Analysis on Distinct Protocols in the Wireless Sensor Networks for Energy Efficiency

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Abstract : Wireless Sensor networks has diverted a lot of attention due to its advantages in surveillance, vibration monitoring, temperature, intruder detection, environment monitoring, health care and safety. The main issue that arises in the wireless sensor networks is energy efficiency. The nodes have limited lifetime and the replacement of nodes has high initial and deployment cost. So, we compare the protocols that have maximum energy efficiency, large coverage area, load balancing and works in heterogeneous networks. Various parameters are compared such as performance analysis, lifetime, throughput, energy latency. The result shows that which protocol is good for the specified factors in wireless sensor network.

Keywords : Cluster head,wireless sensor network,base station, Energy Efficiency.

1. INTRODUCTION

Wireless sensor networks [8] consist of small nodes which have the capability of computation, sensing, data processing. These small nodes are called sensor nodes; sensor nodes have the capability to locate their own position using GPS. The requisite working of the wireless sensor network is that the nodes aggregate the data, perform certain actions and send it to the sink. The wireless sensor network has several advantages such as low cost sensor nodes able to monitor the entire network and deal with the harsh climatic conditions too.
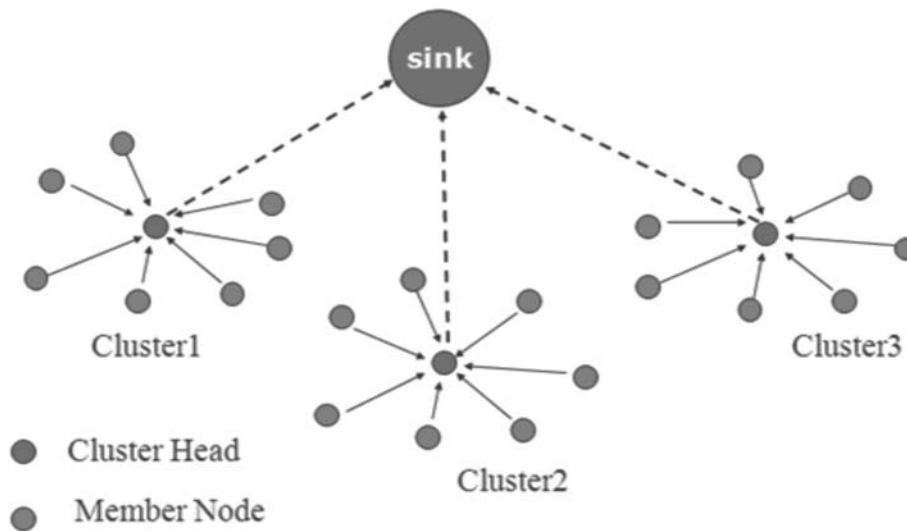

Fig. 1. Wireless Sensor Model.

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The main issuein the entire procedure is the vitality utilization by the sensor nodes [13] as it has restricted battery life. Once the arrangement of the system is done it is extremely hard to supplant the sensor nodes or to supplant the depleted batteries. The minimum consumption of the power will prompt to the extension of the lifetime of the wireless sensor network.

To solve this issue we can use the clustering concept which defines that nodes cluster and synchronizes themselves in the form of clusters and one node acts like a cluster head. The cluster heads aggregate the data and forward it to the sink. Clustering therefore is effective way to increase the energy efficiency. Load balancing done effectively in clustering protocol can therefore increases the energy efficiency and extends the network lifetime.

2. PROTOCOL ALGORITHMS

2.1. Leach

Leach [14] is the hierarchical TDMA, MAC protocol in which most nodes transmit to the cluster heads and CH aggregates, compresses and forwards the data to the base station. Leach assumes that each node has much energy to directly communicate to the sink directly but due to the varied distance, high energy consumption the nodes die at faster rate and arousal of the energy optimization problem.

Leach includes distributed cluster formation, local processing to reduce global communication and randomized rotation of cluster heads with each node having p probability to become CH. For becoming the cluster head in the leach [9] protocol it has to undergo the following procedure. For each node n, it has to choose a random number between 0 to 1.The threshold is determined at:

$$T(n) \ = \ \frac{P}{1 - P*(r \bmod \ 1\% \ P)}, n \in G$$

$$T(n) \ = \ 0, \text{Otherwise}$$

If the number chosen is less than the threshold, then it will be selected as the cluster head. No. of rounds is represented by 'r'. Nodes which have not been cluster heads in last 1/p rounds are categorized under 'G'. Nodes which have already become the cluster head in previous rounds have very less chance of being elected as the cluster head. Its working is defined into rounds and each round has two main phases:

   1. Set-up Phase   2. Steady Phase

In the Setup Phase, formation of cluster and election of cluster head is done. In the Steady Phase, the data transfer from the cluster head to the base station is performed. Leach has the ability to perform local aggregation in clusters which reduces the amount of data required to reach BS leading to less energy consumption.

