Adaptive Clustering Habit (ACH) routing scheme to maximize lifetime and throughput of WSNs [11]. The technique proposed here, increases the stability period, Network lifetime and throughput of WSN. It controls CHs selection to ensure uniform load distribution on CHs.

Jin Wang, Zhongqi Zhang, Jian Shen, proposed in their paper a SEP based MSE algorithm for energy efficient routing protocol for WSNs, which divide the network into clusters and selecting CH based on fraction of nodes with additional energy and ratio between residual energy and initial energy. MSE algorithm improves the performance in WSNs in energy balancing and prolongs the network lifetime.

M. S. Fareed, N. Javaid, M. Akbar, S. Rehman, U. Qasim, Z. A. Khan , in their work compare problems of cluster formation and CH selection between different protocols for data aggregation and transmission [13].

F. Saleem, Y. Moeen, M. Behzad, M. A. Hasnat, Z. A. Khan, proposed in their paper the Improved Density Controlled Divide and Rule Scheme (IDDR) [13] for Energy efficient routing in WSNs. IDDR is proposed to avoid the energy hole creation through uniform energy consumption. Reduces coverage and energy hole by dividing network into small segments with static number of CH in each round. The work focuses on minimization of energy hole by using dynamic clustering technique.

Mahmoud M Salim, Hussein A. Elsayed, Salwa H. El Ramly, provided improved technique PR-LEACH approach for balancing energy dissipation of LEACH protocol for WSNs [1]. The work is implemented multi-hop inter clustering algorithm that leads to better performance than LEACH. PR-LEACH organizes CHs selection based on relationship between its residual energy and a certain threshold. The overall responsibility of selecting CH is handled by the BS which computes the threshold value at BS itself and distributing that values to respective CHs and then to cluster members. It increases overhead on BS. The proposed protocol improves the CH selection criteria to increase the lifetime of sensor nodes in the network but require more energy to transmit the sensed information from respective CH to the BS at each round of CH selection mechanism. This also increases the probability of energy holes creation in WSNs.

III. PROPOSED METHODOLOGY

The improved energy efficient clustering protocol is proposed to overcome the limitations of existing traditional cluster based routing protocol and its latest enhancements. The basic idea is to uniformly distribute the energy load among all sensor nodes by significantly improving the cluster head selection approach.

Most of the schemes of energy efficient clustering protocol are focused on extending the overall network lifetime without minimizing the variations between energy of sensor nodes which leads to dead-spot occurrence.

Several clustering algorithms proposed for energy efficient technique for WSNs consisting of fixed sensor nodes improve the CH selection approach to extend the lifetime of networks. In WSNs, there are some applications, where some sensor nodes may require moving and changing their location. In the traditional clustering algorithms for CH selection in WSNs is based on the decision taken from the residual energy and certain threshold value of the respective nodes. The threshold is set as –

$$T(n) = \begin{cases} \left(\left(\frac{P}{1-P*(r \bmod (\frac{1}{P}))}\right)\frac{E_{residual}}{E_{initial}}\right) * K_{optimal}, & n \epsilon G \\ 0, & otherwise \end{cases} \quad (2)$$

Using this threshold, each node will be fairly selected as CH at some point within 1/P rounds of the CH selection mechanism.

Where $K_{optimal}$ is the optimal number of CH during the state of cluster formation and is defined as follows:

$$K_{optimal} = \sqrt{\frac{N}{2\pi}} * \sqrt{\frac{E_{fs}}{E_{AMP}}} * \sqrt{\frac{M}{d^2_{toBS}}} \quad (3)$$

Where, N is the number of nodes, M is the network area, and E_{fs} and A_{mp} are the amplification power losses and d is the distance between the selected CH and BS.

The desired percentage of CHs depends upon various network topological parameters like average distance between sensor nodes and BS, area of the field and number of sensor nodes deployed over the field. Since this percentage varies at each round of CH selection, it affects the clustering algorithm

seriously. As the infrastructure of network changes dynamically, this threshold calculation at each round increase the overhead in the network. These two complex formulas are required to calculate at each round of CH selection which consumes huge amount of energy during the calculations that leads to energy minimization in WSNs.

