RECENT ADVANCEMENTS OF LEACH PROTOCOL IN WIRELESS SENSOR NETWORK: A REVIEW

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Abstract : ***Wireless Sensor Network is becoming popular day by day due to its growing applications in various fields. Researchers find lots of things to do in Wireless Sensor Network (WSN) due to its challenges and design issues. Due to limited battery power, WSN is constrained to extend the lifetime of network by minimizing the energy consumption. In this Clustering method is proven to be the best to reduce energy consumption and LEACH is the most popular clustering-based routing algorithm in which total energy consumed along the path for data transfer is minimized. In this paper, I have made a survey on LEACH (Low Energy Adaptive Clustering Hierarchy) and its various descendants, which help in extending the lifetime of wireless sensor network. I have also discussed the pros and cons of LEACH and a comparison is also made based on different parameters.***

IndexTerms **- Clustering, Cluster Head, LEACH, WSN.**

I. INTRODUCTION

In the past few years wireless sensor networks (WSNs) have gained the focus of the researchers as the wealth of theoretical and practical challenges [1]. WSN comprises of one or more sinks and hundreds or thousands of sensor nodes scattered in an area. With integration of information sensing, processing, and wireless communication, a physical information is sensed by the sensor node, crude information is processed, and reported to the sink. The sink sends queries to the sensor nodes for information. WSNs have several distinctive features like:

a) Varying network Structure
b) Vast number of applications
c) Varying traffic, and
d) Big constraints on resources

WSN node consists of sensing devices with limited power capabilites, embedded processor, sensor and power module. The embedded processor basically collects and processes the data received from the sensors in the form of signals. A Sensor measures the change in the physical condition like temperature, humidity, pressure etc and generate the response [3]. The wireless communication channel is used to provide a medium(channel) to transfer the information extracted from a sensor node to the outside world which may be a network of multiple computers and inter-network communication [2]. Users can not access the sensor node; So, it is impossible to recharge their battery and hence energy consumption is the most concerning point in WSN. Hardware with the low energy consumption are also taken in focus in some of the previous researches. Clustering is the most efficient scheme to WSN is typically divided into two types of network scheme:

One is Flat and other one is hierarchical. In flat routing scheme all nodes are identical in terms of functionalities. Limitation of this scheme is scalability. Hierarchical technique partitions the network to form cluster of nodes an

some nodes are selected as special nodes based on certain criteria. These special nodes are called cluster heads (CHs). CH collects, aggregates and compresses the information received from member nodes, and finally transmit the compressed information to the Base Station. The CH provides more functionalities than non-cluster head nodes in the cluster and hence it consumes more energy than other nodes of the cluster. One common method is adapted to balance the energy dissipation within a cluster called Cluster Circulation. Advantages of Hierarchical routing is better energy efficiency and scalability because to its architecture. The first hierarchical routing protocol was proposed by Heinzelman et al. [9] known as LEACH [7].

In the rest of the paper, section II is the introduction of LEACH, section III provides the various improvements proposed by various authors, details of its various descendants are given in section IV, and in section V comparison is made among all descendants, and in the last section conclusion is made.

II LEACH PROTOCOL

1. Theory of Leach protocol:

To minimize the energy consumption and extend the network life time of WSN, LEACH protocol is discovered by Heinzelman [5][6]. Low Energy Adaptive Clustering Hierarchy (LEACH) algorithm is an algorithm based on data aggregation and Clustering

to balance energy among nodes. In LEACH, each node sends data to its corresponding CH, which aggregates data delivered by their member nodes and sends the aggregated directly to the BS.

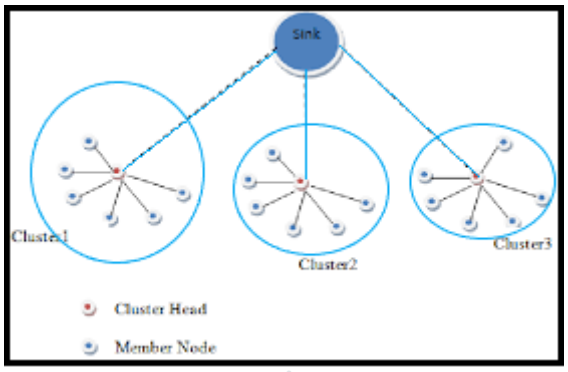

Fig. 1: LEACH

The CH is changed periodically. The communication time is divided into no. of rounds. Each round contains two phases 1. Setup phase and 2. Steady state phase.

