Chain of Clusters for Improving Network Lifetime of Sensor Network

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Abstract: **In wireless sensor network increasing life time of sensor node and there by network is the main motive for development of a protocol for the sensor network. LEACH (Low Energy Adaptive Clustering Hierarchy) is an energy-efficient hierarchical protocol that balances the energy consumption, saves the node energy as compared to flat communication protocols and hence prolongs the lifetime of the network. Here, we planned a new hierarchical cluster based protocol for varied sensor networks. Instead of selecting the cluster head randomly, we include chain forming concept of PEGASIS (Power Efficient Gathering in Sensor Information System). In our work we consider heterogeneous nodes. Unlike LEACH, proposed protocol uses the selection criteria for Cluster-Head depending on the residual energy of the nodes and relative distance of cluster heads. A chain of Cluster Head will be formed using chain formation technique of PEGASIS protocol. Successful implementation of data aggregation has reduced the energy-consumption.**

Keywords: **Energy efficiency, chain formation, LEACH protocol, PEGASIS protocol, Heterogeneous wireless network, Data aggregation.**

I. INTRODUCTION

Wireless sensor networks (WSNs), are generally used for monitoring some phenomena or certain parameters. They are generally formed with ample number of small, resource constrained, sensing nodes which are spread either with some criteria or randomly in a geographical area of interest. Sensing data and communicating them to the data collecting sink are major operations taking place. But major component for success of the wireless sensor network applications is the way of communication among the sensor nodes. This is because more energy of the energy restricted nodes gets drained for communication in comparison with energy consumed in computation or processing the information collected. So for designing any wireless sensing application one has to keep in mind the critical parameter of energy utilization in the network. Delivery of data in a specific time slot is again very essential for the successful task completion of nodes that's why routing parameters are essential. Routing path of the data in WSN determines how data hops from node to node in order to reach the destination when the destination is not directly reachable from the source node. If source and destination nodes are at a shorter distance ($d<d_0$, where d_0 is a cross over distance) then communication energy required is less and is in proportion to d^2, where as if the distance is more than d_0 then more energy is consumed and is in proportion to d^4. So if long distance communication is done frequently node battery will drain quickly. Efforts are being taken to reduce this communication power and boost the life of the nodes in the network so that they can serve the purpose for longer time. Such energy efficient wireless sensor network applications are highly demanded, for different scenarios.

The forthcoming paper is divided in following sections. Part 2 will discuss about LEACH protocol and PEGASIS protocols. In section 3, discussion about proposed protocol and radio energy model is done. Section 4 will tell about results of proposed method in comparison with LEACH and PEGASIS protocol. Lastly in section 5conclusion and future scope of proposed method are discussed.

II. RELATED WORKS

Protocols have been developed for communication purpose in WSN since its inception. Earlier Direct Transmission, Minimum Energy Transmission (MTE) protocols were used, which are considered as flat routing. W.R.Heinzelman then added a milestone to these protocols with design of LEACH protocol [1]. In the cluster based approach given by LEACH, considerable energy saving was achieved when the base station is distant as compared to the sensor nodes deployment. Lot of work is done on this protocol and various enhancements are available. Chandrashekharan provided another concept of chain based communication, which outperformed as compared to LEACH. But certain limitations were there. In this section we discuss about these protocols in brief.

A. The LEACH protocol

LEACH protocol is proposed by W.R. Heinzelman [1]. LEACH i.e. Low Energy Adaptive Cluster Hierarchy, is hierarchical clustering protocol. It is self organized protocol and nodes are divided in clusters for sharing information to base station via cluster head (CH). The idea of hierarchical routing approach provided in LEACH is an inspiration, an anchor for development of many other hierarchical protocols, although some of them are having novice idea and are developed independently [2]. This protocol assumes that all the nodes have equal initial energy, E_0, they are homogeneous in nature and they are randomly placed in the

sensor field. It includes two operations performed in each round of working, namely setup and steady state operation. Clusters of nodes are formed in first phase- setup, where, a part of nodes, P, which is predetermined, elect themselves as CHs as follows.

