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Master's Degree Thesis

Clustering with Intermittent Setup for Balancing Node Lifetime in Wireless Sensor Networks

Graduate School of Chosun University

Department of Computer Engineering

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무선 센서 네트워크에서의 노드 수명 균형을 위한 간헐적 설정 기반 클러스터링

August 25，2014

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Clustering with Intermittent Setup for Balancing Node Lifetime in Wireless Sensor Networks

Advisor: Prof. Sangman Moh, Ph.D.

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이향의 석사학위논문을 인준함

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ABSTRACT

Clustering with Intermittent Setup for Balancing Node Lifetime in Wireless Sensor Networks

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In wireless sensor networks with inexpensive battery-operated sensors, clustering saves energy efficiently and is effectively used for many applications including environment monitoring. The most famous clustering protocol, LEACH (Low Energy Adaptive Clustering Hierarchy), consumes extra energy and time to reform clusters at the setup phase of every round. In the recently developed COTS (Clustering with One-Time Setup), the cluster-reforming process is removed by allowing that the role of cluster head is rotated among members in a cluster, resulting in reduced energy consumption. In COTS, however, members in some clusters consume more energy and have shorter lifetime because clusters are never reformed but fixed up after the first round. This thesis presents a new clustering scheme called CIS (Clustering with Intermittent Setup) which reforms clusters intermittently to enable the balanced lifetime of nodes. In CIS, the role of cluster head is swapped among members in a cluster between two successive setups. By

reforming clusters intermittently, clusters are not fixed up and energy consumption and lifetime are balanced among nodes. The period of intermittent setup is $1/p$ that is the average number of nodes per cluster, where p is the desired percentage of cluster heads over the total number of nodes, but it can be adjusted to adapt to the operational environment. According to the performance study, as the number of clusters increase, the node lifetime is more balanced.

한글요약

무선 센서 네트워크에서의 노드 수명 균형을 위한 간헐적 설정 기반 클러스터링

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건전지로 동작하는 저렴한 센서로 구성된 무선 센서 네트워크에서 클러스터링은 효율적으로 에너지를 절약하며 환경 감시를 포함한 많은 응용 분야에 효과적으로 사용되고 있다. 가장 유명한 클러스터링 프로토콜인 LEACH (Low Energy Adaptive Clustering Hierarchy)는 모든 라운드의 설정 단계에서 클러스터를 재형성하기 위하여 추가적인 에너지와 시간을 소비한다. 최근에 개발된 COTS (Clustering with One-Time Setup)에서는 클러스터 헤드의 역할을 클러스터 내 멤버들 사이에서 교대로 맡게 함으로써 클러스터 재형성 과정이 제거되며, 결과적으로 에너지 소비가 줄어든다. 그러나 COTS 에서는 일부 클러스터의 멤버들이 더 많은 에너지를 소비하고 짧은 수명을 갖는데, 그 이유는 클러스터들이 첫 라운드 후에는 재형성되지 않고 고착되기 때문이다. 본 논문에서는 센서 노드 수명의 균형을 위하여 간헐적으로 클러스터를 재형성하는 CIS (Clustering with Intermittent Setup)라 불리는 새로운 클러스터링 기법이 제안된다. CIS 에서는 잇따르는 두 설정 사이에서 클러스터 헤드의 역할을 클러스터 내 멤버들

사이에서 교대로 맡게 한다. 클러스터를 간헐적으로 재형성함으로써 클러스터들이 고착되지 않고 노드들 사이에서 에너지 소비와 수명이 균형을 이루게 된다. 간헐적 설정의 주기는 클러스터당 평균 노드 수인 1/p 이다. 여기서, p 는 총 노드 수에 대한 클러스터 헤드의 비율로서 운용 환경에 따라 조정될 수 있다. 성능 평가에 의하면, 클러스터 수가 증가함에 따라 노드 수명이 더욱 잘 균형을 이룬다.

I. INTRODUCTION

In wireless sensor networks(WSNs) with inexpensive battery-operated sensors, clustering algorithm saves energy efficiently and is effectively used for many applications including environment monitoring. WSNs, restricted by the energy consumption, forward the data packet from the source node through the network to the destination node to achieve energy consumption. It looks for optimal path between the source node and destination node, and forwards the data packet along the optimal path correctly [2].

Routing protocols usually have the following characteristics. Considering the node energy consumption as well as the equilibrium and practical problem of network energy, priority must be given to energy [5, 20]. In order to save energy, WSNs usually adopt multi-hop communication. However, the limited storage and computing resources of the node make it unable to store large amounts of routing information or do complex routing calculation. So when designing the new routing protocol, local topology information should be taken into account before implementing [9]. Since sensor network application environments differ in innumerable ways and data communication modes are quite different from each other, any single routing mechanism is not suitable for all applications. Therefore, designers need to satisfy the need for each specific application [10]. In addition, traditional routing protocols usually take addresses as the identification of nodes. But in WSNs, a large number of nodes are randomly deployed, the focus is on the detection and the perception of data. It tries to form an information-forwarding path with the data [12, 18].

This thesis presents a new clustering scheme called CIS (Clustering with

Intermittent Setup) which reforms clusters intermittently to enable the balanced lifetime of nodes. In CIS, the role of cluster head is swapped among members in a cluster between two successive setups. By reforming clusters intermittently, clusters are not fixed up and energy consumption and lifetime are balanced among nodes. The period of intermittent setup is $1/p$ that is the average number of nodes per cluster, where p is the desired percentage of cluster heads over the total number of nodes, but it can be adjusted for adapting operational environment. According to the performance study, as the number of clusters increases, the node lifetime is more balanced.

The rest of the thesis is organized as follows. Chapter II is related works. In chapter III, the CIS protocol is introduced. In chapter IV the author gives a performance evaluation and makes a discussion in chapter V.

II. RELATED WORKS

Routing protocols can be roughly divided into flat routing protocols, geographic routing protocols, and hierarchy routing protocols.

A. Flat Routing Protocols

1) Flooding

The algorithm of flooding and gossiping is also the most basic form in the traditional network routing. It is not necessary to know the network topology structure and the use of any routing algorithm. Each sensor node sends the packet that it receives to all its neighbor nodes. This process is repeated until the group reach the sink node or the group's life expires (TTL, in sensor networks is usually defined as a maximum hop number). Gossiping algorithm improved the flooding process. Each sensor node only sends the packet that it receives to one of its neighbor nodes randomly, other unchanged [7]. This way, though simple, is not practical to related applications, and it may easily lead to implosion and overlap. Figure 1 is the flooding routing.