In the setup phase, the cluster heads election is performed and a cluster head is selected for each cluster based on a specific criterion. Each sensor node is assured to be chosen as a cluster head with some probability and a CH is selected in a cluster based on a some threshold value:

$$\text{Th(n)} = \begin{cases} \frac{Pr}{1-Pr\left(cr \bmod \left(\frac{1}{Pr}\right)\right)} & if\ n \in C \\ 0 & otherwise \end{cases}$$

Where,

Pr: desired number of CHs
cr: current round,
C: set of nodes that have not been CHs in the last 1/Pr rounds.

CHs that are selected, send the information to its neighbour nodes about being chosen as CH, and rest of the nodes will choose the cluster according to the strength of broadcast signal, they received from CH and request the CH to join the cluster [4]. It increases the network life time significantly because any CH is not chosen repeatedly in the next rounds until all the sensors in the network are selected as CHs.

In the steady state phase, cluster heads create a time slot by TDMA for each node belonging to their cluster, and broadcast the information about time slots to all its corresponding members. Thus, each node only sends data in its own time slot, and for rest of the time the node will enter into a sleep mode, hence saving energy. During this phase, member nodes in the cluster will transfer the sensed data to related cluster head in its time gap. Phase is divided into no. of frames and the length of each frame is determined by the number of nodes in the cluster. At the end of each round, setup phase is again performed, which need energy consumption. In order to reduce the overhead of the system, duration of steady state phase in each round is much longer than that of the setup phase. Once cluster head receives all data from its member nodes, it processes the data such as data fusion, data fusion lowers down the redundant data and so reduces the amount of data in communication. Thereby, comparing LEACH with other static and general routing protocols, it extends the network lifetime about 15% [8]. Finally, the cluster head sends the processed data to base station [6].

2. Basic LEACH algorithm:

The algorithm for LEACH implemented is:

Setup phase

1. Candidate node (CN) that want to become CH chooses a random value k.

$0<k<1$

2. If k for any CN > T(n), then CN becomes CH for round r.

Else go to step 1.

3. CH broadcasts adv messages including its id in G to let the other nodes to be able to join the CH and wait for join-REQ message from other nodes.
4. Depending upon the signal strength received from CH, other nodes wait for adv message to join the CHs and send join-REQ message to CH.
5. CH creates TDMA schedule and assigns the time stamp to all its member to be able to transmit data in that time stamp only.

Steady State phase:

1. All the member nodes sends the sensed information to its corresponding CH.
2. CH aggregates the received data and sends to the base station.

3. Advantages and Disadvantages of LEACH:

The main advantages of LEACH include the followings:

1. Due to less or no communication between sensor nodes and the base station, LEACH protocol enhances the network lifetime.
2. Member nodes are made to go into sleep mode after their TDMA schedule which prevents collisions among nodes's data in a cluster and enhances the battery lifetime of sensor nodes.
3. Every sensor node is given equal chance to become the CH at least once. This rotation of the CH improves the network lifetime [11].
4. It follows hierarchical topology in which most of the communication takes place through CHs, thus it provides better scalability.
5. In LEACH, The CH performs aggregation on the data generated by the nodes. This imposes a limit on the traffic generated in the network. Hence, it is possible to deploy a large-area network without traffic overload and to improve energy efficiency compared to the flat-topology [12].

Besides the ADVANTAGES LEACH has some DISADVANTAGES also:

1. Clusters formation is on random basis, which results in uneven distribution of Clusters. For e.g. some clusters may have only few countable nodes and some may have significant number of nodes. Some cluster heads may be at the center of the cluster and some cluster heads may be in the edge of the cluster [10];
2. Random election of CHs does not ensure the optimal number and distribution of CH and even the nodes having low energy possess the equal priority to be a CH as the node having high energy. Therefore, the nodes having less energy may be chosen as the CHs resulting early depletion of those nodes.
3. As LEACH protocol doesn't consider the authenticity of the node while selecting CHs, which may result in some malicious nodes to be CHs ˈthus destroying the data collected or transmitting false information [4]

III. PROPOSED IMPROVEMENTS ON LEACH

1. In the basic LEACH, the CH aggregates the data received from cluster members and then sends it to the BS that might be located far away from it. The CH performs additional functions like receiving, transmitting, aggregating and overhearing so it will die earlier than the other nodes in the cluster. If the CH depletes, the data gathered by the cluster nodes will be lost and never reach to the BS and thereby making the cluster useless. In this proposed work, they tried to improve the network life on the basis of two parameters: distance and energy. Initially when the CHs are formed based on their energy value;
   if the CH is near the BS then the CH directly sends data to the BS. CH ----->BS
   else if d_{toBS} is greater than $d_{toMaxClCH} + d_{MaxClCHtoBS}$. we select the Cluster Head located in the Max_Cluster which is a cluster having a maximum total energy (∑e: Sum of energy of cluster nodes)
   CH ------>CH_{MaxCl} --->BS
   And if there are two clusters with the same total energy values, the one that is having the minimum distance (min($d_{toMaxClCH} + d_{MaxClCHtoBS}$)) is chosen. This will lower down the energy consumption of the network [22].