Here, a random number r, between 0 and 1is selected by the sensor node. T(n), a threshold value, is considered as given in below mentioned Eq.1. If r is less than T(n), then this node declares itself as CH for present round. The threshold value depends upon the expected percentage P, for number of CH in present round. Only that set of nodes can become a CH that has not yet become CH in the previous (1/P) rounds. Such nodes which are involved in cluster head selection [14], are denoted by set G. This T(n) is calculated by:

$$T(n) = P/(1-P(r \bmod (1/P)), \text{ if } n \epsilon G \quad (1)$$

In the current epoch T(n) value is zero for the nodes who have been the cluster heads in subsequent rounds. Each CH elected transmits an announcement message to other nodes in the network about their role as the new cluster-heads. Other Non-CH nodes select the nearest CH and join that respective cluster as a member. CHs create and broadcast a TDMA plan for their associate nodes for data transmission so that collisions are avoided.

During the steady state phase actual work of the sensor nodes begins. They sense and transmit the data to the cluster-heads. The cluster head receives the data from members and aggregates it to reduce the size, before sending it to the sink and then transmits this data. This data compaction will reduce the communication energy needed during transmission.

In the next round again the setup and steady state operations are repeated.

B. The PEGASIS protocol

PEGASIS i.e. Power-Efficient Gathering in Sensor Information Systems (PEGASIS) protocol is proposed by S. Lindsey and C. S. Raghavendra [2]. This is chain based protocol in which each node in network will form a chain and can only communicate with their adjacent node. Each node finds its closest node with the help of signal strength received.

In this, main communicating node, the leader, is chosen based on energy remained with the nodes. Leader will be responsible for gathering data from each node in chain and then sending that data to BS. PEGASIS does not form cluster and uses only leader node for communicating with sink. This will reduce overhead of cluster head selection as well as the bandwidth needed in messaging.

But drawback with LEACH and PEGASIS is that, In LEACH there is no certainty about cluster head selection since CH is selected randomly. In PEGASIS, it may be possible that leader that is responsible for sending network information to BS, will be located at some point which far from BS. So, leader may consume more energy for sending information from longer distance to BS. These two major drawbacks of LEACH and PEGASIS are overcome in our proposed method.

III. THE PROPOSED PROTOCOL

The proposed protocol uses the advantages of the clustering mechanism of improved LEACH protocol and chain formation technique of PEGASIS protocol. The protocol results in improved life of sensor node which ultimately increases lifetime of network. In this section we will discuss the details of our protocol. Unlike LEACH, proposed protocol uses heterogeneous nodes in the network; also cluster heads are selected on basis of residual energy of nodes. In basic LEACH, selection of CH is depends upon the probability function but this criteria is useful only if energy of nodes in the network is uniform. Second most important issue in LEACH is that, there is no certainty about whether the CHs are distributed uniformly in network or not. This problem of LEACH is resolved by forming clusters according to the distances of nodes along the x-axis.

Secondly, in PEGASIS all nodes have probability to become leader node for a particular round. Therefore there are chances that node selected as leader node for that round may not have sufficient amount of energy to survive in the network for longer time. If the leader node dies then no communication can be done with the base station and results in breakage of network. Also there are chances that selected leader node is located far away from a base station. Therefore, time and energy dissipation for sending network data to base station is high. This issue of PEGASIS protocol is resolved by selecting a leader node which will have maximum amount of energy and which is located nearer to the base station. Only this last leader node will be communicating with the base station.

A. Working of protocol

The heterogeneous nodes are deployed randomly in the sensor field and groups are formed by arranging sensor nodes according to x-axis at some fixed point in the network area. This process leads to the formation of clusters in network along x- direction. After creating clusters, energy of each sensor node of cluster is calculated and two nodes with highest energy are selected. First node with the highest energy is the CH node and second highest energy node is stand by CH. If first cluster head dies then sensor node with second highest energy i.e. stand by CH will act as CH. Once this clustering is over, formation of chain between CHs of neighbouring clusters is done. All the sensor nodes of cluster will send their information to the respective CH of the cluster. Then selected CH will perform aggregation of this information and forward this to the CH of neighbouring cluster. CH of neighbouring cluster will add this received information with its own cluster's information and then again it will carry forward this whole information to the next neighbouring CH of cluster. This process will continue till information of every cluster will reaches to the CH of last cluster of the network. Now, this CH will aggregate this whole information in small but meaningful message and send it to the base station. CH of last cluster is selected so that distance between this CH and base station is minimum. Following Fig.1 shows the entire process of clustering and chain formation between CHs.

