A Survey on Multi-Hop Heterogeneous Distributed Energy-Efficient Clustering Scheme

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Abstract

The rising popularity of heterogeneous Wireless sensor network is because of the potential of increasing the lifetime of the network, while contribution toward the cost is very negligible. The restricted battery power of the sensors not only hamper the efficiency of the network but also reduce the long-term life of the WSNs. So, the main focus of this paper is to reduce the energy consumption by the sensor nodes and to increase the network lifespan. As, heterogeneous clustering shows more excellent result as compare to homogenous clustering, so in this paper, we proposed a Multi-hop Heterogenous Distributed Energy Efficient Clustering(MHDEEC) scheme for wireless sensor network. This technique is based on two level of heterogeneity with more efficient and dynamic selection of cluster head(CH) which follow multi-hop, where the sensors communicate with each other through multi-hop wireless link and the last sensor of the multi-hop deliver the aggregate data to the base station(BS).

Keywords: *Homogeneous clustering, Heterogeneous clustering, Multi-hop routing, Network lifetime, Energy-efficiency, Clustering, WSNs.*

1. Introduction

Wireless sensor network consists of large number sensors spread over a large geographical area. These sensors work with each other to sense various physical phenomenon from environment. The major application area includes military surveillance, area monitoring, medical, domestic etc. Also, these applications are also having limitation because of short lifespan of the sensors [16]. This is because sensors have limited battery life and replacing and recharging the battery is not possible as they are generally deployed in harsh location where human existence is not possible.

To increase scalability and the lifespan of the network a technique called clustering is used. Clustering divide the entire network in group of nodes called “cluster”. Each cluster elects a cluster head (CH) according to their residual energy and minimum distance from the sink or base station (BS) and the rest of the sensors in the cluster function is to sense the environment and send the sensed data to their respective CH. The CH then sends the aggregate data collected from all the CH to the BS. Data aggregation reduces the amount of data send from the CH to the BS. The efficiency in wireless sensor network is increased due to the transmission capability, data fusion, TDMA scheduling and collision free transmission in clustering [13].

Clustered sensor network is basically divided into two type Homogenous Sensor network and Heterogeneous Sensor network. In Homogenous wireless sensor network, the entire sensor node hassame capability in term of power and hardware complexity. The CH elected, drains more energy than the rest of the node in the networks because it has to do extra processing for data fusion and send the aggregate data to the BS. As a result, CH node are subjected to die soon. One way to overcome this situation is proposed in LEACH algorithm. In LEACH, CH is rotated periodically so all the node gets equal chance to become the CH. This somehow increase the lifespan of the entire network. Whereas in heterogeneous wireless sensor network some of the sensors have higher capability in terms of power the rest of the nodes in the network [10,16]

Most clustering protocol uses single-hop data transmission. To do this, the main requirements is to able to communicate between any pair of sensors in the same cluster directly. In larger network, this requirement may lead to the creation of large number of CHs. As a result, it increases the inter-cluster information flow which lead to consume more energy and bandwidth. Moreover, as compare to single-hop, multi-hop communication is proved to be more energy-efficient.