2. Twin Nodes Detection [13]
   Sometimes after random and dense deployment, some sensor nodes are deployed very near to their neighbours. These nodes are inside the red circles, as shown in the figure given below, we call them twin nodes. Due to being very near to each other they may sense the same result. So, it can be concluded that there is no need of both, anyone out of both can be kept asleep until the other one exhausts its energy. In this way, network's lifetime may be enhanced.
   During the set-up phase, a small interval of time is added before CH election for the detection of twin nodes. For this, a minimum signal level S_{min} is defined and it is stored in the memory of each sensor node.

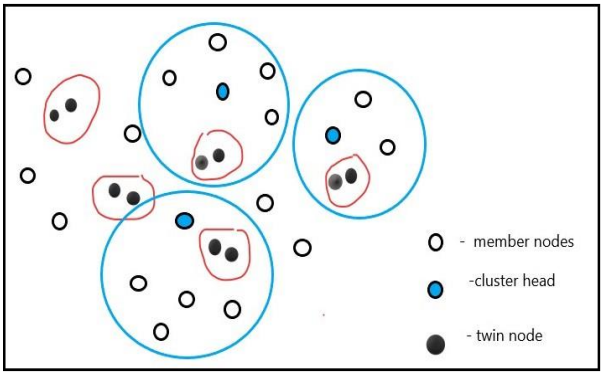

Fig. 2: Twin Node Detection

S_{min} is determined depending upon the request received from sensors and the no. of sensor nodes in the network. During twin nodes detection time, a "Hello" packet is broadcasted by each node with the signal energy of S_{min} by CSMA/CA. Only twin nodes are able to receive this packet, upon reception of Hello packet, Twin node send back an acknowledgement that it is the twin node, and then switches into sleep mode for the current round. Duration of twin node detection is very small and it consumes very less energy as the "Hello" packet contains very less information and sent at a low energy. When new round starts, then during the twin nodes detection time, each sleeping node wakes up, and send a message to its twin node. If no response is received, that means the brother node is dead due to depleted energy, then the sleeping node wakes up and acts like a normal node.

3. Sub Cluster Head Assignment [13]:

Fig. given below shows a scenario of clusters that may be constructed by LEACH. Nodes filled with blue colour represent cluster heads. In this scenario, All the cluster heads selected are on the upper right corner, which results in two problems:

1. When The nodes which are at the left side need to communicate with their CHs requires high energy.
2. Some CHs have no more than 5 cluster members, on the other side one CH contains at least 20 cluster members. It is clear that the CH with atleast 20 members needs high energy to gather and process the data from its cluster members; apparently this node may die out earlier.

In order to avoid this scenario to be happened, an improvement is proposed on the basic LEACH. In this proposed work size of each cluster is confined. The selection of CH is same as in LEACH, and the threshold is given as follows:

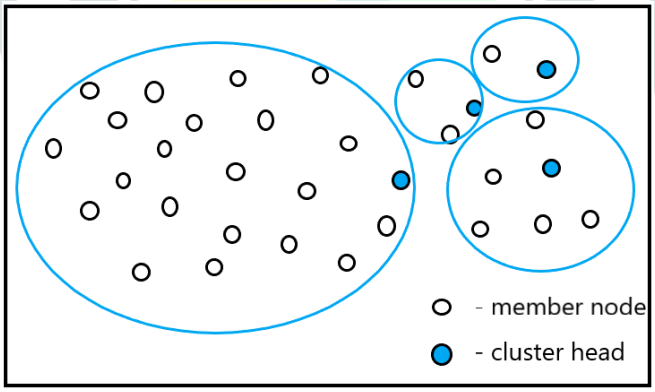

Fig. 3: Imbalance Clusters

$$\text{Th(n)} = \begin{cases} \frac{Pr}{1-Pr\left(crmod\left(\frac{1}{Pr}\right)\right)} & if\ n \in C \\ 0 & otherwise \end{cases}$$

where Pr is the probability of CH willingness, cr is the current round and C is the set of nodes that are not elected as cluster-heads in the last 1/Pr rounds. The expected number of clusters is:

$E[CH] = \sum_{i=1}^{n} Pr * 1 = N*Pr$

Where N = the total number of nodes in the network.

then the expected number of member nodes in each cluster is:

$$E[M]= \frac{N}{N*Pr} = \frac{1}{Pr}$$

E[M] is chosen as a threshold. Once cluster formation is done, its CH has the information about the number of member nodes in this cluster, lets say N_i. If $N_i \leq E[M]$, then its fine and nothing is to be done with this cluster; However, if $N_i > E[M]$, sub-CHs are formed to share the load of CH and so it reduces the energy consumption of CH. Number of sub-CHs is calculated as:

$$SCH = \left\lfloor \frac{Ni}{E[M]} \right\rfloor$$

Sub-CHs are decided at the time of TDMA schedule set up by CH. In LEACH protocol, CH takes its place in the last slot of the frame; When choosing Sub Cluster Head, the member node which is assigned second last slot will be qualified to become the first sub-CH, and so on. CH will collect the data of only first E[M] slots. After that, sub-CH 1 will collect data during the time slot of E[M] +1 slot to 2E[M] slot, and then will sub-CH 2, etc.

CH stays awake during sub-CHs' slots, collects the aggregated data from sub-CHs also and forwards it to the base station during its own slot.

4. Using Residual Energy:

LEACH protocol selects cluster heads according to the random number, the nodes generate and the threshold, the threshold does not take the residual energy into account, resulting in the node with low energy to be a cluster head, thus leading to premature death of clusters and affecting the lifetime of network. In [4] an idea is proposed on the residual energy of the nodes, that is:

$$T(n) = \begin{cases} \frac{Pi}{1-Pi\left(rmod\left(\frac{1}{Pi}\right)\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

Where, $P_i = \frac{(Ei-Er)\text{^}2}{ER}$ (2)

E_i : Residual energy of each node in i round;

E_r : average energy of rest nodes in the i round;

E_R : total residual energy of rest nodes in the i round;

Formula of average energy of rest nodes

$E_r = E_R * (1 - \frac{ri}{rmax}) /N$ (3)

r_i : current round

r_{max} : maximum rounds of network simulation

In the formula (1) and (2), more the residual energy of the node, more will be the value of P_i. As P_i increases, T(i) is also increased. Therefore, by considering the residual energy of nodes, optimized cluster heads formation can be ensured, extending the network lifetime[4].

5. Improvement of Cluster Mechanism [14]

In this proposed work, the energy and the position of nodes are taken into account to optimize the selection mechanism. This improved algorithm includes three parameters: residual energy of the node, the number of neighbours of node, the distance between node and BS to correct threshold.

1) Considering the current residual energy of the energy adjustment parameter $T_1(n)$ is introduced.

$$T_1(n) = \begin{cases} \frac{Ei}{Eav} & if\ Ei > \text{Eav} \\ 0 & otherwise \end{cases}$$

E_i = residual energy of i^{th} node

E_{av} = average energy of all nodes

2) when the distance between the node and the base station is considered, the distance adjustment parameter $T_2(n)$ is introduced.

$$T_2(n) = \begin{cases} \frac{Di}{Dav} & if\ Di > \text{Dav} \\ 0 & otherwise \end{cases}$$

D_i = distance between i^{th} node and BS

D_{av} = average distance of all nodes from BS

3) The density of nodes is considered, the number of neighbour nodes adjustment parameter $T_3(n)$ is introduced.

$$T_3(n) = \begin{cases} \frac{Ni}{Nav} & if\ Ni > \text{Nav} \\ 0 & otherwise \end{cases}$$

N_i is the no. of neighbour nodes of i.

N_{av} is the no. of neighbour nodes of all nodes

The improved threshold is expressed as follows:

$$T(n) = [w_1*T_1(n) + w_2*T_2(n) + w_3*T_3(n)]*P$$

Where w_i is the weight of the factors, $0 \leq w_i \leq 1$

w_1 is the weight assigned to the residual energy of the node, w_2 is the weight assigned to the distance between node and the base station, w_3 is the weight assigned to the number of neighbour nodes, and $\sum_{i=1}^{3} wi = 1$.