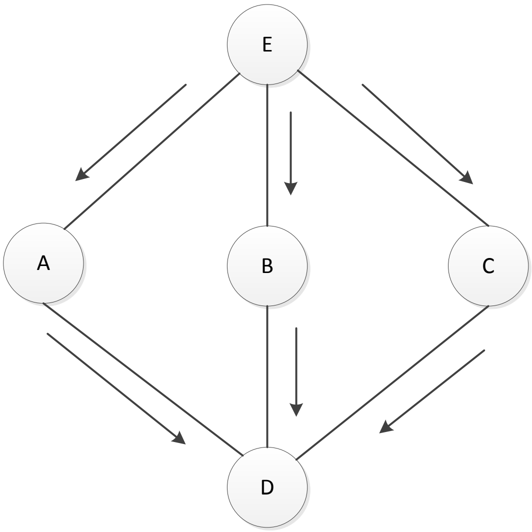


Figure 1. Flooding

2) SPIN

SPIN (Sensor separate Protocols for Information via Negotiation) is a set of information transmission protocols that is based on negotiations and has automatic energy adaptive function. It uses three types of information for communication, namely the ADV, the REQ and DATA Information. Before transmitting DATA Information, sensor node only broadcasts the ADV Information which includes DATA description mechanism. When it receives the corresponding REQ request information, it sends out DATA Information on purpose. Use of consultation mechanism based on DATA description and energy adaptive mechanism of SPIN protocol can effectively solve the problems of the information explosion, repetition and resource waste caused by traditional flooding gossiping protocol. Figure 2 is the SPIN routing protocol process.

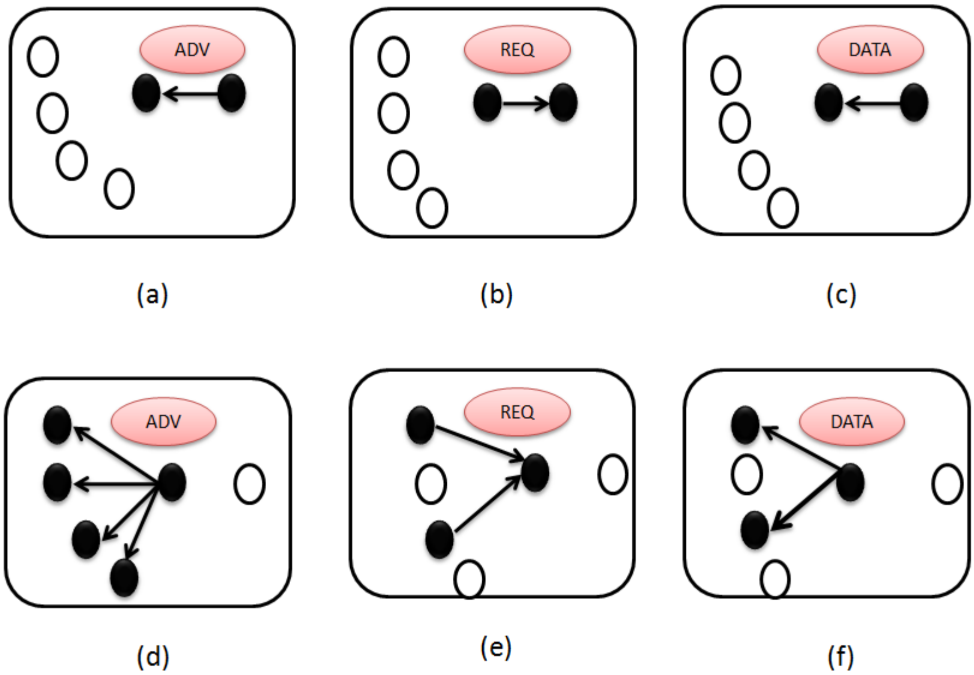
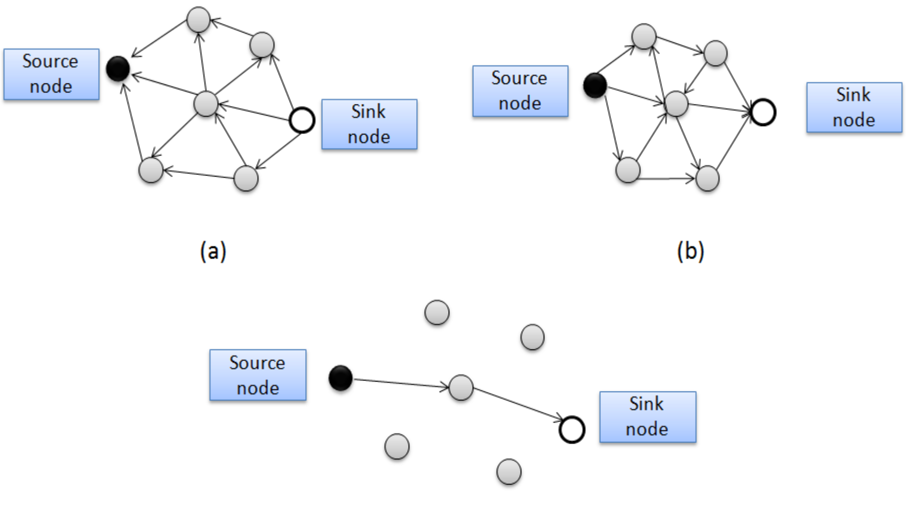


Figure 2. SPIN routing protocol

3) DD

DD (Directed Diffusion) is a kind of data-centered information transmission protocol. Its mechanism is utterly different from the existing routing algorithms. Running the DD sensor nodes use a naming mechanism based on attributes to describe data. It completes the data collection by sending the interest of some named data to all the nodes (task descriptors). In the process of dissemination of interest, the nodes within a specified range use caching mechanism dynamic maintenance to receive data attributes, other information pointing to the source of the information such as the gradient vector. Meanwhile, and it activates the sensor to pick up the information which matches the interest. After a simple pretreatment of the collected information, the node establishes a best path to reach the destination by using local rules and strengthening algorithm. Through the simulation analysis, it is found out that the algorithm has good energy saving and extensible features. Figure 3 is the Directed Diffusion routing protocol process.



(c)

Figure 3. Directed diffusion routing protocol

4) Rumor Routing

In the foresaid algorithm, each sensor node maintains a list of events, which contains a basic description of events, the source node broadcasting the event, the sensor node of last hop which passes the event firstly. In addition, a message which has a long life cycle. Agent, is introduced in to be used into the description information of the source node broadcast perception event and transmitted in the network. The algorithm is same as SPIN algorithm in essence, but the difference between the two is that by sensor nodes maintaining the list of events information, the algorithm is capable of maintaining a route between itself and the source node. Therefore, after the initialization of flooding, the corresponding routing information is established, in which way the massive flooding process of the agreement in SPIN protocol is avoided and the goal of saving energy significantly is achieved. The algorithm is mainly suitable for the application contexts that include a large number of queries and few events. If the network topology changes frequently, the performance of the algorithm drops dramatically. The algorithm also sees an improvement compared with the algorithm directed coursing, which will be introduced later.