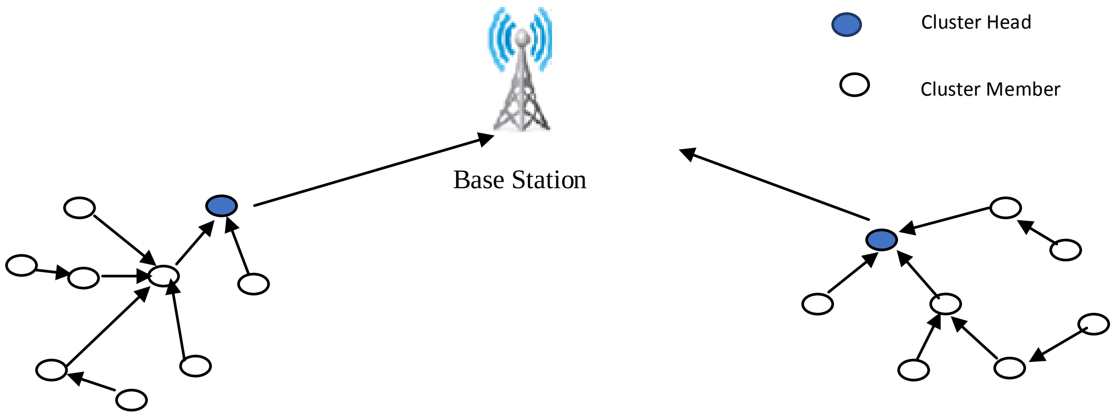

Figure 1 Multi-hop Hierarchical clustering

If the BS is out of the transmission range of the CH then multi-hop technique is used for data transmission. This is because the energy consumption of a node generally depends on the distance to which it transmits data. If the distance for transmission is greater, than the energy consumption is also high. The parameter used for selecting the next hop is the shortest distance from CH and maximum residual energy of the nodes. So, by doing this, energy consumption by a node for data transmission is reduce and distributed among the node in the path form source to the destination.

So, the main focus of our paper is to find an effective solution to prolong the network lifespan of the network by integrating distributed clustering approach which uses two level of heterogeneity with multi-hop technique.

2. Literature Review

WSNs in today’s world is an emerging technology which attract many researches because of their wide application area. But at the same time, they have also facing many challenges like scalability, simplicity, area of coverage, security, energy efficiency etc. Above all, the most important challenges that researcher is working is the network lifetime enhancement. Hence several techniques and protocol are developed to minimize the energy consumption and increases the network lifespan [3]. The very first technique was developed for homogenous wireless sensor network by Heinzelman et al. in 2000 called low energy adaptive clustering hierarchy(LEACH). It is a cluster-based protocol. In this technique the CH is randomly selected and the role is rotated uniformly to distributed energy load evenly among the sensors. Major problem here is the random selection of CH and the number of CHnodes are also not fixed. This problem is solved in LEACH-C proposed by Heinzelman et al. It is a centralized algorithm. In this protocol CH is scattered all over the network to provide an improved performance [4].

The LEACH is improved by Lindsey and Raghavendra and called it power efficient gathering in sensor information systems(PEGASIS). It is a chain-based protocol where every node receives and transmit data to its immediate neighbour. Each node in the chain perform data aggregation. Here no cluster is formed and no CH is selected. A single node is used to transmit data to the BS. Nodes takes turn to transmit data to the sink. So, the energy consumed by each round is minimized. Clustering overhead is removed by this algorithm. Main drawback of this algorithm is that it introduces chain shaping overhead and packet delay problem because data are transmitted between sensors and BS by using multi-hop transmission [7].

Manjeshwar et al. give the threshold sensitive energy efficient sensor network (TEEN) protocol. It is based on hierarchical approach. This algorithm is basically designed for re-active networks. Here, if the sensors receive some interesting facts then only an event is reported to the BS. TEEN is most appropriate for real time application and also is an efficient approach in terms of energy. Main drawback of TEEN is that it is least suitable for periodic data gathering as the end-user do not receive any data if the values sensed by the sensors do not reach the required threshold value set. This algorithm maintains a trade-off between energy consumption applications and accuracy [8].

Manjeshwar et al. extend TEEN and give adaptive threshold sensitive energy efficient sensor network (APTEEN) protocol. This protocol is both a pro-active and re-active network. It helps to collect periodic data at the same time also provide time-critical events. Main drawback of APTEEN is its complexity and overhead in forming cluster [9].

Smaragdakis et al. proposed Stable Election Protocol (SEP). It is an extension of LEACH. Here two level of heterogeneity is used, which consist two different kind of node in terms of power i.e. normal node and advance node. Here advance node has more power than normal node. So, the chances of advance node to become the CH is more as compare to that of the normal node. CH elected on the basis of the residual energy relative to that of the other nodes [10].

Samayveer Singh et. al. gives Distributed Energy-Efficient Clustering (DEEC) algorithm. DEEC is design for two and multilevel heterogeneity, where CH is elected on the basis of probability of ratio of remaining energy of the nodes and average energy of the network. Higher energy node has more chance to become the CH. Role of CH is rotated among the node to perform energy uniformity in wireless sensor network [12].