Most of the schemes of energy efficient clustering protocol are focused on extending the overall network lifetime without minimizing the variations between energy of sensor nodes which leads to dead-spot occurrence.

Major areas to be considered to further improve the overall performance of WSNs over the traditional LEACH protocol are as follows:

1. Reduce energy consumption

In number of clustering algorithms used to improve lifetime of WSNs, the decision to select the CH is based on residual energy and certain threshold value which can be formulated using fitness function that depends on various topological parameters, like average distance between sensor nodes and BS, area of the field and number of sensor nodes deployed over field.

The sensor nodes belongs to a particular clusters in the WSNs, transmits the sensed data along with their residual energy to the CH of that cluster, the CH aggregate the data from the cluster members and forward that data along with its own residual energy to the faraway BS that require more energy to transmit these information to the BS. Base station, on receiving the information from CHs, calculate the Energy Level value (ELV) for cluster members and CH and transmit to the respective CHs, which consume more energy in transferring the ELV to the CH, in order to select optimal CH.

The energy dissipation models for the transmitter and the receiver along d distance are respectively given by:

$$E_{TX}(l.d) = \begin{cases} lE_{elec} + lE_{fs}d^2, & if\ d \le d_0 \\ lE_{elec} + lE_{mp}d^4, & if\ d > d_0 \end{cases} \quad (4)$$

$$E_{RX}(l) = lE_{elec} \quad (5)$$

where E_{elec} is the energy required to transmit or receive one bit and 1 is the length of the message. The cost of data aggregation is modeled by $T_{DA,}$ E_{fs} is the free space model power loss, while E_{mp} is the power loss of the multi path model. The used model depends on the acceptable bit-error rate chosen and the distance to the receiver. The threshold distance d_0 which determines that which model to use is provided in [8] and is given by:

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \quad (6)$$

The calculation of threshold value at BS which is required to select the optimal CH in the clustering algorithm and transmitting the calculated ELV from BS to CHs, consume much time as well. At the BS, there is considerable consumption of energy in calculating the ELV and transmitting this, increase overhead on BS unnecessarily information to the CHs. This energy and time consumption at BS can be reduced if the entire threshold is calculated at CHs itself.

2. Improve lifetime of nodes

The optimal CH selection clustering protocol for WSNs, which is based on the residual energy and threshold value in order to determine the energy efficient CH. The node having higher threshold value than its residual energy is being selected as CH which increases the lifetime of individual cluster members reducing the probability of energy holes in the network.

The energy efficient clustering algorithm allows fair distribution of CH selection, maximum possible distance minimization among nodes and CHs to utilize less energy, as the considerable amount of energy can be saved by imposing the decision of next CH selection on CHs and not on the BS. This helps to increase the lifespan of member nodes significantly and hence of the WSNs as whole.

3. Reduce bandwidth consumption

At each round of cluster head selection of clustering protocol for WSNs, on imposing the CH selection decision on CH prevents transmitting the information of residual energies from CHs to the BS and forwarding the calculated ELV information from BS to CH, which may seriously affect the bandwidth on network. This leads to prevents from filling the data packets in the network which decreases the bandwidth of the network, effectively.

4. Increase overall performance of a network

The proposed energy efficient decentralized cluster based protocol where the selection process of CHs in each simulation round is conducted in each cluster instead of the BS, improves CH selection approach. This leads to significant increase in energy consumption preventing data transmission with BS require for CH selection decision. The optimal selection of CH by CHs itself using multi-hop inter-clustering approach , based on residual energy and threshold value at each node, that preserve the energy consumption of nodes , thus increasing the lifespan of sensor nodes in the WSNs and hence of the whole network.

By extending the lifespan of each individual node, the percentage of occurrence of dead spots in the network decreases to certain extent. This increase the number of packets transmitting from selected cluster to reach to the BS in

each rounds of CH selection mechanism, which ultimately increases the throughput of the network and also reducing overall latency of Network.