2.2. Peer

In this section, we discuss the peer protocol [6] where the peer stands for Pairs Energy Efficient Routing Protocol (PEER) in which we use the dual power management. The dual power mechanism consists of two energy levels that are high energy level and low energy level. High energy level nodes transmit the data from node to sink and low energy nodes transmit data to its partner. There are 3 phases of the protocol:

   1. Joining phase

   2. Transmission Phase

   3. Changing Pair Phase

   1. Joining Phase : The node tries to form a pair with the other node by using the following mechanism.

      After forming the pair, they work as peer to peer and first will send data packet using high energy level and second at low energy level.
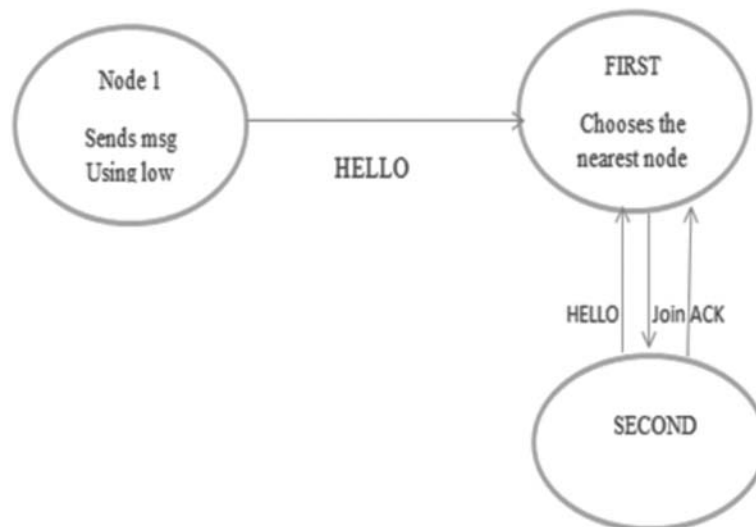
Fig. 2. Working of transmission Phase

2. **Transmission Phase :** In this phase, the data is being sent to the sink or towards the sink if sink is at distance from the node. There are different tasks done by sink, high node (which has high energy level), low node (which has low energy level) individual nodes (which do not form a pair in joining phase)

2.1. Sink task

- Turn on its receiver, listen and process the data.
- Send control messages to know the location with the routing table frequent updates retrieved from sensor nodes.
- Send control messages to confirm that the data should be send continuously or on intervals based on inquiries only.
- Low node tasks
- Turn off its receiver until it becomes high node
- If the reading changes to the previous reading. Send the updated reading to high node and set flag to high node and turn on its receiver.
- The low node becomes high node according to the reply of the high node it informs the updated routing table, changes of regions and inquires.
- Notify high node with the death of the low node when energy decreases to minimum level of energy.
- High node tasks
- Turn on its receiver
- If it receives the data from its partner, it accumulates its reading with the low node reading, process and sends the data waiting for some delay period.
- If in the same region the data message is listened from high node, it compares with its own data, if both are equal, discard its own data
- From different region, it checks its routing table to whether forward the message towards sink or not. Forwarding includes aggregation of coming and its own data and informing about the change of roles
- Individual node task
- High node tasks are formulated and if one node of an old pair is dead, it sends hello messages to another node to form a pair
3. **Changing Pair Phase :** When one node is dead in the pair, other node looks for a pair. It sends the hello message to its neighbor or another node which has also lost its pair and waiting for the join message from an individual node.

Advantage : This protocol results in increment of sensor nodes and enlarging the area of deployment.

2.3. EELBC

In this section we will discuss about the EELBC algorithm for WSN.EELBC [3] stands for energy efficient load balancing clustering. Clustering is an effective technique for maintaining the energy level. We consider two kinds of nodes – sensor nodes and cluster heads. The network setup includes the bootstrapping and clustering.

- In Bootstrapping, all the sensor nodes and gateways are assigned unique ids. Sensor nodes broadcast their location and Id's to the gateways within the communication range to calculate the distance from sensor nodes to all the gateways.
- In clustering phase, sink performs clustering and all the sensors are informed about their id's of the gateway they belong depending upon the communication range between the sensor node and gateways , two types of sensor nodes in the system exist
    1. Restricted node – It communicated only with one gateway.
    2. Open node – They communicate with more than one gateway node.