Younis O et. al. proposed Hybrid Energy-Efficient Distributed (HEED) This algorithm offers uniform distribution of CHs across the network. HEED considers the sensors' residual energy and their communication cost as the main parameter for cluster formation. In HEED two sensors are thought of as neighbour sensors as long as they are within each other's' power range. Therefore, two neighbouring sensors wouldn't be elected as CHs. Also, in this algorithm, CHs form a single-hop routing protocol from CHs into the BS. HEED showed better performance in terms of energy efficiency when put next to LEACH. The main drawback here is that it is not able to fix the cluster count in each round as it periodically selects CHs according to a node's residual energy [15].

Parulsaini et. al. proposed Enhanced Distributed Energy-Efficient Clustering Scheme (EDEEC) for heterogenous WSN. Here they proposed three types of nodes super, advance and normal nodes to prolong the network lifespan and to provide network stability. This shows better performance than SEP [14].

Javaid et al. discuss Enhance Developed Distributed Energy-Efficient Clustering (EDDEEC) for heterogenous WSNs. It is an adaptive energy aware protocol which dynamically choose CH in an efficient and balanced manner [5].

BrahimElbhiri et. al proposed Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogenous WSNs. DDEEC is the extension of DEEC. The difference between DEEC and DDEEC is DDEEC has more efficient CH selection probability. It implements a balanced and dynamic way to distribute the spent energy more equally among nodes [2].

T. Qureshi et. al. proposed Balanced Energy-Efficient Network Integrated Super Heterogenous (BEENISH) protocol for WSNs. Here four level of heterogeneity is used.CH is selected on the basis of remaining energy of the nodes and average energy of the network. So high energy nodes have more chance to be elected as CH, as compare to low energy nodes in the network. By using four types of node i.e. normal, advance, super and ultra-super nodes, it shows that BEENISH perform better than the existing clustering protocol. Network stability, lifetime and efficiency is more in BEENISH as compare to DEEC, DDEEC and EDDEC. But the major disadvantages of BEENISH is the cost [10].

S. Bandyyopadhyay et al. has first developed multi-hop hierarchical clustering algorithm for WSNs, but the major disadvantage of this approach is that it does not consider residual energy of the node. As a result, it does not guarantee in prolong the lifespan of the network [1].

D. Kumar et. al. proposed an Energy-Efficient Heterogenous Clustering scheme EEHC. It increases the lifespan of the network as compare to LEACH by 10%. Hence, the performance of the proposed system is better in terms of reliability and lifetime [6].

3. Radio Dissipation Energy Model

The Radio Model that is used in [10,14] is describe as shown in the Fig. 2.

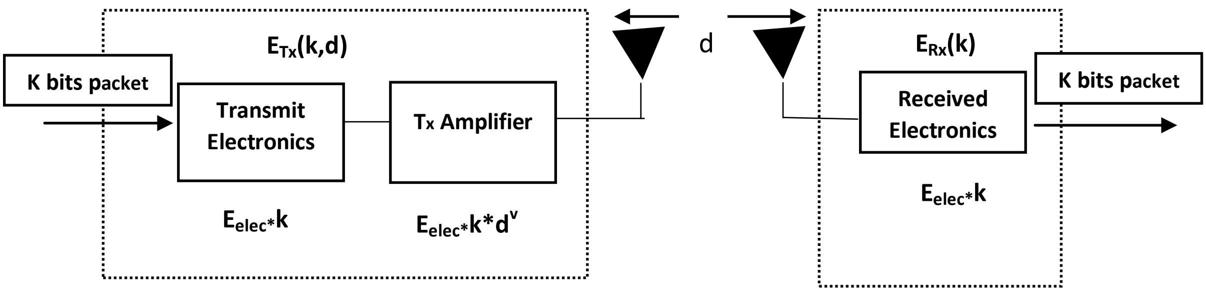

Figure 2. Radio Energy Dissipation Model[10]