IV. LEACH DESCENCDANTS

1. E-LEACH(Energy LEACH)

Fan. X. N. et.al. proposed E-LEACH [20] protocol in 2007. It is an improvement over setup phase of LEACH protocol. The E- LEACH is also divided into different rounds as LEACH protocol. In the first round, all the sensor nodes have the same probability Pr =1/N to be CH of the cluster, where N represents the total number of sensor nodes in the network. Afterwards the first round, each node possess different residual energy and the node who have the highest residual energy is chosen as CH of the cluster and other nodes in the cluster become the cluster member. So the number of CHs in the first round are n = Pr∗N. Where n is, Pr is the probability of becoming CH and. During first round every nodes would have lost some energy in sensing and data transmission, So in the next round, remaining energy of every node is not left same as in previous. So, sensor nodes which have higher residual energy (greater than a threshold) are chosen as CHs and sensor nodes with lesser energy than a threshold value are become member nodes. Data transmission is taken place in multi-hop which reduces the energy consumption and enhances the network lifetime. The main disadvantage of this protocol resulted from selection of the CH based on residual energy, is non-uniform cluster sizes and so load distribution in the network.

2. B-LEACH(Balanced LEACH)

this algorithm is proposed by Depedri.A.et.al. [18]. In LEACH-B protocol every sensor node only has the information about its own position and location of final receiver. Nodes don't have the information about the position of other sensor nodes. It reduces the problem of uneven cluster sizes of basic LEACH. It combines both the factors for selecting the CHs so that evenly balanced clusters are formed.

1. percentage of willingness for becoming CHs of each cluster node, and
2. the residual energy of sensor nodes.

LEACH-B operates in following phases: CH selection algorithm, cluster formation and data transmission with multiple accesses. Each sensor node chooses its CH by evaluating the energy dissipated in the path between final receiver and itself. It reduces energy consumption more efficiently to the network than LEACH, but the CH energy gets drained out quickly. LEACH-B operation can be described as follows:
Number of CHs in each round should be a constant number N ∗ Pr, where Pr is the percentage of willingness of some nodes lets say M(M<N) for becoming CHs and N is the number of sensor nodes in the network.
Pr = 1/M
Random CH selection is same as in basic LEACH protocol, then each CH broadcasts its status and residual energy to each member node. Lets say number of randomly selected CH be R Now there are two scenarios which are possible to occur.

1. if R<N ∗Pr, a factor T is calculated by T = k/E_i where E_i represents residual energy of i^{th} sensor node and k is a constant factor, then sensor nodes with less k value (high residual energy) are selected as CHs and added into CH set S to make n[S] = N*Pr
   then these CHs broadcast their status to the network.

2. if R>N ∗ Pr, then make some CHs with low energy normal nodes to satisfy n[S] = N∗P. To achieve this, all the CHs are arranged in descending order based on their residual energy, so CHs at the end of the list have less energy and the CHs after N*Pr no. are excluded from the set and made normal nodes. Being distributed protocol, LEACH-B improves the uneven energy-load balance problem of the cluster and efficiently reduces the energy consumption of sensor nodes in WSN compared to LEACH. The disadvantage of this protocol is it includes overhead of messages, it doesn't ensure scalability and is very complex.

3. **C-LEACH**

Heinzelman.W.et.al. [19] proposed centralized version of LEACH routing protocol called centralized Leach (LEACH-C), in which central entity is BS i.e. that handles all the functions like CH selection, cluster formation and distribution of information into the network. Basic LEACH is the distributed or decentralized algorithm which suffers from unfair placement, uneven clusters, and unoptimized number of CH nodes. However, using a centralized algorithm to form the clusters may produce better clusters by evenly distributing the CH nodes throughout the network. LEACH-C uses a centralized clustering algorithm for set up phase and steady-state phase is same as in LEACH

4. **TL-LEACH (Two Level LEACH)**

A two-level hierarchy of clusters has been proposed by author Loscri et al. [21] for efficient energy conservation and uniform distribution of energy load in large scale networks. In TL-LEACH data is transmitted in two levels. CHs are distributed in these two levels. CHs at upper level are called primary CHs and at lower level are called as the secondary CH. Each secondary level CH performs partial local computation of data received from its member nodes and each primary level CH performs complete global computation of data received from different secondary CHs and transmit data directly to the BS. TL-LEACH enhances the lifetime of a sensor network by evenly distributing the energy among sensor nodes. This protocol is best suited to high density and large scale networks and performs better than basic LEACH and LEACH-C. The main disadvantage of this algorithm is that the primary level CHs located near the BS are suffered from a hotspot problem.