5) HREEMR

The difference between HREEMR (Highly Resilient, Energy - Efficient Multipath Routing) and the former agreement is that HREEMR achieved the effective fault recovery, solved the problem of DD in an effort to improve the strength of agreement, and also solved the energy wasting problem caused by diffusing data in low rate cycle. It adopts the same localization algorithm as DD to establish the optimal paths p between source and sink. In order to ensure that the agreement works properly even when p is down, several other paths disjoint with p are built, so that in the event of p failure, the redundant paths can be used for communication.

6) SMECN

SMECN (Small Minimum Energy Communication Network) protocol is a routing protocol based on the node location. It has been improved on the basis of MECN protocol which was designed for ad hoc network. This agreement, by building a sub graph with ME (Minimum Energy), reduces the energy consumed by a data transmission, so that the WSN demand for saving energy is better satisfied. Simulation results show that, when the broadcasting range can include all the nodes around the area of the broadcast machine, the sub graph built by SMECN is smaller than the one built by MECN, and it can be well applied into those sensor networks where topology changes less frequently.

7) SAR

SAR (Sequential the Assignment Routing) protocol is the first protocol with a sense of QoS routing. The protocol, by taking sink one hop neighbor node as the root node of the multicast tree, builds a multi-hop path between the sensor nodes to the sink. It has a feature that routing decisions not only consider each path of energy, but also involves the end-to-end delay requirements and momentum to send packets priority. Simulation results show that, compared with the minimum energy measurement protocol that only considers path energy consumption, SAR consumes less energy. The disadvantage of the algorithm is that it is not applicable to large and network topology that changes frequently.

B. **Geographic Routing Protocols**

1) GEAR (Geographic and Energy Aware Routing)

This algorithm sees a set of improvements on the basis of the algorithm of directed diffusion. Considering the location information of sensor node, it adds interest packet into address information field, and accordingly sends interest to a specific direction to replace the original way of flooding, which saves energy consumption significantly. The algorithm introduces in the estimated cost and learning cost. By calculating the difference value, it picks the senor nodes closer to the sink node as the next hop. Figure 4 is the GEAR routing protocol process.

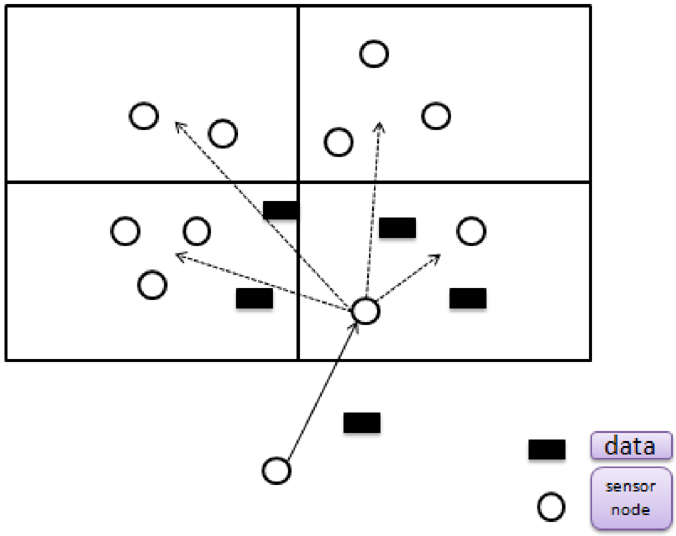


Figure 4. GEAR routing protocol

2) MECN (Minimum Energy Communication Network)

The protocol is designed for wireless network in essence, but it can also be used in wireless sensor network. It noticed that in some situations, the direct communication cost between two nodes is higher than that of several relay nodes forwarding. So the concept of "relay region" is introduced. Including all relay nodes that conform to the standards as its components. When two nodes need to exchange data, the agreement will select a transmitting path consuming least energy according to Bellmann - Ford, the shortest path selection method. It is clear that the algorithm can realize self-configuration, well solve the problem of node failure, but for node movement situation, the algorithm of calculating relay area price rises sharply.

3) GEDIR (Geographic Distance Routing)

The algorithm is a greedy algorithm in essence. When sensor nodes forward groups, they select neighbor nodes closest to the sink node according to geographic information. The algorithms are also quite close to MFR (Forward within the Radius) algorithm. Similarly, GOAFR and SPAN algorithms can be directly applied to the sensor network.

C. **Hierarchy Routing Protocols**

1) **LEACH**

LEACH (Low Energy Adaptive Clustering Hierarchy) is a kind of routing protocol based on cluster structure. Its basic idea is that by selecting cluster head nodes randomly and recurrently, the total energy of the network is allocated to each sensor node averagely, so as to reduce the network energy consumption and improve the overall survival time in the network. In the process of running cycle, LEACH constantly repeats cluster refactoring process. Each reconstruction process can be divided into two phases, the establishment of the cluster (setup phase) and the steady-state of the data transmission phase. In order to save resources cost, the steady-state phase lasts longer than the establishing phase. Compared with general routing protocol based on planar structure and static routing protocol based on cluster structure, LEACH can extend network overall survival time by 15% [3, 4].

In its running process, LEACH continuously implements the reconstruction process of the clusters recurrently [6]. The setup phase can be divided into four phases. The selection of cluster head nodes, the cluster head nodes broadcast, the establishment of the cluster head nodes and the generation of scheduling mechanism [8].

The choice of cluster head nodes depends on the total number of cluster nodes in need by the network and the times of each node becoming cluster head nodes so far.

In setup phase, sensor nodes randomly generates a number between 0, 1, and compares it with threshold T (n). If it is less than the threshold, the node will be elected to the cluster head right away. T (n) is calculated according to the following formula:

$$T(n)=\begin{cases}\dfrac{P}{1-P(r \bmod \frac{1}{P})} & if \quad n \in G \\ 0 & otherwise\end{cases} \tag{1}$$

P is the percentage of cluster head nodes, r is the current round number, G is the collection of nodes which are not elected as cluster head nodes in the recent round of 1/*P*. After the cluster head node is decided, it broadcasts the news itself, and according to the strength of the received message, nodes make decisions about which cluster it is to join, informs the corresponding cluster head, completing the process of the establishment of the cluster. After that, cluster nodes adopt the method of TDMA to allocate time slots of sending data within the cluster members. Figure 5 is the rounds of the leach protocol. Black squares indicate the setup phase, squares with diagonal lines are multiple TDMA time slots for sensors.

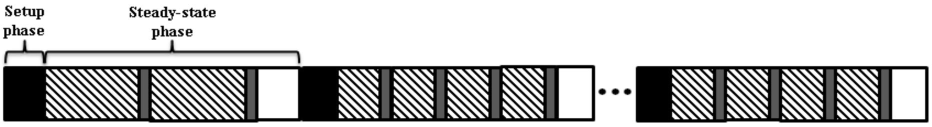


Figure 5. Rounds of the LEACH protocol

After the cluster head node is selected out, the message spreads to the entire network. Other nodes in the network decides subordinate cluster according to the signal strength of received information, and inform the corresponding cluster head nodes to finish the establishment of a complete variety [11, 13]. Finally, the cluster head nodes allocate points in time for each node in cluster to transfer data to it by using

TDMA mode.