This figure shows that 1 bit of information is transmitted over d distance. Depending on the distance between sender n receiver both the multi-path fading (d^4 power loss) and free space (d^2 power loss) channel model is used [3,4]. If distance (d) is more than the threshold d_0, multi-path model is used; otherwise, free space model is used. Assuming that our clustering is multi-hop and the density of the sensor nodes near the BS is high. Also, all the sensors have the same capability. Here the location of the sensors and the BS is fixed and the communication between CHs and BS is multi-hop. So, to transmit an N-bit message over distance d, the radio expands to as follow:

$$E_{Tx}(N, d) = \begin{cases} N * E_{elec} + N * E_{fs} * d^2 & \text{if } d<d_0 \\ N * E_{elec} + N * E_{mp} * d^4 & \text{if } d \geq d_0 \end{cases} \quad (1)$$

Here E_{elec} is energy used per bit to run transmitter(E_{Tx}) or receiver(E_{Rx}) circuit. E_{elec}depend on many factors such as modulation, filtering, spreading of the signal and digital coding. Here d is the distance between sender and receiver, E_{mp} and E_{fs} depend on transmitter amplifier used. If the distance is more than threshold the multi path (mp) is used otherwise free space (fs) model is used. To receive an N bit message the radio expands as follow:

$$E_{Rx}(N, d) = N * E_{elec} \quad (2)$$

Value of threshold distance d_0 is given by

$$d_o = \sqrt{\frac{E_{fs}}{E_{mp}}} \quad (3)$$

4. Proposed 2 level heterogeneity multi-hop network model

Here we are going to discuss our proposed 2-level heterogenous network based on their energy level with multi-hop transmission technique used to increase the lifespan and stability of the network. In this proposed model two types of sensors are used, normal nodes and advance nodes. The initial energy of the normal node is E_0. and let k be the fraction of th`e advance nodes which are equipped with more energy than the normal nodes. Thus, there are k * N advance nodes equipped with E_0 (1+a) initial energy and (1-k) * N normal nodes that are equipped with initial energy of E_0[2,5,10,14]. The total initial energy of the new heterogenous network is given below:

$$\begin{aligned} T_{Energy} &= N * (1 - k) * E_0 + k * N * (1 + a) * E_0 \\ &= N * E_0 * (1 + a * k) \quad (4) \end{aligned}$$

So, the two level heterogenous network have a * k times more energy and virtually a * k more sensors [14].

Our proposed protocol uses the same concept as describe in DEEC, in term of CH selection criteria based on the remaining energy of the sensors with respect to the average energy of the network [10].

5. Assumptions and properties of the network

The basic assumption that are made for our network is as follow [10,14]:

- Sensors are uniformly and randomly deployed in the network.
- After deployment, all Sensors and BS are stationary.

- Nodes are not aware of their location that means they are not equipped with GPS-capable antenna.
- Each sensor has the data aggregation capabilities
- All sensor has same capabilities in terms of processing and communication, but different in terms of energies.

6. CH Selection Process

According to LEACH protocol, CH selection process is divide into number of rounds. Sensors decide at the beginning of each round to become CH based on the threshold as derived by the suggested percentage of CHs for the network and the number of times the node has been a CH so far. The decision to become a CH is normally taken by the sensors themselves by choosing a random number form 0 to1. A node is elected as CH for the current round if the threshold T(s) is greater than the random number [2,5,10,14] The threshold is set a:

$$T(s) = \begin{cases} \frac{p}{(r.mod\frac{1}{p})} & \text{if } s \in G \\ 0 & \text{Otherwise} \end{cases} \quad (5)$$

Here p, r, G denotes percentage of CHs desired, current round and set of sensors that has not been selected as CHs in last 1/p rounds.

In two level of heterogenous networks there are two types of nodes normal and advance nodes according to their initial energy. Therefore, the reference value of p is different for these types of nodes. The probability (P_i) of normal and advance nodes is:

$$P_i = \begin{cases} \frac{P_{opt}E_i(r)}{(1+m(a*m))\bar{E}(r)} & \text{if } s_i \text{ is normal node} \\ \frac{P_{opt}(1+a)\,E_i(r)}{(1+m(a*m)\bar{E}(r)} & \text{if } s_i \text{ is advance node} \end{cases} \quad (6)$$

Threshold for CH selection is calculated for normal and advance nodes by using the above value in :

$$T(s_i) = \begin{cases} \frac{p_i}{1 - Pi(r.mod\left(\frac{1}{Pi}\right))} & \text{if } p_i \in G \\ \frac{p_i}{1 - Pi(r.mod\left(\frac{1}{Pi}\right))} & \text{if } p_i \in G` \\ 0 & \text{Otherwise} \end{cases} \quad (7)$$

Here G is the set of normal nodes that have not become CH within the last $1/P_i$ rounds of the epoch where s_i is normal node, G` is the set of advanced nodes that has not become the CHs within the last $1/P_i$ round of epoch where s_i is advance node [2,5,10,14].