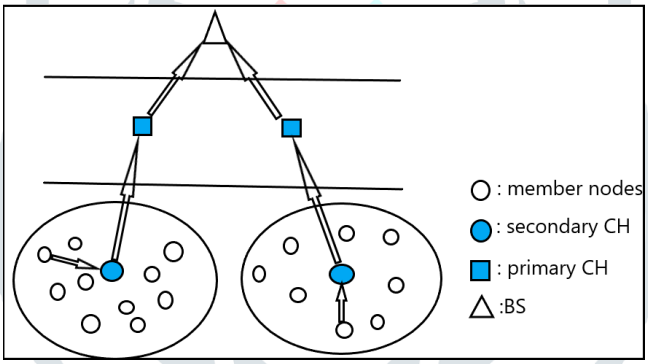

Fig. 4: TL-LEACH

5. **M-LEACH**

M-LEACH is a mobility scenario of LEACH proposed by Authors in [17]. LEACH M has same setup phase and threshold calculation as LEACH, but data transfer phase considers the mobility of nodes. As mobile node can be out of its cluster any time. Worst time of its being out is when data transmission is taking place with CH, which makes mobility very challenging. LEACH-M ensures about the presence of node in its cluster in the following way:

At the start of each TDMA slot, the CH broadcasts the "req-data-transmission" message and waits for the response from nodes in the next TDMA slots. If the node responds within next two successive TDMA frames, CH considers it in range, and else it removes that unreachable node from its member list.

6. V-LEACH

Authors in [15] proposed this version of LEACH protocol. In basic LEACH protocol, setup phase doesn't consider the energy of nodes and the CH is selected based only on a probability. This leads to the problem that some CHs may die soon even before the completion of their running round because of very low residual energy. In V-LEACH there is one more CH in each cluster called vice CH.

So in V-LEACH protocol, there exists three types of nodes in each cluster: 1. CH (that receives data from its member nodes), 2. Sensor nodes (which sense the environment and sends data to CH or vice CH) and 3. The vice CH (which acts as CH after original CH dies) Original CH is selected in the same manner as in basic LEACH protocol and vice CH are selected on the basis of residual energy of the nodes. The node which has highest residual energy is selected as vice CH. By doing that, data that are gathered by the CHs, are always assured to reach the BS. So now it is not required to elect a new CH each time on depletion of current CH. This will extend the overall network lifetime. The steady state phase of V-LEACH is same as of basic LEACH protocol.

Compared to the basic LEACH, success rate of data delivery is increased because of two CHs in a cluster rather than only one. Disadvantages of this protocol are: 1. Increased overhead due to one extra CH and 2. Scalability is not there due to single hop communication between the CH and the BS [7].

7. **W-LEACH (Weighted-LEACH)**

W-LEACH [16] is a newly proposed data aggregation algorithm by Abdul salem et al. for WSNs that is able to control both uniform and non-uniform networks. Each sensor has been assigned a weight w_i. Weight is given by remaining energy e_i and the density d_i of node. The d_i is the fraction of all active nodes in the vicinity of a sensor node with all active nodes in the whole network. The w_i can be calculated using Equation

$$w_i = = \begin{cases} ei * di & if\ di > \text{dthres} \\ di & otherwise \end{cases}$$

Where, d_{thres} is threshold on density. Sensors with less than threshold value of density are selected for the data transmission. So, all the nodes of a cluster are not required to be in active mode in each round, like basic LEACH. This way, this algorithm extends the average lifetime of nodes and the lifetime of network.

V. COMPARISON OF LEACH Descendants from basic LEACH

LEACH descendants	Difference from BASIC LEACH	Clustering type	Mobillity
E LEACH	**Unlike random selection of CH in LEACH, it uses residual energy to select CH**	**Distributed**	**No**
B LEACH	**Unlike LEACH, nodes choose its CH on the basis of energy requirement for the path between the node itself and the destination**	**Distributed**	**No**
C-LEACH	**As in LEACH nodes are responsible for making cluster but in C LEACH BS takes the responsibility of making cluster on the basis of residual energy and location of all nodes.**	**Centralized**	**No**
TL LEACH	**An other CH lies between the CH and BS, through which data pass**	**Distributed**	**No**
M LEACH	**It is best suited for highly mobile environments**	**Distributed**	**Yes**
V LEACH	**A vice CH exists for the situation when CH dies**	**Distributed**	**No**
W LEACH	**Each node is given some weights and CH is selected on the basis of residual energy and weights.**	**Centralized**	**No**

Table 1: Comparison of LEACH Descendants

VI. SIMULATION ANALYSIS

In this section a simulative comparison is made to check the performance of LEACH protocol against original RPL.