In the steady-state phase, the sensor nodes send the collected data to the cluster head nodes. The cluster head nodes blend all the data collected by each node within the cluster and then transmits it to the gathering node, which is a reasonable working model for little communication amount. After the steady-state phase lasts for some time, the network moves back into the stage of establishing a cluster and implements the next round of cluster refactoring, and repeats it recurrently [15, 19]. Each cluster adopts different code CDMA communication to reduce the interference of other nodes within the cluster.

2) TEEN

TEEN (Threshold sensitive Energy Efficient sensor Network protocol) is a real-time routing protocol. It uses the same cluster structure and operation mode as the LEACH. The difference is, in the process of the establishment of the clusters, as the cluster head nodes are decided, cluster heads not only schedule data through TDMA method but also broadcasts the two parameters of hard threshold and soft threshold within the cluster members [14]. By setting the two parameters of hard threshold and soft threshold, TEEN can greatly reduce the times of data transmission, so as to achieve the purpose of saving more energy than LEACH algorithm. The advantage of TEEN agreement is that it is more suitable for real-time application system and can make quick response to emergencies. Its disadvantage is that it is not applicable to application environments where data needs to be collected continuously.

3) APTEEN

APTEEN (Adaptive Periodic Thresh old - sensitive Energy Efficient sensor Network protocol) sees an improvement on TEEN's shortcomings. It is a hybrid network routing protocol that combines response and active sensor network strategies.

APTEEN defines a counting time on the basis of TEEN. When the node does not send data after this counting time after last time sending, the data will be sent out whether the current data meets the requirements of soft and hard threshold or not. APTEEN can control energy consumption by changing the counting time [14].

4) COTS

COTS (Clustering with One-Time Setup) is based on LEACH protocol. In the setup phase the cluster-reforming process is removed by allowing that the role of cluster head is rotated among members in a cluster, resulting in reduced energy consumption. In COTS, however, members in some clusters consume more energy and have shorter lifetime because clusters are never reformed but fixed up after the first round. Figure 6 is the rounds of the COTS protocol.

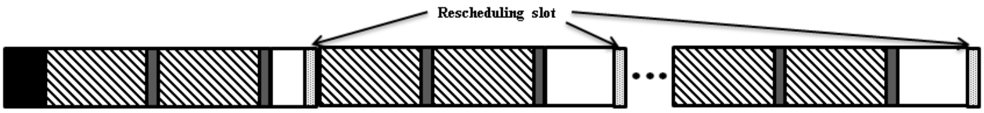


Figure 6. Rounds of the COTS protocol

III. CLUSTERING WITH INTERMITTENT SETUP FOR BALANCING NODE LIFETIME IN WIRELESS SENSOR NETWORKS

In its running process, CIS continuously implements the cluster-reconstruction process every 1/*p* round. Each round can be divided into two phases, setup phase and steady-state phase. The process of setting up a cluster can be divided into five phases. Choosing the cluster head node, broadcasting the cluster head node, building the cluster head node, generating the scheduling mechanism and each 1/*p* round of reconstruction.

The choice of cluster head nodes depend on the total number of cluster nodes in need by the network and the times of each node becoming cluster head nodes so far. The specific choosing method is that each sensor node randomly chooses a value between 0 and 1. If the selected value is less than a certain threshold, then the node will become cluster head nodes.

After the cluster head node is selected out, the message spreads to the entire network. Other nodes in the network decides subordinate cluster according to the signal strength of received information, and inform the corresponding cluster head nodes to finish the establishment of a complete variety. Finally, the cluster head nodes allocate points in time for each node in cluster to transfer data to it by using TDMA mode. Figure 7 is the rounds of the CIS protocol.

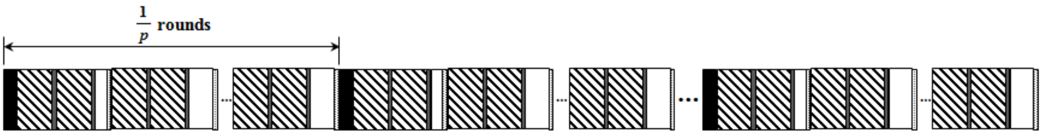


Figure 7. Rounds of the CIS protocol

A. **CIS Setup-Phase**

The period of intermittent setup is 1/*p* that is the average number of nodes per cluster, where *p* is the desired percentage of cluster heads over the total number of nodes, but it can be adjusted to adapt to the operational environment.

As Figure 8 shows, when a new round starts or since the last setup 1/*p* rounds, it enters the step phase. If it does not enter steady-state phase directly, the node that becomes cluster head should declare that it becomes the cluster head, and then waits for the information of members which is to join the cluster. After it receives the information of the cluster members, it will create TDMA schedule and send to the cluster members. Those nodes which did not become cluster heads will wait for the result about cluster head, and send the read-to-join message to the corresponding cluster head, and enters the steady-state phase after it gets the schedule sent by the cluster head.