Algorithm :
1. Assignment of restricted nodes to their corresponding gateway
2. Built a Min heap using the gateways
3. Gateway1 has been assigned by the minimum number of sensor nodes
4. If restricted set is not equal to null
    - Assign the successive sensor nodes S_i to the corresponding gateway G_j such that S_i belongs to the restricted set and gateway of set j is within the communication range
    - Delete S_i from restricted set and set of sensors
5. Build a min heap from the number of allotted nodes to gateways
6. While the set of sensor nodes is not equal to null
    - Take the root node of the Min heap (G_j)
    - Select and assign the open sensor node to G_j such that G_j belongs to the communication range of sensor node set and sensor node Si is the nearest sensor node to G_j.
    - Delete Si from sensor node set
    - Adjust the min heap in such a way that minimum loaded gateway will be present at the root node
7. Exit on completion of the algorithm

Here the gateways are treated as cluster heads. With the selection CH, EELBC takes care of load balancing and energy efficiency.

4.1. BEENISH

BEENISH stands for balanced energy efficient network integrated super heterogeneous protocol .In BEENISH [4], the selection of cluster head is done on the basis of residual energy level of the nodes with respect to average energy of the network. BEENISH uses the concept of 4 types of nodes – normal node, advance node, super node, and ultra-super node.

Let Ni shows the round for a node Si to become CH; we refer it as rotating epoch. In the homogeneous networks, every node in the sensor node set is given a chance to become the cluster head. In BEENISH, high energy nodes (ultra-super nodes) are often selected as cluster head and energy consumed by all the nodes are same. According to its working, all nodes will die at the same time. The threshold is calculated for each level of node which has different probability. The equation will be:

- If S_i is the normal node

$$P_i = \frac{P_{opt}E_i(r)}{(1 + m(a + m_0(-a + b + m_1(-b + u))))E(r)}$$

- If S_i is the advanced node

$$P_i = \frac{P_{opt}(1 + a)E_i(r)}{(1 + m(a + m_0(-a + b + m_1(-b + u))))E(r)}$$

- If S_i is the super node

$$P_i = \frac{P_{opt}(1 + b)E_i(r)}{(1 + m(a + m_0(-a + b + m_1(-b + u))))E(r)}$$

- If S_i is the ultra-super node

$$P_i = \frac{P_{opt}(1 + u)E_i(r)}{(1 + m(a + m_0(-a + b + m_1(-b + u))))E(r)}$$

The value of theis placed in threshold equation:

$$T(S_i) = 0 \quad \frac{T(S_i) = P_i \text{ if } S_i \in G}{1 - P_i * (r \bmod 1/P_i)} \text{ , Otherwise}$$

From the equation we find the nodes with the greater residual energy. The aim of this mechanism is to efficiently divide the energy consumption in the network and extend the stability period for heterogeneous networks.

5.1. Clustering routing protocol based on genetic clustering algorithm:

This algorithm[5] combines the fuzzy c-means clustering and genetic algorithm which overcomes the sensitivity of the initial value of FCM, balances the energy cost and increases the network lifetime efficiently. Certain conditions needs to be followed:-

- Position of the nodes should be known with the help of positioning function
- Nodes should be static, same status of energy and perform full duplex communication.

The protocol uses FCM to divide the network into clusters and select the cluster head and the CH send the data to sink after data fusion. After certain amount of time, CH is reselected according to the surplus energy situation and nearest rule in distance. Clustering Protocol used by the protocol is based on fuzzy logic.