The proposed algorithm takes into account following assumptions:

1. Base station is far away from the nodes.
2. Member nodes transmit to their cluster head in one-hop transmission and cluster head to base station via multi-hop transmission.
3. The responsibility of CH selection in the current round is handled by the CH of the previous round by inter-clustering mechanism to conserve energy instead of handling it by BS.
4. Selection of CH depends on residual energy and certain Threshold, calculated by CH instead of calculating it by BS to reduce overhead and energy consumption at BS.
5. The mobile sensor nodes in the network infrastructure are excluded from being involved in the CH selection mechanism to increase the stability in the network.

The main steps of the proposed protocol are as follows.

1. Basically the algorithm is divided into the number of rounds.
2. For the first round the nodes with highest energy for that particular cluster, are selected as CHs, randomly and data transmission is performed.
3. At the start of second round, the CH aggregates the residual energy of the respective members and calculates the threshold at that CH.
4. All the CHs do the same with their members and effective inter-clustering is performed to reach the BS by selecting optimal CH.
5. The appropriate CH calculates the Network Energy Range (NER) from the minimum and maximum energies and transmits it back to the nearby CH, and consequently the CHs transmit to their member nodes.
6. Every node now has the NER value and can calculate the threshold value (ThreVal).
7. If the threshold value of a node >= ThreVal, the node will be candidate for the CH of that cluster for the next round.
8. Data transmission is performed using intra and inter-clustering with the new formation of CHs and their members.
9. The mobile sensor nodes can be a part of network infrastructure at any round of CH selection, but preventing them from being selected as CHs to reduce the dead spot occurrence.
10. The optimal CH at each round will transmit the information to the BS and do not involve BS to select CH at each round, to reduce energy consumption at each round.

The proposed algorithm is based on LEACH protocol which achieves significant performance improvement goal of WSNs. By considering the residual energy and threshold value, the algorithm guarantees sustained lifetime across the entire network.

IV.CONCLUSION

From the existing research work, it has been concluded that there are various energy efficient techniques for WSNs which consists of fixed and mobile sensor nodes that improve the cluster head selection approach to extend the lifetime of WSNs.

Hence, the issue of energy consumption will be addressed and investigated further by using the proposed methodology, to increase the performance of the WSNs in terms of reducing energy consumption and also average latency, by improving lifetime of sensor nodes, and by reducing bandwidth consumption. Similarly based on this formulation, the optimum clustering technique can further be developed to extend the lifetime of WSNs that significantly reduce the number of rounds for selecting optimal CH.

The protocol considerably increases the lifetime of the whole network than the original LEACH and PR-LEACH protocol. Also the balancing energy distribution among all nodes of the network increases the round number at which the first node dies which minimizes the dead-spot occurrences.

REFERENCES

[1] Mahmoud M. Salim, Hussein A. Elsayed, Salwa H.El Ramly,"PR-LEACH: Approach for Balancing Energy Dissipation of LEACH Protocol for WSNs"in 31st National Radio Science Conference (NRSC2014), April 28-30, 2014 Ain Shams University, Egypt.

[2] Van-Trinh HOANG, Nathalie JULIEN, Pascal BERRUET "Cluster Head Selection Algorithm to Enhance the Energy Efficiency and Reliability of the WSNs "2nd International Conference on WSNs and Research Areas, VDE VERLAG GMBH, Berlin, Offenbach, Germany. ISBN978-3-8007-3621-8, European Wireless 2014

[3] Osama Moh'd Alia, Zyad Shaaban, Ahmad Basheer, Alaa Al-Ajouri, Ahmed Alsswey, "Musician - Inspired Clustering

Protocol for Efficient Energy in WSNs", Sensor Networks and Cellular Systems (SNCS) Research center, Saudi Arabia, 2014 IEEE

[4] Itika Gupta, A. K. Daniel, "An Energy Efficient Position Based Clustering Protocol for WSNs using Round Robin Scheduling Technique", 3rd International Conference on Advanced Computing and Communication Technologies, 10.1109/ACCT. 2013.59

[5] A. Haider, N. javaid, N. Amjad, A. A. Awan, A. Khan, N. Khan," REECH - ME: Regional Energy Efficient Cluster Heads Based on Maximum Energy Routing Protocol for WSNs " 8th International Conference on Broadband, Wireless Computing, Communication and Applications, 2013 IEEE

[6] Sushant Miglani, Rajoo Pandey, "Optimization of Clustering Probability of LEACH Protocol for Lifetime Maximization of Wireless Sensor Networks" 2nd International Conference On Parallel, Distributed and Grid Computing 2012 IEEE

[7] M.Natranjan, R.Arthi, K.Murugan,"Energy Aware Optimal CH Selection in WSNs " in IEEE 4th ICCCNT, Tiruchengode, India. July 4-6, ICCCNT 2013.