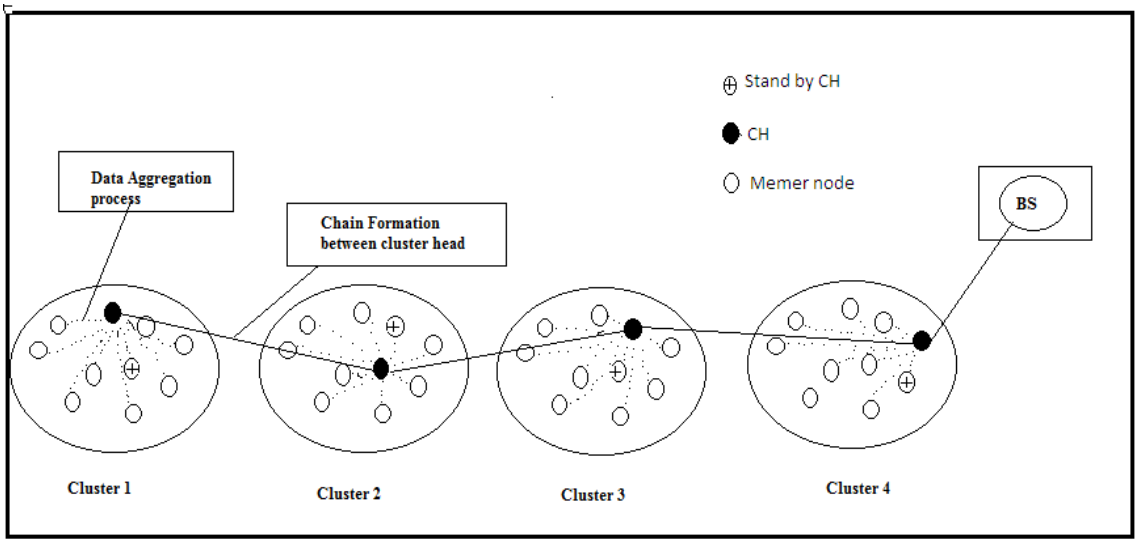

Fig. 1. Cluster and chain formation of nodes.

B. Radio and energy model

In the proposed method the nodes are communicating to their neighbouring nodes, so long distance communications are avoided. Radio models for a distance less than cross-over distance and for distance greater than cross-over distance are projected by W.R. Heinzelman [1], that are used here.

In our protocol d^2 path loss model is utilized for data transmission, since the nodes communicate the data to their CH in close vicinity. Transmission and reception costs for message with k bits over a distance d are as given in Eq. 2 and Eq. 3.

Cost for Transmission:

$$ET_x(k,d) = E_{elec}*k + E_{amp}*k*d^2, \quad if\ d < d0 \qquad (2)$$

Cost for Reception:

$$ER_x(k) = E_{elec}*k \qquad (3)$$

In the equations, d is path-loss exponent depending on distance between source and destination. Here it has been taken of order d^2 for experimentation. Again k, the number of bits transmitted and received should be less because high amount of energy is spent in transmission and reception of data in comparison data processing. Long distance communication may take place only between the leaders and sink node if it is placed beyond the cross-over limit in the network. The network scenario used is given in the next section.

C. Network parameters

The proposed protocol has been simulated in one of the most popular and appropriate Network simulator i.e. NS2, version ns2.35. In the scenario considered there are total 40 nodes in network which are placed randomly in the area 1300 X 1000 meters. Each node has different initial energy as the nodes are of heterogeneous type. Initial energies of the nodes are also assigned randomly, indicating values between 0 and 1000. Energy dissipation during data communication is dependent on distance between the source and sink node. Therefore the energies of the nodes will always be different, keeping the nodes heterogeneous. Table I below lists the simulation parameters considered.

TABLE I: NS2 SIMULATION PARAMETERS

Parameter	Value
Network Size (x, y)	1300*1000
Transmission Power	2.0W
Receiving Power	1.0W
Ideal Power	1.0W
No. of nodes	40
Packet size	1000bits
Base Station location	1400*1100

Fig. 2 shows the placement of nodes in the network area. Clusters are formed according to x-distances of the nodes. Node 40 is the sink node. From each cluster two nodes will be selected as cluster head having maximum residual energy among all nodes in cluster. As shown in Fig. 2, node contains in square and hexagon is the cluster heads of respective cluster. Base station node is shown in green color circle contain in red square box.

