An Energy Efficient and Load Balancing Clustering Scheme for Wireless Sensor Network (WSN) Based on Distributed Approach

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Abstract. One of the most critical problem and challenging in Wireless Sensor Networks (WSNs) is to reduce energy consumption in order to prolong network lifetime of WSNs. Clustering technique is one of the techniques which have been used to provide energy efficiency. However Most of clustering schemes select the cluster head either randomly without considered important parameters or based on centralized approach by utilizing the base station which can affect the network scalability. In addition, single hop communication is used by CHs to forward their sensed data to the CH which lead to increases energy consumption of CHs in large scale network. Therefore in this paper clustering scheme is proposed based on distributed approach, different parameters are consider for cluster head selection and also for multi-hop communication. Results shows that the proposed scheme have better performance in term of energy consumption and number of alive sensor nodes.

1. Introduction
The design and advance in sensor technology such as low power CMOS technology, microprocessors and low power radio frequency (RF) have made it feasible to develop cheap tiny sensors with wireless network. These Sensors will be utilized for monitoring different environments for example, battle fields, tracking objects and construction distortion detection. One of the most critical issues in WSN is power source as powered by limited small batteries that can’t be replaced or recharged. So having power efficient plan for delivering packets to BS is so important due to maximizing life time of network. One of the techniques used to reduce energy consumption and results in prolong network lifetime of WSN is to partition the network into clusters [1]. Clustering technique has a lot of advantages in comparison with flat routing protocols in WSNs, since it adds more scalability, less load, reduce energy consumption. Scalability since only CHs nodes are responsible for data dissemination thus the size of routing table is reduced at the individual sensor node. Also, sensor node can generate redundant data therefore in Clustering algorithm CH node aggregation the received data from its member’s nodes using data aggregation method, which in turn help to reduce redundant data and thus reduce the size of the data packets thus energy is saved [2, 3]. In clustering schemes, there are
mainly two major phases. In first phase, some nodes are appointed as CHs and formulate different cluster while second phase is usually related to data gathering and forwarding. Within each cluster, all member nodes transfer their sensory information towards their respective CH, which perform further processing (i.e. aggregation, compression, and scheduling and resource allocation) and forward their member data towards sink node. As CHs is responsible for several functions thus consume more energy compared to ordinary nodes[4]. Therefore, CH selection plays a vital role and has great impact on network lifetime [5]. However, Most of cluster mechanism selects the CH randomly without considered important parameters where this can lead to select the deficient node as CH. Others clustering mechanisms are based on centralized approach by utilizing the base station which can affect the network scalability as every time nodes require sending its parameters such as energy, number of neighbours to the BS which in turn leads to increases network overhead. Therefore, this paper presents an energy efficient and load balancing clustering scheme based on distributed approach. To optimize the cluster heads selection two parameters are consider for cluster head selection. In addition, multi-hop communication between CHs is employed to reduce the energy consumption in large scale network.

2. Related works
Low Energy Adaptive Clustering Hierarchy (LEACH), which was, proposed in [6] and it is well-known as LEACH protocol. LEACH was aimed to provide a solution to resolve the energy consumption in WSN and prolong the network lifetime. LEACH is a probabilistic on both distributed and single-hop approach. It structures the network into clusters based on the strength of receiving signals. In LEACH, nodes are either ordinary SNs or CHs. Every SN sends their sensing data to its CH. In addition, CHs node work as gateways to the BS, Initially a node in LEACH protocol, generates a random number between 0-1 to decides which node to be a CH and this is done by computed a threshold value T (n). Generally, LEACH provides a good model for energy consumption. To reduce energy consumption in [7] proposed Power efficient gathering in sensor information systems (PEGASIS) was also proposed to form a chain of sensor nodes starting from the farthest node to closest node towards base station. Each node sends and receives data from its neighbours and takes a turn being a leader for transmission towards the base station or destination. However, such a mechanism can produce high transmission delay with an increase in chain or network size. In [8] proposed LEACH-C each node sends its residual energy level and location information to the sink node at the beginning of each cluster formation,. In turns sink node elects CHs and builds clusters based on simulated annealing algorithm. Once the CHs and associated nodes are determined, the sink broadcasts CH IDs and Time Division Multiple Access (TDMA) schedules for each node. All nodes look for their IDs to be matched as the CH ID, if not matched then the nodes follow the Time Division Multiple Access (TDMA) schedule to broadcast their data. The data transmission phase of LEACHC is identical to that of LEACH. Using this scheme in clustering the network can form more uniform sized clusters, but it can suffer from scalability problem and high overheads. To improve LEACH protocol [9] proposed DBCH scheme where the distance from the base station and the energy of the node is considered while selecting the CHs. Based on the specified parameters for selecting CHs, the node which is nearer to the base station and has more residual energy will be elected as the cluster head. The proposed work shows better performance than LEACH in term of energy consumption which it. However, single hop communication is used by CHs to forward their sensed data to the CH which lead to increases energy consumption of CHs in large scale network.