[8] Yiping Yang , Chuan Lai, Lin Wang, Energy Efficient Clustering Algorithm for WSNs "10th IEEE International Conference on Control and Automation (ICCA) Hangzhou, China, June 12-14, 2013

[9] Qingwei Liu, Jin Li and Mandan Liu, "A Clustering algorithm Based on Local Competition and Double Weigh Communication-Energy-Consumption for WSNs", 10th IEEE International Conference on Control and Automation (ICCA) Hangzhou, China, June 12-14, 2013

[10] Lu Gao and Zhongmin Li, "Energy Consumption Balanced Cluster Head Selection Algorithm for Wireless Sensor Networks " International Conference on Computer Sciences and Applications (CSA). IEEE 2013

[11] Ashfaq Ahmad, Nadeem Javaid, Zahoor Ali Khan, Umar Qasim, Turki Ali Alghamdi "(ACH) 2 : Routing Scheme To Maximize Lifetime and Throughput of WSNs" IEEE Sensor Journal. VOL.14 NO10 October, 2014

[12] Jin Wang, Zhongqi Zhang, Jian Shen, "An Improved Stable Election Based Routing Protocol with Mobile Sink for WSNs "2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things And IEEE Cyber , Physical and Social Computing, CPSCom.2013.163

[13] F. Saleem, Y. Moeen, M. Behzad, M. A. Hasnat, Z. A. Khan, U. Qasim, N.Javaid,"IDDR: Improved Density Controlled Divide and Rule Scheme for Energy Efficient Routing in WSNs" in 9th International Conference on Future Networks and Communications (FNC-2014) 1877-0509, 2014

[14] M. S. Fareed , N. Javaid, M Akbar, S. Rehman, U. Qasim, Z. A. Khan, " Optimal Number Of Cluster Head Selection for Efficient Distribution of Sources in WSNs" 7th International Conference on Broadband, Wireless Computing, Communication and Application, 2012

[15] Shalli Rani, Jyotish malhotra, Rajneesh Talwar, "Energy Efficient Protocol for Densely Deployed Homogeneous Network" in International Conference on Issues and Challenges in Intelligent Computing Techniques (ICICT)-2014

[16] Noor Zaman, Tung Jang Low, Turki Alghamdi," Energy Efficient Routing Protocol for WSNs " 3rd International Conference on Advances in Computing Technologies, ISBN 978 - 89968650 - 3 - 2, February16-19, ICACT, 2014.

[17] Abdullah Erdal TUMER, Mesut Gunduz,"An Improved LEACH Protocol for Indoor SN" in International Conference On Signal Processing and Integrated Networks (SPIN) IEEE 2014 Konya, Turkey

[18] Raju Datta, Debraj Paul, Shishir Gupta, Mukul Kumar Das,"The Simulation and Analysis of Modified LEACH Protocol for WSN Using TOSSIM "2013 International Conference of Green Computing, Communication and Conservation of Energy (ICGCE) IEEE Kolkata, West Bengal, India

[19] Munjal R and Malik B. "Approach for Improvement in LEACH Protocol for WSN" in Proc of the 2012 2nd International Conference on Advance computing and Communication Technologies, Rohtak, Haryana India 7-8 Jan 2012 -517-521

[20] Wendi B. Heinzelman and Chandrakasan A. Balakrishnan " Energy Efficient Communication Protocol for Wireless Micro sensor Networks " in 33rd Annual Hawaii International Conference System Sciences ,IEEE 2014

[21] Li Hui, Jiang Hongtao, Li Hua"The improvement algorithm of Cluster Head Election based on LEACH" 6th International Conference on Intelligent Networks and Intelligent Systems, 978 - 1 - 4799 - 2809 - 2013 IEEE