Certain assumptions : All nodes have same energy and BS knows the size of network, energy value and the initial number of nodes. Beacon signal consists of information such as initial energy, number of nodes and network dimension of the network. All the sensor nodes apply same procedure to determine the number of neighbor nodes. The algorithm is implemented in several rounds and neighbor information is updated at the beginning.
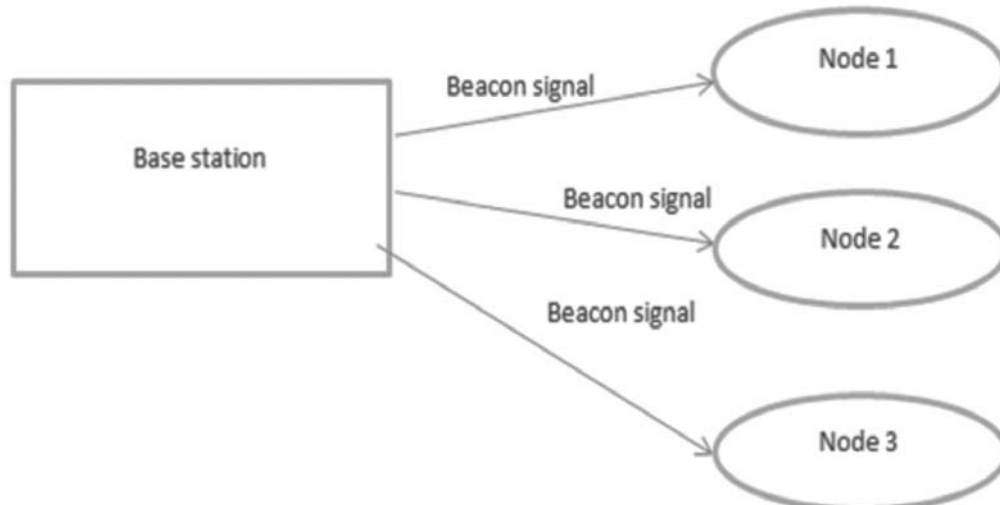

Fig. 3. Working of clustering algorithm for fuzzy logic.

Each node calculates its chance of becoming the cluster head by fuzzy logic [7] which merges the local information of nodes including residual energy, local density and node centrality. Node with greater chance has low delay time. The protocol results in high coverage ratio, low number of orphan nodes and low energy consumption that increases the network lifetime.

6.1. Cluster Head Selection using fuzzy logic in wireless sensor networks

The selection of the cluster head [2] is done with the help of the 3 main parameters which are stated as:

1. Node energy: Describes the total energy which is accumulated in the node
2. Node Centrality: Describes the central location of the cluster node
3. Node Concentration: Describes the total number of nodes in surrounded area

The node centrality can be calculated with the help of base station. The base station calculates the sum of the squared distance of the selected node to every node present in the clusters. The lower value of the centrality leads to the low transmission power required for the process. The usages of the linguistic variables are done which describes the values into certain ranges.The ranges of the linguistic variables can be defined as close, far and adequate for centrality parameter. For energy and concentration parameters it would be high, medium and low.

The working process can be explained as :

- If the energy is high, concentration is low and centrality is close then, the chances of becoming the cluster head are very high.
- If the energy is low, concentration is high and centrality is far then, the chances of the node for becoming the cluster head are precisely very low.

The protocol includes the efficient cluster head selection based on 3 parameters and the efficient cluster head selection leads to less energy consumption as efficient working protocol in WSN using fuzzy logic[7].The two – level fuzzy logic [18] defines the global and local level which enhances the lifetime of the network.

7.1. ME-LEACH

For the efficient cluster based scheme, different architectures are proposed such as : LEACH [2], LEACH-C[16] is a centralized clustering algorithm and cluster heads are elected by base station where each node sends its current position and energy level residing in the node. It gives the surety that desired number of clusters are obtained and evenly distributed among the nodes existing in the network .Lifetime, startup energy dissipation, data signals received at base station will be more compared to the LEACH[10] protocol. Total energy dissipation will be less than the LEACH protocol. SLEACH[17] is the stochastic LEACH[11] which outperforms the leach protocols by selecting the minimum value or maximum value in the area that is it selects the most appropriate data and sends their message to the cluster head .V-leach is also a modified version of the Leach protocol in which besides having the cluster head it includes the vice cluster head which replaces the position of cluster head on its termination and no requirement of electing the new cluster head each time.

It is extension of the LEACH protocol by modifying it on the parameter of selecting the cluster head based on the remaining energy level of sensor nodes needed for the transmission. The extended protocol defines to further reduce and balance the total energy dissipation of sensors.

This Model proposes certain assumptions such as:

1. Immobile sensor nodes
2. Base station is fixed and all nodes are reachable to the base station
3. Sensor nodes are homogeneous with equal energy level
4. Symmetric propagation channel

The random selection of the cluster head in LEACH [9] protocol leads to the unbalanced energy level. It also increases the total energy dissipation. The two main problems are its inability to cover the large area and when the cluster head is located far from the base station it spends more energy in forwarding the data packet. The extended protocol ensures an even energy load distribution over the entire network by including the additional parameter of node's remaining energy. The threshold equation is altered with the inclusion of the additional parameter can be described as:

$$T(n) = \frac{P.\,E_{residual}\,K_{opt}}{1 - P*(r.\,\mathrm{mod}\,1/P)\,E_{initial}}$$

Where $E_{initial}$ is the initial energy before the transmission, $E_{residual}$ is the residual energy of the node, 'r' number of rounds and p is the probability of becoming the cluster head. Kopt can be calculated by:

$$K_{opt} = \frac{\sqrt{N}\,\sqrt{\in_{fs}}\,M}{\sqrt{2\pi}\,\sqrt{\in_{mp}}\,d_{tobs}^2}$$

Where K_{opt} is the optimal cluster head number, N is total number of sensor nodes, M is the length of nodes and d^2_{tobs} is the distance between nodes and the sink.