3. Network model
The network model used in this scheme is based on some assumptions which are listed below.

- N of nodes are distributed uniformly in a square area of M x M.
- Base station or sink is located at one certain location out of the network filed.
- Base station and all the nodes are stationary.
- Same initial energy are equipped to all the sensor nodes.
- Unique ID is assigned for each node.
- Nodes able to estimate its distance from its neighbors and base according to the RSSI.

The same energy model which is given in [6] is used where the energy required for transmitting and receiving ‘l’ bits over a distances ‘d’ is calculated using the following equations

\[
E_{TX}(k, d) = \begin{cases} 
  k * E_{elec} + k * E_{fs} * d^2, & d < d_0 \\
  k * E_{elec} + k * E_{mp} * d^4, & d \geq d_0
\end{cases}
\]

(1)

\[
d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \quad (2)
\]

Where \( E_{elec} \) is energy consumed to transmit or receive a bit, \( E_{fs} \) is transmitter amplifier energy for free-space, \( E_{mp} \) is transmitter amplifier energy for multi-path. While receiving ‘l’ bits, radio consumes energy is calculated as follow

\[
E_{rx}(K) = k * E_{elec}
\]

(3)

4. Proposed scheme
This Clustering scheme configures clusters in every round same as others schemes. The process is divided into two phases such as cluster formation phase and data transmission phase.

4.1 Cluster formation phase
Most of cluster mechanism select the cluster head either randomly without considered important parameters or based on centralized approach by utilizing the base station which can affect the network scalability. Subsequently, distributed cluster head mechanism is utilized that able to reduce the network overheads where nodes only require exchanging its local information with their neighbors in order to calculate their weights. In this scheme, nodes compute their score using weighted parameters, which incorporate the residual energy of nodes and the number of their neighbors. In addition, equation 4 show that the node with highest candidate weight, it is suitable candidate to be elected as CH.

\[
\text{Candidate weight} = E_{resd} + \text{No. of neighbours}
\]

(4)

In this scheme, nodes keep track of their residual energy levels as nodes with sufficient energy resources will be considered for CH selection. Secondly, each node counts the number of its neighbors and the node with highest number of neighbors represents the optimal position inside the cluster. Once, the residual energy and number of neighbors are determined. These values are summed up in weighted form to estimate candidate weight for CH selection.
4.2 Data transmission phase

In order to reduce energy consumption in large scale network multi-hop is employed between CHs nodes. As CHs which located faraway from BS drain out their energy quickly where energy consumption lineally increases as transmission distance increases therefore, multi hop is used for between CHs node which can reduce the energy consumption for data transmission. However, in this scheme, CH selects one of the CHs as relay node according to several parameters that should be considered in the selection of next relay node. To optimize data forwarding, each CH sends a route message to its upper CHs. This message contains the residual energy and number of member nodes of its cluster. By compromising these parameters with distance from the CHs, relay cost is calculated that can reduce energy consumption in data transmission and provide load balancing in WSN. In the relay cost, CH si would choose CH sj as relay node, if its remaining energy is the largest value and have least cluster member nodes and nearest to it. The relay cost is calculated as shown in equation (5) below

\[
\text{Relay Cost} = \frac{\text{distCHij} + \text{No.ofmembernodes}}{\text{Eresd}}.
\]

5. Simulation results and discussion

A simulation of the proposed approach was performed, and two parameters used to evaluate the performance of the proposed work, including number of alive sensor nodes and energy consumed. Also, the performance of proposed work is compared with LEACH. The parameters used for the simulation are given in Table 1.

| Parameter       | Value                  |
|-----------------|------------------------|
| Sensor field    | 100 x100               |
| BS location     | (150, 50)              |
| Number of nodes | 100                    |
| Initial energy  | 2 J                    |
| \(E_{\text{elec}}\) | 50 nJ/bit          |
| \(E_{\text{fs}}\) | 10 pJ/(bit m²)        |
| \(E_{\text{amp}}\) | 0.0013 pJ/(bit m⁴)  |

Figure 1. Energy consumed vs number of rounds
Fig 1 and Fig 2 show that the proposed work outperform LEACH in term of energy consumption and number of alive sensor nodes. The reason behind this is better selection and positioning of the cluster heads. Proposed work is simple and it consider different parameter for cluster head selection and the relay node through multi-hop approach such as remaining energy, number of neighbour nodes and distance between CHs and number of member nodes in the cluster which in turn enhances the network lifetime.

6. Conclusion
In this paper, we proposed an energy efficient and load balancing clustering scheme based on distributed approach both residual energy and number of neighbours are considered in order to optimize the process of cluster head election and the process of datatransmission of network with lesser overheads. This makes the node with more residual energy and has high degree of neighbour nodes in the network has greater potential to be selected as cluster heads. In the data transmission phase, multi-hop data transmission is employed between CHs to avoid the direct communication between CHs and the base station. The results of simulation indicate that the proposed scheme reduces the energy consumption, prolongs the network lifetime, and has a better performance than the original LEACH protocol.

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