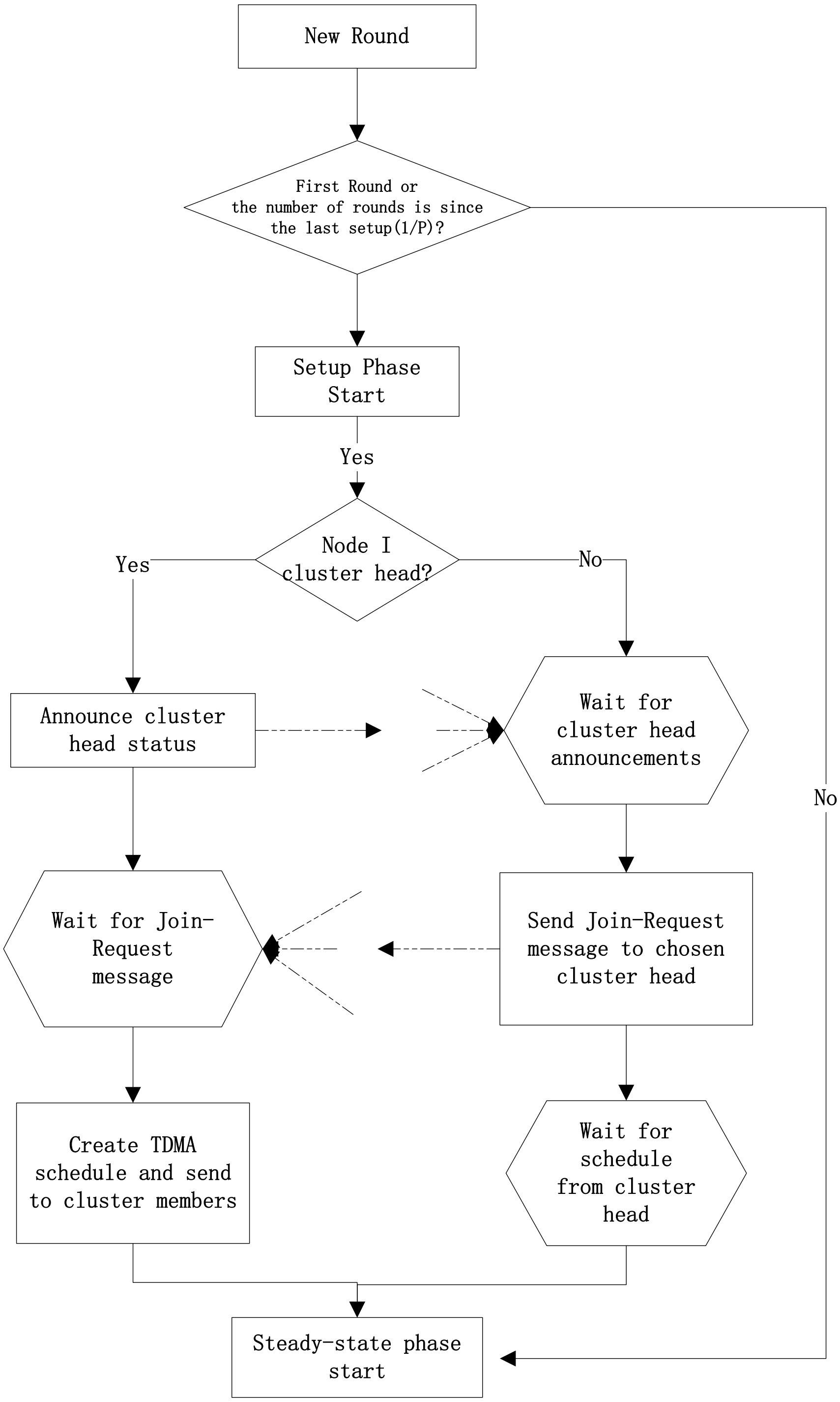


Figure 8. The CIS protocol setup phase

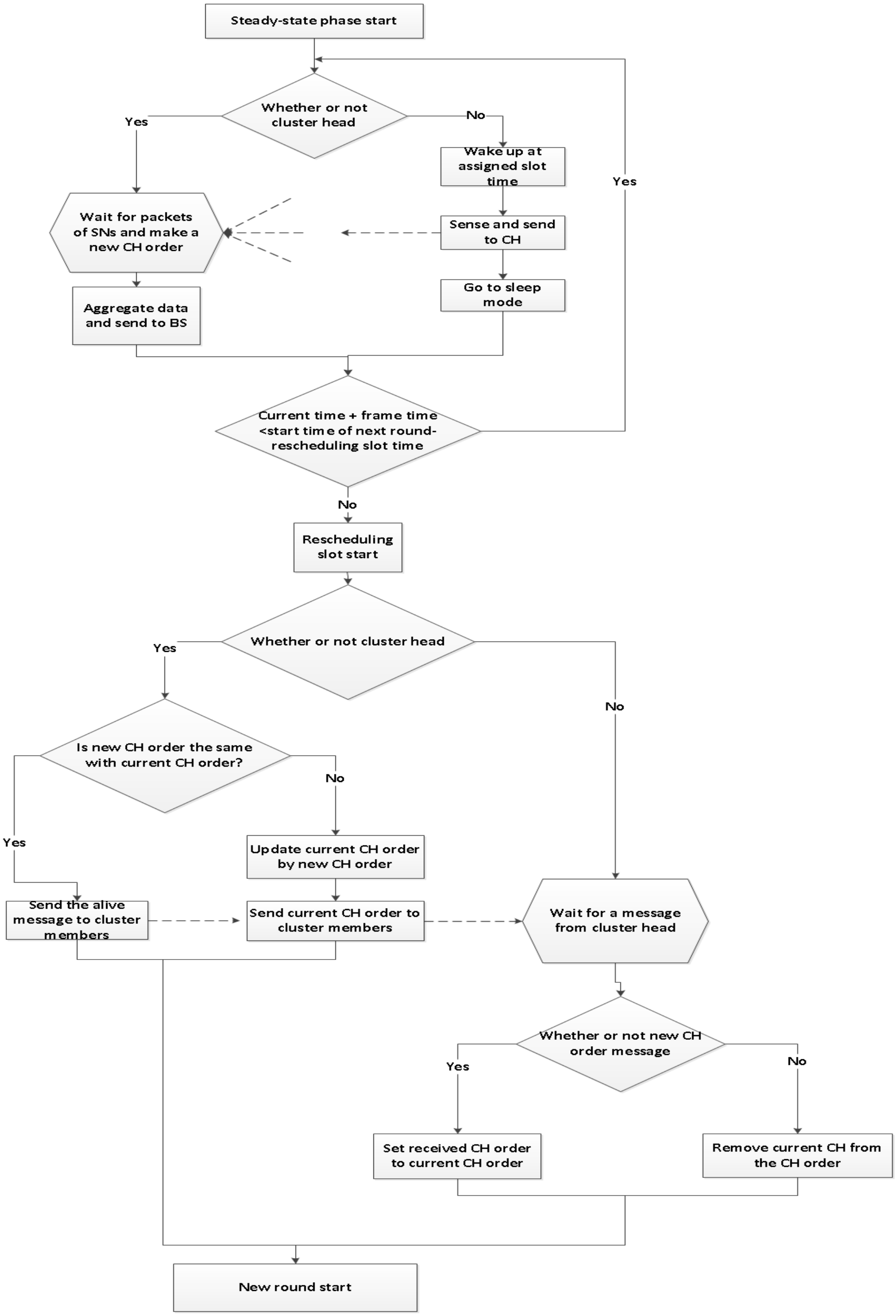


Figure 9. CIS protocol steady-state phase and rescheduling slot

B. **CIS Steady-State Phase**

As Figure 9 shows, when it enters the steady-state phase, it will first check whether it becomes cluster head. The cluster head nodes wait for the data packets sent by sensor nodes and create new cluster head order. The collected data will be sent to BS (base station). The cluster members of each cluster wake up at assigned slot time, sense and send the data to the cluster head, and then go to sleep mode.

In the phase of rescheduling slot, it will check whether it is cluster head first. If the new cluster head order is the same as the current cluster head order, it will send the alive message to cluster members. If the new cluster head order is not the current cluster head order, it will update the current cluster head order by new cluster head order, and then send current cluster head order to cluster members [1].

If it is not the cluster head node, it will wait for a message from cluster head. If it is the new cluster head order message, it will set received cluster head order to current cluster head order. If it is now the new cluster head order message, it will remove the current cluster head from the cluster head order.

IV. PERFORMANCE EVALUATION

The performance of the proposed CIS algorithm is evaluated and compared to the conventional LEACH and COTS algorithms through an extensive computer simulation. The ns-2 network simulator is used in our simulation.