1.**Performance metrices**

here following metrices are used to compare the performance

1. Simulation time vs Energy Consumption
2. Simulation time vs Delay
3. Simulation time vs Packet Delivery Ratio
4. Simulation time vs Throughput
5. Simulation time vs Overhead

2.Simulation Parameters

Simulation parameters are as follows:

Parameters	Values
No. of Nodes	100+1
Simulation Area	1500*1500 m^2
Simulator	NS 2.29
Operating System	Red Hat Linux 9.0
Transmission Range	.84 m

Table 2. Simulation Parameters

According to Table 2, here we have used NS2.29 Simulator with a random deployment of 100+1 nodes in 1500*1500 m^2 area. Nodes are having the transmission range equals to .84 m.

In Simulation following assumptions are made:

1. There are three types of nodes: Sink node, Common nodes and Cluster heads (In LEACH only).
2. Nodes are distributed in random manner
3. Observed results may vary with different topologies, here randomly built topology is considered.
4. Performances are measured at different time instant of simulation.

3.Simulation Results

1**.** Simulation time vs Energy Consumption

Energy Consumption is the total energy consumed by each node until all the nodes die. As original RPL protocol is not a hierarchical Network, all the nodes have to perform all actions including sending, receiving, and aggregation being active all the time so requiring a large amount of energy than in LEACH, as LEACH is hierarchical routing protocol in which common nodes do only sending and receiving in their time slots only which reserve their energy. In simulation result i.e. in fig. 5 we can also see that LEACH outperforms the original RPL in energy consumption. As time increases the energy consumption of both protocol raises but LEACH resides down the original RPL.

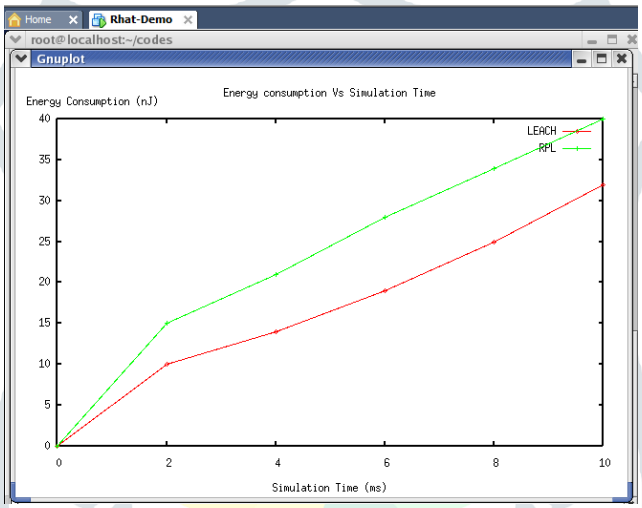

Fig. 5

2.Simulation time vs Delay

The **delay** of a **network** is the time that a bit of data takes to travel through the **network** from one node to another. In RPL all the nodes send data independently to the sink regardless the duplicity of data causing the congestion at sink so increasing the delay in the network but in LEACH CH plays the important role of removing the redundant data at its end only and sending fewer bits than in RPL which reduces the delay. So LEACH outperforms the RPL here also. In fig. 6 it is clearly seen that wrt time LEACH always lies up the RPL.

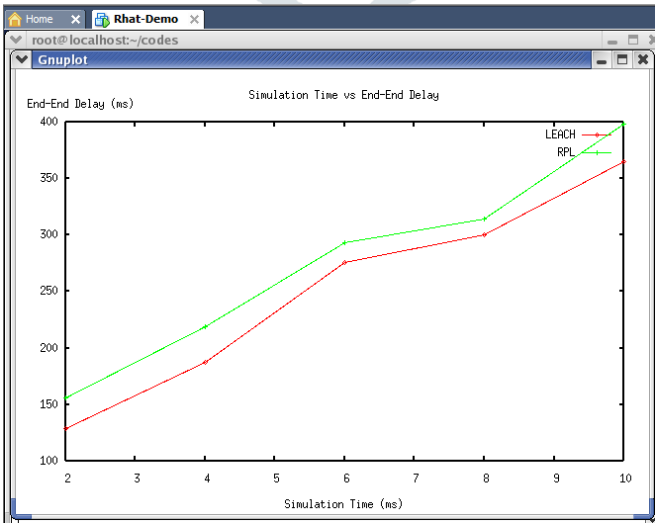

Fig. 6

3.Simulation Time vs Packet Delivery Ratio

Packet Delivery Ratio is the ratio of successfully delivered packets to the total transmitted packets. Due to efficient energy balance in LEACH, nodes survive for more time, which increases the packet delivery ratio. It is proven by simulation that packet delivery ratio is improved in LEACH than in RPL which can be seen in fig. 7. It is measured in percentage.