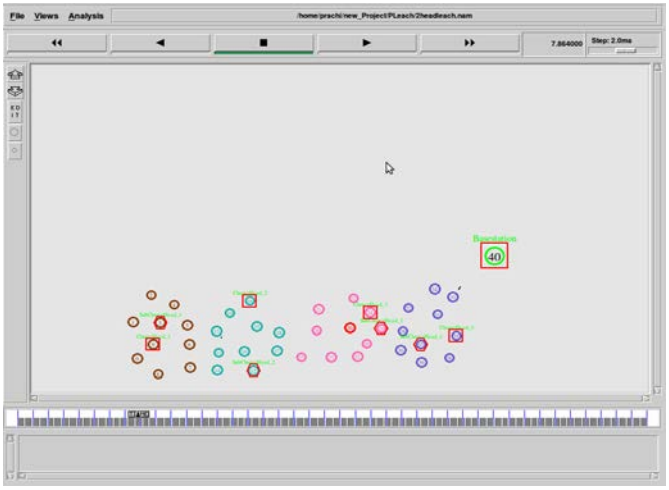

Fig. 2. Deployment of nodes.

Energy of each node is compared and node with highest energy is chosen as the cluster head. Second highest energy node is selected as deputy cluster head. This node will take over the functionality of cluster head when present CH goes down. `Fig .3 below shows selection of CH depending upon the energy level of the nodes in a cluster.

```
prachi@prachi-VirtualBox: ~/new_Project/PLeach
num_nodes is set 40
warning: Please use -channel as shown in tcl/ex/wireless-mitf.tcl
INITIALIZE THE LIST xListHead
Node 0 energy 100.000000
Node 1 energy 916.399840
Node 2 energy 932.106862
Node 3 energy 920.026492
Node 4 energy 885.248095
Node 5 energy 364.736184
Node 6 energy 121.039720
Node 7 energy 314.579225
Node 8 energy 133.039479
Node 9 energy 994.519187
Max energies 994.519187 Node numbers 9
```

Fig. 3. Cluster Head selection.

IV. Results and Discussion

The network consisting of 40 heterogeneous nodes, deployed in an area of 1300 X 1000 and a base station located at 1400 X 1100, is considered for simulation purpose. 7 rounds are simulated here. Three protocols are considered here namely LEACH, PEGASIS and ours P-LEACH. The comparative results are discussed in this section. We considered energy consumption per round, mean delay per round and packet delivery ratio as the parameters for comparison.

A. *Energy consumption*

Energy consumption of the nodes depends on two tasks, i.e. communication and computation. Major energy is spent during communication, as its an energy intensive task. As compared to communication computation energy requirement is very very small. In this section, we will discuss about energy consumption in proposed protocol in comparison with LEACH and PEGASIS protocol.

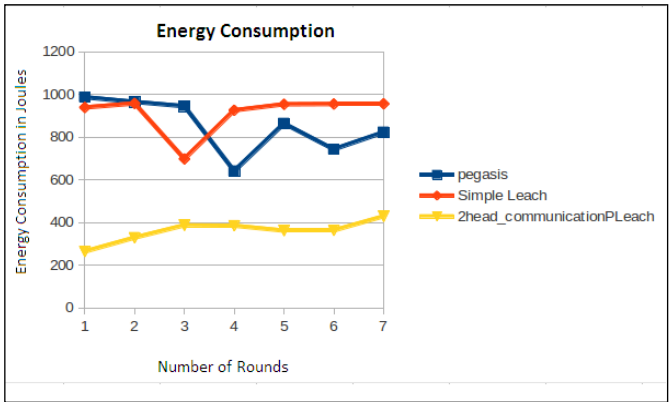

Fig. 4. Energy consumption in proposed method.

In the above Fig. 4 energy consumption in proposed P-LEACH protocol, LEACH and PEGASIS is calculated. As shown in figure, yellow line indicates energy consumption in proposed method, red and blue line indicates energy consumption in LEACH and PEGASIS protocols respectively. From the graph it is clear that energy consumption in our proposed protocol is less as comapre to LEACH and PEGASIS.This result is obtain by using same parameters for all three protocols. In case of LEACH direct communication to base station by each CH consumes more energy and cluster formation also consumes overhead energy. In PEGASIS leader node may be at a longer distance from BS, that consumes more energy. In case of proposed method, energy requirement for communication between nodes is less because CH selected will have maximun residual energy and distance between adjacent CH nodes is very less as compare to other protocols.