A. Simulation Environment

The simulation parameters are shown in Table 1. We set the initial energy as 1 and 2 joule. Rounds of internal is 10sec. free space model is 10 pJ/bit/m^2 . Multi path mode is 0.0013 pJ/bit/m^4 . Network area is the 100x100 m^2. Transmission range is 136m [1, 14, 16, 17]. It should be noted that as in most WSNs, the transmission power of nodes is fixed, and their communication range is fixed as well. Table 1 is the simulation parameters.

Table 1. Simulation parameters

Parameter	Value
Nuber of nodes	100
Nuber of CHs	5(default),10
Initial energy	1,2(default)
Round internal	10sec
E_{da}	5 nJ/bit/signal
E_{elect}	50 nJ/bit
E_{sense}	5nJ/bit
ε_{fs}	10 pJ/bit/m^2
ε_{mp}	0.0013 pJ/bit/m^4
Location of BS	(125, 75)
Network area	100x100 m^2
Transmission range	136m

For our experiment, we used the energy consumption model. Propagation model is the same as LEACH protocol. But it is not considered in the wireless channels error. Here d_0 is the threshold, ε_{fs} is the free space (fs) model, ε_{mp} is the multipath (mp) model, d is the distance [1]. The first function of (2) is an energy consumption value spent by the transmission of an electronic device and the second function (3) is the value by the transmission amplifier.

Radio power is given by the following formula:

$$E_{Tx}(k,d) = E_{tx-elect}(k) + E_{Tx-amp}(k,d)$$

$$= \begin{cases} kE_{elect} + k\varepsilon_{fs}d^2, & d < d0 \\ kE_{elect} + k\varepsilon_{mp}d^4, & \text{otherwise.} \end{cases} \tag{2}$$

The radio energy consumption for receiving k-bit data is calculated as follows:

$$E_{Rx}(\mathrm{k,d}) = E_{Rx-elec}(k) = kE_{elec'} \tag{3}$$

Here E_{elec} is the radio electronics transmission energy. $\varepsilon_{fs}{}^2$ and $\varepsilon_{mp}{}^4$ are constant values for the amplifier energy depending on the distance to the receiver and acceptable bit-error rate. E_{da} is the energy consumption of data aggregation.

B. **Simulation Results.**

In CIS, the role of cluster head is swapped among members in a cluster between two successive setups. By reforming clusters intermittently, clusters are not fixed up and energy consumption and lifetime are balanced among nodes.

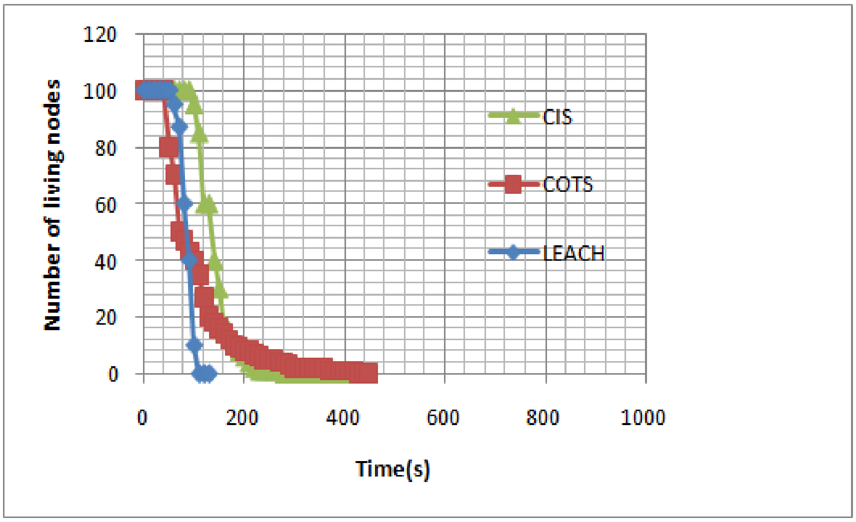


Figure 10. The number of living nodes with the energy of 1 Joule

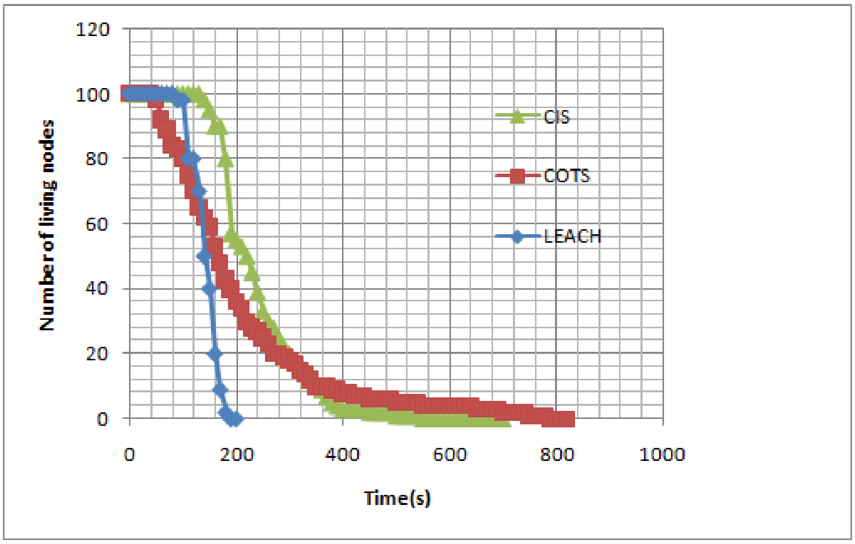


Figure 11. The number of living nodes with the energy of 2 Joule

Figures 10 and 11 show that the numbers of living nodes with the energy of 1 joule and 2 joule. In the graph CIS is more than LEACH and COTS until 110 and 150 seconds for initial energies of 1 and 2 joules, respectively.