Normal and Advance node weighted probability is given by:

$$P_{nrm} = \frac{P_{opt}}{1+a*m} \qquad P_{adv} = \frac{P_{opt}}{1+a*m}(1+a) \tag{8}$$

Our proposed scheme also implements the same formula as describe in DEEC to calculate the energy in the network [2,5,10,14]. The average energy is calculated as:

$$\bar{E}(r) = \frac{1}{N} E_{Total} \left(1 - \frac{r}{R}\right) \tag{9}$$

Here R represent total number of rounds in the network lifespan and can be calculated by the formula as follow:

$$R = \frac{E_{Total}}{E_{round}} \tag{10}$$

$E_{round}$is energy consume in a network in a round and it is calculated as follow:

$$E_{round} = L *(2 * N * E_{elec} + N * E_{DA} + k * E_{mp} * d^4{}_{toBS} + N * E_{fs} * d^2{}_{toCH}) \tag{11}$$

Here k is the number of cluster formed in the network, E_{DA} is the cost of data aggregation, d_{toBS} represent the average distance between BS and CH and d_{toCH} represent the average distance betweensensor node and CH [10,14].

Here d_{toBS} and $d_{toCH}$is given as:

$$d_{toCH} = \frac{M}{\sqrt{2\pi k}} \qquad d_{toBS} = 0.765\frac{M}{2} \tag{12}$$

The optimal number of cluster is given as:

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \frac{M}{d^2 \text{toBS}} \frac{\sqrt{E_{fs}}}{\sqrt{E_{mp}}} \tag{13}$$

Node optimal probability to become CH in round is given by:

$$P_{opt} = \frac{k_{opt}}{\text{n}} \tag{14}$$

7. Performance Criteria Used

The performance criteria are used to evaluate and study the clustering scheme in term of the number of alive node, network lifetime, throughput and number of packet BS received.

Network lifetime: This represent the time interval from the start of the network till the death of the first node that is alive.

Number of Alive node per round: This represent the total number of nodes of each type that has not yet expanded all of their energy.

Data packet received by the BS: This represent the total number of messages received by the BS. This basically varies for all protocols.

Throughput: This measure the total data rate sent over the network, the data rate from CHs to BS and also the data rate from nodes to their CHs.

This metrics is used to evaluate the stability period of the network which is the time interval from the start of the network till the death of the first node, unstable period of the network which represent the time interval from the death of the first node to the death of the last node, the amount of data that is sent from sensors and received by the BS, energy that is consumed by the nodes and the lifespan of the network which represent the number of round till the death of the first node. This shows the stability period of the network. Lifespan of the network directly depend on the stability of the network [6].

Table 1.Comparison of different type of clustering protocol in WSNs

Serial No	Algorithm	Network Lifetime	No. of Alive Node	Packet received by BS	Throughput
1	LEACH	Low	Very Low	Low	Low
2	TEEN	High	High	Low	High
3	HEED	High	Low	Low	Low
4	APTEEN	High	High	High	High
5	DEEC	High	High	High	High
6	DDEEC	High	Higher than DEEC	High	High
7	EDDEEC	High	Higher then DEEC & DDEEC	High	High
8	BEENISH	High	Very High	Very High	High

8. Result and Discussion

The proposed MHDEEC is a two-level clustering protocol for heterogenous wireless sensor network. This protocol consists of n number of normal sensor node, advance node and a single BS which is placed near the network. More over the CH should not overlap with each other hence to maintain the distance between them localization technique is used. If the distance between the CH and BS is greater, than the energy consumption is also high. In this case multi-hop transmission is a good option in terms of energy consumption by the node. The parameter used for selecting the next hop is the shortest distance from CH and maximum residual energy of the nodes. After selection of CH the member node join to the CH according to the residual energy and distance between itself and the CH.