B. *Packet delivery ratio (PDR)*

Following Fig. 5 shows comparison of proposed method, LEACH protocol and PEGASIS protocol.

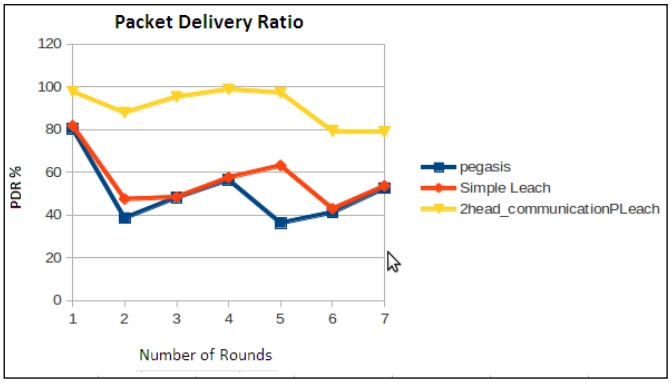

Fig. 5. Packet Delivery Ratio in communication.

In above graph,yellow line indicates the PDR in proposed method. Red and blue line indicates PDR in simpleleach and PEGASIS protocol respectivly. Graph clearly indicates that in proposed method packet delivery ratio is more as compaire to other two protocol. In this we have taken the interval 0.3-0.5sec to send packet from one node to anothet node. PDR in proposed protocol is coming out to be in the range of 80-100 which is good enough for network to become efficient network.

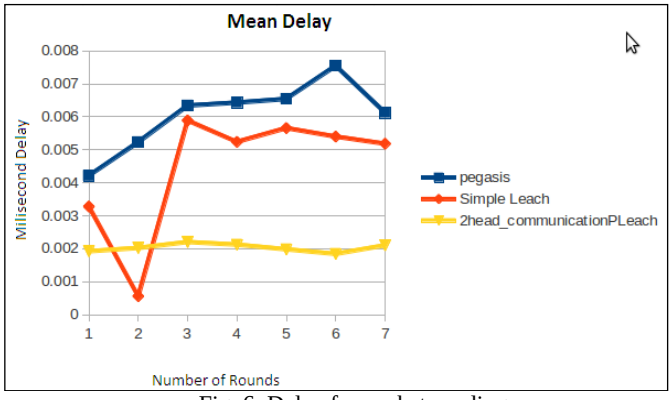

Fig. 6. Delay for packet sending.

Above Fig: 6 shows delay in the network. Yellow line indicates delay in proposed method where as red and blue lines indicate delay in LEACH and PEGASIS protocol repectivly. As shown in figure, in proposed method dealy is very less and it is in the range of 0.001msec to 0.002msec where as in case of LEACH and PEGASIS this delay vary in the range of 0.003msec to 0.0075msec. This result shows that delay in proposed method is very less in comparison with other two protcols which proves that network established using this protocol will be a very efficient network. Above discussed observations show that poposed method gives better result in terms of energy, packet delivery ratio and dealy. Also number of dead nodes in proposed method is less as compared to LEACH and PEGASIS protocol.

V. CONCLUSIONS

The proposed method Improved P-LEACH protocol has been proven to produce a better result as compared to prior protocols such as LEACH and PEGASIS in WSN. Following are the key points which prove that proposed method is better as compare to LEACH and PEGASIS protocol.

Minimum energy consumption: In this protocol, energy required for communication between nodes is very less which results in improving network lifetime and network stability.

Less PDR: Packet delivery ratio is one of measure of judging network efficiency in WSN .In proposed method PDR is communing out to be 97.77% .Which means that there is very less packet drop while node communicates with each other. This results shows that there is less congestion in network which results in improving network efficiency.

Less Delay: In WSN, the network which has minimum delay that network will consider as more efficient network. Because, it takes less time to send packet from source to destination. In proposed protocol, delay is near about 0.009sec, which is less as compare to other two protocols. This shows that node takes minimum time to send packet from source to destination. This results in fast communication between nodes and minimum packet drop. Due to this network lifetime get increase.

Number of Dead Nodes: Dead nodes are responsible for breaking network communication and once the communication is breaks that network will not be useful. In proposed method no. of dead is very less in whole network communication as compare to LEACH and PEGASIS. This result will increase the network's lifetime and efficiency of network.

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