The modified version of the LEACH[1] has the drawback that after several numbers of rounds, the network is stuck.In spite of the presence of several nodes with sufficient energy which can transmit the data to the base station. This problem occurs due the low value of the threshold which satisfies the low energy constraint leading to fault in network. So the threshold equation is further modified in:

$$T(n) = \frac{PE_{residual} + r_s\,\mathrm{div}(1/p)*[1 - E_{residual}]}{1 - P*(r\,\mathrm{mod}\,1\%\,P)E_{initial}}$$

The modified threshold equation only increases the threshold value for the node which has not been the cluster head in last 1/p rounds. Where r_s is the number of consecutive rounds in G. When r_s reach to the 1/p the value of new threshold is reset to the previous value which was before the inclusion of the remaining energy leading to the higher value of the threshold. The value of r_s is reset to zero if node is selected as cluster head. This solves the network issue and transmission of data from the cluster head to the base station is done as long as the node is alive. The protocol leads to better energy efficiency and load balancing issue is resolved.

3. OUTCOME OF ANALYSIS

Approach Used Author Advantage Future Work LEACH M. J. HandyAbility to perform local aggregation in clusters which reduces the amount of data required to reach BS leading to less energy consumptionTo reduce the extra overhead due to dynamic clustering**PEER**Maher ElshakankiriIncrement of sensor nodes and enlarging the area of deploymentIt could not be used in data gathering applications as degradation in the performance of the protocol **EELBC** Pratyay KuilabEELBC takes care of load balancing and energy efficiency.Development of energy efficient clustering and load balancing with variable loads of the sensor nodes for the WSN **BEENISH**T. N. QureshiEfficiently divide the energy consumption in the network and extend the stability period in heterogeneous networksReduce the energy loss due to signal collision and interference **ME-LEACH** Ma Chaw Mon TheinIt further reduces and balances the total energy dissipation of sensors.Network at times stuck after certain number of rounds and delay in using the threshold equation **Genetic Algorithm** Shijun heHigh coverage ratio, low number of orphan nodes and low energy consumption that increases the network lifetime.The mobile nodes support for the wireless sensor networks.**Fuzzy Logic** Maryam mirsadeghi Efficient cluster head selection leads to less energy consumptionUsing both local informationand global information

Table 1. Comparative analysis

Approach Used	Author	Advantage	Future Work
LEACH	M. J. Handy	Ability to perform local aggregation in clusters which reduces the amount of data required to reach BS leading to less energy consumption	To reduce the extra overhead due to dynamic clustering
PEER	Maher Elshakankiri	Increment of sensor nodes and enlarging the area of deployment	It could not be used in data gathering applications as degradation in the performance of the protocol
EELBC	Pratyay Kuilab	EELBC takes care of load balancing and energy efficiency.	Development of energy efficient clustering and load balancing with variable loads of the sensor nodes for the WSN
BEENISH	T. N. Qureshi	Efficiently divide the energy consumption in the network and extend the stability period in heterogeneous networks	Reduce the energy loss due to signal collision and interference
ME-LEACH	Ma Chaw Mon Thein	It further reduces and balances the total energy dissipation of sensors.	Network at times stuck after certain number of rounds and delay in using the threshold equation
Genetic Algorithm	Shijun he	High coverage ratio, low number of orphan nodes and low energy consumption that increases the network lifetime.	The mobile nodes support for the wireless sensor networks.
Fuzzy Logic	Maryam mirsadeghi	Efficient cluster head selection leads to less energy consumption	Using both local information and global information

4. CONCLUSION

One of the major challenges in the Wireless sensor networks is the energy efficiency and lifetime of the network. The problem of the energy efficiency is solved by efficient cluster head selection, reducing the load balance, prolonging the network lifetime by various techniques using fuzzy logic, genetic algorithm, including additional parameters. The heterogeneous [4] and homogenous networks are handled using different approaches. The future work will comprise of the additional parameters studied on various approaches, topologies [12], protocols [15] and doing the comparative study on that basis for the determination of the optimum energy efficient protocol.

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