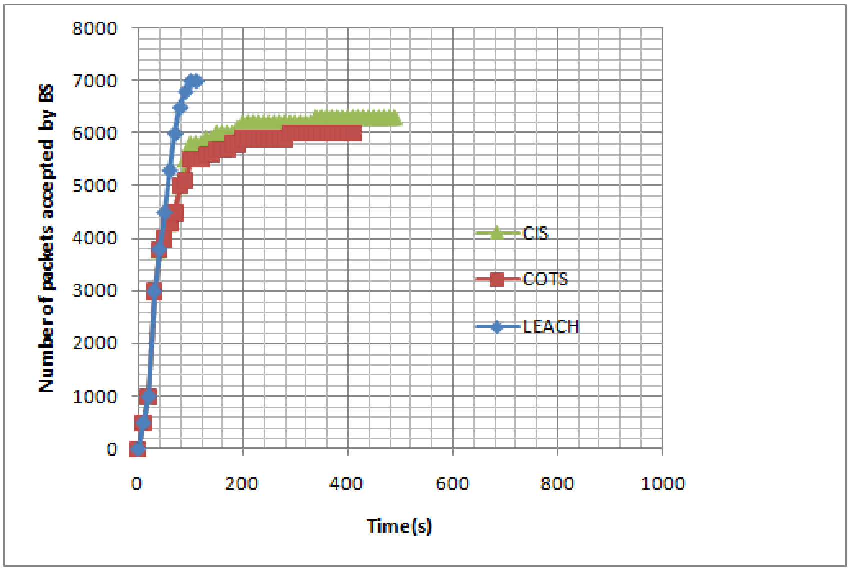


Figure 12. Number of packets accepted by BS with the energy of 1 Joule

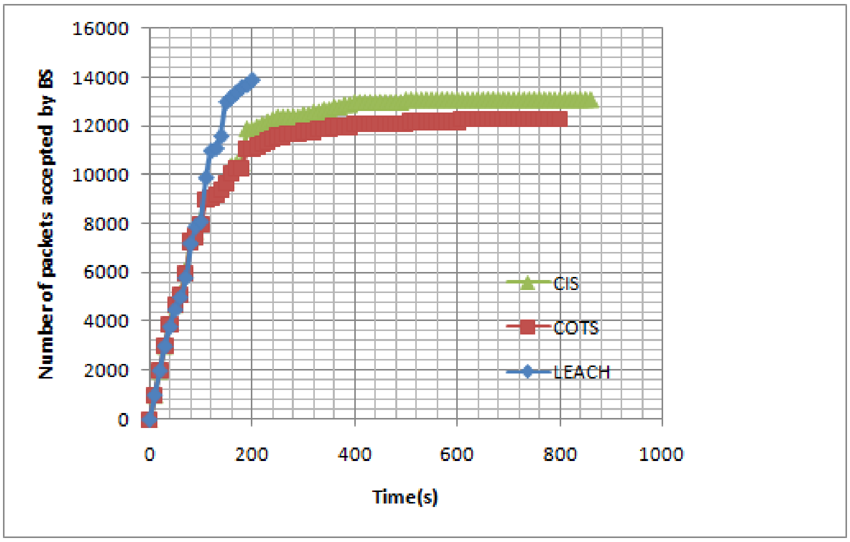


Figure 13. Number of packets accepted by BS with the energy of 2 Joule

Figures 12 and 13 represent the number of packets accepted by BS. Note that the curves of CIS, COTS and LEACH at the network lifetime of them respectively, because no packet is accepted by BS after the lifetime. At the beginning of simulation, all nodes in the network are alive, so there is no difference between COTS and LEACH with respect to the number of packets accepted by BS. We can confirm it from the early slope of the three lines drawn as CIS, COTS and LEACH in Figure 12,13. Later on in the simulation, the longer time in CIS increased lifetime more than LEACH and COTS as shown in Figures 12 and 13.

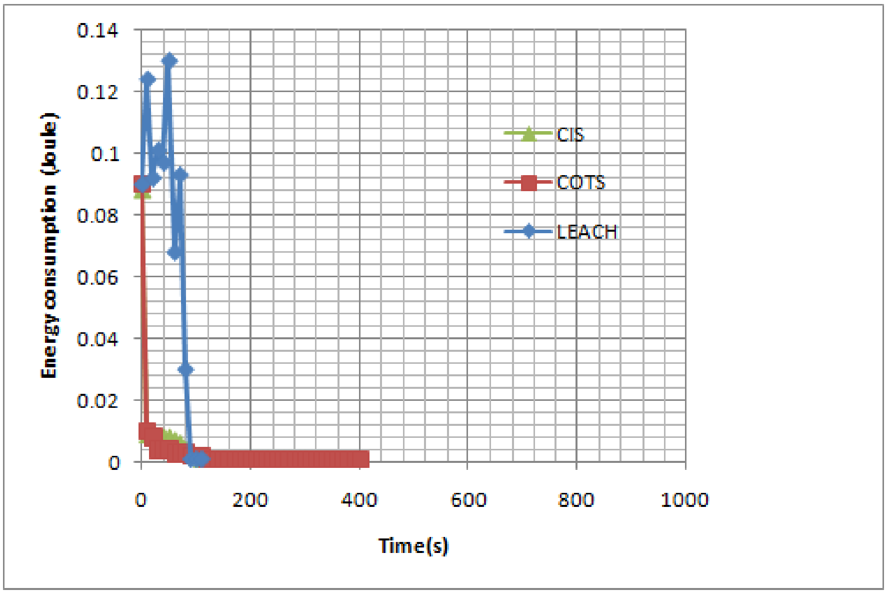


Figure 14. Energy consumption with the energy of 1 Joule

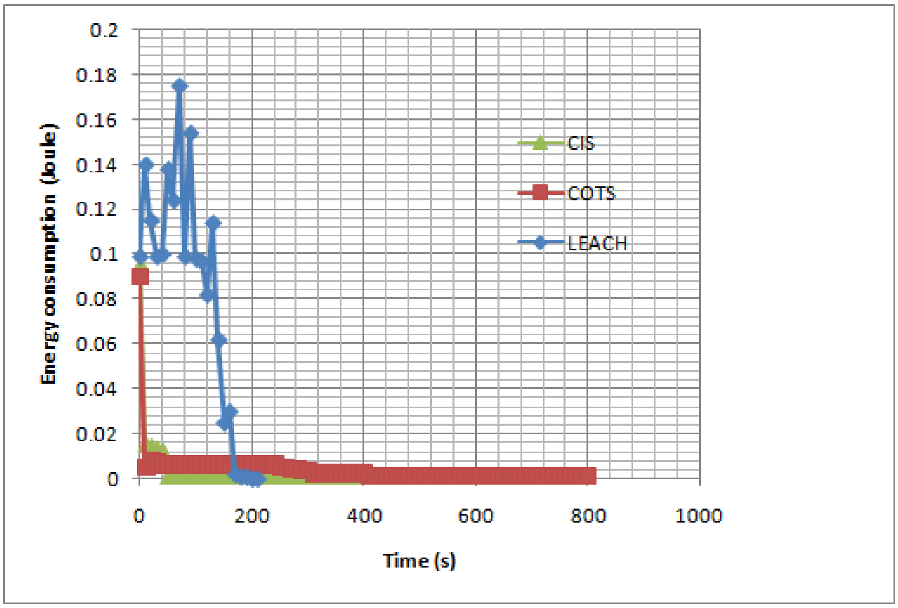


Figure 15. Energy consumption with the energy of 2 Joule

Figures 14 and 15 shows the total energy consumption per round. As shown in the figures, CIS consume much less energy than LEACH. As explained earlier, the setup phase add the 1/*p* condition at the setup phase to achieve network lifetime is balanced. Accordingly, CIS consume less energy than LEACH.