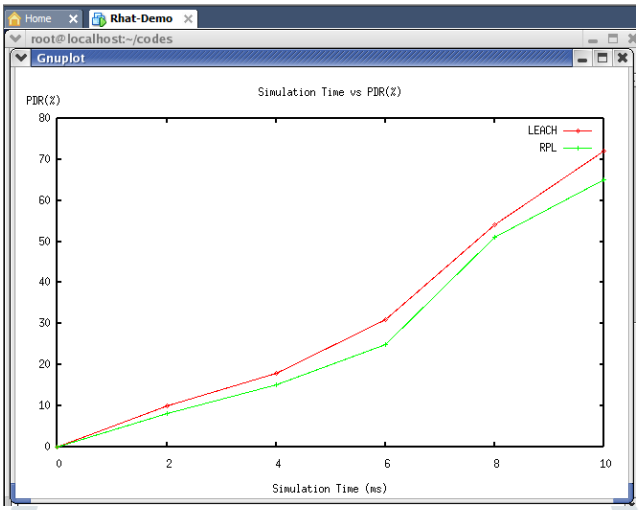

Fig. 7

4.Simulation time vs Throughput

Throughput is the no. of data packets or bits successfully sent per sec. it is measured in kbps. In our simulation result, fig.8 it can be concluded that In terms of throughput LEACH performs better than RPL.

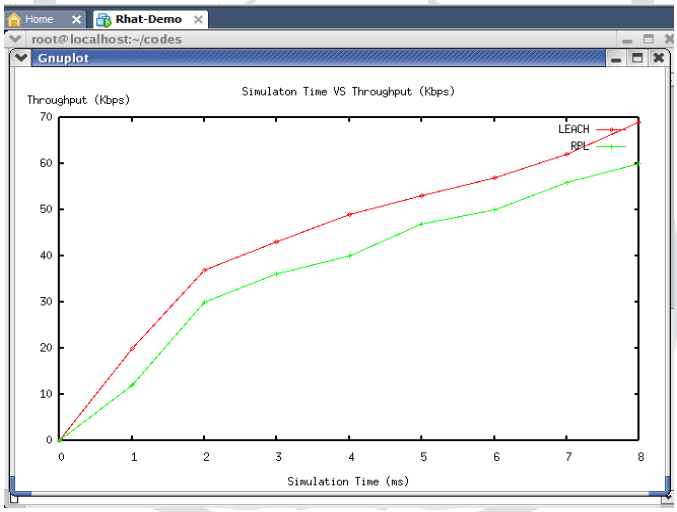

Fig. 8

5.Simulation Time vs Overhead

Overhead is the number of RREQ packets sent. According to the fig. 9 it is clear that overhead is lesser in LEACH than in RPL

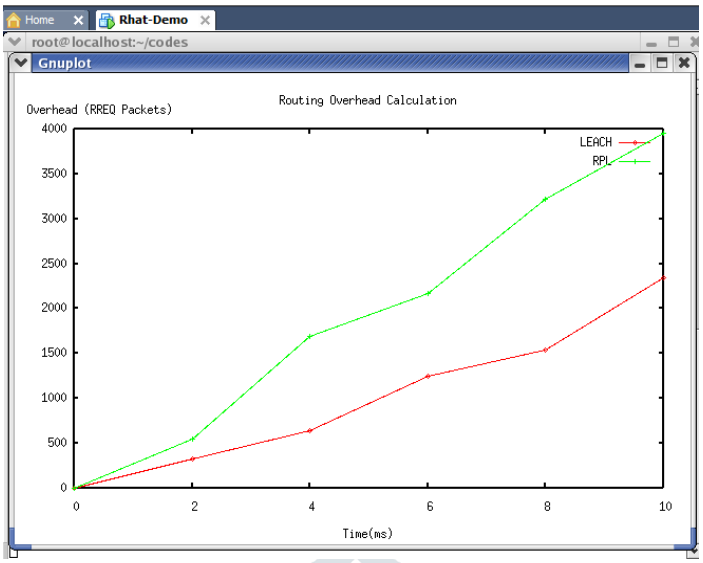

Fig. 9

CONCLUSION:

Due to limited energy in sensor node, energy efficiency becomes main challenge of wireless sensor network. Various routing protocols are designed for Wireless Sensor Networks for ensuring less consumption of energy and extending the whole network lifetime. In this survey paper, a survey is made on various proposed improved on LEACH. Descendants of LEACH protocol has also been discussed in brief and a comparison is also made between them and basic LEACH protocol. The improvements and various protocols based on LEACH solved various disadvantages of LEACH protocol.

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