If a CH finds an advance node which is not a CH for that particular round and whose distance to the BS is less than that between the CH and the BS, than instead of directly sending data to the BS, the CH sends the aggregate data to the advance node, which then deliver the data to the BS. But if the CH do not find an advance node, then it directly sends the data to the BS. So, by introducing this concept our proposed protocol helps in reducing the energy consumption of the node ant thus helps in increasing the lifespan of the network.

9. Conclusion

In Wireless Sensor Network, the main requirement is to increase the lifespan of the network and also to achieve energy-efficiency with stability [14]. So, our proposed protocol for heterogenous WSNs is an energy-efficient clustering protocol with the idea of using two level of heterogeneity and using the multi-hop technique to transmit data to the BS. Here the CH is selected according to the remaining energy of the nodes and the average energy of the network. So, nodes with higher energy is being selected as CH, as compare to those of the lower energy nodes. MHDEEC will increase the performance of the network in term of lifespan of network and stability as compare to DEEC.

References

[1] Bandyyopadhyay S. and Coyle E. J., “An energy efficient hierarchical clustering algorithm for wireless sensors networks”, Proc. IEEE INFOCOM 2003, Vol.3, pp. 1713-1723.

[2] Elbhiri B. et. al., “DDEEC: Developed Distributed Energy-Efficient Clustering for heterogenous wireless sensor network”, 2010, IEEE I/V Communications and Mobile Network (ISVC), 2010.

[3] Heinzelman W. R. et. al., “Energy-Efficient communication protocol for wireless sensor networks”, in the proceeding of the Hawaii International Conference System Sciences, Hawaii, January 2000.

[4] Heinzelman W. R. et. al.”An application specific protocol architecture for wireless microsensor networks, IEEE Transations on wireless Communications 1 (4)(2002)660-670.

[5] Javaid N. et. al., “EDDEEC: Enhance Developed Distributed Energy-Efficient Clustering for heterogenous wireless sensor network”, 2013, ELSEVIER, Procedia Computer Science 19(2013) 914-919.

[6] Kumar D., Trilok C. Aseri, R.B. Patel, “EEHC: Energy efficient heterogeneous clustered scheme for wireless sensor networks”, ELSEVIER, Computer Communications, 32 (2009) 662–667.

[7] Lindsey S. et. al., “PEGASIS: Power Efficient Gathering in Sensor Information Systems”, in the proceeding of IEEE Aerospace Conference, Big Sky, Montana, March 2002.

[8] Manjeshwar A. and Agarwal D. P., "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks," In 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, April 2001.

[9] Manjeshwar A. and Agarwal D. P., "APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks," Parallel and Distributed Processing Symposium., Proceedings International, IPDPS 2002, pp. 195-202.

[10] Qureshi T. N. et. al. “BEENISH: Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol for Wireless Sensor Network”, ELSEVIER, Procedia Computer Science 19(2013)920-925.

[11] Smaragdakis G., Matta I., Bestavros A., “SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks”, in: Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004), 2004.

[12] Singh S. et. al., “Energy Efficient Heterogenous DEEC protocol for enhancing lifetime in WSNs”, Engineering science and technology, an International Journal 20 (2017)345-353.

[13] Singla S. et. al., “Comparative Analysis of Homogeneous N Heterogeneous Protocols in WSN”, International Journal of Science and Research, Volume 5 Issue 6, june 2013, ISSN(online):2319-7064.

[14] Saini P. et. al. “EDEEC: Energy -Efficient scheme for clustering protocol prolonging the lifetime of heterogenous wireless sensor networks”, September 2010, International journal of computer application (0975-8887), Volume 6-No. 2.

[15] Younis O., Fahmy S., "HEED: A hybrid, energy efficient, distributed clustering approach for adhoc sensor networks", IEEE Transactions on Mobile Computing vol 3, no 4, pp 660-669, 2004.

[16] Zaatouri I. et al. “A comparative study of the energy efficient clustering protocols in Heterogenous and Homogenous Wireless Sensor Networks”, (2016) DOI 10.1007/s11277-017-4847-2s.