V. CONCLUSIONS

In wireless sensor network, the node energy is limited and has no supplement. Therefore, routing protocol is required to be efficient in energy consumption. Meanwhile, the nodes can only obtain information from topological structure due to its great number. Routing protocol is supposed to choose the appropriate path based on local network information. The application dependency of sensor network is so strong that there are big differences among the routing protocol in use. The traditional routing protocol seldom considers energy consumption when choosing the best path. Thus, because of limited energy of wireless sensor network, to prolong the life of the entire network has become the top priority in its original design. LEACH is a representative energy aware routing. However, as it assumes there is a direct transmission between all of its nodes and the aggregation nodes, with MAC protocol computer power in each node, this protocol is not advisable to apply in large-scale WSN. What is more, there is no introduction to the distribution of cluster head nodes in the entire network, and thereby there is a likelihood that the cluster head nodes may be in certain area of the network with great density, resulting none in other area. In addition, as LEACH also assumes that all cluster nodes carry and consume the same amount of energy ,this protocol is not suitable for network with imbalanced energy. In this protocol, nodes transmit information via cluster head election, and other nodes choose which cluster to join according to it distance to the cluster head.

According to the performance study, In CIS, as the number of clusters increase, the node lifetime is more balanced.

BIBLIOGRAPHY

[1] H. W. Shin, S. M. Moh, and I. Y. Chung. "Clustering with One-Time Setup for Reduced Energy Consumption and Prolonged Lifetime in Wireless Sensor Networks." *Hindawi Publishing Corporation International Journal of Distributed Sensor Networks* Volume 2013.

[2] V. K. Chaurasiya, S. R. Kumar, S. Verma and G. C. Nandi. "Traffic based clustering in wireless sensor network." *Wireless Communication and Sensor Networks, 2008. WCSN 2008.* Fourth International Conference on, vol. no.pp.83-88, 27-29 Dec. 2008.

[3] A. Badi, I. Mahgoub, M. Slavik and M. Ilyas. "Investigation of the effects of network density on the optimal number of clusters in hierarchical Wireless Sensor Networks (WSNs)." *High-Capacity Optical Networks and Enabling Technologies (HONET),* 2010 , vol. no.pp.171-177, 19-21 Dec. 2010.

[4] M. Hamidzadeh, N. Forghani and A. Movaghar. "A new hierarchal and scalable architecture for performance enhancement of large scale underwater sensor networks." *Computers & Informatics (ISCI),* 2011 IEEE Symposium *on*, vol. no.pp.520-525, 20-23 March 2011.

[5] R. Kumar and U. Kumar. "A Hierarchal Cluster Framework for Wireless Sensor Network." *Advances in Computing and Communications (ICACC),* 2012 International Conference on, vol. no.pp.46-50, 9-11 Aug. 2012.

[6] M. S. Fareed, N. Javaid, S. Ahmed, S. Rehman, U. Qasim and Z. A. Khan. "Analyzing Energy-Efficiency and Route-Selection of Multi-level Hierarchal Routing Protocols in WSNs." *Broadband, Wireless Computing, Communication and Applications (BWCCA),* 2012 Seventh International Conference on, vol. no.pp.626-631, 12-14 Nov. 2012.

[7] P. K. Poonguzhali. "Energy efficient realization of Clustering Patch routing protocol in wireless sensors network," *Computer Communication and Informatics (ICCCI),* 2012 International Conference on, vol. no.pp.1-6, 10-12 Jan. 2012.

[8] A. A. Khan, N. Javaid, U. Qasim, Z. Lu, and Z. A. Khan. "HSEP: Heterogeneity-aware Hierarchical Stable Election Protocol for WSNs." *Broadband, Wireless Computing, Communication and Applications (BWCCA),* 2012 Seventh International Conference on, vol. no. pp.373-378, 12-14 Nov. 2012.

[9] D. T. Ho, E. Grotli and T. A. Johansen. "Heuristic algorithm and cooperative relay for energy efficient data collection with a UAV and WSN." *Computing, Management and Telecommunications (ComManTel),* 2013 International Conference on, vol. no.pp.346-351, 21-24 Jan. 2013.

[10] R. Madan, S. Cui, S. Lall and A. J. Goldsmith. "Modeling and Optimization of Transmission Schemes in Energy-Constrained Wireless Sensor Networks." *Networking,* IEEE/ACM Transactions on, vol.15, no.6, pp.1359-1372, Dec. 2007.

[11] W. Peng and D. J. Edwards. "K-Means Like Minimum Mean Distance Algorithm for wireless sensor networks." *Computer Engineering and Technology (ICCET),* 2010 2nd International Conference on, vol.1, no.pp.V1-120,V1-124, 16-18 April 2010.

[12] M. N. U. Laskar, M. N. A. Tawhid and T. C. Chung. "Extended Kalman Filter (EKF) and K-means clustering approach for state space decomposition of autonomous mobile robots." *Electrical & Computer Engineering (ICECE),* 2012 7th International Conference on, vol. no.pp.113-116, 20-22 Dec. 2012.

[13] P. Sasikumar and S. Khara. "K-Means Clustering in Wireless Sensor Networks." *Computational Intelligence and Communication Networks (CICN),* 2012 Fourth International Conference on, vol. no.pp.140-144, 3-5 Nov. 2012.

[14] Y. Z. Li, A. L. Zhang and J. Shimei. "WSN Clustering Algorithm Based on Cluster Head Reappointment." *Instrumentation, Measurement, Computer, Communication and Control (IMCCC),* 2012 Second International Conference on, vol. no.pp.813-816, 8-10 Dec. 2012.

[15] M. Alnuaimi, K. Shuaib, K. A. Nuaimi and M. Abdel-Hafez. "Performance analysis of clustering protocols in WSN." *Wireless and Mobile Networking Conference (WMNC)*, 2013 6th Joint IFIP, vol. no.pp.1-6, 23-25 April 2013.

[16] R. S. Elhabyan, M. C. E. Yagoub. "Weighted tree based routing and clustering protocol for WSN." *Electrical and Computer Engineering (CCECE),* 2013 26th Annual IEEE Canadian Conference on, vol. no.pp.1-6, 5-8 May 2013.

[17] B. Chang and X. R. Zhang, "An energy-efficient routing algorithm for data gathering in wireless sensor networks." *Cross Strait Quad-Regional Radio Science and Wireless Technology Conference (CSQRWC),* 2012, vol. no.pp.137-141, 23-27 July 2012.

[18] C. Diallo, M. Marot and M. Becker. "Single-node cluster reduction in WSN and energy-efficiency during cluster formation." *Ad Hoc Networking Workshop (Med-Hoc-Net),* 2010 The 9th IFIP Annual Mediterranean, vol. no.pp.1-10, 23-25 June 2010.

[19] M. M. Afsar, M. H. Yaghmaee Moghaddam and Z. K. Esmaeil. "A Fault Tolerant Protocol for Wireless Sensor Networks." *Mobile Ad-hoc and Sensor Networks (MSN),* 2011 Seventh International Conference on, vol. no.pp.475-478, 16-18 Dec. 2011.

[20] R. Dutta, S. Gupta and M. K. Das. "Mathematical modeling of packet transmission through cluster head from unequal clusters in WSN." *Parallel Distributed and Grid Computing (PDGC),* 2012 2nd IEEE International Conference on, vol. no.pp.515-520, 6-8 Dec. 2012.

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